Steady State Thermal Analysis of the 3U SPOC Satellite In ANSYS Workbench

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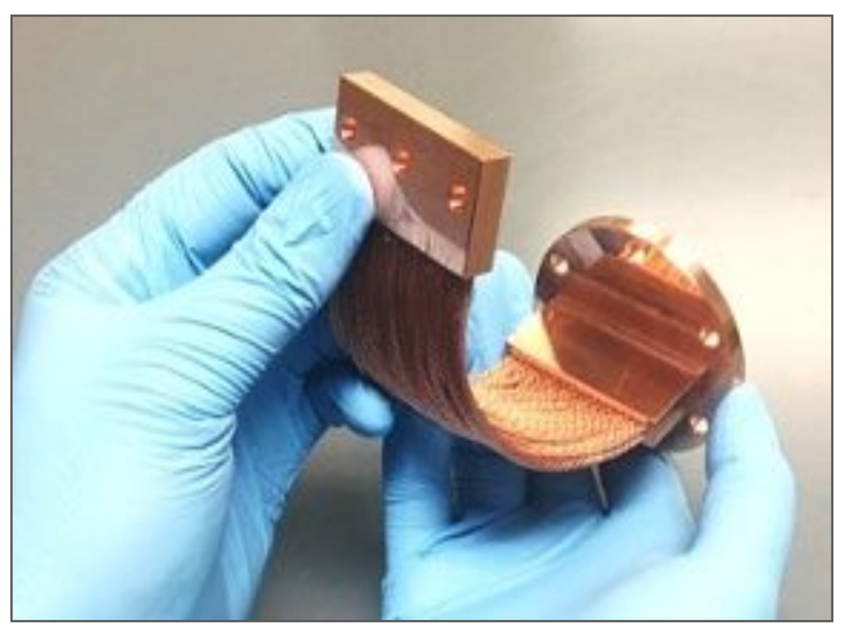
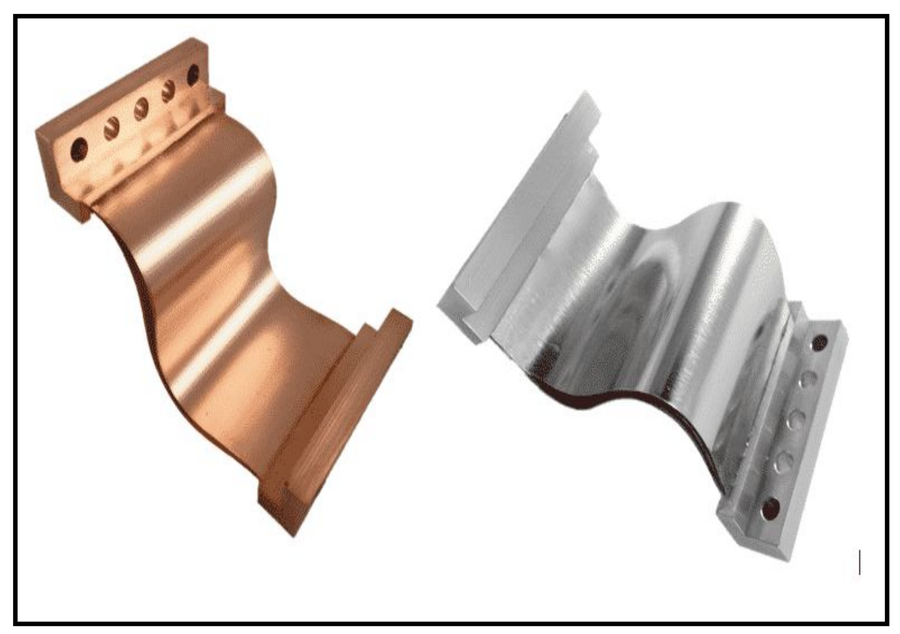
RESEARCH OVERVIEW

The mission of the Spectral Color Ocean(SPOC) CubeSat is to acquire image data to monitor coastal wetlands, wetland biophysical characteristics, and near coastal ocean productivity. The primary purpose of this research was to design and analyze two heat straps which are capable of transferring thermal energy from the S-Band Transmitter board and the Ultra-High Frequency Transceiver (UHF) boards. These boards are used to transmit and receive crucial data for SPOC. To achieve this goal, various analysis constraints were used as provided through the Small Satellite Research Laboratory(SSRL), as listed in the Preliminary Thermal Simulations and Results section of this poster.

However, during the course of this research, a discussion with the University Nanosatellite Program, which is connected to the Air Force Research Laboratory advised the SSRL that the best course of action in relation to heat straps was to use solid copper or aluminum straps and to avoid the braided/foiled variety due to the significant loss of thermal energy transfer within heat straps designed in that manner.

Figure 1: a) image of a thermal strap source: www.techapps.com b) image of foil heat straps source: www.thermal-space.com





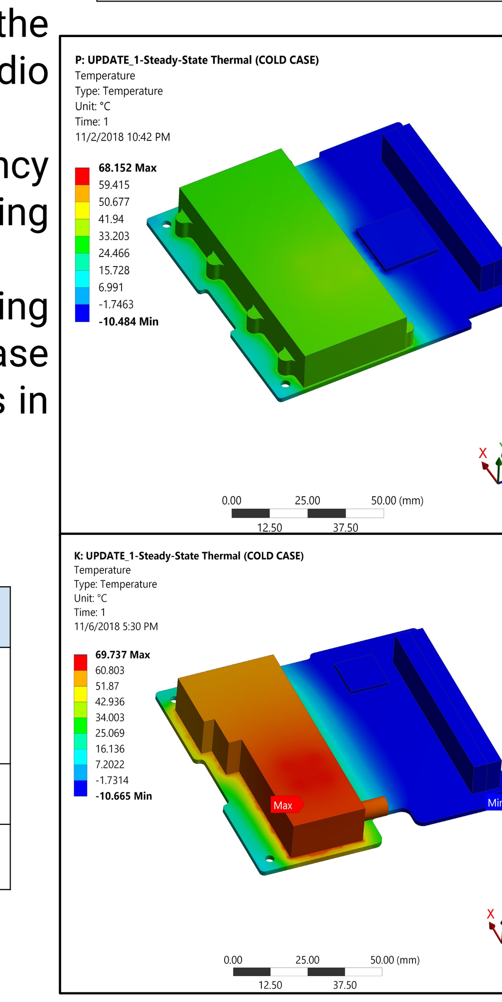
Preliminary Thermal Simulations and Results

Prior to the addition of heat straps, thermal simulations in ANSYS Workbench were run upon the S-Band Transmitter and UHF Boards. Constraints used in the analysis of the S-Band Transmitter board were those of a 4.83W power draw, with a 5% contingency as well as a 20% quoted efficiency from the producer of the board.The simulation was run with an applied load of 3.84W placed on the small copper Radio Frequency(RF) transmitter located under the casing in bottom figure 2.

Constraints applied to the UHF Board were those of a 5.335W power draw with a similar 5% contingency applied. The efficiency of this board was however quoted at 50%, which led to the applied load being 2.6775W placed at the RF transmitter which is similarly housed under the aluminum casing in figure 2.

Simulations were run in both cold and hot case ambient environments to simulate the surrounding temperature within the avionics stack. The hot case ambient temperature was 30 °C while the cold case ambient temperature was -10 °C. Results show that the boards overheat at their maximum temperatures in both the hot and cold cases, which is why heat straps became necessary for the mission to continue.

Figure 2: Thermal gradients from cold case simulations on both boards.



Board	S-Band	UHF
Min/Max Operating Temperatures [°C]	-25.0 °C to +61.0 °C	-25.0 °C to +61.0 °C
Cold Case Temperatures [°C]	-10.7.0 °C to +69.7 °C	-10.5 °C to +68.2 °C
Hot Case Temperatures [°C]	30.2 °C to +93.5 °C	30.2 °C to +96.5 °C

Table 1: Results from the Avionics Thermal simulations representing both extreme ambient situations.

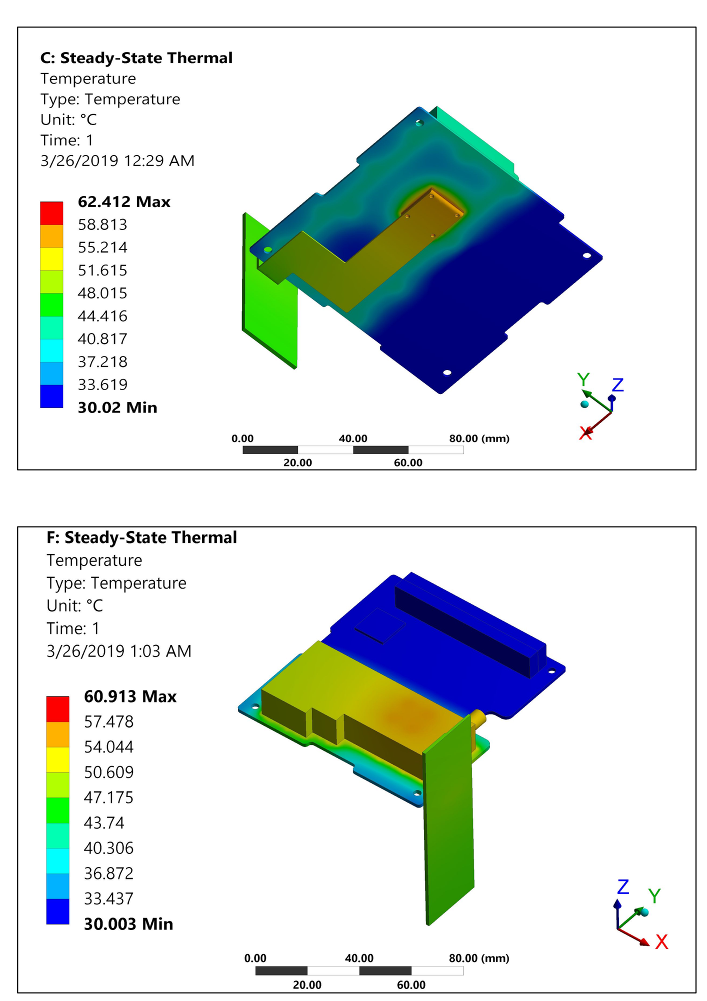
THERMAL SIMULATION PROCEDURES AND RESULTS

For thermal simulations, the geometry of the boards were imported into ANSYS along with the CAD model of the straight copper heat straps. The heat straps were then modeled as C10100 Oxygen Free High Thermal Conductivity(OFHC) material in order to replicate the material properties of the copper that would be used to machine the heat straps.

Afterwards, the hot and cold case steady state thermal simulations were run on the boards with the heat straps attached. Data from these simulations can be found in Table 2.

While the maximum temperature values within the hot case simulations of both boards still goes 1 to 2 degrees above the maximum operating temperature of these boards, a large improvement can be seen within the thermal energy flow from these boards with the use of the copper heat straps. If these simulations had been run using braided or foil heat straps, the thermal conductivity of the straps would have fallen to approximately half of the solid copper straps, causing less thermal energy transfer within the strap itself.

Figure 3: a) Hot case simulation of UHF board using the heat strap. b) Hot case simulation of the S-Band board using the heat strap.



Board	S-Band	UHF
Min/Max Operating Temperatures [°C]	-25.0 °C to +61.0 °C	-25.0 °C to +61.0 °C
Cold Case Temperatures [°C]	-9.98 °C to +29.97 °C	-9.93 °C to +26.52 °C
Hot Case Temperatures [°C]	30.0 °C to +61.79 °C	30.0 °C to +62.4 °C

Table 2: The temperature results for simulations run using the designed heatstraps.

CONCLUSION AND THE FUTURE OF SPOC

Despite the fact that the simulations with the heat straps take away a significant amount of thermal energy from these boards, they remain at a slight risk of overheating in their steady state simulations. However, it remains important to keep in mind that the type of simulation used in this scenario involved applying a load to the board and waiting until the rates of heat transfer became constant.

In reality, these transmitter and transceiver boards will only operate during uplink/downlink periods to transmit and receive information from the SSRL Ground Station, and will not be generating heat for significant amounts of time. This does not excuse us from finding other methods of increasing the rate of thermal energy transfer through the copper heat straps. One option that is currently being considered is the use of Arctic MX-4 Thermal Compound Paste to increase the thermal conductivity at the interface between both the circuit boards/copper heat straps and at the interface between the copper heat straps and the respective locations on the frame they will be attached to.

The designed heat straps are currently at the UGA Instrument Design & Fabrication Shop being cut from C10100 OHFC Copper and will be prepared for the SPOC CubeSat in the coming weeks.

The assembly of the SPOC CubeSat will begin within the next few days, spanning across the next few weeks. Afterwards, SPOC will undergo a series of vacuum chamber and vibration tests in order to guarantee that it will function properly in space and survive the vibrations of the rocket taking it into space. Finally, SPOC will be handed off to Nanoracks in July of 2019 to undergo the final steps of flight preparation.

SPOC will then launch in October or November of 2019.

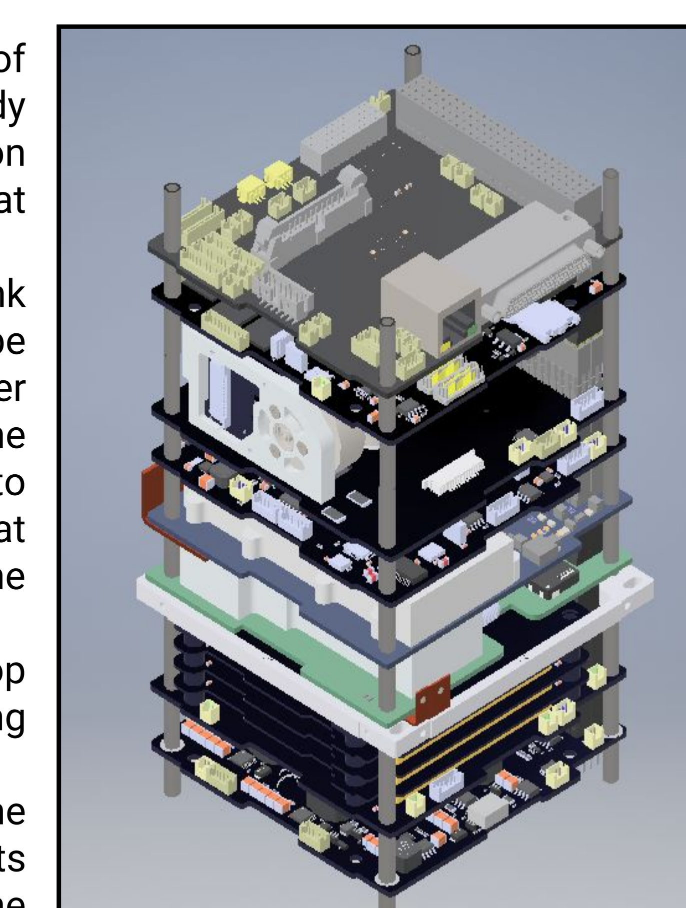


Figure 4: a) CAD of the avionics stack of SPOC with the heat straps attached

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