The Infrared Spectrograph at Helium Exhaustion

C. Grillmair & L. Armus,
Spitzer Science Center
(last updated 12 May 2007)

The Spitzer Space Telescope is expected to exhaust its cryogen supply sometime in April of 2009. There is considerable uncertainty as to the exact time when the helium evaporates completely. No further mass gauge measurements are planned, and OET will make running estimates of depletion date using the more numerous (but noisier) data points from the make-up heater pulses used to bring MIPS down to its best operating temperature. Once the cryogen has completely evaporated, the IRS is expected to warm up within two days to the point where the dark current will saturate every detector in less than one two-second sample. The following summarizes our current knowledge of how events will transpire and how we might usefully respond.

Expected Temperature Profile

The temperature of the telescope itself cannot effectively be driven after helium exhaustion, either through the use of the make-up heater or via pointing within the OPZ. Figure 1 shows the predicted telescope temperature during the first four weeks after helium exhaustion. Note that the final equilibrium temperature of the primary mirror is expected to be 24-25K.

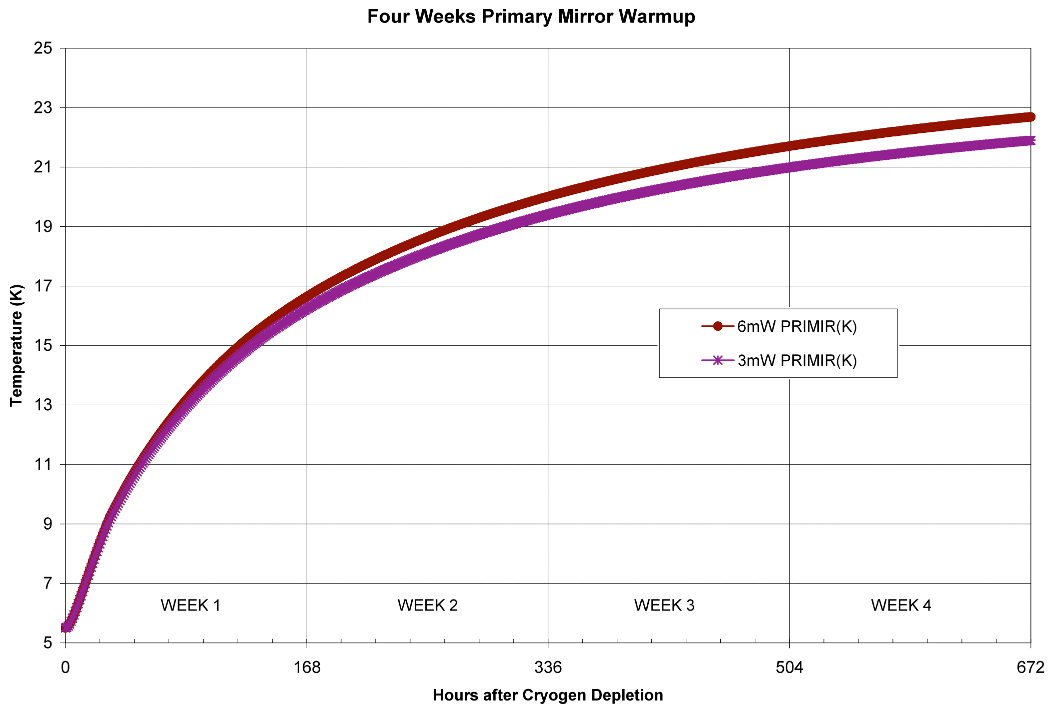

Figure 2. Primary mirror temperature as a function of time after helium exhaustion. (From *CTA Temperature Timelines for Cryogen Depletion*, P. Finley, Ball Aerospace, 23 April 2007).

Cold instrument assemblies will not track the telescope temperature. Moreover, whereas the telescope is expected to stabilize at 24-25 K (with the outer shell reaching ~37 K), the instruments are expect to reach a steady state temperature of between 25 and 29 K. While telescope warming will be nearly independent of what heater operations are occurring at the time of helium depletion, the temperature rise in the multi-instrument cavity will depend on what heater operations are active. Figure 2 shows the predicted temperature rise as a function of which instrument or heater is operating. After 48 hours, the temperature of the telescope is expected to be 11 K, while the predicted temperature in the MIC is 12-16 K.

If the make-up heater is in operation at the time of helium depletion, it will need to be turned off to prevent MIC warm up in excess of the expected steady state temperature of 25-29K. With the make up heater on, the MIC temperature is expected to exceed 20K in four days.

If there is a desire to reach equilibrium temperature more quickly to permit stable, warm IRAC observations at the earliest possible time, the MIC could be brought to 27 K in 26 days using only IRAC heat. If the make-up heater is used at full power, the MIC could be brought to equilibrium temperature in about 48 hours.

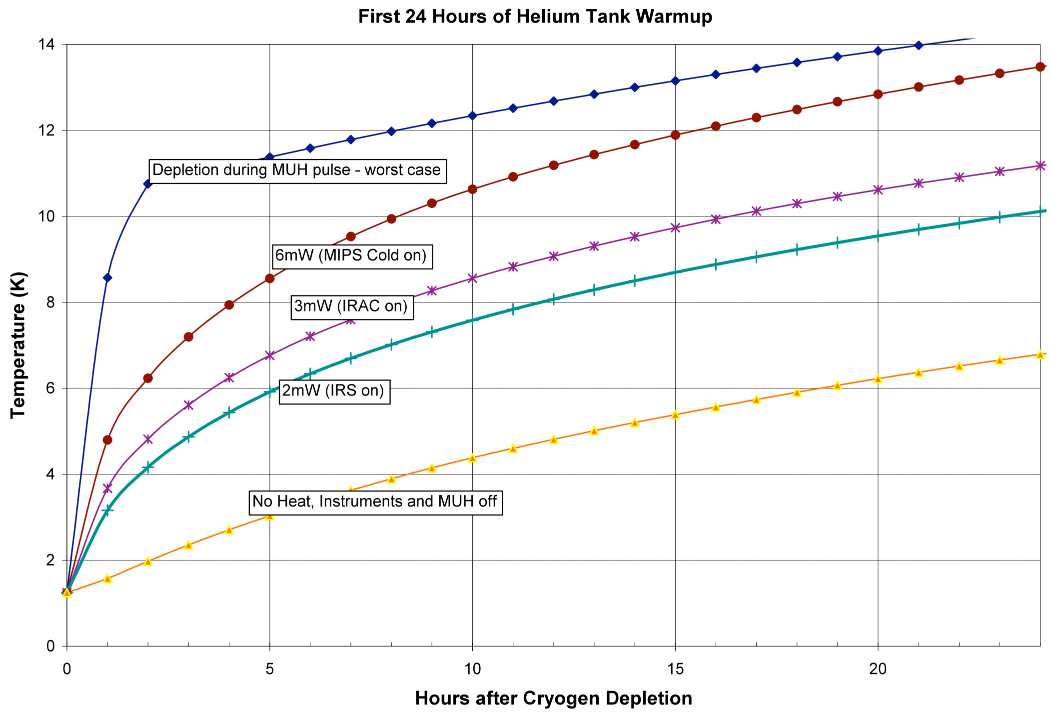

Figure 2. Predicted temperature in the multi-instrument cavity after helium depletion as a function of which instrument or heater is operating. (From *CTA Temperature Timelines for Cryogen Depletion*, P. Finley, Ball Aerospace, 23 April 2007).

Telemetry Indicators

The first sign of helium depletion will be in the helium tank temperatures. O-2203, 2204, and 2205 are normally around 1.2K, and values in excess of 2.2K are a clear indicator of helium depletion. No other early warning signs are expected. These temperatures are not recorded in IRS data headers but are monitored by Flight Software and by OET, and any associated warnings will be communicated to the IRS IST via the stf_evr_rpt files sent by OET.

The Combined Electronics (CE) monitors the temperature in the MIC via several sensors, and the appropriate keywords for the IRS are listed in Table 1. These keywords should be monitored in the course of calibration products generation and quality assurance. Currently, if any IRS detector temperature exceeds a value of 8.0 K, an error message would be sent to the spacecraft requesting a SUSPEND. The spacecraft software will in turn generate one or more EVR_WARNING messages. The IRS IST will be notified of the event via the stf_evr_rpt files sent by OET. In practice, if all temperature limits are left as they are, the flight software is likely to detect an excessive helium tank temperature well before the IRS detectors are affected, and the flight software will have already taken the necessary steps to turn off the instruments and put the spacecraft into STANDBY mode.

Secondary indicators include heater currents for the various detectors. These are given by the ASLHTRI, ASHHTRI, ALLHTRI, and ALHHTRI keywords and are currently (July 2007) running at 130 μAmps for SL and SH, and 84 μAmps for LL and LH. These heaters will be turned off completely (current = 0) when the temperature of the relevant detector exceeds 10.23 K.

Warm Electronics temperatures should not be affected by helium depletion, and CE/IRS current and voltage levels should be similarly unaffected.

Data Indicators

As the temperature of the IRS detectors increases, the dark current will increase rapidly. The dark current at which the A/D signal is railed before the second read is 94,000 e-/s. This dark current is reached at 11.5K for the Si:As arrays, and at 7.1K or 8.2K for the Si:Sb arrays for biases of 1.2 and 2.0 V, respectively. From Figure 2, the time between helium depletion and the complete, single sample saturation of the Si:Sb detectors is therefore between 9 and 13 hours, depending on the bias. Extrapolating from Figure 2, the corresponding time for the Si:As detectors is around 36 hours. In all likelihood, we will therefore have been informed of cryogen exhaustion and temperature increase by OET well before we've had an opportunity to examine the data for either header or data indicators.

As the temperature increases, we also expect the numbers of rogue pixels in LL and LH to increase, and to become more severe. There is currently no quantitative estimate of the expected increase, as experiments (e.g. LL and LH Performance and Responsivity tests) have been limited to three temperatures over a limited range at a given bias voltage. Observers and the IRS IST will simply have to be on the lookout for a significant increase in the number of rogue pixels in data taken after helium depletion.

Given the currently preferred 24 and 36 hour POAs, there will likely be no opportunity to initiate onboard slave sequences that might, for example, alter detector bias voltages, execute AORs selected for their relative robustness to temperature increase, or conduct high-risk, end-of-mission experiments (e.g. spectral observations of Earth). However, the period over which the data may have been compromised (depending on the science), but before the detectors are continuously saturated, can be determined post facto. Affected observers can then be notified of possible deficiencies in their data, and ways these deficiencies might be ameliorated.

An open question is whether, if the cryogen is exhausted during an IRAC or MIPS campaign, there is any benefit to turning on the IRS again. Assuming that the temperature alarms and software response can be circumvented to prevent a SUSPEND or SAFE request, would we get any telemetry that might be useful for closing out the instrument and/or finalizing data processing on the ground? OET has indicated as part of their end-game planning that fault protection would likely be somewhat neutered to prevent instrument and telescope safing events.

Aside from OET and Project notification of helium tank temperatures, we expect a significant rise in dark current and associated noise in the MIPS detectors, or the IRAC 5 and 8 micron arrays, if they happen to be operating at the time. Presumably such an occurrence will be relayed to the IRS IST by the affected teams, just as any marked degradation in IRS performance will be immediately reported to the IRAC and MIPS ISTs. During this phase of the mission, it will likely be in the best interests of the IRS IST to monitor all stf_evr_rpt files regardless of whether IRS is actually turned on.

Keyword	Sensor/Source	Nominal Operating Value (July 2007)	Current Limit Setting	Max Out of Limits (sec)
ASLDTMPA	Short Low Detector Temp A	6.2 K	8.0 K	155
ASHDTMPA	Short High Detector Temp A	6.2 K	8.0 K	155
ALLDTMPA	Long Low Detector Temp A	4.4 K	8.0 K	155
ALHDTMPA	Long High Detector Temp A	4.4 K	8.0 K	155
ASLDTMPB	Short Low Detector Temp B	6.2 K	8.0 K	155
ASHDTMPB	Short High Detector Temp B	6.2 K	8.0 K	155
ALLDTMPB	Long Low Detector Temp B	4.4 K	8.0 K	155
ALHDTMPB	Long High Detector Temp B	4.4 K	8.0 K	155

Table 1. IRS header keywords which report detector temperatures.

Conclusion

The expected time interval between helium exhaustion and the point at which the IRS can no longer take useful data is sufficiently short that no mitigation procedures can usefully be implemented. It is expected that fault protection will have been curtailed somewhat, and (though this has yet to be determined) that the IRS should continue to operate until the next downlink. Any data taken subsequent to helium exhaustion will have to be critically examined by the affected observers. While the onset of increased numbers of rogue pixels could be ameliorated using IRSCLEAN, existing calibration products (dark current measurements in particular) will presumably be of little use. Since we cannot predict the time of helium exhaustion, scheduling more frequent dark measurements (e.g. every few hours) in an attempt to keep track of increasing dark current would clearly cost far more in pre-exhaustion science time than could be rescued after the event. End-game, Si:As observing sequences could be constructed and loaded onboard so as to gather the necessary before-and-after dark measurements. However, given other spacecraft activities that may need to be conducted at this point, it currently appears unlikely that we would be able to initiate such sequences before the IRS becomes completely unusable.

We conclude that, with the possible exception of increasing the red alarm temperature limits on the IRS and thereby relaxing the fault protection, no special efforts on the part of the IRS IST, ISC, Ball Aerospace, or OET will significantly optimize IRS science return during the period when helium exhaustion is imminent. This does not preclude the application of optimum scheduling priorities and practices towards the end of Cycle 5, but science return will best be served by operating and calibrating the IRS normally throughout its final campaign.