
GSFC · 2015

# Thermal Hardware for the Thermal Analyst

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# Reason for This Course

- There are 3 parts to Thermal Engineering:
  1. Thermal Analysis
  2. Thermal hardware installation
  3. Thermal Vacuum Testing

- But many times Analysts are not involved in #2.

# Course Outline

- MLI Blanketing Theory 101
- MLI blanketing installation
- Temperature Measurements
- Heaters and Thermostats
- Optical coatings (Paints and tapes)
- Propulsion Systems (tanks, lines, and thrusters)

# MLI blanketing 101

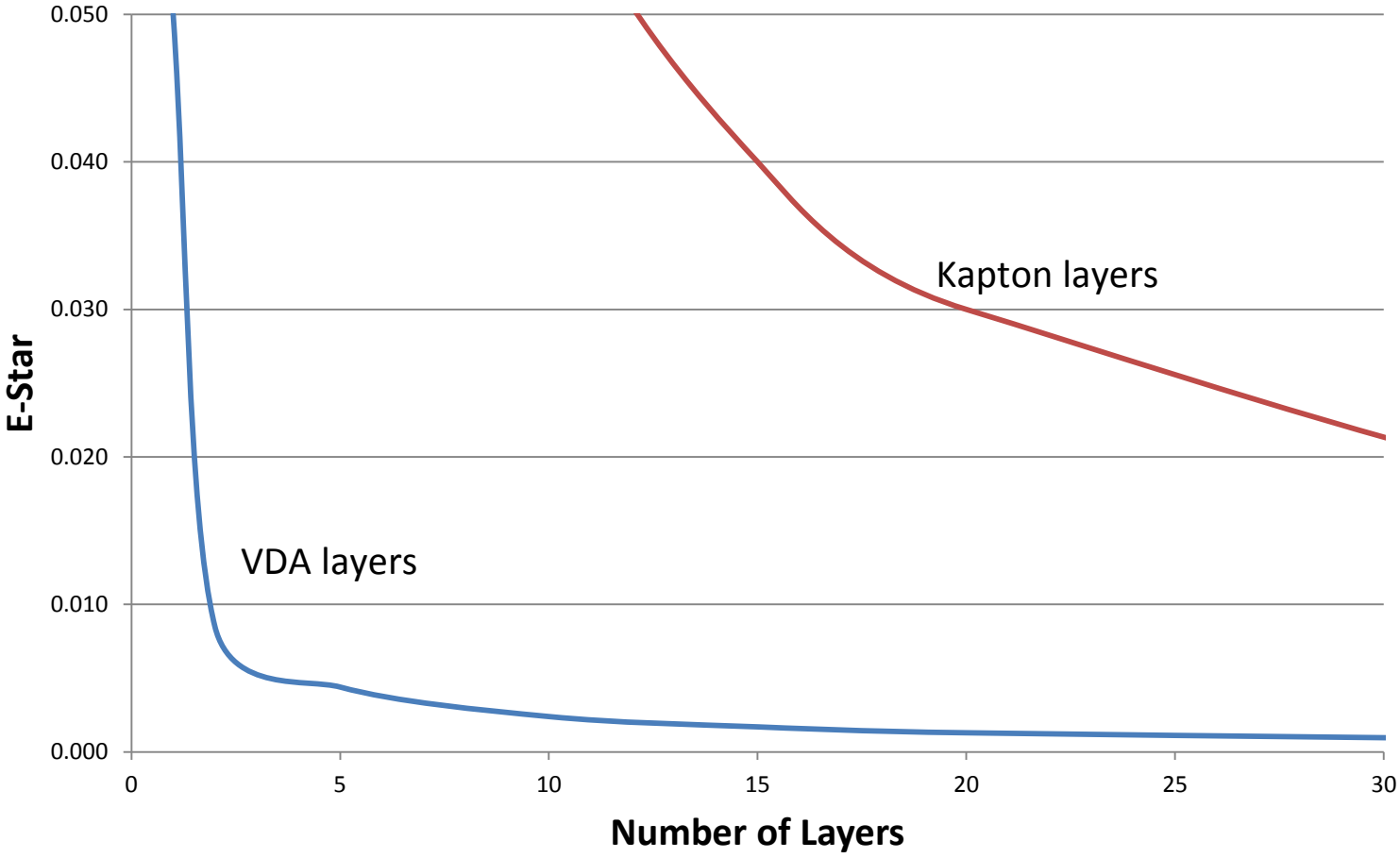
**Analyst:**

"The actual MLI doesn't look like what's in my Thermal Model"

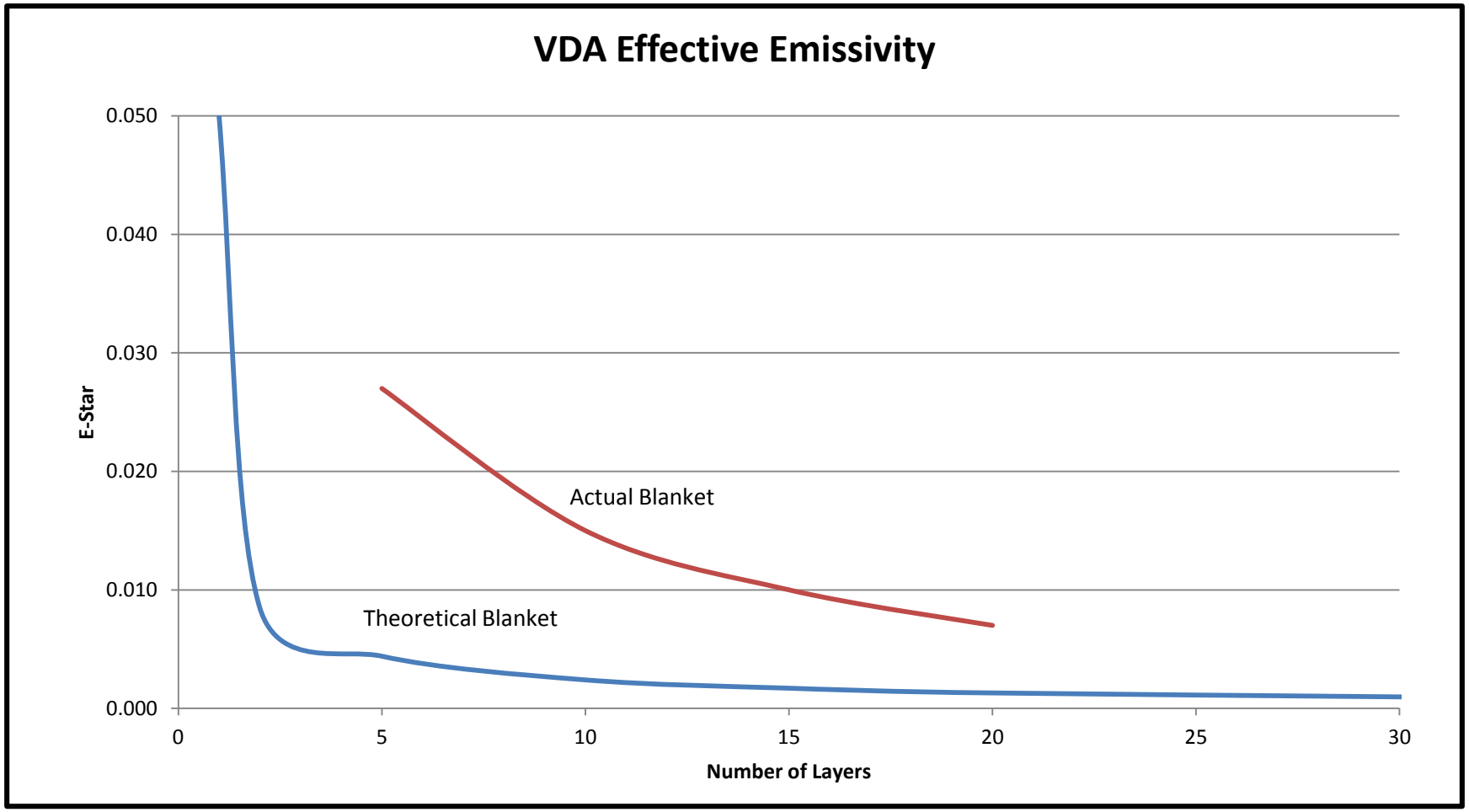
**Blanket Tech:**

"David, can you help me out? The Thermal Analyst can't tell me what he wants"

# Theoretical Blanket Effective Emissivity



# Actual MLI Blanket



# What affects MLI blanket ε*?

- Penetrations
- Ground Straps
- Crinkling
- Stitching
- Vents
- Separator layers
- Tightness
- Cryogenic Temperatures
- Atmospheric pressure

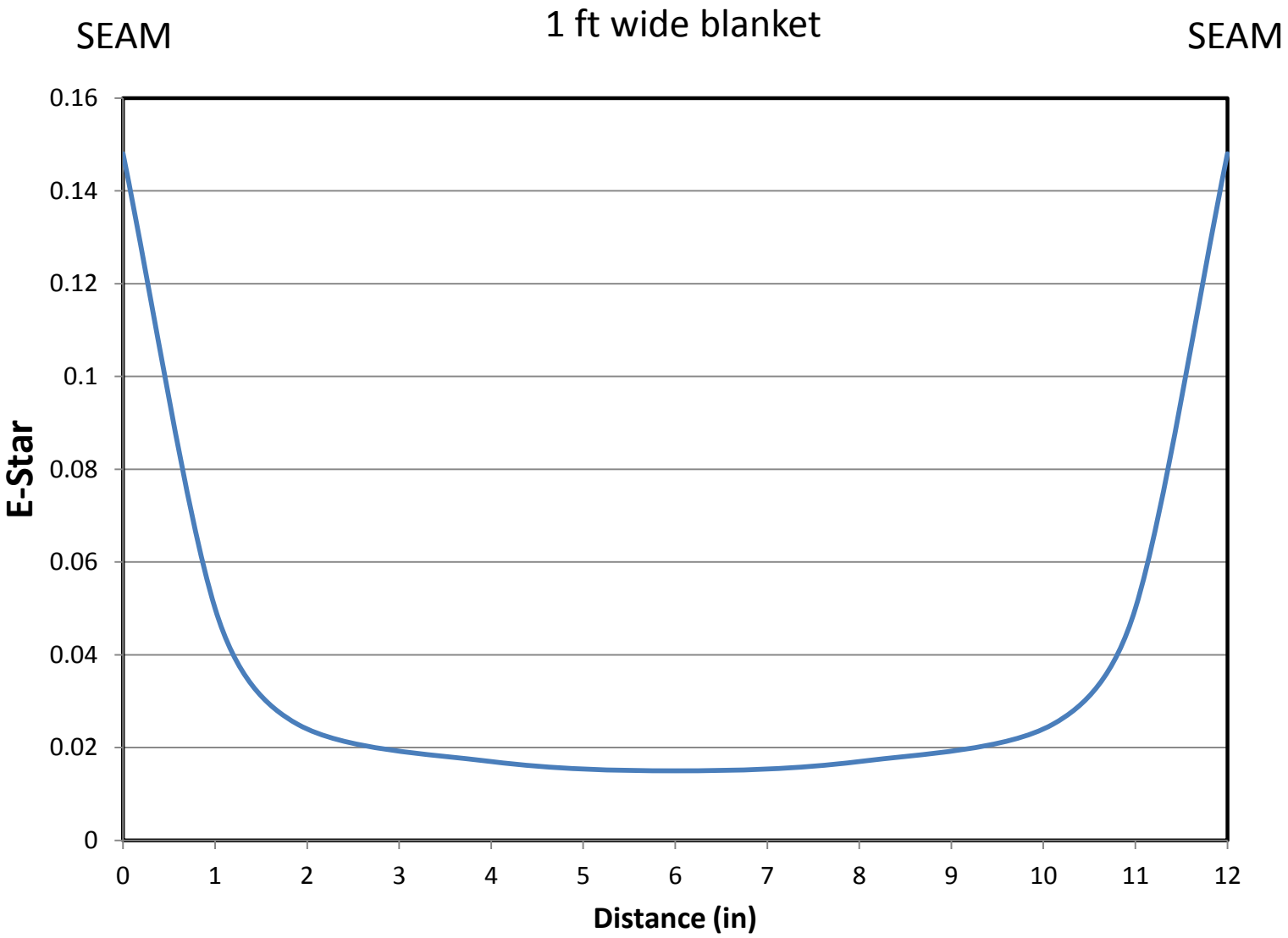
# What affects Optical Properties?

- Emissivity usually not effected.  Solar Absorptance will be with age.
- Atomic oxygen effects outer layer
  - Silver Teflon needs to be 10 mil instead of 5 mil thick in LEO
- Alpha increases with age (BOL vs. EOL)

# Touching Layers = Bad

- 1 $ft^2$ blanket covering $30^{O}C$ surface:
  - Good MLI blanket design = 1.2 watts lost
  - Smashed blanket = 38 watts lost

# Stitching Effects

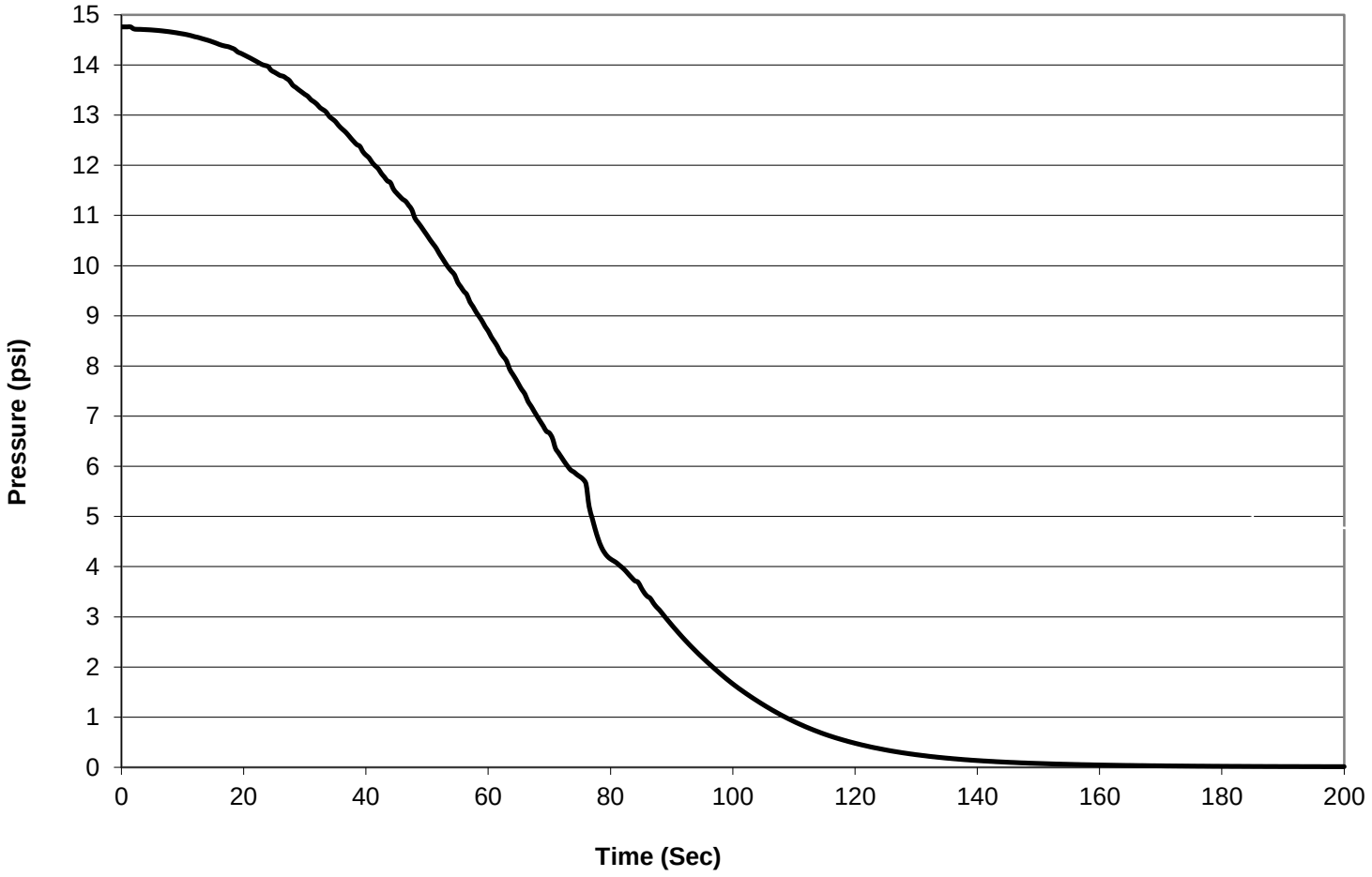


# Blankets Vent or Blow Up

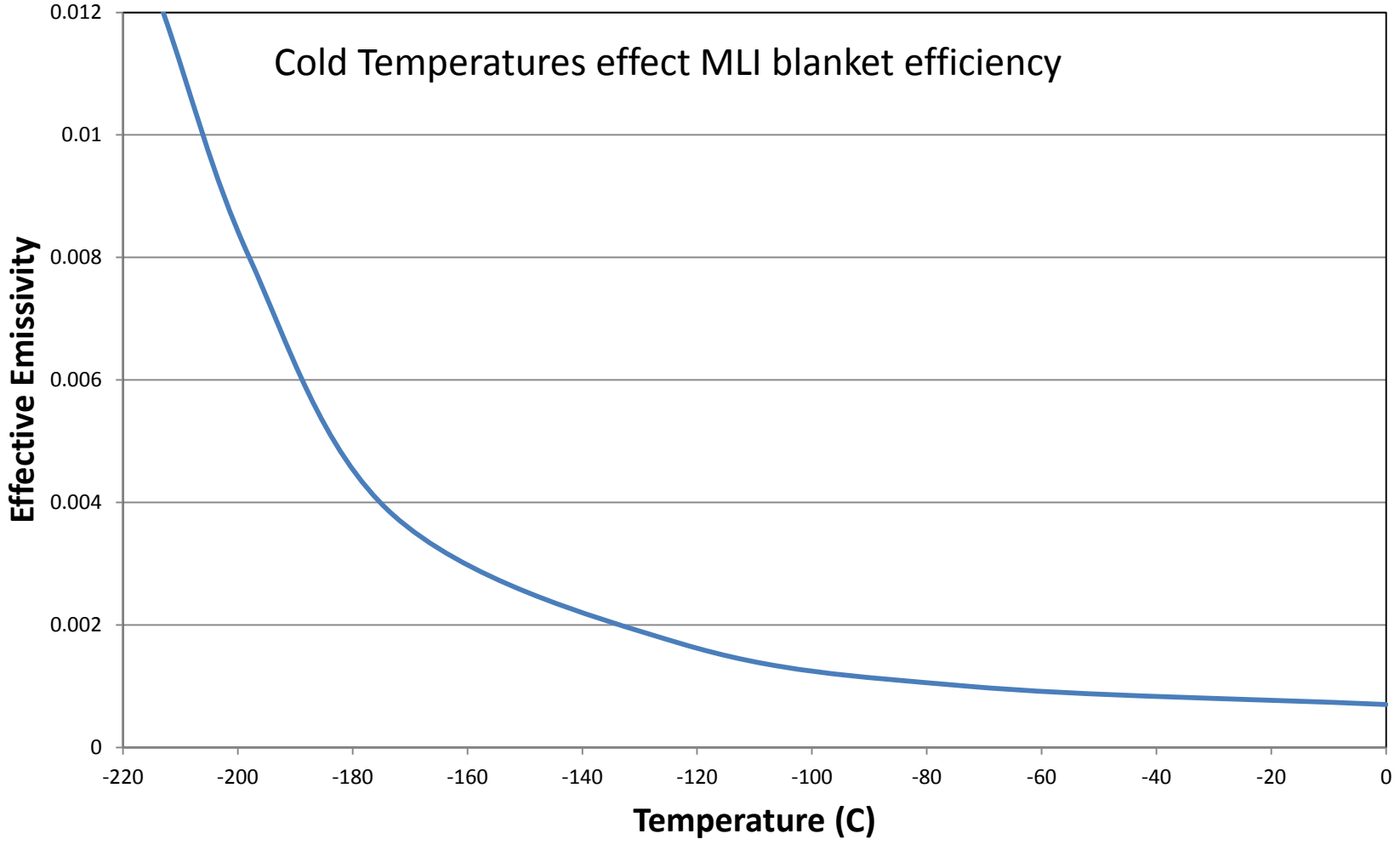
- Air Pressure on ground
  - 14.7 psi
  - 2117 lbs per square foot.
  - But pressure in Space = 0 psi.
- Blankets usually go from Ground to Space (or inside T/V chamber)
  - Air around MLI goes from 14.7 psi -> 0.
- MLI Blankets can only handle 0.1 psi (14.4 lbs per square foot).
- Venting needed:
  - Between MLI layers (or risk blowing up)
  - Between MLI and underlying metal (or risk blowing off surface)
  - Eliminate Gas conduction

# Generic Launch Pressure

Inside Fairing

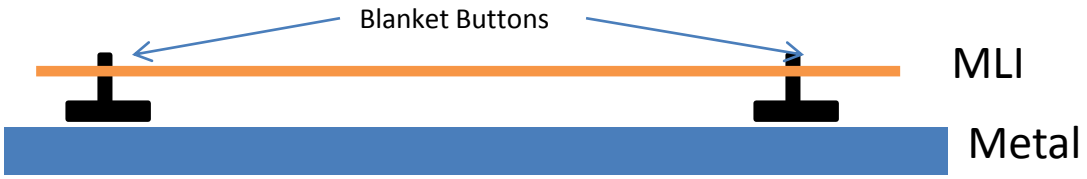


# Cryogenic Temperatures

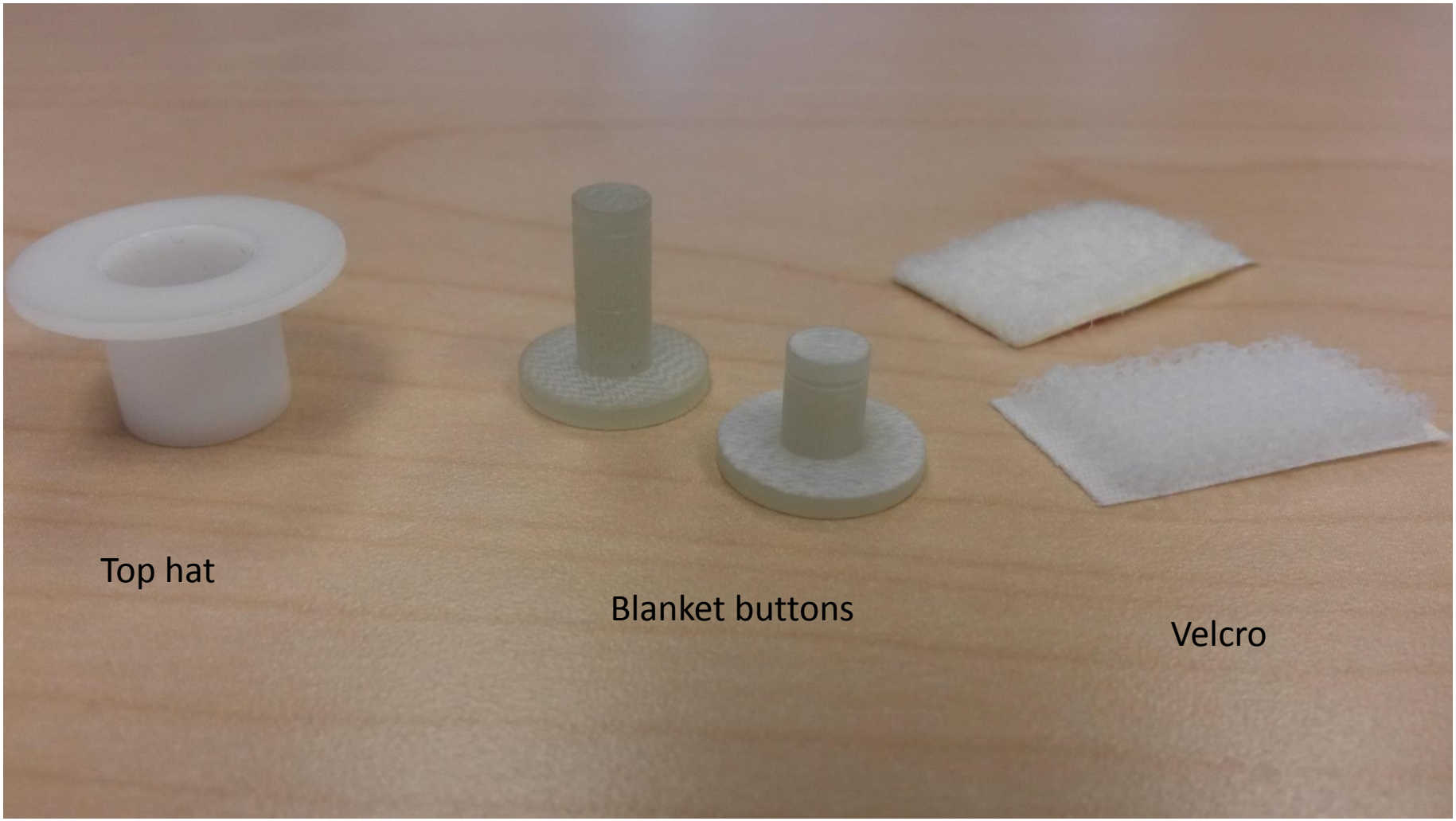


# Things Grow and Shrink

- Coefficient of Thermal Expansion
  - Things grow bigger when hot
  - Things shrink when cold
  - Aluminum shrinks/grows a lot compared to Kapton
    - CTE = 0.000026 in/in $^{O}$C
    - 72 inch piece, from -20 $^{O}$C to +40 $^{O}$C grows 1/8”



# Blanket Buttons, Etc…



# ClickBonds

(For heavier or thicker blankets)

# Bonding techniques

- Buttons, Thermistors, Thermostats typically bonded with Stycast 2850FT Cat 9
  - Small bondline, so thermal resistance is low.
- Polymerics license required for bonding Flight hardware.
- Surface preparation is key to a good bond:
  - Clean surfaces
  - Abrade surfaces with sandpaper
  - Vacuum, then clean surface again
  - Hold down with Kapton until epoxy dries overnight.
    - Think about how to handle vertical surfaces!

# Thermostats

- Typically bought from Honeywell.
- Type 700 is typical thermostat style

Style 701 (standard)

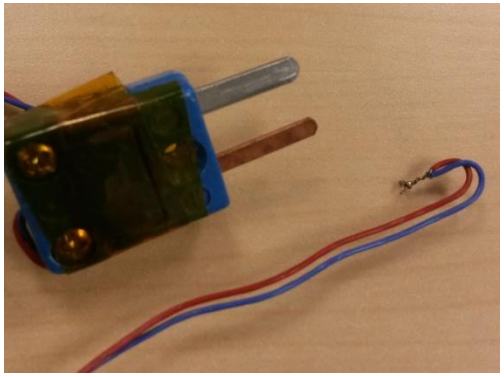
Style 717 (Prop lines)

# Heaters

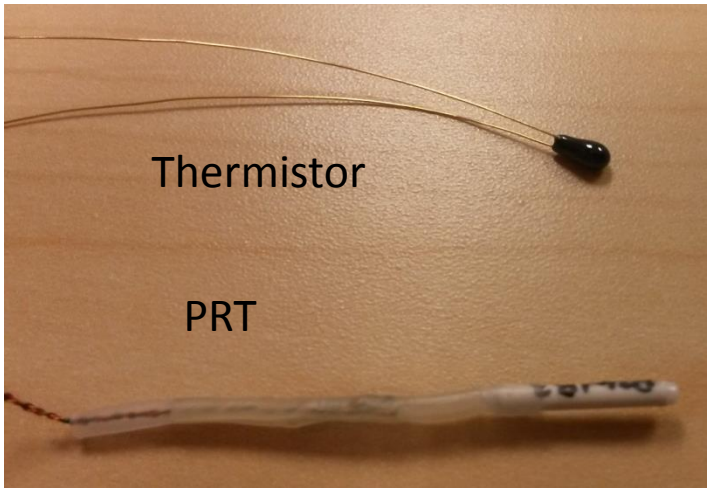
- Kapton Thermofoil Heaters
- Applied with 3M Y966 Acrylic Adhesive
  - Low outgassing
  - Y966 adhesive good to about +100$^{O}$C
    - Bond with Stycast Epoxy if hotter than +100$^{O}$C, or watt density higher than 3.5 W/in2
  - Overtaped with 3M 425 aluminum tape to help spread out heat.

# Temperature Measuring

- Thermocouple
  - Cheap and easy.  Voltage vs. Temperature
    - Remove after T/V testing or flyaway (snip and ground).
    - Type T or Type K.  Make sure which one you are using!
    - Attach with 3M 425 Aluminum Tape



- Thermistor
  - Non linear Ω vs. Temperature (negative slope)
  - Resistances 2252 Ω, 5K, 10K, etc…



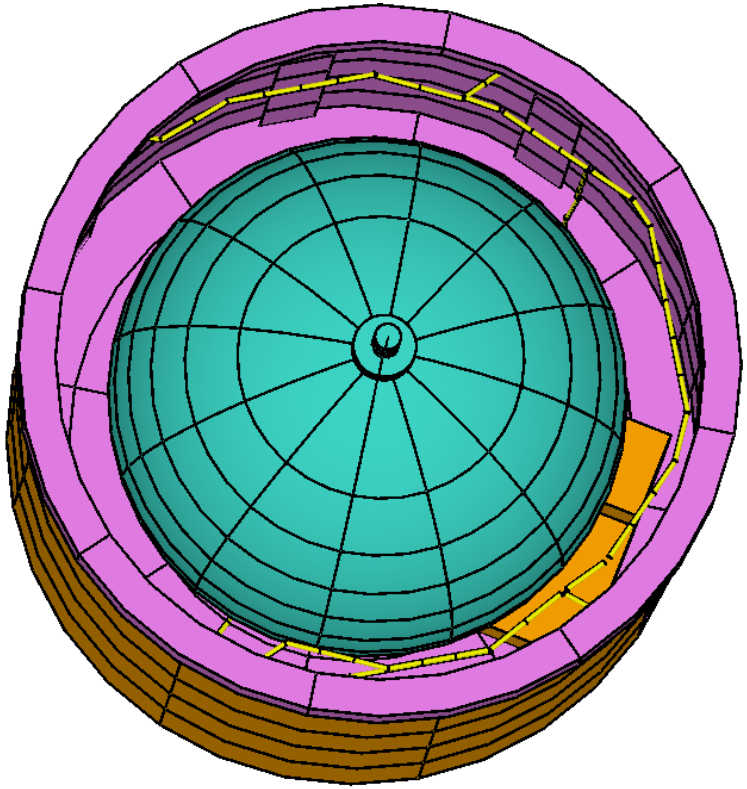

- PRT
  - Very linear Ω vs. Temperature (positive slope)
  - Usually used for high or low (cryogenic) temperature.
  - 4 wire variety enhances accuracy if needed (usually cryogenic).  Removes resistance of leads.
  - Resistances usually 100 Ω

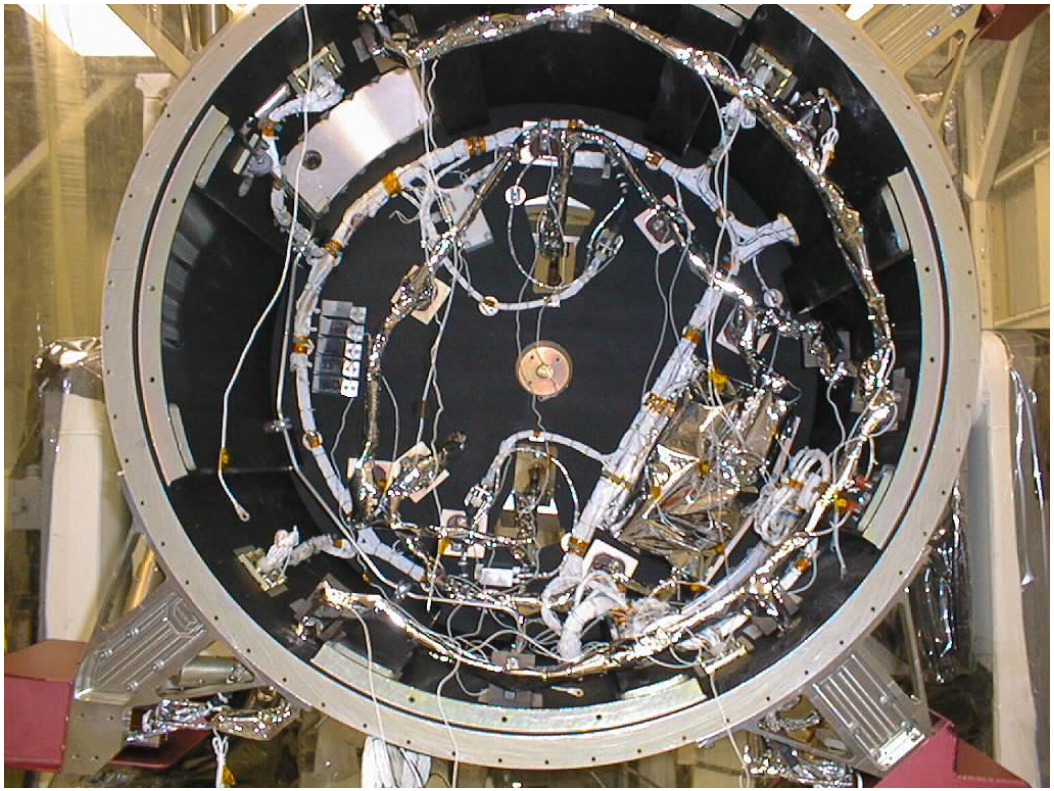
# Thermal Enhancement

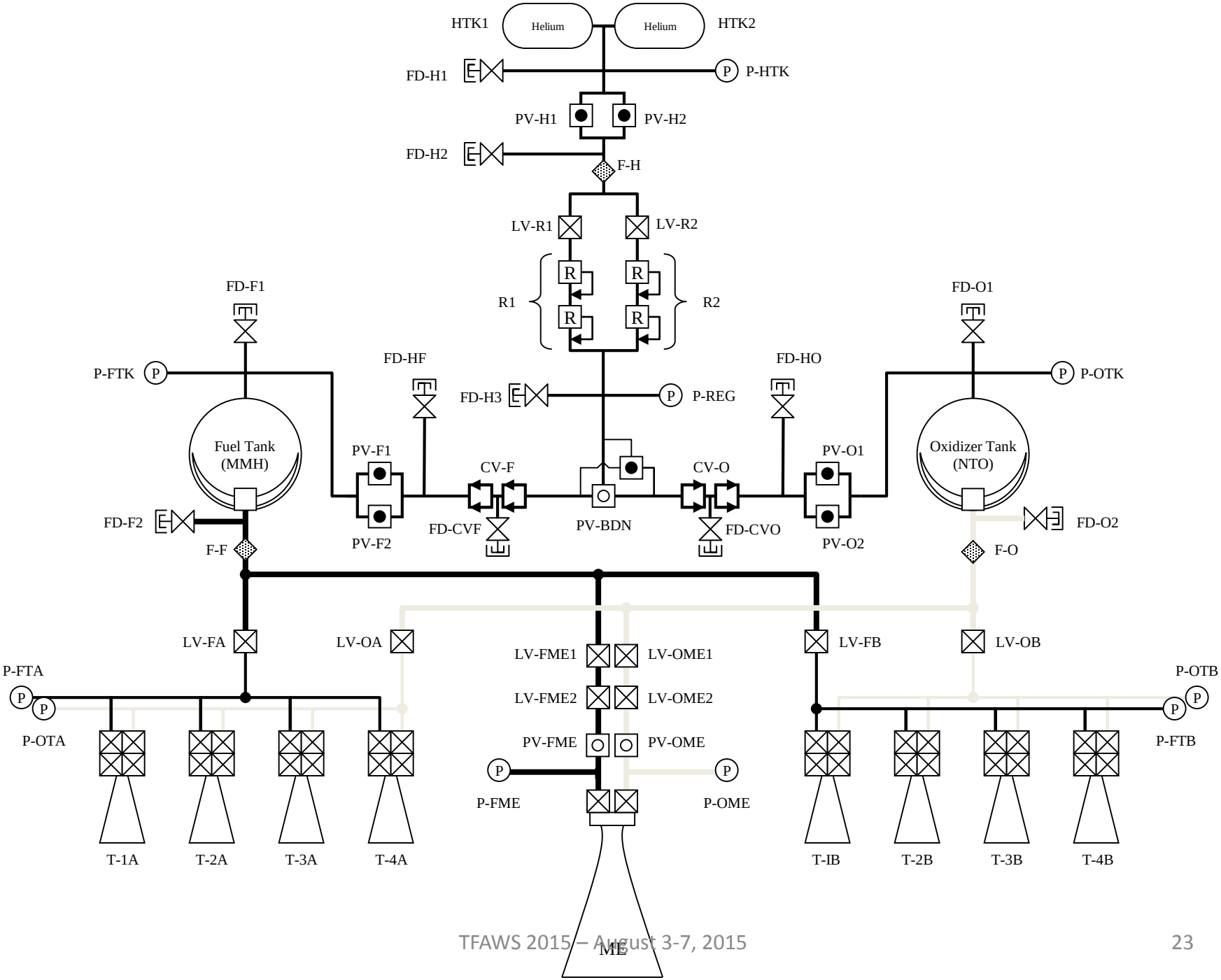
- Nusil CV-2946
  - 2-part material which needs to be mixed beforehand and degassed.
  - Stored in a freezer or hardens in an hour
  - Use Miller-Stephenson MS-143H as a release agent if needed. Teflon particles. Apply 3 layers.


- Arathane
  - mixed with 30-40% Boron Nitride also good.
  - Cabasil makes it thick.

# Propulsion Systems






HTK1
Helium
Helium
HTK2
FD-H1
P
P-HTK
PV-H1
PV-H2
FD-H2
F-H
LV-R1
LV-R2
R1
R2
R
FD-F1
FD-O1
P-FTK
FD-HF
FD-H3
FD-HO
P-OTK
Fuel Tank
(MMH)
PV-F1
CV-F
CV-O
PV-O1
Oxidizer Tank
(NTO)
FD-F2
PV-F2
FD-CVF
PV-BDN
FD-CVO
PV-O2
FD-O2
F-F
F-O
LV-FA
LV-OA
LV-FME1
LV-OME1
LV-FB
LV-OB
P-FTA
P-OTB
LV-FME2
LV-OME2
P-OTA
PV-FME
PV-OME
P-FTB
P-FME
P-OME
T-1A
T-2A
T-3A
T-4A
T-IB
T-2B
T-3B
T-4B
ME

# Analyst vs. Hardware

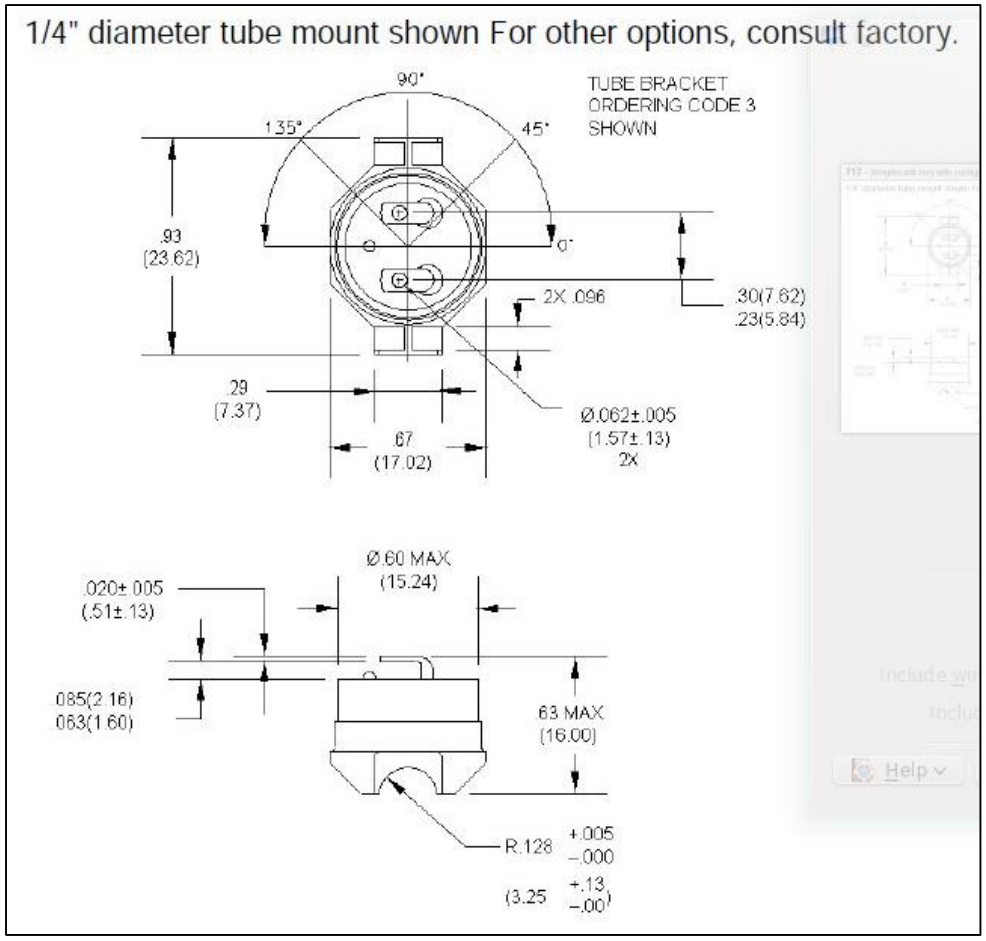
- **Analyst:**
  1. SINDA model has heaters on all nodes of a prop line.
  2. Use CALL HEATER subroutine for thermostat cycling.
  3. Use e* of 0.05 for MLI

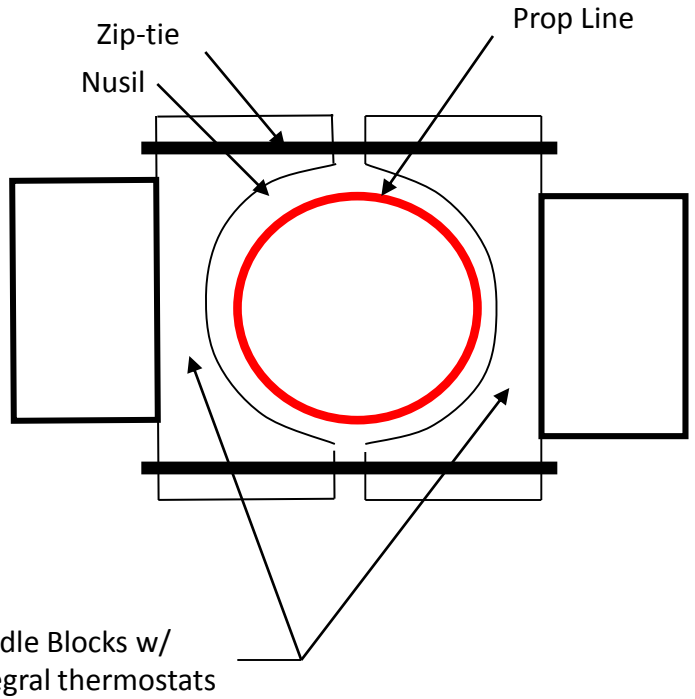
- **Hardware:**
  1. Install Thermostats on Saddle Blocks. Pot terminals if necessary
     Or buy 717 style Honeywell Thermostats.
  2. Install thermostats/Saddle blocks on Prop Lines with Nusil and zip ties.
  3. Wrap spiral Kapton heater around line
  4. Hold down with 1 layer of 3M 425 Aluminum tape.
  5. Apply 2nd layer of Aluminun tape
  6. Add Thermocouple for T/V testing.
  7. Wire everything up
  8. Wrap MLI around pipe
  9. Ground the MLI with its Ground Strap to structure

# Spiral Kapton Heaters for Prop Lines

# Prop Line Tstats on Saddle Blocks

Honeywell Model Style 717



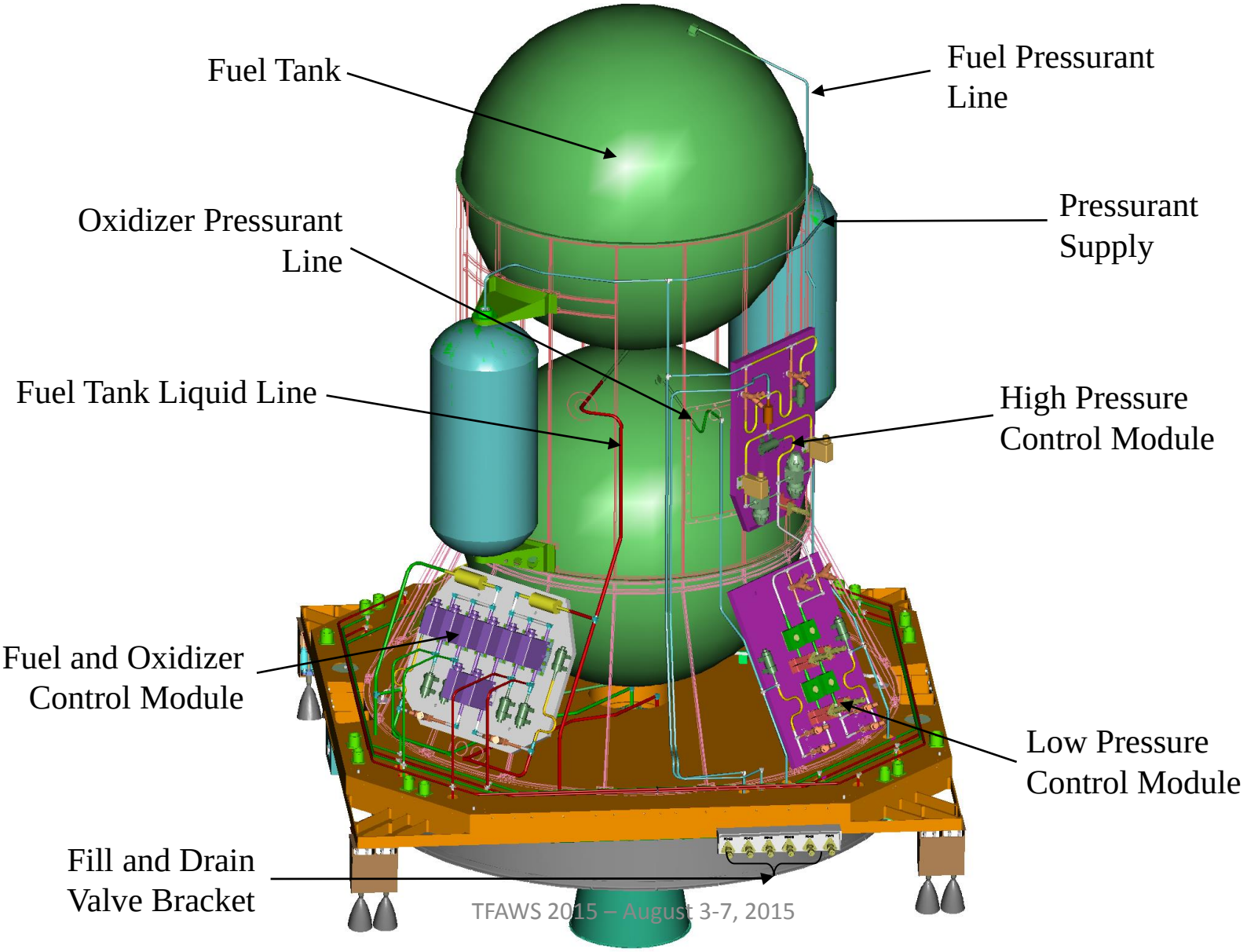



# Propellant Liquids

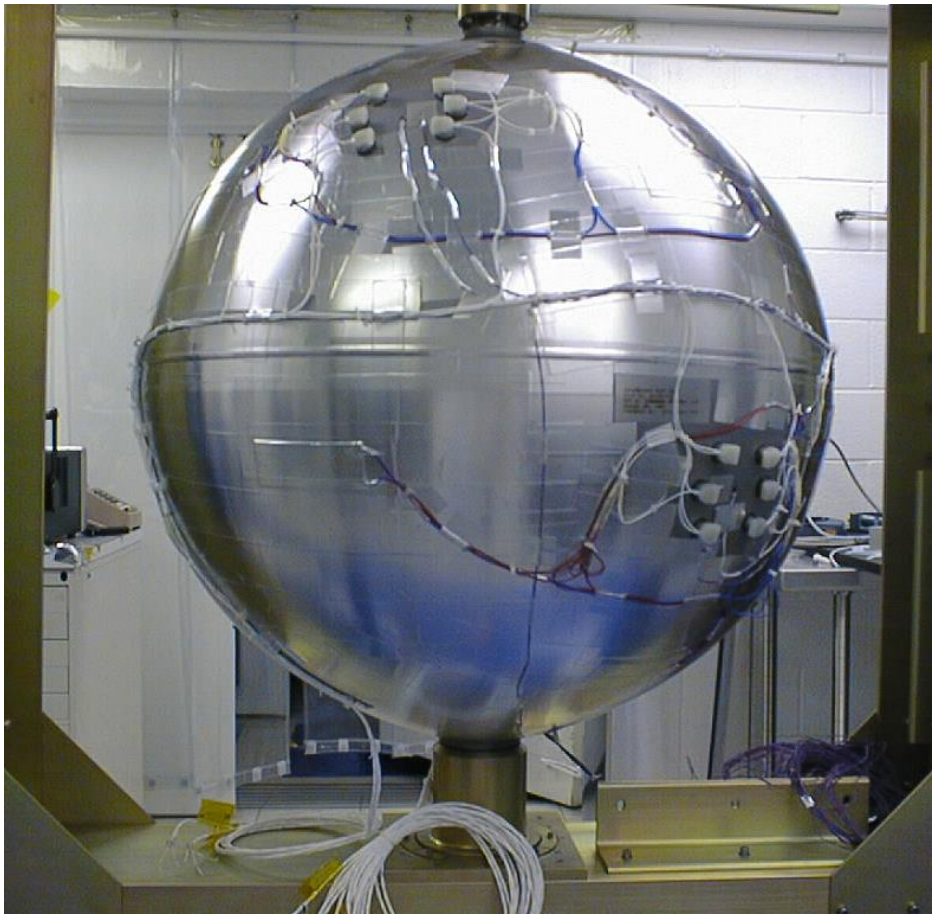
- Monoprop:  Hydrazine

- Bi-Prop (Fuel + Oxidizer)
  - Monomethyl Hydrazine (MMH) is the fuel
  - Nitrogen Tetroxide (NTO) is the oxidizer
    - The freezing point can be lowered if you add nitric oxide.
    - The resulting oxidizer Mixed Oxides of Nitrogen (MON).
    - NTO has a freezing point of about -9$^{O}$C
    - MON-3  (3% nitric oxide) freezes at -15$^{O}$C
    - MON-25 (25% nitric oxide) freezes at -55$^{O}$C

# Propulsion Module Plumbing



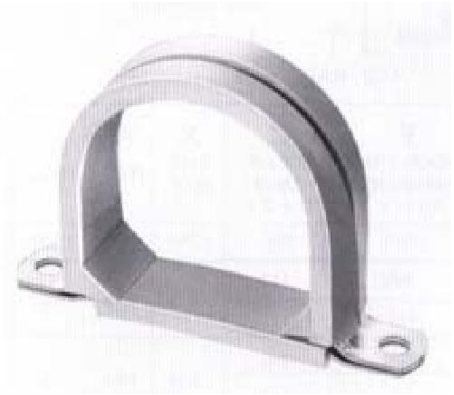
# Propulsion Tanks



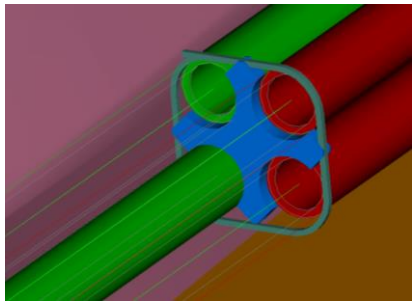
- Aluminum Tape
- Thermostats
- Thermistors
- Heaters
- MLI blanketing

# Propulsion Line Supports

- Plumbing lines are supported by thermally isolating brackets and standoffs
  - Machined Ultem 1000 Or Ultem 1200UC
  - Brackets are bonded or bolted to the primary structure
- Lines can be held with compliant clamps
  - Tefzel Cable ties may be used for off module plumbing runs – common for commercial satellites

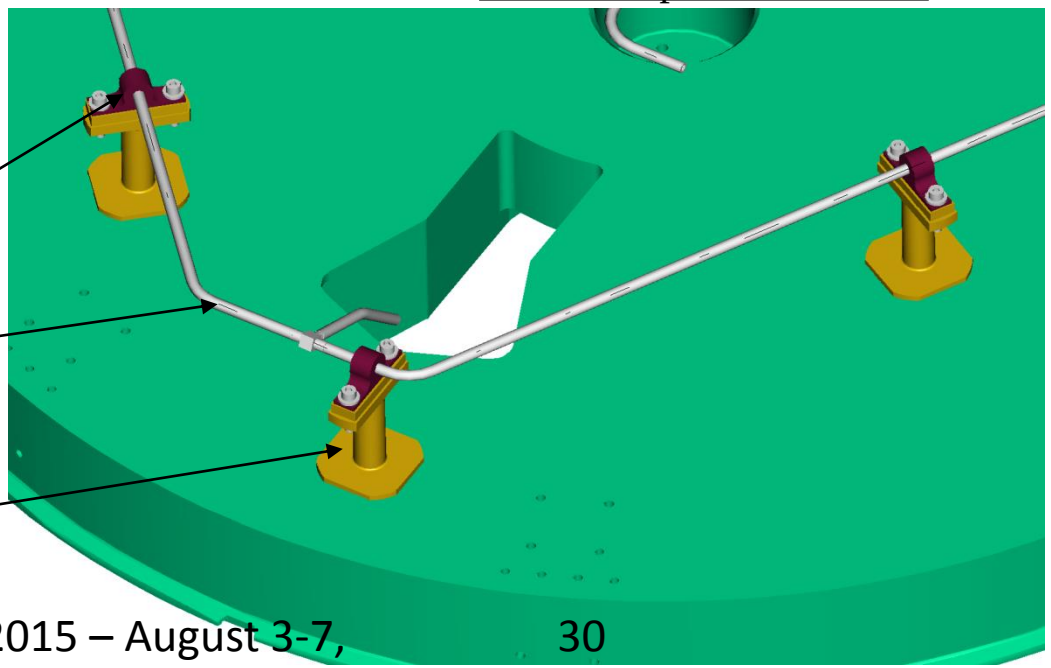


Saddle Clamp

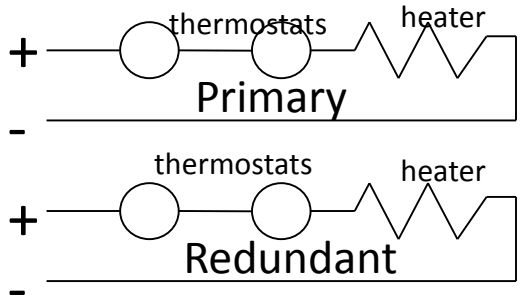


"Racetrack" tube spacer and Tefzel Cable Tie

Triana Propulsion Module

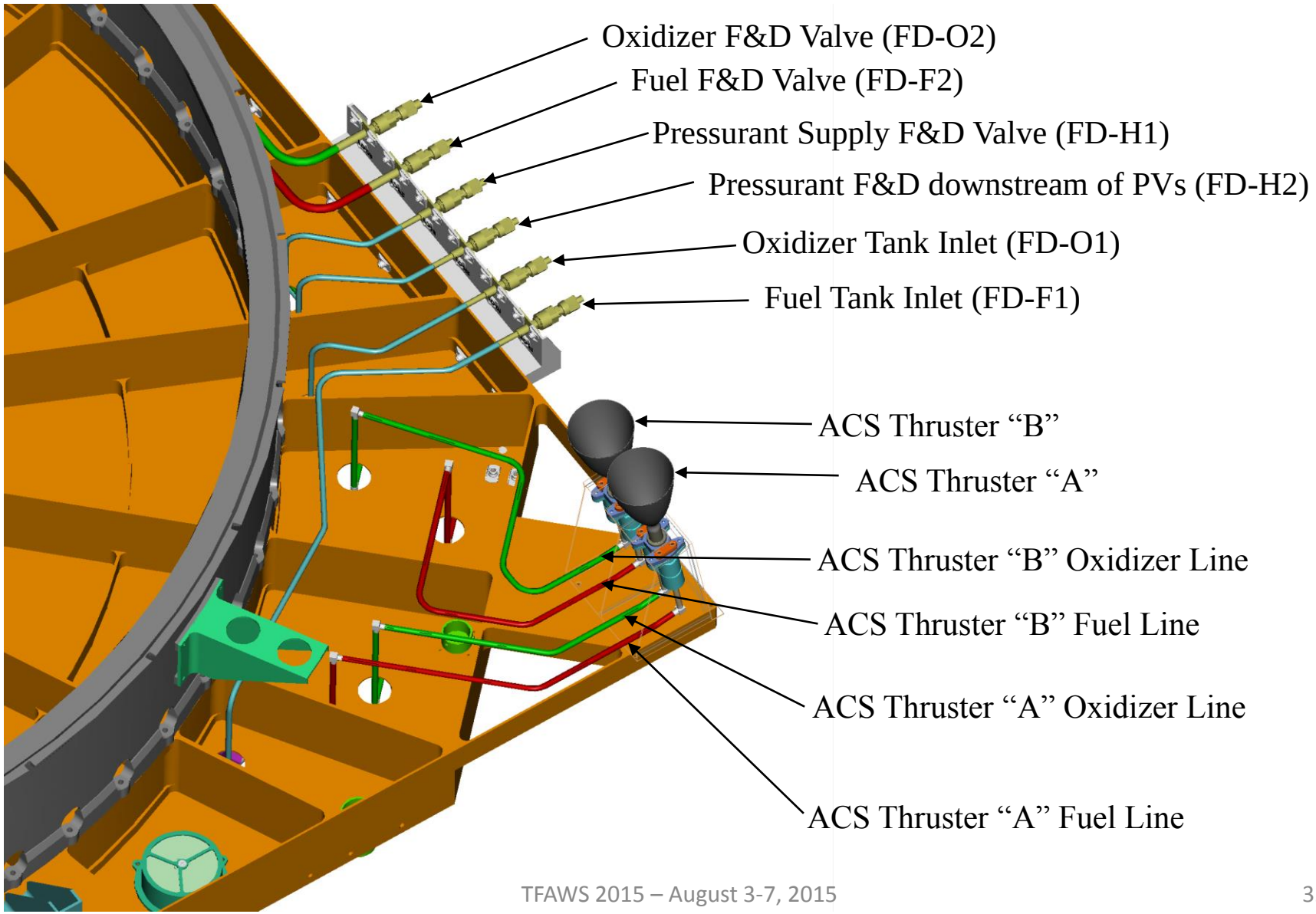


# Propulsion Heaters




- Liquid Lines:
  - Entire length MLI blanketed
  - Heated with standard thermal practices
    - Dual element spiral Kapton heaters adhered with aluminum tape.
    - Two mechanical thermostats in series. Mounted in pairs on saddle blocks.
- Propellant Tanks:
  - Dual element Kapton Heaters
- Control Modules
  - Dual element Kapton patch heaters on baseplate
- Thruster Valves
  - Dual element Kapton patch heaters, mechanical thermostats.
  - Cat bed heater or chamber heater used pre-firing

# Fill and Drain Valve and Thruster Plumbing



# Course Summary

- Learned about “real” vs. theoretical MLI
- Learned about “Actual” thermal hardware instead of “Thermal Model” Hardware.
  - Their bonding techniques and materials.
- Learned about the special case of Propulsion Thermal.