TIRS Cryocooler: Spacecraft Integration and Test and Early Flight Data

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Abstract. The Thermal Infrared Sensor (TIRS) is an instrument on Landsat 8, launched in February 2013. The focal plane is cooled by a two-stage Ball Aerospace Stirling cycle cryocooler, with a coldfinger operating at 40K. This paper describes events during the spacecraft integration and test program, and results from early orbit operation of the cryocooler.

Keywords: LDCM, Landsat, Thermal Infrared Sensor, TIRS, cryocooler, Stirling
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SPACECRAFT INTEGRATION AND TEST

The focal plane of the Thermal Infrared Sensor (TIRS) instrument is cooled by a two-stage Stirling cooler manufactured by Ball Aerospace.[1] TIRS was integrated with the Landsat 8 spacecraft in the spring of 2012. A mishap with the cryocooler, apparently incurred in shipping, allowed the loss of the cooler's helium gas, and forced the team to remove the instrument from the spacecraft for repair[2]. During the time that the TIRS sensor unit and cryocooler electronics (CCE) were de-integrated, the spacecraft had a mishap with harness grounding, delaying the overall I&T program. TIRS was re-installed on the spacecraft in July 2012, and then went into electromagnetic interference/compatibility (EMI/EMC) testing, with the instruments partially functional in an ambient environment. That was followed by vibration and thermal/vacuum testing, and eventually shipment to the launch site.

Environmental Testing

During EMI/EMC testing, the entire spacecraft was at ambient conditions. The cryocooler could be operated at low power for short periods of time, as long as the coldfinger remained comfortably above the dew point of the lab, but except for pre- and post test functional tests, the cryocooler was held in standby mode. The instrument team planned to track the trend of low-power operation, to allow inference of the cryocooler charge pressure. Unfortunately, the calibration of the flight electronics was significantly different that ground support equipment, and an absolute comparison was not possible. Low-power cooldown rates remained self-consistent, suggesting that the cryocooler was experiencing no further loss of gas.

During radiated susceptibility testing, both as a subsystem and integrated with the sensor unit, we noticed that the cryo diodes used for closed-loop temperature control were sensitive to excitation in at least a few frequency bands, rectifying the RF interference and changing the apparent control temperature by as much as 2K for high excitation levels. At the excitation levels the spacecraft is most likely to experience, there will be very little susceptibility, but for control sensors in particular, the team would be reluctant to use diodes in the future.

During vibration and shock testing, the cryocooler was kept in its "caged" mode. While there is not a separate caging mechanism, closed relays in the cryocooler electronics provide low-impedance paths across each of the motor coils in this mode, allowing a high level of electrodynamic damping of each of the moving masses.

Thermal/vacuum (T/V) testing in late 2012 allowed the first opportunity to operate the cryocooler at full power. With some differences related to the operation of the instrument heaters, this cooldown was very similar to the previous instrument-level cooldown in December 2011. (Figure 1)

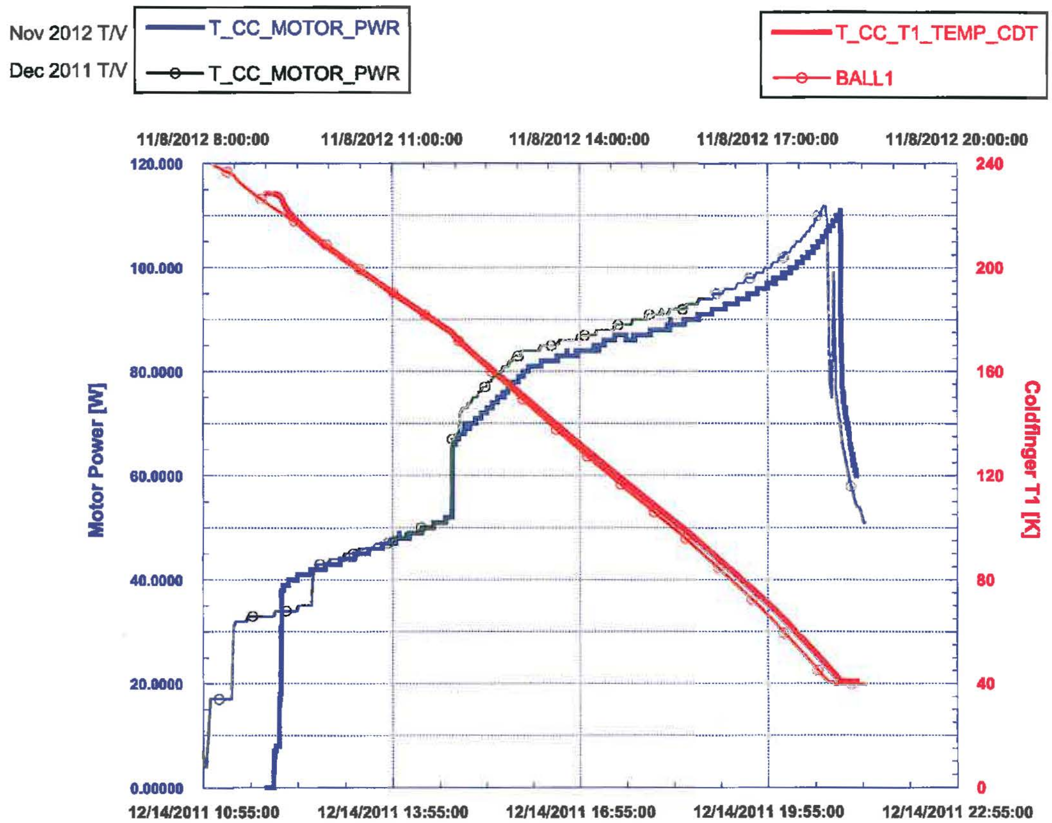

FIGURE 1. Comparison of the last instrument-level cooldown in November 2011, and the cooldown in spacecraft thermal/vac testing.

LAUNCH

The Landsat spacecraft was shipped to Vandenburg AFB in December 2012. Checkout at the launch site included low-power cooldown of the cryocooler, showing similar performance with operation before shipping. The spacecraft was encapsulated and stacked at the end of January, and on February 11, 2013 was launched into a polar orbit at the beginning of its first launch opportunity.

ON-ORBIT OPERATION

The cryocooler electronics were activated about two weeks after launch, while the instrument was still in a dryout phase. Cryogenic cooldown finally began on March 6, with the instrument at a slightly lower temperature than previous cooldowns. Accounting for this, the cooldown rates and power consumption were again very similar to previous experience, suggesting that the cooler performance has been unaffected by launch. (Figure 2)

Cooler-driven jitter was a concern throughout the instrument development process, with a great deal of effort in jitter testing and modeling. The TIRS cryocooler is operating without active vibration control, mounted on a flexure system to reduce transmitted vibration. During ground testing, it was extremely difficult to evaluate the effect of the cryocooler on instrument imaging, and on-orbit, the instruments have not been operated in a cooler-off mode. But since neither of the two Landsat instruments is having difficulty meeting its image stability requirements, cooler-driven jitter is not currently an operational concern.

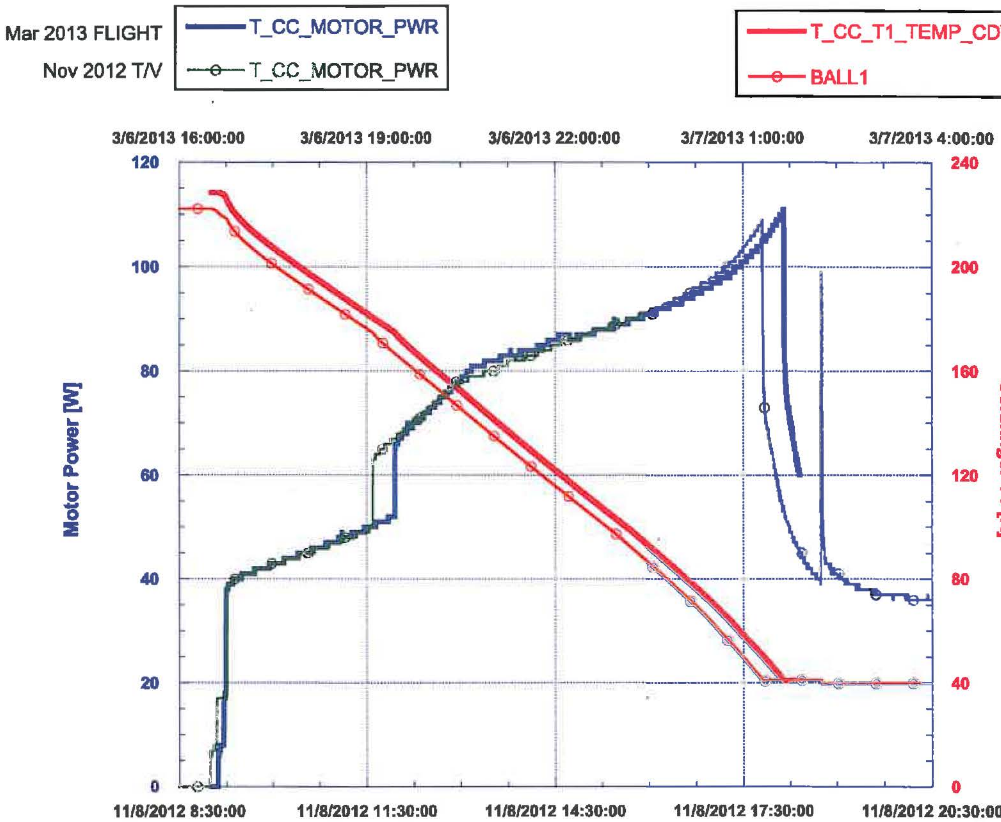

FIGURE 2. Motor power and coldfinger temperature for the on-orbit cooldown of March 2013, compared with the spacecraft thermal/vacuum test in Nov 2012.

Steady-State Operation

The cryocooler has been in continuous operation since cooldown, going into a steady mode of operation around the end of March. Temperature stability has been on the order of 40 mK p-p, low enough for TIRS to meet its temperature stability requirements.

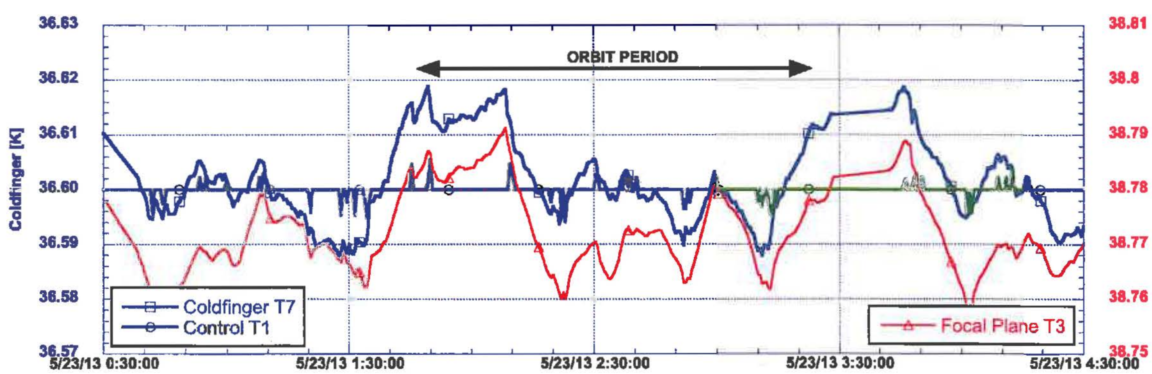

FIGURE 3. Orbital variation of coldfinger and focal plane temperatures.

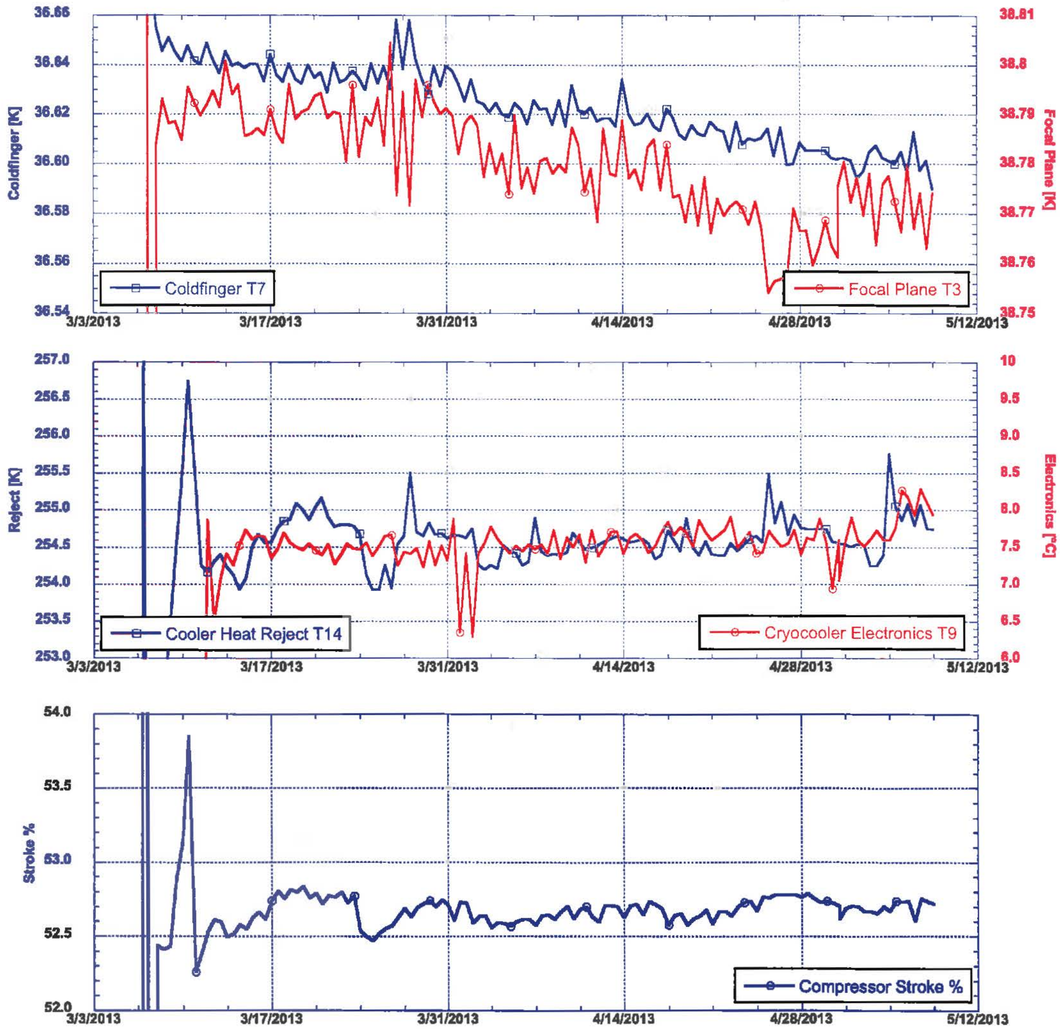

FIGURE 4. Operating conditions of the cooler over the first two months of operation.

During the first two months of operation, with fairly stable operating conditions, the cryocooler has maintained a very level stroke value. (Figure 4) What seems to be a downward drift in coldfinger temperature is under examination.

CONCLUSION

The TIRS cryocooler, repaired in 2012 after an apparent mishap in shipping, is now in orbit on Landsat 8 in stable operation.

REFERENCES

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