TRW Space, Defense & Information Systems

One Space Park
Redondo Beach, CA 90278

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On-Orbit Functional Verification

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A. Momilani Ono, Hyperion Operations Date

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Carol Segal DATE TRW Deputy Project Manager Science and Operations	Steve Carman DATE TRW Hyperion Project Manager
DATE	DATE
DATE	DATE

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1.0 INTRODUCTION

Hyperion is a hyperspectral imaging instrument on the Earth-Orbiter 1 (EO-1) spacecraft that was launched from Vandenberg Air Force Base on November 21, 2000. The other instrument payloads on the spacecraft are ALI (Advanced Land Imager) and AC (Atmospheric Corrector). The first 98 days on-orbit were largely dedicated to instrument activation and check-out. This report has been prepared in two parts to report on activities, results and lessons-learned from this checkout period, EO-1/ Hyperion Early Orbit Checkout Report, Part I: Hyperion Activation and Operation, and Part II: On-Orbit Performance Verification and Calibration. For several reasons, the checkout period was extended from 60 to 90+ days. This document, Part I, describes the results of the functional verification tests carried out during the first 98 (11-21-00 - 12-28-01) days on orbit.

1.1. Scope

This document covers Hyperion operations during the Early Orbit Checkout phase of the EO-1 Mission from launch November 21, 2000 through completion of early orbit checkout February 28, 2001, including instrument activation and on-orbit functional tests. Instrument response to commands and functional performance of all subsystems are included.

1.2. Summary of Results

Hyperion activation and functional checkout were largely a success. All instrument subsystems were activated successfully and have performed nominally throughout the Early Orbit Checkout period. Problems encountered were minor and included a cryocooler position sensor failure on 10 January 2001. The contamination issue has its roots in the 2nd spacecraft-level thermal-vacuum test at GSFC. It limits the time the cooler was able to maintain the SWIR at nominal temperature and is not a problem with the mechanical performance of the cooler. The contamination issue continues to improve and currently the cooler can be run for approximately 80 hrs before a required decontamination cycle. To address the cryocooler compressor sensor failure, we developed and implemented a method of running the cooler without the failed sensor on 30 January 2001. The cooler has been operated in this new configuration without incident since that time. Currently, the cryocooler is performing nominally along with the rest of the instrument.

1.3. Reference Documents

Hyperion On-Orbit Activation Plan

1. IF1-0228, Hyperion Interface Control Document
2. D27802, Hyperion MPT Cryocooler Control Software: Architecture and Software User's Manual
3. D29958, Hyperion Instrument Software User's Manual
4. D32724, Hyperion On-Orbit Activation Plan
5. EO-1 Contingencies Document

6. TRW IOC #HYPER.00.700.02, Hyperion Pre-Launch Functional Verification, Post-Launch Survival Heater Verification, and Day 1 Aperture Cover and Cryocooler Cage Status Verification Procedure
7. D27751, Hyperion Instrument Operations Manual, rev D

1.4. Document Organization

This document contains a summary of Hyperion activation (section 2), followed by an overview of Instrument Operations support at TRW (section 3). Functional performance of each of the major instrument subsystems are described in sections 4-8. These sections include a description of the subsystem's performance during activation and Early Orbit Checkout, its current status, and a discussion of all special tests and anomalies that occurred during checkout. A discussion of commanding anomalies is found in section 9, and a discussion of special tests performed to gain additional information on instrument performance is found in section 10. A summary of required STOL procedures and RTSs for normal operations is found in section 11, and recommendations for normal mission operations are in section 12.

STOL procedure names are given in **bold**. Dates and times are given in calendar days, Mission Day, and in GMT.

2.0 SUMMARY OF HYPERION ACTIVATION

This outline summarizes the as-run instrument power-on and functional check-out for Hyperion on EO-1. These activities occurred from 20 November (pre-launch activities) to 8 December 2000 (termination of heated outgassing and cryocooler activation). A more detailed discussion is given in Reference 4.

1. Pre-Launch 20-21 November 2001: various aliveness, imaging, and launch-configuration tests, Hyperion monitoring at VAFB, GSFC, TRW:
   i. **hyp_pwron.prc**
   ii. **hyp_alive.prc** (aliveness test, with imaging operations)
   iii. **hyp_prelaunch.prc** (closes aperature cover, cages cryocooler, verifies survival bus ON)
   iv. **hyp_cryo_cage_check.prc** (verify cryocooler is caged)
   v. **hyp_pwroff.prc**

2. Post-Launch 21 November 2001, Mission Day 1, Orbit 7: verify survival heaters are powered on, Hyperion monitoring at TRW:
   i. **hyp_pwron.prc** (power-on instrument, send patches, start cryocooler tlm, verify instrument config., aperture closed)
   ii. **hyp_cryo_cage_check.prc** (verify cryocooler still caged)
   iii. **hyp_pwroff.prc**

3. 21-27 November 2001, Mission Days 1 through 6: verify Hyperion at survival temperatures (survival heaters are powered on). Hyperion monitoring at TRW.

4. 28 November 2001, Mission Day 7 Instrument Turn-On and Check-Out, Hyperion monitoring at TRW and GSFC:
   i. **hyp_pwron.prc** (power-on instrument, send patches, start cryocooler tlm, verify instrument config., aperture closed), <5 min.,
   ii. **hyp_cryo_cage_check.prc** (verify cryocooler still caged)
   iii. **hyp_asp_test.prc** (verifies analog signal processors are functional), 1-2 mins.
   iv. **hyp_lamp_test.prc** (verifies in-flight calibration lamps are functional), 1-2 mins.
   v. **hyp_cal_shortprime.prc** (performs short internal cal using primary lamps only), STOL takes ~1 min., RTS 121 and 122 will complete in ~15 mins.
   vi. on pass following v., verify in playback of Spacecraft Event Messages that RTS 168 has completed, **hyp_idle_verify.prc** ~1 min.,
   vii. download image data generated by v.
   viii. Aperture cover test: **hyp_coveropen.prc**, **hyp_coverclose.prc**, **hyp_covercal.prc**, **hyp_coverclose.prc** (verifies that the aperture cover is functional).
   ix. **hyp_idle_verify.prc**. (to verify instrument configuration)), ~1 min.
   x. **hyp_heaterson.prc** and **hyp_idle_verify.prc** (start outgas mode, verify configuration)
   xii. if science data generated by v. are good, load and enable RTS 101, 111, 109
   xiii. short DCE from ATS load (only VNIR data are good, RTS 101, 109)
   xiv. download image data generated by xiii and verify VNIR focal plane is functional.

5. 30 November 2001, Mission Day 9 Instrument Check-Out – Cryocooler Functional Test, Hyperion monitoring at GSFC and TRW:
   i. **hyp_cryo_func_static.prc** (static test of cryocooler), STOL takes ~4 mins, RTS 171, 177, 178 will complete in ~10 mins.
   ii. on pass following iii., **hyp_cryo_func_parm_chk.prc** ~4 mins., **hyp_idle_verify.prc** (verify instrument config) ~1 min.
   iii. <u>WAIT 1 orbit,</u> **hyp_cryo_func_chk_and_off.prc** ~3 mins, **hyp_idle_verify.prc** (verify instrument config) ~1 min.
   iv. **hyp_rtrvdbs.prc** (retrieve databases)
   v. **hyp_cryo_normoff.prc** (verify cooler OFF in nominal configuration)

6. 30 November – 7 December 2001, Mission Days 9 through 17 -- continue to perform DCEs, internal cals, solar cals, etc. as specified by the mission. Hyperion monitoring at TRW.

7. 8 December 2001, Mission Day 18 Complete Outgassing and Full Cooldown of Cryocooler, Hyperion monitoring at GSFC and TRW:
   i. **hyp_set_heaters.prc** (returns heater set points to nominal flight values), ~1 min., Hyperion FOT to verify nominal flight set points.
   ii. **hyp_cryo_init_flight.prc** (sets parameters for full cooldown of cryocooler), STOL takes ~ 2 mins, RTS 176, 177, 178 will complete in ~10 mins.
   iii. on pass following ii., verify in playback of Spacecraft Event Messages that RTS 178 has completed, **hyp_idle_verify.prc** (to verify instrument configuration), ~1 min., monitor cryocooler parameters for 1 orbit
   iv. **hyp_cryo_restart.prc** (initiates full cooldown of cryocooler), ~3 mins.
   v. wait ~ 4 hrs for cryocooler to cooldown

vi. on pass following vii., verify in playback of Spacecraft Event Messages that RTS 124 has completed, **hyp_idle_verify.prc** (to verify instrument configuration), ~1 min.
vii. short DCE from ATS load (RTS 101, 109)
viii. download data generated by vii and verify SWIR focal plane functional.

3.0 OVERVIEW OF INSTRUMENT OPERATIONS SUPPORT

TRW took responsibility for monitoring Hyperion State of Health (SOH) telemetry for most of the Early Orbit Checkout period. TRW provided the following coverage:

Phase	# / Shift	# Shifts	Hrs / Shift	Hrs (GMT)	Days / Week	Location
Pre-Launch Aliveness Testing, Launch	1	2	8	n/a	n/a	GSFC
	1	1	8	n/a	n/a	TRW
	1	1	8	n/a	n/a	VAFB
Mission Days 1-6	2	2	8	0700-2300	7	TRW
Activation (Mission Day 7-8)	2	2	12	0000-2400	n/a	GSFC
	1	1	8	0700-1500	n/a	TRW
MissionDays 9-11	2	3	8	0000-2400	n/a	TRW
Mission Days 12-17	2	2	8	0700-2300	7	TRW
Cryocooler Activation (Mission Day 18-19)	1	2	8	0700-2300	n/a	GSFC
	2	3	8	0000-2400	n/a	TRW
Mission Days 19-22	2	3	8	0000-2400	n/a	TRW
Mission Days 23-30	2	2	8	0700-2300	7	TRW
Mission Days 31-60	2	2	8	0700-2300	5 (no wkends)	TRW

Normal tasks included monitoring real-time telemetry during ground contacts, playing back Hyperion SOH telemetry for all DCEs performed through Mission Day 60, and initiating all cryocooler activities (cooler ON/OFF), instrument and cryocooler SOH trending. Telemetry was monitored and played back via ASIST and telemetry data were trended via DTAS. By monitoring all instrument and cryocooler activities so closely during the first 60 days of the mission, we were able to insure the quality of Hyperion data and the quality of the future state of health of the instrument.

There were four core operations engineers who performed the tasks listed above. To support them, there were specialists representing Hyperion electronics, thermal, mechanical, cryocooler, and flight software on call throughout the Early Orbit Checkout period.

4.0 POWER SUPPLIES/ELECTRONICS/ASPS

4.1. Activation

The HEA and CEA reached nominal voltages during activation. Voltages on the HEA are considered nominal when they are ± 1.0 volts of the target value. When an electronic subsystem, such as the internal calibration lamps or ASPs, are not powered-on, a voltage of 0.0 V $\pm$ 1.0 volts is considered nominal. Table 4.1-1 shows detailed results of the functional tests performed on this day. Green text indicates nominal non-zero values and blue text indicates nominal zero values (e.g.: For the VNIR and SWIR ASPs, power supplies should read 0.0V $\pm$ 0.5V. A blue number indicates a value within specifications.). The values in the table come directly from real-time telemetry from the ASIST workstations. When initially powered-on, Hyperion is in IDLE mode, with internal calibration lamps and ASPs not powered. There were no anomalies during initial instrument power-on and all primary voltages reached nominal values.

During the ASP test, the instrument was commanded to STANDBY mode, which powers on the ASPs. There were no anomalies during the ASP test and VNIR and SWIR ASP voltages reached nominal values.

During the Lamp Test, the secondary calibration lamp string is commanded to level 255 (full power) for 3 minutes. Although the lamps reached a higher voltage than had been previously encountered in ground testing, it was later determined that this was a new, on-orbit operating condition and was NOT an anomaly. During an Internal Calibration sequence, Hyperion is commanded to STANDBY mode which powers on the ASPs and the secondary internal calibration lamp is commanded to level 255. There were no anomalies during this test, and all electronic subsystems reached and maintained nominal values.

Table 4.1-1 Results of Functional Tests on GMT 00-332:1230

	Instrument Power-On (IDLE mode)		ASP Test		Lamp Test		1st Internal Calibration Sequence	
Telemetry Point	**volts/amps**	**ok?**	**volts/amps**	**ok?**	**volts/amps**	**ok?**	**volts/amps**	**ok?**
HEA +5V	4.916	√	4.872	√	4.911	√	4.872	√
HEA +15V	15.01	√	15	√	15	√	14.99	√
HEA -15V	-14.9	√	-14.9	√	-14.9	√	-14.9	√
Cal Lamp +13V	0.041	√	0.259	√	13.06	√	13.06	√
Lamp 1 Current	0.0027	√	0.0027	√	0.0027	√	0.0027	√
Lamp 1 Voltage	0.0418	√	0.0418	√	13.058	√	13.049	√
Lamp 2 Current	0.0027	√	0.0027	√	0.9788	√	0.9788	√
Lamp 2 Voltage	0.0418	√	0.0418	√	7.6422	√	7.6338	√
VNIR +5VD	0.13806	√	5.2324	√	0.13806	√	5.2275	√
VNIR +5VA	0.3008	√	5.0204	√	0.29587	√	5.05037	√
VNIR -5VA	0.29587	√	-4.942	√	0.28107	√	-4.9415	√
VNIR +15VA	0.46033	√	15	√	0.43522	√	14.9832	√
VNIR -15VA	0.26781	√	-14.93	√	0.25944	√	-14.924	√
SWIR +5VD	0.212	√	4.9957	√	0.212	√	4.9957	√
SWIR +5VA	0.64	√	5.0302	√	0.64	√	5.0302	√
SWIR -5VA	0.0443	√	-4.946	√	0.0443	√	-4.946	√
SWIR +15VA	0.3515	√	15.016	√	0.3431	√	15.008	√
SWIR -15VA	0.4101	√	-14.93	√	0.5105	√	-14.91	√

4.2. Current Status

Normally when Hyperion is not actively imaging, it is IDLE mode. The normal DCE sequence, which includes a 10 minute warm up for the SWIR focal plane and a 3 minute warm up for the internal calibration lamps, is as follows:

Table 4.2-1 Nominal nadir-view DCE command script for Hyperion

RTS	Relative Time	Command Mnemonic & Telemetry Words	Notes
101	00:00:00	YHEASTBY	goto STANDBY mode
ATS	00:00:30	YHEASETSWIR GAINA=1 GAINB=1 GAINC=1 GAIND=1 SWIRA=97 SWIRB=97 SWIRC=104 SWIRD=102 INTGTIME=125	set SWIR gain, offset, integration time
ATS	00:00:31	YHEASETVNIR VNIRALV8 VNIRBLV8 VNIRCLV8 VNIRDLV8	set VNIR gain, offset
101	00:10:00	YSCISTART	1 sec dark image
101	00:10:01	YSCISTOP	
101	00:10:03	YCVROPEN	open cover, 15 seconds for cover to reach FULL OPEN
ATS	00:10:25	YSCISTART	30 sec ground image, YCOVERPOS = 2679
ATS	00:10:55	YSCISTOP	
108	00:11:03	YCVRCLOSE	close cover, 15 seconds for cover to reach CLOSED
108	00:11:21	YSCISTART	1 sec dark image, YCOVERPOS = 3424
108	00:11:22	YSCISTOP	
108	00:11:24	YHEASLAMP LEVEL=255	secondary lamps ON with a 3 minute lamp warm up
108	00:14:24	YSCISTART	2 sec cal image with secondary lamps ON YLAMP2CUR ≈ 0.98 YLAMP2VOL ≈ 7.66V
108	00:14:27	YSCISTOP	
108	00:14:29	YHEASLAMP LEVEL=0	secondary lamps OFF
108	00:14:49	YSCISTART	1 sec dark image YLAMP2CUR ≈ 0 YLAMP2VOL ≈ 0
108	00:14:50	YSCISTOP	
108	00:14:52	YHEAIDLE	back to IDLE mode

Table 4.2-1 shows detailed results of a normal ground image data collection event (DCE) performed on mission day 60. As with the previous table, green text indicates nominal non-zero values and blue text indicates nominal zero values (e.g.: For the VNIR and SWIR ASPs, power supplies should read 0.0V ± 0.5V. A blue number indicates a value within specifications.). The values in the table come directly from real-time telemetry from the ASIST workstations. There have not been any instrument electronics anomalies associated with DCEs, solar, lunar, or internal calibration sequences. However, there have been commanding anomalies associated with these events that have affected the Hyperion instrument. When the proper command sequences have been sent, Hyperion has always responded correctly and nominally, although there have been events where the proper command sequences were not sent. These anomalous events will be covered in detail in section **9**.

Table 4.2-2 Telemetry Values during a Normal DCE Event (GMT=01-085:2231)

	Pre-DCE IDLE Mode		**STANDBY Mode**		**Cal Lamps On**		**Post-DCE IDLE Mode**	
Telemetry Point	**volts/amps**	**ok?**	**volts/amps**	**ok?**	**volts/amps**	**ok?**	**volts/amps**	**ok?**
HEA +5V	4.911	√	4.872	√	4.911	√	4.911	√
HEA +15V	14.99	√	14.99	√	15	√	14.98	√
HEA -15V	-14.9	√	-14.9	√	-14.9	√	-14.9	√
Cal Lamp +13V	0.03	√	0.209	√	13.06	√	-0.03	√
Lamp 1 Current	0.0027	√	0.0027	√	0.0027	√	0.0027	√
Lamp 1 Voltage	-0.033	√	0.0418	√	13.058	√	-0.033	√
Lamp 2 Current	0.0027	√	0.0027	√	0.9788	√	0.0027	√
Lamp 2 Voltage	0.0418	√	0.0418	√	7.6254	√	0.0418	√
VNIR +5VD	0.3008	√	5.2275	√	0.13806	√	0.3008	√
VNIR +5VA	0.29094	√	5.01544	√	0.29587	√	0.286	√
VNIR -5VA	0.27121	√	-4.9415	√	0.28107	√	0.17751	√
VNIR +15VA	0.42685	√	14.9832	√	0.43522	√	0.42685	√
VNIR -15VA	0.26781	√	-14.924	√	0.25944	√	0.23433	√
SWIR +5VD	0.212	√	5.0105	√	0.212	√	0.212	√
SWIR +5VA	0.0591	√	5.0302	√	0.64	√	0.0591	√
SWIR -5VA	0.0443	√	-4.946	√	0.0443	√	0.0394	√
SWIR +15VA	0.3347	√	15.008	√	0.3431	√	0.3347	√
SWIR -15VA	0.4435	√	-14.91	√	0.5105	√	0.385	√

4.3. Anomalies

None.

5.0 THERMAL SYSTEM

5.1. Survival Mode, Activation, and Outgas Mode

Hyperion has 6 HEA-controlled heaters: 3 on the OMS, 1 on the GIS, and 1 on each of the ASPs. Thermostatically-controlled survival heaters are used to maintain minimum temperatures of the crycooler radiator, VNIR FPA radiator, VNIR ASP, SWIR ASP, and HSA enclosure at times when the HEA is not powered on. In addition, temperature is monitored at several locations on the instrument.

The EO-1 satellite was launched on Julian day 00-336, (21 November 2000). Hyperion was in survival mode (HEA/CEA powered OFF, survival bus powered ON) for the first 6 days of the mission. Survival heaters kept the instrument at survival temperatures with no anomalies. Hyperion was activated on 00-332:1230 (28 November 2000). Immediately after HEA/CEA power-on the operational heater circuit engaged and the instrument started to warm up to operational temperatures. Operational temperatures were attained within approximately 4 hours. Activation continued through 00-333:0813, when the operational heater set points were set to outgas levels (OMS and GIS to +30C, no change to all other heater set points).

During activation and functional checkout, a short ground image was taken. The instrument temperatures from survival mode, through activation, to the start of outgas mode can be seen graphically in Figure 5.1-1. Heated outgas mode was terminated on Mission Day 18, 00-343, and the operational heater set points were returned to their normal operational values at that time.

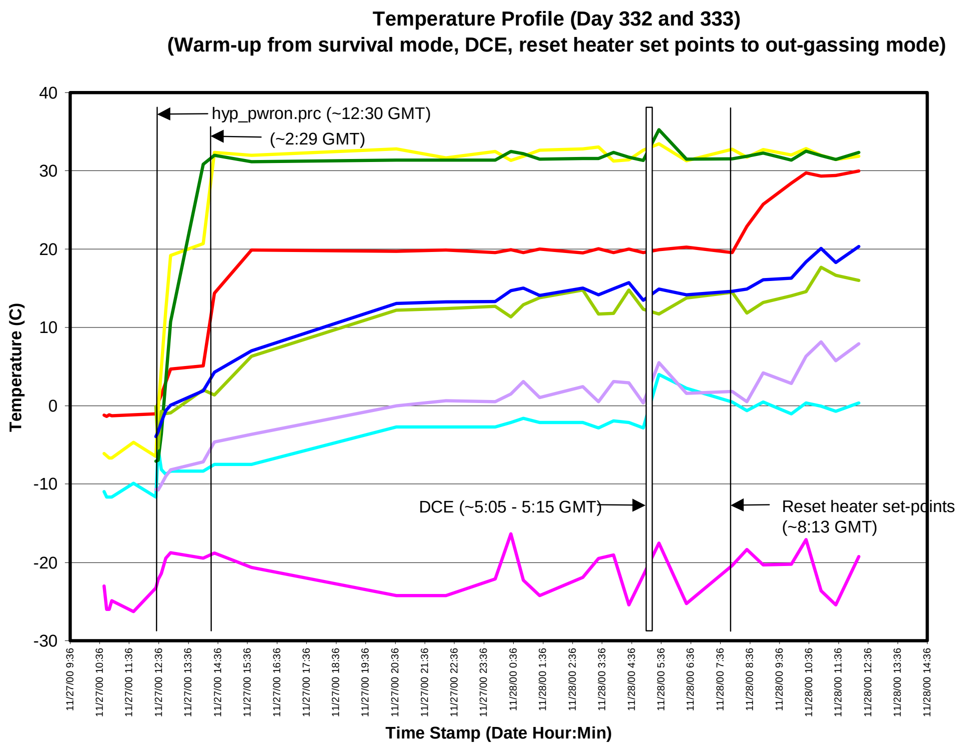

Figure 5.1-1 OMS (red), cryocooler flange (pink), cryocooler LVDT (dark blue), aperture door motor (light green), VNIR ASP (yellow), SWIR ASP (light blue), VNIR FPE (lavendar), and VNIR FPGA (dark green) temperatures from survival mode, through instrument activation, the first DCE and into outgas mode. All temperatures are nominal.

5.2. Current Status

Since returning to normal operational temperatures, the heaters have maintained Hyperion temperatures without incident or anomaly. Figures 5.2-1 and 5.2-2 show Hyperion temperatures for Day 01-030. Figure 5.2-1 shows the OMS temperature (pink), the aperture door motor temperature (brown) and the cryocooler flange temperature (green), together with a spacecraft ACS mnemonic that indicates eclipse status (blue, high indicates nightside, low indicates dayside). During ground testing at TRW it was discovered that the aperture door motor does not function normally when its temperature drops below –20C. As a result, the TRW Hyperion Team has made specific recommendation, and prepared specific Operations Alerts and Contingency Trees to try to cover this situation. However, figure 5.2-1 clearly shows that in this nominal configuration, the aperture door motor temperature does not drop below +10C at any time in the orbit at this time in the mission.

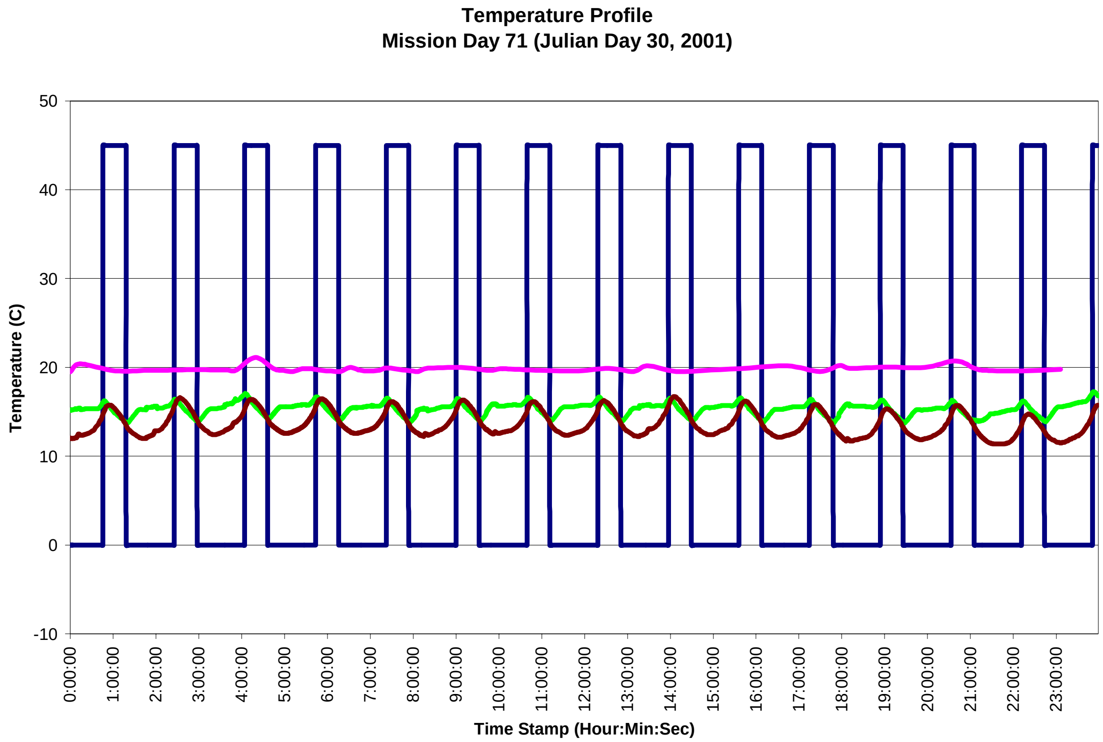

Figure 5.2-1 OMS (pink), cryocooler flange (green), and aperture door motor (brown) temperatures, together with a spacecraft ACS software eclipse indicator (blue). The OMS and cryocooler flange temperatures are actively controlled with heaters. There is no heater on the aperture door motor. All temperatures are nominal.

Figure 5.2-2 shows ASP temperatures for both VNIR (purple) and SWIR (yellow), the SWIR FPE temperature (green) and VNIR FPGA temperatures (blue) for the same time period as figure 5.2-1. The SWIR FPE temperature is only valid as a relative measure and is only valid as such during STANDBY and IMAGING modes. During IDLE mode the SWIR FPE temperature reads an invalid high value (~200). As such, it is a good indication of when DCEs occur. All temperatures are within the expected range and are within normal operational limits.

Figure 5.2-2 clearly shows the temperature cycling due to imaging activities of the VNIR and SWIR. However, all temperatures are within normal operational limits. The VNIR ASP heats up to ~35C (from 33C) and takes approximately 90-120 minutes, about an orbit, to return to 33C. The VNIR FPGA has a similar cycle, but its maximum temperature is ~45C. The SWIR ASP has a somewhat longer time constant, but it also stays within normal operational limits.

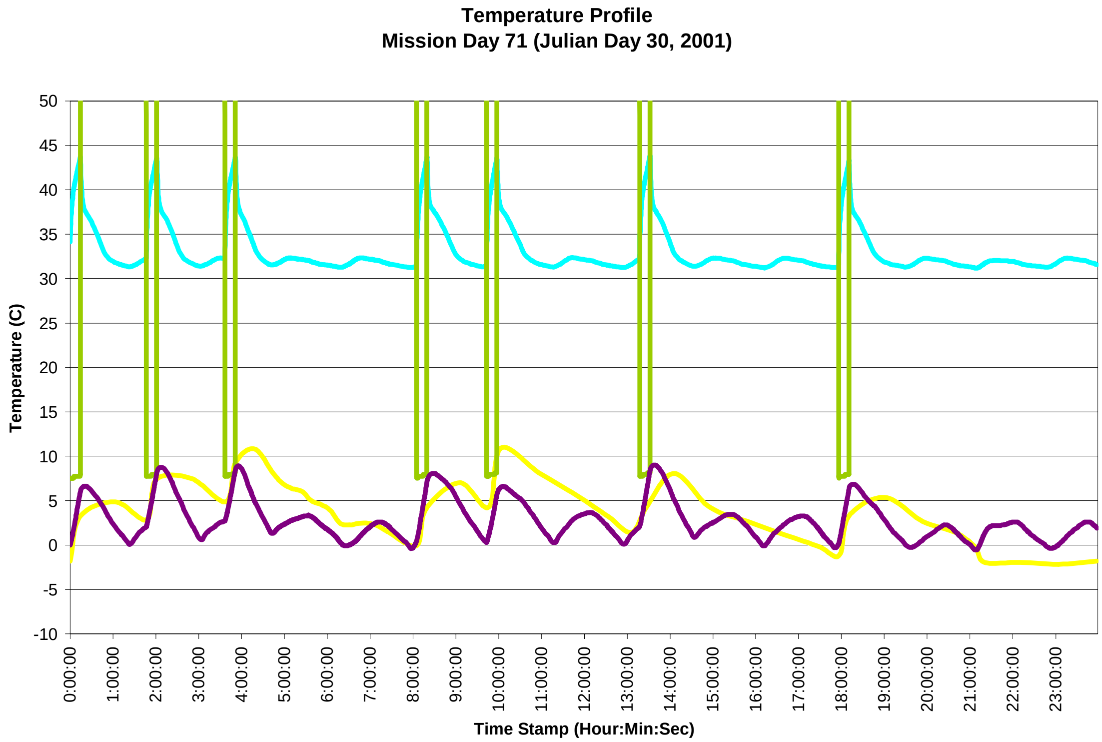

Figure 5.2-2 VNIR (purple) and SWIR (yellow) ASP, SWIR FPE (green) and VNIR FPGA (blue) temperatures. The SWIR FPE value is only valid in STANDBY and IMAGING modes. Thus it is a good indicator of imaging events. The ASPs heat up when powered and take ~60 minutes to recover. The VNIR FPGA, which is in the same box as the ASP has similar behavior. All temperatures are nominal.

Heaters 1 and 2, on the OMS have a duty cycle of less than 5% and they each turn on for roughly 10 minutes at a time. Heater 3, also on the OMS, has a duty cycle of about 10% and comes on for about 1-2 minutes each time. Heater 4, on the GIS, has a duty cycle of about 70% and comes on for about 30 minutes each time. Heater 5, on the VNIR ASP, has a duty cycle of about 50% and comes on for 30-60 seconds each time. Heater 6, on the SWIR ASP, is set such that it has not come on yet. These estimates are based on data during quiescent times, when the instrument is in IDLE mode and not during an imaging event or recovering from one.

5.3. Thermal Anomalies

None.

There were no thermal anomalies associated with the survival heaters or the HEA-controlled operational heaters. There was a single event where the VNIR ASP reached its YELLOW HIGH temperature. However, this was not due to a heater, but rather to commanding issues. As such, it will be discussed in section **9.0**.

5.4. Special Tests

The only special tests that involved the Hyperion heaters were tests to change the temperature of the VNIR ASP. The normal operational value for the VNIR ASP heater is between +32C and +34C. Table 5.4-1 shows the dates, times, and test values for 4 VNIR ASP temperature tests that were performed during the Early Orbit Checkout period.

Table 5.4-1 Summary of VNIR ASP Temperature Tests

Start Time	Stop Time	Minimum (C)	Maximum (C)
00-362:0619	00-362:1455	+35	+37
01-018:1226	01-018:2215	17	18
01-020:0344	01-020:1406	20	21
01-022:2011	01-023:0425	23	24

During each of these tests, the VNIR ASP heater set points were changed, the VNIR ASP was allowed to equilibrate at its new temperature, and at least one DCE was performed before the heaters were commanded back to the normal operations set points. Hyperion operations were nominal for all tests, with no anomalies reported. **For the results of these tests, please see Volume 2 of this report.**

5.5. Current Configuration

Table 5.5-1 shows the current set points and their corresponding temperatures, plus the yellow and red, high and low limit values for Hyperion. The STOL procedure to set these normal operational values is **hyp_set_heaters.prc**. This procedure is automatically called in the power-on sequence (**hyp_pwron.prc**) and in the instrument reset sequence (**hyp_reset.prc**, and RTS 38 and 39).

Table 5.5-1 Current operational heater set points and corresponding temperatures.

		Flight Set Points					
		MIN			MAX		
Location	Htr #	Hex	Decimal	° C	Hex	Decimal	° C
OMS +Y	1	dda	3546	19	db6	3510	21
OMS –Y	2	dda	3546	19	db6	3510	21
OMS –X	3	dda	3546	19	db6	3510	21
GIS	4	dda	3546	19	db6	3510	21
VNIR ASP	5	ce8	3304	32	cc2	3266	34
SWIR ASP	6	f53	3923	-10	f26	3878	-5

6.0 APERTURE COVER

6.1. Pre-Launch, Launch and Activation

The Hyperion aperture cover had no launch latch per design. During the Pre-Launch Aliveness test, the aperture cover was verified to be in the CLOSED position, and the aperture cover motor was pre-loaded by commanding the cover CLOSED, with the cover already in the closed position. During the 7th orbit, just after launch, Hyperion was powered on briefly to verify that the aperture cover had remained in the CLOSED position throughout launch and early post-launch spacecraft maneuvers. Throughout all Pre-Launch testing and through this time, 00-327:05:30, there were no anomalies in Hyperion aperture cover operations.

The Hyperion aperture cover was activated on 00-332:1910 (28 November 2000). During the initial power-on at GMT=1230, it was verified that the aperture cover had remained in the CLOSED position as expected. The STOL procedures shown in Table 6.1.1 were run to verify proper function of the Hyperion aperture cover.

Table 6.1-1 Hyperion Aperture Cover Test

		Encoder Position (cnts)		
STOL Proc	**GMT**	**Target Value**	**Actual Value**	**Verified (√)**
hyp_coveropen.prc	00-332-1913	2678	2678	√
hyp_coverclosed.prc	00-332-1914	3424	3424	√
hyp_covertocal.prc	00-332-1915	3212	3213	√
hyp_coverclosed.prc	00-332-1916	3424	3424	√

There were no anomalies associated with Hyperion aperture cover activation.

The actual cover position, YCOVERPOS, is reported as an A/D count of a voltage measured across a potentiometer, where the cover position in degrees is given by:

Cover position (degrees) = (3424 – [A/D counts]) * 0.173 degrees/count.

The values for the three operational positions are as follows:

closed = 3424 +/- 6 counts
solar cal = 3212 +/- 6 counts (about 37 degrees)
fully open = 2679 +/- 6 counts (about 129 degrees).

From CLOSED, the cover takes about 13 seconds to reach FULL OPEN. From CLOSED, the cover takes about 8 seconds to reach SOLARCAL. To insure that the proper positions are reached, the cover should always be commanded from the CLOSED position.

6.2. Current Status

As of the end of the Early Orbit Operations Support (Mission Day 60, Julian Day 01-019), the Hyperion aperture cover had been commanded to the FULL OPEN position 219 times and to the SOLARCAL position 10 times. Tables 6.2.-1 and 6.2.-1 show statistics for the aperture cover encoder position from the SOH telemetry data from these events. During each event, the aperture cover is commanded (to FULL OPEN or SOLARCAL) from the CLOSED position. It takes ~13 seconds to reach FULL OPEN and ~8 seconds to reach SOLARCAL. During the transition time, the spacecraft returns red and yellow limit violations on the YCOVERPOS mnemonic, which is the position readout from the aperture door motor encoder, in counts. Yellow limits are defined as +/- 6 counts from the target position. Therefore, the aperture cover can still be in motion even after Yellow limit violation have ceased. Thus, in order to include as few data points from when the door is in motion, we include data from one telemetry packet (usually 1 second) AFTER the yellow limit violations have ceased in the tables. The tables clearly show that the Hyperion aperture cover has reached nominal position each time it has been commanded. There have been no anomalies that have been associated with cover operations.

Table 6.2-1 Statistics for Aperture Cover Encoder Position for FULL OPEN

Encoder Position (YCOVERPOS)	**# Telemetry Points**	**%**
2676	0	0.00
2677	**3**	0.03
2678	**10341**	97.27
2679	**287**	2.70
2680	**0**	0.00
TOTAL (219 Events)	**10631**	

Table 6.2-2 Statistics for Aperture Cover Encoder Position for SOLARCAL

Encoder Position (YCOVERPOS)	**# Telemetry Points**	**%**
3210	**0**	0.00
3211	**42**	13.77
3212	**237**	77.70
3213	**26**	8.52
3217	**0**	0.00
TOTAL (10 Events)	**305**	

6.3. Anomalies

None.

7.0 INTERNAL CALIBRATION LAMPS

7.1. Activation

The internal calibration lamps were activated for the first time on-orbit at 00-332:1422, in the STOL procedure **hyp_lamp_test.prc**. At this time, the voltage for the secondary lamp string was observed to be ~7.6 volts, 0.3 volts higher than it had been during all ground testing (both ambient and in thermal-vacuum conditions). For this reason, we deviated from our planned activation and functional checkout activities by deleting the internal calibration sequence that was to be performed after the aperture cover checkout. Furthermore, all cal lamp activities were temporarily suspended until we studied the science data (all cal lamp commands were removed from all imaging sequences).

Image data revealed that the lamp output was also significantly higher than during ground testing. The cal lamp commands were reinstated into the solar calibration sequence and the housekeeping and science data showed that the on-orbit values for lamp voltage and output were consistant with themselves, although different from ground values. From this the TRW team concluded that the on-orbit operating configuration is somehow different from that on the ground and this change has caused the internal calibration lamps to operate differently than on the ground. The apparent anomalous high lamp voltage is part of the new on-orbit configuration and not a true anomaly. The differences in the operating conditions could be thermal and/or possibly gravitational. For more details on this subject, please see Part 2 of this report. The cal lamp commands were reinstated into all imaging sequences on 4 December 2001.

7.2. Current Status

Figure 7.2.1 shows secondary lamp voltage, VNIR band 40 output, and SWIR band 150 output for the lamp during the first 85 days of the mission. It is clear from the figure that although voltage and output are different from their ground values, they are consistant on-orbit. The slight changes evident in the figure are consistent with our knowledge of how these lamps age. There have been no anomalies in lamp operations to date. For more detailed information on the spectral shape and content of the lamps and on their radiometric performance, please see Part 2 of this report.

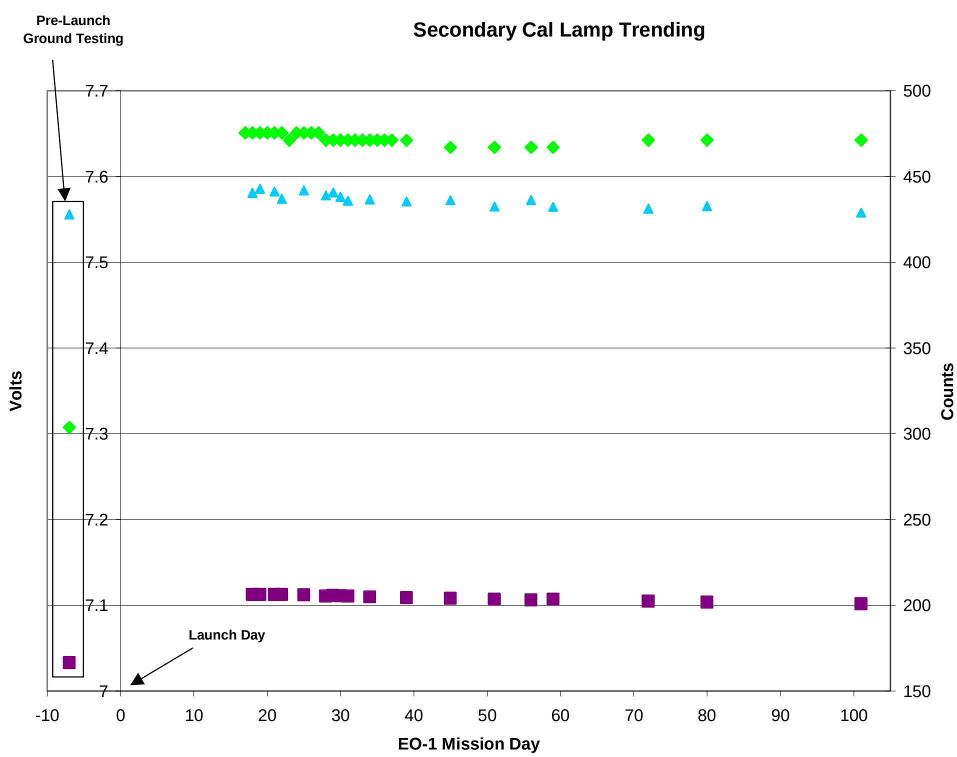

Figure 7.2-1 VNIR Band 40 Output (purple) and SWIR Band 150 Output (blue), and Secondary Calibration Lamp Voltage (green). The Band 40 and Band 150 Output data go with the

right hand axis, labeled “Counts” and the Lamp Voltage goes with the left hand axis, labeled “Volts”. Representative pre-launch data are in the box to the left of Mission Day 0, Launch Day. All three quantities plotted showed significant change from ground to on-orbit values. However, on-orbit these quantities have all shown stability and repeatability, within expectations. This indicates that a new stable operating configuration has been reached on-orbit, and that the internal calibration lamps are functioning nominally.

7.3. Anomalies

None

8.0 CRYOCOOLER SUBSYSTEM

8.1. Cryocooler Activation Period

Initial cooldown of the cryocooler on 12/08/00 with the post cooldown motor drive settling in at 70 $\pm$ 1 % drive level. Cryocooler performance was within nominal operating parameters. The control electronics assembly (CEA) ramped up the drive on the cooler such that the cooler stroke went to a maximum of +3.58 volts on the "plus peak side 1" position sensor. The +3.58 volt stroke limit level is consistent with the commanded stroke trip value of +3.88 volts. Starting from 283K, the cooler reached equilibrium (110.0 $\pm$ 0.2 K) 3 hours and 23 minutes after the restart procedure was started. The temperature undershoot on the setpoint was -2.35K. The vibration control algorithm worked, although the mechanical system transfer gains were substantially different than during ground tests. The initial cold cycle period was limited to less than 19 hours due to external contamination (water vapor) which led to increased thermal load on the cryocooler. The cold head temperature and motor drive are shown on figure 8.1-1.

Several procedure and database changes were incorporated during the activation period and have been documented in the section on current procedures.

Measured Cryocooler system transfer gains @110K CB temp, @283 K reject temp, and @70.82% motor drive.

From the response to command 0x0100C at S/C 343-18:04:48

	Real(hex) row 7	Imaginary(hex) row 8	Engineering Units unit-less transfer gain and phase in degrees
X_1:	53h	253h	$0.6\angle 82°$
X_2:	E55h	FFBFh	$3.7\angle -1°$
X_3:	FF52h	3Edh	$1.0\angle 100°$
X_4:	261h	39Ch	$1.1\angle 57°$
X_5:	B01h	640h	$3.2\angle 30°$
X_6:	10DBh	36CCh	$14.7\angle 73°$
X_7:	F8BDh	F03h	$4.7\angle 116°$
X_8:	29Ah	72Bh	$2.0\angle 70°$
X_9:	1807h	38A2h	$15.7\angle 67°$
X_{10}:	DAF1h	23E3h	$13.2\angle 135°$
X_{11}:	F7AAh	11E2h	$5.0\angle 115°$
X_{12}:	FEF0h	7E3h	$2.0\angle 98°$
X_{13}:	CCh	1776h	$6.0\angle 88°$

X_{14}:	FB2Ch	C71h	3.4∠111
X_{15}:	FEAFh	AE1h	2.8∠97°
X_{16}:	D4h	86Ah	2.2∠84°

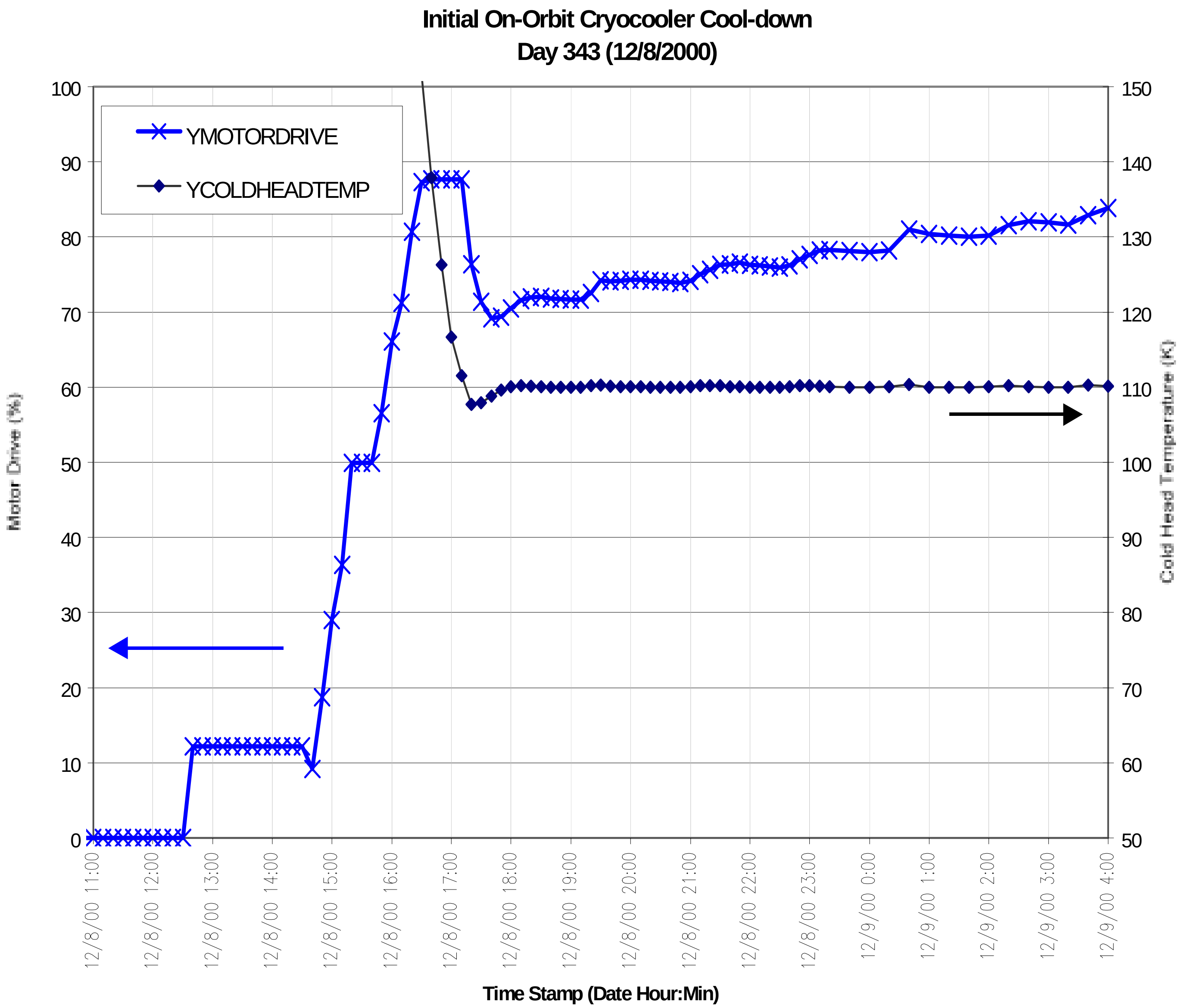

Figure 8.1-1 Initial Cool Down

8.2 Current Cryocooler Status

Cryocooler functions with approximately 80 hours of operation time between decontamination periods (as of 4/16/01).

Cryocooler operations have been streamlined into a set of Procs and RTS's which can be run on an automated schedule.

Current procedures and operational issues are documented in Reference 7.

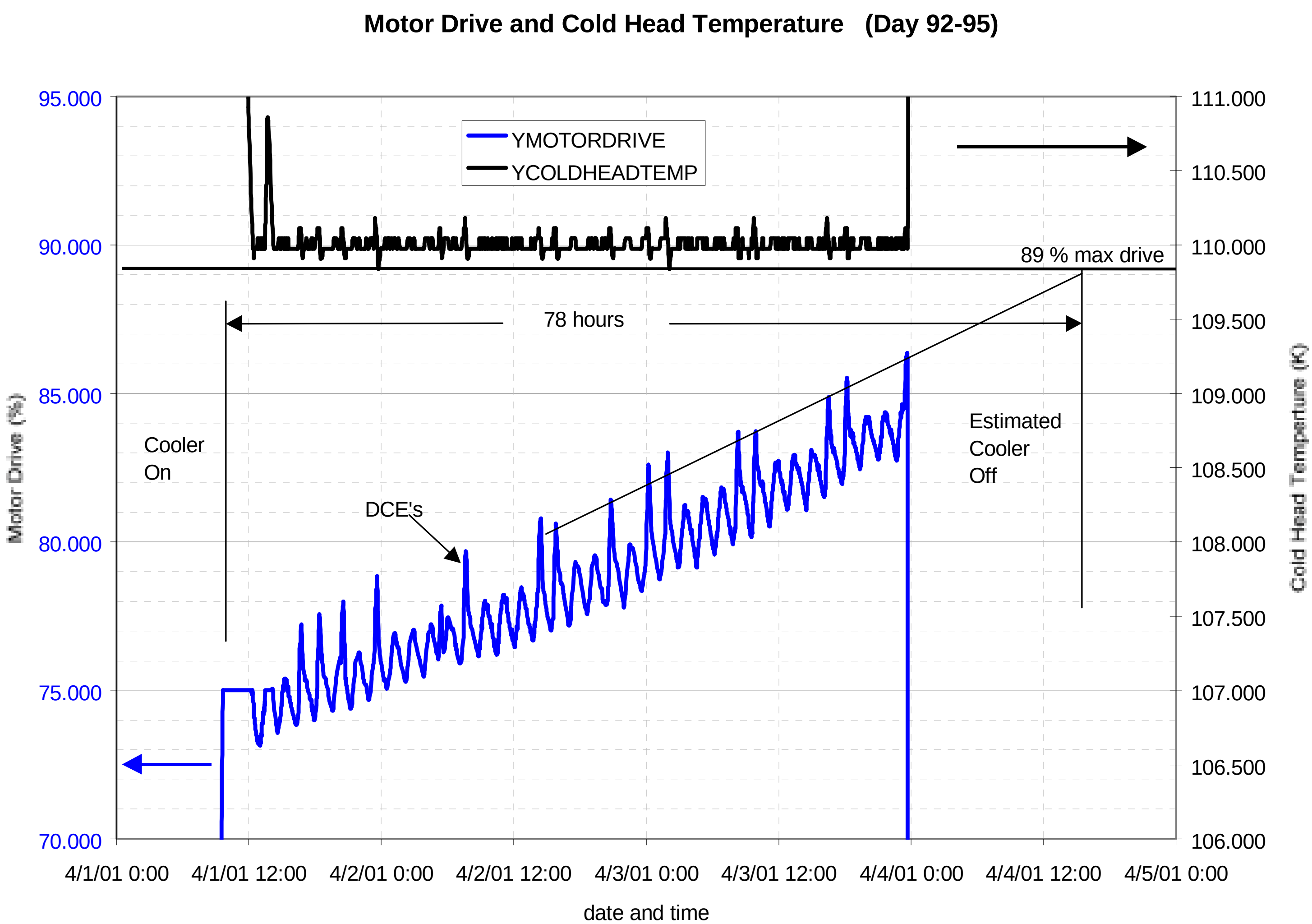

Figure 8.2-1 Motor Drive and Cold head Temperature

8.3 Cryocooler Anomalies

8.3.1 Position Sensor Anomaly

This discussion addresses the loss of position sensor signal in the Hyperion Cryocooler Control Electronics at 10:26:34 GMT, January 10, 2001 as reported by CK Chan in his e-mail message of January 11, 2001. The Cooler Electronics Subsystem consists of three separate boxes: the Accelerometer preamplifier, mounted on the cooler; the LVDT electronics, mounted on the instrument; and the Cooler Control Assembly (CEA) mounted on the spacecraft. This investigation focuses on the LVDT Electronics since the waveforms in Figure 8.3-1 show that the signal is distorted at the input to the CEA, which is the output of the LVDT Electronics. The two waveforms shown are POSNA, the compressor instantaneous position at the input to the CEA; and FOREA, the positive peak-detected value of POSNA. The peak detection circuit is inside the CEA.

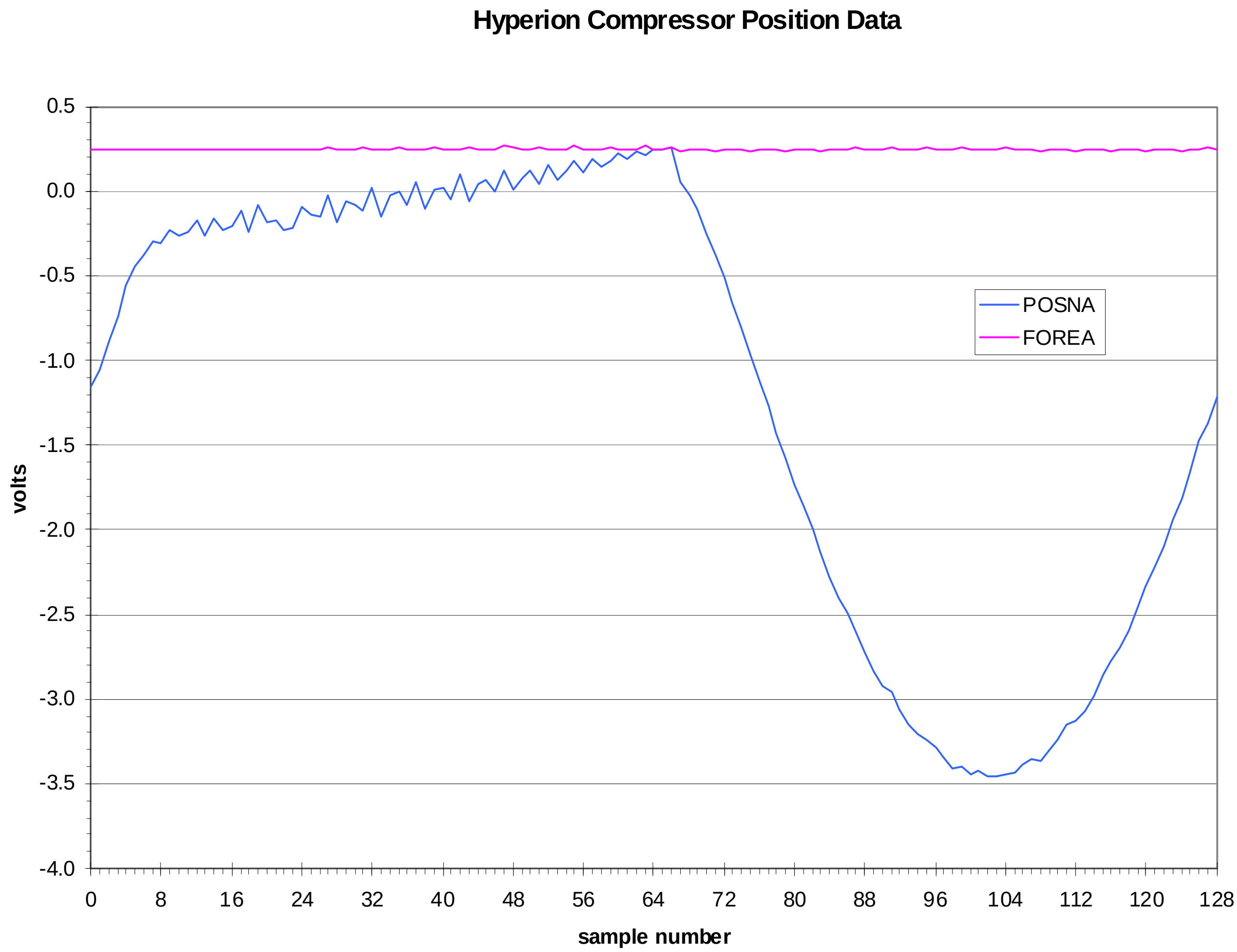

Figure 8.3-1 Hyperion Compressor Position Data

The sensor is essentially a transformer with two secondary connected in series, with their output voltages subtracting (180°out of phase). Mechanical centering of the device causes the outputs of each secondary to be equal, and by subtraction, the output voltage is zero. Movement to either side of center increases one secondary voltage linearly while decreasing the other secondary voltage linearly. The movement of the compressor, in this case, normally produces a nearly sinusoidal output. As can be seen from the figure, the second half of the waveform is a normal sinusoid, while the first half is reduced to less than 0.25 V and has lost the sinusoidal shape. Some high frequency noise and an integration slope appears in this anomalous segment.

For illustration of the LVDT circuit performance, a simplified schematic diagram of the LVDT sensor processing is shown in Figure 8.3-2.

Analysis

(This section written by D. Harvey and R. Carden, III, TRW Avionics Systems Center,Sensor Instruments and Electronics Department)

Because the sensor output coils perform normally during the negative signal transition, open secondary windings are excluded as candidate failures. The electronics must have contributed the failure. Furthermore, the proper operation during the negative position voltage also gives major clues to the sections of the processing circuits that are performing properly, so that we can focus on a smaller group within the electronics.

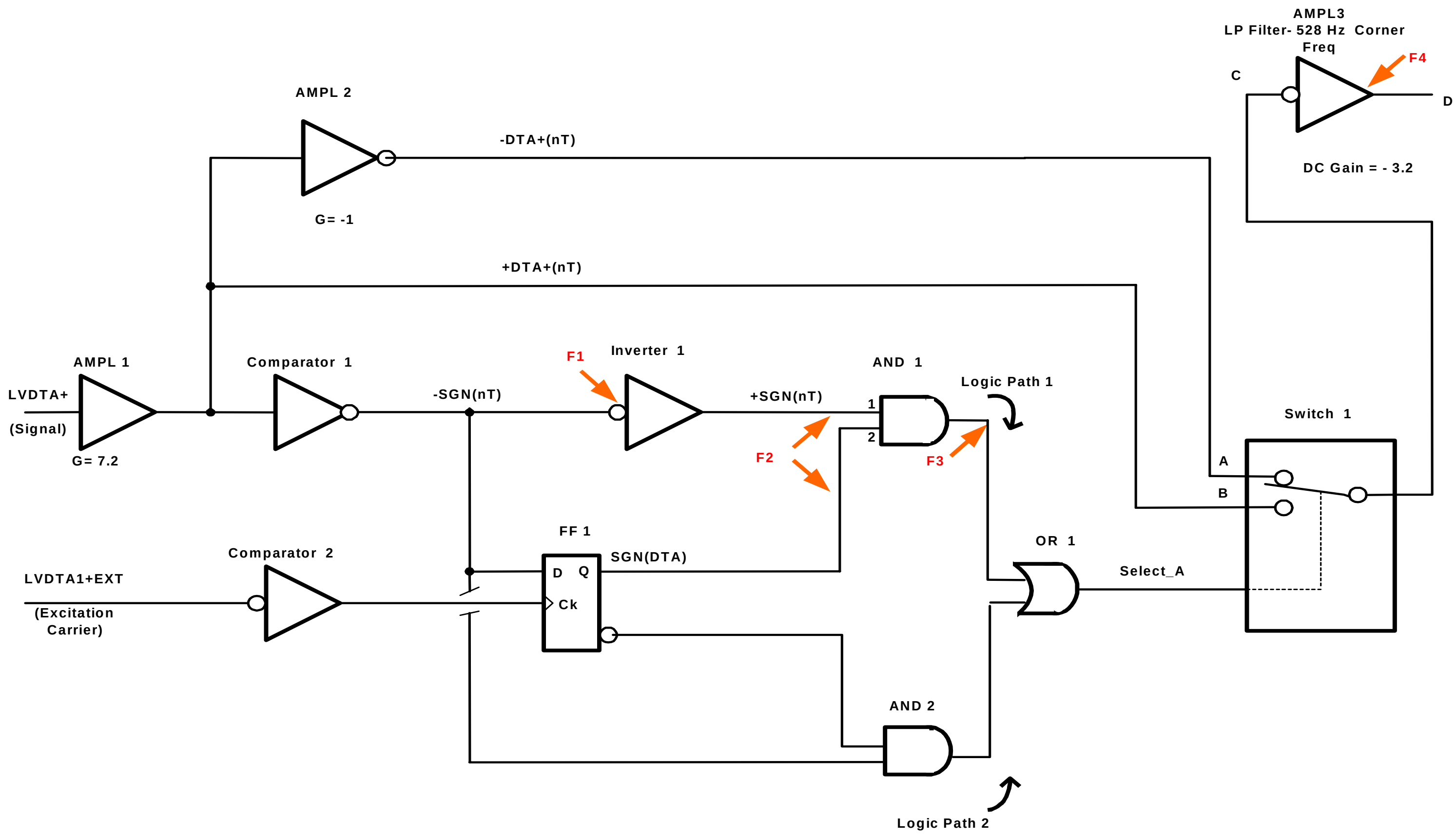

Figure 8.3-2 Simplified LVD Schematic

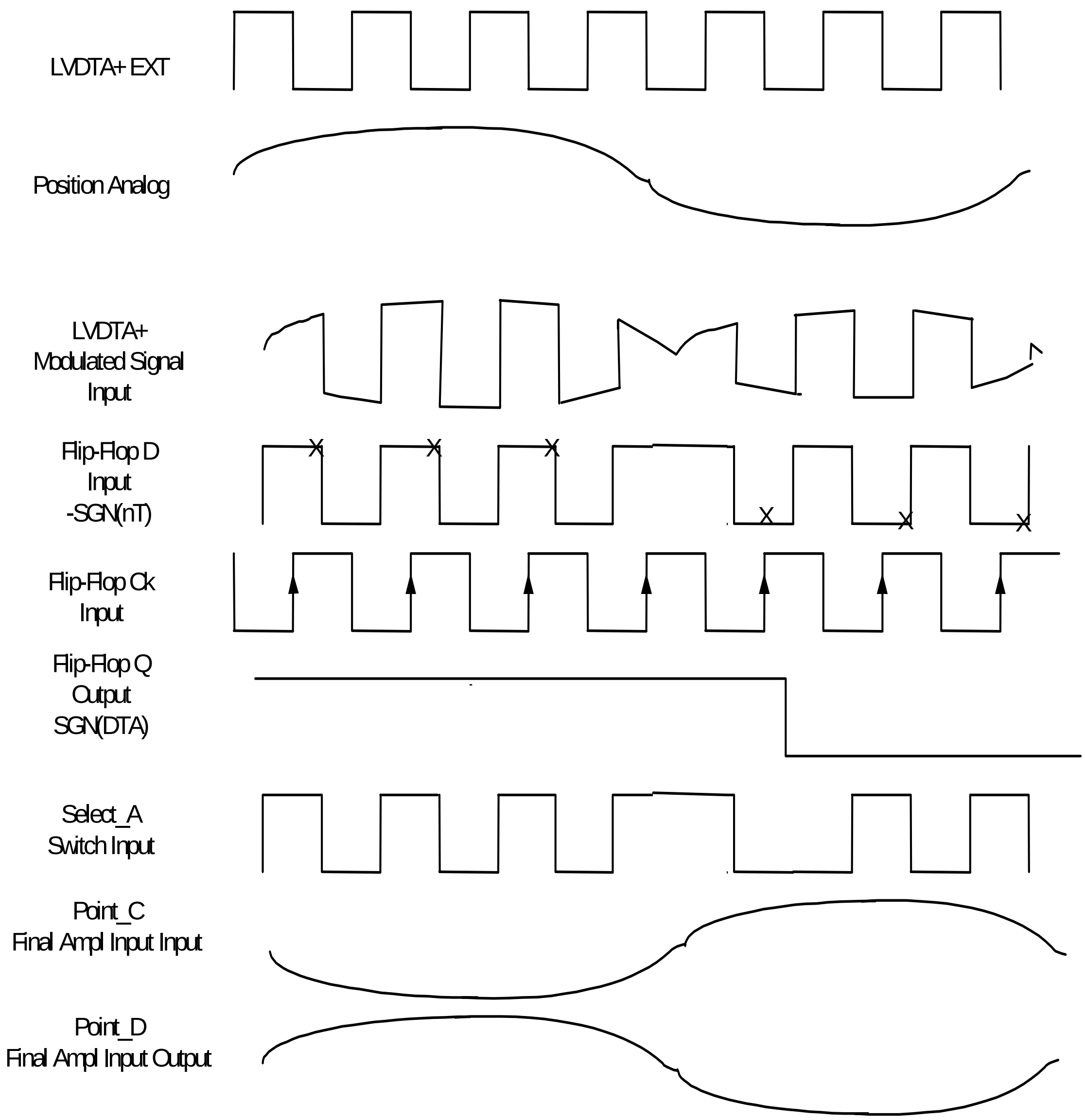

Figure 8.3-3 LVDT Waveforms

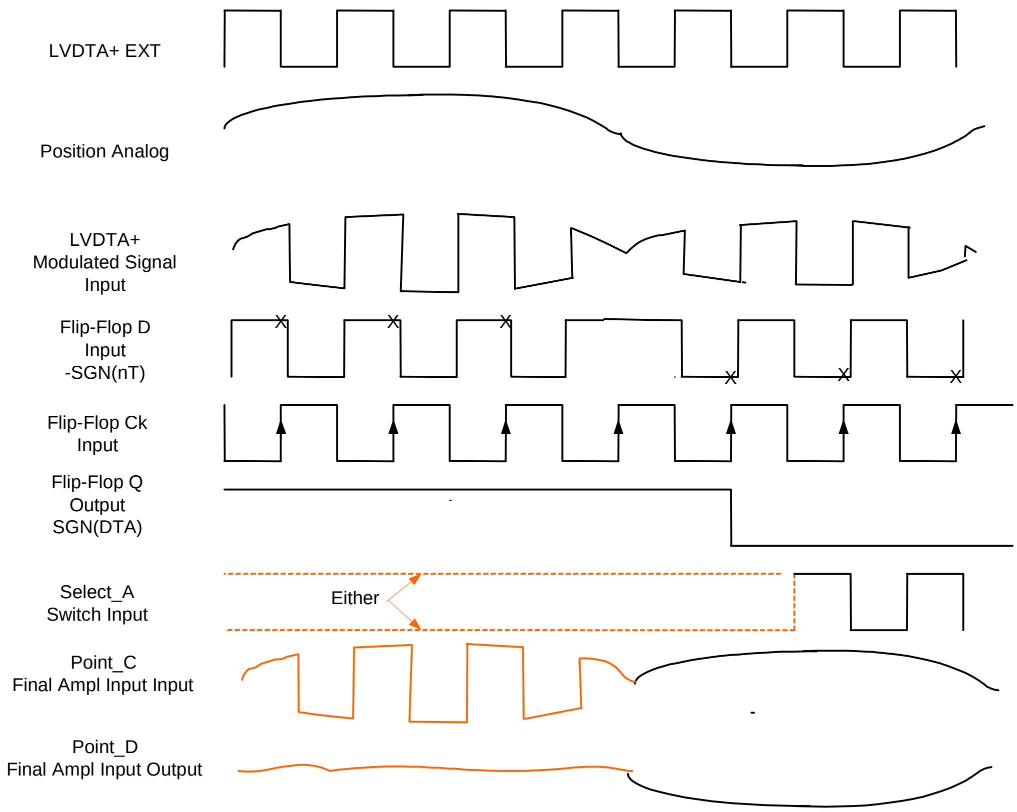

Figure 8.3-4 More LVDT Waveforms

Figure 8.3-3 shows the expected waveforms. The input is similar to that of a balanced modulated signal, chopped, but with horizontal symmetry. The clock or carrier frequency is about 52 KHz. The transitions are occurring on about 10 microsecond centers. The signal is sampled by the flip-flop at the points marked X, and thereby gets the sense of polarity of the original waveform. When the polarity of the sampling changes, the flip flop changes the logic flow through the circuit which causes the pieces of the chopped waveform to be assembled in either the positive or negative polarity regions of the final output. These two logic paths are labeled *logic path 1* and *logic path 2.*

The near absence of the positive half of the output waveform suggests a partial open circuit loss of the positive rail of the output stage *Amplifier 3* as a possibility (at *F4*). The remaining components of analog paths are exonerated from being failure suspects, because they are used in both positive and negative synthesis of the final signal. Because the negative half was ok, therefore -- with the exception of the possible open rail in output stage *Amplifier 3* -- the analog circuits are ok. Removed from failure consideration, then, are the two remaining amplifiers, the switch, *Comparator 1* and probably *Comparator 2.* They were operating correctly because the circuit was able to distinguish between the positive and negative halves of the original signal. By similar reasoning, *Flip-flop 1* is ok, but one output (Q) could have shorted.

This leaves the logic paths as suspect. Logic path 2 is responsible for the negative half of the final signal synthesis, so it is ok. This leaves *logic path 1*. We know the OR gate is working, at least one input and its output. The other input was low to allow the good signals of *logic path 2* through it. This input was from *logic path 1*. It could have stayed low when it was supposed to pulse during the [positive] output synthesis. This could be caused by a low at *F3*, which could be caused by a low signal at the points marked *F2*.

These low signals could be caused by a low signal at the flip-flop output, Q, or by a low signal from the inverter, (which should have been pulsing). This low signal could have been caused by a short at the inverter output line or by an open circuit at the inverter input. We know that the signal *–SGN(nT)* is working, pulsing, because of the proper operation of the negative half output.

Any one of these logic-path failures could cause the sequence shown in Figure 8.3-4. Here the negative part of the output is produced, properly, but during the positive half, the original waveform is presented to the output filter in its modulated form, un-rectified and having an average value close to zero. Imbalance in the waveform or asymmetry can cause a slight positive bias as was recorded. This modulated waveform results from the switch not being driven by *logic path 1* to form the rectification. The filter rolls–off is at 528 Hz and levels off below 48-dB or x 200 attenuation to the signal switching transitions (104 KHz).

Unexplained: The high frequency noise in the output does not correlate to the frequencies involved in this portion of the CCE. The slight ramping is also not attributable to any know bias current integration, and remains unexplained.

Opens and Shorts: The amplifier partial open-circuit and logic open-circuits offer no problem with failure propagation. Short circuits can cause power supply overloading or overheating in a low impedance circuit. This is not the case in this failure. The logic involved is the HCS family. Specifically HCS 132 and HCS 74. The output impedance is approximately 100 ohms, so that the short current magnitude will be limited to 50 mA. It would create a 250-mW thermal anomaly, and of course exceeds the chip output rating (25 mA). The thermal rise would be less than 3 or 4 degrees C. These effects would be contained and not propagated to other circuits within the CCE or other units on the spacecraft.

Conclusion

The failure occurred at one of three integrated-circuit devices in the LVDT signal processing of the CCE. The failure was (1) caused by an open-circuit in the final amplifier stage positive rail, or, alternatively, (2) by either an open-circuit, or short-circuit at two logic devices comprising a logic path of the CCE LVDT processing circuit. The failure power and thermal effect is either zero or minimal in either case, and is well contained within the CCE. The failure is expected not to propagate and not to cause other failures.

It must be noted that these findings are preliminary. We have a breadboard of the LVDT circuit which could be used to test these hypotheses at some future date.

Anomaly Resolution

It was determined that the cooler could be run safely without the sensor information if the DC control loop were disabled and a non-default, fixed DC offset were implemented.

The new DC offset (1965 counts) was uploaded in a software patch as part of RTS 176 at 01-030:1743. To further ameliorate risk, the internal maximum drive limit was reduced to 75% during the cooldown process. This limit is increased to 89% (the original on-orbit value) after the cold head temperature has equilibrated at 110K. These changes have been incorporated into the normal operations, RTSs and STOL procedures, of the cooler. The cooler has been operated in this configuration since 30 January 2001 and performance has met on-orbit expectations.

8.3.2 Cryocooler Cooling Capacity Anomaly

Background information:
Due to the position sensor anomaly on Jan 10 the compressor piston bumped the end stop for several hours. Subsequent to this event period the cooler motor drive limit was set to 75% and the DC offset was disabled for the period from Jan 12 to Jan 30. With the DC offset control 'off' and a drive limit of 75% the cooler was working "nominally" up through Jan 21. Typically, the post cooldown drive settled in at about 70% and then would ramp up to the 75% limit in 12 hours due to contamination deposition on the cold head. For the 12 hour post cooldown period the cryocooler would maintain a temperature of 110 Kelvin on the cold head.

Anomalous Operation:
Between Jan 22 and Jan 29, during 4 cold cycles, the cold head temperature only reach 120K for while the motor drive was at 75%.

Anomaly Review:
Extensive review of the cryocooler and instrument telemetry indicates no apparent explanation for the drive increase. The following telemetry values were reviewed:

Cooler setpoints: OK
Cooler vibration signature: OK
Cooler stroke vs drive transfer function: OK
Cooler centerplate temperature: OK

Instrument: VNIRASPT3: OK YHSATMP1-6: OK

Two possibilities for the change in cooler performance were:

(i) There was an increase in external load.
(ii) There was an internal contamination inside the cooler due to the event period of the position sensor anomaly.

Reset and normal operation:
On late Jan 30 the cooler CEA was warm booted and a software patch was uploaded to 'fix' the DC offset drive. During the initial cooldown there was an "extra" heat load which caused the motor drive to ramp up to 87% during the later part of the cooldown. The "extra" load was caused by a commanding error which left the instrument in STANDBY mode for about 35 minutes. In STANDBY mode, both the VNIR and SWIR ASPs are powered and power to the SWIR ASP causes a direct load to the cold head through the focal plane. The cooler drive subsequently dropped back to 70% with the cold head at 110K when the "extra" heater load was removed.

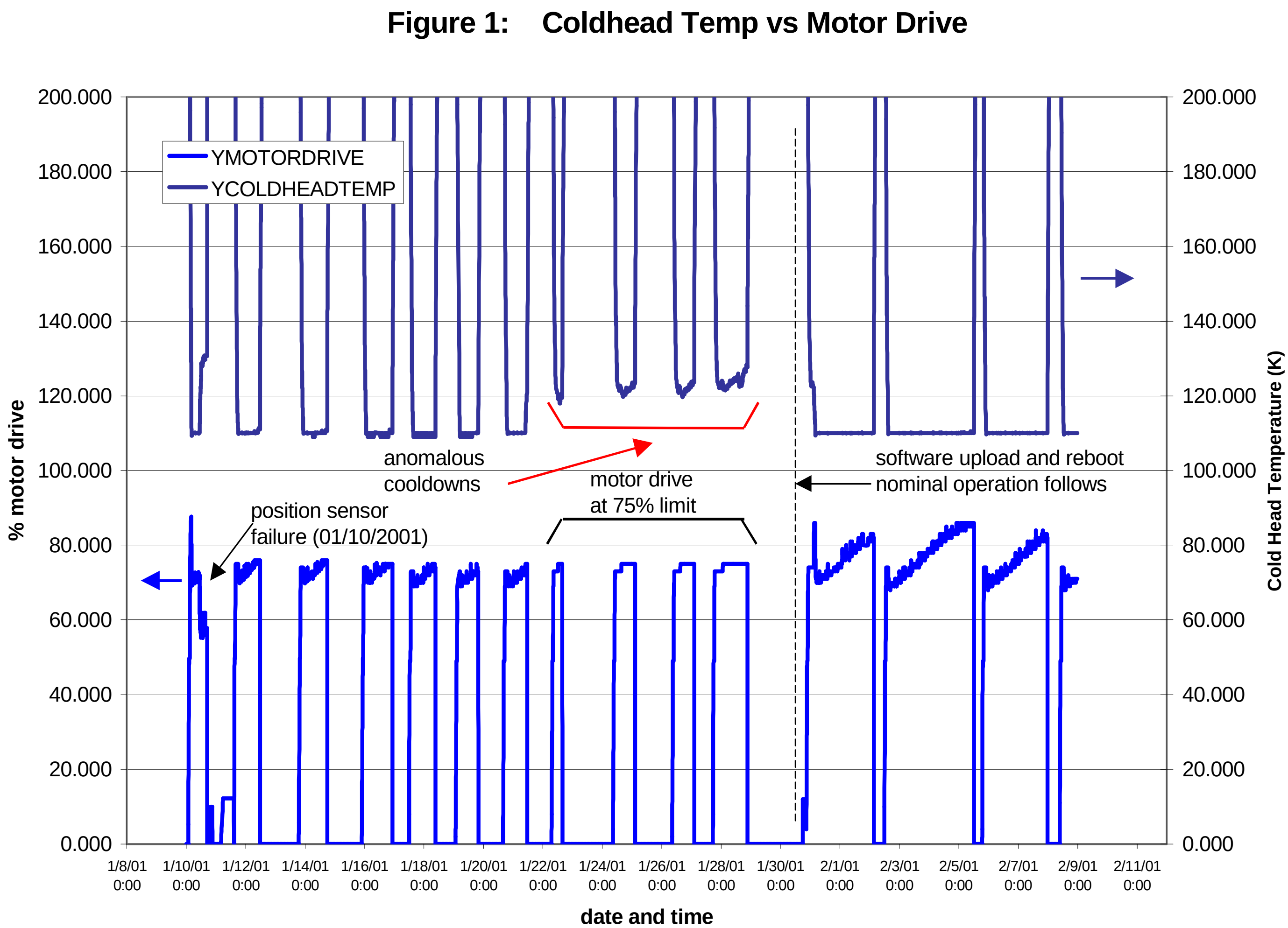

Figure 8.3-2 Cold head Anomaly

Figure 8.3-2 description:
The positive peak position measurement failed on 01/10/2001 and the cooler was turned off. The cooler was then turned back ON 01/12/2001 with the DC offset drive disabled and the drive limit set to 75%. The cold cycles (Jan 12-21) all reached the 110 Kelvin setpoint and maintained that setpoint temperature for approximately 12 hours before the motor drive ramped up to 75%, due to external contamination.

Note: Once the motor drive reaches the drive limit of 75% the cold head temperature would start to drift up.

The next four cold cycles between Jan 22-30 had the anomalous cold head temperatures results.

On Jan 30 a software upload was used to set the DC offset to a fixed value and a warm boot was also done which reinitialized the databases. Nominal cooler operation has been observed since that time.

8.3.2.2 Cryocooler Cold Cycle Anomaly Report 3/19/01

On March 19, 2001 the cryocooler had a small change in the motor drive while maintaining the 110 Kelvin cold head temperature. The motor drive had a step increase of 5% with no apparent change in heat load on the cooler.

Current Cold Cycle Trending:
Instead of settling in at around 69-70% drive level "post cooldown" the cryocooler drive now goes to 74-75% (see following chart). There is no "porpoising" in the motor drive which would suggest that the cause of this drive change is not a “volatile” condensing within the cryocooler but more likely due to a “floating particle” in the bypass line area of the cryocooler. The particle was probably generated when the piston hit the fore end stop during the position sensor anomaly period.

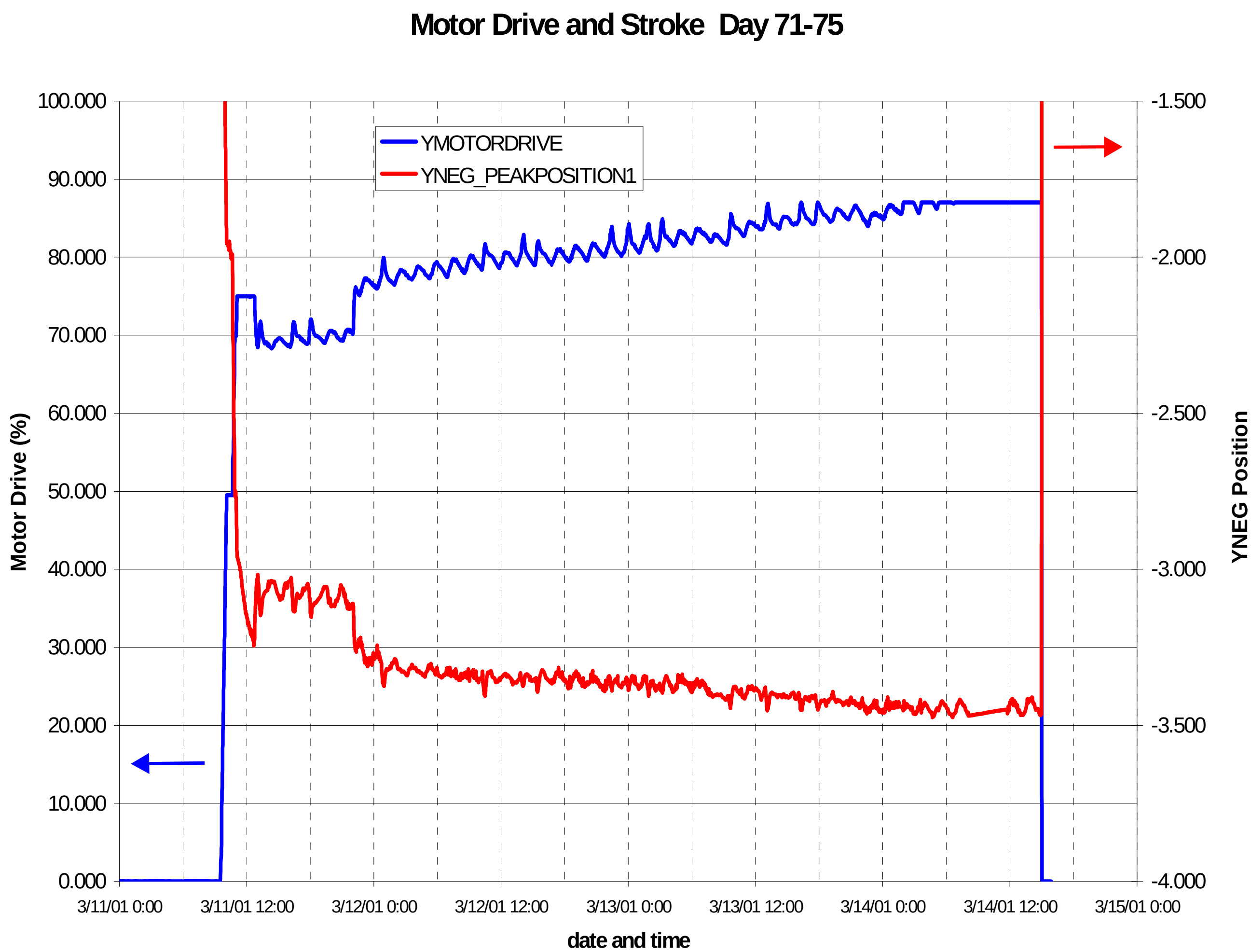

Figure 8.3.3-2 Cold head anomaly day 71-75

8.4 External Contamination

8.4.1 Cause of Contamination

During thermo-vac testing at GSFS there was an event which caused water moisture to be trapped with the Hyperion instrument. After the review of this event, it was decided that decontamination before launch was not feasible. Therefore, On orbit, as the cold block of the cryocooler reached 110K, water vapor would start to condense on the cold block. This increased the heat load due to (i) 'heat of condensation' and (ii) by changing the surface emissivity of the cold surfaces.

8.4.2 Cryocooler Run Times for the First 30 Days of Operation

During the initial 30 day operation period of the cryocooler the run time increased as the instrument was exposed to more outgassing time. After each decontamination cycle less water would remain inside the instrument and the run time of the next cold cycle would be increased.

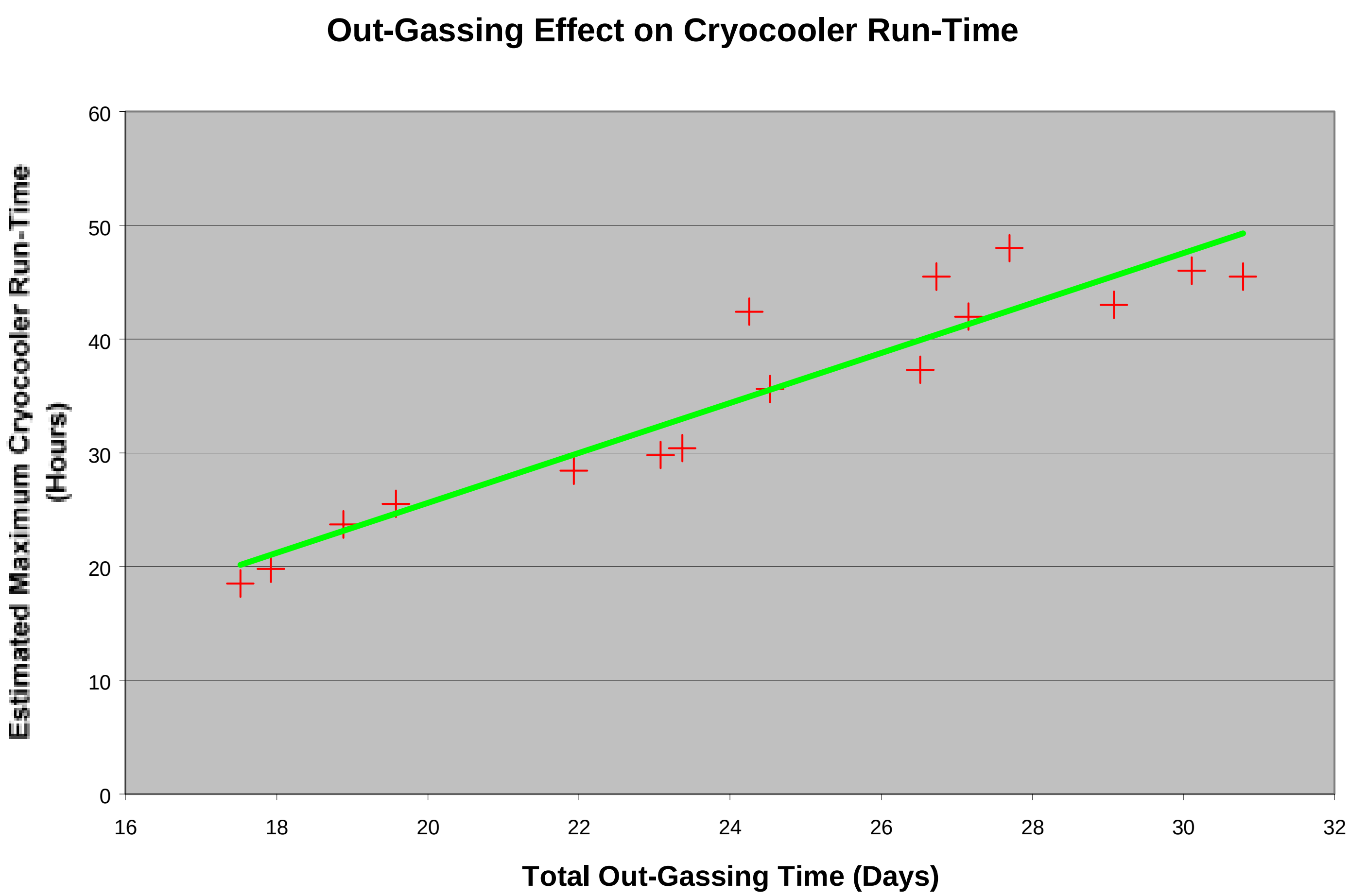

Figure 8.4-1 Cryocooler Run Times for First 30 Days of Operation

8.4.3 Cryocooler Run Times for post 120 day Period

The cryocooler can operate for approximately 80 hours as of 4/16/01 before decontamination is necessary. Of the 80 hour operation period, 76 hours are at 110K.

With an 8 hour decontamination period and a 4 hour cooldown (12 hours not at 110K) and 76 hours at 110K the cryocooler currently has a cold/warm duty cycle of approximately 86%. The cooler on time is currently increasing at approximately 0.4 hours per day which will allow the cooler to reach a 90% cold duty cycle in approximately 32 days.

See the Reference 4 for specific criteria regarding decontamination cycles.

9.0 COMMANDING ANOMALIES

This section covers those events where Hyperion responds nominally to issued commands from the spacecraft, but where a problem or error occurred in the sequence of issued commands.

9.1. 5 December 2000, GMT=00-340:1839, RTS 115 Not Enabled as Requested

9.1.1. Introduction

This section describes the events associated with a Hyperion on-orbit contingency that took place on 5 December 2000, at around 1039 PST (= 340/1839 GMT). The instrument was left in STANDBY mode (with ASPs powered) and with the aperture cover in the SOLARCAL position for approximately 1 hour. Data and analysis to date do not indicate that Hyperion sustained any damage. The aperture cover in the SOLARCAL position does not permit direct solar illumination of the focal planes and, in that way, they were protected. It appears that the internal safeguard within Hyperion, which turns off the ASPs and closes the cover upon reaching an ASP temperature of 50C, was tripped.

9.1.2. Background Information

Most Hyperion imaging events are performed by running existing command sequences called Relative Time Sequences (RTSs). After being created or modified, RTSs must be loaded and enabled prior to being performed. RTSs can be initiated during a real time pass or can be run from the daily ATS load (Absolute Time Sequence, the set of commands performed by the spacecraft for imaging and other activities, created and loaded on a daily basis). Additional commands can be added to an RTS manually as part of the ATS load (this allows for flexibility in synchronizing imaging events between the 3 EO-1 instruments).

The sequence of commands shown in Table 9.1.2-1 performs a typical solar calibration. This sequence can be initiated in an ATS load, by calling **RTS 111 and 115**. It is assumed that, prior to the start of this sequence, Hyperion is powered on and in nominal flight configuration (IDLE mode, aperture cover closed, ASP's and cal lamps NOT POWERED). Commands noted as "manual" are not included in either RTS 111 or 115, and are manually added to the sequence by the EO-1 Planning Team.

RTS 115 was created on 30 November 2000 per an Ops Instruction generated by Momi Ono. The Ops Instruction listed the commands to go into RTS 115 and also requested that the new RTS be uploaded to the spacecraft and enabled prior the first Hyperion solar calibration event (see Table 9.1.2-1 for a listing of commands in RTS 111 and 115).

Table 9.1.2-1 Command Sequence for Hyperion Solar Cal

Relative Time	Command	RTS	Notes
00:00:00	YHEASTBY	111	goto STANDBY mode
00:00:30	YHEASETSWIR GAINA=1 GAINB=1 GAINC=1 GAIND=1 SWIRA=97 SWIRB=97 SWIRC=104 SWIRD=102 INTGTIME=125	manual	set SWIR gain, offset, integration time—
00:00:31	YHEASETVNIR VNIRALV8 VNIRBLV8 VNIRCLV8 VNIRDLV8	manual	set VNIR gain, offset
00:10:00	YSCISTART	111	1 sec dark image
00:10:01	YSCISTOP	111	
00:10:03	YCVRTOCAL	111	open cover to cal position
00:10:19	YSCISTART	manual	10 sec solar cal image
00:10:29	YSCISTOP	manual	
00:10:34	YCVRCLOSE	115	close cover
00:10:52	YSCISTART	115	1 sec dark image
00:10:53	YSCISTOP	115	
00:10:55	YHEASLAMP LEVEL=255	115	secondary lamps ON with a 3 minute lamp warm up
00:13:55	YSCISTART	115	3 sec cal image with secondary lamps ON
00:13:58	YSCISTOP	115	
00:14:00	YHEASLAMP LEVEL=0	115	secondary lamps OFF
00:14:20	YSCISTART	115	1 sec dark image
00:14:21	YSCISTOP	115	
00:14:23	YHEAIDLE	115	back to IDLE mode

9.1.3. Contingency Event

At 00-340:1839 GMT, the EO-1 spacecraft was performing a Hyperion solar calibration maneuver per the sequence described above in Table 9.1.2-1. RTS 111 had run to completion, the solar-illuminated target image had been taken, and the instrument was at the place in the sequence indicated by "* * * * *". The Hyperion aperture cover was in the SOLARCAL position and the instrument was in STANDBY mode. At this time, the spacecraft received an event message that indicated that RTS 115 had not been enabled and was being rejected. The Hyperion Ops Team verified that this meant that all the commands in RTS 115 would NOT be performed. At 00-340:1842 GMT, commanding to the spacecraft was lost due to the spacecraft moving out of ground station contact. The next scheduled ground station pass was in another 5 hours.

The Hyperion Ops Team and the EO-1 MOC, Systems, Power, Thermal, and C&DH Teams all worked together to find a solution. An emergency TDRSS pass was arranged over McMurdo Ground Station during which the MOC would perform the

hyp_safehold.prc STOL procedure, and would enable RTS 115 to avoid this situation during the next Hyperion solar calibration event. The **hyp_safehold.prc** procedure sends the SAFEHOLD command, which sends the instrument to IDLE mode and closes the aperture cover, sends an additional COVER CLOSE command only if required, and then verifies nominal flight configuration (IDLE mode, instrument voltages, cover position). TDRSS was acquired at 00-340:1935, and **hyp_safehold.prc** was initiated by the MOC. When live telemetry was acquired at the Hyperion Ops Center at TRW, the instrument was already in IDLE mode, with the aperture cover in the CLOSED position, encoder telemetry value = 3424. The VNIR ASP and FPGA temperatures were ~48C. Instrument telemetry was monitored during the remainder of the pass, and it became clear that Hyperion had responded to the internal ASP temperature safeguard prior to the MOC performing the safehold procedure. Trending data during this time period (stored instrument telemetry recorded between ground station passes) show that when the VNIR ASP reached 50C, power to the ASPs was cut and the VNIR ASP temperature began to drop (see figure 9.1.3-1). This indicates that the instrument went from STANDBY to IDLE mode. Since this transition occurred when the spacecraft was not commandable, we can assume that the internal software safeguard on board Hyperion was triggered to commence the transition to IDLE mode and to close the aperture cover.

By 00-340:2130 GMT, roughly 2 hours later, telemetry indicated that the VNIR ASP and FPGA had both returned to their nominal values of 32C.

9.1.4. Conclusions

All available data to date indicate that the instrument is functioning nominally. The temperature data was reviewed by the TRW Hyperion Thermal Engineer, who confirmed that the instrument returned to nominal temperatures (particularly the VNIR ASP), and that, from the thermal perspective, the instrument is good-to-proceed. The TRW Hyperion Electrical and Flight S/W Engineer confirmed that although the VNIR FPGA temperature exceeded its Red High Limit during the event (55C), there is about 15 degrees of margin built into that number. Thus, a VNIR FPGA temperature of 60C or less is does not a pose much of a potential problem.

Hyperion is accepting and executing commands normally. Several DCEs have been taken since the time of the event. Preliminary analysis performed by the TRW Hyperion Focal Plane Engineer of dark files prior to and after the event indicates that the focal planes and the focal plane electronics are functioning nominally (see figures 9.1.4-1a and b). For more details, please refer to the Part 2 of this report.

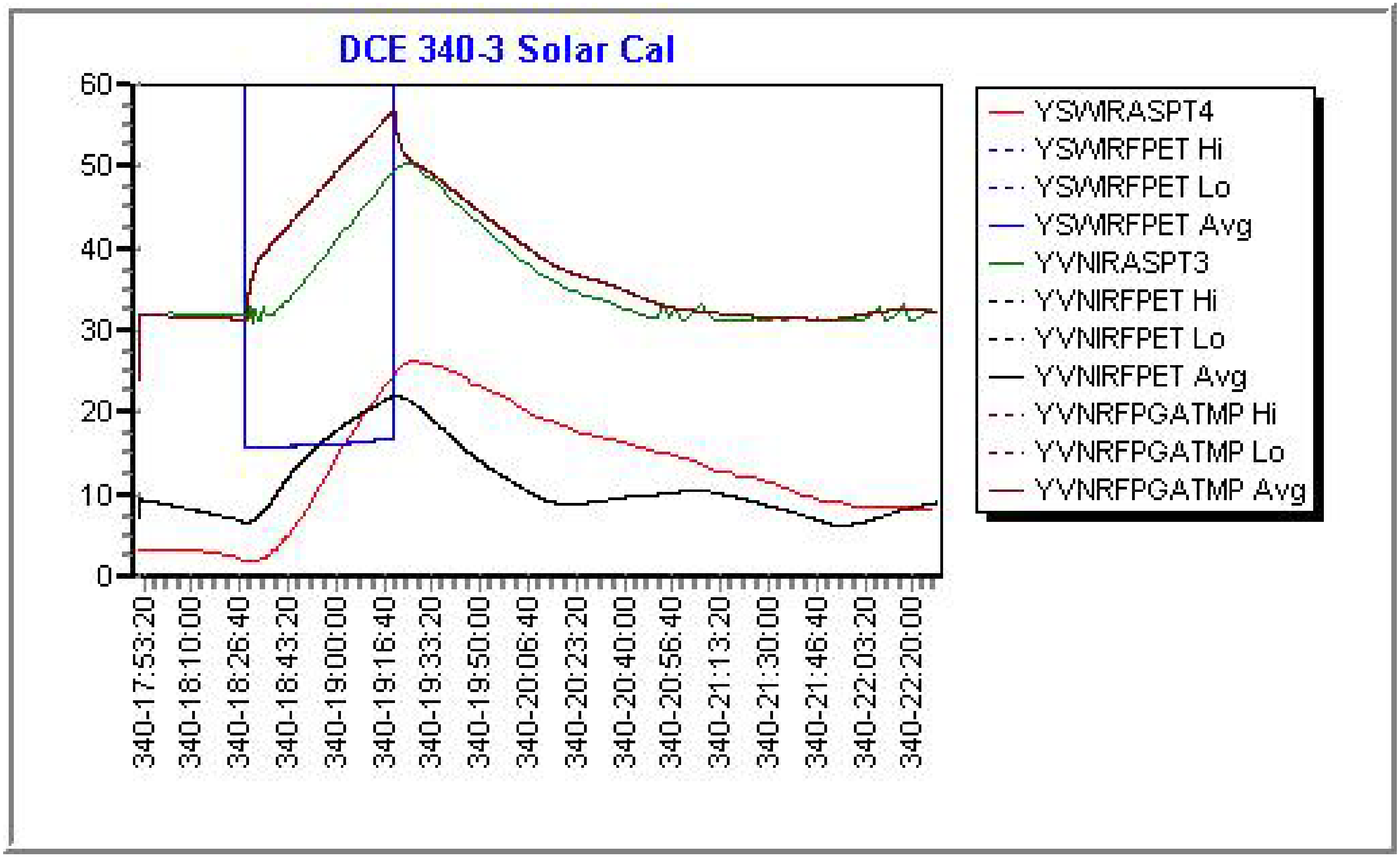

Figure 9.1.3-1 Temperature profiles of the warm up and cool down associated with the Contingency Event.

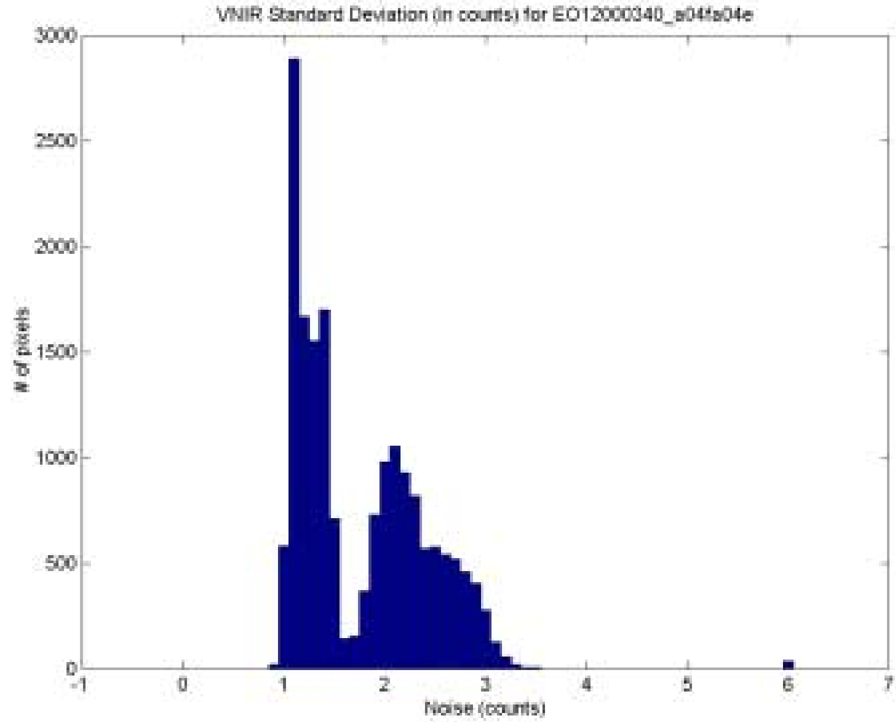

Figure 9.1.4-1a – Dark file noise statistics prior to the Contingency Event.

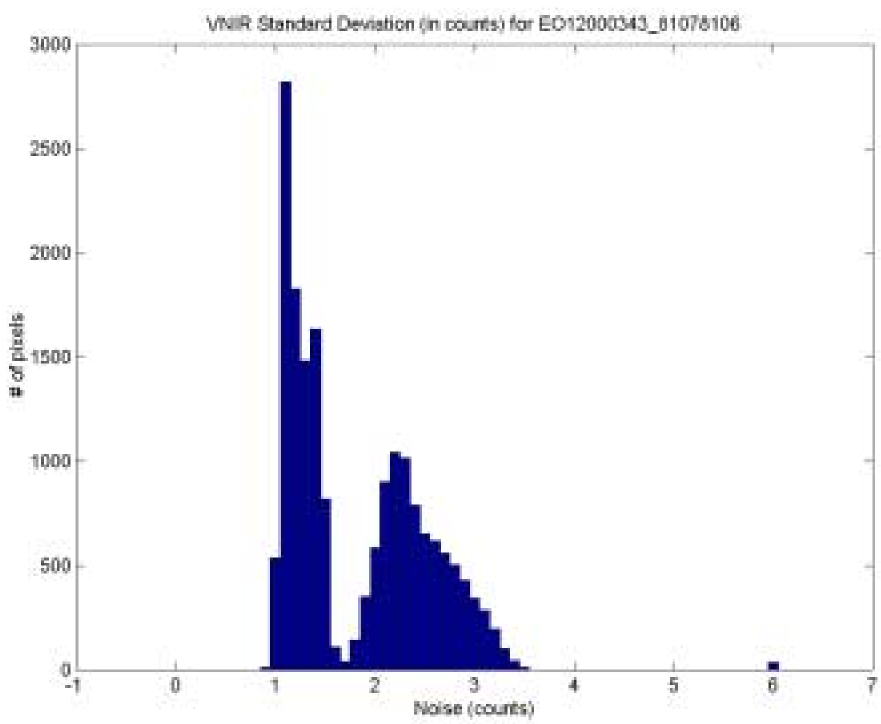

Figure 9.1.4-1b – Dark file noise statistics after the Contingency Event.

9.2. 4 January 2001, GMT=01-004, RTS 101 Scheduled But Not Performed

9.2.1. Background

During pre-launch testing there was some concern about the ability of the VNIR ASP to cool between DCEs. This led to the rule for on-orbit operations of 1 DCE per orbit for Hyperion. However, the ability of the VNIR ASP to cool on-orbit has exceeded our expectations and we have been able to relax the 1 DCE/orbit rule for certain special cases.

9.2.2. Contingency Event

On Day 004, 4 January 2001, 4 scenes were scheduled for early in the day as shown in Table 9.2.2-1.

Table 9.2.2-1 Scene schedule for Day 004 between 0000 and 1100 GMT

Scene	GMT	Δ-time
E. Antarctica	0133	66 mins
Tangshan China	0239	
Polar Ice Fields	0945	64 mins
Humber Bridge	1049	

The TRW Hyperion Ops Team was contacted by Mission Planning to confirm that taking 2 scenes in a time period less than one orbit was allowed. The scenes were scheduled to include Hyperion, but when the instrument state of health data was examined by the TRW Hyperion Ops Team, it was discovered that Hyperion was not commanded to STANDBY mode for the 2nd scene in each pair, Tangshan China and Humber Bridge. This resulted in Hyperion missing those scenes. Furthermore, it was discovered that RTS 101, the Hyperion DCE Imaging Prep Sequence, was not performed for either Tangshan nor for Humber Bridge. It was confirmed that although Mission Planning had believed that RTS 101 was scheduled for those scenes, the CMS system did not allow RTS 101 to be scheduled per a rule built into it by the CMS/Planning Team Lead, per the original TRW edict of 1 DCE per orbit.

9.2.3. Conclusions

An Enhancement Request (ER #38) was generated and discussed at length in both the EO-1 CCB, the daily Mission Planning/Scheduling Meeting, and the Instrument Team Meeting during the week following the event. A general policy of having the Planners insert RTS 101 by hand ONLY for those key scenes where 2 scenes in 1 orbit is explicitly requested and agreed to by TRW has been implemented. Since the new policy has been implemented, several “double scenes” have been scheduled and carried out with no further anomalies.

9.3. 31 January 2001, GMT=01-031:0200, Hyperion Left in STANDBY mode with Aperture Cover in Full Open Position Due to RTS 108 Being Disabled

9.3.1. Background

On 19 January 2001, there was a teleconference attended by representatives from all spacecraft subsystems and instruments and the EO-1 Mission Operations Team. The goal of the meeting was to determine which RTSs were required for normal spacecraft operations, which were of secondary importance, and which, if any, could be disabled and deleted from spacecraft memory, in order to improve the spacecraft cold restart procedure. During the RTS meeting, the TRW Hyperion Operations Lead supplied the EO-1 Mission Operations Team with the requested information but mistakenly instructed MOC personnel that RTS 108 was not required for routine operations (the intended instruction was to disable RTS 109, which is not required for normal imaging operations). The EO-1 Mission Operations Team brought this mistake to the attention of the TRW team during a phone conversation on 21 January 2001, and it was thought that no further action by TRW was required. No follow up was done.

9.3.2. Contingency Event

On Day 031, approximately GMT =0200, during a routine pass, the TRW Hyperion Operator noticed that Hyperion was left in STANDBY mode with the aperture cover in the FULL OPEN. The VNIR ASP was just under 45C. The Hyperion Operator instructed the MOC to perform the Hyperion safehold procedure, **hyp_safehold.prc**. This was accomplished and it was confirmed that Hyperion was back in IDLE mode, with the aperture cover in the CLOSED position prior to the end of the pass. Upon examination, it was discovered that during the pass at GMT=01-030:2247, RTS 108, the Hyperion DCE Imaging Post Sequence (which includes the commands to close the cover and put the instrument back in IDLE mode) had been DISabled per the RTS Meeting of 19 January 2001. RTS 108 was re-enabled to allow normal imaging operations and RTS 109 was DISabled. Hyperion returned to nominal temperatures in roughly 2 hours and no further anomalies were observed.

9.3.3. Conclusions

A Discrepancy Report, DR # 354, was generated and discussed at length in the EO-1 Change Control Board and the Instrument Team Meeting during the week following the event. Both the MOC and the TRW teams have acknowledged responsibility for this error. The correction has been made and duly noted. No further anomalies have been observed due to this event. No damage to the instrument has been observed in either telemetry or imaging performance.

10.0 SPECIAL TESTS

10.1. SWIR-only Test

During ground testing at TRW, it was determined that the SWIR focal plane required a 10-minute warm-up period for thermal stability. Without this warm-up, the changing SWIR focal plane temperature caused changes in focal plane noise, which reduced the accuracy of SWIR measurements. The goal of the SWIR-only test was to revisit the duration of the SWIR warm-up period in the true on-orbit configuration. In order to measure dark noise on the SWIR focal plane as a function of warm-up time, dark data are collected periodically over a 30-minute period. In this test, Hyperion was patched to operate in SWIR-only mode in order to avoid overheating of the VNIR focal plane. Table 10.1-1 shows an outline of the test sequence.

Table 10.1-1 SWIRonly Test Sequence

1	Send SWIR-only patch.
2	STANDBY mode
3	Send SWIR gain/offset/integration time
4	Wait 10 minutes
5	1 second dark image, repeat at 15, 20, 25, 30 minute mark
6	Send VNIR+SWIR patch for normal ops
7	IDLE mode
8	Verify IDLE mode
9	Verify VNIR+SWIR normal ops mode via **hyp_asp_test.prc**

The test was performed on 1 February 2001, GMT=01-032:0419. It was initiated during a ground support and SWIR-only operation was confirmed and verified by the TRW Hyperion Operations Team. The command sequences were stored in RTSs 112 and 113, except for step 8, which was performed manually, and step 9. Steps 8 and 9 were performed during the ground support at GMT=01-032:0555. Hyperion operations were nominal with no anomalies. Most notably, Hyperion was commanded to SWIR-only mode and back to VNIR+SWIR normal operations mode successfully. For the science results from this and other special tests, please refer to Part 2 of this report.

10.2. Lamp Stability

Given the change in the operating environment of the internal calibration lamps between ground testing and on-orbit use, discussed in section 7.0, it was decided to verify that the 3-minute lamp warm-up was sufficient to achieve lamp output stability. In addition, we wanted to develop a test, which could be performed periodically throughout the mission to monitor the lamp output in more detail. Table 10.2-1 shows an outline of the test sequence.

Table 10.2-1 Lamp Stability Test Sequence

1	STANDBY mode
2	Send VNIR and SWIR gain/offset/integration time
3	Wait 10 minutes
4	1 second dark image
5	2^{ndary} Lamps on (level 255)
6	1 second lamp image, repeat every 15 seconds for 6 minutes of lamp on-time
7	2^{ndary} Lamps off (level 0)
8	1 second dark image
9	IDLE mode

The test was performed on 28 February 2001, GMT=01-059:0550 and again on 5 March 2001, GMT=01-064:0300. The test was repeated because all science data were not recorded during the first attempt due to commanding conflicts with the AC instrument. However, Hyperion functioned nominally during both attempts. For the science results from this and other special tests, please refer to Part 2 of this report.

10.3. Solar Scans

There have been some well-documented problems during the early orbit checkout period of the EO-1 Mission with spacecraft pointing during science data collection events. In particular, because the Hyperion solar calibration requires non-nadir pointing, there was some question as to the exact illumination angle of the sun, through the solar baffle, onto the solar diffuser surface on the inside of the aperture cover. In order to verify this angle, the TRW Hyperion team requested scans of the sun across the acceptance cone angles of the solar baffle in both the azimuth and elevation angles with respect to Hyperion. These special scans required extra planning to command the spacecraft but used the normal solar calibration command sequences (RTSs 111 and 115) to command the instrument. Hyperion functioned nominally during these scans. For the science results from this and other special tests, please refer to Part 2 of this report.

11.0 COMMAND SEQUENCES REQUIRED FOR INSTRUMENT AND CRYOCOOLER NORMAL OPERATIONS

11.1. Required STOL procedures

Table 11.1-1 shows the required STOL procedures for normal operation of Hyperion and the cryocooler, not including those used in power-on, activation, or functional checkout. Note that the STOL procedure **hyp_cryo_autorestart.prc** must be performed to start the **first** cooldown cycle after database initialization (**hyp_cryo_init_flight.prc**). However, thereafter, the cooler can be restarted via RTS 172 and 183 only in the daily ATS.

Table 11.1-1 Listing of Hyperion and Cryocooler STOL Procedures

STOL Procedure	Function
hyp_idle_verify.prc (rev E, 09-Jun-00)	Verify nominal IDLE mode configuration
hyp_flt_config.prc (rev --, 12-Jun-00)	Verify nominal IDLE mode + cold SWIR
hyp_cal_redund.prc (rev C, 20-Sep-00)	Perform internal calibration sequence, calls RTSs 165, 166.
hyp_cal_shortredund.prc (rev C, 20-Sep-00)	Perform short internal calibration sequence (3 seconds of science data), calls RTSs 167, 168.
hyp_cryo_init_flight.prc (rev F,26-Jan-01)	Initialize databases, calls RTSs 176, 180, 177, 178.
hyp_cryo_autorestart.prc (rev B, 22-Feb-01)	Start cryocooler cool-down process, calls RTS 172, 183.
hyp_cryo_autonormoff.prc (rev --, 22-Feb-01)	Normal shutdown of cryocooler, calls RTS 179.
hyp_cryo_getwavs.prc (rev --, 26-Jan-01)	Retrieves position sensor and balancer wave forms.
The following are for general contingency or diagnostic use:	
hyp_safehold.prc (rev --, 03-May-00)	Cover CLOSED, lamps, ASPs OFF, IDLE mode
hyp_reset.prc (rev K, 09-Jun-00)	Hyperion instrument reset, re-sends patches and resets op. htr. set points, clears RESET bit, returns instrument to normal ops config
hyp_clear_reset.prc (rev C, 09-Jun-00)	Clears s/c reset bit, after TSM/RTS-induced s/c reset.
hyp_cryo_emergoff.prc (rev E, 19-Nov-99)	Emergency shutdown of cryocooler.
hyp_cryo_retvdbs.prc (rev B, 27-Nov-00)	Retrieves cooler databases.
The following are for use in response to specific anomalies or changes in mission requirements:	
hyp_pwroff.prc (rev D, 28-Sep-00)	Properly shutsdown Hyperion instrument, should be performed AFTER cooler shutdown.
hyp_vnironly.prc (rev C, 9-May-00)	Disables SWIR ASP for VNIR-only operations.
hyp_swironly.prc (rev C, 9-May-00)	Disables VNIR ASP for SWIR-only operations.
hyp_heatersoff.prc (rev C, 9-May-00)	Turns ALL operational heaters OFF.
hyp_heaterson.prc (rev C, 9-May-00)	Sets operational heaters to OUTGAS setpoints.
hyp_heater1off.prc (rev --, 4-May-00)	Turns heater 1 (OMS) off.
hyp_heater2off.prc (rev --, 4-May-00)	Turns heater 2 (OMS) off.
hyp_heater3off.prc (rev A, 31-May-00)	Turns heater 3 (OMS) off.
hyp_heater4off.prc (rev --, 4-May-00)	Turns heater 4 (GIS) off.
hyp_heater5off.prc (rev --, 4-May-00)	Turns heater 5 (VNIR ASP) off.
hyp_heater6off.prc (rev --, 4-May-00)	Turns heater 6 (SWIR ASP) off.
hyp_cryo_enabtt.prc (rev B, 15-Jun-00)	Enables cooler temperature trips.
hyp_cryo_diag1.prc (rev A, 11-Jan-01)	For troubleshooting mode, change max drive to 76%.
Hyp_cryo_diag2.prc (rev --, 11-Jan-01)	Restart for troubleshooting mode, C1=9.0, C3=2.0, max drive=74%.
hyp_cryo_cage_check.prc (rev E, 09-May-00)	Verify cage status of cooler. Cooler should remain UNCAGED on-orbit for the duration of the mission.

11.2. Required Real-Time Sequences (RTSs)

Table 11.2-1 shows the current Hyperion instrument RTSs loaded into spacecraft RAM as part of nominal cold-restart procedure (included in the primary and secondary cold-restart procedures). These RTSs are required for normal operations of Hyperion and for certain special diagnostic tests. However, these are NOT part of the spacecraft TSM system for automatic triggering for SAFEHOLD mode or instrument RESET mode. It is assumed that Hyperion is in IDLE mode prior to the start of any and all of these sequences, with the aperture cover in the CLOSED position.

Table 11.2-1 Listing of Current Hyperion RTSs

RTS #	**Function**
	Nadir Imaging (ground, lunar, stellar/planetary)
101	Pre-Imaging (STANDBY mode, 1st dark image, cover OPEN)
108	Normal Post-Imaging (cover CLOSED, 2nd dark, cal, 3rd dark images, IDLE mode); *for collecting more than 5 seconds of image data*
109	Short Post-Imaging (cover CLOSED, 2nd dark image, IDLE mode); *for collecting 5 seconds of image data for S-band downlink*
	Solar Calibration Imaging
111	Pre-Imaging (STANDBY mode, 1st dark image, cover to SOLARCAL)
115	Post-Imaging (cover CLOSED, 2nd dark, cal, 3rd dark images, IDLE mode)
	Internal Calibration Imaging
165	Short Internal Cal part 1 (3 seconds of data)
166	Short Internal Cal part 2
167	Normal Internal Cal part 1 (5 seconds of data)
168	Normal Internal Cal part 2
	Special Tests
171	Diagnostic heater test (part 1)
172	Diagnostic heater test (part 2)
173	Diagnostic heater test (part 3)
151	Pre-Dark Cal Imaging (STANDBY mode, 1st dark image, cover CLOSED)
184	Special Lamp Stability (part 1)
185	Special Lamp Stability (part 2)
186	Special Lamp Stability (part 3)

Table 11.2-2 shows the current Hyperion cryocooler RTSs loaded into spacecraft RAM as part of nominal cold-restart procedure (included in the primary and secondary cold-restart procedures). These RTSs are required for normal operations of the Hyperion cryocooler. However, these are NOT part of the spacecraft TSM system for automatic triggering for SAFEHOLD mode or instrument RESET mode. It is assumed that Hyperion is in IDLE mode prior to the start of any and all of these sequences, with the automatic cryocooler telemetry enabled (YCRYOTLM=”on”).

Table 11.2-2 Current Listing of Cryocooler RTSs

RTS #	Function
Initialization for Functional Test and Normal Flight Operations	
171	Functional Test (10% Drive Test) parameters, Initialization part 1
176	Normal Ops initialization parameters, Initialization part 1
180	Initialization part 2 – fixed DC offset, disable DC loop
177	Normal Ops Initialization part 3/Functional Test Initialization part 2
178	Normal Ops Initialization part 4/Functional Test Initialization part 3
Normal Ops	
172	Cryocooler Restart (from cooler STANDBY mode) part 1
183	Cryocooler Restart part 2
179	Cryocooler Normal OFF

12.0 RECOMMENDATIONS

Because the red and yellow limits on telemetry points are defined to protect the instrument and spacecraft (and NOT necessarily to insure the quality of the science date), it is easy to miss the cryocooler cold head temperature being out of the nominal range for science data. Therefore, we recommend that the operators run the appropriate STOL procedure once per shift.

STOL Procedure	Condition
hyp_flt_config.prc	1. cryocooler is ON (YMOTORDRIVE $\neq$ 0) **AND** 2. 5 hrs or more after a cryocooler restart (via **hyp_cryo_autorrestart.prc,** or RTS 172, 183)
hyp_idle_verify.prc	1. cryocooler is OFF (YMOTORDRIVE + 0, or just completed hyp_cryo_autonormoff.prc, just completed RTS 179,) 2. less than 5 hrs after a cryocooler restart (via **hyp_cryo_autorrestart.prc,** or RTS 172, 183)

Both procedures check for nominal IDLE mode configuration (aperture cover in CLOSED position, internal calibration lamps and ASPs powered OFF, SWIR50 patch has been sent). **hyp_flt_config.prc** goes one step further to verify the proper temperature of the cold head. Failures during either of these procedures are covered in the latest revision of the Hyperion Contingency Trees (see Reference 7).

The cryocooler may be restarted and shutdown via STOL procedure OR via RTS, as indicated in the table 12.0-1. The STOL procedures were developed to require as little real-time support as possible (they each take less than 90 seconds to complete). The RTSs were developed in order to allow cooler operations to be automated and incorporated into the daily ATS load.

Table 12.0-1 Cryocooler Restart/Shutdown Procedures and RTSs

Function	STOL Procedure	Equivalent RTS(s)
cryocooler RESTART	**hyp_cryo_autorestart.prc**	172, 183
cryocooler SHUTDOWN	**hyp_cryo_autonormoff.prc**	179

The one exception to this rule is that any time the cryocooler databases are reinitialized (via **hyp_cryo_init_flight.prc**), it must be restarted via the STOL procedure **hyp_cryo_autorestart.prc** because the STOL contains a memory checksum test that is required after database reinitialization.

13.0 SUMMARY

The activation and Early Orbit Checkout of the Hyperion instrument have largely been successful. Operational difficulties due to the single on-orbit hardware failure (the cryocooler position sensor, 10 January 2001, see section 8), have been completely resolved and the instrument and cryocooler are performing nominally at this time.

14.0 ACRONYMS

AC	Atmospheric Correct
ACS	Attitude Control System
ALI	Advanced Land Imager
ASP	Analog Signal Processor
ATS	Absolute Time Sequence
CEA	Cryocooler Electronics Assembly
DCE	Data Collection Event
FPE	Focal Plane Electronics
FPGA	Focal Plane Gate Array
GIS	Grating Imaging Spectrometer
GMT	Greenwich Mean Time
HEA	Hyperion Electronics Assembly
LVDT	Linear Voltage Differential Transistor
MOC	Mission Operations Center, Goddard Space Flight Center
OMS	Opto-Mechanical System
RAM	Random Access Memory
RTS	Relative Time Sequence
STOL	System Test and Operating Language
SWIR	Short-wave Infrared
TDRSS	Tracking and Data Relay Satellite System
TSM	Telemetry and Statistics Monitor
VNIR	Visible Near Infrared