The thermal analysis was carried out using the multi-purpose software tool COMSOL Multiphysics. This tool allowed us to model one 4-cell pack with a simplified version of the OBPP. The materials that were used were aluminum (battery cells, battery terminals, heat sink and tray), copper (battery terminals, conductive slabs and power resistor), FR4 (circuit board) and acrylic plastic (bottom plastic frames). The main purpose of this analysis is to:

- Provide an intuitive visual thermodynamic analysis of the proposed system design.
- Figure out the best location to place the temperature sensor on the circuit board is another goal to be accomplished through this analysis.
- Figure out if a heat sink is needed on the circuit board.

There were three scenarios that were simulated with both a stationary analysis and a time-dependent analysis as well. The three (3) scenarios that were done in simulation are the following:

1. One battery cell is overheating.
2. All four battery cells overheating.
3. Bypass resistor overheating with no heat sink.
4. Bypass resistor overheating with heat sink with resistance and heat sink not being thermally in contact.
5. Bypass resistor overheating with heat sink with resistance and heat sink thermally in contact.
6. The final design of the board and overall 4-pack system was modeled and simulated.

The COMSOL Multiphysics tool was used throughout the project for different purposes. At an earlier stage of the project COMSOL was used to get a sense of the thermodynamics of our model. Later on when the board was fabricated and the design was finalized COMSOL was used to model the final design as well as to confirm the Environmental requirements.

- **Conclusion:** After carrying out the thermal analysis we concluded that a heat sink is absolutely necessary for ensuring the integrity of the hardware. Also, the placement of the redundant temperature would ideally be located in the central part of the circuit board. This is dependent on whether the layout of the OBPP board allows it.
Stationary Analysis with one cell overheating

Heat Source is the Battery Cell
Stationary Analysis with four cells overheating

Heat Sources are the four Battery Cells
Bypass Resistor Overheating with no Heat Sink

Heat Source is Bypass Resistor
Bypass Resistor Overheating (With Convective Cooling in Heat sink)
Bypass Resistor Overheating (Heat Sink and Bypass resistor thermally touching)
Final Design Simulation (2 Bypass resistors functioning at 30°C ambient)