SLAC NATIONAL ACCELERATOR LABORATORY

Thermal Performance Testing of LSST Science Raft Towers

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Objectives

The objectives of this research was to analyze data from the charged-coupled devices (CCDs) and the raft electronic boards (REBs) on science raft tower module 005 (RTM-005) and determine how much power is leaking to the CCDs when power is sent to the heaters. It was also important to identify the percent error of the given thermal impedance budget of the RTM design and the calculated thermal impedance from the CCDs and REBs data.

Background

The Large Synoptic Survey Telescope (LSST) Commissioning Camera (ComCam) is a smaller version of LSST that contains a single science RTM. ComCam will be used for early testing and integration on the telescope. Therefore, data from the CCDs and REBs on RTM-005 was collected as it underwent different states as, shown in Table 1, to ensure it meets thermal requirements.

Table 1: Different stages of thermal and power conditions.

State	State Description
A	Turn off RTM. Set cryo plate to -130°C and cold plate heaters to -49°C.
B	Turn on REBs in quiescent mode with CCDs and RSA heaters off.
C	Apply voltage to CCDs and turn on into CCD quiescent mode.
D	Run a repeating series of bias frames with read-out. Collect temperature, voltage, and current telemetry, including cryo and cold plate temperatures and heater load, and REC sidewall temperature telemetry for the 5 minute interval.
E	Stop continuous read-outs and initiate continuous clears, repeating indefinitely without added latency.
F	Run RTM in quiescent-0% heater mode for 30 minutes or until REB, CCD, RSA, and REC wall temperatures are stable to within +/- 0.1 C.
G	Run RTM in quiescent-50% heater mode for 60 minutes or until REB, CCD, RSA, and REC wall temperatures are stable to within +/- 0.1 C.
H	Run RTM in quiescent-100% heater mode for 60 minutes or until REB, CCD, RSA, and REC wall temperatures are stable to within +/- 0.1 C.

The RTM is assembled using 12 different materials with different thermal capabilities. Figure 1. shows the thermal resistance circuit on RTM along with its thermal properties as each resistance. Understanding Figure 1. with respect to our data is key to meeting our objectives.

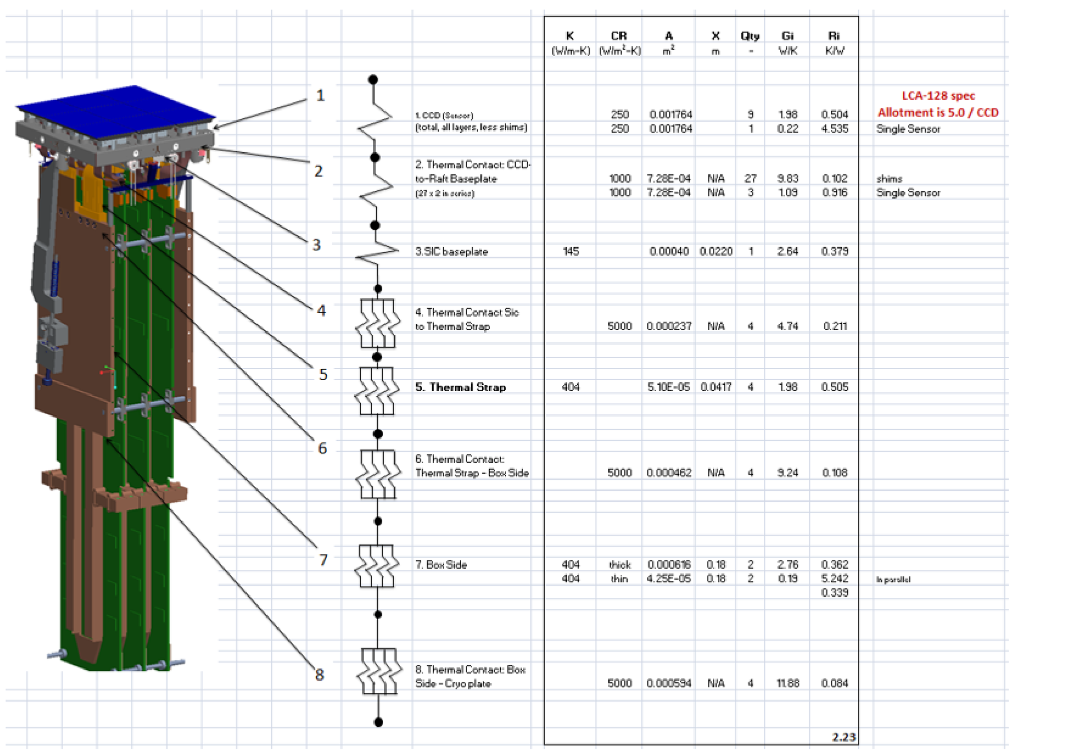

Figure 1: RSA/RTM Thermal Impedance Budget

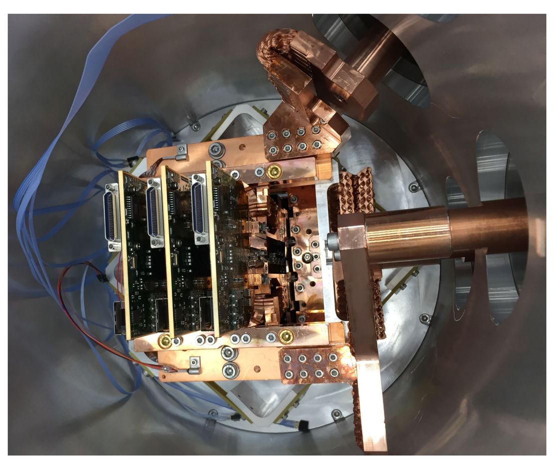

Figure 2: Rear view of RTM overlooking REBs and copper plates.

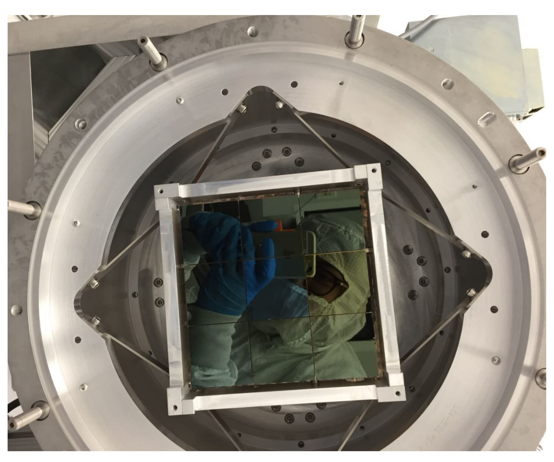

Figure 3: Front view of CCDs. RTM inside cryostat

Methods

Unknown Variables

The CCDs are turned on at state F so we wish to find the following unknown variables:

- $\Delta T_{CCD,FG,meas}$, change in temperature of the CCDs for state $F \rightarrow G$,
- $\Delta T_{CCD,GH,meas}$, change in temperature of the CCDs for state $G \rightarrow H$,
- $\Delta P_{FG,meas}$, change of power $F \rightarrow G$,
- $\Delta P_{FG,meas}$, change of power $G \rightarrow H$,
- $R_{i,FG,meas}$, thermal impedance $F \rightarrow G$, and
- $R_{i,GH,meas}$, thermal impedance $G \rightarrow H$.

After finding change of temperature and power for each state, we can use $R_i = \frac{\Delta T}{\Delta P}$ to obtain the thermal impedance for $R_{i,FG,meas}$ and $R_{i,GH,meas}$. This will allows us to find the percent error between the two measured resistances and the calculated resistance, $R_{i,cal}$, presented in Figure 1.

Results

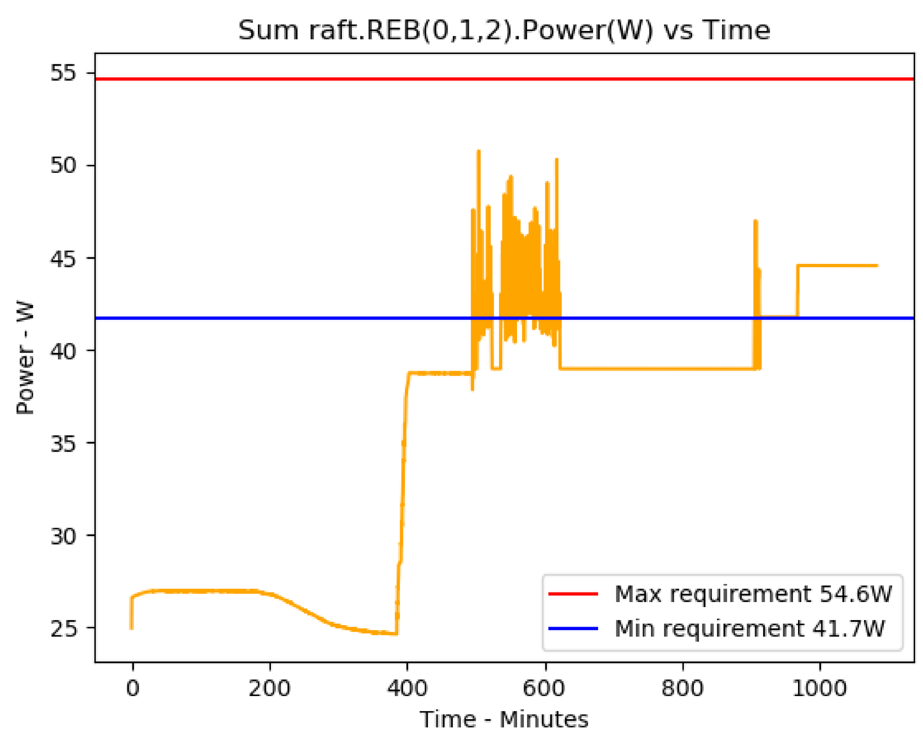

Figure 4: The change of power of the REBs through states C to H from Table 1.

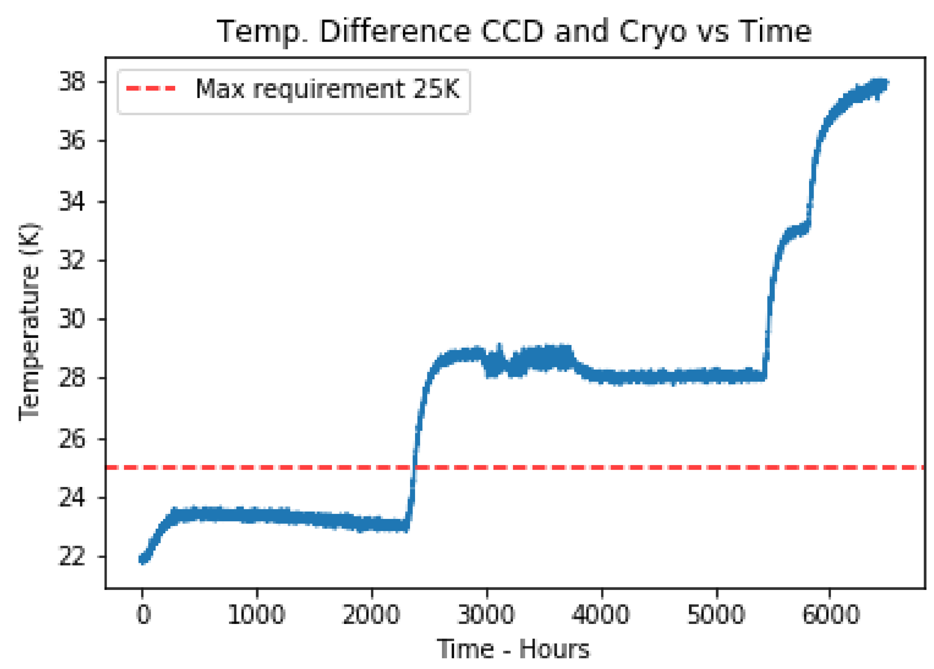

Figure 5: Temperature difference between the CCDs and cryo plate.

Table 2: Measured results for change of temperature of the CCDs, thermal impedance, and percent error at state F to H.

	$F \rightarrow G$	$G \rightarrow H$
ΔT_{CCD}	4.93	9.81
ΔP_{heater}	2.8 W	5.6 W
$R_{i,2\rightarrow 8,meas}$	1.760714286 $\frac{K}{W}$	1.751785714 $\frac{K}{W}$
$R_{i,2\rightarrow 8,calc}$	1.731	1.731
Percent Error	1.7%	1.2%

We know the following:

- Max CCD package load is 1.15W so the total power out cryo system is about 10.35W.
- If RTM's thermal impedance is 2.23$\frac{K}{W}$ when $\Delta T_{cryo\rightarrow CCD}$ is 28K, then the power going to the CCDs is about 12.5W
- Therefore, we have 2.2W of extra power.

Conclusion

In conclusion, four important findings were discovered. First, the temperature difference of the cryo plate and the CCDs fails to be $< 25°C$ when the CCDs are turned on. Second, the working power range of the REBs must be between 41.7W and 54.6W. Figure 4. shows that this requirement is not met either because too little power was put into the system. Thus, both thermal performance requirements failed. Next, we found that the percent error between the thermal impedance of the RTM, as calculated by Brookhaven National Laboratory, and the thermal impedance calculated from our data is less than 2%. Finally, the power that leaks to the CCDs is 2.2W.

Acknowledgements

The 2018 STEM Teacher and Researcher Program and this project have been made possible through support from Chevron, the National Marine Sanctuary Foundation, the National Science Foundation, the California State University Office of the Chancellor, and California Polytechnic State University. Financial support for LSST comes from the National Science Foundation, the Department of Energy, and private funding raised by the LSST Corporation. Also, a special thanks to Margaux Lopez and Kevin Reil for the guidance this summer. Participant in the LSST Corporation's Summer 2018 Undergraduate Research Program.

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