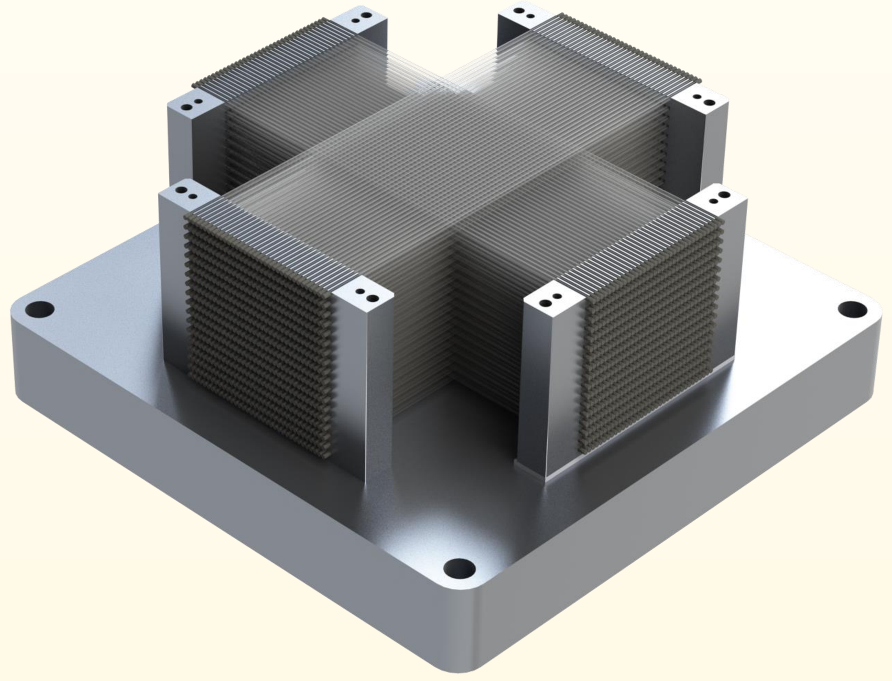

Design of Neutron Spectrometer Housing by Analysis of Failure Criterion

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Background

- Personnel in space are exposed to high-energy neutrons
- The amount of exposure that a human may be exposed to in these environments is a limiting factor in space exploration
- NASA will attach a neutron spectrometer to the International Space Station (ISS) to measure and record the quantity and trajectory of neutrons to develop a safety exposure limit

Objective and Approach

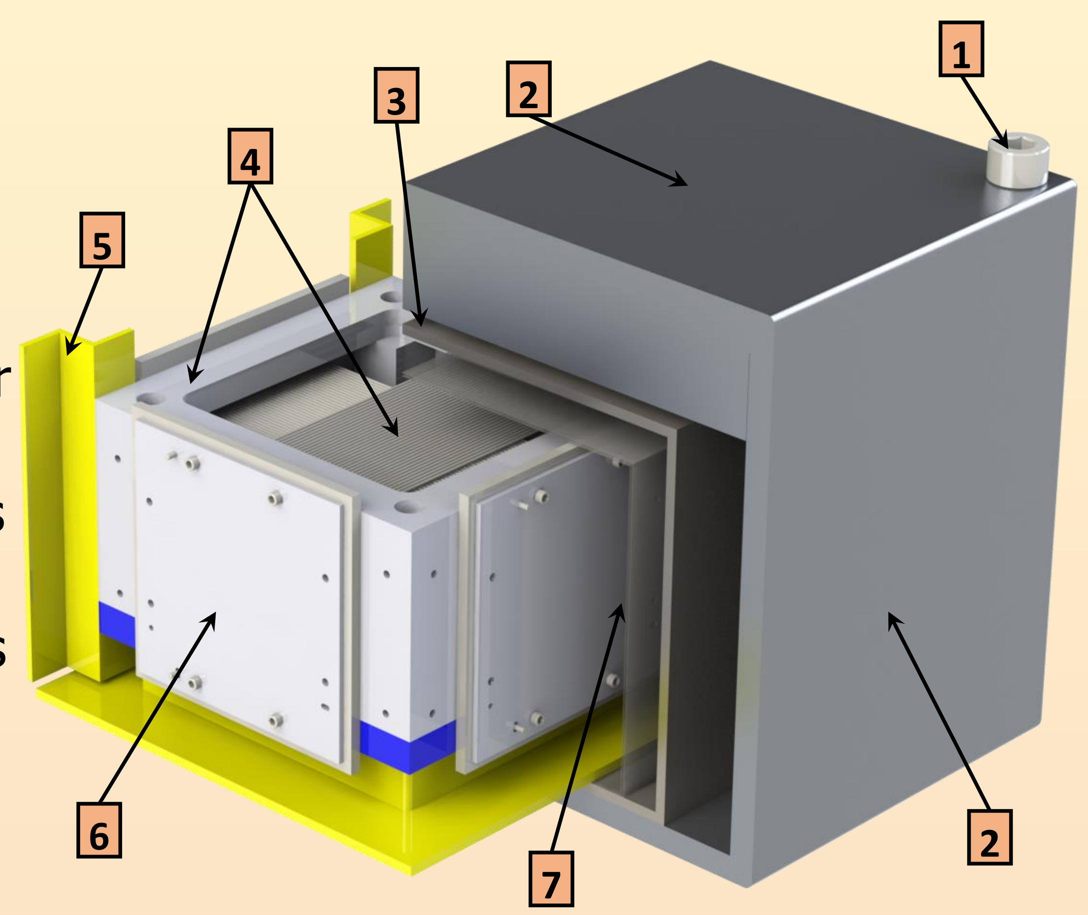
- Analyze thermal, vibrational, and structural loads that the spectrometer's transportation and operating environment present
- Design a housing for the neutron spectrometer to ensure its functionality
- Analyze and report the expected impact that the housing will have on the neutron spectrometer survivability

Design Criteria

- Spectrometer must maintain internal temperature between 15 and 45ºC to ensure functionality
- Housing shall withstand combined loading scenarios ranging from +8.5 to -4G of axial and ±3G of lateral acceleration
- Prevent fiber craze by designing against natural resonance
- Housing will utilize the least amount of material possible

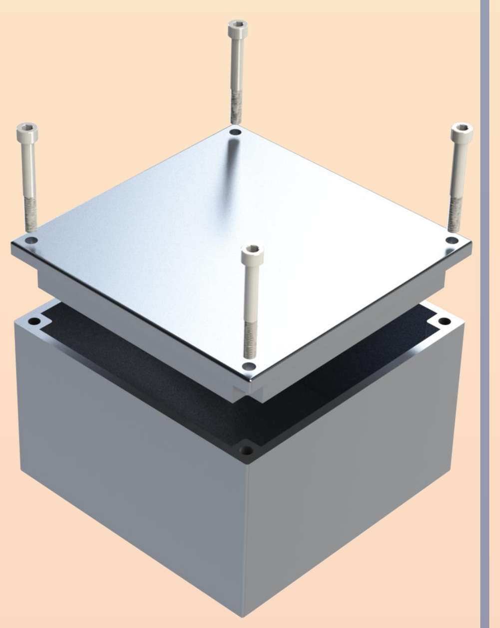
Key

1) Bolt for housing
2) Proposed housing
3) "Light Tight" Insulating container
4) Fiber network w/supporting shims
5) Spectrometer supporting brackets
6) Electronics
7) Inner Dual-layer polystyrene wrap



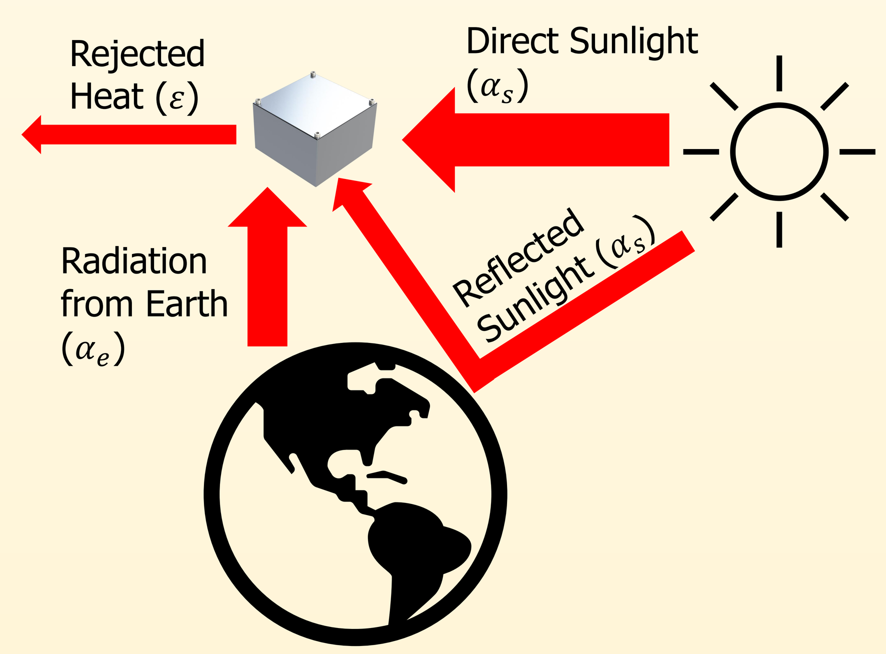
Housing Design Decisions

1. ***Fastening Solution:*** Partially threated bolts
2. ***Housing Type:*** Fully Encapsulated
3. ***Housing Material:*** Aluminum 2024
4. ***Machining Parameters:***
   a) .5mm filleted edges & corners
   b) 7.5mm wall thickness
   c) 80mm tapped holes

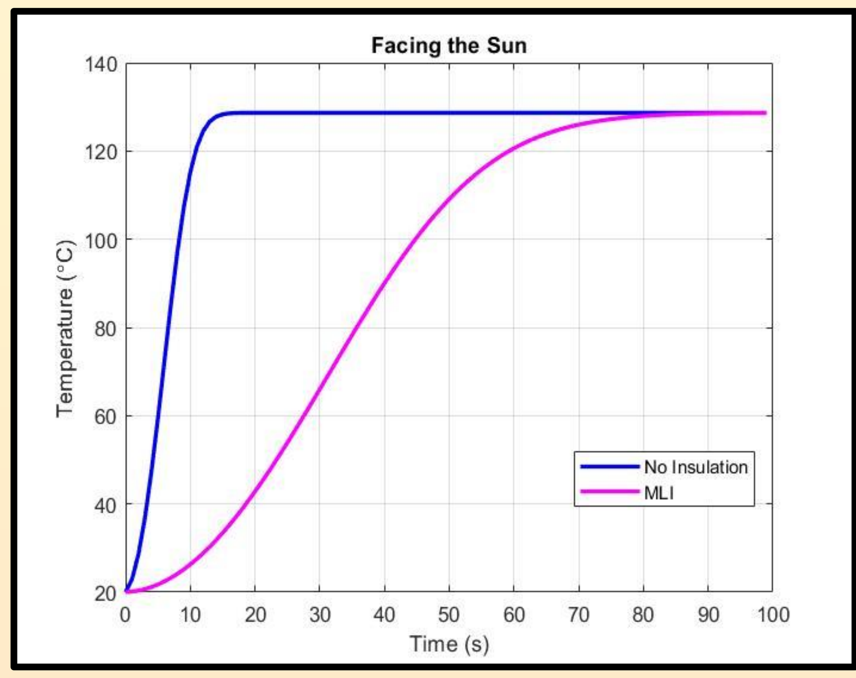


Thermal Analysis

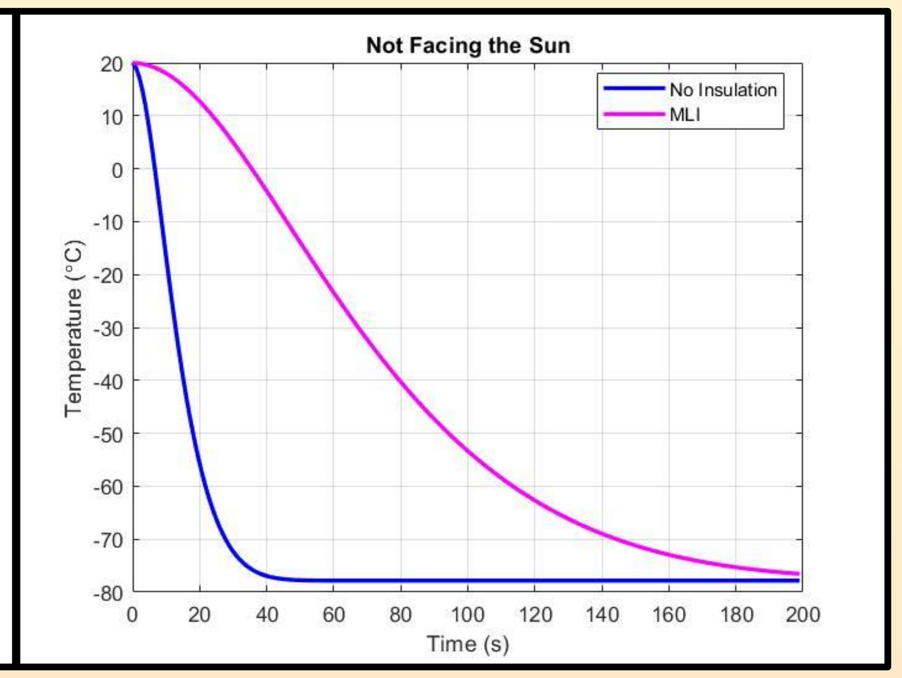
- Derived equations from energy balance eq.
- Absorptivity (α) from the Sun's radiation is greater than the absorptivity from Earth's radiation
- Aluminum 2024 has an emissivity (ε) of 0.09
- Sun is black body w/ a solar flux of 1418 $\frac{W}{m^2}$
- Earth releases an average infrared radiation flux of 237 $\frac{W}{m^2}$ which fluctuates ± 21 $\frac{W}{m^2}$
- Mass of housing is 10.767 kg



$$T(s) = \frac{\alpha_e G_e A + \alpha_s G_s A + Q_{albedo} - \varepsilon\sigma A_s T_s^4}{M C_p} t + T_s$$



Surface temperature profile while ISS faces the sun



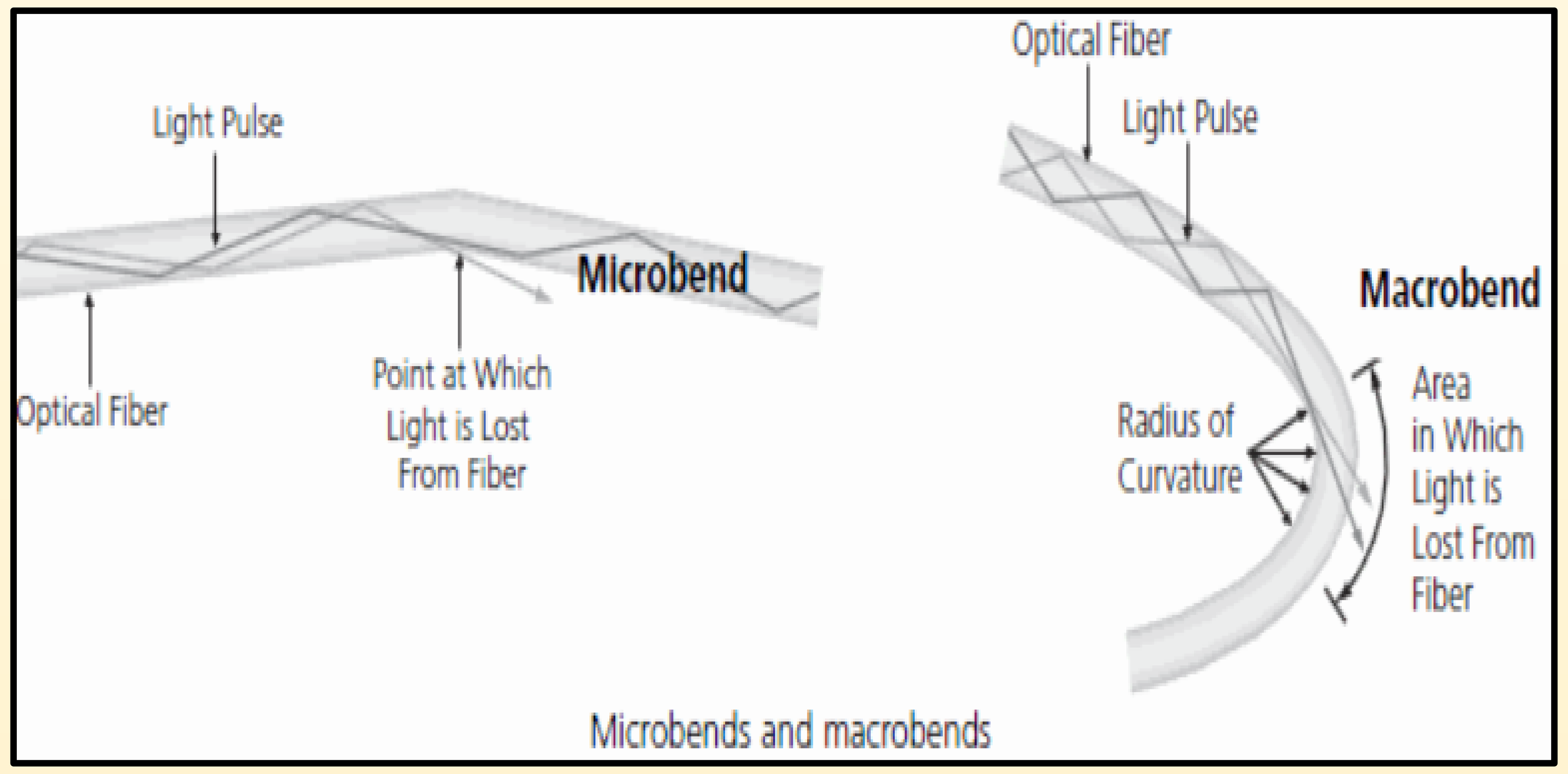
Surface temperature profile while ISS faces into space

- Final maximum temperature is 128.7°C
- Final minimum temperature is -77.83°C
- The Multi-Layer Insulation (MLI) blocks 96% of radiation
- MLI slows radiation process down by 6 times
- This analysis is only for aluminum 2024 and doesn't account for the extra time it would take for the inside of the housing to change temperature
- Another temperature controlling device is needed, MLI is not an independent solution
- Reflective material can help reduce radiation effects

Vibrational Analysis

Purpose

- Risk of fiber resonance due to scintillating fibers being mounted to shims on both ends
- If crazing occurs, then light in the fiber may be lost and measurements from the spectrometer may become inaccurate



Types of Vibrations

- Data from SpaceX's guide on the Falcon 9 rocket indicate that there are 3 vibrational force sources: Sinusoidal, aeroacoustics, and random booster vibrations
- The random & aeroacoustics vibrations have little impact because:
  - Random vibrations are attenuated by SpaceX
  - The housing is designed so that it minimizes the risk of failure
- The sinusoidal vibrations, which occur from 20 to 100 Hz pose the greatest threat
- Resonant frequency is derived from: $\omega_n = r * \pi \sqrt{\frac{T}{m * L^2}}$
  - This equation is dependent on the mass, length, tension in the fiber and the Rth natural frequency

rth natural Frequency Mode	Natural Frequency of Fibers (rad/sec)	Natural Frequency of Fibers (Hz)
1	2376.6	378.4
2	4753.1	756.9
3	7129.7	1135.3
4	9506.2	1513.7
5	11882.8	1892.2
6	14259.3	2270.6
7	16635.9	2649.0
8	19012.4	3027.5
9	21389.0	3405.9
10	23765.5	3784.3

Project Conclusion

- From the preliminary SpaceX data and analyses conducted upon the neutron spectrometer and its housing, a full-scale prototype is recommended for future work