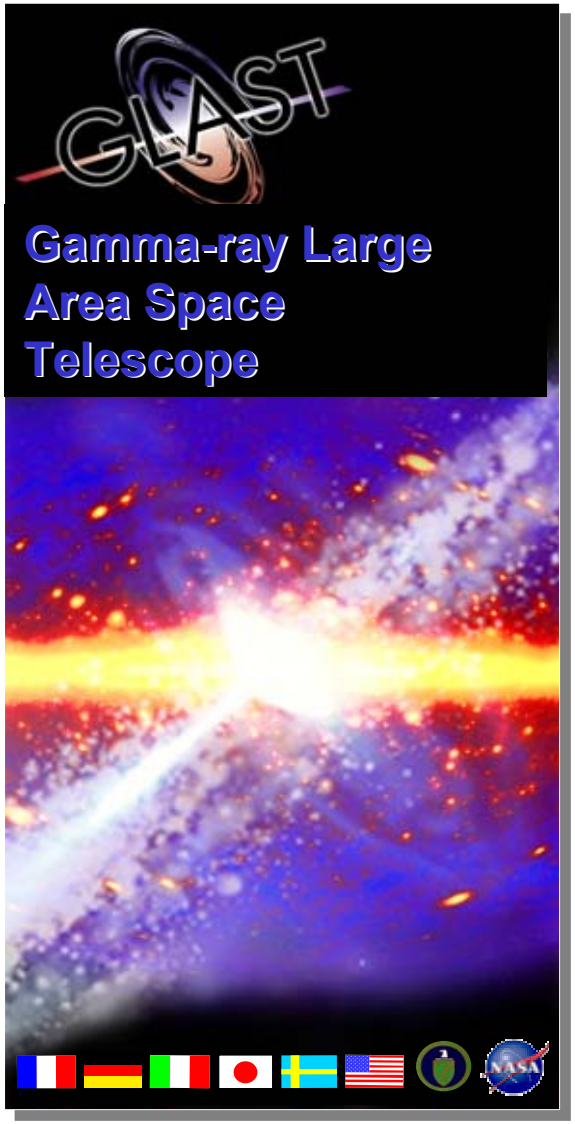


# GLAST Large Area Telescope:

## AntiCoincidence Detector (ACD)

## Safety & Mission Assurance

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# Safety & Mission Assurance

## General

- The ACD S&MA Program is being conducted in accordance with:
  - LAT MAR, GSFC 433-MAR-0001
  - LAT PAIP, SLAC LAT-MD-00039-1
  - ACD Quality Plan, ACD-QA-001
- The ACD technical review program utilizes a typical GSFC technical review program, tailored via the LAT MAR/PAIP as well as the ACD Quality Plan.
- The ACD design verification program is described in the “ACD Integration and Test” and “ACD Verification Matrix” presentations of this review.
- Lessons learned from other programs will be utilized through-out the program.
- The ACD/GLAST Systems Assurance Manager (SAM) manages with the ACD S&MA program with the ACD Hardware QE acting as the ACD S&MA team lead for the SAM.

# Safety & Mission Assurance

## System Safety Program

- The ACD safety program is being conducted in accordance with the LAT System Safety Program Plan, SLAC LAT-MD-00078-01.
- Updated ACD inputs have been submitted to the LAT System Safety Engineer at SLAC for the LAT Preliminary Hazard Analysis.
- A Hazard Control Verification Plan has been developed in accordance with EWR 127-1.
- The ACD system safety engineers have provided guidance to ACD designers with respect to materials that will easily demise in accordance with orbital debris mitigation procedures.
  - The ACD team has chosen mostly demisable materials; however, where necessary, non-demisable materials were selected in order to meet mission requirements.
  - The Micrometeoroid Shield (MMS) contributes largely to the debris casualty area (DCA); however, the shield is necessary to protect the tile assemblies and to ensure the overall ACD reliability.
  - GLAST will use controlled reentry as the disposal option.

# Safety & Mission Assurance

## Parts and Packaging Program

- See “ACD Electronics Design” presentation.
- The ACD is utilizing the LAT EEE Part Program Control Plan, LAT-MD-00099-02, and the LAT EEE Parts Identification List, LAT-TD-00401.
  - The LAT Parts Control Board (PCB) manages ACD parts activities.
  - The LAT PCB is responsible for verifying that all parts meet radiation, quality level, qualification, screening, destructive physical analysis (DPA), particle impact noise detection (PIND) testing, and other test or source inspection requirements in accordance with the applicable parts control documents including GSFC 311-INST-001 and GSFC PPL-21.
  - Weekly (when possible) PCB meetings/telecons are held with ACD design engineering participation.
  - The Front End Electronics (FREE), High Voltage Bias Supply (HVBS), and Resistor TAP Network boards parts lists are currently under PCB review.

# Safety & Mission Assurance

## Parts and Packaging Program (Continued)

- Stress analysis is being performed by the design engineers on all EEE parts to verify conformance to the derating guidelines in Appendix B of GSFC PPL-21.
- Initial parts activities are focused on long lead and difficult to test parts such as the ASIC's and Photo Multiplier Tubes (PMT's).
- Circuit Functions Inc. in Carson City, NV, was surveyed as a potential supplier of high voltage ceramic capacitors for the high voltage power supply system.
- The MAX494ESD, a plastic encapsulated microcircuit requiring lengthy radiation and qualification testing, has been procured and immediate testing (upon delivery) has been planned.
- Flight parts will be stored in nitrogen cabinets in GSFC building 2 in a bonded area that was previously used by the SWIFT project.
- Printed wiring board coupons will be evaluated prior to population.

# Safety & Mission Assurance

## Materials & Processes Program

- The ACD Materials Program will comply with the LAT Mechanical Parts Plan, LAT-SS-00107-1, and the LAT Mechanical Materials and Parts List, LAT-DS-00405-3.
- The ACD materials engineers have formulated a comprehensive materials and processes (M&P) program to ensure the success and safety of the mission by selecting appropriate materials and lubricants to meet the operational requirements of the instruments.
- To the maximum extent practicable, conventional and compliant materials with flight heritage have been chosen to avoid costly and time consuming testing of unproven M&P.
- When non-conventional or non-compliant materials are considered for use or when off-the-shelf items for which there is no flight history or clear identification of materials are considered, the ACD Materials Engineer will thoroughly investigate the material prior to its incorporation into the ACD.

# Safety & Mission Assurance

## Materials & Processes Program (Continued)

- The ACD will participate in the LAT M&P Control Board process.
  - The board will include engineering, quality assurance, materials engineering, and other disciplines which may be applicable to the particular situation.
  - The board will make decisions on out-of-spec materials, material failures, out-of-date items, and limited-life items.

# Safety & Mission Assurance

## Reliability & Continuous Risk Management (CRM) Program

- The ACD reliability and risk programs are being conducted in accordance with the LAT MAR, LAT PAIP, and LAT Risk Management Plan, LAT-MD-00067-03.
- As part of the reliability/risk program, the following activities have been performed in preparation for CDR:
  - Failure Modes and Effect Analysis, ACD-RPT-000042
  - Limited-Life Item Analysis, ACD-RPT-000039
  - Worse Case Analysis, ACD-RPT-000071
  - Numerical Reliability Assessments, ACD-RPT-000071
  - Parts Stress and Derating Analysis (Documentation to be released)
- Reliability and risk activities will continue throughout the development process with corresponding analysis updates as applicable.

# Safety & Mission Assurance

## Reliability & CRM Program - Limited-Life Analysis

### Key Results

- Due to their inherent gain degradation characteristics, the Photo Multiplier Tubes (PMT's) are the ACD's only identified "potential" limited-life items.
- The ACD design can accommodate, by at least a factor of eight, both an individual PMT gain decrease and a gain degradation between PMT's serviced by the same HVBS.
- Based on gain degradation curves, a gain degradation–induced failure would not be expected to occur for at least 10 years.

### Plans

- The PMT's do not need to be included in the Limited-Life Items List.

# Safety & Mission Assurance

## Reliability & CRM Program – Failure Modes and Effects Analysis

### Key Results

- A total of 13 different ACD failure modes were evaluated in terms of their effects on the overall GLAST mission; however, the MMS is the only identified single point failure (SPF).

### Plans

- Perform a worse case debris and micrometeoroid penetration analysis.
- Update reliability assessments with an emphasis on the SPF.

# Safety & Mission Assurance

## Reliability & CRM Program – Worse Case Analysis

### Key Results

- The estimated probability of no debris and/or micrometeoroid penetration through the MMS is 0.9665 over 5 years using the Orbital Debris Model (ORDEM 1996).
  - This value is slightly above the ACD goal of 0.95.
  - The worse case effect under this scenario is the loss of a maximum of 2 working tiles.
- When looking at the scenario of the loss of 2 working tiles as the result of debris/micrometeoroid penetration, the estimated reliability significantly improves to a value of 0.99.

### Plans

- Since the project may be required to perform recalculations using ORDEM 2000 which takes into account a higher debris flux than ORDEM 1996, continue evaluations to improve the design to meet the overall ACD reliability requirements.

# Safety & Mission Assurance

## Reliability & CRM Program – Numerical Reliability Assessments

### Key Results

- Based on the latest overall efficiency simulation and test results, the current ACD reliability is estimated to be 0.92 over a 5 year period.
  - Although this estimate assumes that no tile failures would be allowed in order to meet the 0.9997 ACD detection efficiency requirement; even if one tile was lost, the LAT would be capable of meeting level 1 science requirements.
  - Note: The higher the efficiency, the greater the inherent fault tolerance built into the ACD design.

### Plans

- Review the requirement to achieve a 0.96 probability that the 0.9997 ACD detection efficiency will be met.

# Safety & Mission Assurance

## Reliability & CRM Program – Parts Stress & Derating Analysis

### Key Results

- All analyses to date has shown that electrical, electronic, and electromechanical (EEE) components meet both the manufacturer's maximum stress tolerances and the GSFC Preferred Parts List (PPL-21) requirements.
- The FREE thermal circuit board analysis is in-process and results should be available shortly.

### Plans

- Continue completing analysis documentation so it will be available as a reference for any future parts and associated design changes.

# Safety & Mission Assurance

## Software Quality Assurance Program

- Electrical ground support equipment (EGSE) test displays are being created to verify the correctness of ACD hardware registers.
- The ACD Software QE will have insight into the ground software activities including development, testing, and verification.

# Safety & Mission Assurance

## Hardware Quality Assurance Program

- The ACD Hardware QE is an integral part of the ACD team that is developing the hardware designs, selecting the parts and materials, and participating in reliability studies and analyses as well as procurement activities, trade-off studies, and the development of ACD S&MA documentation.
- The ACD Hardware QE's program participation will continue through design, fabrication/assembly, integration, and testing with the QE performing workmanship inspections and test monitoring.
- The ACD hardware will be built utilizing NASA workmanship standards with only certified personnel performing fabrication, assembly, and inspection duties.

# Safety & Mission Assurance

## Contamination Control Program

- The ACD contamination control program will be governed by the LAT and GLAST contamination control plans which are under development.
- To be consistent with the LAT/GLAST contamination control plans:
  - All materials used in the ACD will meet space flight quality levels (i.e., TML < 1.0%, CVCM < 0.1%).
  - The ACD will be assembled in an appropriately clean environment consistent with LAT/GLAST requirements including the use of clean room garments and equipment.
  - All ACD surfaces will meet visibly clean flight levels per Level 750B of MIL-STD-1246).

# Safety & Mission Assurance

## Back-up Information

# Safety & Mission Assurance

| UNCONTROLLED REENTRY FORM DECAYING ORBIT | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| ***Parent object is in line 1*** | | | | | | | | | | |
| Object | | | | | | Material Type | Demise Altitude (km) | Qty | Casualty Area (m^2) | |
| Surface | Type | Diameter (m) | Length (m) | Height (m) | Mass (kg) | | | | Incident | Total |
| | | | | | | | | | | |
| ACD | Box | 2.0000 | 2.0000 | 2.0000 | 452.0000 | Al 2024-T3 | 77.944 | 1 | 0 | 0 |
| Flexure | Box | 0.0900 | 0.0600 | 0.5400 | 0.5000 | Titanium | 0 | 8 | 0.5447 | 4.3576 |
| ACD flex | Box | 0.0900 | 0.0600 | 0.5400 | 0.5000 | ACD flex | 77.944 | 8 | 0 | 0 |
| Totals | | | | | | | | | | 4.3576 |
| Scenario - flexure modeled as box using DAS 1.5.3 - ACD flex = synthetic Ti | | | | | | | | | | |

# Safety & Mission Assurance

## Primary Materials Reference Documentation

- GSFC 731-0005-83, "General Fracture Control Plan for Payloads Using the Space Transportation System (STS)", November 25, 1988.
- GSFC 541-PG-8072.1.2, "GSFC Fastener Integrity Requirements", March 5, 2001.
- NASA-STD-5001, "Structural Design and Test Factors of Safety for Spaceflight Hardware", June 21, 1996.
- NASA Reference Publication 1124, "Outgassing Data for Selecting Spacecraft Materials" June 1997
- NASA-STD-6001, "Flammability, Odor, Off-gassing and Compatibility Requirements & Test Procedures for Materials in Environments That Support Combustion" February 9, 1998.
- MSFC-STD-3029, "Design Criteria for Controlling Stress Corrosion Cracking"
- MIL-HDBK-5H, "Metallic Materials and Elements for Aerospace Vehicle Structures", December 1998.
- SP-R-0022A, "General Specification-Vacuum Stability Requirements of Polymeric Materials for Spacecraft Applications".
- ASTM E-595, "Standard Test Method for Total Mass Loss and Collected Volatile Condensable Materials from Outgassing in a Vacuum Environment, Re-approved 1999.

# Safety & Mission Assurance

**REQUIREMENT:**

Reliability Assessment Scope (MAR/PAIP Paragraph 8.2.4): **"**When necessary/prudent or when agreed upon with the GSFC Project Office, GLAST LAT will perform comparative numerical reliability assessments to**:**

a) Evaluate alternate design concepts, redundancy and cross-strapping approaches, and part substitutions

b) Identify the elements of design which are the greatest detractors of system reliability

c) Identify those potential mission limiting elements and components that will require special attention in part selection, testing, environmental isolation, and/or special operations

d) Assist in evaluating the ability of the design to achieve mission life requirement and other reliability goals as applicable

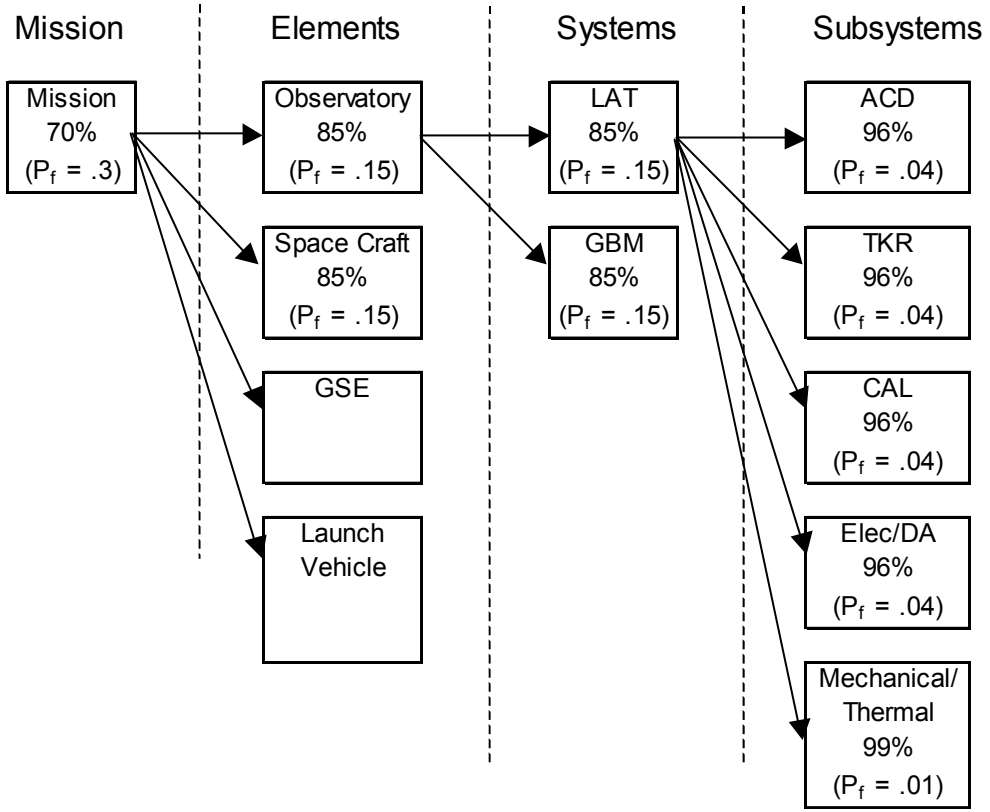
e) Evaluate impact of proposed engineering changes and waiver requests on Reliability"

**ACD ASSESSMENT:**

- In accordance with Paragraph 8.2.4a of the LAT PAIP and MAR, a numerical assessment was performed to evaluate ACD component reliability allocations as well as different High Voltage Power Supply redundancy approaches in order to maximize the probability for mission success over the life (5 Year minimum) of GLAST.
    - Analysis indicates that the current design falls slightly below the Mission Success Reliability Target of 0.96 over 5 years and 10 years. This analysis assumes that at least one level of stand-by Power Supply redundancy is incorporated, and that the ACD Tile Shell Assembly (TSA) are capable of meeting assigned reliability allocations.

# Safety & Mission Assurance

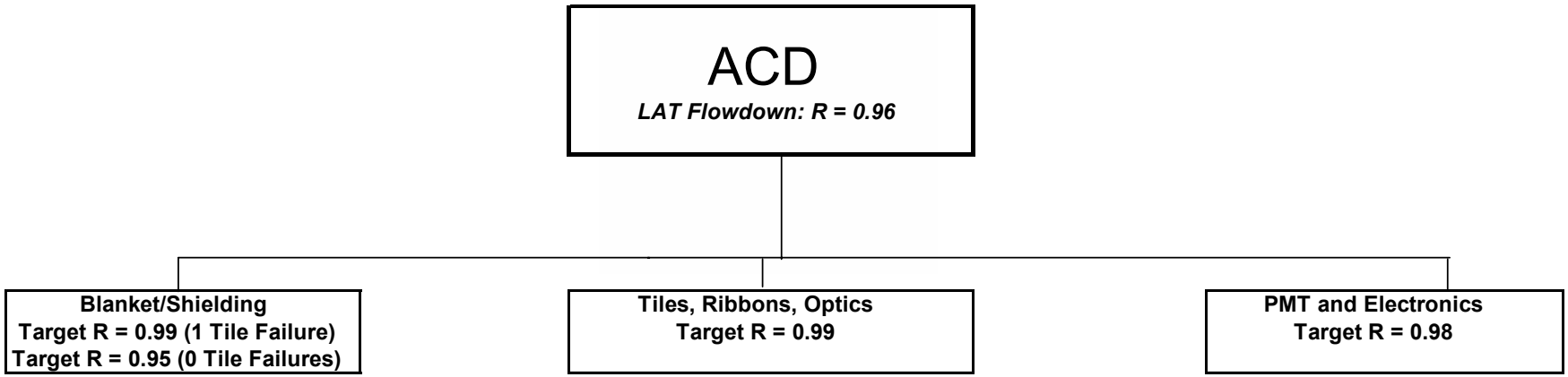
## Reliability Allocation




**Reliability** - is defined as the probability of successfully meeting mission objectives at end of life. $P_f$ is probability of failure.

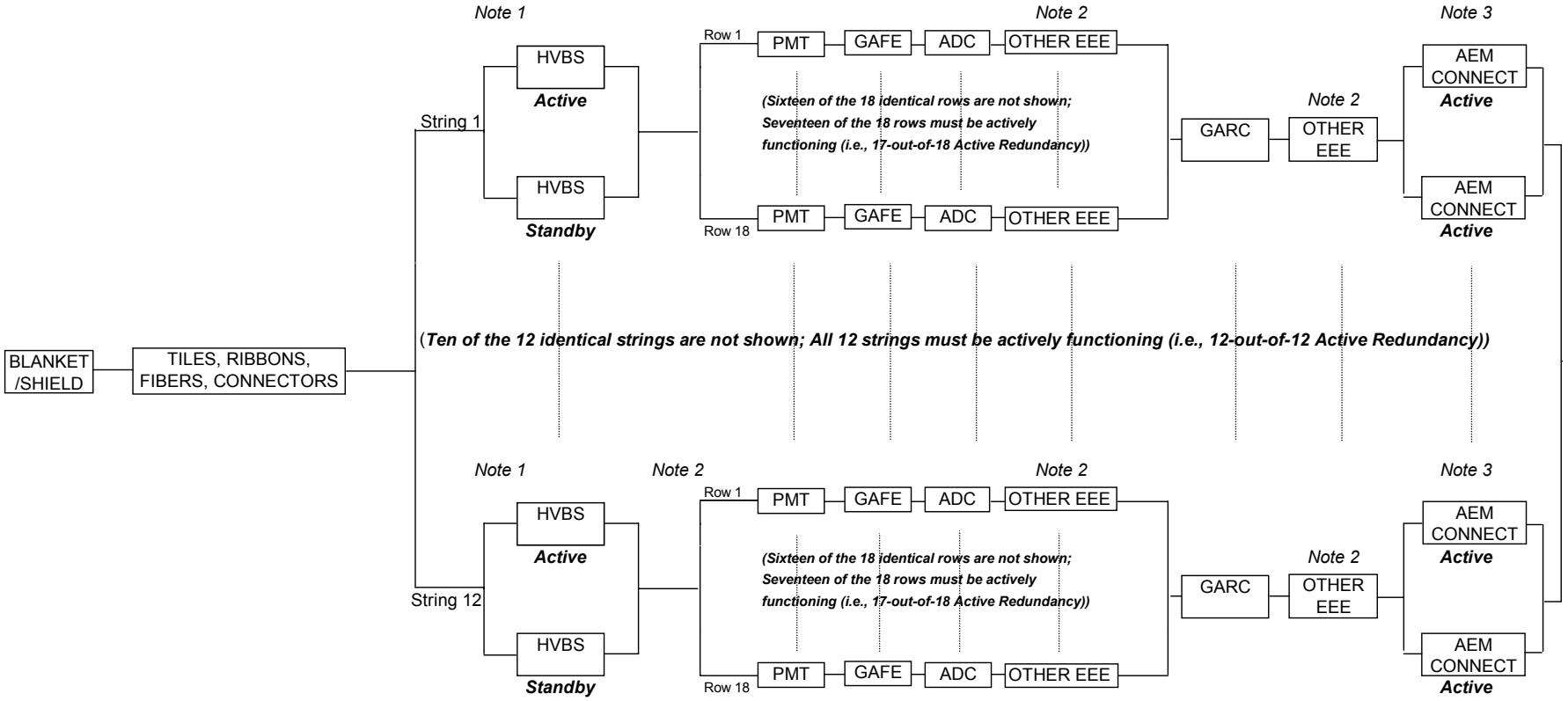
# Safety & Mission Assurance

## ACD Reliability Allocation



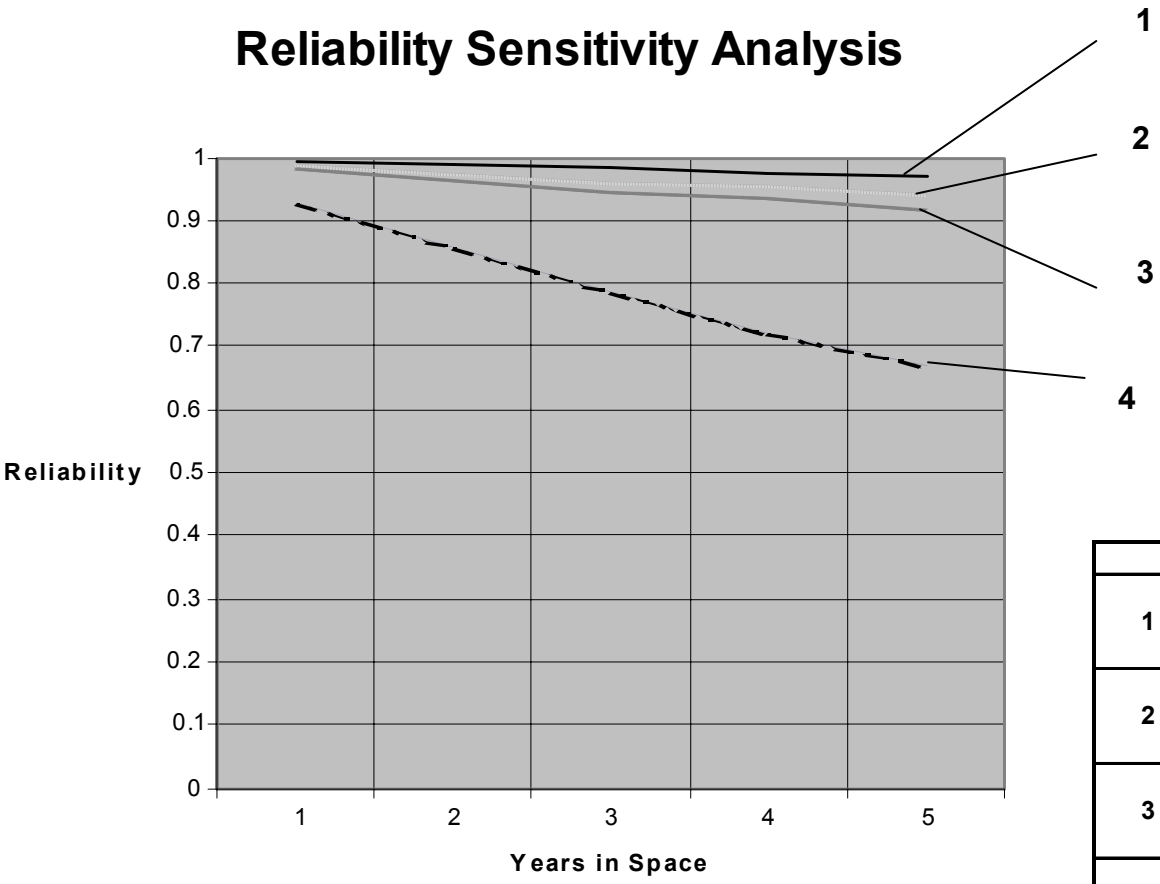
# Safety & Mission Assurance

## ACD Reliability Block Diagram




*Note 1: One of the two HVBSs may be held in a non-active standby mode until the other HVBS fails (i.e., 1-out-of-2 Standby Redundancy)*
*Note 2: Other EEE parts have much lower failure rates than the other components listed and were not included in the reliability calculations.*
*Note 3: One of the two AEM Connections needs to be actively functioning (i.e., 1-out-of-2 Active Redundancy)*

# Safety & Mission Assurance




| LEGEND | |
|---|---|
| 1 | One tile failure allowed<br>One board failure allowed<br>Stand-by redundant Bias Supplies |
| 2 | One tile failure allowed<br>Zero board failures allowed<br>Stand-by redundant Bias Supplies |
| 3 | Zero tile failures allowed<br>Zero board failures allowed<br>Stand-by redundant Bias Supplies |
| 4 | One tile failure allowed<br>Zero board failures allowed<br>Stand-by redundant Bias Supplies |

# Safety & Mission Assurance

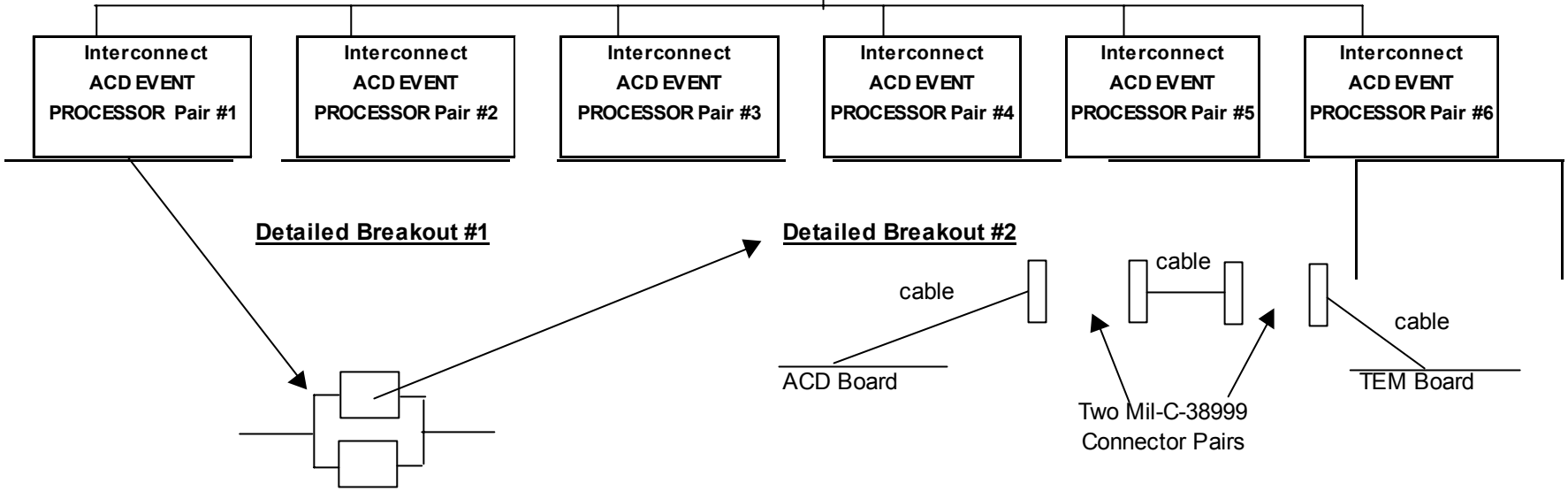
## Redundancy

### Assumptions/Ground Rules

- The ACD Electronics allocation is 0.98, flowed down from the ACD reliability target of 0.96 reliability at 80% operability or, in other words, no more than 20% degradation of the overall effective LAT area.
- Several EEE parts (e.g., resistors, capacitors) have been left out of the model since their corresponding failure rates are believed to be orders of magnitude less than the other components/assemblies identified.
- An inability to process information from any tile constitutes failure.
- The ACD Electronics is comprised of the PMT & Bias, High Voltage B/S, Analog ASIC, Digital ASIC, ADC, & AEM Connects. With the exception of the High Voltage Bias Supply, failure rates are based on vendor data for the same or similar components for all electronic parts.
- High Voltage Bias Supply failure rates are based on MIL-STD-217F (Notice 2).
- PMT failure rates are based on Hamamatsu projections for fully screened space parts.
- Solder connection and board reliability need not be considered.
- Stand-by switching operates without any anomalies.

# Safety & Mission Assurance

## ACD_TEM Interconnect




The cables, consisting of 65 conductors each, are attached as follows:

1) Boards - each cable conductor is hand soldered to a Plated Though Hole on the board;
2) Connectors - each cable conductor is crimped to a pin/socket in the connector.