PM-LOC-1099

Summary: HIRDLS Unverified Failures

Item	Level	Title	Mission Impact	Likelihood	DR Association
1	Subsystem - TSS	Increased SMA Azimuth Stiction	5 – Reduced Data	Low	LM DR AC2158
2	Subsystem – CSS	CCU Caging Circuit Relay	6 – No Impact	Low	Ball MDR 19813 LM Ref DR AD7186
3	Subsystem – CSS	CCU Reset	5 – Reduced Data	Low	Ball MDR 12955 LM Ref DR AD7185
4	Subsystem – TSS	Chopper Speed Fluctuation	3 – Loss of Redundancy	Low	LM DR AB5509
5	Subsystem – IPS	Uncommanded IPU Reset	5 – Reduced Data	Low	LM DR AB7707
6	Subsystem – PSS	PCU Current Monitor Failure	3 – Loss of Redundancy	Low	HIR-AR-RAL-085/46-1 LM Ref DR AD7173
7	Subsystem – PSS	PCU Transistor 2N2222A Failure	3 – Loss of Redundancy	Low	HIR-AR-RAL-085/68 LM Ref DR AD7188
8	Subsystem – PSS	+5V Current Trip Transistors Blown	3 – Loss of Redundancy	Low	HIR-AR-RAL-085/45 LM Ref DR AD7187

Instrument Level UVF's:

Item	Level	Title	Mission Impact	Likelihood	DR Association
1	Instrument Level	D0 Temperature Sensor Anomaly	5 – Reduced Data	Medium	LM DR AD7147
2	Instrument Level	CMU Contamination During Tvac Test	4 – Degraded Performance	Low	LM DR AD7455
3	Instrument Level	Excess Noise on Heater Temperature Sensors	5 – Reduced Data	Medium	LM DR AD7248

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MISSION SUCCESS REVIEW
QUESTIONS FOR UNVERIFIED FAILURES

Program HIRDLS **Spacecraft** EOS **Subsystem** CSS **Box** CCU

Document #________ **Risk Level** Category 1 **Likelihood** Low

Prepared by S. Colaprete date 11/14/00

Title: CCU Caging Circuit Relay

Concurrence:

Program Manager	Steve Richard	date
RPE	Brenda Costanzo	date
Engineering	Ray von Savoye	date
Ball Aerospace	Steve Colaprete	date 11/14/00
Procurement	Jeanne Ledbetter	date
Mission Success	J. Wittenauer	date

1. What was the anomaly? Describe all significant events leading up to the occurrence. Describe the trouble shooting conducted and the results.

A relay in the caging circuits failed. This relay acted differently than the other relays in that its operation when actuated by a momentary toggle switch on the GSE appeared to be sluggish. At a convenient point during a repair to the CCU, the opportunity was taken to check out this relay. It was discovered at that time that the relay had failed. Attempts to reposition this latching relay were unsuccessful. The relay was removed from the circuit board and replaced with a new relay. The original relay was sent off for DPA.

1a. What was the hardware configuration at the time of the test anomaly? (i.e. If at system test, were all flight items installed? Were some non-flight items installed? If at subsystem or box level, were all flight components installed?) Describe the level of any software in use at the time of the anomaly, if applicable (i.e. was flight code installed at the time of the anomaly?) Describe the Test Hardware/Software configuration at the time of the anomaly.

The CCU was in full flight configuration ready for Acceptance Test when the "sluggish" response was noted. However, because of the redundancy of the circuit, it is unclear when the anomaly first occurred.

1b. What was the most likely cause of the anomaly? Is there a fishbone analysis, fault tree or similar analysis performed as part of the trouble shooting? Have all other suspect causes been eliminated?

The most likely cause of the anomaly was a short of the damaged contact's pin to the adjacent coil 28 vdc pin outside the relay. This could have been caused by debris outside the relay on solder joints. There was no fishbone, fault tree or similar analysis performed as part of the trouble shooting. All other suspect causes have been eliminated.

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2. What test was in process? Were multiple tests being performed simultaneously?

No test was in process at the time of determining that the part was failed. The CCU was disassembled for repair of another item and it was the opportunity needed to check out the part after observing suspect behavior. The suspect behavior was first noticed during functional test when the caging function was tested.

3. Did the anomaly repeat? Describe the troubleshooting performed while the anomaly was present.

No

4. When/If the anomaly cleared? What happened to cause the anomaly to clear? What efforts were made to get the anomaly to repeat? Were the Hardware/Software configurations identical to the original condition? If not, what were the differences, why were the differences necessary?

The failed part was replaced with a new part. Testing of the caging circuits afterward indicated normal operation.

5. List all accumulative anomaly free re-testing and "on-time". Is all test time documented?

The cooler completed 116 hours in full functional testing and "penalty" Thermal/Vacuum testing without any anomalies. All this test time is documented. Another full functional was completed after the CCU was exposed to workmanship vibration following the Thermal/Vacuum test.

6. Does the failure analysis of the problem clearly lead to assigning the anomaly to a specific element? Was that element replaced? If so, when the element was fixed, was the problem cleared?

Yes. DPA revealed a damaged contact within the relay. The relay was replaced which resulted in normal operation of the CCU.

7. What would be required to perform a worst case repair? Was that performed? If not, describe the reason.

The PWM board would have to be replaced. This was not done. The board was dispositioned as acceptable to use as is because the circuits work normally after replacement of the relay. The small traces on the board are not capable of withstanding the power necessary to damage the relay contacts without fusing open. This leads to the conclusion that the damaging current did not go through any of these traces and must have come from some other foreign source such as debris outside on solder joints that could short one pin to another. The board cannot be readily inspected (beyond what was done in connection with the relay replacement) because the board has a copper plane on top and bottom that covers the inner layers of the board. So any signs of trace damage would be concealed. The relay is used to enable and disable the Compressor drive H-bridge circuit. On the ground prior to launch the relay is closed (Compressor caged). This disables the H-bridge and is detectable through IPS telemetry. On orbit the relay is opened to allow the H-bridge to be enabled. This relay is one of a redundant pair in series. A failure of one relay to open would not jeopardize the mission.

8. Did the anomaly cause any overstress (consequential impact)? Is the overstress analysis documented and accepted by the REE, Program Manager and Engineering?

See the discussion in 7., above. This is documented in the BATC Reliability Analysis report attached to Material Discrepancy Report C19813. See REE, Program Manager and Engineering acceptance signatures above.

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9. If not addressed, what was the rationale for not addressing the overstress issue?
   N/A

10. Are there other relevant failures on other sibling items or other systems? If the failure is in a component/piece part, what is the failure history of that part? What is the Mission history of sibling units? How many have been built, delivered and what is their performance record?
   There are no other relevant failures on BATC hardware. We understand, however, that there have been other relay failures in other HIRDLS subsystems, but BATC is not privy to details of those failures. Failure history of relays in general is not as good as other parts/components because of the mechanical nature of the mechanism and the inherent risk of making and/or breaking a DC circuit. The operating constraints for these relays clearly state that they are not to be actuated while power is applied across the relay contacts.

11. If the anomaly was traced to a part, what were the results of the failure analysis/DPA? e.g., did DPA confirm the failure?
   Prior to DPA, there was no indication, either electrically or audibly, that the armature was moving when current was applied to either of the coils. No anomalies were noted in the Radiographic Examination. The DPA internal visual revealed that one set of contacts had been exposed to excessive current causing the contacts to "weld" together and severely melt some material. After the contacts were mechanically broken loose the relay began functioning properly again.

12. Were any trouble shooting steps considered and not performed due to cost or schedule concerns? Could these trouble shooting steps determine the cause of the anomaly. Describe the risks in performing this trouble shooting now.
   See the discussion in 7., above for inspections considered but not implemented.

13. Are there operational work arounds possible to mitigate the effect of this anomaly? Could they be implemented within the Mission?
   The relay is used to enable and disable the Compressor drive H-bridge circuit. On the ground prior to launch the relay is closed (Compressor caged). This disables the H-bridge and is detectable through IPS telemetry. On orbit the relay is opened to allow the H-bridge to be enabled. This relay is one of a redundant pair in series. A failure of one relay to open would not jeopardize the mission.

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14. What is the worst case scenario of this anomaly recurring during the Mission? What is the consequence of this occurrence without intervention? If intervention is possible, describe the steps needed and the result to the Mission. Impact categories are: 1) Mission Loss, 2) Mission Degradation, 3) Loss of Redundancy, 4) Degraded Data or Payload Performance, 5) Reduced Data or Payload Performance, Partial Loss of Redundancy or Change to Mission Operation, 6)No Impact

The worst case scenario is that both relays in the series circuit fail closed and they cannot be opened. This would render the cooler inoperative for the remainder of the mission and the mission for HIRDLS would be lost. Caging would be employed during shipment but could be confirmed to be fully functional up to the time of launch. The Compressor and Displacer will be caged for launch. Once on orbit the Compressor and Displacer will be uncaged. This is the critical moment. One of the two series relays must open. Once this is done, there is no reason to operate the relays again for the remainder of the mission. Impact of one relay failure is 6) No Impact. Impact of two series relay failures is 1) Mission Loss.

15. How likely is the occurrence of this anomaly during the Mission? (High/Medium/Low) Explain the rational used for the determination.

The likelihood of one relay failing during the Mission is Low. The likelihood of two series relays failing during the Mission is extremely low. These relays will operate through many cycles as long as the are operated without power applied across their contacts when operated. The appropriate discipline of the Instrument integrator and the spacecraft integrator to assure that no power is applied across the relay contact during Integration and Test operations will assure that there will be no failures.

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Program HIRDLS **Spacecraft** EOS **Subsystem** CSS **Box** CCU

Document #__________ **Impact Level** Category 5 **Likelihood** Low

Prepared by S. Colaprete date 11/14/00

Title: CCU Reset

Concurrence:

Program Manager	Steve Richard	date
RPE	Brenda Costanzo	date
Engineering	Ray von Savoye	date
Ball Aerospace	Steve Colaprete	date 11/14/00
Procurement	Jeanne Ledbetter	date
Mission Success	J. Wittenauer	date

1. What was the anomaly? Describe all significant events leading up to the occurrence. Describe the trouble shooting conducted and the results.

The processor in the CCU reset during Acceptance testing of the CSS in the cleanroom. The cooler had been operating normally with no unusual activity before the reset occured. The reset put the cooler in the electronics only mode. In this mode, the cooler is not operating and the electronics is waiting for instructions. There are only two things that can cause a reset; power up of the CSS or a watchdog timer "time out". Trouble shooting at the time did not indicate that either event was present. Subsequent events revealed that the watchdog timer was not correctly functioning and would not have reset the processor. A command was sent to the electronics to resume operation, which it did normally. There was no recurrence of the anomaly immediately afterward nor since.

1a. What was the hardware configuration at the time of the test anomaly? (i.e., If at system test, were all flight items installed? Were some non-flight items installed? If at subsystem or box level, were all flight components installed?) Describe the level of any software in use at the time of the anomaly, if applicable (i.e. was flight code installed at the time of the anomaly?) Describe the Test Hardware/Software configuration at the time of the anomaly.

The hardware was in the full-up flight CSS configuration for Acceptance Test with flight CCU that included the flight software. The BATC test rack GSE that uses standard lab power supplies and DVMs and a PC computer with LabView software was controlling the CCU.

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1b. What was the most likely cause of the anomaly? Is there a fishbone analysis, fault tree or similar analysis performed as part of the trouble shooting? Have all other suspect causes been eliminated?
The most likely cause of the anomaly was a brief external interruption in power which would have looked like a power up condition to the CCU. There was no fishbone, fault tree or similar analysis performed as part of the trouble shooting. As noted above, the few possible causes were investigated with no positive results.

2. What test was in process? Were multiple tests being performed simultaneously?
The cooler was being operated in Thermostatic mode cooling from room temperature to 57 K per Acceptance Test Procedure 540822, Section 8. There were no other tests being performed.

3. Did the anomaly repeat? Describe the troubleshooting performed while the anomaly was present.
The anomaly did not repeat. The result of the anomaly was to put the CCU into electronics only mode, which puts the cooler into standby. The GSE reports a message in the telemetry from the CCU indicating the reset which is normal after power up or after watchdog timer reset. If it were due to an overstroke the message would have read "overstroke" in the telemetry. A command to set the cooler back into operation was sent and accepted. The cooler performed normally thereafter.

4. When/If the anomaly cleared? What happened to cause the anomaly to clear? What efforts were made to get the anomaly to repeat? Were the Hardware/Software configurations identical to the original condition? If not, what were the differences, why were the differences necessary?
See the response to 3. Above. No attempt was made to get the anomaly to repeat except to put the cooler in the same operational mode it was in when it occurred, so that if there was a hardware or software problem it would have likely re-occurred.

5. List all accumulative anomaly free re-testing and "on-time". Is all test time documented?
Many hundreds of hours of testing and other operation has occurred since. The testing includes two EMI test sequences, Thermal/Vacuum testing, several full functional tests. In addition, qualification level launch vibration tests were performed on the CMA and CCU non-operational with functional test performed before and after. The CCU was also subjected to two other non-operational workmanship vibration tests. All formal test time is documented but trouble shooting time and post repair checkout time is not documented.

6. Does the failure analysis of the problem clearly lead to assigning the anomaly to a specific element? Was that element replaced? If so, when the element was fixed, was the problem cleared?
As indicated above, the failure analysis does not lead to assigning the anomaly to any element of the CSS. We believe the problem had an external cause, but cannot prove that either.

7. What would be required to perform a worst case repair? Was that performed? If not, describe the reason.
The worst case repair would be to completely replace the CCU. This was not done due to the cost and schedule impact of such an action and no indication that such action was warranted.

8. Did the anomaly cause any overstress (consequential impact)? Is the overstress analysis documented and accepted by the REE, Program Manager and Engineering?
There was no overstress associated with this anomaly.

9. If not addressed, what was the rationale for not addressing the overstress issue?

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N/A

10. Are there other relevant failures on other sibling items or other systems? If the failure is in a component/piece part, what is the failure history of that part? What is the Mission history of sibling units? How many have been built, delivered and what is their performance record?
N/A

11. If the anomaly was traced to a part, what were the results of the failure analysis/DPA? E.g., did DPA confirm the failure?
N/A

12. Were any trouble shooting steps considered and not performed due to cost or schedule concerns? Could these trouble shooting steps determine the cause of the anomaly? Describe the risks in performing this trouble shooting now.
NO

13. Are there operational work arounds possible to mitigate the effect of this anomaly? Could they be implemented within the Mission?
The work around is simple: command the cooler to operate the way it was before the anomaly.

14. What is the worst case scenario of this anomaly recurring during the Mission? What is the consequence of this occurrence without intervention? If intervention is possible, describe the steps needed and the result to the Mission. Impact categories are: 1) Mission Loss, 2) Mission Degradation, 3) Loss of Redundancy, 4) Degraded Data or Payload Performance, 5) Reduced Data or Payload Performance, Partial Loss of Redundancy or Change to Mission Operation, 6)No Impact
If this anomaly recurs during the Mission, the detector temperature will rise to an unacceptable level and the science in progress at that time will be lost. Intervention is possible and necessary, assuming restoration of power is not a problem. Simply command the cooler as if was prior to the reset and allow sufficient time for the detector temperature to stabilize. Impact category 5. The action required to correct for the recurrence of this anomaly is the same as for an overstroke or watchdog timer "time out".

15. How likely is the occurrence of this anomaly during the Mission? (High/Medium/Low) Explain the rationale used for the determination.
Low. This anomaly has not recurred and it is expected that the anomaly was caused in the first place by an external power interruption.

Follow-up MS Questions:

1. Can permanent damage accrue if system warms up due to cooler shut-down. A: No

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2. Lab power supplies are usually stable, how can this anomalous power supply story be explained? A: Main power in Bldg dropped out.
3. Were there any recorders going that captured power disruption? A: No
4. Why don't we have a fishbone analysis for this failure? A: Answer provided in Q1, only two possible causes, one was immediately ruled out.

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MISSION SUCCESS REVIEW
QUESTIONS FOR UNVERIFIED FAILURES

Program **HIRDLS** **Spacecraft** **AURA** **Subsystem** **TSS** **Box** **Chopper**

Risk Level **3: Loss of Redundancy** **Likelihood** **Low**

CHOPPER SPEED FLUCTUATION

Prepared by (RPE) W. Opyd date 25 APR 2001

Concurrence:

Program Manager________________________ date_______

Mission Success________________________ date_______

Engineering________________________ date_______

Product Assurance________________________ date_______

1. What was the anomaly? Describe all significant events leading up to the occurrence. Describe the troubleshooting conducted and the results.

Anomaly: Rotational speed of the optical chopper was noted to fluctuate while the command clock, to which the chopper is to synchronize, was stable. Speed fluctuations were in the direction of slower speed than nominal (CDRS DR# AB5509).

Events Leading to Occurrence: Chopper motor was assembled and powered for the first time two days prior to the observed anomaly, and had only been operated for a few minutes to verify direction of rotation. At the time of the anomaly the motor had just been mounted in the balancing fixture and powered for the first time for which constant speed operation was required in support of balancing.

Troubleshooting: Connectors on the motor cable were verified to be securely mated. Fluctuations continued. Leads from the chopper motor connector to the photodetectors mounted on the chopper were noted to be in contact with the balancing fixture cradle. To eliminate a potential error in balance measurement the lay of the leads was adjusted (see figure 1). At this point speed fluctuations stopped. A search for a potential intermittent was conducted by flexing chopper leads while monitoring speed (per DR# AB5509). No further fluctuations were observed as leads for the optical emitters, photodetectors, and cable extension were flexed. Testing was performed with the chopper shaft horizontal and vertical. Leads were flexed in all directions at each end and in the middle. Leads were x-rayed to look for breaks, shorts, debris, and full contact insertion in connector shells. No defects were found. The test cable and cable adapter were inspected for proper assembly and debris. No defects were found.

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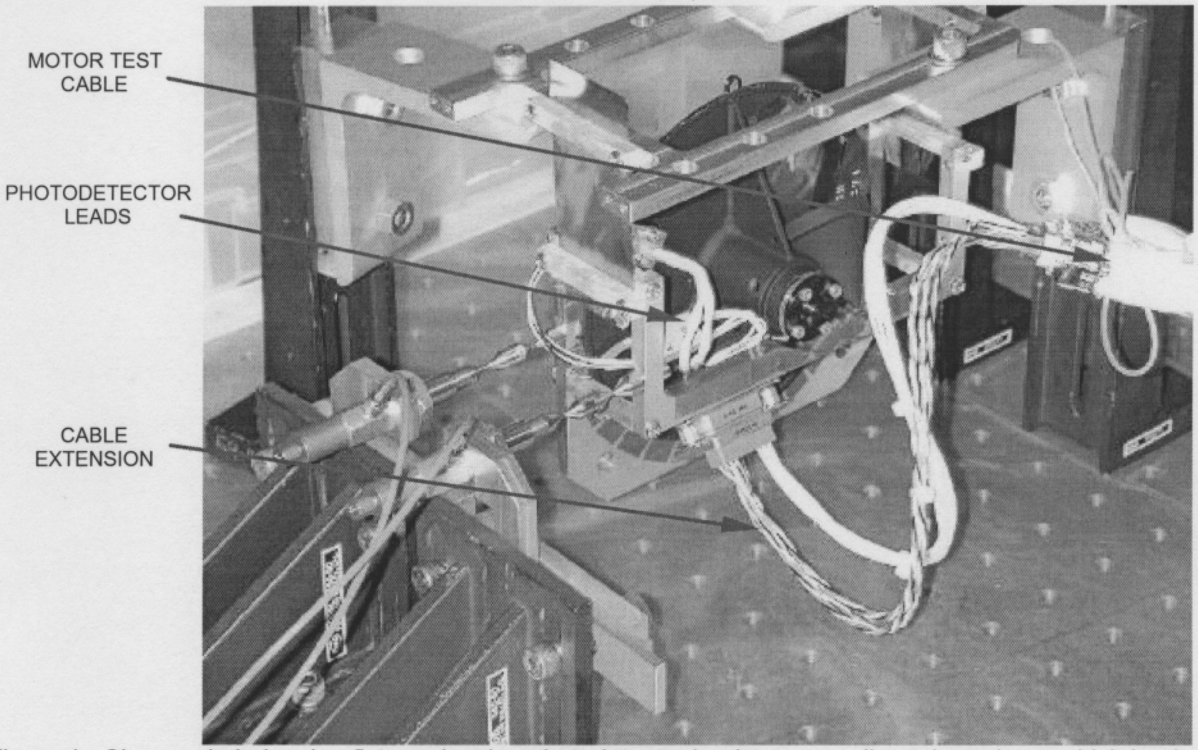

Figure 1. Chopper in balancing fixture showing photodetector leads near cradle at the point at which leads enter connector.

1a. What was the hardware configuration at the time of the test anomaly? (i.e. If at system test, were all flight items installed? Were some non-flight items installed? If at subsystem or box level, were all flight components installed?) Describe the level of any software in use at the time of the anomaly, if applicable (i.e. was flight code installed at the time of the anomaly?) Describe the Test Hardware/Software configuration at the time of the anomaly.

Hardware Configuration: Subassembly (optical chopper motor) test. All flight components were installed on the optical chopper motor subassembly. Environment was ambient temperature and pressure.

Test Hardware / Non-flight Items: Non-flight items used that directly affect motor operation included a cable extension used to allow free cradle motion for balance measurement, motor test cable (built to flight cable drawing), engineering model motor controller board, and GSE box for interfacing motor cable to controller board.

Software: No software.

1b. What was the most likely cause of the anomaly? Is there a fishbone analysis, fault tree or similar analysis performed as part of the trouble shooting? Have all other suspect causes been eliminated?

The most likely cause of the anomaly is that one or more contacts on the photodetector leads were not fully seated in the connector shell (per SO-LOC-0143-0060). Loose contacts would cause the low-current photodetector signal to be susceptible to noise, presenting the controller with excess signal transitions. Excess transitions would appear to the controller as an over-speed condition, causing the controller to reduce current, slowing the chopper, as observed. The anomaly was only noted for a short time following initial motor assembly, and ceased when photodetector leads were adjusted near the connector shell, which may correlate with seating of the contacts.

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Fault analysis began 11 April 2000 and was completed on 18 May 2000 as documented in DR# AB5509. The analysis included identifying configuration components that could impact chopper speed as observed, then sequentially testing for each. These items are the ones listed in the investigation described in the troubleshooting section of #1 above. SEE ATTACHED FISHBONE

All other suspect causes have been eliminated as described in the troubleshooting section of #1.

2. What test was in process? Were multiple tests being performed simultaneously?

Test in process was chopper motor assembly balancing check (SO-LOC-0168). No other tests were being performed in conjunction.

3. Did the anomaly repeat? Describe the troubleshooting performed while the anomaly was present.

The anomaly did not repeat after the leads to the photodetector were adjusted. Troubleshooting while the anomaly was present included checking cables for secure connections.

4. When/If the anomaly cleared? What happened to cause the anomaly to clear? What efforts were made to get the anomaly to repeat? Were the Hardware/Software configurations identical to the original condition? If not, what were the differences, why were the differences necessary?

See #1 for details of when anomaly cleared. Troubleshooting in an effort to repeat the anomaly included a configuration identical to the original configuration.

5. List all accumulative anomaly free re-testing and "on-time". Is all test time documented?

All on-time is recorded in logs associated with the authorizing documents listed below.

Before Anomaly:	
<0.1 hours	SO-LOC-0155 Assembly & Rotation Check
After Anomaly:	
3.2 hours	SO-LOC-0168 Balance Check
27.4 hours	SO-LOC-0177 Run-in
8.3 hours	OO-LOC-0199 Acceptance Test
5.1 hours	OO-LOC-0201 Post-Vibe Performance
73.9 hours	OO-LOC-0203 Thermal-Vac
38.3 hours	DR# AB6410 Stability Check

Continuous Failure-Free On-Time After Anomaly : 156 hours

6. Does the failure analysis of the problem clearly lead to assigning the anomaly to a specific element? Was that element replaced? If so, when the element was fixed, was the problem cleared?

Failure analysis does NOT clearly lead to assigning this anomaly to a specific element, but implicates a pin that was initially not fully inserted in the connector shell (see question #1b). If the anomaly was due to an unseated pin that is now seated, element replacement is not an issue.

7. What would be required to perform a worst case repair? Was that performed? If not, describe the reason.

Worst case repair would involve replacement of the photodetector board, which provides speed feedback for the motor (approximately two weeks for preparation and assembly, and four weeks for retest). This was not performed because there was no justification for this repair since, as stated in #1b, the most likely cause was corrected, and as indicated in #3 and #5, considerable failure-free on-time has been accumulated including post-vibe and environmental extremes.

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8. Did the anomaly cause any overstress (consequential impact)? Is the overstress analysis documented and accepted by the REE, Program Manager and Engineering?

No formal overstress analysis was performed. It is estimated that the anomaly did not cause overstress since the discrepant motor operation was at too low a speed, rather than too high, and the motor is designed to function at speeds lower than normal operating speed.

9. If not addressed, what was the rationale for not addressing the overstress issue?

Overstress is addressed in question #8.

10. Are there other relevant failures on other sibling items or other systems? If the failure is in a component/piece part, what is the failure history of that part? What is the Mission history of sibling units? How many have been built, delivered and what is their performance record?

There are no sibling units, and no failure history was identified on the part.

11. If the anomaly was traced to a part, what were the results of the failure analysis/DPA? e.g., did DPA confirm the failure?

Not applicable.

12. Were any trouble shooting steps considered and not performed due to cost or schedule concerns? Could these trouble shooting steps determine the cause of the anomaly. Describe the risks in performing this trouble shooting now.

No troubleshooting steps considered were not performed (see #1 above).

13. Are there operational work-arounds possible to mitigate the effect of this anomaly? Could they be implemented within the Mission?

Switching to the redundant side of the optical switch is the operational work-around. This capability is a designed and tested operating mode.

14. What is the worst case scenario of this anomaly recurring during the Mission? What is the consequence of this occurrence without intervention? If intervention is possible, describe the steps needed and the result to the Mission. Impact categories are: 1) Mission Loss, 2) Mission Degradation, 3) Loss of Redundancy, 4) Degraded Data or Payload Performance, 5) Reduced Data or Payload Performance, Partial Loss of Redundancy or Change to Mission Operation, 6) No Impact

Worst-case scenario during the Mission would be manifested in unstable operation of the chopper.
Without intervention, this may result in a complete loss of usable mission science data.
Intervention would involve selection of the redundant side of the optical switch, which should restore instrument operation to normal.
Impact category would be 3) Loss of Redundancy.

15. How likely is the occurrence of this anomaly during the Mission? (High/Medium/Low) Explain the rational used for the determination.

Probability is Low for anomaly occurrence during the Mission. This is based on three observations: 1) the inability to reproduce the anomaly during the troubleshooting described in #1 above; 2) the 156 hours of continuous failure-free on-time described in #5 above; and 3) the inability of contacts to become loose under the scenario of probable cause postulated in #1b above and verified by post-vibe testing listed in #5 above.

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Mission Success Follow-Up Questions:

1 As part of troubleshooting, were photodetector leads inspected for damage or subjected to a mate/demate cycle to see if loose or unseated pin is a repeatable phenomenon?

Metal pins snap into place in these connectors, process is not repeatable. Leads were inspected via X-ray, visual inspection, and subjected to mate/demate.

2 By evaluating chopper performance with axis in both horizontal and vertical, what failure root cause was being probed?

Effects of gravity sag of cables and connectors was being investigated.

3 Was any troubleshooting performed to exonerate the EM controller board?

EM Controller board was operated for 100's of hours both before and after observed anomaly, no out-of-family behavior has ever been observed with the board.

4 When is/was the EM controller board replaced with the flight board? How many successful hours of "run time" with flight board?

EM Controller Board was replaced with Flight Board during integration of TSS in early '01.

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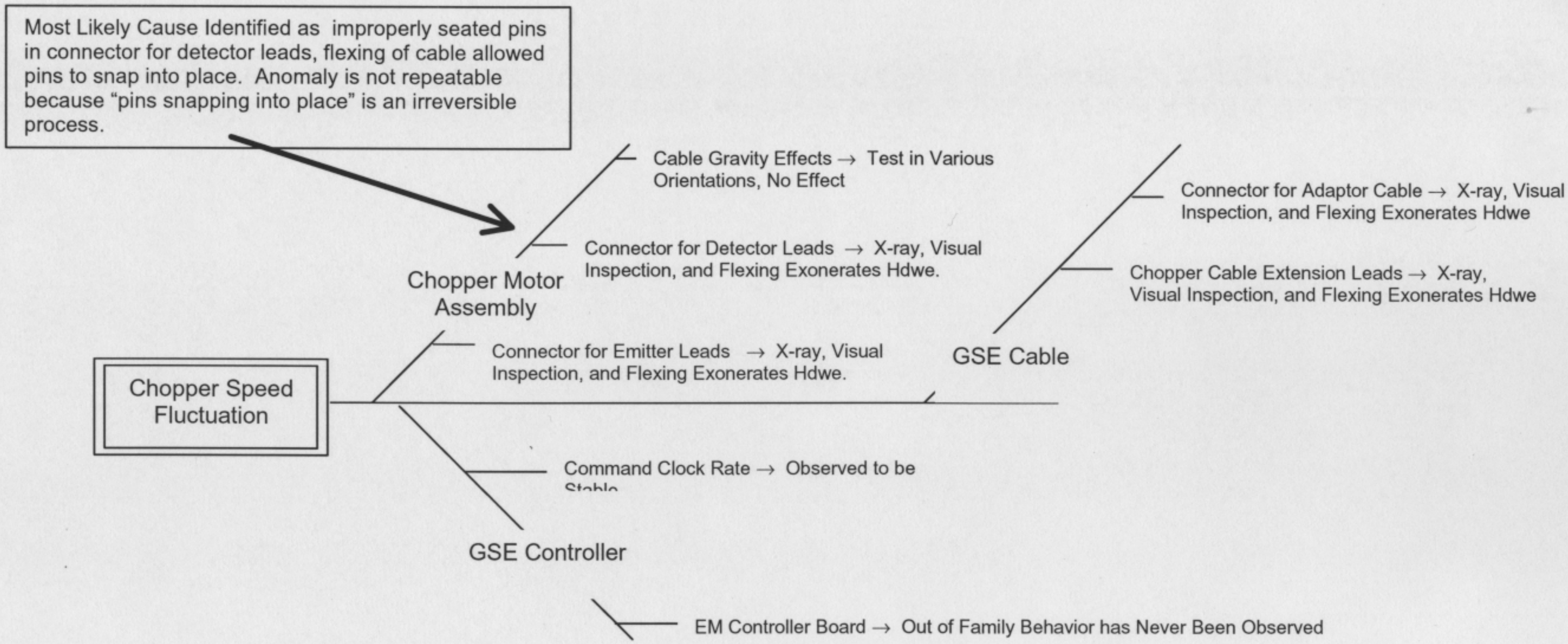

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Program **HIRDLS** **Spacecraft** **EOS** **Subsystem:** **Instrument-Level**

Document #DR AD7455 **Impact Level** Category 4 **Likelihood** **Low**

Prepared by R. Von Savoye date 14 August 2002

Title: CMU Contamination During TVac

Concurrence:

Program Manager	Eric Johnson	date
Hardware Engineering	Ray von Savoye	date
Product Assurance	Althea McField	date
Mission Success	J. Wittenauer	date

1. What was the anomaly? Describe all significant events leading up to the occurrence. Describe the trouble shooting conducted and the results.

On the final day of Tvac testing for the HIRDLS Instrument (4 August 2002), the chamber was re-pressurized while portions of the instrument were still below the specified repress temperature (15-20 degC). Instrument temperature at the time of the anomaly ranged from 20C to 33C except for the radiator, compressor, and displacer of the Cooler Mechanical Unit (CMU). These latter items were at a temperature of 5C during repressurization. This resulted in deposition of a molecular contaminant, subsequently identified as phenyl silicone. The contaminant appearance was described as a fog of transparent, colorless liquid found on about ½ of the CMU radiator and compressor. Subsequent tests revealed that no other parts of the HIRDLS Instrument were contaminated. The source of this contaminant has not been identified.

1a. What was the hardware configuration at the time of the test anomaly? (i.e., If at system test, were all flight items installed? Were some non-flight items installed? If at subsystem or box level, were all flight components installed?) Describe the level of any software in use at the time of the anomaly, if applicable (i.e. was flight code installed at the time of the anomaly?) Describe the Test Hardware/Software configuration at the time of the anomaly.

The HIRDLS Instrument was in its final Mission Configuration.

1b. What was the most likely cause of the anomaly? Is there a fishbone analysis, fault tree or similar analysis performed as part of the trouble shooting? Have all other suspect causes been eliminated?

True Root Causes can be viewed from two perspectives:

1. Procedural error occurred when the chamber was repressurized prior to the instrument reaching the required temperature. In this sense, the root cause is understood.
2. A substance may remain that could cause a similar contamination event in the future. This substance is either in the chamber, associated with test ground support equipment, or associated with the

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HIRDLS Instrument itself. Since the source of this contaminant has not been identified, there is the potential that a similar event could occur in the future and put the instrument at risk.

2. What test was in process? Were multiple tests being performed simultaneously?
No instrument-level test was in progress. The Tvac testing had concluded and the B/205 Search Chamber was simply being re-pressurized.

3. Did the anomaly repeat? Describe the troubleshooting performed while the anomaly was present.
No attempt has been made to get the anomaly to repeat. The instrument has been cleaned and meets its cleanliness requirements. The instrument will see additional thermal vacuum testing at Oxford University and at TRW. Lockheed Martin personnel will have the opportunity confirm that proper test procedures are in place and to inspect for this contamination subsequent to those tests.

4. When/If the anomaly cleared? What happened to cause the anomaly to clear? What efforts were made to get the anomaly to repeat? Were the Hardware/Software configurations identical to the original condition? If not, what were the differences, why were the differences necessary?
We interpret "anomaly cleared" here to mean that the source of the contaminantion has been identified and effectively neutralized. This has not been done.

5. List all accumulative anomaly free re-testing and "on-time". Is all test time documented?
This contamination event can only occur when the instrument (or its support equipment) is outgassing in vacuum and condensing onto a cold location. Since the anomaly was observed, this test condition has not been duplicated. This question is not applicable to the failure.

6. Does the failure analysis of the problem clearly lead to assigning the anomaly to a specific element? Was that element replaced? If so, when the element was fixed, was the problem cleared?
The failure analysis has not isolated the source of the contamination.

7. What would be required to perform a worst case repair? Was that performed? If not, describe the reason.
Worst-case repair would involve a continuation of the troubleshooting until the true source of contaminant is identified. This would include sampling of all not-metallic materials in the instrument and in the supporting test GSE. This sampling would continue until the true source is identified - even if dis-assembly of the instrument were required.

8. Did the anomaly cause any overstress (consequential impact)? Is the overstress analysis documented and accepted by the REE, Program Manager and Engineering?
There was no overstress associated with this anomaly. The worst possible case event associated with this anomaly would occur if the optical components were the coldest portion of the instrument during the repressurization – this would cause contamination of the optics. This did not, in fact, occur.

9. If not addressed, what was the rationale for not addressing the overstress issue?
The "overstress" – defined as contamination of the optical path – was addressed through inspection and contaminantion sampling. The results indicated that the optical path was not contaminated.

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10. Are there other relevant failures on other sibling items or other systems? If the failure is in a component/piece part, what is the failure history of that part? What is the Mission history of sibling units? How many have been built, delivered and what is their performance record?
    We have spoken to the SBIRS program regarding contamination that the SIRTF instrument sustained during recently-completed Tvac testing. The contamination that they observed is not related to the HIRDLS contaminant. Our extensive inspection, sampling, and chemical analysis investigation has not found a match between the observed contaminant and any parts, materials, or processes known to be in common use on other flight hardware programs at MSO. It is known that the contaminant matches chemical components found in diffusion pump oil and uncured RTV silicone rubber.

11. If the anomaly was traced to a part, what were the results of the failure analysis/DPA? E.g., did DPA confirm the failure?
    N/A

12. Were any trouble shooting steps considered and not performed due to cost or schedule concerns? Could these trouble shooting steps determine the cause of the anomaly? Describe the risks in performing this trouble shooting now.
    NO

13. Are there operational work arounds possible to mitigate the effect of this anomaly? Could they be implemented within the Mission?

Operational work arounds include 1) insuring that Tvac testing is only terminated after the instrument has been uniformly warmed to ambient temperature or higher and 2) insuring that the HIRDLS optical elements are not serving as the coldest portion of the instrument. The first of these work-arounds is assured through rigorous test practice. The second is achieved as a design feature of the HIRDLS Instrument. The optics aperture for HIRDLS faces the "anti ram" orbital direction and the optical elements are maintained at a warm temperature during mission operations. The nominal Mission Operations Temperature is 20 deg C.

14. What is the worst case scenario of this anomaly recurring during the Mission? What is the consequence of this occurrence without intervention? If intervention is possible, describe the steps needed and the result to the Mission. Impact categories are: 1) Mission Loss, 2) Mission Degradation, 3) Loss of Redundancy, 4) Degraded Data or Payload Performance, 5) Reduced Data or Payload Performance, Partial Loss of Redundancy or Change to Mission Operation, 6)No Impact

If this anomaly recurs during the Mission, the worst case sceneario would involve contamination of optical elements. This would result in impact category "4 – Degraded Payload Performance"

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QUESTIONS FOR UNVERIFIED FAILURES

15. How likely is the occurrence of this anomaly during the Mission? (High/Medium/Low) Explain the rationale used for the determination.

The probability that the worst case condition (contamination of the optical elements) will be realized on orbit is low for the following reasons:

- The nominal Mission Operations Temperature is 20 deg C. Our test data indicates that phenyl silicone will not condense in vacuum at 20 deg C. There is a possibility of off-nominal times when the optics are cooler. However, if condensation occurs at this worst-case off-nominal condition, the instrument can simply be warmed to 20C to allow the molecular contamination to volatalize.

LOCKHEED MARTIN

MISSION SUCCESS REVIEW
QUESTIONS FOR UNVERIFIED FAILURES

Program HIRDLS **Spacecraft** EOS **Subsystem** CSS **Box** CMU

Document #DR AD7147 Impact Level Category 5 **Likelihood** Medium

Prepared by R. Von Savoye date 13 August 2002

Title: Anomalous Behavior in CSS Temperature Sensor D0

Concurrence:

Program Manager	Eric Johnson	date
Hardware Engineering	Ray von Savoye	date
Product Assurance	Althea McField	date
Mission Success	J. Wittenauer	date

1. What was the anomaly? Describe all significant events leading up to the occurrence. Describe the trouble shooting conducted and the results.

The HIRDLS Instrument has a mechanical cryocooler cooler subsystem that includes a pair of Silicon Diodes used for temperature measurement. Output from the Silicon Diodes is used to control the cooler subsystem. Two devices are incorporated into the design to provide redundancy. The Silicon Diodes are provided by Lakeshore Cryotronics, P/N XDT-570-LR-175. The two diodes are expected to track within 1ºK of each other and have done so in all previous tests. On HIRDLS test day 183 (7 July 2002) a performance test indicated that the two diodes were performing nominally. An aliveness test performed on HIRDLS test day 186 (10 July) indicated that diode D0 was reading 100ºK lower than diode D1, D1 appeared to be indicating the true temperature. Throughout the approximately 29 days of Tvac testing, through multiple hot and cold cycles, the temperature offset was maintained, although the magnitude of the offset varied between 27K and 70K. When the instrument was returned from its final cold operating temperature to ambient temperature on 3 August, and while still under vacuum, the observed temperature offset gradually disappeared. Since that time, the two diodes, D0 and D1 are once again indicating nominally the same temperature.

On 11 August, during troubleshooting, the anomaly repeated. It now appears likely that this temperature sensor (or its associated wiring and circuitry) has failed. The true root cause has not been established.

1a. What was the hardware configuration at the time of the test anomaly? (i.e., If at system test, were all flight items installed? Were some non-flight items installed? If at subsystem or box level, were all flight components installed?) Describe the level of any software in use at the time of the anomaly, if applicable (i.e. was flight code installed at the time of the anomaly?) Describe the Test Hardware/Software configuration at the time of the anomaly.

The HIRDLS Instrument and Flight S/W were in their final Mission Configuration, undergoing Tvac Testing. The Instrument was positioned on a tilted bench with rotational capability and surrounded by thermal control panels.

MISSION SUCCESS REVIEW
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1b. What was the most likely cause of the anomaly? Is there a fishbone analysis, fault tree or similar analysis performed as part of the trouble shooting? Have all other suspect causes been eliminated?

Potential Root Causes that have been considered include the following:

Physical Damage to Sensor or Cabling (most likely cause)

- Device Hermeticity/Fracture – thermal cycling could have caused fracture of the ceramic package for the temperature sensor. This is low likelihood because the device is placed into a 3 mm dia cavity and potted in with epoxy.
- Thermal Cycle Causes Cold Flow of Teflon Insulation on Wires – a possibility but the wires are not in an area that allows for inspection. A "cold flow" scenario must allow for either an increase in the device excitation (nominal excitation is 10 microamps) or an amplification of the output signal (nominally 0-2V). Simple shorts to grounded structure will not achieve either of these conditions.
- Test GSE Causes Nicked or Damaged Wire – all critical wiring is located on the interior of the instrument, our test technicians could not have inadvertently damaged any of the exposed wiring. This area could not be inspected without instrument dis-assembly.

Intermittent Behavior with Sensor Electronics within the CCU. Troubleshooting performed on 11 August has eliminated this as a possibility.

- Circuitry responsible for 10 microamp excitation – not so likely because both devices are excited by a common 10 microamp source. Further, troubleshooting performed on 11 August using a break-out box indicated that the expected nominal excitation was being supplied to both temperature sense diodes (actual readings of 9.859 uA and 9.953 uA).
- Circuitry responsible for amplification and processing of 0-2V voltage readout. Signal processing is accomplished for each sensor using a separate string. Device failure or cold solder joints in one of these strings could account for the observed behavior. This has been eliminated as a possibility. Troubleshooting performed on 11 August indicates that the failed diode D0 is receiving the proper excitation (9.859 uA) but is outputting an anomalously high voltage value (1.0229V measured, 0.8769V expected based on D1 output at 62K).

Interpretation of Data (not a likely cause)

- Changes to Conversion Tables – Not possible – flight S/W was stable throughout this phase of testing. Further, troubleshooting performed on 11 August has definitely narrowed the possible cause to the sensor or its associated wiring.

2. What test was in process? Were multiple tests being performed simultaneously?

An aliveness test was in progress, immediately prior to door closure for thermal vacuum test. The anomaly was not noticed at this time and the authorization to proceed with Tvac testing was given by the Program. Subsequent data mining revealed that the output from detector D0 was in fact anomalous at this time.

3. Did the anomaly repeat? Describe the troubleshooting performed while the anomaly was present.

The anomalous condition (30-70K offset below "true" temperature) manifested itself throughout the Tvac test with no evidence of intermittent behavior. Prior to chamber repressurization, as the instrument was being warmed to ambient temperature, the anomalous behavior disappeared and has not reappeared in subsequent (ambient) testing. Troubleshooting was limited to mechanical jostling of nearby cold wall panel.

Additional troubleshooting was performed during a repeat of the anomaly on 11 August. A breakout box was used to confirm that both sensors are receiving the proper excitation and that sensor D0 is outputting an anomalously high voltage. Actual troubleshooting data included in DR AD7147.

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4. When/If the anomaly cleared? What happened to cause the anomaly to clear? What efforts were made to get the anomaly to repeat? Were the Hardware/Software configurations identical to the original condition? If not, what were the differences, why were the differences necessary?

The anomaly was cleared when the instrument was restored to ambient temperature. It is to be noted however, that the instrument was taken through 4 hot and 4 cold cycles during the 29 days of Tvac testing, and at no other time did this anomaly clear itself.

5. List all accumulative anomaly free re-testing and "on-time". Is all test time documented?

There has been no additional time in the Tvac chamber. There has been approximately 100 hrs of further testing of the HIRDLS Instrument and the D0 sensor continues to exhibit an offset when the cooler subsystem is chilled to its operating temperature of 60K.

6. Does the failure analysis of the problem clearly lead to assigning the anomaly to a specific element? Was that element replaced? If so, when the element was fixed, was the problem cleared?

The failure analysis has not identified any single element. The investigation has examined the possibility that the temperature diode can be compromised, that the wiring could be damaged, or that the cooler control electronics could be performing anomalously. Troubleshooting performed on 11 August indicates that failure of the sensor itself or damage to its wiring harness are responsible for this anomaly.

7. What would be required to perform a worst case repair? Was that performed? If not, describe the reason.

Worst case repair would involve replacement of Temperature diode D0 and its associated wiring. This repair was not performed because it would impart approximately a three month schedule slip to the program and because redundant temperature sensors are available. From a technical risk standpoint, disassembly of the cooler to access the sensor and associated wiring would involve disassembly operations that were never intended in the design and fabrication of the cooler. This poses a high technical risk.

8. Did the anomaly cause any overstress (consequential impact)? Is the overstress analysis documented and accepted by the REE, Program Manager and Engineering?

The possibility of electrical overstress is unlikely with this anomaly. Cooler control was never compromised during the test (since sensor D1 was available). The level of device excitation is 10 microamps with a capability of withstanding 1 mA continuous without damage. The device output is in the range of 0 to 2.0V. For these levels of input excitation and output signal, it seems unlikely that electrical overstress could propogate to other components in the circuitry.

9. If not addressed, what was the rationale for not addressing the overstress issue?

See Above

10. Are there other relevant failures on other sibling items or other systems? If the failure is in a component/piece part, what is the failure history of that part? What is the Mission history of sibling units? How many have been built, delivered and what is their performance record?

This temperature sensor diode is in routine use on other cooler hardware built by our subcontractor (Ball Aerospace). When asked, they reported that there is no history of anomalous behavior associated with this type of silicon diode sensor.

11. If the anomaly was traced to a part, what were the results of the failure analysis/DPA? E.g., did DPA confirm the failure?

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N/A

12. Were any trouble shooting steps considered and not performed due to cost or schedule concerns? Could these trouble shooting steps determine the cause of the anomaly? Describe the risks in performing this trouble shooting now.

The hardware could be broken down for more thorough inspection and troubleshooting. However, the resulting break in configuration (and regression testing upon re-assembly) would pose an unacceptable delay in shipping and eventual launch.

From a technical risk standpoint, disassembly of the cooler to access the sensor and associated wiring would involve disassembly operations that were never intended in the design and fabrication of the cooler. This poses a high technical risk.

13. Are there operational work arounds possible to mitigate the effect of this anomaly? Could they be implemented within the Mission?

1. Control the cooler based on temperature knowledge provided by sensor D1, accessible by both "A-side" and "B-side" of the CCU. There is some chance that sensor D0 will still be useable as well.

2. Control the cooler based on temperature knowledge provided by FPA_TMP_A and FPA_TMP_B sensors located on the detector focal plane in the DSS. These temperature sensors do not become active until the temperature drops to 100K. At temperatures above 100K, the method below can be used:

3. Control the cooler based on stroke commands using the piston displacement transducer as feedback for control loop and using temperature knowledge provided by FPA_TMP_A and FPA_TMP_B sensors located on the detector focal plane in the DSS.

14. What is the worst case scenario of this anomaly recurring during the Mission? What is the consequence of this occurrence without intervention? If intervention is possible, describe the steps needed and the result to the Mission. Impact categories are: 1) Mission Loss, 2) Mission Degradation, 3) Loss of Redundancy, 4) Degraded Data or Payload Performance, 5) Reduced Data or Payload Performance, Partial Loss of Redundancy or Change to Mission Operation, 6)No Impact

If this anomaly recurs during the Mission, there is a possibility that the detector temperature will have some hours of unstable temperature. At these times, the quality of the data will suffer. Impact category 5.

If cooler control cannot be accomplished through use of D0 or D1, it will be necessary to re-configure the instrument to achieve cooler control using the FPA_TMP_A and FPA_TMP_B sensors located on the detector focal plane in the DSS. This will require a change to mission operations, Impact Category 5.

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15. How likely is the occurrence of this anomaly during the Mission? (High/Medium/Low) Explain the rationale used for the determination.

The probability of re-occurrence is medium for the following reasons:

- An additional 4 months of testing in the UK and S/C level testing at TRW will provide additional opportunity to assess the stability of this subsystem.
- Extensive testing of the HIRDLS Instrument performed to date has likely unmasked all defects. There have been no "shortcuts" in testing at either subsystem or system level. The extensive testing performed to date provides confidence that no further instrument-level failures will occur.
- Not having a "strongly probable" root cause provides sufficient uncertainty to rate this as a "medium". The availability of the redundant sensor and the two back-up sensors in the DSS and the capability to operate the cooler in "stroke control" allow us to avoid rating this as a "high".

ADDED NOTES

1. Brainstorming here: Device Function: Feed a constant current of 10 micro amps to the device, device outputs a voltage that can be converted to a temperature. Since device is reading 30K-70K too low, this means that it is either
   a. Receiving an excitation that is higher than 10 microamps (higher excitation = higher output = lower indicated temperature).
      - Is there a "cold flow scenario" that could be consistent with higher amperage being provided to diode D0? *August 11 troubleshooting rules out this as a possibility.*
      - If higher input amperage is provided, does Volts vs Current calibration curve shift uniformly or is this an unknown? (We do not observe a uniform voltage shift). *Complicates possible fix of "adding an offset" via software – the offset may be temperature dependent and variable if degradation continues.*
      - What level of excitiation would be required to change the output of the device by 0.16V (250K) or 0.05V (70K) *Bob Stack at Ball has agreed to perform some circuit simulations to help answer this question.*
   b. Outputting a voltage that is somewhat higher than expected (we expect 1.053V at 60K, and we expect 1.1070 at 30K)
      - Is there a "cold flow scenario" that could be consistent with voltage output from D0 being amplified? *A pinched wire would cause an increased resistance and increased voltage output. However, it is hard to see how this would be a reversible process.*
   c. Receiving proper excitation, outputting expected voltage, but the output signal is being corrupted by the CCU. *Bob Stack at Ball has agreed to perform some circuit simulations to help answer this question.*

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Data from CPT2 2002/191

D1 Temp Reading	D0 Temp Reading	Delta	Delta Volts
250	180	70	0.16297
200	155	45	0.1021
150	115	35	0.0756
100	70	30	0.073
70	40	30	0.05356
57	30	27	0.0489

2. Can we verify what type of wire is used in external cabling? The Ball parts list indicates that the wire should be either M22759/33 (cross-linked ETFE) or M22759/11 (Teflon). If we are using the "/11" wire, it would be susceptible to cold flow and would remain high on our potential root cause list.

   Ball confirms that Teflon insulated wire travels within the vacuum space.

3. Can Ball provide specific details on the design and construction of the cryo sensor. The part number is XDT-570-LR-175. Our conversations with Lakeshore Cryotronics were not helpful because this is a custom part and they need further details before they can help us with our troubleshooting questions. Specific information that would be useful:

   a. Device packaging (materials used, hermeticity?, sealing method, wire feed through method)

   b. Reliability report for this device – how many thermal cycles is it good for? *Ball opinion – devices good for thousands of cycles, no failure ever noted in the past.*

   c. Any history of defective parts, bad production lots, returns from users? *Ball reports no history of failure with these devices, many years of use.*

   d. How is heat-sinking, thermal anchoring of lead wires accomplished? Is it a credible explanation that "cold flow" of Teflon insulation allowed one critical wire to become warm (through contact with a warm source), that the warm wire conducted heat to the sensor chip, and this resulted in an offset from the true sample temperature? *Lead wires are Constantin, thermally anchored and varnished in-place per manufacturers guidance*

MISSION SUCCESS REVIEW
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(confirmed by checking Lakeshore website). Constantin wires are solder spliced to Teflon-insulated wire and travel within the vacuum enclosure to a hermetically-sealed feed-through to an external connector.

e. LMSSC is experiencing tin-whisker related defects in other programs due to the use of pure tin at the EEE part level. Is there any chance that pure tin was used to prepare the device leads for soldering? *Not probed with Ball*

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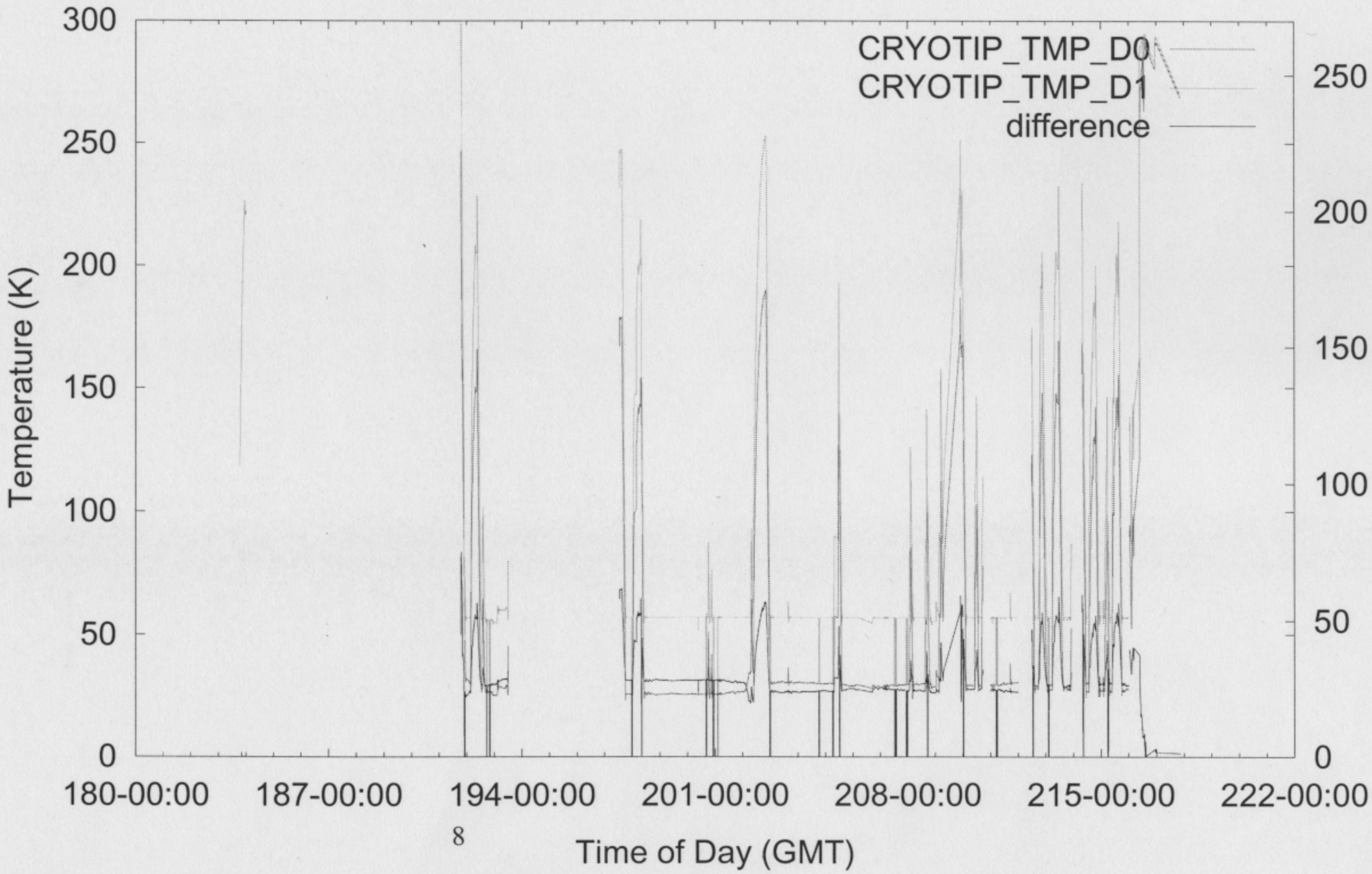
MISSION SUCCESS REVIEW
QUESTIONS FOR UNVERIFIED FAILURES

LOG of DATA from THERMAL VACUUM TESTING

HIRDLS CryoTip Temps: 2002/183-218



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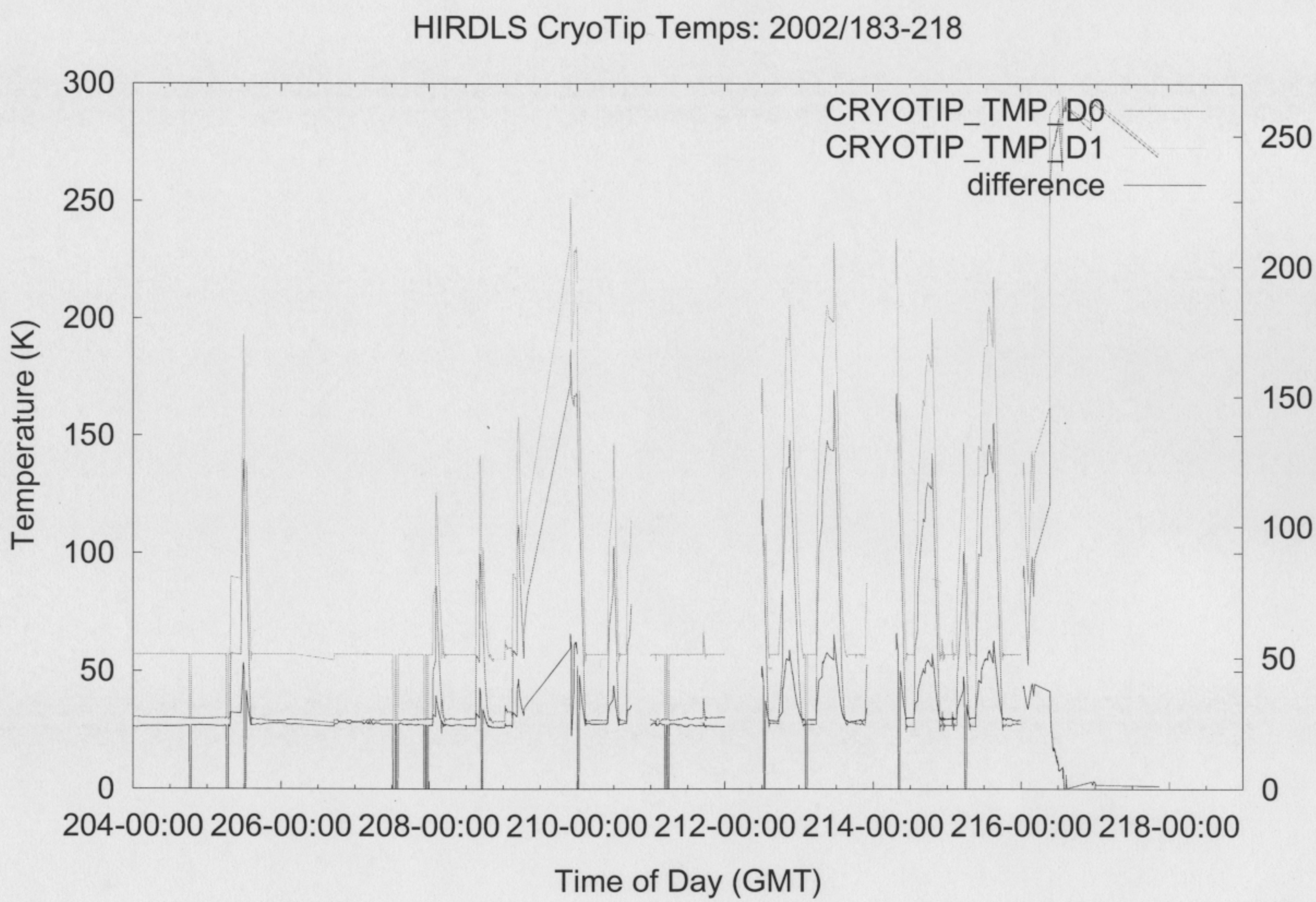

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MISSION SUCCESS REVIEW
QUESTIONS FOR UNVERIFIED FAILURES

Program HIRDLS Spacecraft **Subsystem:** IPS **Box** IPU

Document #____________ **Risk Level** 5-Reduced Data **Likelihood** LOW

Uncommanded IPU Reset

Prepared by (REE) R. Lindgren Date 6 Oct 00

Concurrence:

Program Manager____________________________ date_______

Mission Success____________________________ date_______

Engineering (RPE) ____________________________ date_______

Procurement____________________________ date_______

1. What was the anomaly? Describe all significant events leading up to the occurrence. Describe the trouble shooting conducted and the results.

Loss of telemetry during IPU thermal vacuum testing occurring at sporadic intervals. Monitoring of the PSA-32 UART indicates that the IPU is being reset. This has occurred on both the A and B sides and at both hot and cold temperatures. The anomaly occured only during weekdays (when the electrical environment is known to be relatively noisy) and never occured on weekends when .external events (noise in the chamber room, power line voltage spikes, etc.) are at a minimum. The anomaly first occurred while an adjacent vacuum chamber and heaters were being powered up to begin bake-out of components for another program. Monitoring of the PSA-32 UART during test confirmed that the PSA-32 was being reset.

1a. What was the hardware configuration at the time of the test anomaly? (i.e. If at system test, were all flight items installed? Were some non-flight items installed? If at subsystem or box level, were all flight components installed?) Describe the level of any software in use at the time of the anomaly, if applicable (i.e. was flight code installed at the time of the anomaly?) Describe the Test Hardware/Software configuration at the time of the anomaly.

Protoflight model IPU installed in vacuum chambers. TV test cables (approx 30 ft of unshielded twisted pair) through chamber wall to GSE test equiptment (two interface simulators, power supplies and switch, reset box, IEGSE computer). Software load was current version of flight code. The environment around the chamber appears to be electrically noisy.

MISSION SUCCESS REVIEW
QUESTIONS FOR UNVERIFIED FAILURES

1b. What was the most likely cause of the anomaly? Is there a fishbone analysis, fault tree or similar analysis performed as part of the trouble shooting? Have all other suspect causes been eliminated?
The most likely cause is believed to be noise, either in the ground connections or coupled into the reset lines.

There are 4 ways by which the processor can be reset:

1)Watchdog timer timeout

2) Noise on reset lines going from outside the chamber (unshielded and not twisted pair, therefore susceptible to noise pickup) to the backplane of the IPU.

3) Noise spikes on the 3.3 volt or 5 volt power lines to the processor (PSA-32) card.

4) Bleed through of internal power supply voltages between A and B sides triggering the power on reset circuits.

A watchdog timer timout was ruled out by software tests (the watchdog timer timeout was not enabled and test showed it could not cause a reset. Monitoring of the 3.3V and 5V power lines during later reset events showed no spikes or dropout which could cause resets. Measurement of bleed through voltages showed levels (max 300 mV) well below the level which could cause problems. This leaves only noise on the external test reset line as a probable cause.

2. What test was in process? Were multiple tests being performed simultaneously?
Thermal vacuum cycling with the IPU in normal operating mode.

3. Did the anomaly repeat? Describe troubleshooting performed while the anomaly was present.
The anomaly occurred a total of ten times as follows:
1) Tue. 22 Aug. 22:03, Temp = 37.5 deg C, A Side, telemetry restored 04:35.
2) Thu. 24 Aug. 00:35, Temp = -25.6 deg C, B Side, telemetry restored 02:24.
3) Thu. 24 Aug. 10:01, Temp = 46.9 deg C, B Side, telemetry restored 11:04.
4) Thu. 24 Aug, 12:06, Temp = 46.9 deg C, B Side, telemetry restored 12:29.
5) Thu. 24 Aug. 12:39, Temp = 42.4 deg C, B Side, telemetry restored 13:42.
6) Thu. 24 Aug. 13:49, Temp = 42.4 deg C, B Side, telemetry restored 18:05.
7) Thu 24 Aug. 20:14, Temp = 1.7 deg C, B Side, telemetry restored 20:58.
8) Fri. 25 Aug. 16:00, Temp = 36.7 deg C, Bside, telemetry restored 16:15.
9) Tue. 29 Aug. 13:28, Temp = 38.8 deg C, A Side, telemetry restored 13:45.
10) Wed 30 Aug. 05:02, Temp = 1.4 deg C, A Side, telemetry restored 05:10.

Trouble shooting while the anomaly was present was limited to monitoring power supply parameters and ground noise (communication with the PSA-32 computer was not possible during anomaly).

MISSION SUCCESS REVIEW
QUESTIONS FOR UNVERIFIED FAILURES

4. When/If the anomaly cleared? What happened to cause the anomaly to clear? What efforts were made to get the anomaly to repeat? Were the Hardware/Software configurations identical to the original condition? If not, what were the differences, why were the differences necessary?

The anomaly was somtimes cleared by simple re-boot (no power cycle) of the IPU. Other times a power cycle was required to clear the anomaly. Efforts to induce noise into the test environment using hair drier and walkie-talkie were unsuccessful. The only changes to the test setup after the original anomaly were the addition of a DVM to measure noise voltage between common ground and the chamber wall (approx 100 mV), and a chart recorder to monitor power supply voltages. The software configuration was the same throughtout.

Tests were run to measure the threshold of the external reset line and it susceptability to noise spikes. These reavealed that pulling this signal down from it's normal 3.3V to 1.835V would cause a loss of telemetry (and communication) which required a power cycle to clear. Pulling this signal to ground would cause a clean reset (loss of telemetry and communication could be cleared without power cycle). In other words, all of the conditions seen during test anomalies could be recreated. In addition, a pulse generator was coupled through a capacitor into this line to measure the pulse width required to cause the anomaly. This test demonstrated that pulling the reset line down to 1.7V for 10 nanoseconds was sufficient to cause the anomaly.

5. List all accumulative anomaly free re-testing and "on-time". Is all test time documented?

The IPU ran anomaly free from 05:10 30 Aug to the end of TV tests at 19:43. The test was then broken down and moved from the vacuum chamber to the lab area in room 138 for final functional tests and anomaly investigation. The IPU was allowed to run overnight (18:00 to 08:30) on 6/7 Sep and 7/8 Sep. The IPU was also run over the weekend from 18:00 9 Sep to 08:30 11 Sep with no anomalies.

6. Does the failure analysis of the problem clearly lead to assigning the anomaly to a specific element? Was that element replaced? If so, when the element was fixed, was the problem cleared?

There is no apparent hardware failure. Analysis leads to noise on the external reset line as the only likely cause. This line is not intended for flight use and will be removed.

7. What would be required to perform a worst case repair? Was that performed? If not, describe the reason.

Removal of two twisted pairs from external test cable.

8. Did the anomaly cause any overstress (consequential impact)? Is the overstress analysis documented and accepted by the REE, Program Manager and Engineering?

Reset cannot cause any overstress in the IPU. Noise coupled into external cables from laboratory environment cannot couple sufficient power to cause damage.

9. If not addressed, what was the rationale for not addressing the overstress issue?

N/A

MISSION SUCCESS REVIEW
QUESTIONS FOR UNVERIFIED FAILURES

10. Are there other relevant failures on other sibling items or other systems? If the failure is in a component/piece part, what is the failure history of that part? What is the Mission history of sibling units? How many have been built, delivered and what is their performance record?
    N/A (proto-flight system)

11. If the anomaly was traced to a part, what were the results of the failure analysis/DPA? e.g., did DPA confirm the failure?
    N/A

12. Were any trouble shooting steps considered and not performed due to cost or schedule concerns? Could these trouble shooting steps determine the cause of the anomaly. Describe the risks in performing this trouble shooting now.
Reset lines (from reset box) were left connected by direction of FRB. Disconnection (at the IPU) would require opening chamber door. Entire TV test would have to be repeated, however chamber is not available to support this additional time.

13. Are there operational work arounds possible to mitigate the effect of this anomaly? Could they be implemented within the Mission?
The HIRDLS instrument requires a functioning IPU in order to collect data and perform its intended mission. If the IPU requires power cycling to reset, this can be performed through human command from a ground station. This commanding can be performed within the scope of the mission.

MISSION SUCCESS REVIEW
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14. What is the worst case scenario of this anomaly recurring during the Mission? What is the consequence of this occurrence without intervention? If intervention is possible, describe the steps needed and the result to the Mission. Impact categories are: 1) Mission Loss, 2) Mission Degradation, 3) Loss of Redundancy, 4) Degraded Data or Payload Performance, 5) Reduced Data or Payload Performance, Partial Loss of Redundancy or Change to Mission Operation, 6)No Impact

The anomaly can be cleared in two ways: 1) The anomaly can be cleared by an automated re-boot of the IPU that would occur on-orbit within seconds of the anomaly being detected. 2) If automated re-boot is not successful, the anomaly can be cleared by cycling the power to the IPU. This requires human intervention and will require several orbital periods (up to 6 hrs).

The impact to each interfacing subsystem for each recovery scenario has been considered and is summarized below.

Interfacing Subsystem	Recovery via Automated (instantaneous) IPU Reboot	Impact Category	Recovery via Ground-Commanded Power Cycle to IPU	Impact Category
Telescope (TSS)	TSS will await instructions from the IPU. It cannot harm itself. Data will not be collected without the IPU.	5	TSS will await instructions from the IPU. It cannot harm itself. Data will not be collected without the IPU.	5
Signal Processing Unit (SPU)	SPU stops receiving timing signals and stops functioning. It has no modes or states that can be damaged while awaiting IPU reset.	5	SPU stops receiving timing signals and stops functioning. It has no modes or states that can be damaged while awaiting IPU reset.	5
Gyro (GSS)	Gyro runs autonomously, not dependent on IPU instructions.	5	Gyro runs autonomously, not dependent on IPU instructions.	5
Detector (DSS)	Passive system, cannot be harmed by loss of communication with IPU.	5	Passive system, cannot be harmed by loss of communication with IPU.	5
In-Flight Calibration (IFC)	IPU automated reset requires 13 seconds, this is not enough time to cause drift of IFC temperature.	6	IPU controls temperature of IFC. Loss of IPU will result in several hours of recovery time to re-establish proper IFC temperature.	5
Sunshield	IPU auto-reboot is a 13 second event, wax actuator is a 20 minute event, no impact seen.	6	If IPU drops out while we are in the midst of operating the wax actuator, major melting of wax can occur, resulting in contamination of optical path and degraded performance.	4
Operational Heaters	Duty cycles on heaters is considerably longer than 13 seconds that it would take for IPU auto reboot. No impact.	6	If heaters are stuck "full-on" because of IPU drop-out, it may take 2-3 hrs to restore proper thermal equilibrium once control is re-established. If heaters are stuck "full-off", the survival heaters will function (they are on an independent bus).	5
Cooler (CSS)	No effect on CSS	6	IPU re-boot does not affect operating mode or status of CSS. CSS is autonomous, knows how to shut down if anomalous condition develops – independent of IPU.	5
Housekeeping Sensors	13 second loss of telemetry will not impact mission.	6	Loss of housekeeping telemetry while IPU is down means that we cannot rely on these data for troubleshooting of any anomaly that occurs while IPU is down.	5
Power (PSS)	There are no automated tasks between the IPU and the PSS. IPU reboot will cause the power to cycle	5	There are no automated tasks between the IPU and the PSS. IPU reboot will cause the power to cycle	5

MISSION SUCCESS REVIEW
QUESTIONS FOR UNVERIFIED FAILURES

Interfacing Subsystem	Recovery via Automated (instantaneous) IPU Reboot	Impact Category	Recovery via Ground-Commanded Power Cycle to IPU	Impact Category
	for the TSS, GSS, and DSS. This will affect the science stream from the instrument.		for the TSS, GSS, and DSS. This will affect the science stream from the instrument.	

15. How likely is the occurrence of this anomaly during the Mission? (High/Medium/Low) Explain the rational used for the determination.

Very low. The external wires believed to be susceptable to noise will not exist in the flight configuration.

Program HIRDLS Spacecraft EOS Aura Subsystem PCU Box ________

Document # ____________ Risk Level 3 **Loss of Redundancy** **Likelihood Low**

Title: +5VC Current Trip Transistor Blown

Prepared by (REE) GSFC/Edward Bielecki date 8 July 2002

Concurrence:

Concurrence provided by NASA Direction to Proceed With Hardware Processing. Letter is attached (see item #2).

1. What was the anomaly? Describe all significant events leading up to the occurrence. Describe the trouble shooting conducted and the results.
   There was a failure in the current limiter circuit in the +5V power line to the PCU telemetry. See attached memo from Diane Yun. See RAL NCR HIR-AR-RAL-085/45 in Section 24 of RAL Acceptance Data Package.

1a. What was the hardware configuration at the time of the test anomaly? (i.e. If at system test, were all flight items installed? Were some non-flight items installed? If at subsystem or box level, were all flight components installed?) Describe the level of any software in use at the time of the anomaly, if applicable (i.e. was flight code installed at the time of the anomaly?) Describe the Test Hardware/Software configuration at the time of the anomaly.

   Details contained in attached memo from Diane Yun. See RAL NCR HIR-AR-RAL-085/45 in Section 24 of RAL Acceptance Data Package.

1b. What was the most likely cause of the anomaly? Is there a fishbone analysis, fault tree or similar analysis performed as part of the trouble shooting? Have all other suspect causes been eliminated?
   Details contained in attached memo from Diane Yun. See RAL NCR HIR-AR-RAL-085/45 in Section 24 of RAL Acceptance Data Package.

2. What test was in process? Were multiple tests being performed simultaneously?
   See RAL NCR HIR-AR-RAL-085/45 in Section 24 of RAL Acceptance Data Package.

3. Did the anomaly repeat? Describe the troubleshooting performed while the anomaly was present.
   Details contained in attached memo from Diane Yun. See RAL NCR HIR-AR-RAL-085/45 in Section 24 of RAL Acceptance Data Package.

4. When/If the anomaly cleared? What happened to cause the anomaly to clear? What efforts were made to get the anomaly to repeat? Were the Hardware/Software configurations identical to the original condition? If not, what were the differences, why were the differences necessary?
   The circuit was re-designed per schematic KE-0123-820-02-D (attached).

5. List all accumulative anomaly free re-testing and "on-time". Is all test time documented?

Since the circuit re-design, the anomaly-free PCU run time is over 100 hrs.

6. Does the failure analysis of the problem clearly lead to assigning the anomaly to a specific element? Was that element replaced? If so, when the element was fixed, was the problem cleared?

   Details contained in attached memo from Diane Yun. See RAL NCR HIR-AR-RAL-085/45 in Section 24 of RAL Acceptance Data Package.

7. What would be required to perform a worst case repair? Was that performed? If not, describe the reason.

   Circuit was re-designed and worst-case repair was performed. Details contained in attached memo from Diane Yun. See RAL NCR HIR-AR-RAL-085/45 in Section 24 of RAL Acceptance Data Package.

8. Did the anomaly cause any overstress (consequential impact)? Is the overstress analysis documented and accepted by the REE, Program Manager and Engineering?
   Overstress analysis performed, led to replacement of additional parts. Details contained in attached memo from Diane Yun. See RAL NCR HIR-AR-RAL-085/45 in Section 24 of RAL Acceptance Data Package.

9. If not addressed, what was the rationale for not addressing the overstress issue?

   Overstress analysis was performed.

10. Are there other relevant failures on other sibling items or other systems? If the failure is in a component/piece part, what is the failure history of that part? What is the Mission history of sibling units? How many have been built, delivered and what is their performance record?

    No sibling unit issues, this is a unique design.

11. If the anomaly was traced to a part, what were the results of the failure analysis/DPA? e.g., did DPA confirm the failure?
    Anomaly was traced to a bad design that resulted in electrical overstress to several parts.

12. Were any trouble shooting steps considered and not performed due to cost or schedule concerns? Could these trouble shooting steps determine the cause of the anomaly. Describe the risks in performing this trouble shooting now.
    More than adequate time and resources were devoted to understanding and solving the problem. Diane Yun/GSFC spent one week at RAL in support of the effort to probe into the potential causes of this unverified failure. All of the considered troubleshooting steps were performed successfully.

13. Are there operational work arounds possible to mitigate the effect of this anomaly? Could they be implemented within the Mission?
    There are no operational workarounds if the current limiter supplying the input voltage to the +5 volt regulator fails, since telemetry is a shared resource for sides A and B. If the +/-15 volt internal power converter fails, simply switching the internal supply to the other side should solve the problem.

14. What is the worst case scenario of this anomaly recurring during the Mission? What is the consequence of this occurrence without intervention? If intervention is possible, describe the steps needed and the result to the

Mission. Impact categories are: 1) Mission Loss, 2) Mission Degradation, 3) Loss of Redundancy, 4) Degraded Data or Payload Performance, 5) Reduced Data or Payload Performance, Partial Loss of Redundancy or Change to Mission Operation, 6)No Impact
The worst-case scenario of this anomaly recurring during the mission would include a complete loss of PCU housekeeping/engineering telemetry and an increase of power dissipation of the 15V internal power converter. Payload performance/mission success should not be compromised since other subsystem telemetry would still be available. The increased power dissipation should still be within the advertised performance capability of the internal supply. The expected temperature increase of the internal supply was also considered by RAL and deemed to be of minimal impact.

15. How likely is the occurrence of this anomaly during the Mission? (High/Medium/Low) Explain the rational used for the determination.
The likely occurrence of this failure/anomaly during the mission is considered to be low. Since the final modification/improvement to the PC board was completed, and including only the post-rework PCU operation, the estimated (see above) anomaly-free operating time for the PCU is well over 100 hours.

214.3 April 22, 2002

Lockheed Martin Corporation
Missiles & Space
Attention: Mr. Bill Haynes
Department 25-64, Building 255
3251 Hanover Street
Palo Alto, CA 94304-1191

SUBJECT: NAS5-99244; Response Concerning Government Furnished Equipment (GFE) Subsystem Readiness for Environmental Testing

With regards to Lockheed Martin's letter regarding GFE subsystem readiness for environmental testing, Aura Project provides this letter as a formal response. The questions posed in the January 7, 2002 letter (LMMS/WLH-01-272) are restated below with a response and reference to Aura Project's correspondence regarding the issue.

1. For the In-Flight Calibrator (IFC), certain EEE parts were not PIND tested. This was an open item at the Pre-Ship Review for this subsystem held in August 2000. Please indicate if we should proceed with this known risk.

<u>NASA EOS Aura Project Response</u>: The IFC successfully passed the dynamic environmental tests and was further subjected to shipping and additional handling. Additional dynamics and shipping will be experienced at the instrument level. While it would have been desirable to have every cavity device PIND tested for presence of particles, based on test results for the parts that were PIND tested, and based on proper subsystem function, the risk of proceeding with HIRDLS instrument level testing is thought to be very minimal. Aura Project considers this as a low risk to Mission Success and Lockheed should proceed with instrument level testing. (E-mail from Terry King (EOS Aura Parts Engineer) to Ed Bielecki (Aura Project Systems Engineer) dated Fri, 19 Apr 2002.)

2. The Power Subsystem (PSS) had two unverified failures that were not documented as such (in-rush current and current monitor failure). The standard approach to addressing unverified failures is to assess the likelihood of recurrence and the potential impact to the mission. This risk assessment has not been performed to our knowledge.

<u>NASA EOS Aura Project Response</u>: The risk assessment has been performed and presented to the Lockheed Martin quality team for discussion. For both of these unverified failures, the probability of recurrence is low and the potential impact to the mission is low. Mission impact is low because both anomalies affect only the PCU housekeeping/engineering telemetry and do not affect the instrument science telemetry. Aura Project considers this as a low risk to Mission Success and Lockheed should proceed with instrument level testing. (Memo from Edward Bielecki (GSFC) to Tim Crews dated February 21, 2002).

3. The requirements verification matrix for the PSS indicates a large number of requirements that have not been formally verified or documented as verified. Of principal concern is an analysis verifying the radiation hardness of the as-built PSS. Failure to address this issue will result in an eventual lien against launch when Lockheed Martin delivers the instrument to NASA.

<u>NASA EOS Aura Project Response</u>: The requirements verification matrix for the PSS has now been completed, as reviewed at Lockheed Martin on 14 March. Parts in the PCU are acceptable for use and a risk analysis was completed on parts of concern. The Aura Project considers this as a low risk to Mission Success and Lockheed should proceed with instrument level testing. (Memo from Art Ruitberg, Code 563 to Aura Project on March 6, 2002; HIRDLS Mission Success IRR presentation PM-HIR-371, March 13-14, 2002; Mission Success Review UVF Survey for part #2N2222A dated March 22,2002)

4. The Gyroscope Subsystem (GSS) exhibited a heater relay failure when tested in a cold condition. Although this discrepancy has the appearance of an unverified failure, it was dispositioned as "Use As-Is". We would like written concurrence from NASA that this is acceptable.

<u>NASA EOS Aura Project Response</u>: Aura Project is confident that the heater relays are fully operational over the required temperature range and at the expected/predicted cold survival temperature. Aura Project considers this as a low risk to Mission Success and Lockheed should proceed with instrument level testing. (Memo from Edward Bielecki (GSFC) to Tim Crews dated March 3, 2002).

5. The GSS has a test connector that will fly with the instrument. This connector requires a flight-quality cover prior to initiation of instrument-level testing. To date this cover has not been supplied.

<u>NASA EOS Aura Project Response</u>: On March 14, 2002, Aura Project Instrument Manager confirmed with LMSS Program Manager that LMSS has the connector. Aura Project considers this no longer a risk to schedule and Lockheed should proceed with instrument level testing.

6. The GSS had several exceedances during its EMI/EMC test at the subsystem level. A copy of the test report is requested to assist us with troubleshooting during EMI/EMC testing at the instrument level. Not having this knowledge is a potential schedule impact.

<u>NASA EOS Aura Project Response</u>: Aura Project provided the report on March 26, 2002 thus making it available for instrument level testing. Aura Project considers this no longer a risk to schedule and Lockheed should proceed with instrument level testing. (E-mail from Neil Martin (GSFC) to Timothy Crews (LMSS) dated Tue, 26 Mar 2002 16:52:14.)

The NASA EOS Aura Project appreciates the Lockheed Martin HIRDLS Team's effort to make Aura a Mission Success and look forward to working closely during instrument level testing.

Please do not hesitate to call. I can be reached on telephone (301) 286-2094 or facsimile (301) 286-0383. My e-mail address is Linda.Kelley@gsfc.nasa.gov.

Original Signed By

Linda S. Kelley

Contracting Officer

MISSION SUCCESS REVIEW
QUESTIONS FOR UNVERIFIED FAILURES

cc: 424/Jackson
424/McIntyre
424/Fontaine
214.3/File

Program <u>HIRDLS</u> **Spacecraft** <u>EOS Aura</u> **Subsystem** <u>PCU</u> **Box**__________

Document #____________ **Risk Level** <u>3 Loss of Redundancy</u> **Likelihood** <u>Low</u>

Title: +5VC Current Trip Transistor Blown

Prepared by (REE) <u>GSFC/Edward Bielecki</u> date <u>8 July 2002</u>

Concurrence:

Concurrence provided by NASA Direction to Proceed With Hardware Processing. Letter is attached (see item #2).

1. What was the anomaly? Describe all significant events leading up to the occurrence. Describe the trouble shooting conducted and the results.
   <u>There was a failure in the current limiter circuit in the +5V power line to the PCU telemetry. See attached memo from Diane Yun. See RAL NCR HIR-AR-RAL-085/45 in Section 24 of RAL Acceptance Data Package.</u>

1a. What was the hardware configuration at the time of the test anomaly? (i.e. If at system test, were all flight items installed? Were some non-flight items installed? If at subsystem or box level, were all flight components installed?) Describe the level of any software in use at the time of the anomaly, if applicable (i.e. was flight code installed at the time of the anomaly?) Describe the Test Hardware/Software configuration at the time of the anomaly.

   <u>Details contained in attached memo from Diane Yun. See RAL NCR HIR-AR-RAL-085/45 in Section 24 of RAL Acceptance Data Package.</u>

1b. What was the most likely cause of the anomaly? Is there a fishbone analysis, fault tree or similar analysis performed as part of the trouble shooting? Have all other suspect causes been eliminated?
   <u>Details contained in attached memo from Diane Yun. See RAL NCR HIR-AR-RAL-085/45 in Section 24 of RAL Acceptance Data Package.</u>

2. What test was in process? Were multiple tests being performed simultaneously?
   <u>See RAL NCR HIR-AR-RAL-085/45 in Section 24 of RAL Acceptance Data Package.</u>

3. Did the anomaly repeat? Describe the troubleshooting performed while the anomaly was present.
   <u>Details contained in attached memo from Diane Yun. See RAL NCR HIR-AR-RAL-085/45 in Section 24 of RAL Acceptance Data Package.</u>

4. When/If the anomaly cleared? What happened to cause the anomaly to clear? What efforts were made to get the anomaly to repeat? Were the Hardware/Software configurations identical to the original condition? If not, what were the differences, why were the differences necessary?
   <u>The circuit was re-designed per schematic KE-0123-820-02-D (attached).</u>

5. List all accumulative anomaly free re-testing and "on-time". Is all test time documented?

Since the circuit re-design, the anomaly-free PCU run time is over 100 hrs.

6. Does the failure analysis of the problem clearly lead to assigning the anomaly to a specific element? Was that element replaced? If so, when the element was fixed, was the problem cleared?

   Details contained in attached memo from Diane Yun. See RAL NCR HIR-AR-RAL-085/45 in Section 24 of RAL Acceptance Data Package.

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   Circuit was re-designed and worst-case repair was performed. Details contained in attached memo from Diane Yun. See RAL NCR HIR-AR-RAL-085/45 in Section 24 of RAL Acceptance Data Package.

8. Did the anomaly cause any overstress (consequential impact)? Is the overstress analysis documented and accepted by the REE, Program Manager and Engineering?
   Overstress analysis performed, led to replacement of additional parts. Details contained in attached memo from Diane Yun. See RAL NCR HIR-AR-RAL-085/45 in Section 24 of RAL Acceptance Data Package.

9. If not addressed, what was the rationale for not addressing the overstress issue?

   Overstress analysis was performed.

10. Are there other relevant failures on other sibling items or other systems? If the failure is in a component/piece part, what is the failure history of that part? What is the Mission history of sibling units? How many have been built, delivered and what is their performance record?

    No sibling unit issues, this is a unique design.

11. If the anomaly was traced to a part, what were the results of the failure analysis/DPA? e.g., did DPA confirm the failure?
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12. Were any trouble shooting steps considered and not performed due to cost or schedule concerns? Could these trouble shooting steps determine the cause of the anomaly. Describe the risks in performing this trouble shooting now.
    More than adequate time and resources were devoted to understanding and solving the problem. Diane Yun/GSFC spent one week at RAL in support of the effort to probe into the potential causes of this unverified failure. All of the considered troubleshooting steps were performed successfully.

13. Are there operational work arounds possible to mitigate the effect of this anomaly? Could they be implemented within the Mission?
    There are no operational workarounds if the current limiter supplying the input voltage to the +5 volt regulator fails, since telemetry is a shared resource for sides A and B. If the +/-15 volt internal power converter fails, simply switching the internal supply to the other side should solve the problem.

14. What is the worst case scenario of this anomaly recurring during the Mission? What is the consequence of this occurrence without intervention? If intervention is possible, describe the steps needed and the result to the

Mission. Impact categories are: 1) Mission Loss, 2) Mission Degradation, 3) Loss of Redundancy, 4) Degraded Data or Payload Performance, 5) Reduced Data or Payload Performance, Partial Loss of Redundancy or Change to Mission Operation, 6)No Impact
The worst-case scenario of this anomaly recurring during the mission would include a complete loss of PCU housekeeping/engineering telemetry and an increase of power dissipation of the 15V internal power converter. Payload performance/mission success should not be compromised since other subsystem telemetry would still be available. The increased power dissipation should still be within the advertised performance capability of the internal supply. The expected temperature increase of the internal supply was also considered by RAL and deemed to be of minimal impact.

15. How likely is the occurrence of this anomaly during the Mission? (High/Medium/Low) Explain the rational used for the determination.
The likely occurrence of this failure/anomaly during the mission is considered to be low. Since the final modification/improvement to the PC board was completed, and including only the post-rework PCU operation, the estimated (see above) anomaly-free operating time for the PCU is well over 100 hours.

214.3 April 22, 2002

Lockheed Martin Corporation
Missiles & Space
Attention: Mr. Bill Haynes
Department 25-64, Building 255
3251 Hanover Street
Palo Alto, CA 94304-1191

SUBJECT: NAS5-99244; Response Concerning Government Furnished Equipment (GFE) Subsystem Readiness for Environmental Testing

With regards to Lockheed Martin's letter regarding GFE subsystem readiness for environmental testing, Aura Project provides this letter as a formal response. The questions posed in the January 7, 2002 letter (LMMS/WLH-01-272) are restated below with a response and reference to Aura Project's correspondence regarding the issue.

1. For the In-Flight Calibrator (IFC), certain EEE parts were not PIND tested. This was an open item at the Pre-Ship Review for this subsystem held in August 2000. Please indicate if we should proceed with this known risk.

<u>NASA EOS Aura Project Response</u>: *The IFC successfully passed the dynamic environmental tests and was further subjected to shipping and additional handling. Additional dynamics and shipping will be experienced at the instrument level. While it would have been desirable to have every cavity device PIND tested for presence of particles, based on test results for the parts that were PIND tested, and based on proper subsystem function, the risk of proceeding with HIRDLS instrument level testing is thought to be very minimal. Aura Project considers this as a low risk to Mission Success and Lockheed should proceed with instrument level testing. (E-mail from Terry King (EOS Aura Parts Engineer) to Ed Bielecki (Aura Project Systems Engineer) dated Fri, 19 Apr 2002.)*

2. The Power Subsystem (PSS) had two unverified failures that were not documented as such (in-rush current and current monitor failure). The standard approach to addressing unverified failures is to assess the likelihood of recurrence and the potential impact to the mission. This risk assessment has not been performed to our knowledge.

<u>NASA EOS Aura Project Response</u>: *The risk assessment has been performed and presented to the Lockheed Martin quality team for discussion. For both of these unverified failures, the probability of recurrence is low and the potential impact to the mission is low. Mission impact is low because both anomalies affect only the PCU housekeeping/engineering telemetry and do not affect the instrument science telemetry. Aura Project considers this as a low risk to Mission Success and Lockheed should proceed with instrument level testing. (Memo from Edward Bielecki (GSFC) to Tim Crews dated February 21, 2002).*

3. The requirements verification matrix for the PSS indicates a large number of requirements that have not been formally verified or documented as verified. Of principal concern is an analysis verifying the radiation hardness of the as-built PSS. Failure to address this issue will result in an eventual lien against launch when Lockheed Martin delivers the instrument to NASA.

<u>NASA EOS Aura Project Response</u>: The requirements verification matrix for the PSS has now been completed, as reviewed at Lockheed Martin on 14 March. Parts in the PCU are acceptable for use and a risk analysis was completed on parts of concern. The Aura Project considers this as a low risk to Mission Success and Lockheed should proceed with instrument level testing. (Memo from Art Ruitberg, Code 563 to Aura Project on March 6, 2002; HIRDLS Mission Success IRR presentation PM-HIR-371, March 13-14, 2002; Mission Success Review UVF Survey for part #2N2222A dated March 22,2002)

4. The Gyroscope Subsystem (GSS) exhibited a heater relay failure when tested in a cold condition. Although this discrepancy has the appearance of an unverified failure, it was dispositioned as "Use As-Is". We would like written concurrence from NASA that this is acceptable.

<u>NASA EOS Aura Project Response</u>: Aura Project is confident that the heater relays are fully operational over the required temperature range and at the expected/predicted cold survival temperature. Aura Project considers this as a low risk to Mission Success and Lockheed should proceed with instrument level testing. (Memo from Edward Bielecki (GSFC) to Tim Crews dated March 3, 2002).

5. The GSS has a test connector that will fly with the instrument. This connector requires a flight-quality cover prior to initiation of instrument-level testing. To date this cover has not been supplied.

<u>NASA EOS Aura Project Response</u>: On March 14, 2002, Aura Project Instrument Manager confirmed with LMSS Program Manager that LMSS has the connector. Aura Project considers this no longer a risk to schedule and Lockheed should proceed with instrument level testing.

6. The GSS had several exceedances during its EMI/EMC test at the subsystem level. A copy of the test report is requested to assist us with troubleshooting during EMI/EMC testing at the instrument level. Not having this knowledge is a potential schedule impact.

<u>NASA EOS Aura Project Response</u>: Aura Project provided the report on March 26, 2002 thus making it available for instrument level testing. Aura Project considers this no longer a risk to schedule and Lockheed should proceed with instrument level testing. (E-mail from Neil Martin (GSFC) to Timothy Crews (LMSS) dated Tue, 26 Mar 2002 16:52:14.)

The NASA EOS Aura Project appreciates the Lockheed Martin HIRDLS Team's effort to make Aura a Mission Success and look forward to working closely during instrument level testing.

Please do not hesitate to call. I can be reached on telephone (301) 286-2094 or facsimile (301) 286-0383. My e-mail address is Linda.Kelley@gsfc.nasa.gov.

Original Signed By

Linda S. Kelley

Contracting Officer

MISSION SUCCESS REVIEW
QUESTIONS FOR UNVERIFIED FAILURES

cc: 424/Jackson
424/McIntyre
424/Fontaine
214.3/File

Program HIRDLS **Spacecraft** EOS **Subsystem** PCU **Box**__________

Document #____________ **Risk Level** 3 Loss of Redundancy **Likelihood** Low

Title: Power Converter Unit (PCU) Current Monitor Failure

Prepared by Wittenauer/Savoye date 4/19/01

Concurrence:

Concurrence provided by NASA Direction to Proceed With Hardware Processing. Letter is attached (see item #2).

1. What was the anomaly? Describe all significant events leading up to the occurrence. Describe the trouble shooting conducted and the results.

Intermittent Failure of the current monitor on the Quiet "A" Bus. The PCU includes a quiet and a noisy bus, each is a redundant system denoted as "A" or "B".

1a. What was the hardware configuration at the time of the test anomaly? (i.e. If at system test, were all flight items installed? Were some non-flight items installed? If at subsystem or box level, were all flight components installed?) Describe the level of any software in use at the time of the anomaly, if applicable (i.e. was flight code installed at the time of the anomaly?) Describe the Test Hardware/Software configuration at the time of the anomaly.

Anomaly was observed at the PCU (subsystem) level. The PCU was in its final flight configuration. The first occurrence of this problem was after vibration of the PCU while the unit was undergoing a functional test known as LPT (Limited Performance Test). The problem occurred again during T-Vac testing after the third cold soak.

1b. What was the most likely cause of the anomaly? Is there a fishbone analysis, fault tree or similar analysis performed as part of the trouble shooting? Have all other suspect causes been eliminated?

No fishbone analysis was performed. The following possible causes have been identified:

- Solder (cold joint)
- Vishay Resistor
- Capacitor
- 10 Meg Resistor
- Internal Connector (pushed out or recessed pins)
- Controller (AMUX) Board

Additionally, a top-level fault propagation has been conducted and the conclusion is that this fault could not cause any further faults to occur in the PCU.

2. What test was in process? Were multiple tests being performed simultaneously?

On first occurrence (9 Jul 00), the PCU was undergoing post-vib functional testing. On second occurrence (24 Jul 00), the PCU was undergoing a cold soak as part of the Thermal Vacuum Testing.

3. Did the anomaly repeat? Describe the troubleshooting performed while the anomaly was present.

The anomaly did not repeat other than the two occurrences described above.

4. When/If the anomaly cleared? What happened to cause the anomaly to clear? What efforts were made to get the anomaly to repeat? Were the Hardware/Software configurations identical to the original condition? If not, what were the differences, why were the differences necessary?

The first anomaly cleared during EMC testing on 13 July. (Did it clear during the test or was it observed to be working nominally at the start of the test?) The second anomaly cleared during the hot soak that immediately followed the cold soak on which the anomaly occurred.

5. List all accumulative anomaly free re-testing and "on-time". Is all test time documented?

Since the occurrence of the second anomaly, the PCU has been run for over 100 hrs without reoccurrence of the anomaly. The test time has been logged in the PCU log. In March/April '01, certain elements of the PCU (Ray please provide) were replaced – including the AMUX board that contains the current-monitoring circuit. Since that time, the PCU has operated for 58 hrs and has not exhibited the anomaly.

6. Does the failure analysis of the problem clearly lead to assigning the anomaly to a specific element? Was that element replaced? If so, when the element was fixed, was the problem cleared?

During March/April, certain elements of the PCU (Ray please provide) were replaced – including the AMUX board that contains the current-monitoring circuit. Penalty testing of the refurbished PCU included (Ray please provide). Since that time, the anomaly has not been observed.

7. What would be required to perform a worst case repair? Was that performed? If not, describe the reason.

Worst-case repair would involve replacement of the AMUX board on which the current monitor circuit is located. This repair was performed in Mar/Apr '01.

8. Did the anomaly cause any overstress (consequential impact)? Is the overstress analysis documented and accepted by the REE, Program Manager and Engineering?

The anomaly is a monitoring circuit only and would not have caused any overstress to related components.

9. If not addressed, what was the rationale for not addressing the overstress issue?

See above, overstress not believed to be a factor with this anomaly

10. Are there other relevant failures on other sibling items or other systems? If the failure is in a component/piece part, what is the failure history of that part? What is the Mission history of sibling units? How many have been built, delivered and what is their performance record?

The failure investigation determined that a malfunctioning Vishay resistor is though to be the true root cause. The current monitors on HIRDLS are redundant and the "B side" current monitor has not exhibited an anomaly. Further, both "A side" and "B side" monitors on the replacement AMUX board are functionaing anomaly-free.

11. If the anomaly was traced to a part, what were the results of the failure analysis/DPA? e.g., did DPA confirm the failure?

Ray – is rutherford Labs doing any further troubleshooting of the AMUX board that was removed? Can/should we push for this?

12. Were any trouble shooting steps considered and not performed due to cost or schedule concerns? Could these trouble shooting steps determine the cause of the anomaly. Describe the risks in performing this trouble shooting now.

Troubleshooting was limited because of schedule impact on delivery of PCU to LMSSC and the concurrence of the HIRDLS team (Rutherford-GSFC-LMSSC) that loss of the current monitor has a low impact to the mission (see below).

13. Are there operational work arounds possible to mitigate the effect of this anomaly? Could they be implemented within the Mission?

One operational work-around would be to use the current monitor on the QB bus (which has never shown any sign of failure). This solution would be ineffective if the QB monitor were to fail for any reason. As an alternative, the current draw of the HIRDLS instrument could possibly be derived if the current drawn by other instruments were known and the total current drawn by the S/C were known.

14. What is the worst case scenario of this anomaly recurring during the Mission? What is the consequence of this occurrence without intervention? If intervention is possible, describe the steps needed and the result to the Mission. Impact categories are: 1) Mission Loss, 2) Mission Degradation, 3) Loss of Redundancy, 4) Degraded Data or Payload Performance, 5) Reduced Data or Payload Performance, Partial Loss of Redundancy or Change to Mission Operation, 6)No Impact

Impact is loss of redundancy (Category 3) and reduced housekeeping data (Category 5) The current monitor is only one parameter that is used to monitor the health of the HIRDLS instrument. Loss of the monitor does not present an unacceptable risk to the program.

15. How likely is the occurrence of this anomaly during the Mission? (High/Medium/Low) Explain the rational used for the determination.

The likely occurrence is low. The failure was only observed twice and each time, the anomaly corrected itself. The PCU operated in the laboratory for over 100 hrs with no repeat of the anomaly. Since then, the AMUX board that contains the current monitor was replaced, and subjected to 58+ additional hrs of anomaly-free testing.

214.3 April 22, 2002

Lockheed Martin Corporation
Missiles & Space
Attention: Mr. Bill Haynes
Department 25-64, Building 255
3251 Hanover Street
Palo Alto, CA 94304-1191

SUBJECT: NAS5-99244; Response Concerning Government Furnished Equipment (GFE) Subsystem Readiness for Environmental Testing

With regards to Lockheed Martin's letter regarding GFE subsystem readiness for environmental testing, Aura Project provides this letter as a formal response. The questions posed in the January 7, 2002 letter (LMMS/WLH-01-272) are restated below with a response and reference to Aura Project's correspondence regarding the issue.

1. For the In-Flight Calibrator (IFC), certain EEE parts were not PIND tested. This was an open item at the Pre-Ship Review for this subsystem held in August 2000. Please indicate if we should proceed with this known risk.

NASA EOS Aura Project Response: The IFC successfully passed the dynamic environmental tests and was further subjected to shipping and additional handling. Additional dynamics and shipping will be experienced at the instrument level. While it would have been desirable to have every cavity device PIND tested for presence of particles, based on test results for the parts that were PIND tested, and based on proper subsystem function, the risk of proceeding with HIRDLS instrument level testing is thought to be very minimal. Aura Project considers this as a low risk to Mission Success and Lockheed should proceed with instrument level testing. (E-mail from Terry King (EOS Aura Parts Engineer) to Ed Bielecki (Aura Project Systems Engineer) dated Fri, 19 Apr 2002.)

2. The Power Subsystem (PSS) had two unverified failures that were not documented as such (in-rush current and current monitor failure). The standard approach to addressing unverified failures is to assess the likelihood of recurrence and the potential impact to the mission. This risk assessment has not been performed to our knowledge.

NASA EOS Aura Project Response: The risk assessment has been performed and presented to the Lockheed Martin quality team for discussion. For both of these unverified failures, the probability of recurrence is low and the potential impact to the mission is low. Mission impact is low because both anomalies affect only the PCU housekeeping/engineering telemetry and do not affect the instrument science telemetry. Aura Project considers this as a low risk to Mission Success and Lockheed should proceed with instrument level testing. (Memo from Edward Bielecki (GSFC) to Tim Crews dated February 21, 2002).

3. The requirements verification matrix for the PSS indicates a large number of requirements that have not been formally verified or documented as verified. Of principal concern is an analysis verifying the radiation hardness of the as-built PSS. Failure to address this issue will result in an eventual lien against launch when Lockheed Martin delivers the instrument to NASA.

<u>NASA EOS Aura Project Response</u>: The requirements verification matrix for the PSS has now been completed, as reviewed at Lockheed Martin on 14 March. Parts in the PCU are acceptable for use and a risk analysis was completed on parts of concern. The Aura Project considers this as a low risk to Mission Success and Lockheed should proceed with instrument level testing. (Memo from Art Ruitberg, Code 563 to Aura Project on March 6, 2002; HIRDLS Mission Success IRR presentation PM-HIR-371, March 13-14, 2002; Mission Success Review UVF Survey for part #2N2222A dated March 22,2002)

4. The Gyroscope Subsystem (GSS) exhibited a heater relay failure when tested in a cold condition. Although this discrepancy has the appearance of an unverified failure, it was dispositioned as "Use As-Is". We would like written concurrence from NASA that this is acceptable.

<u>NASA EOS Aura Project Response</u>: Aura Project is confident that the heater relays are fully operational over the required temperature range and at the expected/predicted cold survival temperature. Aura Project considers this as a low risk to Mission Success and Lockheed should proceed with instrument level testing. (Memo from Edward Bielecki (GSFC) to Tim Crews dated March 3, 2002).

5. The GSS has a test connector that will fly with the instrument. This connector requires a flight-quality cover prior to initiation of instrument-level testing. To date this cover has not been supplied.

<u>NASA EOS Aura Project Response</u>: On March 14, 2002, Aura Project Instrument Manager confirmed with LMSS Program Manager that LMSS has the connector. Aura Project considers this no longer a risk to schedule and Lockheed should proceed with instrument level testing.

6. The GSS had several exceedances during its EMI/EMC test at the subsystem level. A copy of the test report is requested to assist us with troubleshooting during EMI/EMC testing at the instrument level. Not having this knowledge is a potential schedule impact.

<u>NASA EOS Aura Project Response</u>: Aura Project provided the report on March 26, 2002 thus making it available for instrument level testing. Aura Project considers this no longer a risk to schedule and Lockheed should proceed with instrument level testing. (E-mail from Neil Martin (GSFC) to Timothy Crews (LMSS) dated Tue, 26 Mar 2002 16:52:14.)

The NASA EOS Aura Project appreciates the Lockheed Martin HIRDLS Team's effort to make Aura a Mission Success and look forward to working closely during instrument level testing.

Please do not hesitate to call. I can be reached on telephone (301) 286-2094 or facsimile (301) 286-0383. My e-mail address is Linda.Kelley@gsfc.nasa.gov.

Original Signed By

Linda S. Kelley

Contracting Officer

MISSION SUCCESS REVIEW
QUESTIONS FOR UNVERIFIED FAILURES

cc: 424/Jackson
424/McIntyre
424/Fontaine
214.3/File

LOCKHEED MARTIN

MISSION SUCCESS REVIEW
QUESTIONS FOR UNVERIFIED FAILURES

Program HIRDLS Spacecraft AURA Subsystem TSS BoxSMA-AzAxes

Document # ______________ **Mission Impact:** 2 – Mission Degradation **Likelihood** HIGH

Increased Azimuth Stiction After Thermal Cycle

Prepared by (REE) Marion Barker date 04 Feb 02

Concurrence:

Program Manager ______________________ date ________

Asst. Program Manager (Tech) ______________________ date ________

Mission Success Mgr ______________________ date ________

TSS CPE ______________________ date ________

1. What was the anomaly? Describe all significant events leading up to the occurrence. Describe the trouble shooting conducted and the results.

There were 3 anomalies documented in DR# AC2158. Item 1 is well understood and accommodation was made to correct it. Item 3 occurred only one time. Item 2 and 3 are related with the root cause not fully determined. **This unverified failure documentation is submitted to assess the risk associated with DR Items #2 and #3.**

(1) When the scan mirror assembly was less than 10C, the azimuth was not able to reach the specified sweep rates of 10 deg/s as shown in Figure 1 The root cause for this is increased viscosity with low temperature of the lubricant used for the azimuth axis bearings. The disposition was to attach operational heaters to maintain SMA temperatures at 10C or higher.

(2) When the scan mirror was stationary during a thermal cycle from colder to hotter temperatures, the first azimuth move required a higher torque than normal to break stiction. Successive moves required the nominal torque expected for the given temperature. An example is shown in Figure 2.

(3) In one case, the scan mirror azimuth axis did not break stiction with the application of the maximum available torque. Repeated application of the maximum torque did eventually free the axis and normal operation resumed. . As shown in Figure 3, each attempt resulted in a successively larger move than the preceding attempt. This was the only instance in which the azimuth did not achieve break-away motion with the first attempt.

Several days of tests at ambient plus two additional thermal cycles were performed in an attempt to replicate Item 3 with the azimuth spin axis horizontal. Configuration was then changed to have the azimuth axis vertical to more closely resemble the external forces on the mirror expected in space. Two more thermal cycles were performed with the axis vertical. The behavior was essentially unchanged in the vertical configuration as shown in Figure 4. Item 2 was repeatedly demonstrated. Item 3 did not recur.

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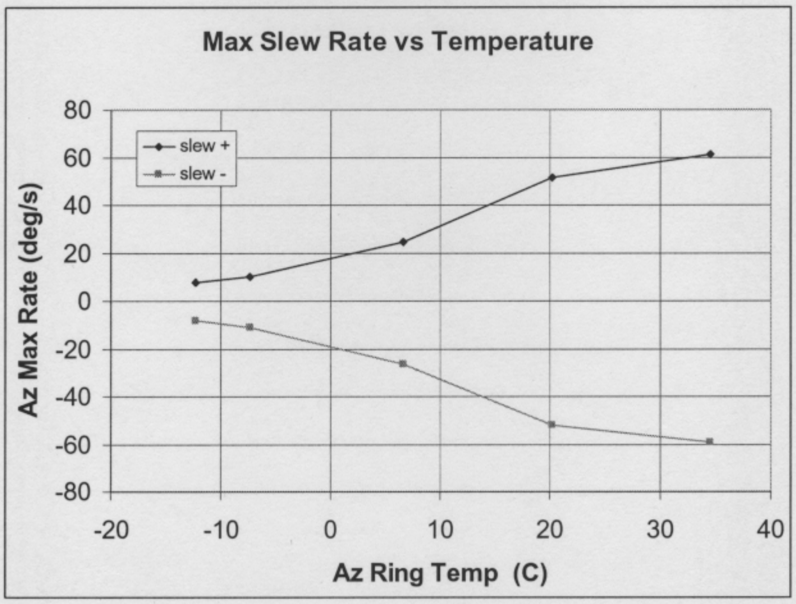

Figure 1 **Slew rate vs temp. Temp cycle –12 to +35 then back to ambient. The 20 C data was from the final ambient temperature.**

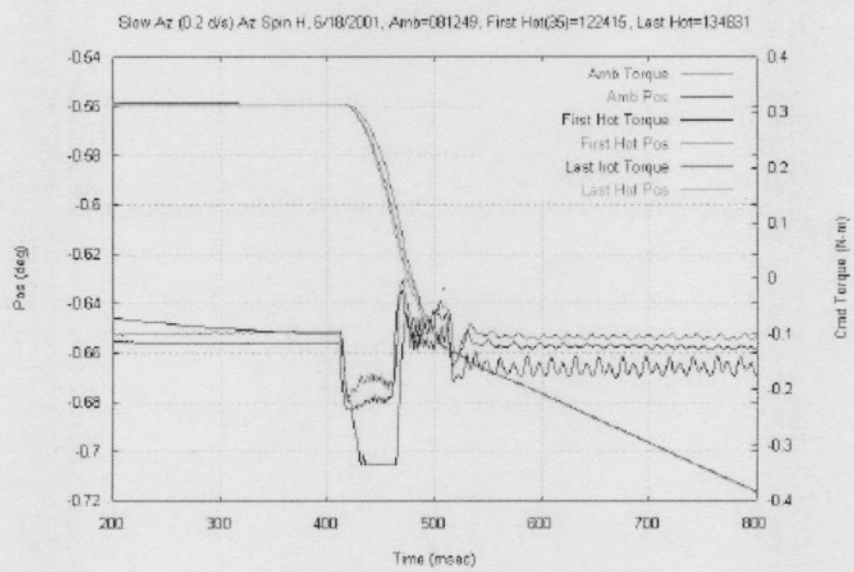

Figure 2 **Slow az (0.2 deg/s +/- 2 deg). Hot result is after staring at 0,0 while ramping from ambient to hot. This plot shows torque required for the initial move at hot compared to ambient and later hot move.**

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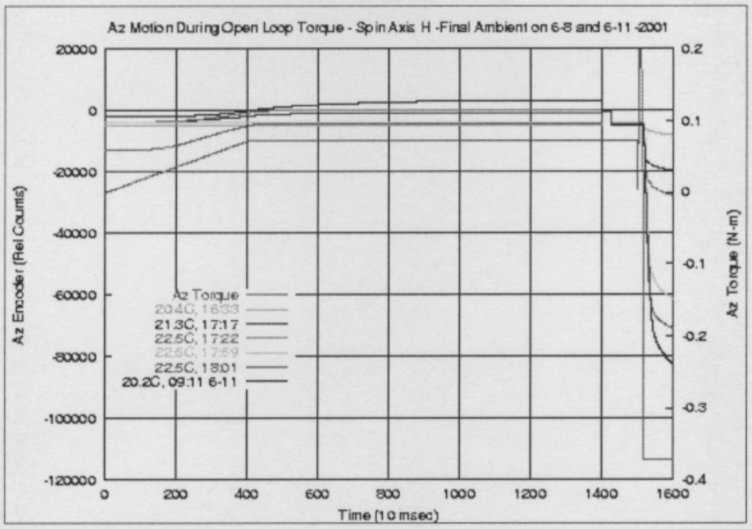

Figure 3 **Azimuth motion for encoder inits at third anomaly – final ambient. This time the mirror required multiple pulses (full torque for 100 sec, followed by torque from gravity only). Twelve attempts made on 6-8-01. Mirror finally moved on the second attempt on 6-11-01.**

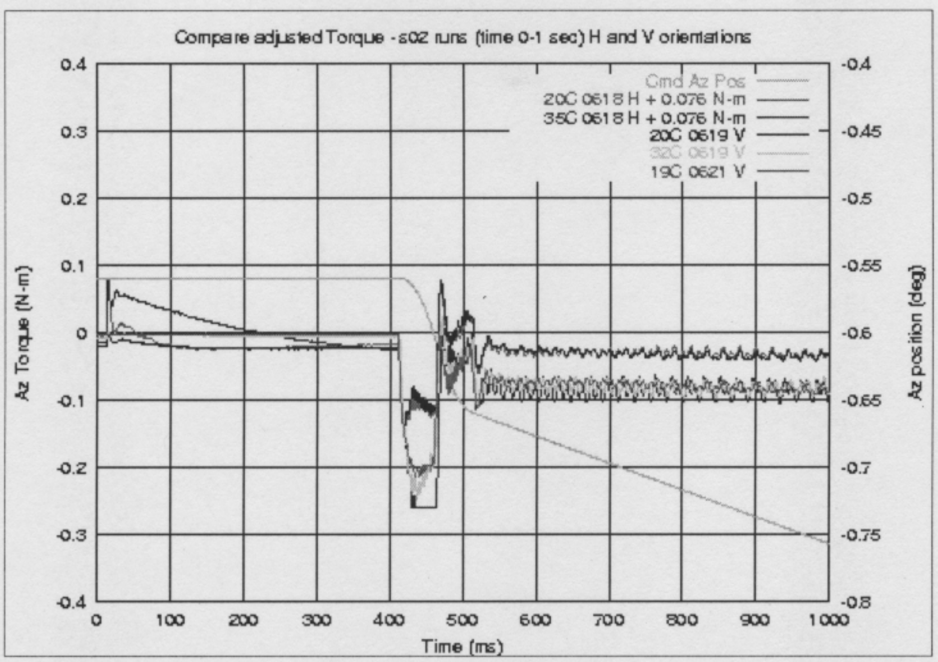

Figure 4 **Test A analysis comparing H and V results following lower temperature to warmer temperature cycle with an offset applied to H torque to compensate for gravity effect.**

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1a. What was the hardware configuration at the time of the test anomaly? (i.e. If at system test, were all flight items installed? Were some non-flight items installed? If at subsystem or box level, were all flight components installed?) Describe the level of any software in use at the time of the anomaly, if applicable (i.e. was flight code installed at the time of the anomaly?) Describe the Test Hardware/Software configuration at the time of the anomaly.

This anomaly was noted with the TSS sub-system configured in the B205 SEARCH chamber. This configuration was used for both the Elevation Encoder Calibration and the TEU thermal-vacuum testing as specified in Test Plans: TP-LOC-645, SMA Elevation Encoder Calibration Test Procedure, and TP-LOC-788, TEU Thermal Vacuum Test Procedure. The SMA was mounted with the azimuth axis horizontal. This applied a torque to the azimuth axis from gravity pulling the mirror to the positive hard stop. The initial motion following a thermal cycle would be to work against gravity and move the mirror towards the negative hard stop. The flight hardware utilized in this test included the TEU, EEA, WSEA, and SMA. The TEU software used was the special TEST version build4.41. The actual input current to the azimuth motor was monitored and matched that expected by the commanded torque. The GSE equipment was primarily associated with the elevation encoder calibration measurement. The GSE associated with scan mirror performance included the aluminum mount (as opposed to the beryllium and titanium mounting structure for flight) and the bench power supplies that substituted for the PCU. In addition, a spare chopper was attached to the TEU so the performance of the flight chopper control card in the TEU could be monitored at each temperature.

1b. What was the most likely cause of the anomaly? Is there a fishbone analysis, fault tree or similar analysis performed as part of the trouble shooting? Have all other suspect causes been eliminated?

The anomaly was likely caused by a combination of two factors – (1) limited amount of torque available from the azimuth motor - driver – power supply combination and (2) increased need for torque following a thermal cycle with the azimuth axis stationary. The amount of torque supplied by the azimuth motor at the maximum available current from the TEU is limited to 0.335 N-m. This is normally sufficient at temperatures above 10C, but during the azimuth axis horizontal testing, the amount of torque due to gravity that needed to be overcome was approximately 0.075 N-m. The root cause for the increased torque after a thermal cycle was never completely identified. This was documented in DR# AC2158, defect #2 and #3. The most likely sources identified by the FRB was (a) cage blocking of the azimuth bearing, (b) a viscosity effect of the Penzane lubricant or (c) housing distortions of the bearing housing arising from thermal expansion coefficient mis-match of the Aluminum (non-flight) mounting ring and the berylium housing. The flight housing is titanium.

2. What test was in process? Were multiple tests being performed simultaneously?

Both the Elevation Encoder Calibration and the TEU thermal-vacuum testing were performed simultaneously per TP-LOC-645, SMA Elevation Encoder Calibration Test Procedure, and TP-LOC-788, TEU Thermal Vacuum Test Procedure.

3. Did the anomaly repeat? Describe the troubleshooting performed while the anomaly was present.

The anomaly of slightly increased torque requirement following thermal cycle was repeatable, DR# AC2158, defect #2. The anomaly of multiple pulses of maximum torque to begin normal azimuth motion could not be duplicated, DR# AC2158, defect #3.

MISSION SUCCESS REVIEW
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4. When/If the anomaly cleared? What happened to cause the anomaly to clear? What efforts were made to get the anomaly to repeat? Were the Hardware/Software configurations identical to the original condition? If not, what were the differences, why were the differences necessary?

   The anomaly of the azimuth axis not moving normally was cleared by repeated application of azimuth torque. The thermal cycle was repeated for the SMA both with the azimuth axis horizontal, then again with the azimuth axis vertical, which removes the torque due to gravity from the azimuth portion of the mirror assembly. The slightly increased torque requirement, DR# AC2158, defect #2, following thermal cycle was again observed, but motion occurred normally. The repeated azimuth pulses required in defect #3 could not be duplicated.

5. List all accumulative anomaly free re-testing and "on-time". Is all test time documented?

   The SMA has been tested for over 100 hours following the anomaly in several different configurations. One week of testing included additional thermal cycles. All testing is recorded and telemetry has been stored which reports the torque required for commanded mirror motions. In no cases has this anomaly, defect #3, been repeated. The data is stored on the XGSE computer, the samit computer, the hirdls\TestData server and on CD.

6. Does the failure analysis of the problem clearly lead to assigning the anomaly to a specific element? Was that element replaced? If so, when the element was fixed, was the problem cleared?

   The anomaly was assigned to the SMA assembly, primarily the bearing and motor combination. The element was not replaced. The failure to move initially was cleared by repeated attempts, which then succeeded.

7. What would be required to perform a worst case repair? Was that performed? If not, describe the reason.

   The worst case repair would be to replace the azimuth motor with one that provides increased torque for a given current – or to replace the motor driver card and / or power supply so that the current motor would be provided with increased voltage. This latter option is being pursued by the program.

8. Did the anomaly cause any overstress (consequential impact)? Is the overstress analysis documented and accepted by the REE, Program Manager and Engineering?

   No overstress was caused by the anomaly. The electrical and mechanical design accommodates maximum current to all motors simultaneously with no negative effects on the hardware. A temperature delta across the assembly of 7degC or greater would be sufficient to cause balls and races to be compressed into each other, possibly initiating damage to the balls or races (brinnelling). However, the rate of temperature change during test was about 1.5 deg C per hour and it is believed that this is sufficiently slow to allow for thermal equilibration among the various elements of the SMA.

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9. If not addressed, what was the rationale for not addressing the overstress issue?

   N/A

10. Are there other relevant failures on other sibling items or other systems? If the failure is in a component/piece part, what is the failure history of that part? What is the Mission history of sibling units? How many have been built, delivered and what is their performance record?

    The same bearings are used on SBIRS. In that case, the motor was sized to provide significantly more torque. For the SBIRS case, the main reason to design the system with increased torque was to reach the required rate of response, which greatly exceeds that required for HIRDLS. SBIRS test experience confirms the increased azimuth torque with lower temperatures due to lubricant viscosity. The increased torque at higher temperature was not expected, but was not looked for in SBIRS.

11. If the anomaly was traced to a part, what were the results of the failure analysis/DPA? e.g., did DPA confirm the failure?

    N/A

12. Were any trouble shooting steps considered and not performed due to cost or schedule concerns? Could these trouble shooting steps determine the cause of the anomaly. Describe the risks in performing this trouble shooting now.

    Troubleshooting tests were performed for approximately 11 days following the completion of the Elevation Encoder Calibration and TEU Thermal-Vaccuum test. This included tests for "cage blocking", two thermal cycles with azimuth axis horizontal and two thermal cycles with azimuth axis vertical.

    Additional thermal cycles with the azimuth axis horizontal were considered, but not performed. The main reason for this was that the test configuration did not match the expected stresses on the azimuth in flight. An additional consideration was cost and schedule.

13. Are there operational work arounds possible to mitigate the effect of this anomaly? Could they be implemented within the Mission?

    Should the Item 3 anomaly recur in flight when the SMA has been sitting idle during a thermal cycle, several steps can be taken which are expected to clear the anomaly. First the azimuth would be pulsed with max azimuth torque – with same procedure used during DR# AC2158, defect #3. Should this fail to clear the anomaly, then the operational heaters could be used to run the azimuth bearing through a thermal cycle while pulsing the azimuth motor. It is expected that this would clear the anomaly.

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14. What is the worst case scenario of this anomaly recurring during the Mission? What is the consequence of this occurrence without intervention? If intervention is possible, describe the steps needed and the result to the Mission. Impact categories are: 1) Mission Loss, 2) Mission Degradation, 3) Loss of Redundancy, 4) Degraded Data or Payload Performance, 5) Reduced Data or Payload Performance, Partial Loss of Redundancy or Change to Mission Operation, 6)No Impact

    IF the worst-case repair / redesign is not performed, the expected Mission Impact (2) Mission Degradation because the scan mirror would not be able to perform its intended scanning function.

15. How likely is the occurrence of this anomaly during the Mission? (High/Medium/Low) Explain the rational used for the determination.

    If the worst case repair/redesign is not performed, the likelihood is considered HIGH because the mechanism has limited torque ratio now and by the end-of-life, it is a near certainty that the required torque to operate this mechanism will increase.

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Additional Mission Success Mgr Notes:

1. Influence of Thermal Expansion Mismatch The SMA includes bearing races made from 440C SS (cte 10.2 ppm/C), placed into beryllium housing (CTE 11.6), and clamped in place by titanium rings (CTE 8.6). The diametral clearance between the bearing races and the Be housing is 0.0006 inches. On cool down from +25C to –30C, SS/Be diametral difference is 0.00055 inches – nearly consuming all of available gap.
2. Influence of Temperature Gradient If at any time during test, the temperature difference between the inner and outer beryllium bearing housings is 7deg C or greater, the available 0.0006 inch clearance between races and housing will be consumed. Detailed thermal analysis to see if such a gradient is possible was not performed. Analysis of temperature instrumentation to see if such a gradient existed during test was not possible because not enough thermocouples were used in the right places to provide the data. This potential root cause is somewhat mitigated by slow temperature change during test (1.5 degC per hour) that probably allowed for temperature equilibration within the SMA.
3. Influence of Bearing Preload Bearings are preloaded with 100 lbf. The magnitude of this preload is certain to be affected by each of the factors cited above in (1) and (2). A higher pre-load will result in greater torque requirements. Analysis of preload variation for various test conditions would require a sophisticated analytical model, this was not pursued.
4. "Starting Friction" vs "Running Friction" Textbook treatments of bearings describe that the friction required to initiate motion in a roller bearing is 2X the friction needed to maintain steady state motion. This would translate into a torque requirement differing by a factor of 2 for "starting" vs "running". For the HIRDLS SMA, the starting torque is consistently 2X of the running torque, see for example Figure 2. Since the maximum torque available is ±0.335 N-m, the maximum running torque that can be accommodated is half of this value, or ±0.17 N-m. A review of the "running torque" data for various test cases is shown below in Figure 5. There are two points to make with respect to these data:
    - For the bearing to operate successfully, a running torque of less than ± 0.17 N-m is required. Inspection of the data show that this condition is achieved for all temperatures above 5 deg C. As part of the corrective action for Item #1 on this DR, operational heaters were installed to maintain the housing temperature at 10C or higher throughout the mission life.
    - If gravity effects are accounted for, both curves would shift upwards by a factor of 0.07 N-m. When this change is factored in, the SMA is seen to have sufficient torque to operate successfully at temperatures as low as –10C.

5. Subsequent HIRDLS Program Analysis: This mechanism has insufficient torque ratio to perform global scan, to achieve 30 deg/sec rate, and to initiate the scan motion. In each of the three cases, the torque ratio is 1.2 vs required value of 2.0. HIRDLS Program office at GSFC agrees, program is pursuing design modification.

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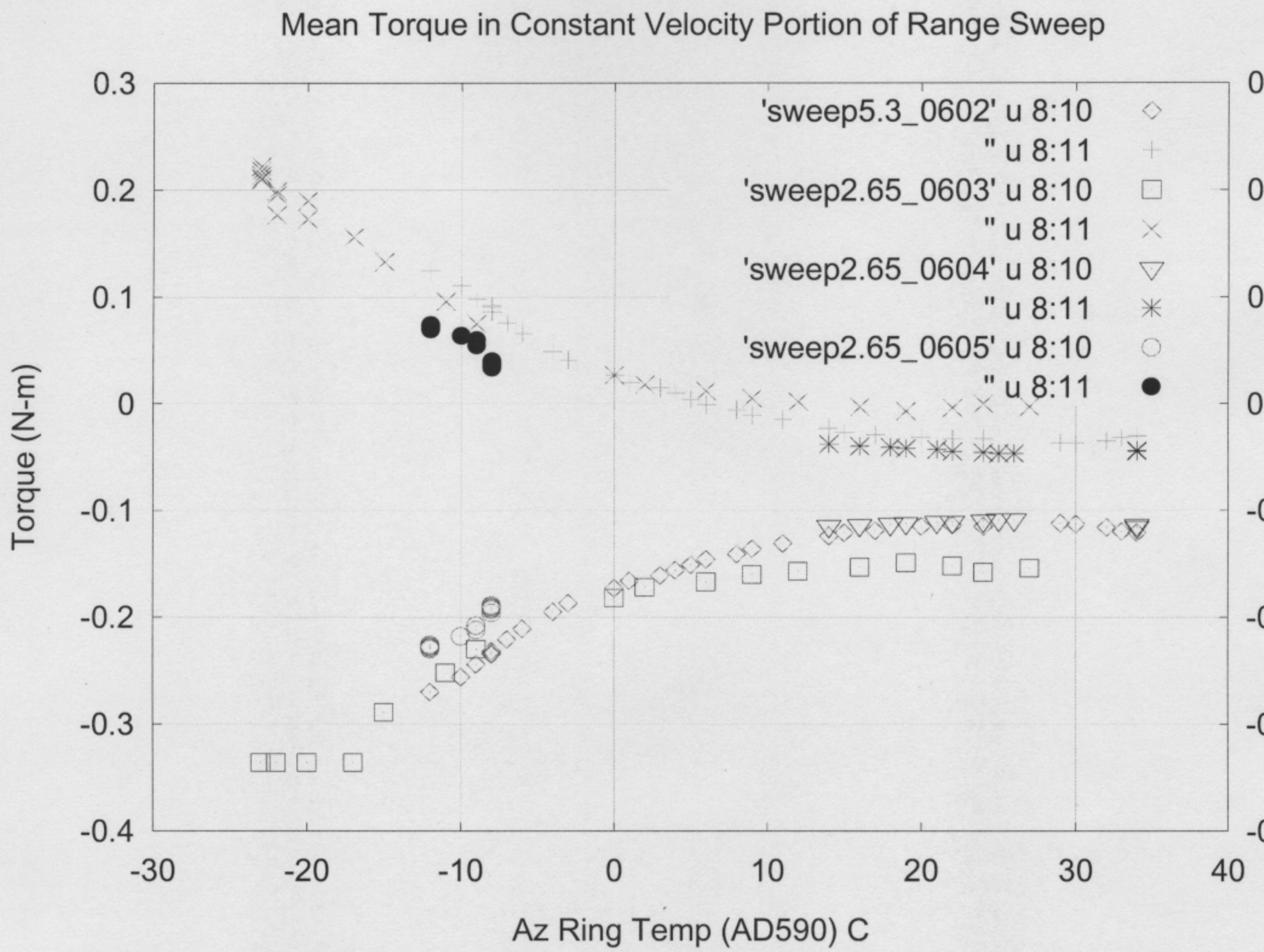

Figure 5 **Torque data from all range sweep data taken during temperature cycling. This is the torque required to maintain a constant velocity once a constant rate has been achieved. (The 0603 cold data starts out with the negative torque limit of –0.335 N-m)**

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Date	Temperature Cycle (SMA Az Ring)	Constant Velocity Rate Commanded	Processing Times for Torque Mean
0602	Hot to Cold (34C to –12C)	5.3 deg/sec	Neg Rate 10-12 sec Pos Rate 22-24 sec
0603	Cold to Hot (-23C to +27C)	2.65 deg/sec	Neg Rate 30-32 sec Pos Rate 52-54 sec
0604	Hot to Cold (34C to 14C)	2.65 deg/sec	Neg Rate 30-32 sec Pos Rate 52-54 sec
0605	Cold to Hot (-12 to -8C)	2.65 deg/sec	Neg Rate 30-32 sec Pos Rate 52-54 sec

LOCKHEED MARTIN

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QUESTIONS FOR UNVERIFIED FAILURES

LOCKHEED MARTIN

MEMO

3 JANUARY 2002

To: Peter Dean, HIRDLS TSS CPE

From: J. Wittenauer Manager, ATC Mission Success

Concurrence: Independent Review Team – Dennis St. Clair, Frank Morgan, Dave Putnam, Larry Naes, Stu Loewenthal

Subject: 21 December Independent Evaluation of HIRDLS Azimuth Bearing "Stiction" Anomaly

Summary

In response to a 10 December HIRDLS Return to Green Action Item, an independent Mission Success Review has been conducted for the HIRDLS Scan Mirror Assembly (SMA) Azimuth Bearing "Stiction" anomaly. To date, the root cause for this anomaly has not been determined and an Unverified Failure Risk Assessment is in-progress. The consensus opinion of the independent review team is as follows:

- The current design has insufficient torque margin to confidently predict successful mission performance. Risk of mission failure is high. Do not fly this design as-is.
- To facilitate a risk assessment, the analyses conducted to date to determine root cause should be more formally documented. Additional analyses to be performed with existing data were suggested.

Review Team / HIRDLS Team

The review was conducted on Friday 21 December from 8:30 to 11:00 am. Participants included the following:

Independent Reviewers	HIRDLS Team
Larry Naes (ATC Thermal Sciences)	Peter Dean (TSS CPE)
Dennis St. Clair (Gravity Probe B)	Marion Barker (TSS Test & S/W Engineering)
Dave Putnam (Solar Array Mechanisms)	Wayne Rudolf (HIRDLS Chief Instrument Engineer)
Stu Loewenthal (SBIRS Mechanisms)	
Frank Morgan (Product Ctr. Mission Success)	
J. Wittenauer (ATC Mission Success)	

Detailed Discussion

Discussion points included the following:

Nature of Anomaly Two torque problems were discussed. The first is a "stiction" torque anomaly that has only been observed with rising temperature at slow scan speeds (never with falling temperature). In one instance, the torque stalled the motor. At other times, which are frequent, the torque comes within 10% to 20% of stalling the motor. The second torque problem is that – under certain temperature conditions - the motor drive system has insufficient torque to meet the 30 deg/sec scan rate requirement.

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Torque Margin† The current *starting torque margin* is in the range of 0% to 20% based on beginning-of-life mechanical resistance in the mechanism. The *running torque margins* are generally acceptable except at the highest scan rates. It is standard design practice to allow for a factor of 2 increase in End-of-life bearing drag resistance. The consensus among the reviewers is that Lockheed Martin (nor other aerospace companies) does not fly mechanisms with torque margins less than 100%. (The NASA requirement is a torque margin of 125%, but Mil-Standard mechanism design allows for a worst case margin of 100%). The recommendation to the HIRDLS Program is that available torque must be increased by at least 100% - increases of 0% to 20% provide insufficient confidence for mission performance.

Data Mining Suggestions for further analysis of existing data included

a) Calculating the torque ratio for various conditions of scan speed, temperature, and test configuration. Ultimately, torque ratio is the key figure of merit in determining acceptability of this design, availability of data on torque ratio would facilitate discussions of design capability and design margin.

b) Analyze torque data to separate out effects of torque requirements arising from separate factors such as control system demands, gravity effect, and mechanism running friction.

Investigation Documentation A comprehensive report, tied to a fishbone analysis, would facilitate our ability to conduct a risk analysis and determine the potential mission impact of this anomaly. To date, a great deal of analyses and experimentation has been conducted in order to determine root cause of the anomaly. These investigations have not been well-documented.

On-Orbit Work-Around Two ideas were discussed that would help overcome this anomaly should it occur on orbit. These include the following:

a) Preliminary calculations predict that heaters on the (outer) SMA Stationary Housing will temporarily establish a favorable thermal gradient in the mechanism that will lower the bearing preload and lessen the required torque by as 10% to 20% of the total torque.

b) Incorporation of a "dithering" or "rocking" motion in the Az Bearing initiation control logic could help overcome the initial "stiction" event.

Additional Areas to Pursue: A Fishbone has been prepared by the HIRDLS team but was not reviewed at this meeting. Two areas (not previously considered) can be added to the fishbone based on this review:

a) Control Loop Command Rate A question was raised regarding the relationship between duration of a stiction event (50 msec) and the control loop command rate (30 msec). Can the control systems gains be amplifying the effects of this stiction event? The HIRDLS team will investigate this further.

b) Deformation of Teflon Bearing Spacers during thermal cycling could contribute to stiction event: added friction due to ball seating in deformed teflon spacer.

Specific Reviewer Recommendations

Dennis St. Clair:	Do not fly mechanism as-is. Find a way to apply more power to the motor.
Dave Putnam:	More torque is necessary. Possible on-orbit fix for starting "stiction" is to add dithering capability to control logic. More information can be extracted from existing test data to aid root cause investigation.
Stu Loewenthal:	Concurs that more torque is needed, 100% torque margin is desired minimum design goal. Advises that bearing torques do double in practice during the course of a mission.

† For design purposes, the capability of the drive mechanism can be expressed in two ways: *Torque Ratio* = (Available Torque ÷ Required Torque). *Torque Margin* = (Available Torque ÷ Required Torque) – 1, expressed as a percentage. A torque ratio of 2.0 is equivalent to a torque margin of 100%. In this memo, *torque margin* is used to describe the system capability.

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	Recommends formal documentation of efforts conducted to date to resolve the anomaly.
Larry Naes:	More root cause analysis/testing recommended to better understand relationship between "stiction" and thermal cycling.
Frank Morgan:	Recommends more formal fishbone analysis. Better understanding of End-of-life mechanism requirements should be established. Concurs that more torque is required.
J. Wittenauer:	Concurs that more torque is needed, investigation conducted to date should be more formally documented.

Next Steps

The recommendations of the independent reviewers will be presented to the HIRDLS Program Management Team. The HIRDLS Program will be formally requested to formulate a plan to address this mission success risk.

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Program HIRDLS Spacecraft EOS Subsystem: Instrument-Level

Document #DR AD7248 Impact Level "4 – Degraded Data" Likelihood LOW

Prepared by R. Von Savoye date 14 August 2002

Title: Excessive Noise on Temperature Sensors

Concurrence:

Program Manager	Eric Johnson	date
Hardware Engineering	Ray von Savoye	date
Product Assurance	Althea McField	date
Mission Success	J. Wittenauer	date

1. What was the anomaly? Describe all significant events leading up to the occurrence. Describe the trouble shooting conducted and the results.

Analysis of telemetry from temperature sensors used on the HIRDLS Instrument indicates excessive noise. Noise is observed on telemetry from both AD590 sensors as well as PRT sensors, nearly 90 sensors in total. This condition was first observed at the time when the first comprehensive performance test was performed on the instrument, prior to EMI testing, in May 2002. Since that time the noise condition is routinely observed, it is not intermittent, and it has not gotten worse with time. The noise was observed through all phases of the environmental test program. This noise appears to be an outcome of the HIRDLS design and not the result of a specific failure event.

1a. What was the hardware configuration at the time of the test anomaly? (i.e., If at system test, were all flight items installed? Were some non-flight items installed? If at subsystem or box level, were all flight components installed?) Describe the level of any software in use at the time of the anomaly, if applicable (i.e. was flight code installed at the time of the anomaly?) Describe the Test Hardware/Software configuration at the time of the anomaly.

The instrument is in its final flight configuration. The noise was observed at both hot and cold temperature extremes and at high power and low power comprehensive performance testing.

1b. What was the most likely cause of the anomaly? Is there a fishbone analysis, fault tree or similar analysis performed as part of the trouble shooting? Have all other suspect causes been eliminated?

The noise is related to two causes – lack of shielding on the temperature sensor lead wires coupled with a source of electronic noise within the HIRDLS Instrument that has not been isolated.

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2. What test was in process? Were multiple tests being performed simultaneously?
This noise condition is observed every time that the comprehensive performance test is run, regardless of environmental condition.

3. Did the anomaly repeat? Describe the troubleshooting performed while the anomaly was present.
The anomaly repeats, this is viewed as a feature of the current design and not as an intermittent failure. Troubleshooting included the following:
- Multiple tests to isolate noise sources and timing relationships by adjusting S/W controllable timing parameters and turning power on and off to various components.
- Examined S/W modifications for data averaging algorithms, peak removal, and modifications to heater PWM frequency.
- Troubleshooting eliminated S/W as a root cause for this observed noise.
- Possible root cause was identified: synchronous noise associated with the chopper frequency. This was seen by randomly changing the timing for data collection (relative to chopper frequency) while continuing to run the instrument in synch with the chopper.

4. When/If the anomaly cleared? What happened to cause the anomaly to clear? What efforts were made to get the anomaly to repeat? Were the Hardware/Software configurations identical to the original condition? If not, what were the differences, why were the differences necessary?
The anomaly has never cleared. It has been demonstrated that a software algorithm can smooth the data to minimize or eliminate the noise. This software algorithm has not been incorporated into the flight software.

5. List all accumulative anomaly free re-testing and "on-time". Is all test time documented?
All test time is documented. CPT data from each time that the CPT is executed is available. Review of these data from past tests indicates to us that the noise condition is stable.

6. Does the failure analysis of the problem clearly lead to assigning the anomaly to a specific element? Was that element replaced? If so, when the element was fixed, was the problem cleared?
Failure analysis to date assigns the problem to a combination of unshielded lead wires (known) and a noise source within the instrument (unknown).

7. What would be required to perform a worst case repair? Was that performed? If not, describe the reason.

Two things: 1) install new sensors throughout the instrument (there are approximately 90) and insure proper shielding of lead wires, and 2) isolate and eliminate the source of internal electrical excitation that is causing the noise.

8. Did the anomaly cause any overstress (consequential impact)? Is the overstress analysis documented and accepted by the REE, Program Manager and Engineering?
No overstress has occurred. Overstress could occur if heater control authority is lost. The noise did not rise to a level that would cause this to occur.

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9. If not addressed, what was the rationale for not addressing the overstress issue?

N/A, see above

10. Are there other relevant failures on other sibling items or other systems? If the failure is in a component/piece part, what is the failure history of that part? What is the Mission history of sibling units? How many have been built, delivered and what is their performance record?

At about the time that the noise was first observed, an Supplier Bulletin was issued that describes the noise susceptibility for AD590 temperature sensors. The bulletin was issued by Analog Devices as Application Note AN-273. Also, as part of the troubleshooting investigation, we learned (through Jim Lukash, MSO Specialty Engineering) that this problem has been encountered before on LMSSC-AO flight hardware programs.

11. If the anomaly was traced to a part, what were the results of the failure analysis/DPA? E.g., did DPA confirm the failure?

No DPA was performed. All AD590 and PRT's are affected. This is not a lot-specific or vendor-specific parts failure.

12. Were any trouble shooting steps considered and not performed due to cost or schedule concerns? Could these trouble shooting steps determine the cause of the anomaly? Describe the risks in performing this trouble shooting now.

A software algorithm has been developed that effectively smooths the temperature sensor telemetry. This modification to the flight software has not been implemented, however. It is anticipated that this change to the flight S/W will be implemented at a future date, together with other modifications identified by the S/W team.

13. Are there operational work arounds possible to mitigate the effect of this anomaly? Could they be implemented within the Mission?

The current level of noise will not require work-arounds. There is a concern that the noise could worsen to the point that a work-around would be required. Four work-arounds have been identified that could be effective either singly or in combination:

1) Accurate temperature data is needed to improve quality of science data. To achieve this goal, an averaging algorithm can be applied to the telemetry data as part of the ground-based data analysis task.
2) The flight S/W can be modified to incorporate an averaging algorithm to smooth the data prior to its use in the heater control loop.
3) The SAIL code has the capability to average the data prior to its use in the heater control loop.
4) Heaters could be run "open loop" rather than in PID mode (e.g., duty cycle could be set at xx%).