Preliminary Thermal Modeling

Andrew Motz

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1 Overview

From the previous models, discussions with other AIMS staff, and review of literature and relevant forum posts, a thermal solution that will allow heat to dissipate from the electronics into the water is necessary. The simplest and most effective solution is to add a direct conductive pathway for heat to travel from the source, namely the Jetson module, to an aluminium face that is exposed to seawater. The result shows effective heat dissipation, and with a few minor design changes, shows promise for a practical thermal solution.

2 Revised First-principles Model

2.1 Revised Model

The revised model ignores some material properties and is only valid for steady state solutions. The conductive and convective resistances from the previous model were carried over with the exception of a new pathway from the Q_{input} to the inner face of the aluminium end cap. This conduction was modeled as conduction through aluminium. A block diagram is illustrated in Figure(1).

2.2 Assumptions

For the purpose of this model, many assumptions will be made:

- The housing dimensions are the same as the transom camera housing, except longer
- 100% of input energy to electronics components becomes heat
- The air temperature in the housing is the value of concern for electronics max operating temperature
- The Jetson module reaches a steady temperature of 90 °C (max temp is 99 °C) [1]
- All input heat that is not transferred from the Jetson board via conduction is completely transfered into the air within the housing via the stock heat sink
- The seawater around the housing is an infinite heat sink at 30°C
- Natural convection governs heat transfer between the interior air and the boundaries materials, and again between the boundary materials and the sea water

[1] For very high values of h_{water}, T_{board} can be defined relative to another value e.g. $T_{air} + 30$ to avoid large negative heat transfer values and extreme temperatures, however the model is limited in these cases and values will non-physical

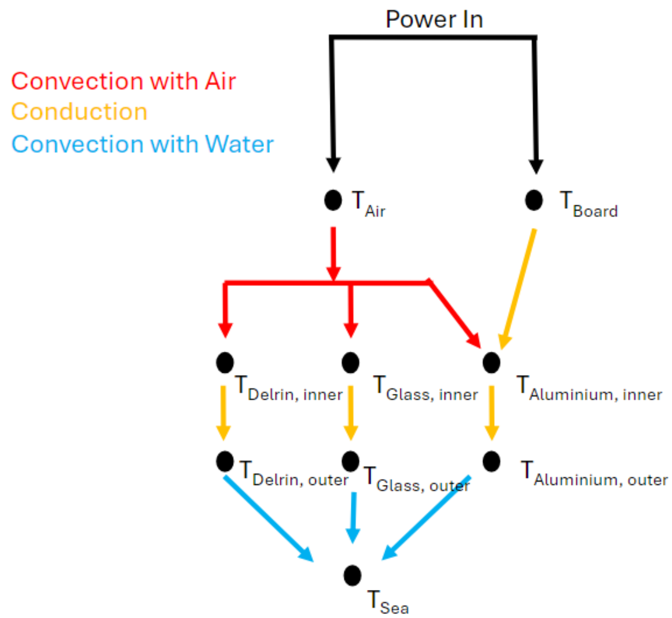

Figure 1: New Block Model

2.3 Values

From the design specifications the following values will be used. These values were largely derrived from the CAD model of the Reefscan Transom camera housing.

$\dot{W}_{elec}$	$23.9W$	h_{water}	$50\frac{W}{m^s \cdot K}$	R_o	$0.050m$
A_{glass}	$0.0114m^2$	h_{air}	$3.5\frac{W}{m^2 \cdot K}$	R_i	$0.039m$
$A_{cap-outer}$	$0.005404m^2$	L_{glass}	$0.005m$	L_{tube}	$0.250m$
$A_{cap-inner}$	$0.003185m^2$	L_{alum}	$0.015m$	T_{sea}	$30°C$
K_{glass}	$1.38\frac{W}{m \cdot K}$	K_{alum}	$235\frac{W}{m \cdot K}$	K_{Delrin}	$0.37\frac{W}{m \cdot K}$

The new heat sink was modeled with length of 0.054 m, corresponding from the center of the PCB to the endcap, and the area was modified to find an optimal solution.

2.4 Mathematical Representation

The model was constructed in MATLAB as a system of equations with one equation for each heat transfer interface and one equation for conservation of energy at each temperature node. The overall heat flow to the sea was set to be equal to the input power. The result was a system of 18 equations with 18 unknowns. The unknowns were the heat flow at each interface, and the temperature of each node of the model.

3 Results

T_{air} was solved for A_{sink} of 115, 150, 180, and 200 mm^2 and h_{water} of 50, 75, 100, and 125 $\frac{W}{m^2 \cdot K}$. The resulting values are below:

		A_{sink}			
		$115mm^2$	$150mm^2$	$180mm^2$	$200mm^2$
h_{water}	50	89.48°	85.48°	82.94°	81.57°
	75	75.86°	69.26°	64.91°	62.50°
	100	66.25°	57.27°	51.17°	47.72°
	125	59.03°	47.93°	40.21°	35.78°

4 Discussion

From the results, it is possible to achieve sufficient heat dissipation to maintain an acceptable temperature within the housing using this heat sink method. A $180mm^2$ aluminium sheet placed between the Jetson board and the heat sink is sufficient if the h_{water} can be increased to at least 75 $\frac{W}{m^2 \cdot K}$. This can be achieved easily by the introduction of basic fins to increase the surface area exposed to the sea water.

One observation of note is that the temperature of the end cap will reach 65°C in this model. As a result, the aluminium end cap transfers heat back into the air within the housing due to the ΔT. The heat transfer back into the air is minor and should not pose any issues. However, it should be investigated if the increased end cap temperature will have an impact on any of the seals or penetrators being used. Thermal expansion will be non-negligible as well.

In summary, my reccomendations are to:

- Insert a 4.5mm sheet of aluminium between the PCB and the heatsink and use a Thermal Interface Material (TIM) to ensure good heat conduction
- Connect the aluminium directly to the aluminium end cap maintaining at least 180 mm^2 area of aluminum. Use TIM to ensure good conductivity from the aluminium sheet to the endcap
- Add basic fins to the exterior of the end cap. Can be achieved by extending the depth of the endcap or by cutting them into the existing depth of the endcap
- Investigate temperature bounds of seals/penetrators being used to ensure compatibility with increased aluminium temperatures