# New Electrical Grounding Method for MLI via Metallized Discrete Spacers

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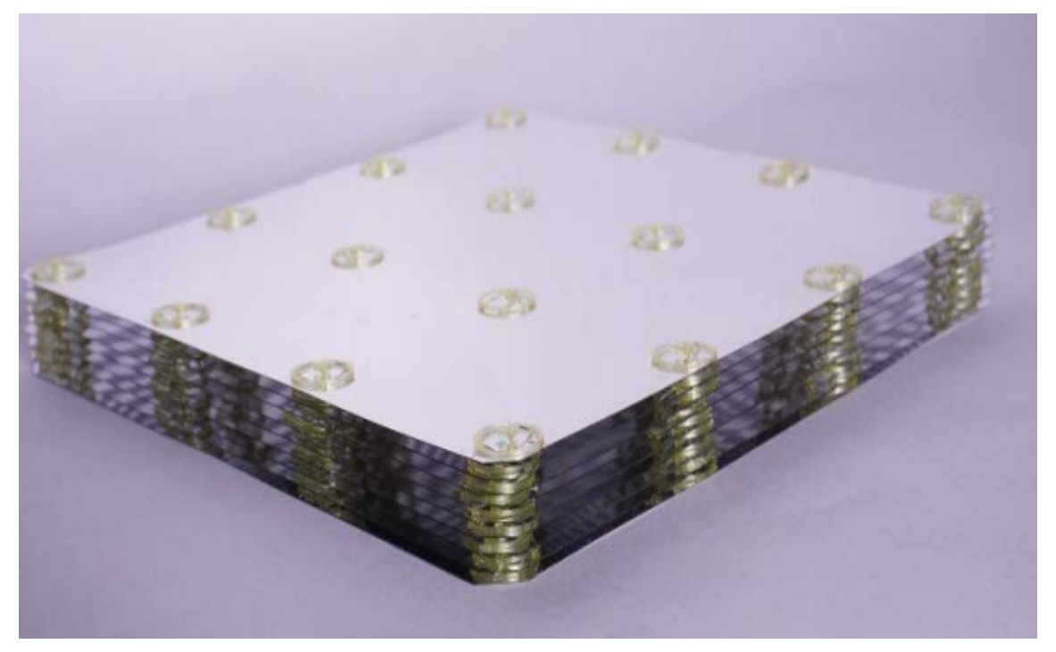
## Introduction

Many spacecraft carrying sensitive electronics, controls and instruments are required to operate in orbits - such as Low Earth, geosynchronous as well as orbits around Jupiter and Saturn - where significant buildup of electrostatic charge on the surface or within a multilayer insulation (MLI) blanket can occur. Static discharges of any type can interfere with payload operation or damage key electronic components and possibly result in complete mission failure. In order to prevent or dissipate damaging electrostatic buildup or differential electrical potential, multilayer insulation blankets need to be grounded to the spacecraft structure. Blankets are grounded to the spacecraft through grounding straps (ground tails) that must meet specific mission grounding requirements while maintaining thermal performance requirements. Multilayer insulation blankets have specific grounding requirements that meet NASA/TP-1999-209263 and SSP-30245.

General Grounding Requirements include 1 or or more ground tabs to the vehicle structure, ≤ 5000 Ω from aluminized surface to ground, and ≤ 1 Ω from tab to chassis surface. Typical grounding schemes involves connecting each MLI layer with a grounding tail, which provides an electrical short between layers and the chassis, but also is a direct thermal short between layers.

Quest Thermal Group has developed advanced Integrated Multilayer Insulation (IMLI) using proprietary Discrete Spacer Technology™ replacing the Dacron netting found in traditional MLI (tMLI) . Quests IMLI has about half of the heat leak per layer, lower mass and better predictability than tMLI. The discrete spacers provide unique capabilities, such as structural strength, and have been used for an improved method for electrically grounding multilayer insulation blankets that minimizes the thermal penalty and reduces mass.



IMLI blanket with Discrete Spacer Technology™

VDA metalized spacers bonded to radiant barriers

## Improved Grounding Methods

Grounding of traditional netting based MLI is done with ground tails that directly connect all layers. A tab from each of layer is gathered up in a stack with copper tape interleaved between each layer. The result is a direct thermal short of all layers of the blanket, which can have substantial heat penalty. IMLI spacers have a low Area/Length ratio to minimize conducted heat across the layers, and with a thin VDA layer applied have low electrical resistance (< 2.0 Ω). A column of metalized spacers within the IMLI provides electrical continuity directly through the blanket, and only one layer requires a tab connected to chassis ground. This eliminates direct thermal shorting from gathering layers together and reduces heat leak.

In this new proprietary method, the discrete polymer spacers that separate radiation barriers in Integrated MLI (IMLI) have a thin metal VDA coating to provide electrical continuity across the spacer. The electrically conductive spacer provides grounding paths inherently distributed throughout all layers of an integrated multilayer insulation. With each layer electrically continuous to adjacent layers only one layer requires a chassis ground. A ground tail can be extended from any single layer within the multilayer structure not only simplifying the chassis ground but also preventing additional heat leak. For thicker blankets with higher layer count, one layer from each sub blanket is strategically selected for similar temperature matching (i.e. layer 10 and 11 for 10 layer sub blankets) is gathered together and either a grommet and ground wire clamps the tail together or the tail can be screwed directly to chassis ground

Selective columns of metalized spacers are bonded up in an IMLI blanket using conductive adhesive creating an electrical ground path directly through the blanket. A small hole in the radiant barrier can allow the conductive adhesive to express through creating electrical continuity across the dual aluminized film. Multiple columns of spacers can be applied to provide redundant ground paths. Conductive tapes are used to provide continuity across adjacent panels drastically simplifying the grounding scheme while maintaining a low heat flux penalty.

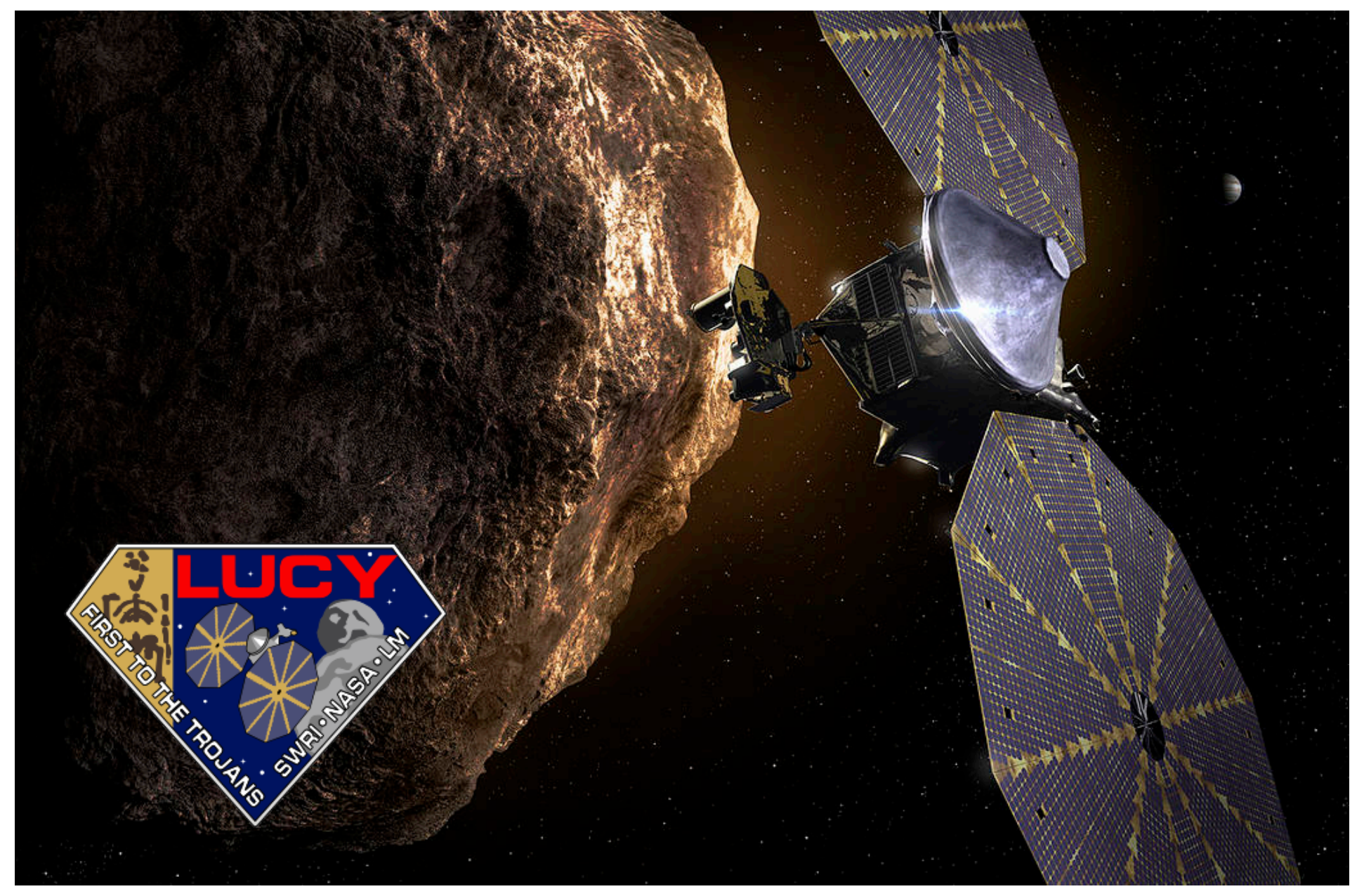
## Ground Tail Thermal Penalty

Thermal performance is always a key performance requirement for spacecraft applications. Zero or low cryogenic propellant boiloff is required during extended or deep space missions and lengthy on-orbit times. Multilayer insulation is a critical component in achieving the best thermal performance. Electrical grounding of the MLI blankets is generally required to prevent unwanted electrostatic buildup posing risk to sensitive electronics and controls.

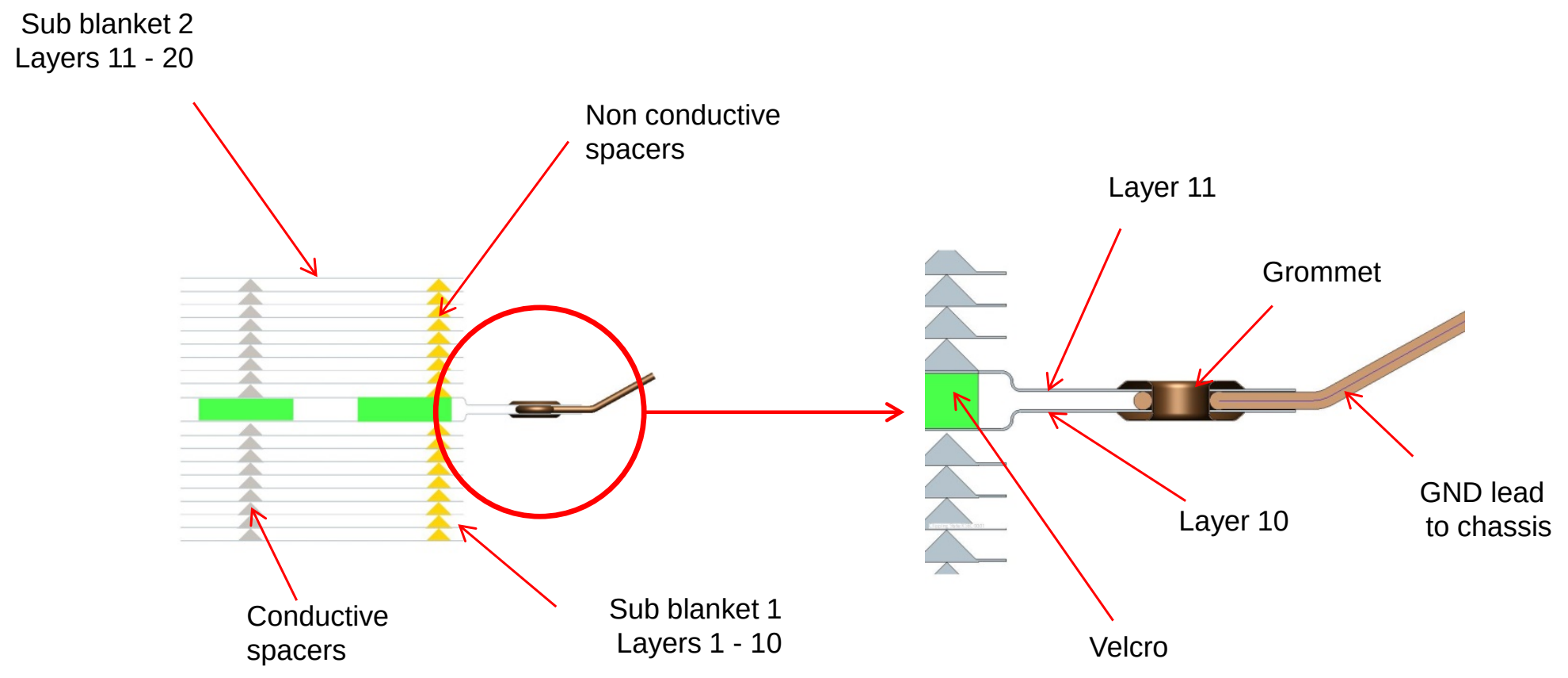
For small blankets < 0.25 $m^2$ insulating sensitive instruments, tanks or control systems, typical electrical multilayer grounding can increase heat flux through the blanket by 6.9% for a 20 layer structure; whereas grounding through electrically conductive spacers reduces the heat leak penalty to 0.19%. For larger traditional MLI blankets > $1m^2$ multiple ground tails are required and heat flux with traditional grounding can increase heat leak by 24.5% for a 60 layer structure; whereas grounding a similar blanket through electrically conductive spacers reduces that to 0.048%, over 500 fold lower heat leak penalty.

In the quest for very low or zero boiloff reducing thermal performance penalties is critical. Grounding Quest's Integrated Multilayer Insulation through metalized spacers helps minimize the thermal penalty induced from electrical grounding requirements.

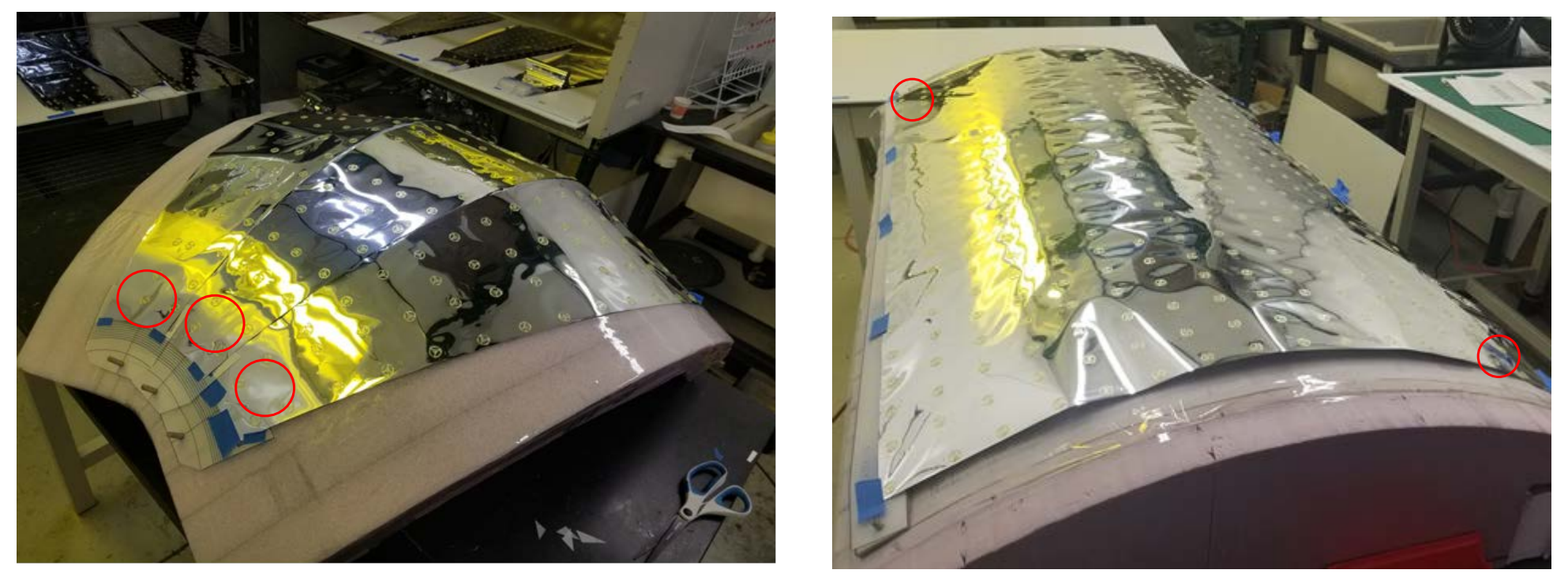
| For a 0.25 $m^2$ Blanket | IMLI Heat Leak No Grounding (W) (20K – 295K) | IMLI Heat Leak with Grounded Post and Tail (W) | Increase in Heat Leak from Grounded Post and Tail % | IMLI Heat Leak with traditional Grounded Tail (W) | Increase in Heat Leak from traditional Grounded Tail % |
|---|---|---|---|---|---|
| 10 Layer | 0.2582 | 0.2586 | 0.18% | 0.2630 | 1.84% |
| 20 Layer | 0.1268 | 0.1270 | 0.19% | 0.1361 | 6.86% |
| | | | | | |
| For a 1 $m^2$ Blanket | IMLI No Grounding (W) (20K – 295K) | IMLI with Grounded Post and Tail (W) | Increase in Heat Leak from Grounded Post and Tail % | IMLI Heat Leak with traditional Grounded Tail (W) | Increase in Heat Leak from traditional Grounded Tail % |
| 20 Layer | 0.5070 | 0.5073 | 0.07% | 0.516 | 1.84% |
| 40 Layer | 0.2512 | 0.2514 | 0.05% | 0.288 | 12.8% |
| 60 Layer | 0.1669 | 0.1670 | 0.05% | 0.221 | 24.6% |



IMLI Spacers: VDA metalized spacers (left) and nonmetalized polymer spacers (right)



Schematic of grounding with single layer tails



Approximate metalized spacer location (red circles) for cryogenic tank dome (left) and barrel section (right)

## Flight Heritage: Lucy Spacecraft

Lucy is the first mission to study the Trojan asteroids that lead and trail Jupiter's orbit. They consist of remnants of our early solar system which can provide insights to formation of the solar system including Earth.

NASA Goddard Space Flight Center (GSFC) developed the LEISA detector, on the L'Ralph instrument, which has a passive radiator with a view to space, designed to cool the detector to 100K. The backside of this radiator has a view to the warmer Telescope Detector Assembly (TDA), which presents a significant source of heat into the radiator. Quest Thermal Group designed, analyzed, fabricated and installed the IMLI that goes on the backside of the L'Ralph LEISA Radiator to minimize heat leak into the radiator.

The IMLI blanket presented unique challenges to electrical grounding of the entire blanket. There were a number of island panels that fit down within ribs of the radiator, each of which required grounding. Using metalized discrete spacer grounding, each of the island panels could be effectively grounded to the rest of the blanket. Two metalized spacer columns per island provided redundant electrical paths through the layers within each ribbed section of the radiator and electrically connected them to the full circular layers above the ribs.

The upper layers were then grounded via a tail to the metal radiator and out to spacecraft chassis ground. Resistance from the innermost to outermost layer measured 130 Ω, well below the 5000 Ω requirement. Grounding of a conventional netting based MLI would have required 12 chassis ground tails resulting in significant thermal penalty.

Results from thermal analysis illustrate the extremely low thermal penalty due to blanket grounding via conductive spacer stacks. The heat leak contribution due to grounding was estimated to be 3% - 5% of the total blanket heat leak.

| Lucy L'Ralph Radiator | | |
|---|---|---|
| | Max | Min |
| Ground tail heat leak (W) | 0.0018 | 0.0007 |
| Total Heat Leak (W) | 0.0348 | 0.0257 |
| | | |
| Thermal Penalty | 5% | 3% |

## Minimizing resistance by panel combination and redundancy

The schematic shown (right) illustrates implementation of conductive spacers on real world cryogenic tanks. The dome is constructed from 18 identical gore panels, each of which has a conductive spacer on each layer.

- Circumferential direction
  - Furthest ground post oriented 180° to nearest tail (Chassis GND)
  - 18 panels around circumference (domes)
  - Estimated panel-to-panel resistance = 10 Ω
  - Max resistance to ground tail: (18/2) * 10 = 90 Ω
- Layer-to-layer direction
  - 9 IMLI post layers per sub-blanket
  - Resistance across metalized spacers ≈ 2 Ω
  - Estimated resistance layer-to-layer = 10 Ω (includes bonding)
  - Max resistance through blanket: 9 * 10 Ω = 90 Ω

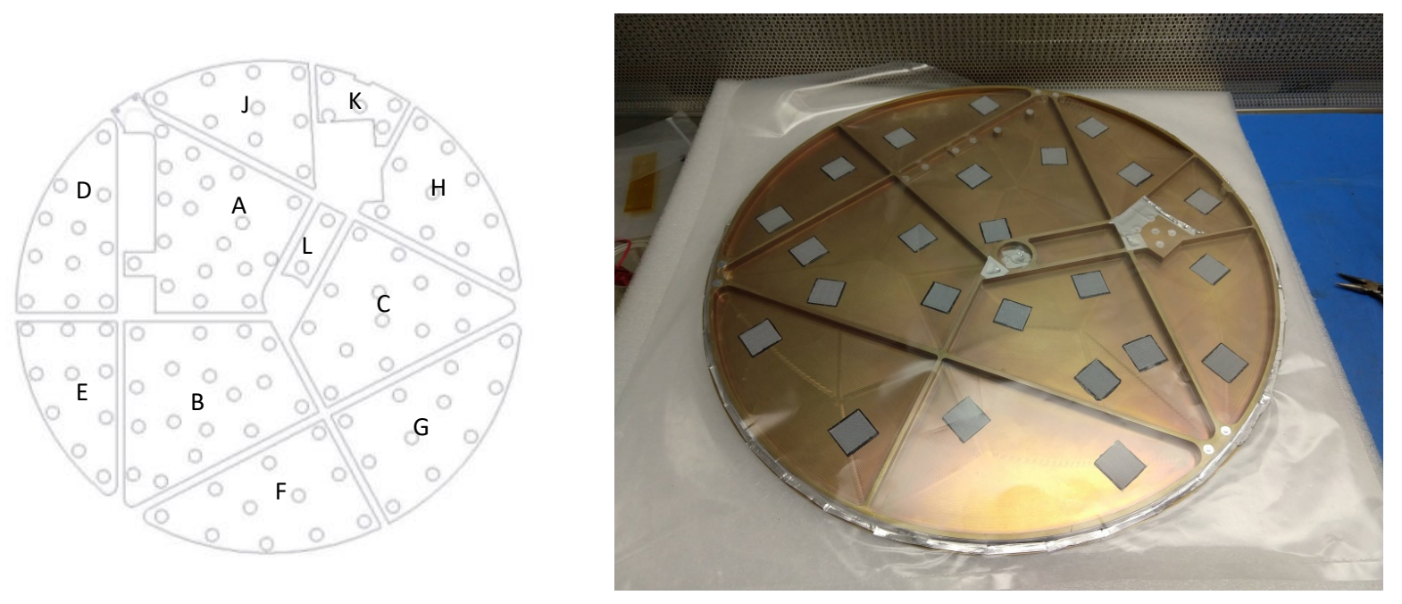
  - Theoretical maximum grounded resistance = 180 Ω

Many parallel pathways provide grounding redundancy.
Maximum ground resistance of 180 Ω easily meets the 5,000 Ω requirement.
Grounding using metallized spacers has a near zero mass penalty.

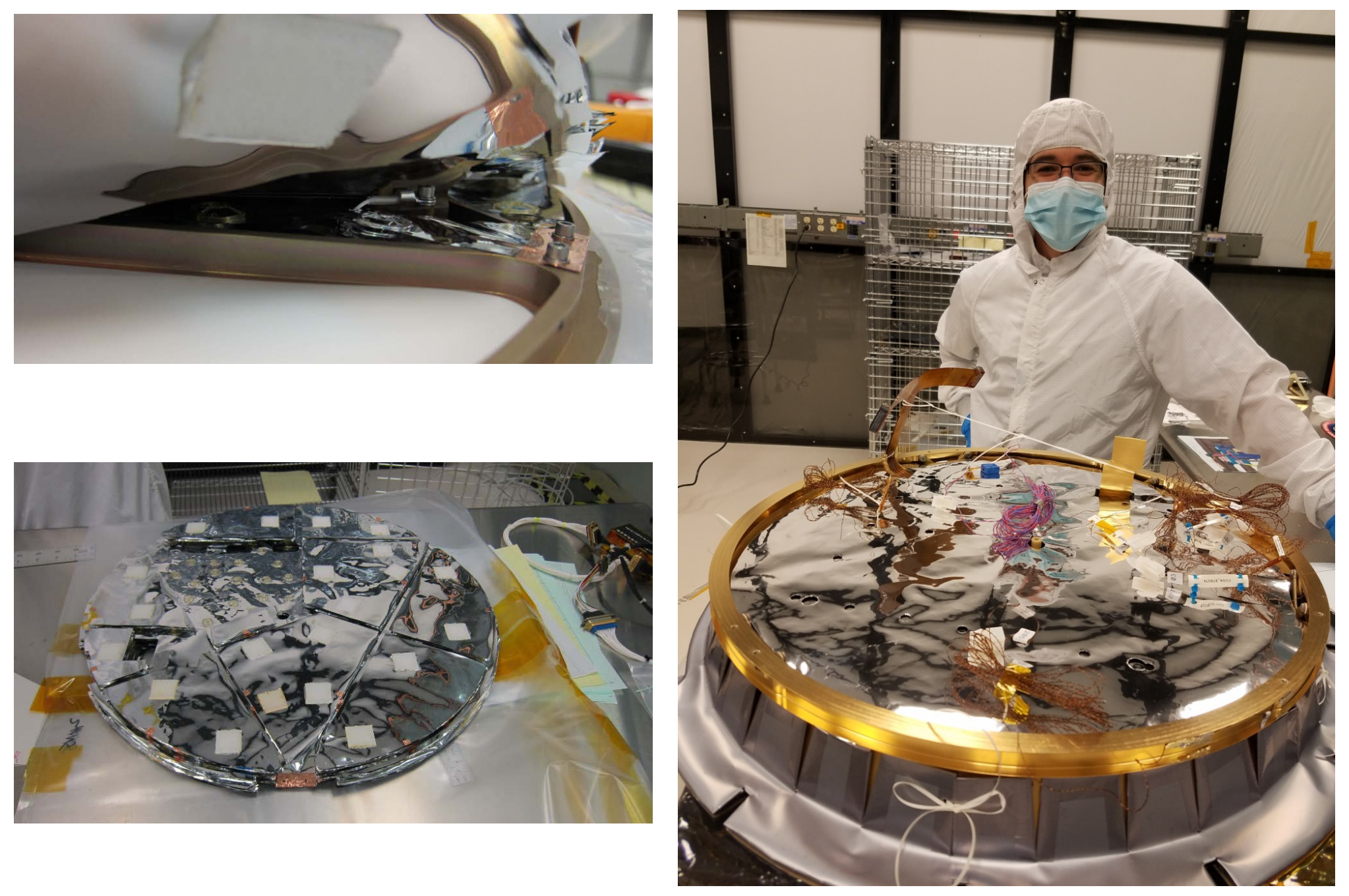
## Continued Implementation

Quest continues to have opportunities to implement unique grounding schemes utilizing Discrete Spacer Technology™ and metalized spacers. With NASA's commitment to Sustained Lunar Development, application to real world size tanks for Lunar Landers, Cis Lunar Transfer Vehicles, and Lunar ISRU grounding needs should allow Quest continued opportunities to develop creative IMLI blanket grounding.

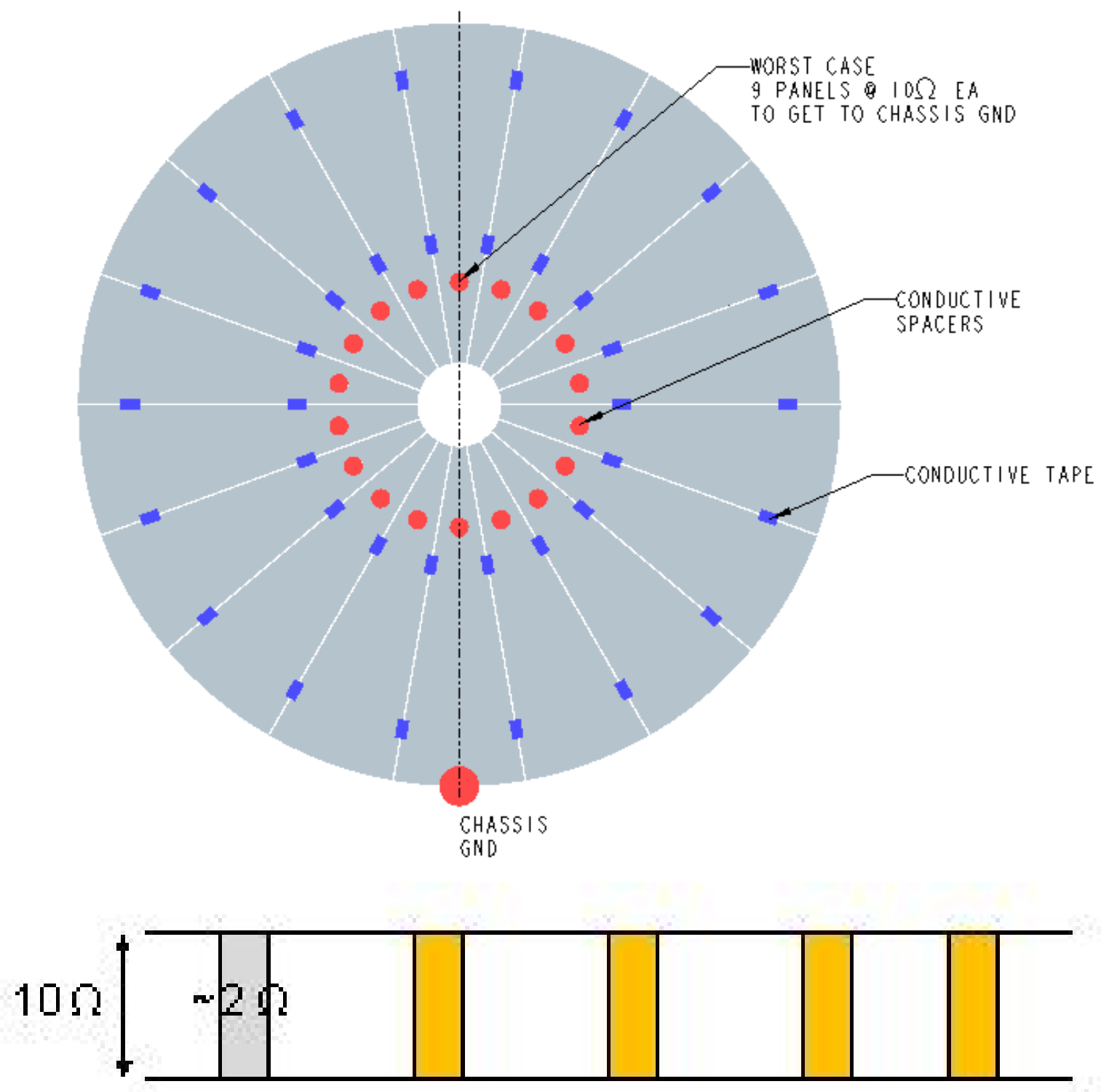
For a reasonable size tank (shown to right) of 12.7 $m^2$, Quest can easily meet the NASA/TP-1999-209263 grounding requirement. By definition the number of ground tails to chassis is only five, and through a sophisticated matrix of grounded spacers and IMLI panel combinations, Quest has developed a simplified method of grounding the nearly 100 panels.



Island panels required for backside of L'Ralph radiator



Pictures of the Lucy/ L'Ralph radiator IMLI blanket



Schematic of grounding scheme for dome section comprised of 18 panels

General location (red boxes) of ground tails to chassis