HESSI

High Energy Spectroscopic Imager (HESSI) Instrument Failure Mode Effects and Criticality Analysis (FMECA)

HSI_SYS_023B.doc

Version B – 2000-October-05

Dave Curtis, U.C.Berkeley HESSI System Engineer

Peter Harvey, U.C.Berkeley HESSI Project Manager

Document Revision Record

Rev.	Date	Description of Change	Approved By
A	1998-Nov-13	Preliminary Draft	-
B	2000-Oct-5	Update severity of some failures based on ability to recover in data analysis and the addition of the PMT-RAS	

Distribution List

Peter Harvey, Project Manager, U.C.Berkeley
Dave Curtis, System Engineer, U.C.Berkeley
Dave Pankow, Mechanical Lead, U.C.Berkeley
Tim Quinn, Mission Operations Lead, U.C.Berkeley

Table of Contents

1. Introduction

This document describes the credible in-flight failure modes for the HESSI Instrument at the subsystem and component level. For each failure mode, the effects on the system are analyzed (including redundancy and work-arounds), and the criticality of the failure is rated against the Mission Requirements. Failures are analyzed assuming single-point failures; the effects of multiple failures are not analyzed. Failures during ground operations have not been assessed.

Failure mode effects have been categorized as follows:

- Level 1: End of Mission (no science data returned)
- Level 2: Loss of Minimum Science Requirement
- Level 3: Loss of science goal, but still meet minimum science requirements
- Level 4: Recoverable (no loss of science)

Note: in assigning failure effect categories, where on-orbit mitigation options exist which have a high likelihood of working, they are assumed to work.

HESSI is a simple single-string spacecraft, so there are many Critical and Severe failure modes. This document shall be used as a starting point for risk mitigation planning; to determine what can be done to reduce the risk of those failures (extended testing, minor design changes, etc.), and to prepare contingency plans for ground operations for those failures that have ground-commanded work-arounds (particularly those that require early action). Note that most possible design optimizations to reduce risk have already been made before this document was started.

2. Failure Modes

Summary

Failure Level	Number of Failure Mechanisims
1	19
2	4
3	36
4	47
Total:	**107**

1. Spectrometer

1.1. Cryocooler

Any failure of the cryocooler which results in its inability to get the cold plate to <85°K will violate Mission Requirement INS-1.1, effecting the mission life due to radiation damage in the detectors and worsening the detector energy resolution. The radiation damage can be mitigated by detector annealing. Inability to keep the cold plate below 130°K will end the mission as the detectors will no longer be operable. The cryocooler is a limited life item (gas contamination issues).

MITIGATIONS:

- Detector anneal capability to allow operation with poor cryocooler performance (correct radiation damage)
- Extensive cryocooler qualification
- Thermal design margins.
- Limit operation time of cryocooler on the ground after last gas recharge.
- Operation of cryocooler in optimal power range for reliability
- On-orbit trending of cooler performance to optimize operational strategy as the cooler ages.

1.1.1. Cryocooler Failure

>> Level 1.

1.1.2. Loss of performance

1.1.2.1. Cannot keep detectors below 85°K

Reduced Mission life, possible impact on science (detector energy resolution) – see section 1.1.

>> Level 3

1.1.2.2. Cannot keep detectors below 130°K

>> Level 1

1.1.3. Cooler heater

The cryocooler heater is a replacement heater, only needed when the cooler is off or at a low power mode. This is only expected to occur at the start of the mission (first few hours), and the cooling rate of the cryostat is sufficiently large to keep the cryocooler warm for on the order of a day.

MITIGATIONS:

- Should the cooler heater fail, the Mission Operations team should get the cooler operating as soon as possible.
- Cooler heater is on a spacecraft power service that is current limited, so a short circuit in the heater should not cause other failures. The Mission Team should identify an over-current trip on this service and have a diagnostic procedure in place to determine which load has failed.

>> Level 4

1.1.3.1. Short

Loss of heater. Remainder of systems protected by a current limiter (circuit-breaker).

>> Level 4

1.1.4. Radiator temperature sensor

The cryocooler heater is remotely controller (by the IDPU) based on a temperature measurement made by the Radiator Temperature Sensor. In addition, the cryocooler operation is controlled to second order by the cryocooler temperature. Loss of the temperature measurement will make it hard to control the cryocooler heater (see 1.1.3), and make it hard to control the cryocooler optimally.

MITIGATIONS:

- Redundant radiator temperature sensors.
- Indirect control can be used based on modeling and other temperature sensors on the spacecraft (requires Mission Operations team intervention).

>> Level 4

1.1.5. Harness Failure

A failure of the primary load carrying part of the cryocooler harness is identical to a cryocooler failure (1.1.1), ending the mission. A failure of the balancer service would cause spacecraft vibrations which might degrade science by moving the spacecraft imaging axis or microphonic pick-up in the detectors.

MITIGATIONS:

- Redundancy in the primary load-carrying harness wires and connector pins.
- Solar Aspect System can be operated at a high rate to model vibrations (some loss of science due to increased SAS telemetry impact on primary science downlink capability).
- Detectors designed to provide maximum immunity to microphonics.

1.1.5.1. Short

End of mission (loss of cooler). May be able to survive a short in the balancer service if the short causes the drive FET to fail open (must operate without a balancer, degraded science)

>> Level 1

1.1.5.2. Open

Degraded science, may still meet minimum science objectives.

>> Level 3

1.2. Cryostat

1.2.1. Vacuum failure

A failure during launch could contaminate the detectors and/or provide sufficient gas in the cryostat to make it hard to cool down. On-orbit a vacuum failure has no effect. Detector contamination could reduce the detector life or, in a severe case, render them useless (end of mission). Inability to cool the detectors is also critical (see 1.1).

MITIGATIONS:

- Vibration testing of the cryostat at subsystem and mission levels in the launch configuration to verify the design
- A vacuum valve has been added to the cryostat to allow the spectrometer to vent to space. The valve will be opened by ground command if the detectors are found to be contaminated, if there is too much gas in the cryostat to allow the cooler to reach temperature, or if the detectors need to be annealed due to radiation damage. This contingency should solve any problem caused by a vacuum failure during launch.

>> Level 4

1.2.2. Coldplate Heater

The cold plate heater is required to perform a controlled cryostat warmup such that out-gassing products from the thermal blankets do not contaminate the detectors (on the ground). It is also used to anneal the detectors in case of detector contamination or excessive radiation damage (this is a contingency operation). Warm-ups are only performed on the ground, and anneal mode is a contingency mode operation (not expected to be required)

MITIGATIONS:

- Heater Redundancy. There are three separately conditioned cold plate heaters. They do have a common power supply (see section 3.1.1.1.5).
- Cryosorb material in the cryostat will help protect the detectors from contamination in the absence of the heaters.

1.2.2.1. Open

Heater redundancy will overcome this problem.

>> Level 4

1.2.2.2. Short

Separate heater conditioning circuitry should allow the remaining heaters to continue to operate even if one is shorted.

>> Level 4

1.2.3. Loss of temperature sensor

Temperature sensors in the cryostat are used to monitor the cryostat cool-down and operation. Knowledge of temperatures in the cryostat is required for correct operation of the cryocooler and to correct the detector energy spectrum.

MITIGATIONS:

- Temperature sensor redundancy.

- Loss of temperature information in the cryostat could be worked around with thermal modeling and pre-launch data to some extent.

>> Level 4

1.2.4. Loss of cryosorb

The cryosorb material in the cryostat absorbs contaminants to keep them away from the detectors. Detector contamination issues are described in 1.2.1 and 1.2.2.

MITIGATIONS:

- A contingency system (vacuum valve and cold plate heaters) allows the detectors to be annealed, which should drive off any contaminants.

>> Level 4

1.2.5. Loss of S-link

The S-link connects the cryocooler to the cold plate (via the Sapphire link). The S-link provides a physically flexible thermal path, keeping launch loads off the cryocooler cold-tip and cryocooler operational vibration off the detector (microphonics). Failure of the S-link (loss of thermal connection between the cryocooler and coldplate) will keep the detectors from getting cold, which ends the mission.

MITIGATIONS:

- Vibration testing at subsystem and mission levels to prove the resiliency of the S-link. Operational tests to prove the thermal and vibration-damping characteristics before and after vibration.

>> Level 1

1.2.6. Loss of Sapphire link

The Sapphire link connects the cryocooler (via the S-link) to the coldplate. The sapphire link provides a thermal switch, having good conductivity at low temperature and poorer conductivity at higher temperatures. This is important is controlling the cool-down of the detectors such that they do not get contaminated. Failure of the sapphire-link (loss of thermal connection between the cryocooler and coldplate) will keep the detectors from getting cold, which ends the mission.

MITIGATIONS:

- Vibration testing at subsystem and mission levels to prove the resiliency of the S-link. Operational tests to prove the thermal and vibration-damping characteristics before and after vibration.

>> Level 1

1.2.7. Loss of intermediate stage attachment of cooler to thermal shield

This attachment allows the thermal shield and thermal blankets to get cold while the detectors are kept warm by the coldplate heater. This is important for the cryostat cool-down cycle at the start of the mission to keep the detectors from being contaminated. Detector contamination and mitigations (anneal cycle) are described in 1.2.4. You might also impact

thermal performance, which in the worst case could be a Level 1 problem (see 1.2.8)
>> Level 1

1.2.8. Thermal blanket or thermal shield failure

The thermal shield and thermal blankets are important to the ability of the cryostat to keep the detectors cold.

1.2.8.1. Cannot keep detectors below 85°K

Reduced Mission life, possible impact on science (detector energy resolution) – see section 1.1.
>> Level 3

1.2.8.2. Cannot keep detectors below 130°K

>> Level 1

1.2.9. Cold plate strap failure

The cold plate straps suspend the coldplate in the cryostat with minimum thermal conduction, while maintaining adequate support for launch loads. Loss of a strap during launch could cause physical damage to the detectors, ending the mission. Loss of a strap at any time could effect the thermal performance of the cryostat. Thermal performance issues and mitigations are described in section 1.1.

<u>MITIGATIONS (mechanical failures):</u>

- Adequate design margins
- Finite Element modeling and mechanical stress testing of the strap assemblies.
- Cryostat vibration testing at subsystem and mission levels to prove the reliability of the strap assembly. Operational tests to prove the thermal characteristics before and after vibration.

>> Level 1

1.2.10. Liquid Nitrogen system

This is a ground support system only. The only credible failure mode during launch and orbit is a vacuum leak, which is covered in section 1.2.1.
>> Level 4

1.2.11. Accelerometer

The accelerometer is used to measure the cryocooler vibrations and their transmission to the cryostat on-orbit. This is a diagnostic measurement. The system will meet all requirements without the accelerometer.
>> Level 4

1.3. Vacuum Valve

The vacuum valve is part of a contingency system to allow the detectors to be annealed in the event of detector contamination or radiation damage, or cryostat over-pressure. It should not be required for nominal operations.

1.3.1. Cannot open

If the valve cannot be opened, the detectors cannot be annealed. Annealing is a contingency operation.

MITIGATIONS:

- The valve actuator is redundant.

>> Level 4

1.3.2. Premature opening

This is equivalent to a loss of vacuum (1.2.1)

>> Level 4

1.3.3. Harness

Failure of the harness is the same as 1.3.1 (cannot open), and is mitigated by the redundant actuator (which has its own harness and switch).

>> Level 4

1.3.3.1. Short

The actuator service should be protected from a short in the actuator harness by spacecraft bus current limiters on the instrument switched service supply. The failure should not effect any other systems.

>> Level 4

1.4. GeD

There are 9 Germanium detectors, which are the primary science data collectors. Minimum science can still be achieved if one of the detectors is lost.

1.4.1. Noisy detector

A noisy detector must be 'fixed' or it will swamp the telemetry system.

MITIGATIONS:

- A noisy detector can sometimes be fixed by raising a programmable threshold for that detector. The threshold can be raised as high as 20keV (from about 3keV) on all detectors and still meet minimum science requirements.
- If the noise is due to contamination it might be mitigated by an anneal cycle.
- If the noise cannot be reduced to acceptable levels, telemetry from the noisy detector can be disabled (the remaining detectors will be unaffected).

>> Level 3

1.4.2. Detector Contamination

Detector contamination will result in a poorly performing detector.

MITIGATIONS:

- An anneal cycle should improve a contaminated detector's performance.

>> Level 4

1.4.3. Excessive radiation damage

Radiation damage will result in a poorly performing detector.

MITIGATIONS:

- An anneal cycle should improve a radiation damaged detector's performance.

>> Level 4

1.4.4. Dead detector

If the detector cannot be revived (perhaps by an anneal cycle). Minimum science requirements will still be met.

>> Level 3

1.4.5. HV contact failure

This will result is loss of data from the affected detector. Minimum science requirements will still be met.

>> Level 3

1.4.6. Signal contact failure

This will result is the loss of data from the affected segment of the affected detector. Minimum science requirements will still be met.

>> Level 3

1.4.7. FET failure

This will result is the loss of data from the affected segment of the affected detector. Minimum science requirements will still be met.

>> Level 3

1.4.8. Internal harness / feed-thru

Loss of one segment or a whole detector. Minimum science requirements will still be met.

>> Level 3

1.4.8.1. Short

The power supply is protected such that a failure in the internal harness cannot affect more than one detector.

>> Level 3

1.4.9. Internal HV harness

Each detector has an individual high voltage supply.

1.4.9.1. Open

Loss of the affected detector. Minimum science requirements will still be met.
>> Level 3

1.4.9.2. Short

Loss of the affected detector. No affect on other detectors. Minimum science requirements will still be met.
>> Level 3

1.4.9.3. Arc

A high voltage arc could cause damage to the detector, FET or CSA depending on the current path of the arc. Continuous arcing will also be a noise problem, which can be eliminated by turning off the offending high voltage supply. Unlikely to affect more than one detector and minimum science can be met with the loss of a detector.
>> Level 3

1.5. CSA

Each detector segment has a separate Charge Sensitive Amplifier (CSA). These CSAs are mounted on the outside of the spectrometer, with the two CSAs for each detector mounted in a common box.

1.5.1. Dead CSA

Loss of detector segment. Minimum science requirements will still be met.
>> Level 3

1.5.2. Noisy CSA

A noisy CSA must be 'fixed' or it will swamp the telemetry system.
<u>MITIGATIONS:</u>

- A noisy CSA can sometimes be fixed by raising a programmable threshold for that detector. The threshold can be raised as high as 20keV (from about 3keV) on all detectors and still meet minimum science requirements.
- If the noise cannot be reduced to acceptable levels, telemetry from the noisy detector can be disabled (the remaining detectors will be unaffected).

>> Level 3

1.5.3. Harness

A short or open in a CSA harness can only effect the CSAs for one detector (power to the affected CSA can be individually switched off). Minimum science requirements will still be met.
>> Level 3

1.6. HV Filter

Each detector has an individual high voltage supply, which is filtered by individual filters mounted to the outside of the Spectrometer.

1.6.1. HV noisy

Should the filter fail in such a way that noise was getting into the spectrometer via the high voltage supply, the associated detector would get noisy. If the noise level was sufficiently high, multiple detectors might be effected.

MITIGATIONS:

- A noisy detector can sometimes be fixed by raising a programmable threshold for that detector. The threshold can be raised as high as 20keV (from about 3keV) on all detectors and still meet minimum science requirements.
- If the noise cannot be reduced to acceptable levels, telemetry from the noisy detector can be disabled (the remaining detectors will be unaffected).

>> Level 3

1.6.2. HV Harness:

External high voltage harness failures are identical to internal failures. (1.4.9)

>> Level 3

1.7. Service Filter

The service filter contains EMC filters on cold plate heater and temperature sensor circuits going into the cryostat to keep noise out. It also contains conditioning circuits for the temperature sensor and accelerometer (see 1.2.11). The service filter is mounted on the outside of the cryostat.

1.7.1. Services noisy

Should the filter fail in such a way that noise was getting into the spectrometer via the heaters or temperature sensors, one or more detectors might get noisy.

MITIGATIONS:

- A noisy detector can sometimes be fixed by raising a programmable threshold for that detector. The threshold can be raised as high as 20keV (from about 3keV) on all detectors and still meet minimum science requirements.
- If the noise cannot be reduced to acceptable levels, telemetry from the noisy detector(s) can be disabled (the remaining detectors will be unaffected).

>> Level 3

1.7.2. Coldplate Heater

The coldplate heater is described in section 1.2.2. It is a redundant system.
>> Level 4

1.7.3. Temperature sensor conditioning

Temperature sensors are described in section 1.2.3. Critical temperature sensors are redundant.
>> Level 4

1.7.4. Harness:

Most of the harness carries redundant signals. The only problem is the power service to the temperature sensor conditioning circuit. Loss of this service would cause the loss of all internal cryostat temperature information.

MITIGATIONS:

- Indirect control can be used based on modeling and other temperature sensors on the spacecraft (requires Mission Operations team intervention).

>> Level 4

1.7.4.1. Short

A short in the power bus to the service filter could short the power for critical electronics in the IDPU. For this reason the service is resistively current limited.
>> Level 4

1.8. Shutters / Attenuators

The shutter attenuators are not required to meet minimum science requirements.

1.8.1. Failure to uncage

The shutters will remain in their default location.
>> Level 3

1.8.2. Stuck at a stop

MITIGATIONS:

- An emergency un-stick actuator can be used to put the shutter back into the default location. This might unstick the actuator, putting it back into service, it might lock the shutter into the default location, or it might do nothing. Even if it does nothing, minimum science requirements can be met with the attenuators at any stop.

>> Level 3

1.8.3. Stuck between stops

MITIGATIONS:

- An emergency un-stick actuator can be used to put the shutter back into the default location. This might unstick the actuator, putting it back into service, it might lock the shutter into the default location, or it might do nothing. If it does nothing and the shutter remains stuck half way in, significant analysis will have to be done on the ground to understand the detector response, but minimum science requirements should still be met.

>> Level 3

1.8.4. Position Sensors

The position sensors tell the IDPU how to run the actuators and tell the ground data processing where the shutters are. Failure of one sensor can be worked around, with some ambiguity of exactly when the shutter reaches its stop, causing some undesirable loss of science data.

>> Level 3

1.8.5. Harness

Failure of the harness is equivalent to failure of an actuator or sensor.

>> Level 3

1.8.5.1. Short

Protection circuits should limit the failure to a single actuator.

>> Level 3

2. Imager / RAS

2.1. Alignment

2.1.1. Grid tray twist

Grid tray twist will reduce the x-ray modulation, resulting in a loss of image contrast at the finest resolution. Grid tray twist can be measured on-orbit using the SAS. The failure classification depends on the amount of twist, as called out in Mission Requirement 2.5.

2.1.1.1. Grid Tray Twist of < 1.7 arc minutes

Acceptable modulation

>> Level 4

2.1.1.2. Grid Tray Twist of < 3 arc minutes

Loss of modulation at finest resolution, but sill meet minimum science requirements

>> Level 3

2.1.1.3. Grid Tray Twist of > 3 arc minutes

Loss of minimum science resolution, but mission continues with impaired resolution plus spectroscopy

>> Level 2

2.1.2. Grid twist

An individual grid twisting is less serious than the whole tray twisting since only one resolution element is effected, and minimum science can be achieved with the loss of any one grid-pair. Also, the tolerance to twist is only tight on the finest grid.

>> Level 3

2.1.3. SAS/RAS co-alignment

Loss of SAS-RAS co-alignment knowledge will affect the ability to place images on the sun.

MITIGATIONS:

- The SAS to RAS co-alignment can be determined in-flight using visible sun-spot features

>> Level 4

2.1.4. Imager Alignment to Bus (Spin axis)

If the imager axis is not aligned with the spacecraft spin axis, the imager axis will not meet its alignment requirement (0.2 degrees of the sun).

MITIGATIONS:

- The Bus includes Inertia Adjustment Mechanisms that can be used on-orbit to adjust the imager axis with the spin axis.

>> Level 4

2.1.5. Alignment to Spectrometer

If the Imager-to-Spectrometer alignment is not maintained (to 1mm), the grids will not be aligned with the sensitive area on the detector, and sensitive area will be lost. Given the size of the tolerance, a significant loss in sensitivity is unlikely.

>> Level 3

2.2. Grid Tray heaters

The grid tray heaters are required to maintain the grid trays at the same temperature (to 3C). Failure could cause the grid pitches on the trays to be different due to thermal expansion, decreasing the modulation efficiency of the finest grids. Even without the heaters, the temperature difference would not be large, and only the most sensitive grids would be affected.

MITIGATIONS:

- Redundant heaters, harness, and switches. Redundant temperature sensors.

>> Level 4

2.2.1. Short

MITIGATIONS:

- The circuit is protected by current limiters in the spacecraft, and the harnessing and switches are redundant.

>> Level 4

2.3. Grid Tray Thermistor

There are 4 thermistors on each grid tray. The grid tray thermistors are required for controlling the grid tray heaters, and also as a diagnostic to measure the variation in temperature. Loss of tall temperature information on the trays would delete the possibility of controlling the grid tray heaters. Loss of a single thermistor will reduce some diagnostic capability, but should not impact science.

MITIGATIONS:

- Redundant thermistors (4)

>> Level 4

2.4. Thermal Performance (blanket)

The tube and grid trays are blanketed to help keep the tube and grid trays isothermal. This prevents distortions due to uneven heating, and reduces the power budget for the grid tray heaters. Loss of performance in the blanketing could cause the tube to twist (unlikely since the tube points at the sun), or the grid tray heater capability could be exceeded. Either could reduce modulation efficiency in the finest grids.

MITIGATIONS:

- Excess heating capacity in the grid tray heaters (using redundant heaters)
- Test of the tube twist in non-isothermal conditions shows no significant twist.

>> Level 4

2.5. Antenna Mount

Failure of the antenna mount would cause the forward antenna to point in an indeterminate location, or in worst case might short the forward antenna.

MITIGATIONS:

- In the worst case, the rear antenna is still available and electrically isolated by the switch. There would be a loss of data downlink capacity, which could be mitigated by extra ground contacts.

>> Level 4

2.6. FSS Mount

The Fine Sun Sensor is used to point the spacecraft at the Sun. Loss of the FSS mount could make the FSS pointing indeterminate, or in the worst case could disable the FSS.

MITIGATIONS:

- The SAS can be used by the ACS to point the spacecraft at the Sun.

>> Level 4

2.7. SAS

The SAS is used to determine the position of the Sun in the imager FOV. Failure of the SAS would make it difficult or impossible for the ground software to reconstruct images. There are 3 SAS detectors, any two of are sufficient for the imaging task. The third SAS provides a twist diagnostic (not a science requirement).

MITIGATIONS:

- The SAS sensors are redundant.

>> Level 4

2.7.1. Harness Short

MITIGATIONS:

- The SAS sensors are redundant, with separate wiring and power limiter / switches.

>> Level 4

2.8. RAS

The RAS provides the roll-aspect data needed to position the image on the sun, as well as the accurate roll-rate data needed to generate images.

MITIGATIONS:

- RAS-PMT should make the same measurement
- The SAS sensors can be used to get roll rate data (provided nutation effects are small and the spin axis is not exactly aligned with the imager axis).
- The SAS can also be used to get absolute roll angle data by looking for optical solar flares and matching with known flare locations using ground observatories. This requires special full-detector readouts from the SAS (this capability exists, but takes more telemetry).
- The magnetometer can be used (with low resolution) to get roll rate and absolute roll information using filed models. This is probably not adequate for imaging, but can serve as a starting point for the SAS data analysis.

>> Level 4

2.8.1. Harness Short

MITIGATIONS:

- The RAS harness power is separately switched and limited. Only the RAS will be effected by a short.

>> Level 4

2.9. RAS-PMT

The RAS-PMT is a backup to the RAS. It makes the same measurement in a slightly different way. If it fails, the RAS will make the measurement

>> Level 4

3. IDPU

3.1. IPC

3.1.1. LVPS

3.1.1.1. Service Failure

3.1.1.1.1. +5VD, +/-12V, +/-5V

Loss of one of these supplies prevents and science data from being collected.

MITIGATIONS:

- Overridable current limiter in the spacecraft bus on the Instrument power service from which these supplies derive (protects against temporary fault)
- .Individual current limiters on each of these services in the IPC

>> Level 1

3.1.1.1.2. +15V

This supply is only used by the ADP. Loss of this supply would disable the RAS and SAS data collection, virtually eliminating the ability to image

MITIGATIONS:

- Overridable current limiter in the spacecraft bus on the Instrument power service from which this supply derives (protects against temporary fault)
- .Individual current limiter on this services in the IPC

>> Level 2

3.1.1.1.3. +28V

This is a secondary regulated supply used as the source for the +5D, +/-5, +/-12, and +15 as well as the HVPS.

MITIGATIONS:

- Overridable current limiter in the spacecraft bus on the Instrument power service from which this supply derives (protects against temporary fault)

>> Level 1

3.1.1.1.4. Actuator Power

This supply provides power for the actuators. Failure of this supply will disable the following:

- Shutters. These are not required for minimum science (see section 1.8).
- Vacuum Valve. This is not required for normal operations (see section 1.3)
- RAS Shutter. If the service fails before the RAS shutter is opened, the RAS would be lost (see section 2.8)

MITIGATIONS:

- Overridable current limiter in the spacecraft bus on the Switched Service power service from which this supply derives (protects against temporary fault)
- See mitigations in sections 1.8, 1.3, and 2.8.

>> Level 3

3.1.1.1.5. Cold Plate heater Power

This supply provides power for the cold plate heaters. Loss of cold plate heater power (see section 1.2.2). Contingency mode operation only on-orbit.

MITIGATIONS:

- Overridable current limiter in the spacecraft bus on the Instrument power service from which this supply derives (protects against temporary fault)

>> Level 4

3.1.1.2. Regulation Failure

Loss of regulation would cause the secondary voltages to track the primary. This could put the instrument out of calibration, and possibly degrade instrument operation.

MITIGATIONS:

- Secondary voltage monitors can be used to attempt to recover at least some of the data on the ground.

>> Level 2

3.1.1.3. Noisy Service

An excessively noisy service could insert noise into the sensitive detector electronics, degrading instrument performance

MITIGATIONS:

- Bypass filtering in IDPU VME box should remove any noise generated by the IPC (redundant filtering).
- Instrument thresholds can be raised above the noise threshold, at the loss of low energy measurements

>> Level 3

3.1.1.4. Current monitor failure

The current monitors are diagnostics only

>> Level 4

3.1.1.5. IDPU harness failure

The IDPU harness takes the output of the IPC to the IDPU VME box. Loss of any one of several wires in the IDPU harness would disable all data collection.

>> Level 1

3.1.1.6. Spacecraft Harness failure

The spacecraft to IPC harness provides primary power to the IPC, and from there to the rest of the instrument. Loss of any one of several wires in the Spacecraft harness would disable all data collection.

>> Level 1

3.1.2. HVPS Failure

There are 9 High Voltage Power Supplies providing bias to each of the nine GeDs. Failure of one HVPS would disable the associated detector. The primary power for the nine HVPS is common.

3.1.2.1. Loss of one HVPS

>> Level 3

3.1.2.2. Loss of all 9 HVPS

This can be caused by a failure on the primary side of any one HVPS.

>> Level 1

3.1.2.3. HVPS Noisy

A sufficiently high noise level to get into the cryostat could add noise to one or more of the detector signals.

MITIGATIONS:

- The output of each HVPS is heavily filtered by the HV Filter before entering the Cryostat.
- The detector thresholds can be raised to eliminate noise at the cost of low energy measurements.

>> Level 3

3.1.2.4. HVPS Regulation

Loss of HVPS regulation would cause the output to vary with primary voltage level, load variations, and temperature, and would invalidate the supply calibration.

MITIGATIONS:

- There is virtually no load on the HVPS, and the input is already regulated. Thermal variations over the expected temperature range should be small.
- The output of the supply is monitored, and slow variations could be compensated for by varying the control voltage
- At worst, only one detector is lost, and minimum science can still be achieved.

>> Level 3

3.1.3. Thermostat / Heater

The IPC thermostat controls the IPC heater to keep the IPC above its minimum turn-on temperature. Once turned on, the IPC is expected to achieve operational temperature without heating. Also, given the close coupling to the deck, it is unlikely that the minimum turn-on temperature would be a problem (this heater is a backup system).

3.1.3.1. Thermostat failed closed

The heater would be on whenever the IDPU heater power service was powered on, possibly over-heating the IPC (this is considered an unlikely failure mode).

MITIGATIONS:

- The IPC temperature and heater power service current can be monitored from the ground, and the IDPU heater service can be switched off if the it appears the IPC thermostat is stuck on. Given the size of the IPC heater and the IPC conduction capability to the deck, the IPC should not overheat before the ground can intervene.

>> Level 4

3.1.3.2. Thermostat failed open, harness open, or heater failed

The IPC could not be heated. This should not be a problem for the nominal mission design.

>> Level 4

3.1.3.3. Harness short

MITIGATIONS:

Current limiters on the IDPU heater service would prevent this problem from propagating. Loss of IDPU heaters should not be a problem for the nominal mission design

>> Level 4

3.2. CPC

3.2.1. Main service failure

Loss of the CPC main output will disable the cryocooler, ending the mission.

>> Level 1

3.2.2. Balance service failure

A failure of the balancer service would cause spacecraft vibrations which might degrade science by moving the spacecraft imaging axis or microphonic pick-up in the detectors.

MITIGATIONS:

- Solar Aspect System can be operated at a high rate to model vibrations (some loss of science due to increased SAS telemetry impact on primary science downlink capability).
- Detectors designed to provide maximum immunity to microphonics

>> Level 3

3.2.3. Heater / Temperature sensor failure

Same as IPC Heater / Thermostat (section 3.1.3)
>> Level 4

3.2.4. Spacecraft Harness

The spacecraft to CPC harness provides primary power to the CPC, and from there to the cryocooler. The power service to the CPC is carried on redundant wires. However an open wire would cause excessive current to flow in the remaining wire.
>> Level 1

3.3. IDPU VME Box

The IDPU VME box consists of a 12 boards connected by a common signal and power bus. Failures on any board which can propagate to the bus are considered separately in section 3.3.5.

3.3.1. Detector Interface

There are 9 Detector Interface Boards, one for each detector. Minimum science requirements can be achieved with the loss on one of these boards.
>> Level 3

3.3.2. Aspect Data Processor

The ADP is the interface between the Aspect sensors (RAS and SAS) and the IDPU. Failure of the ADP would cause loss of key solar aspect information, making imaging nearly impossible.
>> Level 2

3.3.3. Data Controller

All science data goes through the Data Controller. Almost any failure on the Data Controller is catastrophic.
>> Level 1

3.3.4. Power Controller

All instrument power except the cryocooler power goes through the Power Controller, where it is switched, routed, and monitored.

3.3.4.1. HV control

The Power Controller includes 9 DACs to control the detector HV supplies. Minimum science can be achieved with the loss of any one HVPS.
>> Level 3

3.3.4.2. Cooler control

The Power Controller generates the control waveforms for the CPC. Loss of these signals would disable the cooler.
>> Level 1

3.3.4.3. Grid Tray heater control

The Imager heater is described in section 2.2.

MITIGATIONS:

- Redundant heaters, harness, and switches.

>> Level 4

3.3.4.4. Actuator control

Loss of actuator services is discussed in section 3.1.1.1.4

>> Level 3

3.3.4.5. Cryocooler Heater control

Loss of the cryocooler heater is discussed in section 1.1.3.

>> Level 4

3.3.4.6. CPC Heater control

Loss of the CPC heater is discussed in section 3.2.3.

>> Level 4

3.3.4.7. Coldplate Heater Control

Loss of a coldplate heater is discussed in section 1.2.2.

>> Level 4

3.3.4.8. Temperature sensor conditioning

Temperture sensors are described above.

MITIGATIONS:

- All significant temperature sensors are redundant.

>> Level 4

3.3.4.9. Accelerometer conditioning

Loss of accelerometer data in section 1.2.11.

>> Level 4

3.3.4.10. Voltage/Current Monitors

All voltage monitors are diagnostic.

>> Level 4

3.3.5. Common Bus failure

Almost any failure of the bus or a short in an interface to the bus is catastrophic.

>> Level 1

3.3.6. Spacecraft Harness

The spacecraft to IDPU harness caries all science data to the spacecraft. Most failures in this harness are catastrophic.

>> Level 1

3.3.7. Thermostat / Heater

Same as IPC Heater / Thermostat (section 3.1.3)

>> Level 4