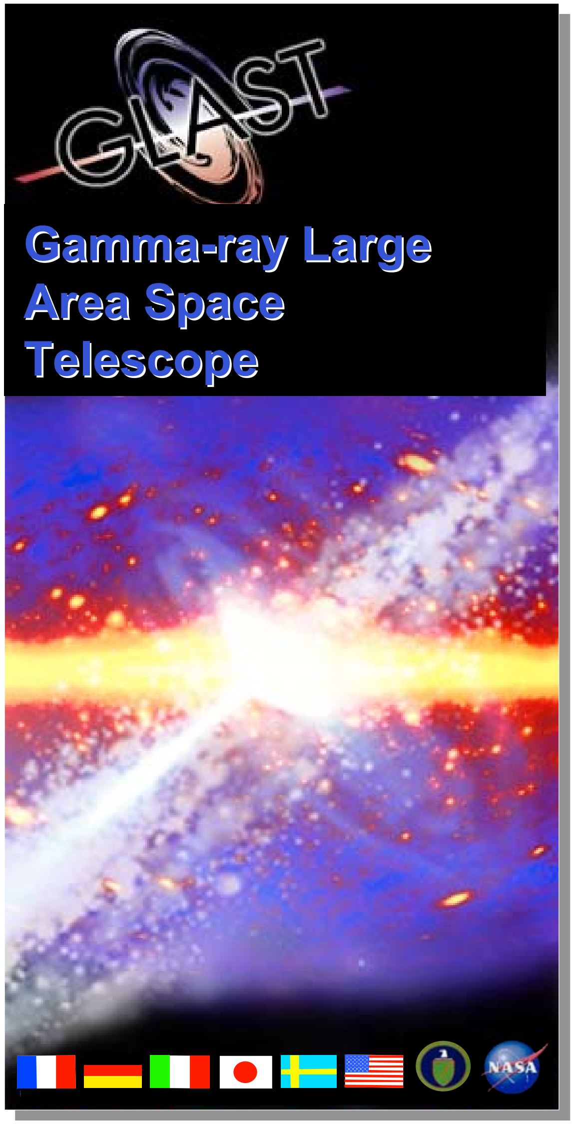


GLAST Large Area Telescope:

AntiCoincidence Detector (ACD) Subsystem
WBS: 4.1.6

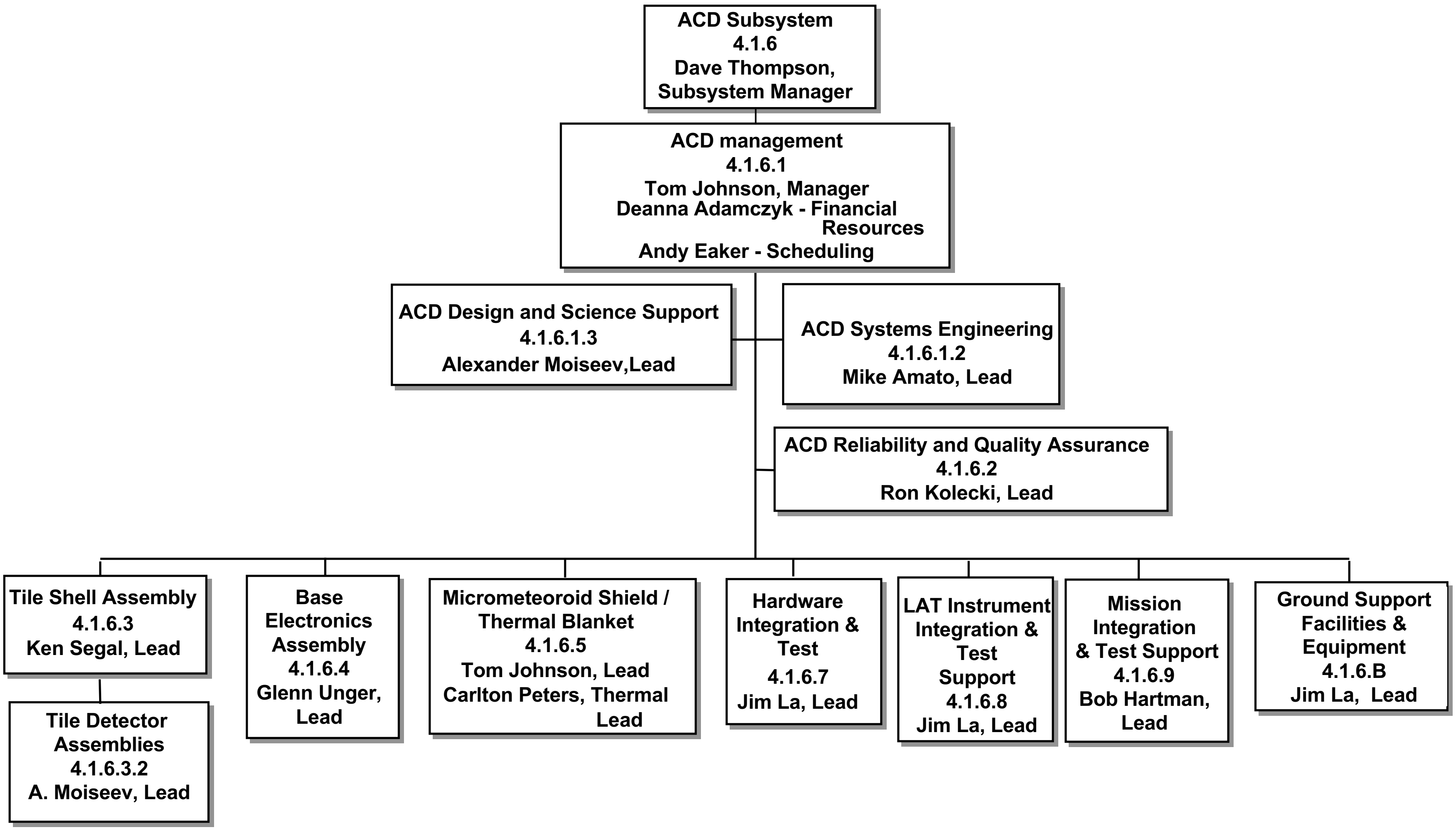
David J. Thompson
Thomas E. Johnson
NASA Goddard Space Flight Center
Subsystem Manager/Instrument Manager

David.J.Thompson@nasa.gov
Thomas.E.Johnson@nasa.gov

Overview

Section 11-1

ACD Organization Chart

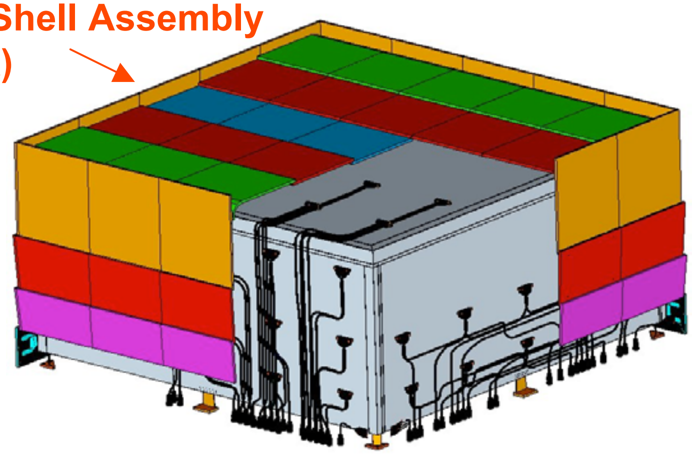


ACD Team Partners

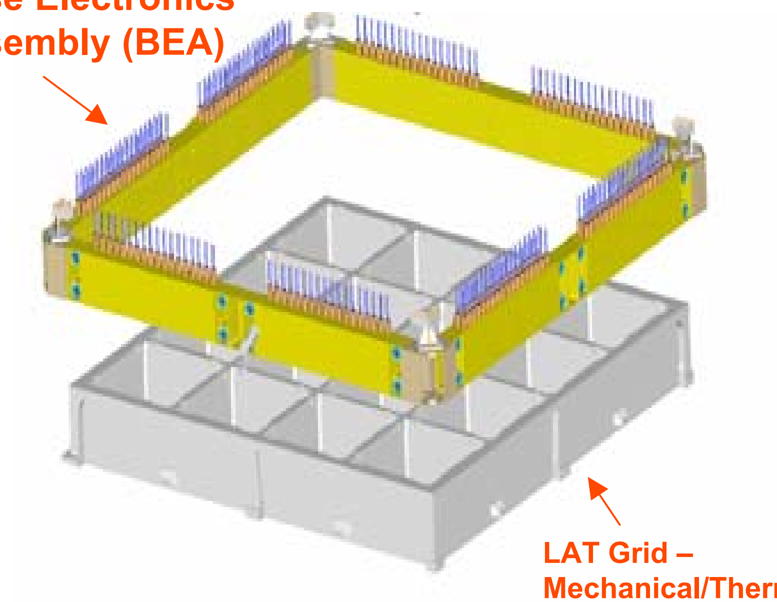
- Micrometeoroid Shield Design – Johnson Space Center
  - NASA Center of Excellence for micrometeoroid protection
  - Eric Christiansen and Jeanne Crews
- Tile Detector Assemblies – FermiLab (Department of Energy)
  - Experts in fabrication of scintillator detectors
  - Phyllis Deering and Todd Nebal
- Scintillating Fiber Ribbons – Washington University, St. Louis
  - Leaders in scintillating fiber production
  - Professor Robert Binns
- ASICs - Stanford Linear Accelerator Center (SLAC)
  - Extensive experience in ASIC design
  - Gunther Haller, Oren Milgrome, Dietrich Freytag

ACD Overview

Tile Shell Assembly (TSA)



Base Electronics Assembly (BEA)



LAT Grid – Mechanical/Thermal Interface to LAT

- TILE SHELL ASSEMBLY
  - 89 Plastic scintillator tiles (8.6 m^2 total)
  - Waveshifting fiber light collection, with clear fiber light guides for long runs (6.7 km total)
  - Two sets of fibers interleaved for each tile
  - Tiles overlap in one dimension
  - 8 scintillating fiber ribbons cover gaps in other dimension (not shown)
  - Supported on self-standing composite shell
  - 376 composite flexures support tiles
  - Covered by thermal blanket + micrometeoroid shield (not shown)
- BASE ELECTRONICS ASSEMBLY
  - 194 photomultiplier tube sensors (2/tile)
  - 12 electronics boards (two sets of 6), each handling up to 18 phototubes. Two High Voltage Bias Supplies on each board.
  - 24 electrical interface connectors (1600 pins total)

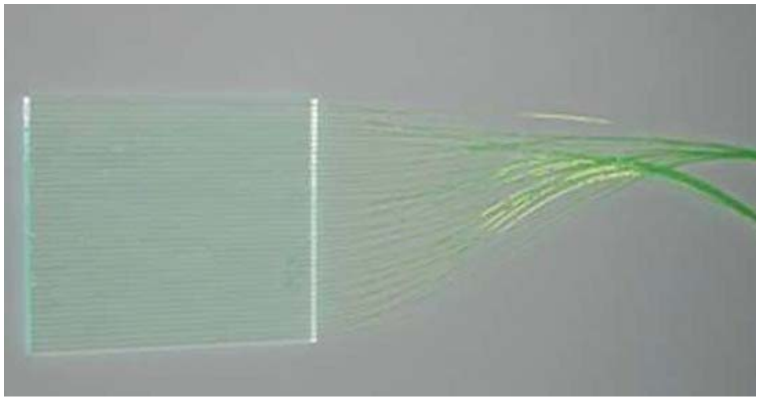
ACD Changes Since PDR

- Light Collection
  - Fibers were re-routed to shorter paths to minimize losses.
  - Use of fiber connectors and clear fibers was optimized.
  - The top center row of tiles was thickened to give more light.
  - Tile overlaps were increased to allow for vertical gaps required by acoustic loads.
  - A triple layer (had been two) of square 1.5 mm fibers with offset centers was adopted for the ribbons, to increase efficiency.
- Mechanical
  - Mechanical design was optimized to meet all environmental requirements, including new orbital debris model.
  - A trade study for improving the light-tightness of the phototube housing was conducted, and a new design was developed.
- Electrical
  - In order to improve reliability, a redundant High Voltage Bias Supply was added to each electronics card.
  - The ASIC and electronics card designs are being finalized, correcting some deficiencies from earlier versions.

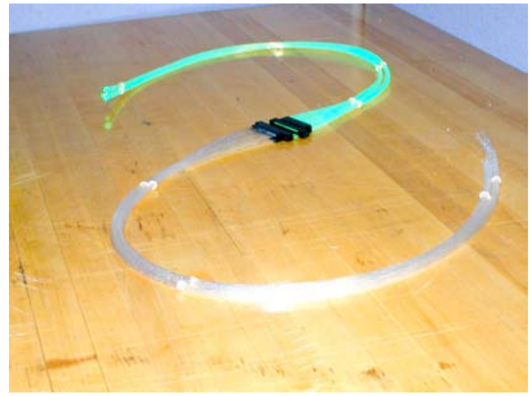
ACD Technical Heritage

- Plastic Scintillator - used in all previous gamma-ray telescopes OSO-3, SAS-2, COS-B, CGRO (all 4 instruments), plus many cosmic ray experiments.
- Waveshifting fibers - used in GLAST LAT Balloon Flight Engineering Model (BFEM). Waveshifting bars used by HEXTE on RXTE (same material in a different geometry)
- Photomultiplier tubes - used in all previous gamma-ray telescopes. HEXTE/RXTE used a commercial version of the same tube we are using (Hamamatsu 4443), and GOLF on SOHO used the same tube as the ACD except for the cathode material (Hamamatsu 4444)
- High Voltage Bias Supplies - used in all previous gamma-ray telescopes, plus many cosmic ray experiments.
- Electronics - experienced ASIC designers. Discriminators, PHA and logic signals similar to many flight instruments.
- Micrometeoroid Shield - Improved version (more layers, stronger materials) of shield that protected EGRET successfully for nine years.

ACD Tile Detector Assembly (TDA)



Scintillator tile/Waveshifting fibers



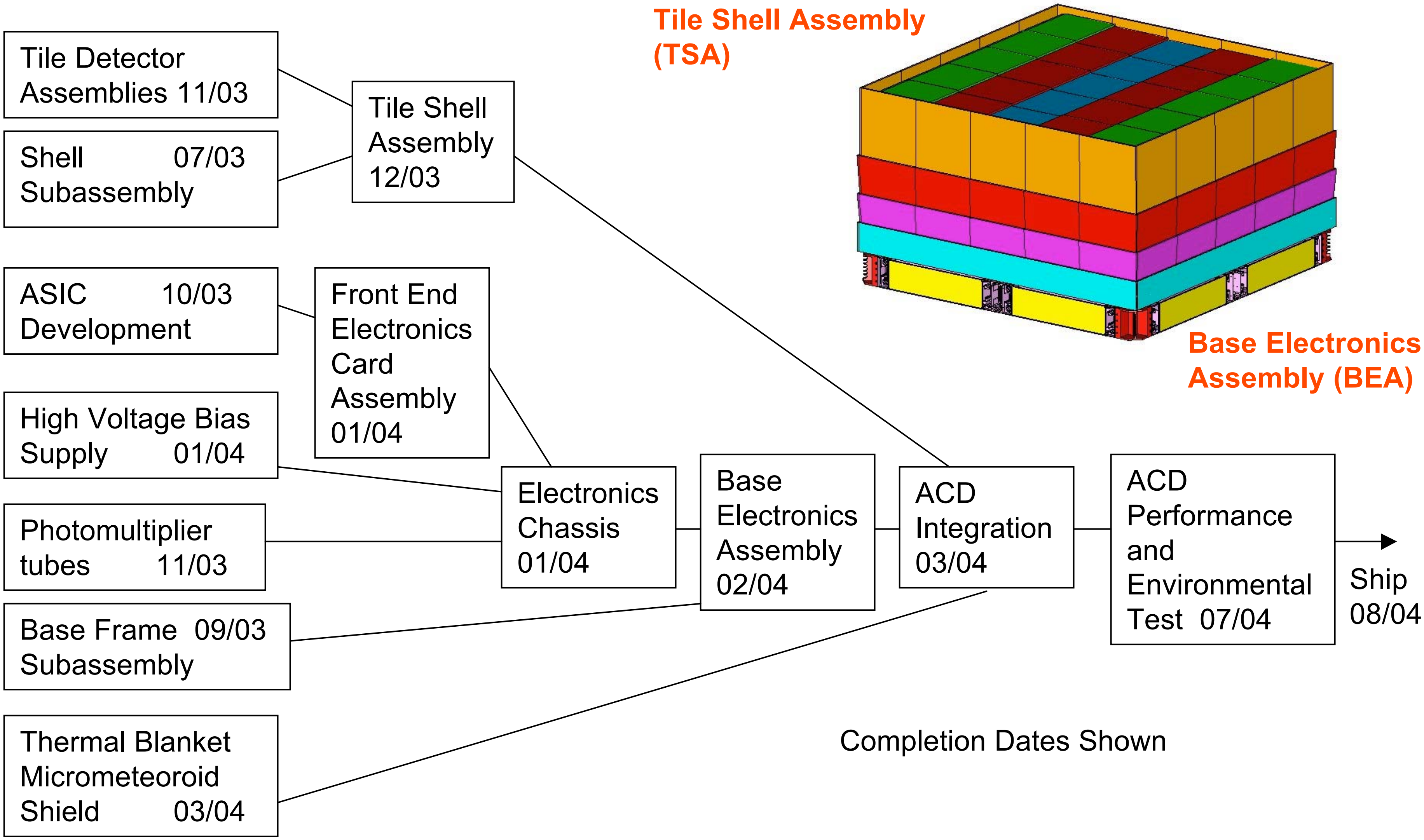
Optical connector/Clear fibers

Phototube/Resistor Network

Flight-design TDAs have been successfully built, performance–tested, mounted on a flight-like composite structure, and environmentally tested to qualification levels (vibration and thermal vacuum).

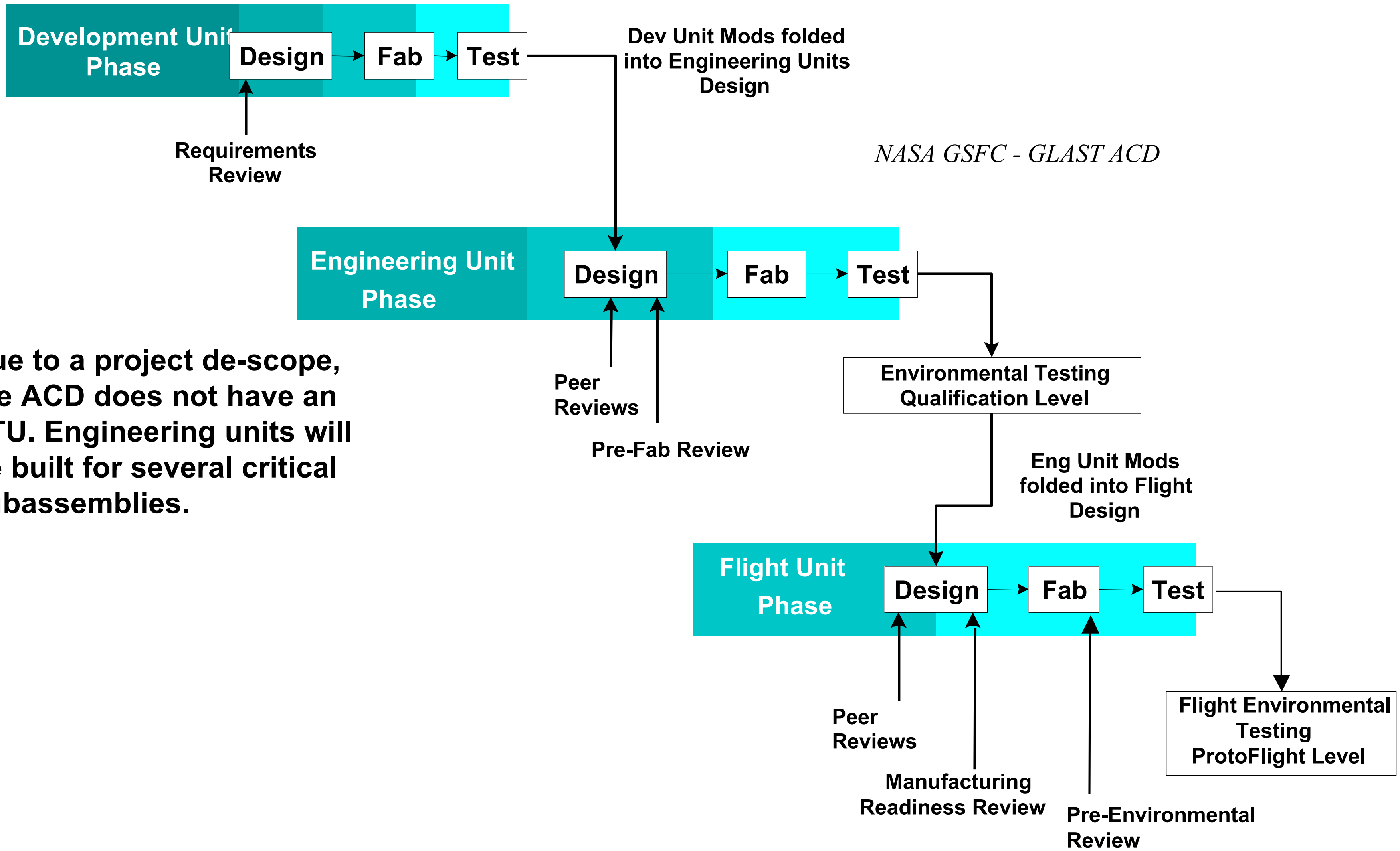
The TDAs are the basic detector units for the ACD

ACD Work Flow Overview



Completion Dates Shown

ProtoFlight Development Flow



Due to a project de-scope, the ACD does not have an ETU. Engineering units will be built for several critical subassemblies.

ACD CDR RFA Responses

- Of the 19 Requests for Action (RFA), only two involved the actual design of the ACD (micrometeoroid shield, details of mounting the long bottom tile).
- Other RFAs involved testing, risk, spares plan, contamination, product assurance, GSE, and schedule.
- 17 of the 19 are now closed (and we expect the other two to be complete soon).
- Sample responses are shown on the next chart.

RFA Responses (samples)

ID #	Status	RFA Description	RFA Response/Closure Plan
ACD-11	Open	Provide correct standard for FREE rigid-flex Printed Circuit Board	Specification is being written by the LAT Parts Engineer, Nick Virmani
ACD-13	Open	Describe problem reporting and corrective action system.	Documentation of the existing system is being written by Ron Kolecki, Systems Assurance Manager.
ACD-14	Closed	Provide the ACD spares plan	ACD-PLAN-000125, ACD Spares Plan, is now in the ACD Configuration Management system
ACD-15	Closed	Evaluate mounting for the long bottom tile that does not involve stick-slip design.	New design is similar to the flexures used for mounting the other tiles, not a stick-slip approach.
ACD-18	Closed	Document the QA plan for work at Fermilab	ACD-PROC-00059, Fabrication and Assembly Procedure for the ACD Tile Detector Assembly (TDA), includes the Fermilab QA plan.

CDR Subsystem Status Summary

- Final Design Established With Known Closure Plans For Design Trades
  - Light-tight phototube housing design - ECD: 5/30/03
  - Suitability of recently-delivered ASICs for flight – ECD 5/23/03
- Internal & External Interfaces Established
  - ICD and IDD signed, outline drawing in progress – ECD: 6/5/03
- Performance Analyses Show Compliance Including Sufficient Design Margin
- Qualification & Verification Plans In Place
- Subsystem Risk Areas Identified And Mitigation Plans Established
- Cost & Schedule Manageable
  - $720K (12%) cumulative variance with recovery plans established
  - 2 month Schedule Float to Flight Delivery Need Dates

Requirements

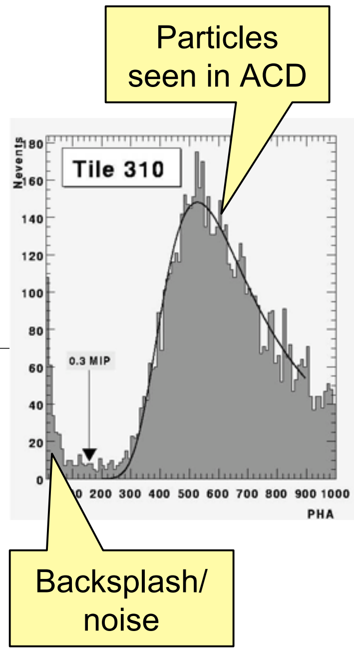
Section 11-2

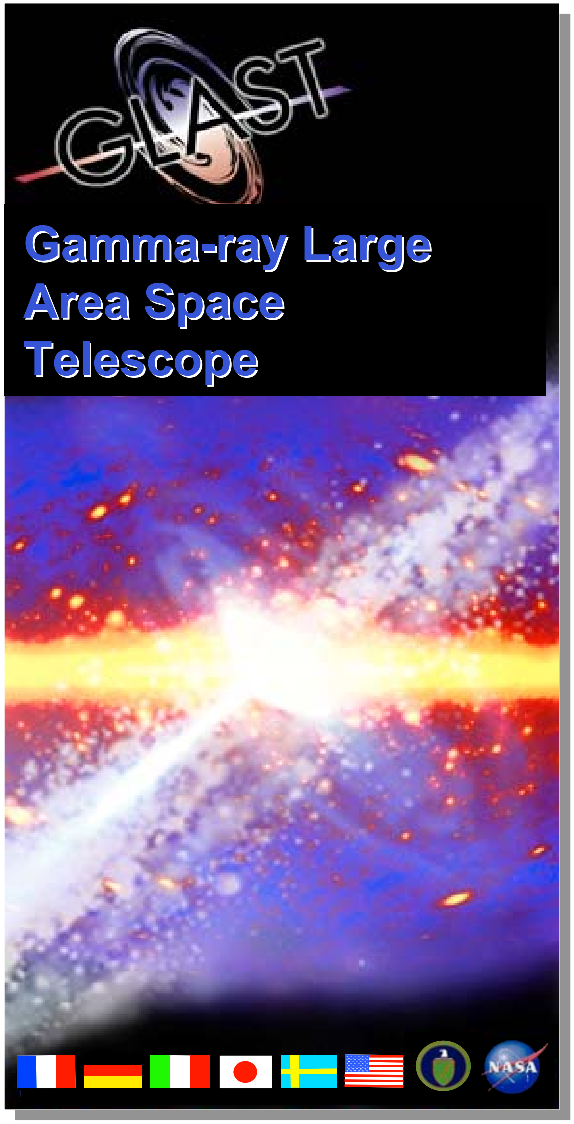
Level III Key Requirements Summary

Reference: LAT-SS-00016

Parameter	Requirement	Expected Performance	Verification Method
Detection of Charged Particles	**? 0.9997 average detection efficiency over entire area of ACD (0.99 for bottom row of tiles)**	**?0.9997 ?0.999 (bottom tiles)**	**Test and Analysis**
Fast VETO signal	Logic signal 200-1600 nsec after passage of charged particle	200-1600 nsec	Demonstrate
PHA signal	For each phototube, pulse height measurement for each Trigger Acknowledge (TACK) Below 10 MIP, precision of <0.02 MIP or 5% (whichever larger) Above 10 MIP, precision of < 1 MIP or 2% (whichever larger)	< 0.02 MIP or 5% < 1 MIP or 2%	Test and Analysis
False VETO rate - backsplash	**< 20% false VETO's due to calorimeter backsplash at 300 GeV**	**< 10%**	**Test and Analysis**
False VETO rate - noise	< 1% gamma-ray rejection from false VETO's due to electrical noise	< 1%	Analysis
High Threshold (Heavy Nuclei) Detection	Detection of highly-ionized particles (C-N-O or heavier) for calorimeter calibration.	Yes	Analysis
Size	Outside: 1796 x1796 x 1050 mm 1806 x 1806 for lowest 310mm Inside Grid: 1574 x 1574 x 204.7 mm Inside TKR: 1515.5 x 1515.5 x 650 mm	1796 x1796 x 1045 mm 1800 x 1800 at connector 1574 x 1574 x 204.7 mm 1515.5 x 1515.5 x 650mm	Demonstrate
Mass	< 280 kg	270 kg	Demonstrate
Power	< 10.5 Watts (conditioned)	9.5 W	Demonstrate
Instrument Lifetime	Minimum 5 yrs	> 5 yr.	Analysis

Flowdown - Requirements to Design

Parameter	Requirement	Constraints	Characteristics Needed	Design
Detection of Charged Particles ACD-SS-00016 ACD3-20	? 0.9997 average detection efficiency over entire area of ACD (less for bottom row of tiles)  	Mass Power Size Lifetime Minimize inert material outside active detector Low backsplash sensitivity	High-sensitivity charged particle detector No gaps Low energy threshold for high efficiency Performance margin to compensate for aging	Plastic scintillator tiles, 1 cm thick, < 1000 cm^2 size Waveshifting fiber light collection, with clear fibers for transmission in long runs Overlap one dimension, seal other with scintillating fiber ribbons Photomultiplier tubes, with gain set low at start of mission to allow increase as tube ages.
False VETO rate – backsplash ACD-SS-00016 ACD3-26	< 20% false VETO's due to calorimeter backsplash at 300 GeV	High charged particle detection efficiency Mass Power Size Lifetime	Detector with low sensitivity to soft photons Segmentation < 1000 cm^2 High energy threshold (backsplash is soft)	Low-noise electronics Threshold well below MIP peak but above most of backsplash

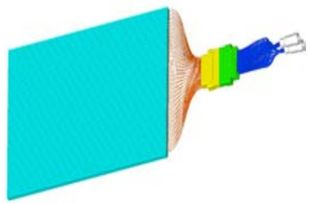


Design

Section 11-3

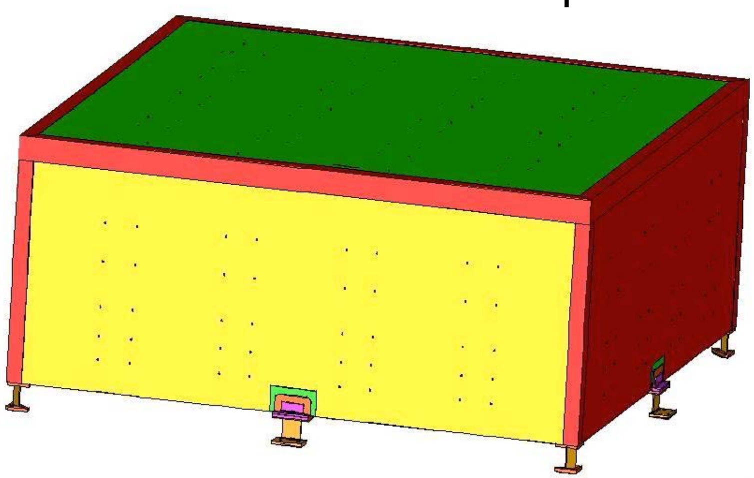
ACD Assembly Overview

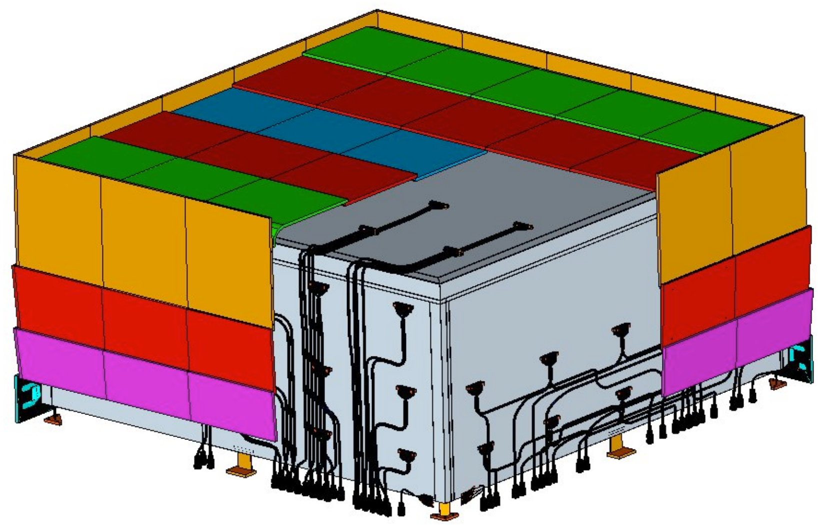
Shell, Tile Detector Assemblies (TDA) & Tile Shell Assembly (TSA)



Tile Detector Assembly (89)

Composite Shell

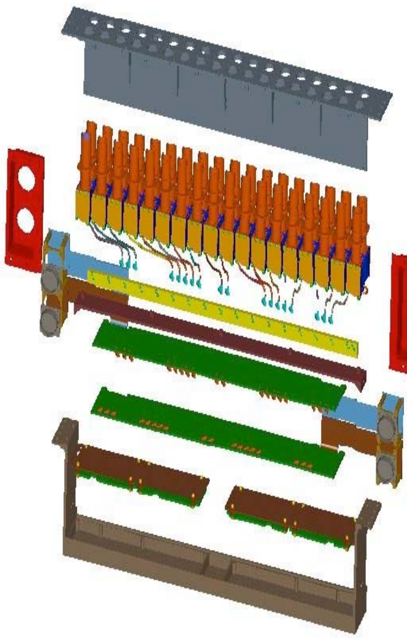




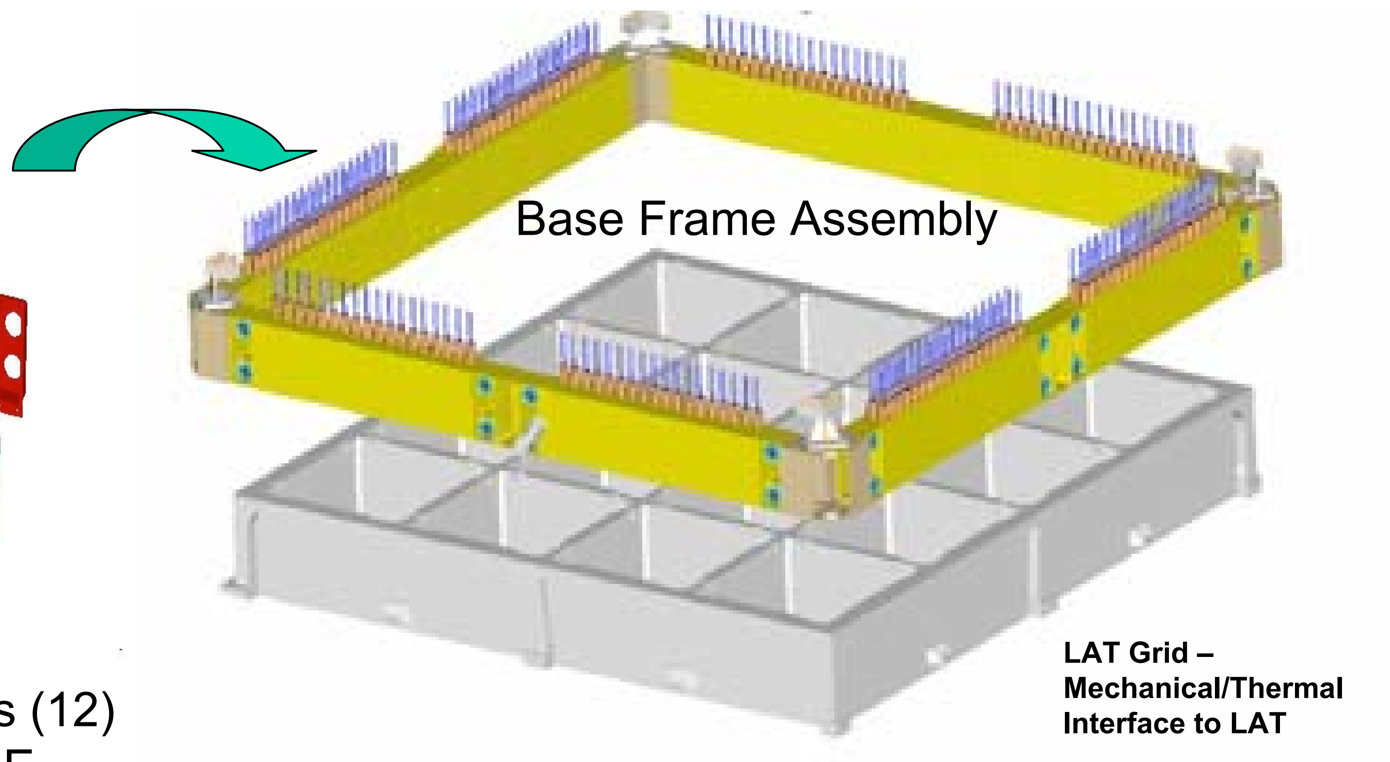
Mounting the TDAs and ribbons on the shell forms the TSA

ACD Assembly Overview

Electronics Chassis, Base Frame, and Base Electronics Assembly (BEA)



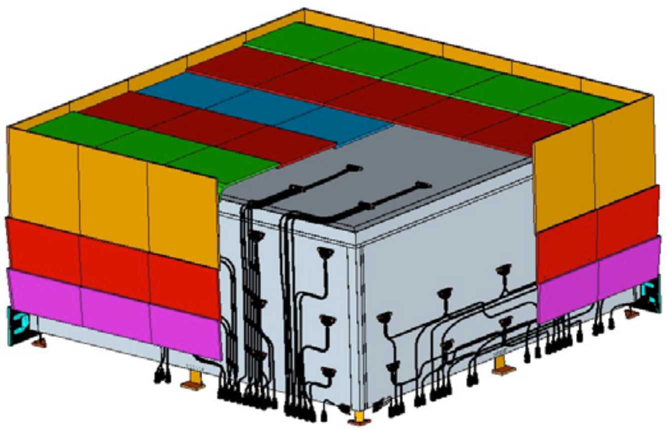
Electronics Chassis (12) – Phototubes, FREE Cards, HVBS

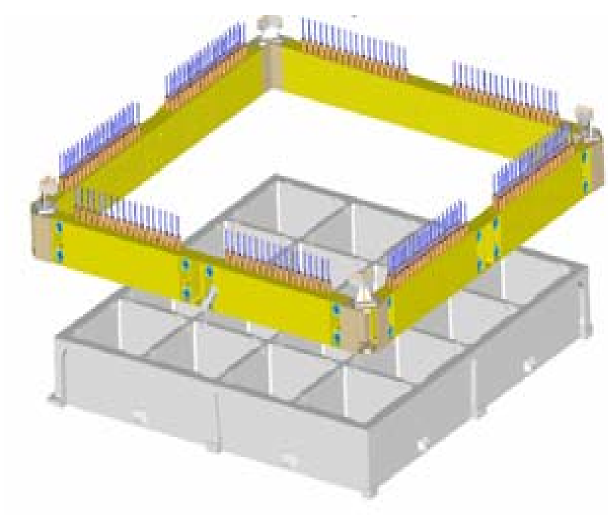


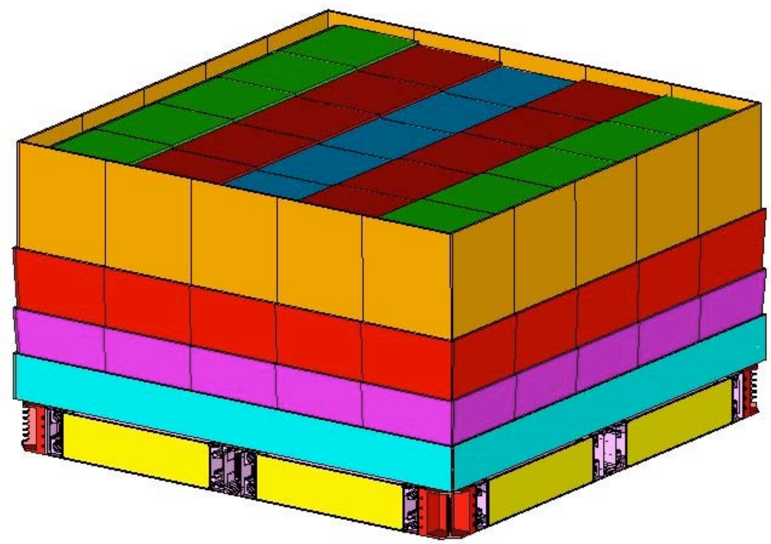
Mounting the Electronics Chassis into the Base Frame Assembly forms the BEA

ACD Assembly Overview

Tile Shell Assembly (TSA), Base Electronics Assembly (BEA), and ACD

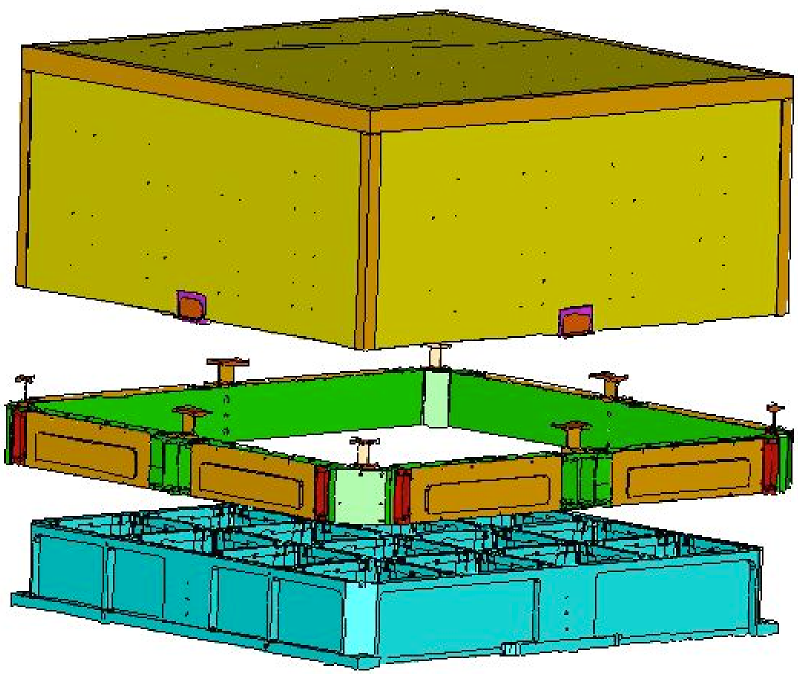






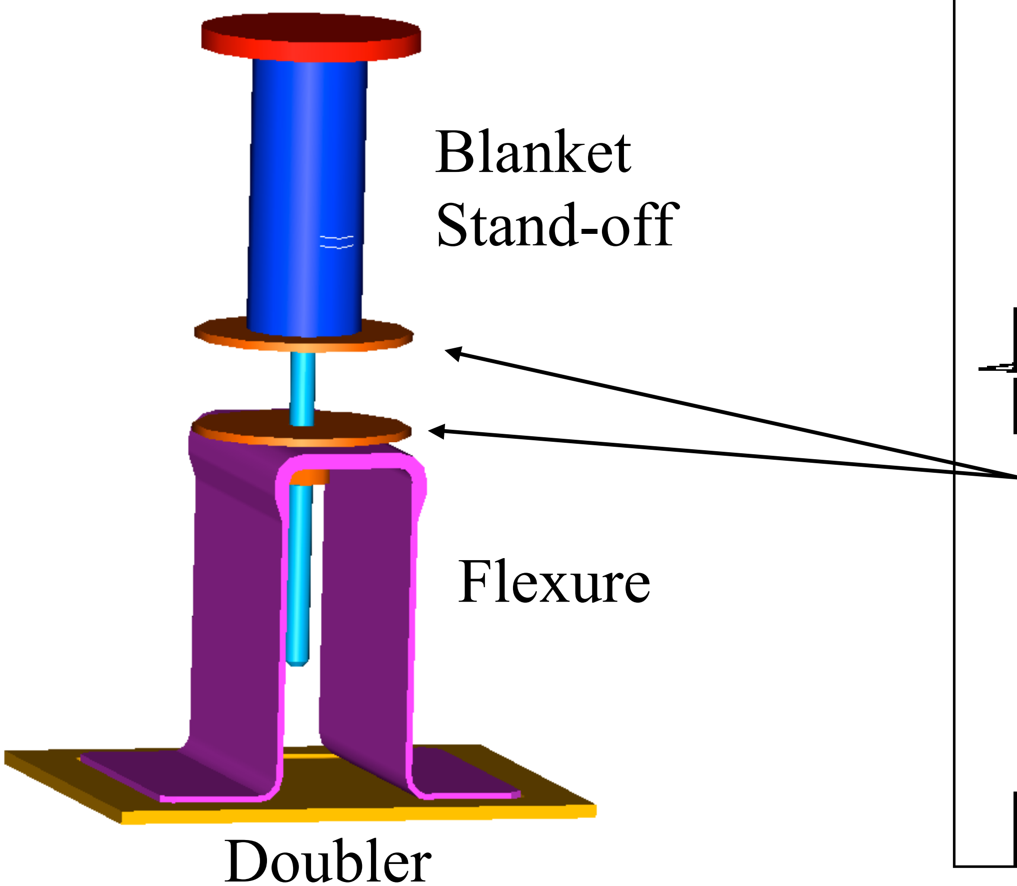
Mounting the TSA onto the BEA forms the complete ACD

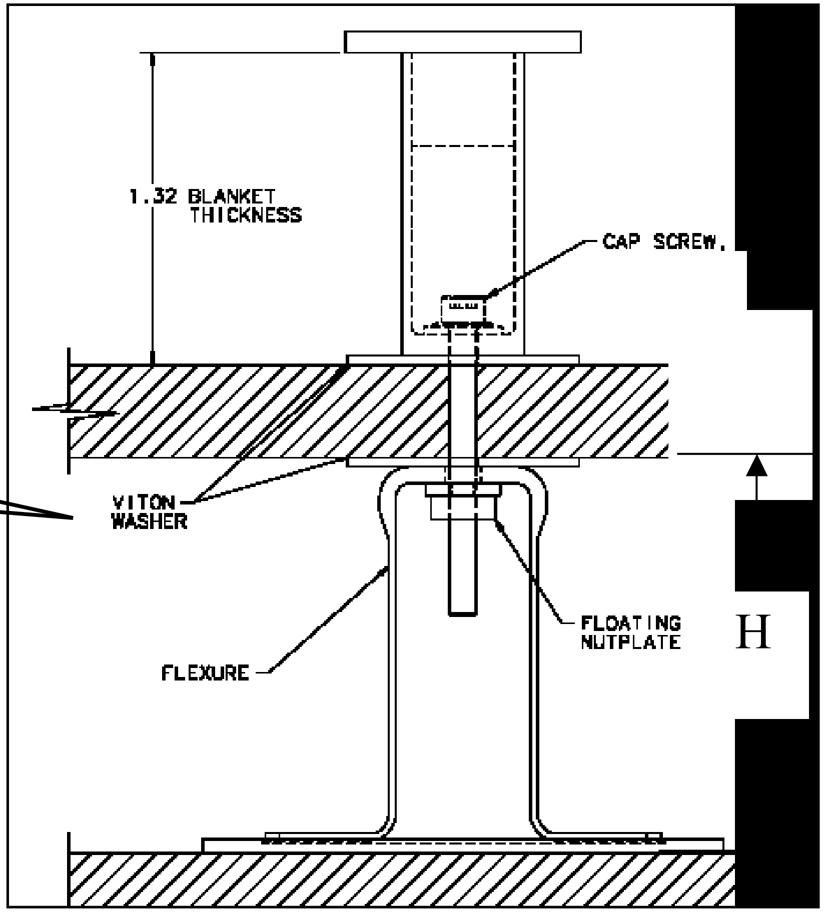
Shell Design



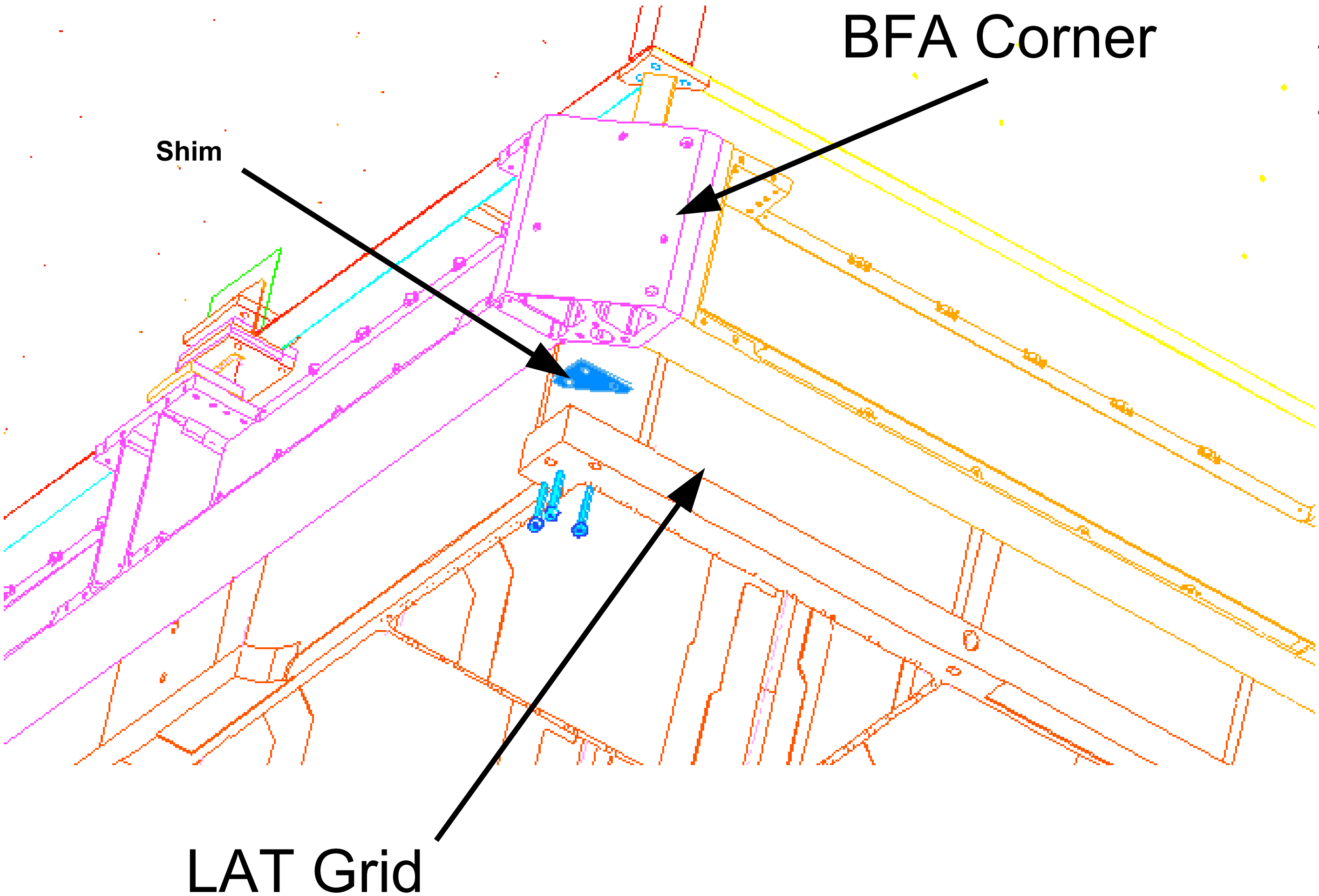
- Top & Side Panels
  - Facesheets: 20- mil M46J/EX1522-2, $[0/45/90/-45]_S$
  - H/C Core 3.1 PCF, 5056, 1"-Thick Sides, 2"-Thick Top
  - Film Adhesive: FM 73M, 0.045 PSF
  - Core fill: EY3010, Syntactic Epoxy
- Panel-to-Panel Joints
  - Mortise & Tenon (Tab & Slot) Features on Mating Edges of Panels
  - 20-mil Internal & External Clips: Braided Tape Wetted with EA9396
  - Edge Bonds: EA 9394 Adhesive
- Flexure Inserts
  - 6061 External Channel/Block Post Bonded with EA9309

Tile and Blanket/Shield Mount Design





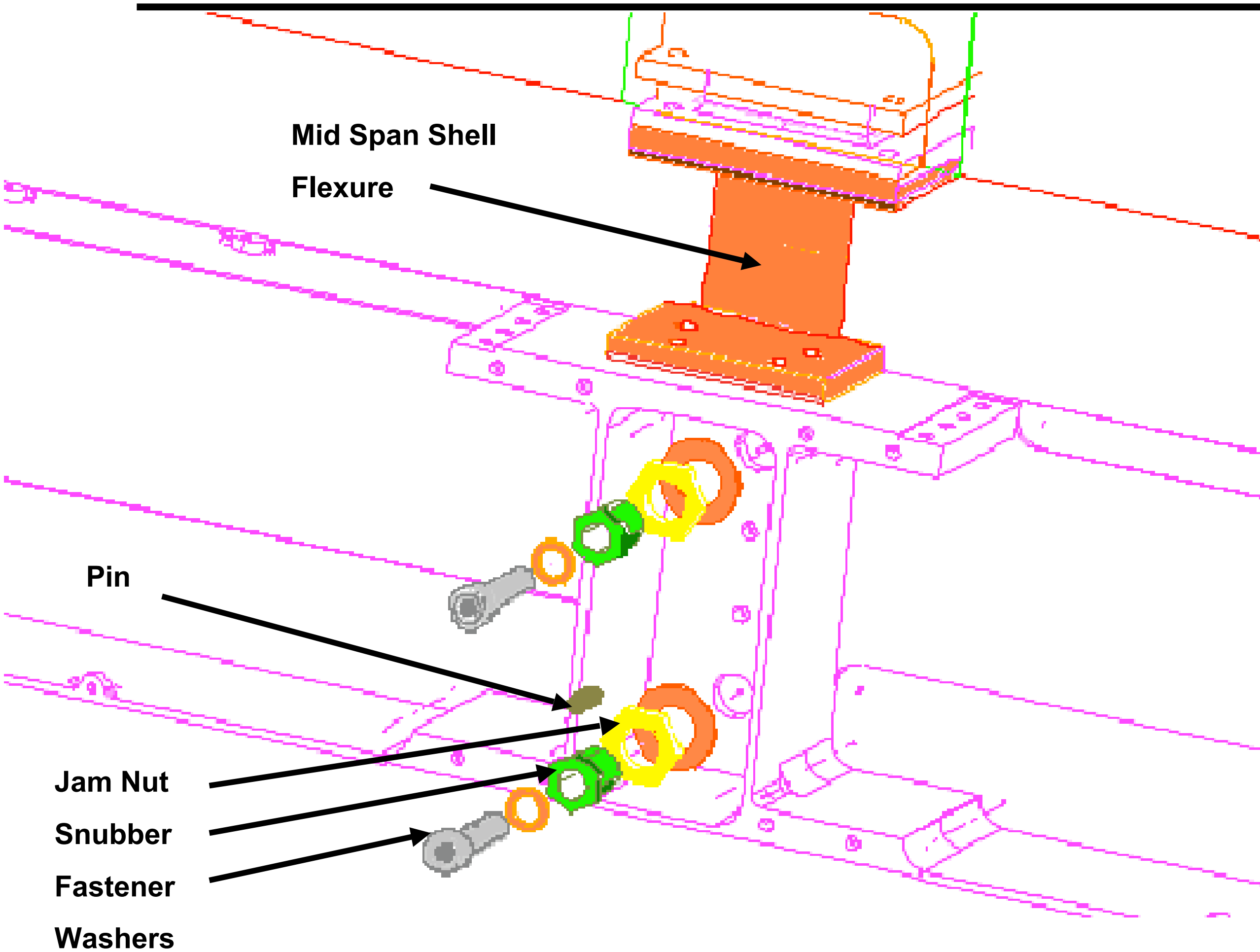
BFA Design



BFA connection to LAT Grid

- Connected in 4 corners, each with 3 fasteners and a shim.
- Registration to LAT Grid is planned via a pin and slot common to both the BFA and the LAT Grid.

BFA Design



BFA connection to LAT Grid

- At each of 4 mid-span locations 2 fasteners and slip fit pin
- Gap Between ACD and LAT Grid is taken up with adjustable snubbers.
- Pin match drilled to LAT Grid after BFA is completed.
- Pin is captured to accommodate slip fit.

Margin of Safety Summary

Tile Shell Assembly

Static

Flexure	Blade	Transverse Shear (Failure Mode of Core @ Flexure Location)	Shell Flexure Insert Block to Facesheet Bond
Corner	+1.47	+0.1 (w/potting)	+0.54
Mid-Span	+0.52	+0.3 (w/o potting)	+0.17

Thermal

Flexure	Blade	Transverse Shear (Failure Mode of Core @ Flexure Location)	Shell Flexure Insert Block to Facesheet Bond
Corner	+1.44	+0.16 (w/potting)	+0.05
Mid-Span	+0.95	+2.36 (w/o potting)	>20.0

Margin of Safety Summary

TDA and its Interfaces

	Part	Loading	Failure Mode	Applied Stress, psi	Allowable Stress, psi	Safety Factor	MS
1a	Tile	Vibro-Acoustic	Bending	660	4450	2.60	1.59
1b			Bearing	1960	6670	2.60	0.31
1c		Vibro-Acoustic+ Preload	Compression	3280 ultimate	4450	2.60	0.36
2a	Flexure & Interfaces	Thermally Induced motion of 0.035"	Lower Radii or Cap Delam	3300	8000	1.50	0.62
2b		Vibro-Acoustic (Strong Axis)	Lower Flange Delam	1540	8000	1.50	2.46
2c			Core Crushing	123	360	1.50	0.95
3	Tile Screw	Vibro-Acoustic	Tension+ Bending	139000 ultimate	160,000	1.40	0.15
4	Blanket Standoff	Handling	Bending	1590	16,500	2.60	2.99

Note: Applied Stress is at the Limit Level unless otherwise indicated

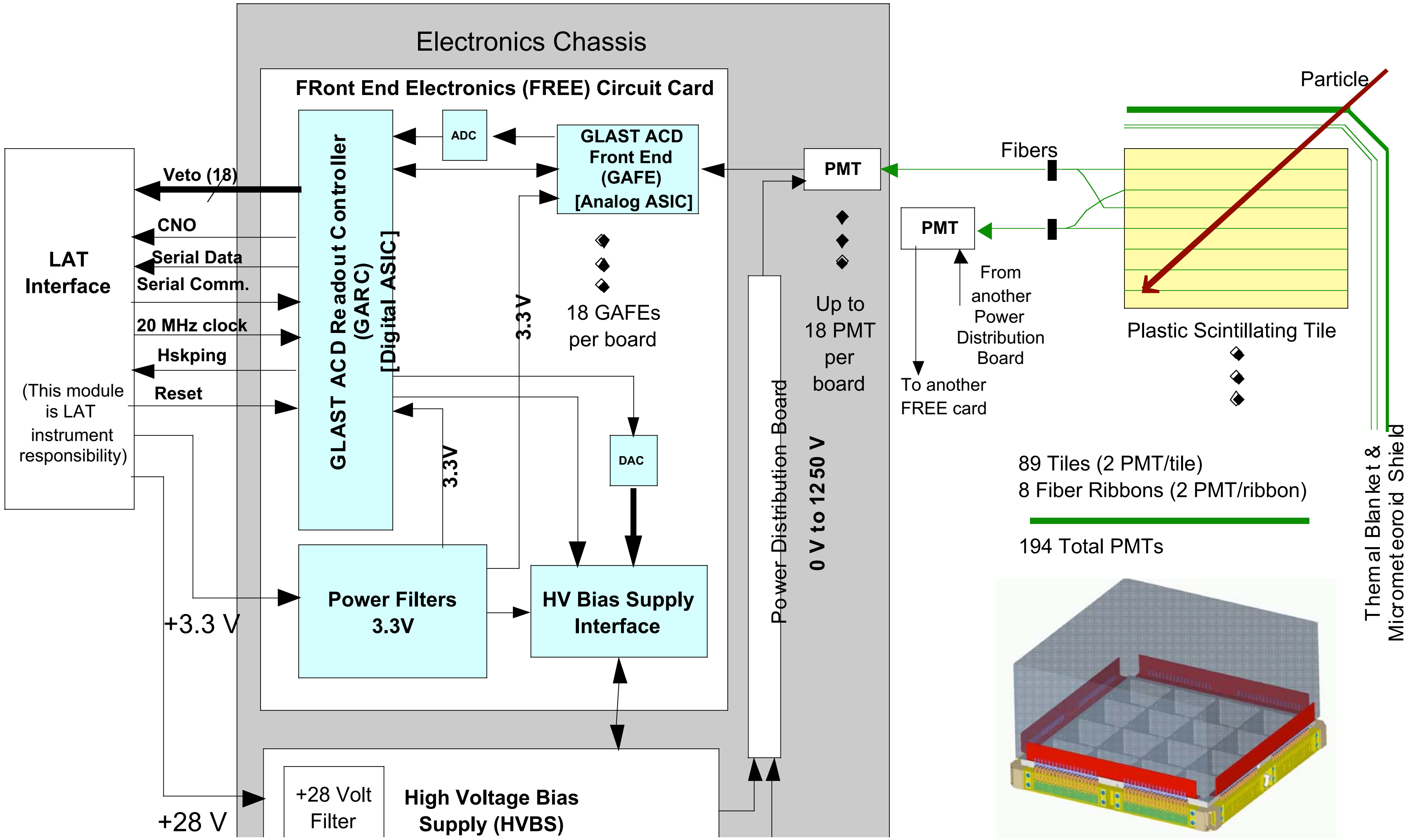
Margin of Safety Summary

Base Frame Assembly and Chassis

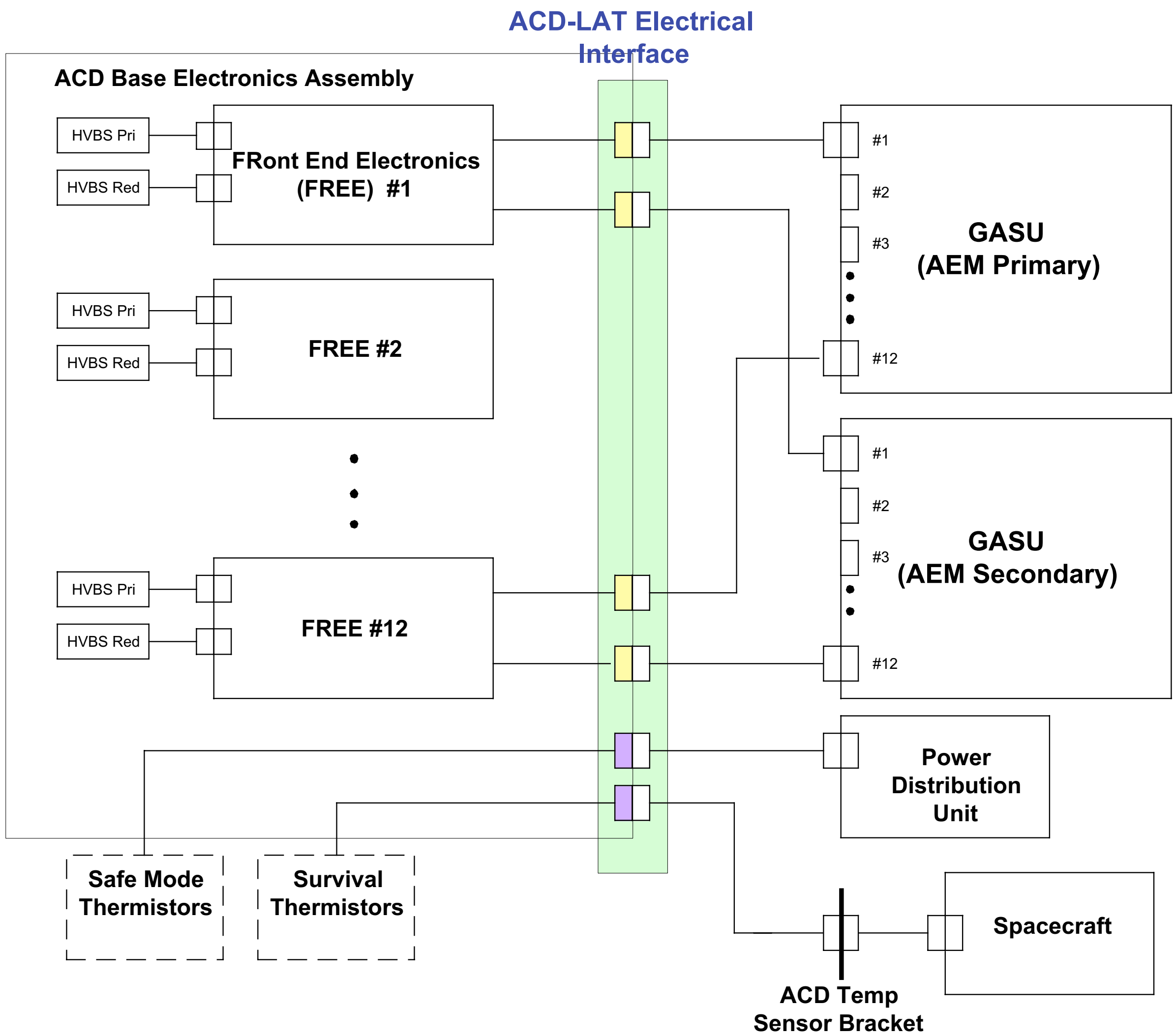
BFA		Lift	Vibro-Acoustic	Design Limit Loads	Thermal
Material Strength					
Yield Stress	ksi	35	35	35	35
Ultimate Stress	ksi	42	42	42	42
Applied Stress	ksi	12.92	7.86	6.35	14.15
Margin of Safety Yield		***0.35***	***1.23***	***1.76***	***0.24***
Margin of Safety Ultimate		***0.25***	***1.06***	***1.54***	***0.14***

Chassis		
Material Strength		
Yield Stress	ksi	35
Ultimate Stress	ksi	42
Applied Stress	ksi	10.27
Margin of Safety Yield		***0.70***
Margin of Safety Ultimate		***0.57***

Electrical Subsystem Topology



Electrical Interface



- 24 identical robust circular connectors (38999, series 2) & 2 circular housekeeping connectors (38999, series 2)
- Parts, pin outs, signal def, grounding all defined in ICD

DATA PRODUCTS
(defined in Reqs. and specified in ICD)

- Channel specific charged particle VETOs
- VETO hit maps
- Pulse Height Analysis (PHA)
- Diagnostics
- Housekeeping (thermistor output, voltage monitor output, direct to AEM)

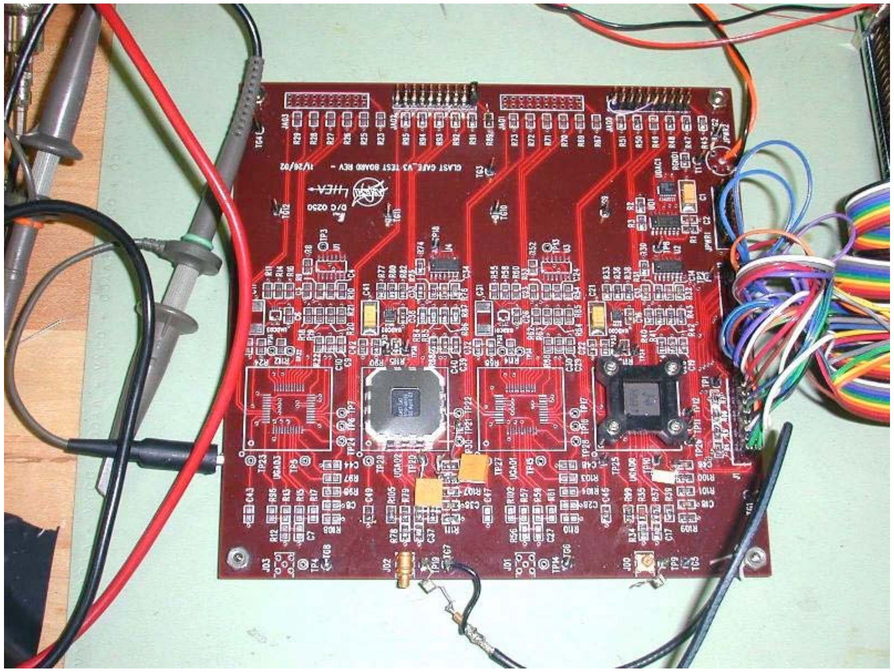
Electronics Component Design Verification

- **ASICs to be tested & screened with a separate bench-top test station at GSFC**
- **Maxim 145 and Maxim 5121 will be screened at NRL and delivered to GSFC**
- **Maxim 494 to be screened by GSFC**
- **Front-end Electronics boards to be performance and environmental tested at GSFC prior to integration with ACD**
- **High Voltage Bias Supplies to be performance and environmental tested at GSFC prior to integration with ACD**
- **Photomultiplier Tubes will be screened by a flight-approved vendor and tested at GSFC prior to integration with ACD**
- **Biasing Resistor Networks will be performance and environmental tested at GSFC prior to integration to ACD**

  – Level IV Requirement 5.12 Radiation Tolerance. The ACD electronics shall remain within specifications after a total ionizing radiation dose of 4.5 kRad(Si).
  – Level IV Requirement 5.12.1 Single Event Upset Tolerance. A single event upset (SEU) shall not cause the ACD electronics to transition to an unsafe state.
  – Level IV Requirement 5.12.2 Latchup Tolerance. Parts that show any SEE's at an LET lower than 37 MeV*cm^2/mg shall not degrade the mission performance.

GAFE (Analog ASIC) Testing

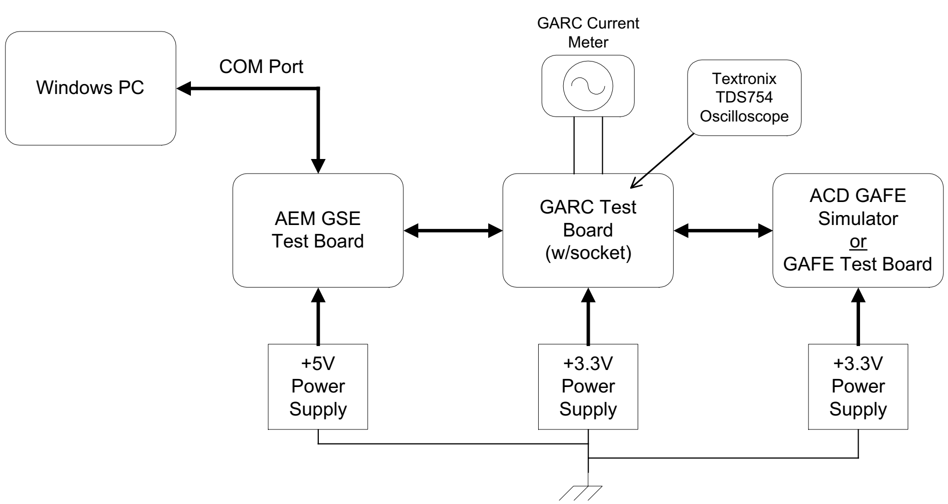
- GAFE v2 testing (ACD-PROC-000067) and test report (ACD-RPT-000073) are complete.
  - Demonstrated GARC-to-GAFE digital core interface
  - Demonstrated GAFE-to-PMT subassembly interface
  - Met noise and Integral non-linearity requirements
  - Inadequate buffers made GAFEv2 unacceptable
- Test procedure was updated for use in GAFEv4 testing.
- GAFEv4 testing in progress; GAFEv5 just delivered, testing started.
- Radiation testing planned for GAFEv5

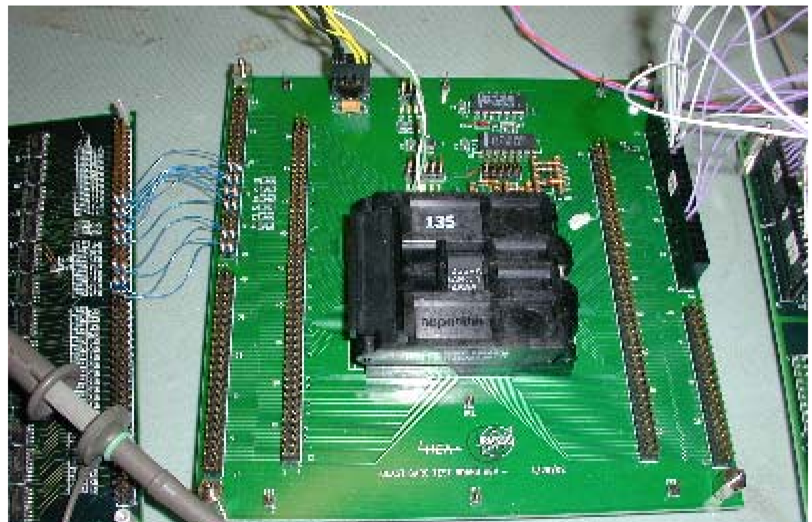


GAFEv4/v5/v6 4-channel test board

GARC (Digital ASIC) Testing

- GARCv1 fully tested. GARCv2 just delivered, testing started.
- Test report details available (ACD-RPT-000073)
  Identified 9 issues with GARCv1. All were straight-forward and simple fixes to a good design. GARCv2 has one known (not fatal) problem.
- GARC test procedure is developed and is being used to test GARCv2





GARC test board

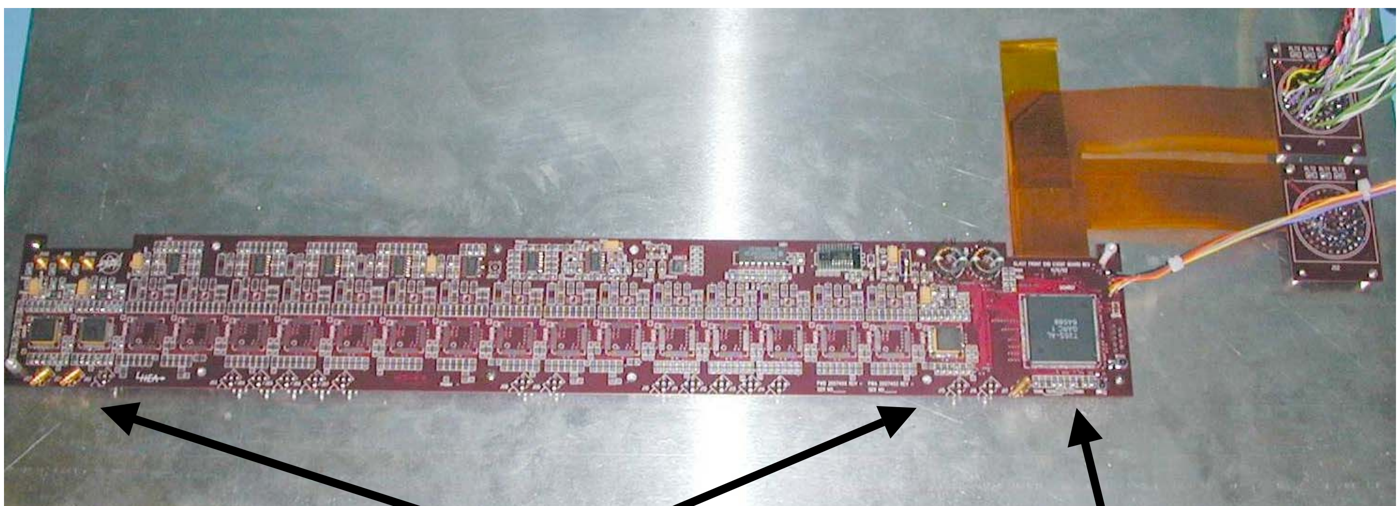
Front End Electronics Board (FREE)

Engineering model FREE card tested with GAFEv4 and GARCv1

Demonstrates functionality of the system

Minor improvements being incorporated into the flight design

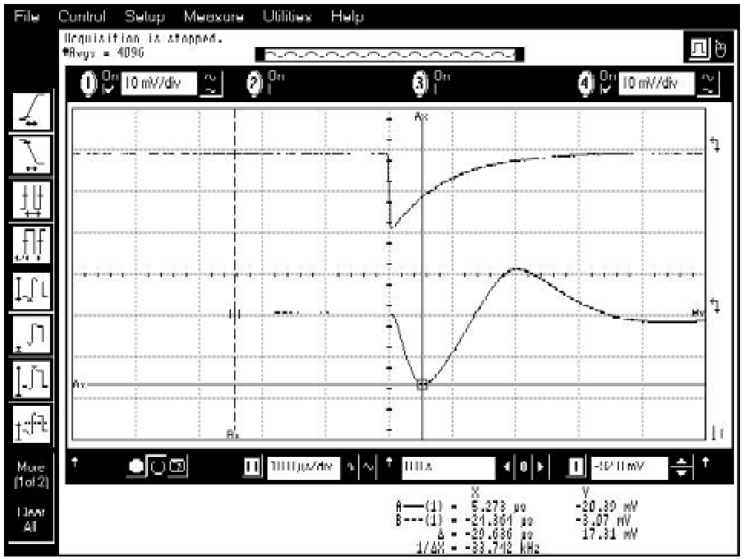
Full FREE card testing will be done with GAFEv5 and GARCv2, just delivered.



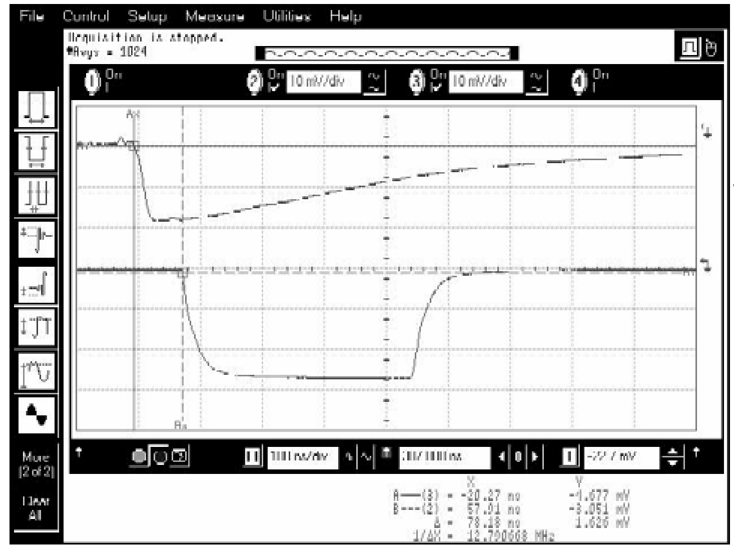
GAFEs GARC

Electronic Bread Board Test Results

Test with PMT

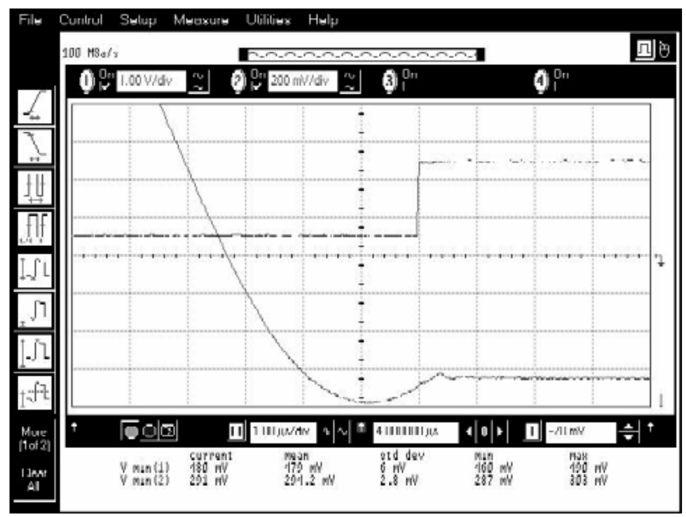


VETO Generation_

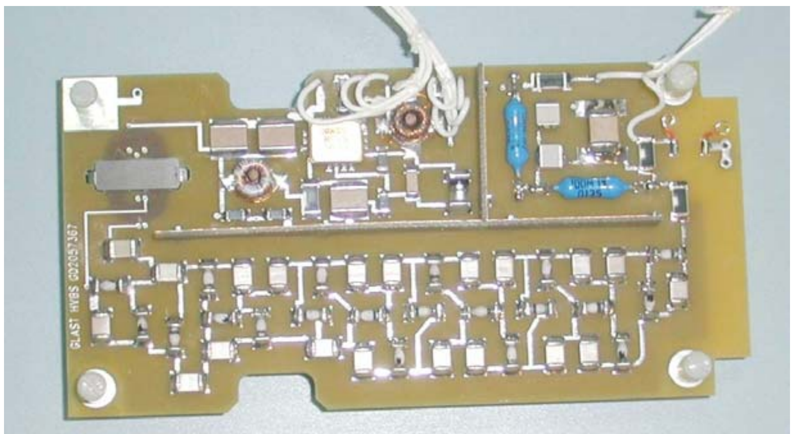


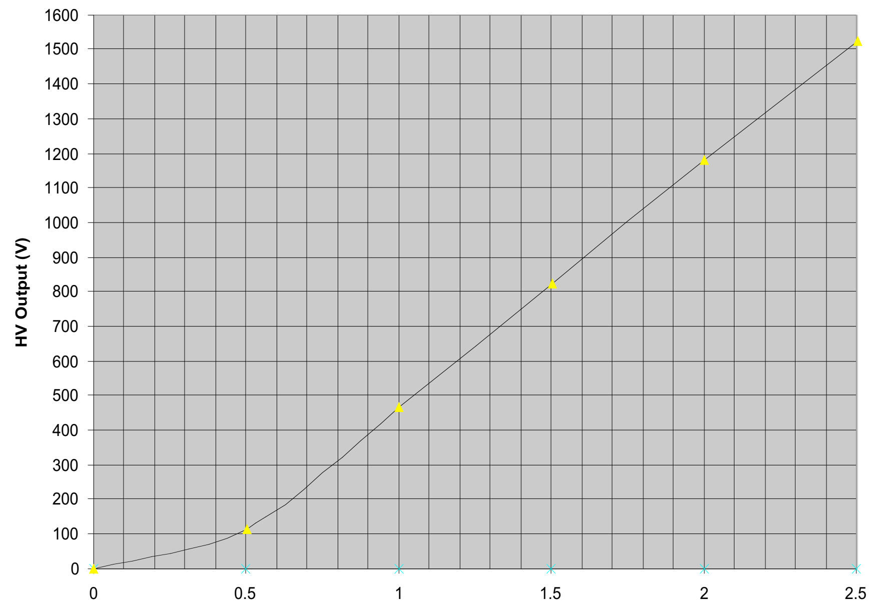
- Demonstrated ACD to LAT interface
- Demonstrated GARC to GAFE communication
- Demonstrated PMT signal processing
- Demonstrated VETO and HLD processing

Sample & Hold_



High Voltage Bias Supply (HVBS)

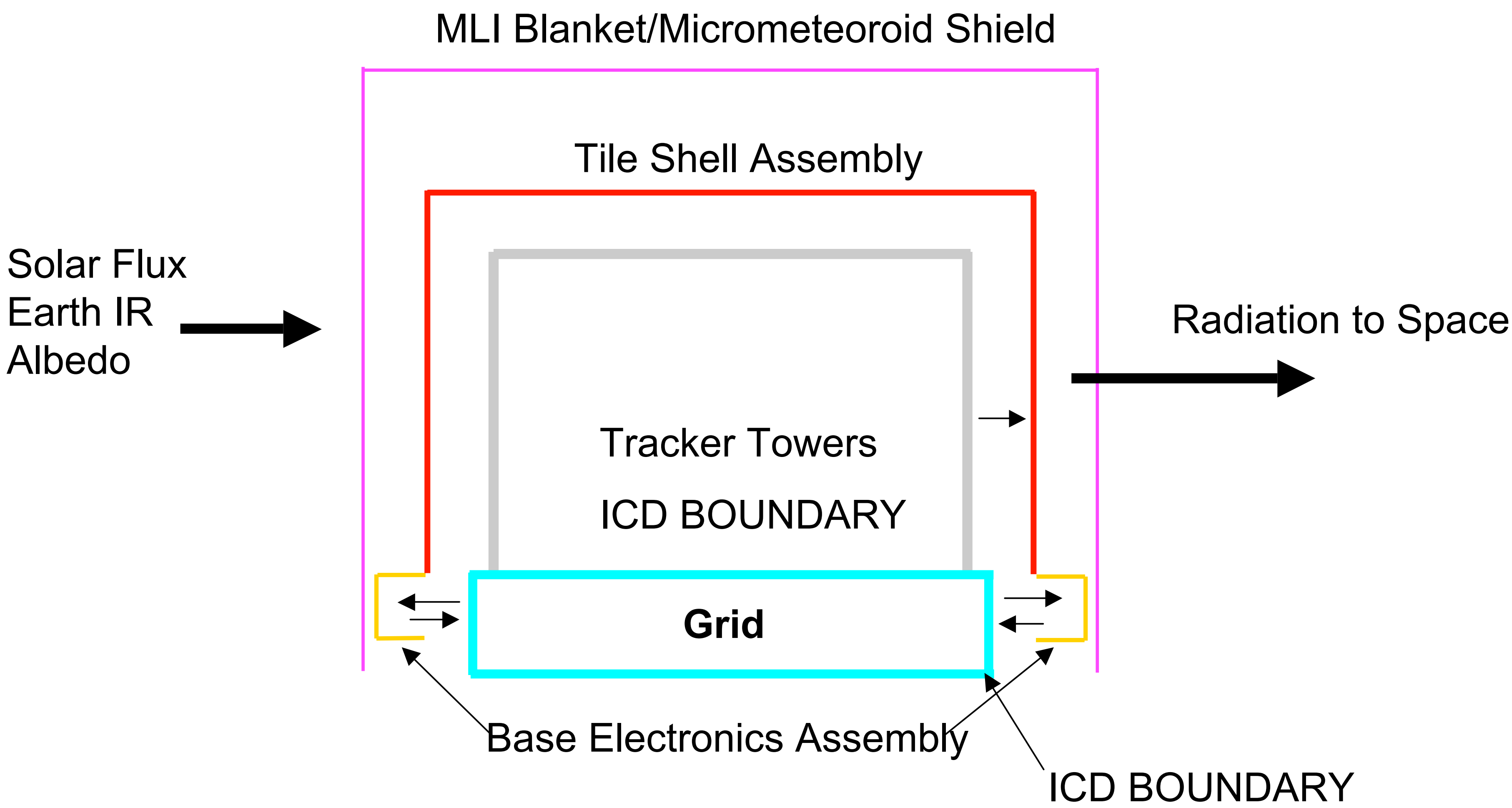




Engineering Unit HVBS currently in testing

Performance meets requirements over expected temperature range

ACD Thermal Design Configuration



Thermal Analyses Assumptions

Orbital Analysis

- Thermal Environment Design Parameters

COLDHOTUNITSEARTH IR6684Btu / Hr sq. ft208265 SOLAR CONSTAN'

- Optical properties

TSS Optics Name	Description	Emissivity (BOL)	Absorptivity (BOL)	Emissivity (EOL)	Absorptivity (EOL)
3_mil_Kapton	Interior Closeouts	0.79	*	0.75	*
3 mil Ge Black Kapton	Exterior MLI Blanket	0.82	0.51	0.78	0.55
Black Anodize	Tracker Towers	0.82	*	0.78	*
Black Anodize	Grid Exterior and BEA	0.82	*	0.78	*
m46J/RS-3	ACD Shell	0.93	*	0.90	*

Thermal Design Results

Description	Cold Operating Temperature	Hot Operating Temperature	Cold Survival Temperature	Hot Survival Temperature	Operating Temperature Limits	Survival Temperature Limits
Grid Boundary	-10	20	-15	30	-	-
Trackers Boundary	-10	25	-20	30	-	-
ACD Composite Shell	-13	26	-23	31	-	-
Tile Detector Assembly	-16	27	-25	32	-30 to 35	-60 to 45
BEA ±X Rail	-10	24	-16	31	-20 to 35	-40 to 45
BEA ±Y Rail	-9	24	-16	29	-20 to 35	-40 to 45

- **All temperatures in ºC**
- **Predictions shown are raw predicts and margin does not reflect 5 ºC analytical uncertainty**

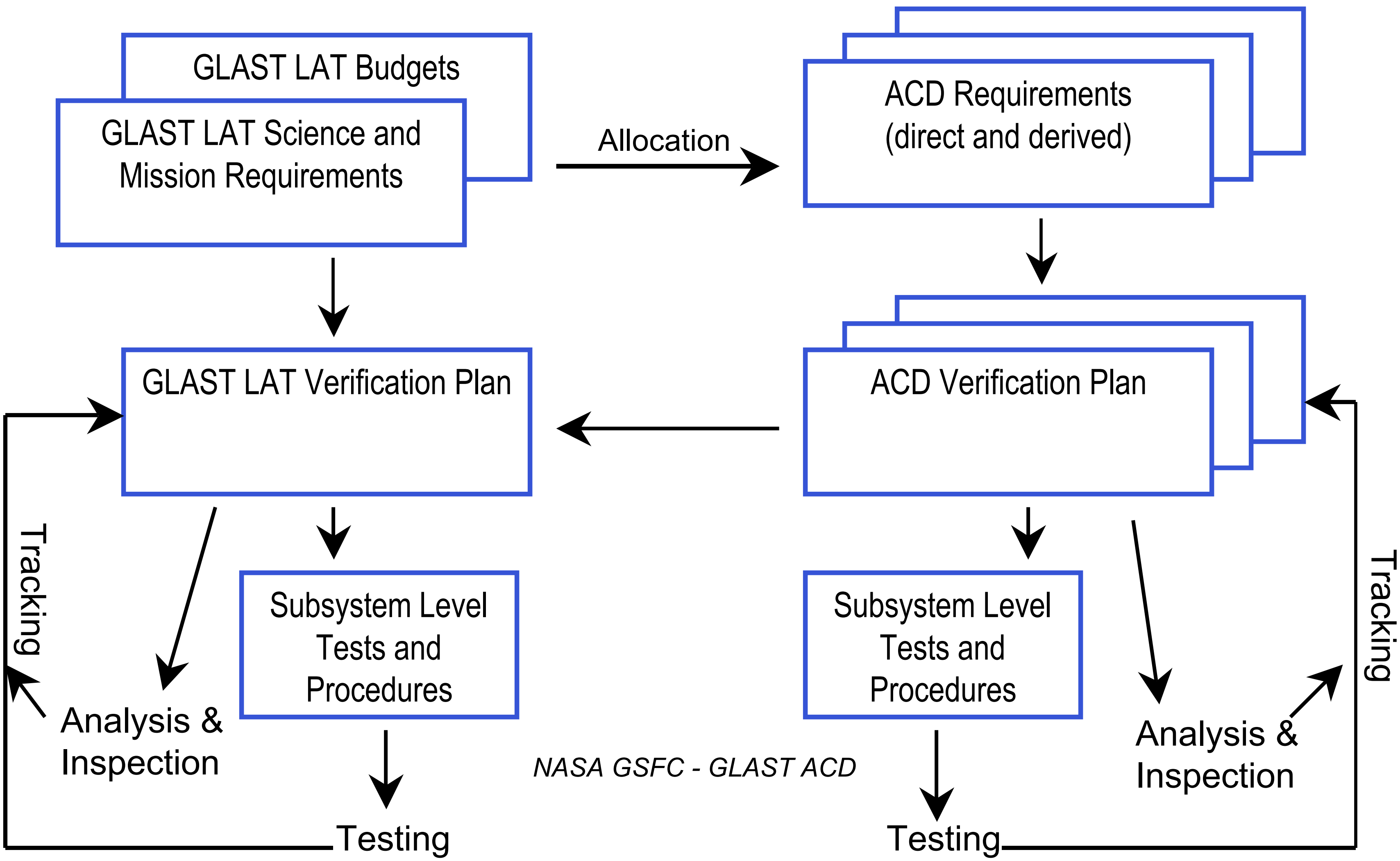
Drawings and Parts

- ACD Drawing Tree (GE 2054502) – 100 drawings
  - 47 Completed
  - 9 In progress
  - All hardware has been modeled
- EEE parts
  - ASICs not yet completed
  - All other parts are approved by Parts Control Board, in testing, or waiting for information
- Mechanical parts and materials
  - All approved

Verification Program

Section 11-4

ACD Requirements and Verification Tracking



NASA GSFC - GLAST ACD

ACD Verification Database

- ACD has created a Verification database in DOORS linked to the Requirements Database to Track Verification (Verification Plan - ACD-PLAN-000050)

ACD Verification Tracking Database

LAT ACD Subsystem Level IV Requirements and Verification Table, LAT-SS-00352	Verification Method	Verification Procedure	Verification Stage/Status	Verification Rationale/Comment	Verification Action	1st tim
5.2 Charged Particle Detection						
The ACD shall produce both fast and slow VETO signals in response to PMT signals resulting from charged particles traversing the ACD tiles and ribbons.	Test	ACD Comprehensive Performance Test (CPT) (ACD-PLAN-000038)	Not Started	Muons test		
5.3 Adjustable Threshold on VETO Detection of Charged Particles						
The threshold for detecting charged particles shall be adjustable from 0.064 to 1.28 pC (0.1 to 2 MIP), with a step size of ≤0.032 pC (0.05 MIP).	Test	ACD CPT (ACD-PLAN-000038) FREE Functional Test (ACD-TBD-XX)	Not Started	The FREE Functional will characterize the adjustable threshold to the spec step size. The CPT will test this adjustabililty with the TCI circuit, however, it currently doesn't have the resolution to fully test this function.		
5.4 False VETO due to Electrical Noise						
The total ACD false VETO trigger rate due to noise shall be less than 10 kHz (~46Hz per channel) at 0.096 pC (0.15 MIP) threshold (assuming 1 us VETO pulses).	Analysis Test Simulation	ACD CPT (ACD-PLAN-000038)	Development	Set threshold to 0.15 MIP and then reduce HVBS output until VETO count rate no longer decreases. The resulting VETO rate is the false trigger rate due to noise.		
5.5 High-Threshold Detection						
The ACD shall detect pulses due to highly ionizing particles, carbon	Test	ACD CPT (ACD-PLAN-	Development	200 to 1000 MIP will be		

Links between Requirements

- ACD Level III and IV Requirements Database
- ACD-LAT ICD Requirements and Verification Database
- ACD Allocation Tables
- ACD Test Databases

Performance Testing - Efficiency Demonstration

The approach:

measure the performance for active elements (tiles, fiber ribbons)

measure the characteristics of passive elements (WLS and clear fibers)

measure values for dead areas (gaps)

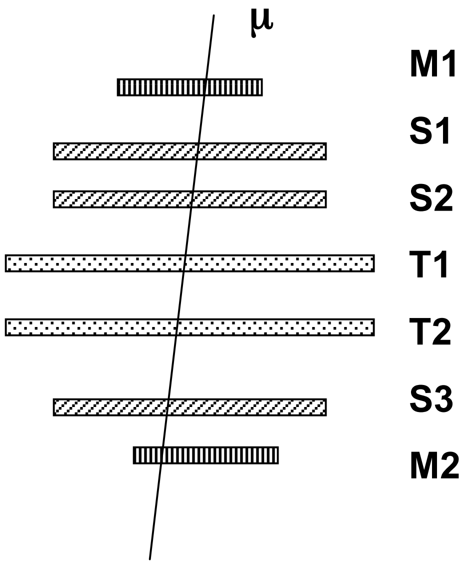
put everything in the simulation code to determine the resulting efficiency

check the results by measuring the efficiency directly in several areas of ACD and comparing with that obtained by simulations

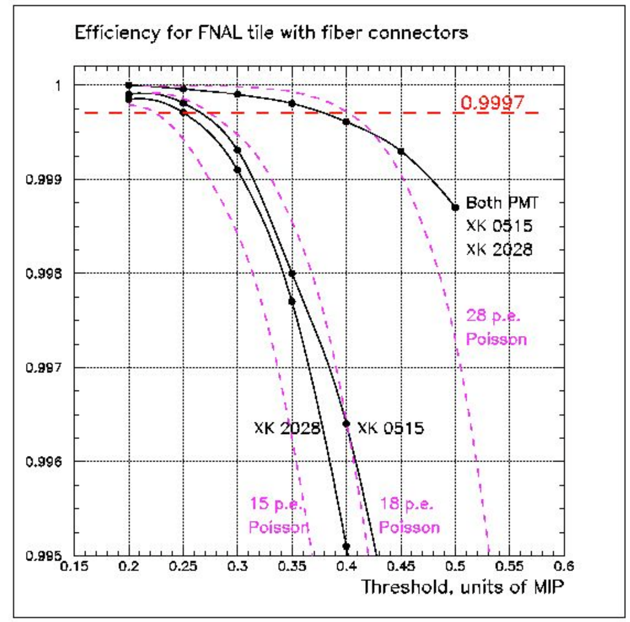
This approach also determines margins and relative importance of the contributors to the entire efficiency

Active elements performance - TDA

(LAT-TD-00843-D1)



Measure the light yield and efficiency for the Fermilab-made TDA prototypes (T1 and T2) equipped with clear fiber extensions and fiber-to-fiber connectors (made by GSFC)



Efficiency measurement setup:

M1, M2 - hardware trigger scintillators

S1, S2, S3 - software trigger scintillators

T1, and T2 - tested TDA's

Conclusion: with one of the two phototubes operating, the TDA efficiency is slightly below the 0.9997 ACD requirement at nominal threshold; with both phototubes operating, the efficiency of the TDA meets the ACD requirement with significant margin.

Efficiency Demonstration – Full ACD

Current gaps at -20 C° are used:

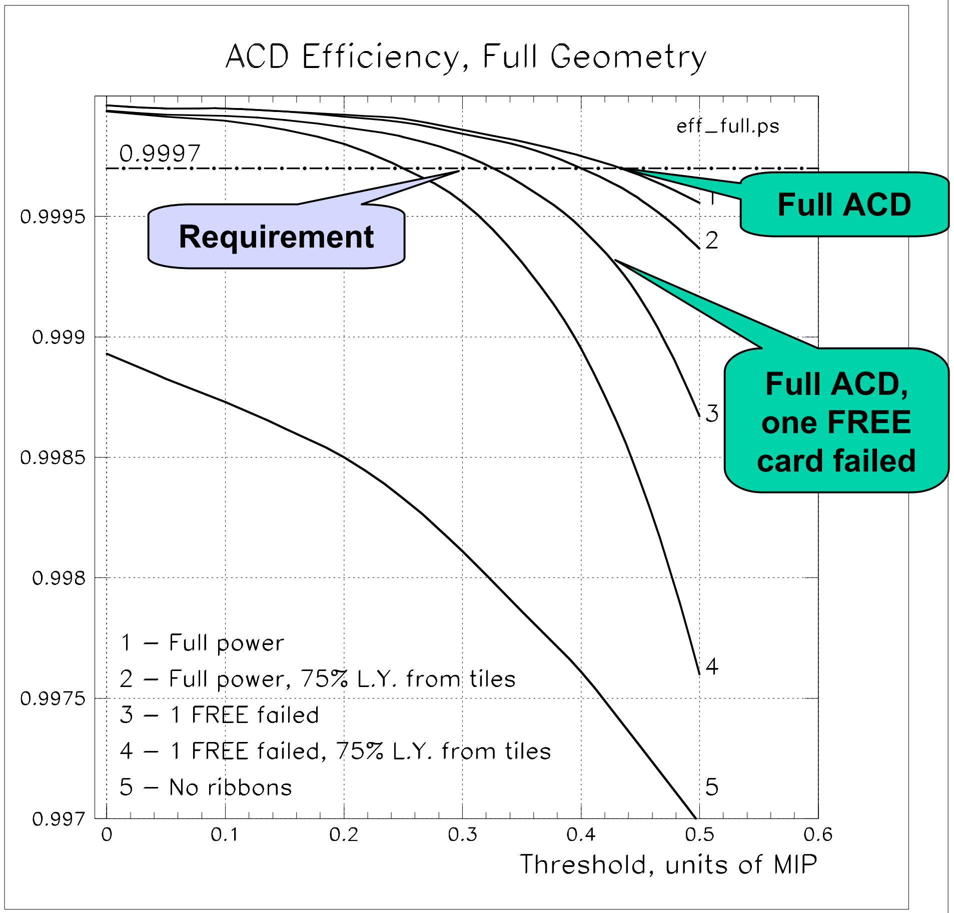
- **between tiles - 3 mm**
- **at the top perimeter - 4 mm**
- **at the vertical corners - 4 mm**
- **vertical clearance between tiles - 2.6 mm**

3-layer fiber ribbon, with light yield of 8 photoelectrons (conservative, measured)

2 cm tile overlap

Light yield at PMT- 26 photoelectrons (conservative, measured)

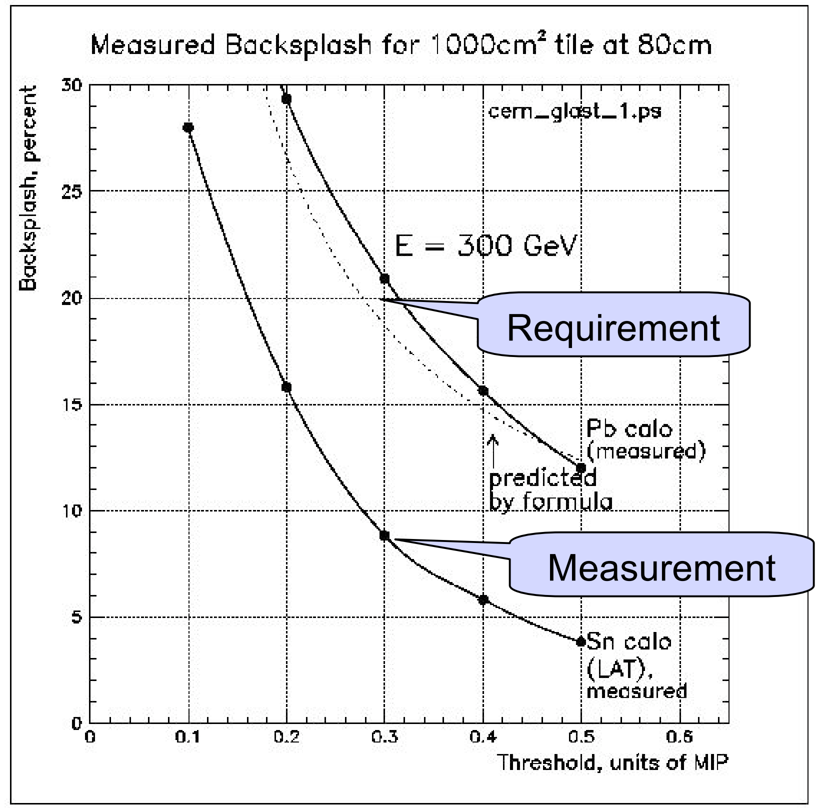
Light propagation based on measured fiber routing and connector efficiency.



ACD meets the efficiency requirement even with one FREE card failed

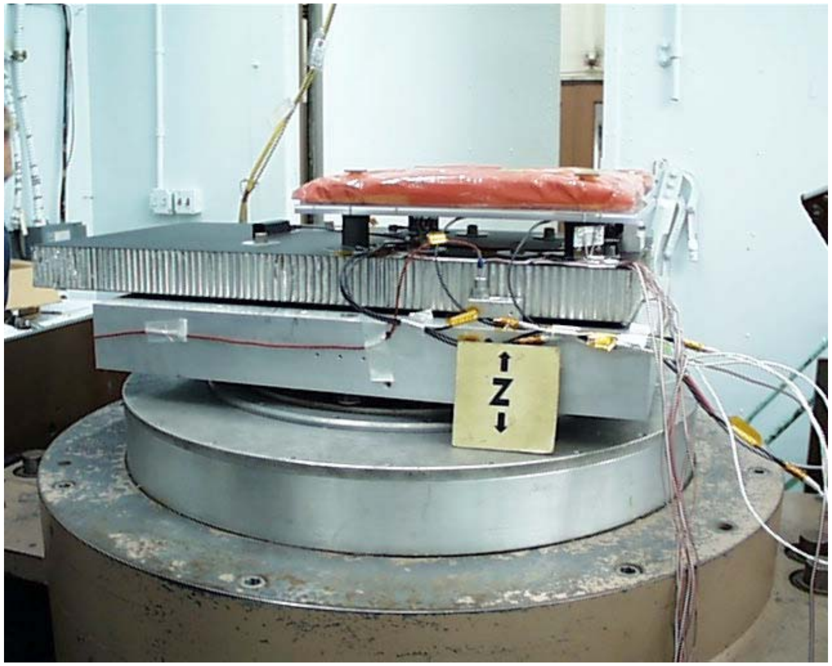
Backsplash Measurement/Simulation

- ACD segmentation is based on a formula developed from 1997 beam tests at SLAC/CERN and checked with a GEANT model.
- Small differences among the methods were investigated at CERN in 2002.
- Consistent results were obtained when the calorimeter material was included in the model (Sn used to simulate CsI).
- The resulting backsplash is now less than originally expected, giving the ACD some margin on this requirement.



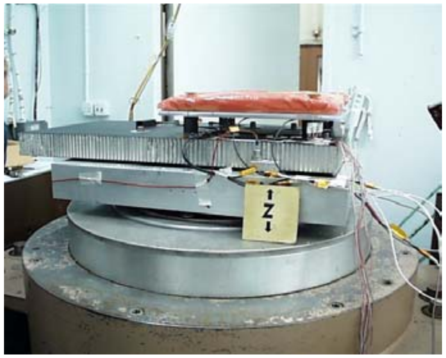
ACD Testing Overview

- Due to size and cost, there is no full-size ACD Engineering Model. The full-size mechanical mockup is used only for fit checks and fabrication of the micrometeoroid shield/thermal blankets.
- Acceptance and Qualification tests, including performance, vibration, EMI/EMC, and thermal vacuum, are carried out at the component and subassembly level. Extrapolation to the full ACD is done by analysis.
- The full protoflight ACD will undergo a complete suite of tests, including absolute efficiency measurement as well as all environmental tests.



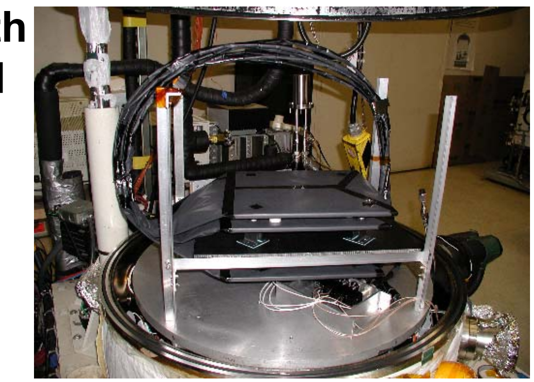
Subassembly vibration testing – a section of support shell, composite flexures supporting a scintillator tile, and a micrometeoroid shield/thermal blanket. A similar test included the waveshifting fibers, optical connector, optical fibers, and phototubes.

Development Environmental Testing – Tile Shell Assembly



Vibration testing – a section of TSA support shell, composite flexures supporting a scintillator tile, and a micrometeoroid shield/thermal blanket. A similar test included the waveshifting fibers, optical connector, and optical fibers.
ACD-PLAN-000032, LAT-ACD Tile Detector Test Vibration Test Plan

Thermal Vacuum testing – a section of support shell with composite flexures, three Tile Detector Assemblies, and four PMT/RN assemblies were exposed to 6 thermal vacuum cycles.
ACD-PROC-000068, TDA-PMT-Resistor Network End-to-End Thermal-Vacuum Test Procedure



Vibration testing – 4 PMT/RN assemblies with clear fibers connected to 3 TDA's (not vibrated) were subjected to vibration testing.

Development Environmental Testing – Base Electronics Assembly

A section of the Base Frame Assembly

- One Electronics Chassis
- Two FREE boards
- Four HVBS boards
- Up to 36 Phototube assemblies
- Mechanical structure

Testing similar to that done for the TSA Engineering Model

- Low-level sine
- Sine burst
- Sine vibration
- Random vibration
- Mass properties
- Interface verification
- Electrical functional
- 12-cycle thermal vacuum

Scheduled for July/August 2003 (driven by ASIC availability)

Test Matrix

Green – Flight

Yellow - Engineering

Green rows - Flight component rows
Yellow rows - Engineering Model rows

	Level of Assembly	Unit Type	Supplier	Test Levels	Test Status	Modal Survey (low level sine survey)	Static Loads	Sine Burst	Sine Vibration	Random Vibration	Mechanical Function/	Optical Performance Testing	Acoustics	Mass Properties	Interface Verif.	EMC/EMI	ESD Compat (Grounding?)	Magnetics	Screening Process	Aliveness (A) / Functional (F) / Comprehensive (C)	Thermal Vacuum Cycle (Total of 12 cyc for qual, 4 for accpt)	Thermal Cycle	Thermal Balance
FULLY INTEGRATED ACD	**S**	**F**	**GSFC**	**Prtoflt**		**X**		**X ?**	**X**			**X**	**X**	**X**	**X**	**X**	**X**			**C**	**4**		**X**
Tile Shell Assembly	SA	F	GSFC	Acpt										X									
Tile Shell Assembly - partial	SA	D	GSFC	Qual		X	X	X	X	X	X			X							6		
ACD Mechanical Subsystem (no	S	F	GSFC	Qual		X-e		X-e	X-e		X		X	X								?	
Shell	C	F	TBD	N/A										X									
Shell - partial	P	D	GSFC	Qual			X-b																
Tile Detector Assembly	SA	F	Fermilab	Acpt								X		X						A, F			
Tile Detector Assembly	SA	S	Fermilab	Acpt				X	X			X	X	X							12		
Tile Detector Assembly	SA	EM	Fermilab	Qual				X	X	X-m		X		X						F	6		
Tile Detector Assembly	SA	D	Fermilab	Qual								X									12		
TDA Tiedown (Flexure)	P	F	GSFC	Prtoflt																			
TDA Tiedown (Flexure)	P	EM	GSFC	Qual			X ?	X	X	X-m	X			X									
TDA Tiedown (Flexure)	P	D	GSFC	Qual			X-b																
WSF/Clear Fiber Connector	C	F	GSFC	Acpt								X		X						A, F			
WSF/Clear Fiber Connector	C	EM	GSFC	Qual			X	X	X	X-m	X	X		X						F			
WSF/Clear Fiber Connector	C	D	GSFC	Qual								X								A		8	
Base Frame	C	F	GSFC	Qual			X				X			X	X								
Partial BFA & Electronics Chassis	SA	EM	GSFC	Qual		X		X	X	X-m				X	X	X	X?	X?		F		2?	
Base Frame - partial	C	D	GSFC	Qual																			
Shield & Thermal Blanket	C	F	GSFC											X									
Shield & Thermal Blanket -see remark	C	EM	GSFC											X									
Shield & Thermal Blanket	C	D	JSC, GSFC	Qual																			
Clear fiber cable assembly	SA	F	GSFC	Qual								X								A			
PMT/Fiber Connector	C	F	GSFC									X								A			
PMT/Fiber Connector	C	EM	GSFC	Qual					X	X	X	X								F	6		
PMT/Fiber Connector	C	D	GSFC	Qual								X								F		8	
Base Electronics Assembly	S	F	GSFC	Acpt										X	X					F			
Electronics Chassis	SA	F	GSFC	Acpt		X			X	X-m				X	X					F	2		
Electronics Chassis	SA	S	GSFC	Acpt		X		X ?	X	X-m				X	X					F	12		

Test Matrix

Green – Flight

Yellow - Engineering

Green rows - Flight component rows; Yellow rows - Engineering Model rows	Level of Assembly	Unit Type	Supplier	Test Levels	Test Status	Modal Survey (low level sine survey)	Static Loads	Sine Burst	Sine Vibration	Random Vibration	Mechanical Function/	Optical Performance Testing	Acoustics	Mass Properties	Interface Verif.	EMC/EMI	ESD Compat (Grounding?)	Magnetics	Screening Process	Aliveness (A) / Functional (F) / Comprehensive (C)	Thermal-Vacuum Cycle (Total of 12 cyc for qual, 4 for accpt)	Thermal Cycle	Thermal Balance
FREE Board (12)	C	F	GSFC	Acpt				1	1	1					X					F		1	
FREE Board (2)	C	S	GSFC	Acpt											X					F			
FREE Board (4)	C	EM	GSFC	Qual		1		1	1	1				X	X		X ?			F		1	
FREE Board (4)	C	D	GSFC									X			X					F			
PMT Rail assembly	SA	S	GSFC	Acpt																			
PMT Rail assembly	SA	D	GSFC	Qual*																			
PMT Subassembly (194)	P	F	H, GSFC	Acpt		1		1	1	1		X			X					F	1		
PMT Subassembly (46)	P	S	H, GSFC	Acpt				X	X	X-m		X			X					F	12		
PMT Subassembly (qual PMTs)	P	EM	H, GSFC	Qual		1		1	1	1		X		X	X		?			F	1		
PMT Subassembly (6)	P	D	H, GSFC	Qual*			X-b		X	X-m					X					F	6		
PMT Subassembly (30)	P	C	H, GSFC												X					F		X	
PMTs (not bonded) (240)	P	F	H	Acpt?						X-s		X							X	F-s			
PMTs (not bonded) (10)	P	D	H	Acpt?						X-s		X							X	F-s			
PMTs (not bonded) (30)	P	C	H	Acpt						X-s		X							X	F			
Resistor Networks now part of PMT subassy	C	D	GSFC											X	X					F			
Power Dist brd	C	F	GSFC	Acpt				1	1	1										F	1		
Power Dist brd	C	S	GSFC	Acpt																F			
Power Dist brd	C	EM	GSFC	Qual		1		1	1	1										F	1		
HVBS (24)	C	F	GSFC	Acpt				1	1	1					X					F	1		
HVBS (2)	C	S	GSFC	Acpt											X					F			
HVBS (4)	C	EM	GSFC	Qual		1		1	1	1					X		?			F	1		
HVBS (3)	C	D	GSFC																	F			

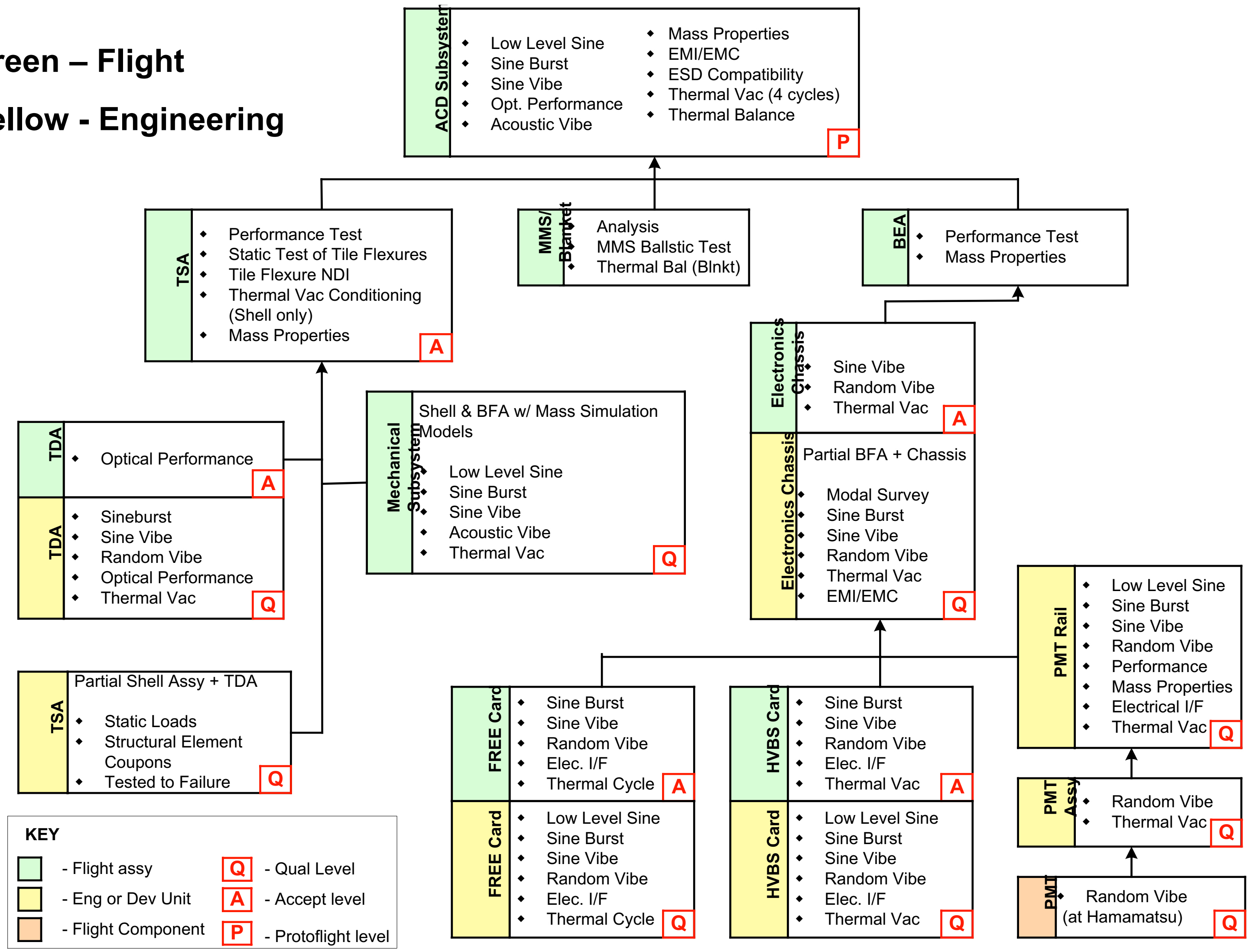
LEGEND:

LEVEL OF ASSEMBLY	UNIT TYPE	SUBNOTES:
S - Subsystem	D - Development Model	1. Only first unit is tested at this assembly level
SA - Subassembly	EM - Engineering Model	b. Test-to-failure
C - Component	F - Flight	c. Some units MAY be tested at next higher ass'y instead
P - Part	S - Spares	e. Test with mass models

Top Level Environmental Test Flow (from matrix)

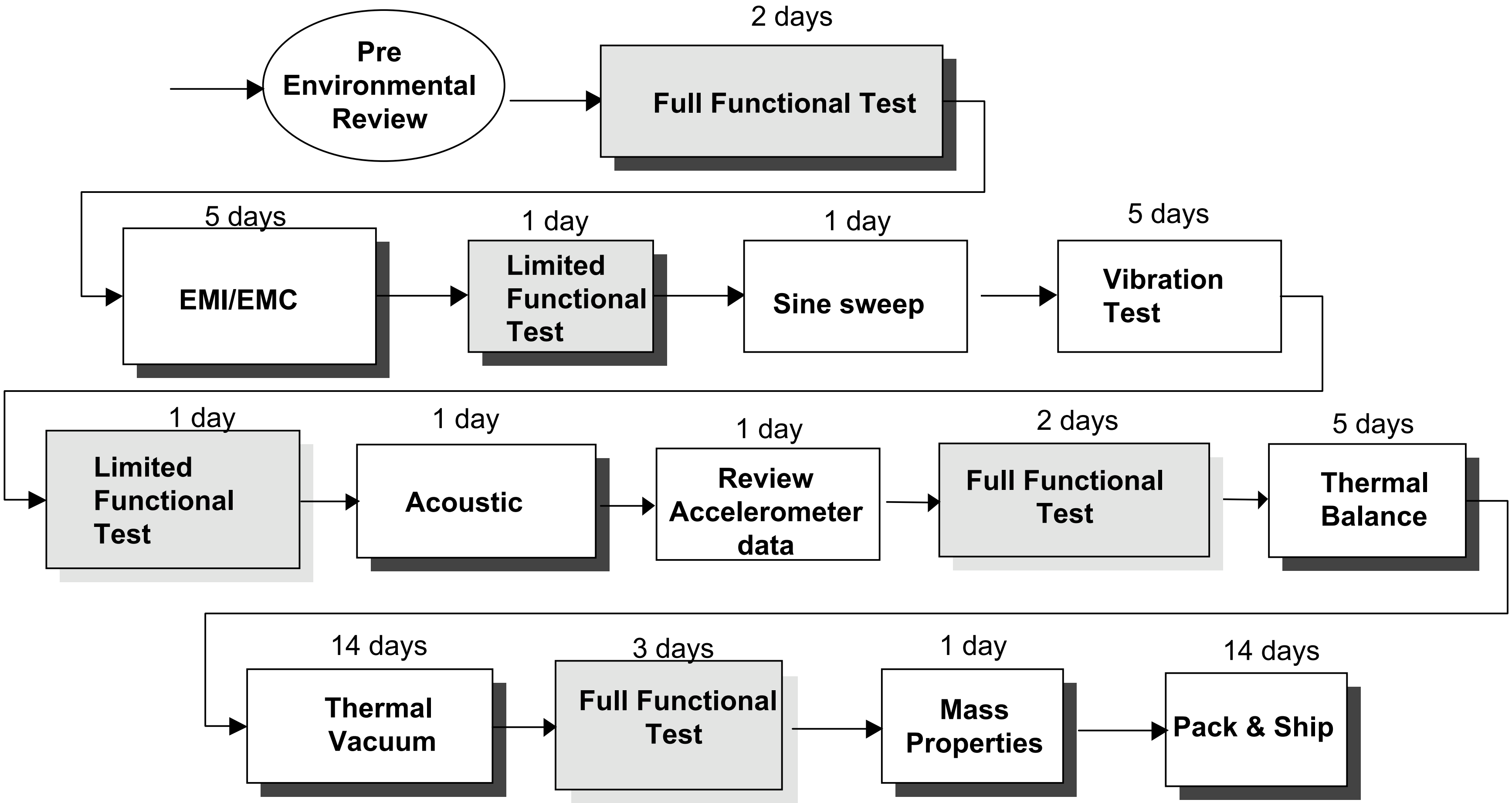
Green – Flight

Yellow - Engineering



Assembled ACD Environmental Test Flow

- **Setup test outlines are consistent with 568-PG-8700.1.1 Rev A**



Performance Tests

LAT-TD-01112-D1, ACD Functional Test Plans (Comprehensive Performance Test)

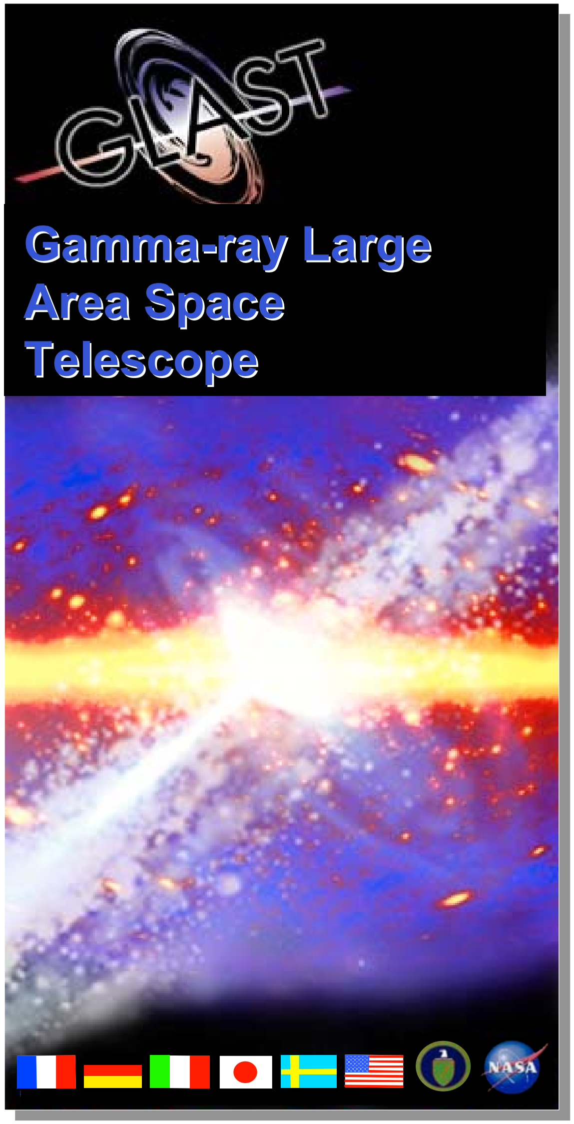
- **Aliveness Test (AT)**

  Functional test that turns on the ACD in a nominal state and verifies basic operation of all channels

- **Functional Tests**
  - Limited Functional Test (LFT) - Test all major functions of the ACD system
  - Full Functional Test (FFT) - Test all functions of the ACD system except a complete measurement of all the ACD tile efficiencies

- **Comprehensive Performance Test (CPT)**

  Test all functions of the ACD system and includes a complete measurement of all the ACD tile efficiencies. Requires rotation of ACD into three different orientations.



Fabrication Process

Section 11-5

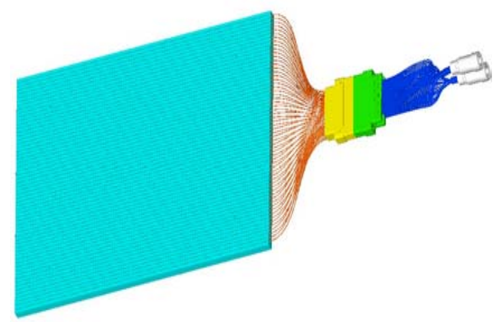
ACD Fabrication Plan

- Tile Detector Assemblies
  - FermiLab
- Scintillating fiber ribbons
  - Manufactured by Washington University, bent and assembled at GSFC.
- Composite Shell
  - Panel fabrication performed by outside vender, assembly and test in house
- Base Frame
  - In house fabrication, assembly and test
- Analog and Digital ASIC's
  - GSFC/SLAC Design, MOSIS fabrication, GSFC acceptance testing
- High Voltage Bias Supplies
  - In house design, fabrication by local vender, testing in house
- PMT/Resistor Network Assembly
  - Procure components and assemble and test in house
- Front End Electronic (FREE) Boards
  - Procure components and assemble and test in house
- Micrometeoroid Shield/Thermal Blanket
  - Shield designed by JSC, Blanket designed by GSFC, In house fabrication
- ACD Integration and Test
  - Building 7, 10, 15, & 29 complex

Qualification phototube in housing with resistor network.

Procurements

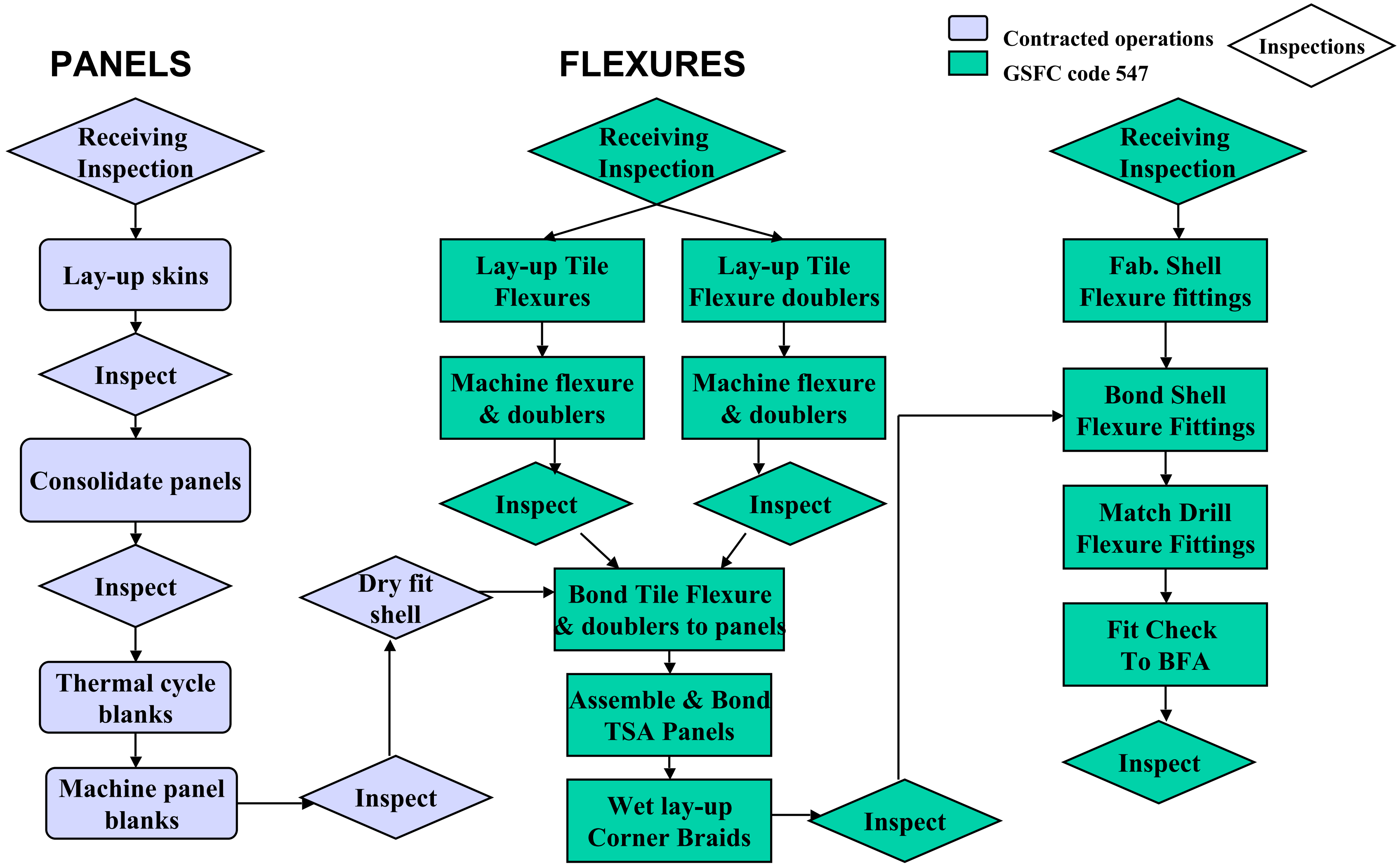
- Long lead procurements
  - Photomultiplier Tubes – Have received all 240 flight tubes
  - TSA Composite Support Shell – contract in place
  - Tile Detector Assemblies (with fibers) – fabrication started
- Major upcoming procurements
  - Base Frame
  - Flight Analog and Digital ASICs
  - High Voltage Bias Supplies
  - PMT Assembly



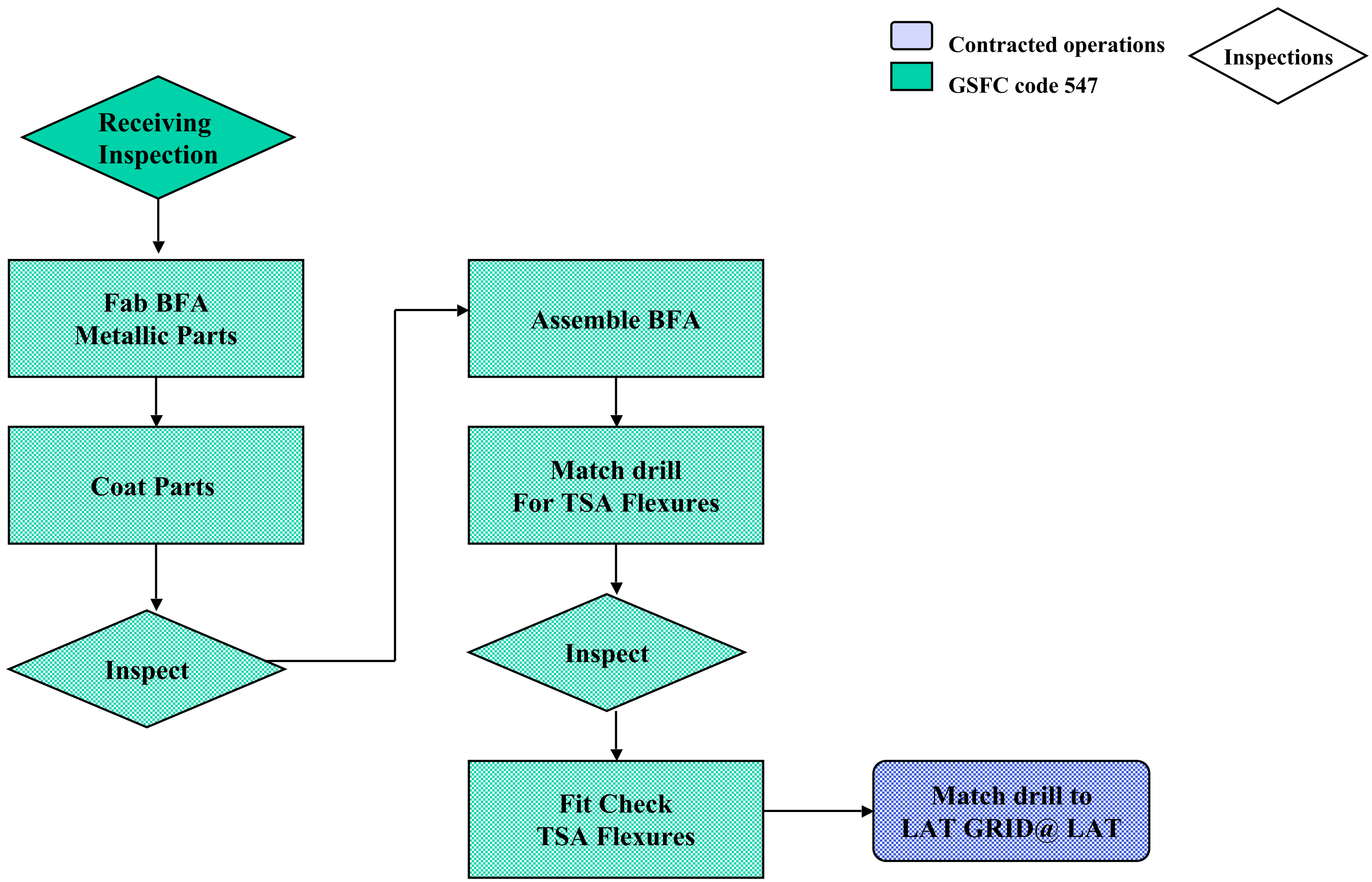
Tile Detector Assembly with
A clear fiber connector

- Smaller upcoming procurements
  - Electrical components
  - Tile Detector Assembly mounts

TSA Manufacturing Flow

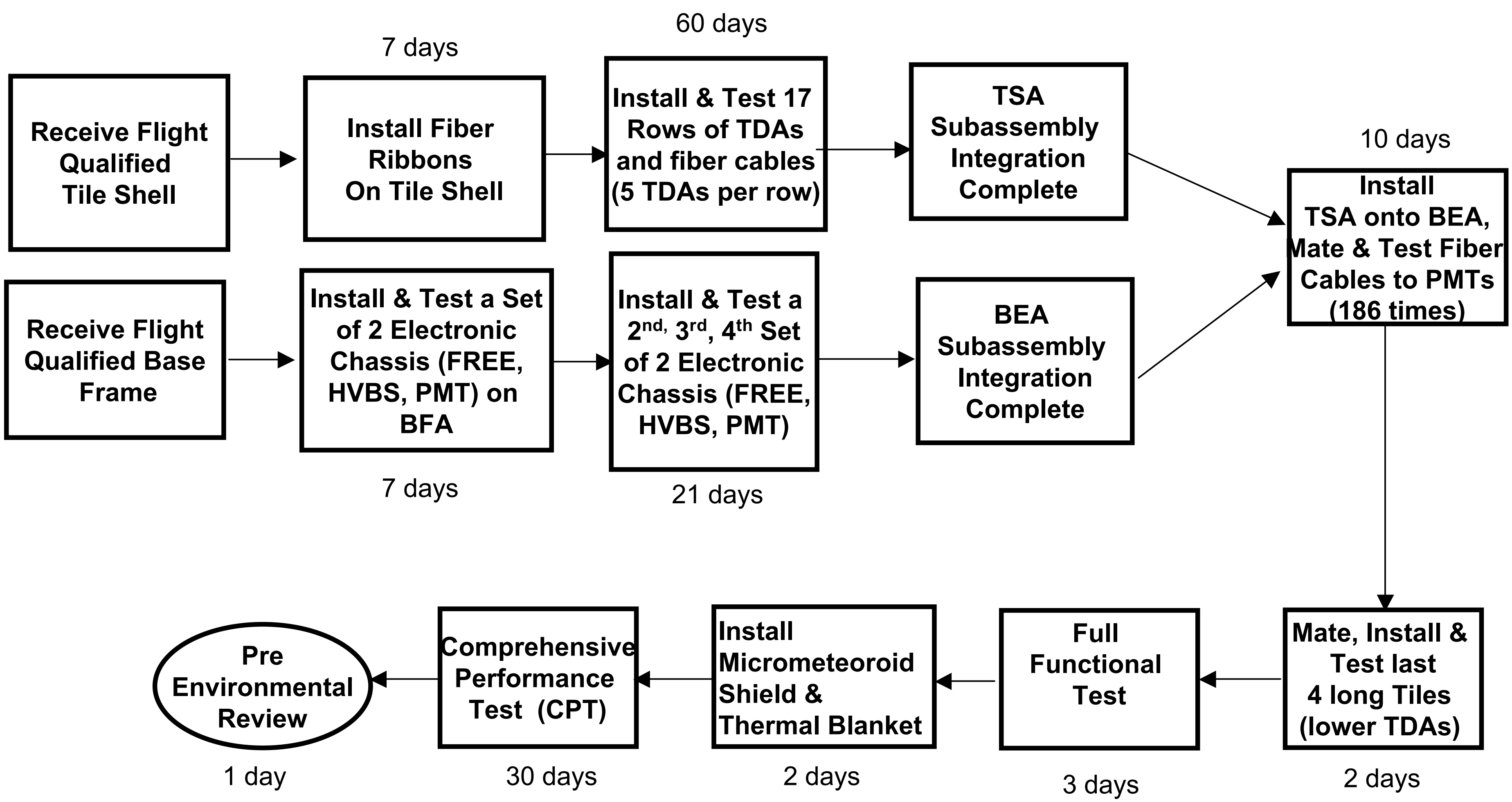


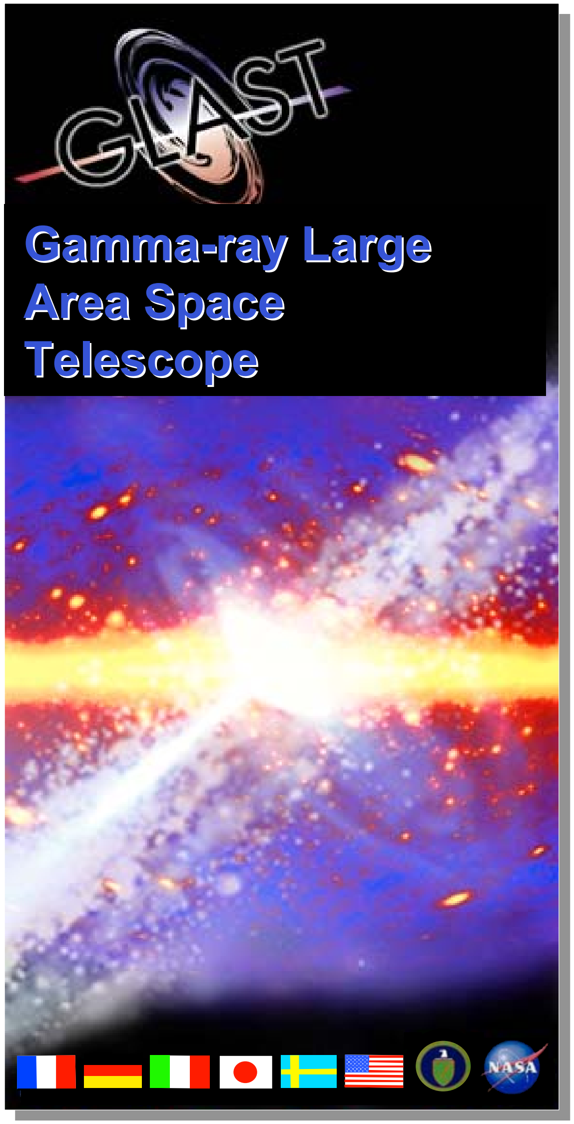
BFA Manufacturing Flow



ACD I&T Assembly/Integration Flow

- **Major activities in I&T flow have been defined (LAT-TD-00430-D1)**





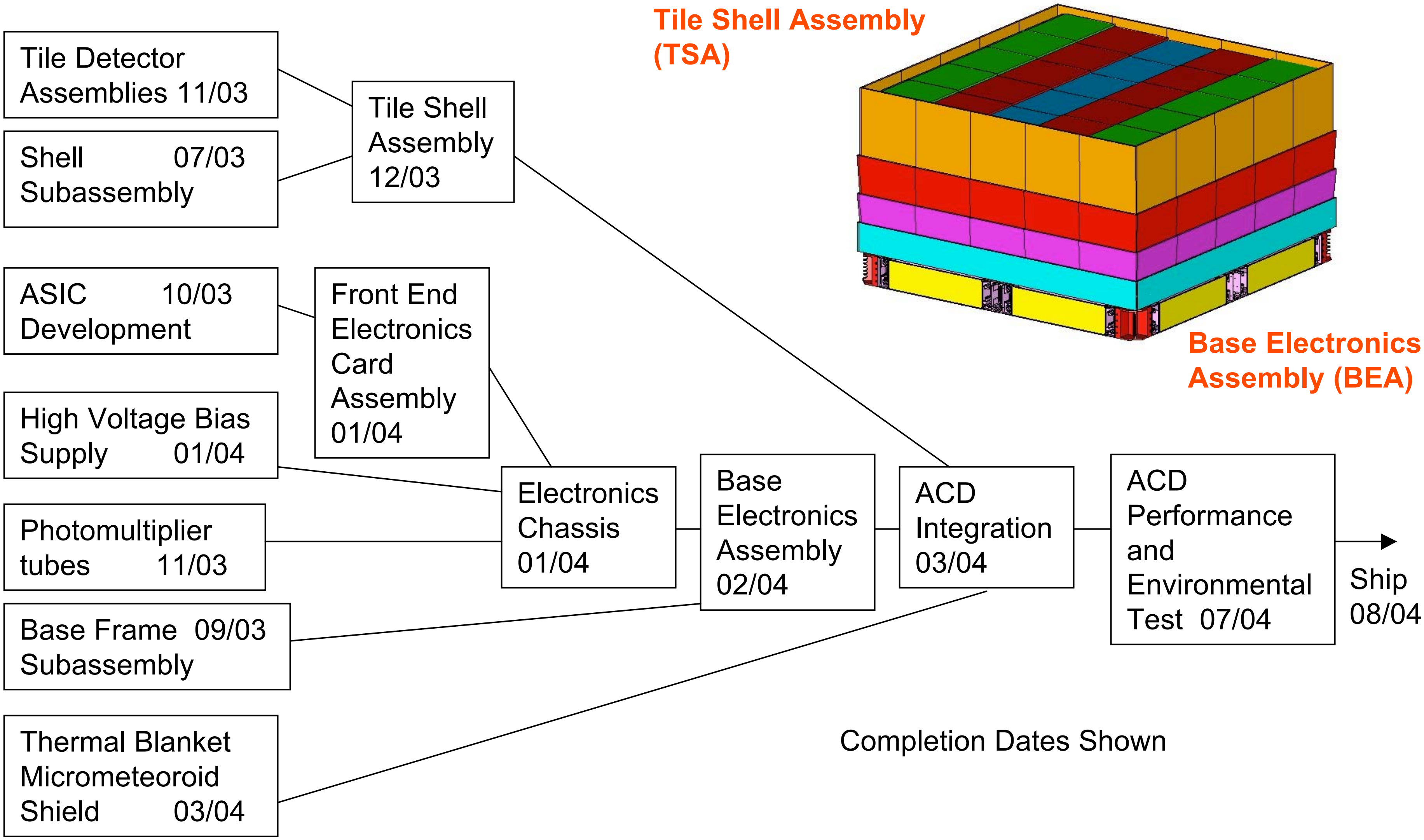
Cost and Schedule

Section 11-6

CCB Actions Affecting 4.1.6

Change Request #	Description	Status
LAT-XR-00770-01	Additional HVBS's	Approved, $60K
LAT-XR-01000-01	FY01 Carryover Costs	Approved, $275K
LAT-XR-01001-01	MPS Tax Rephasing	Approved, $50K
LAT-XR-01009-01	Scheduling Support	Approved, $82K
LAT-XR-01011-01	ASIC Development Support	Approved, $549K
LAT-XR-01119-02	Revised ACD CDR Date	Approved, $0K
LAT-XR-01161-01	Micrometeoriod Shield Design & Test	Approved, $25K
LAT-XR-01192-01	L3 Milestone Changes	Approved, $0K
LAT-XR-01200-01	Mass Allocation Increase	Approved, 45 kg
LAT-XR-01750-01	EGSE S/W Support	Approved, $237K

ACD Work Flow Overview



Completion Dates Shown

1st Critical Path – ASIC Development

- Received updated versions of ASIC's in late April
  - Currently in testing
  - Several problems have been identified and the designs have been updated
    - GARC ready for flight fabrication
    - GAFE design being updated, expected to be completed by May 23

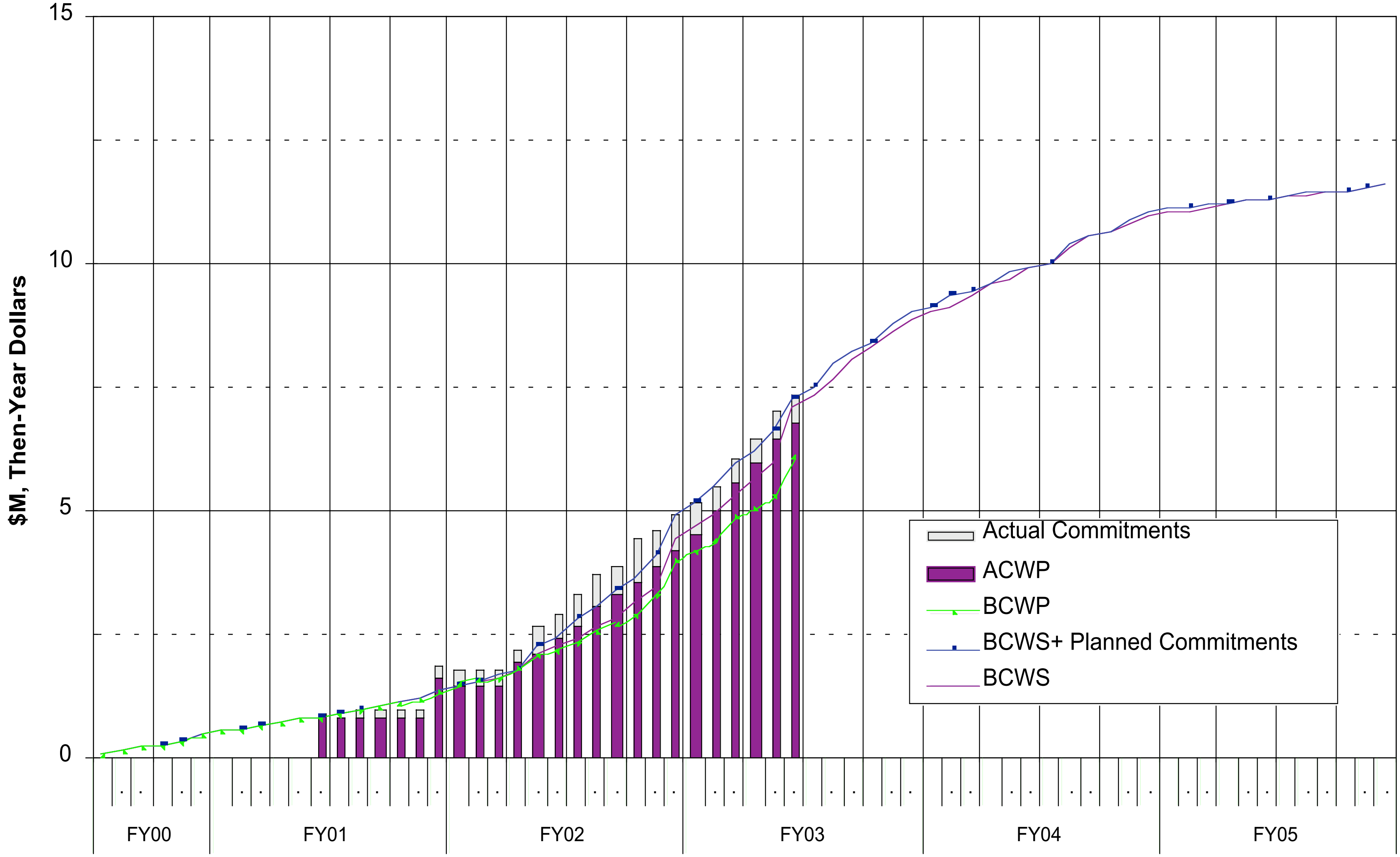
Activity	Dates
ASIC Design	8/22/02-5/16/03
Flight Unit (FU) ASICs submitted to fabrication	5/23/03
FU ASIC Development (fab, package, test, screen)	5/23/03-10/9/03
FREE FU Populate w/Analog ASIC,Digital ASIC, ADC, DAC & Inspection	10/10/03-10/23/03
Electronics Chassis FU Validation Testing	10/24/03-1/15/04
BEA Integration	1/16/04-2/13/04
Install TSA on BEA	2/17/04-3/3/04
ACD Functional and Performance Testing	3/4/04-4/20/04
ACD Environmental Tests	4/21/04-7/2/04
Shipping to SLAC	7/6/04-7/21/04
Post Ship activities	7/22/04-8/10/04
Schedule Contingency	8/11/04-10/25/04
ACD to LAT Integration	10/26/04

2nd Critical Path - Phototube/resistor network assembly

- **Labor-intensive assembly process. Must be light tight and protected against corona for high voltage.**
  - **New light-tight housing design may help.**

Activity	Dates
PMT Procurement (all 240 flight units already received)	10/15/02-6/26/03
Resistor Network Flight Unit procurement, populate, assembly, & test	6/18/03-11/5/03
PMT Integrate & Conformal Coating	7/10/03-11/06/03
Electronics Chassis Flight Unit Pop w/PMT's & Inspect	11/7/03-11/13/03
Electronics Chassis Flight Unit Validation Testing	10/24/03-1/15/04
BEA Integration	1/16/04-2/13/04
Install TSA on BEA	2/17/04-3/3/04
ACD Functional and Performance Testing	3/4/04-4/20/04
ACD Environmental Tests	4/21/04-7/2/04
Shipping to SLAC	7/6/04-7/21/04
Post Ship activities	7/22/04-8/10/04
Schedule Contingency	**8/11/04-10/25/04**
ACD to LAT Integration	**10/26/04**

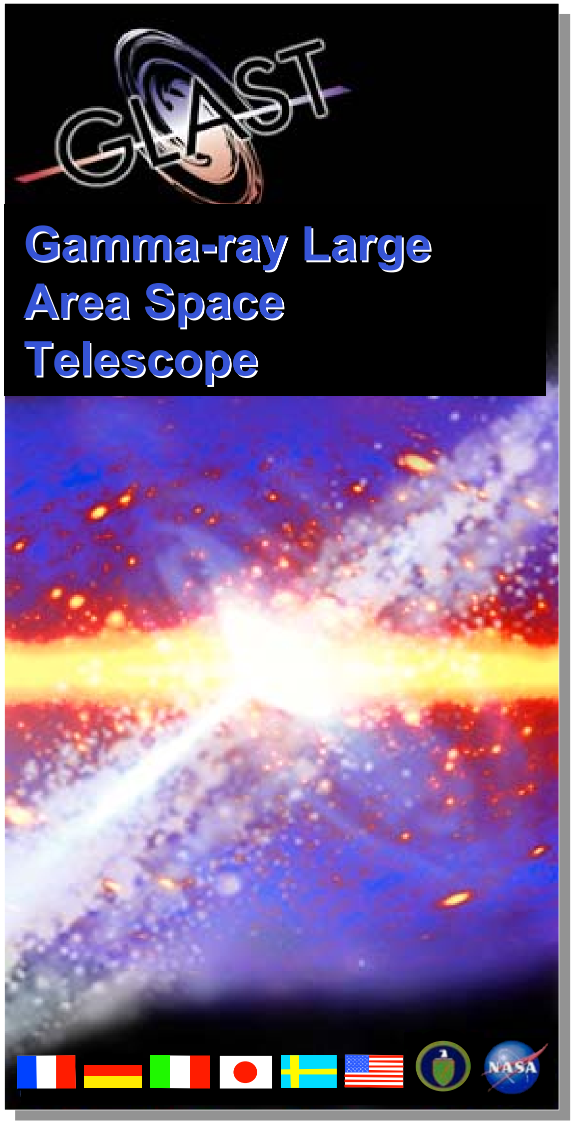
Budget, Cost, Performance



Cost/Schedule Status

- Status as of March 31, 2003:

Item	In k$	
Budget at Complete	11,557	
Budgeted Cost for Work Scheduled (a)	7,048	
Budgeted Cost for Work Performed (b)	6,070	
Actual Cost for Work Performed	6,790	
Cost Variance	-720	-11.9% of (b)
Schedule Variance	-978	-13.9% of (a)



Risk and Summary

Section 11-7

ACD “Top Five” Risk Summary

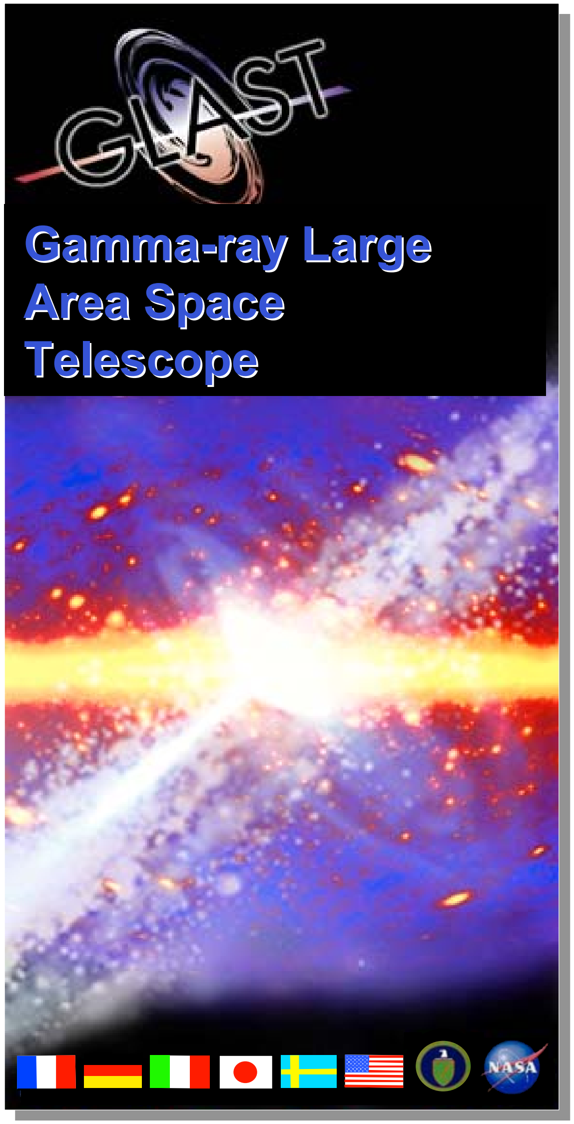
ID #	Risk Rank	Risk Description	Risk Mitigation	Mitigation Status
ACD-0001	Moderate	Design flaw in flight ASIC	Five foundry runs, comprehensive test program, and peer reviews. For radiation, other ASICS using this same process have been successful, and some of the LAT ASICS that are similar in design will be tested first. Contingency plan: Replace with newly designed ASICs	ASICs in testing. Planning work-arounds or re-designs for aspects of the ASICS that have been deficient in earlier versions, in case additional versions are needed.
SE-0001	Moderate	Requirements that the ACD must meet could change, forcing a redesign, loss of performance, or potentially loss of the ACD from inability to meet such requirements. External ACD requirements not under final signature release may change; resulting in cost & schedule impact.	(1) ACD engineers and managers will keep LAT management informed immediately when new requirements seem to appear. In coordination with the LAT Systems Engineering group, we will maintain a table of open items involving requirements on the ACD. (2) LAT systems engineering will help resolve these issues in a timely fashion.	Discussions are ongoing, supplemented by a list of open issues posted biweekly to the ACD Web site.

ACD "Top Five" Risk Summary

ID #	Risk Rank	Risk Description	Risk Mitigation	Mitigation Status
ACD-0005	Moderate	Light Leak in the detector system channel	Early testing & qualification of subassembly, handling procedures. Contingency Plan: Additional light wrap can also be added	Plans for regular light testing and upgrades of light seals are in place.
ACD-0019	Moderate	QA finds problem in part (ie GIDEP alert), or other parts problem develops (such as lead time becoming excessive).	Replace with different part	Watching long lead-time items closely.
ACD-013	Moderate	Civil Servant test conductors pulled off for another project	High visibility with GSFC management. Contingency plan: Hire & Train test conductors	Goddard management has been supportive of ACD use of Civil Servants.

Summary

- The ACD continues to make technical progress. All the technical recommendations from reviews have been resolved.
- The ACD has developed a coherent, verifiable cost and schedule plan. We are not happy with the variances, but they are within typical contingencies for a flight project.
- The schedule has two months of float at the end.
- The ACD faces no unusual risks. The risks are those experienced by any space flight instrument.
- The ACD has an experienced team.
- The ACD is ready to proceed with flight hardware fabrication.



Appendix A Requirements (some duplication of main presentation for completeness)

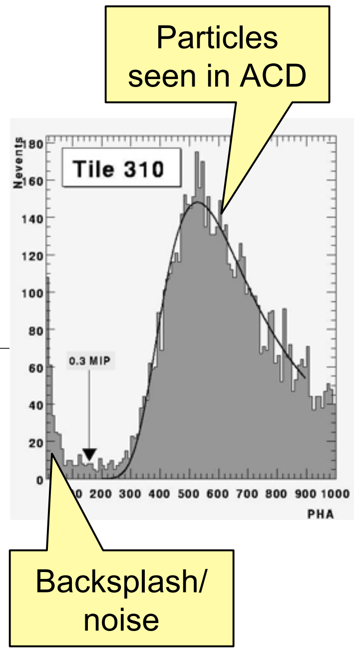
Level III Key Requirements Summary

Reference: LAT-SS-00016

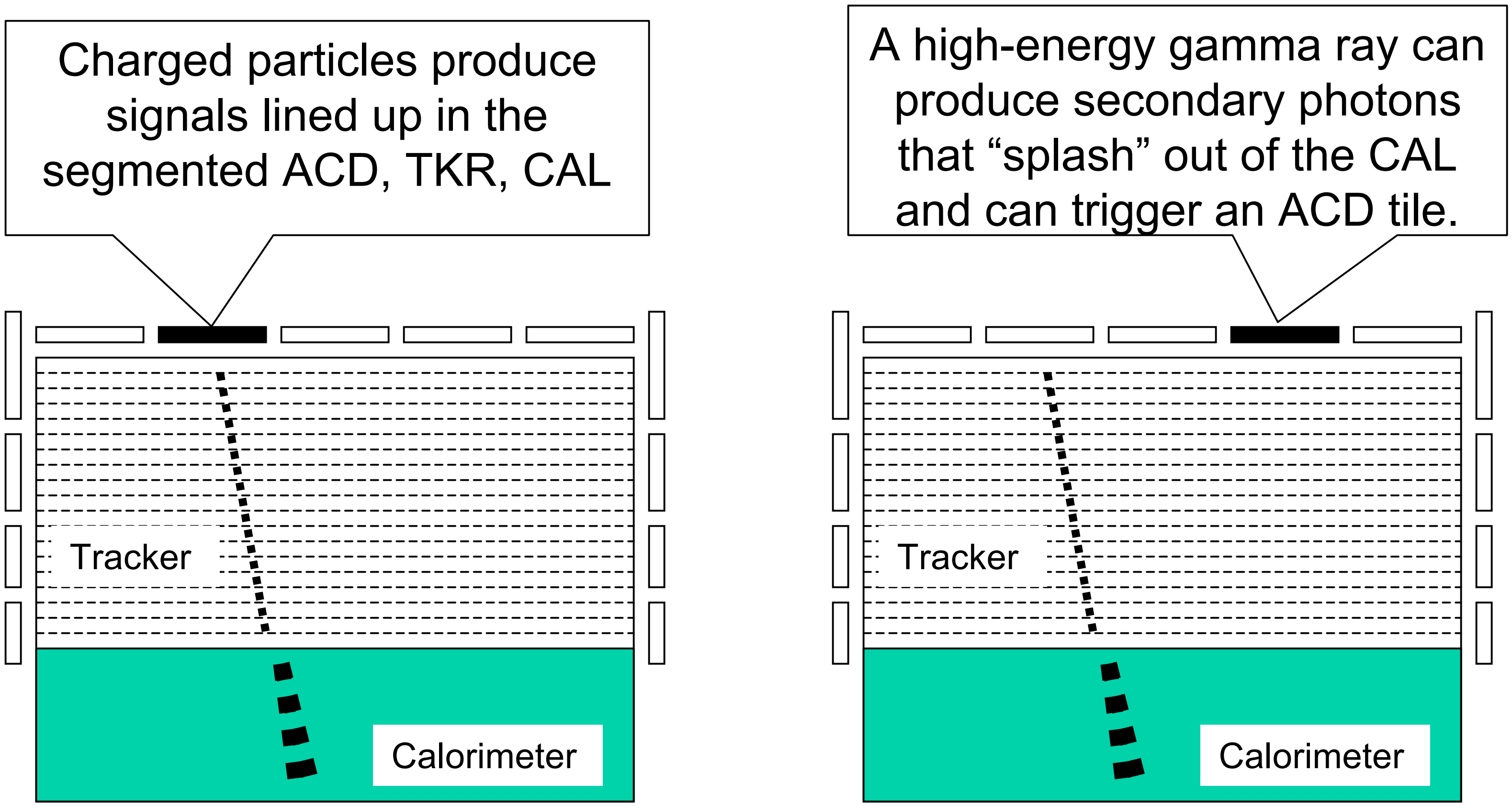
Parameter	Requirement	Expected Performance	Verification Method
Detection of Charged Particles	**? 0.9997 average detection efficiency over entire area of ACD (0.99 for bottom row of tiles)**	**?0.9997** **?0.999 (bottom tiles)**	**Test and Analysis**
Fast VETO signal	Logic signal 200-1600 nsec after passage of charged particle	200-1600 nsec	Demonstrate
PHA signal	For each phototube, pulse height measurement for each Trigger Acknowledge (TACK) Below 10 MIP, precision of <0.02 MIP or 5% (whichever larger) Above 10 MIP, precision of < 1 MIP or 2% (whichever larger)	< 0.02 MIP or 5% < 1 MIP or 2%	Test and Analysis
False VETO rate - backsplash	**< 20% false VETO's due to calorimeter backsplash at 300 GeV**	**< 10%**	**Test and Analysis**
False VETO rate - noise	< 1% gamma-ray rejection from false VETO's due to electrical noise	< 1%	Analysis
High Threshold (Heavy Nuclei) Detection	Detection of highly-ionized particles (C-N-O or heavier) for calorimeter calibration.	Yes	Analysis
Size	Outside: 1796 x1796 x 1050 mm 1806 x 1806 for lowest 310mm Inside Grid: 1574 x 1574 x 204.7 mm Inside TKR: 1515.5 x 1515.5 x 650 mm	1796 x1796 x 1045 mm 1800 x 1800 at connector 1574 x 1574 x 204.7 mm 1515.5 x 1515.5 x 650mm	Demonstrate
Mass	< 280 kg	270 kg	Demonstrate
Power	< 10.5 Watts (conditioned)	9.5 W	Demonstrate
Instrument Lifetime	Minimum 5 yrs	> 5 yr.	Analysis

Flowdown - Requirements to Design

Parameter	Requirement	Constraints	Characteristics Needed	Design
Detection of Charged Particles ACD-SS-00016 ACD3-20 ◄	? 0.9997 average detection efficiency over entire area of ACD (less for bottom row of tiles)	Mass Power Size Lifetime Minimize inert material outside active detector Low backsplash sensitivity	**High-sensitivity charged particle detector** **No gaps** **Low energy threshold for high efficiency** **Performance margin to compensate for aging**	**Plastic scintillator tiles, 1 cm thick, < 1000 cm^2 size** **Waveshifting fiber light collection, with clear fibers for transmission in long runs** **Overlap one dimension, seal other with scintillating fiber ribbons**
False VETO rate – backsplash ACD-SS-00016 ACD3-26	< 20% false VETO's due to calorimeter backsplash at 300 GeV	High charged particle detection efficiency Mass Power Size Lifetime	**Detector with low sensitivity to soft photons** **Segmentation < 1000 cm^2** **High energy threshold (backsplash is soft)**	**Photomultiplier tubes, with gain set low at start of mission to allow increase as tube ages.** **Low-noise electronics** **Threshold well below MIP peak but above most of backsplash**

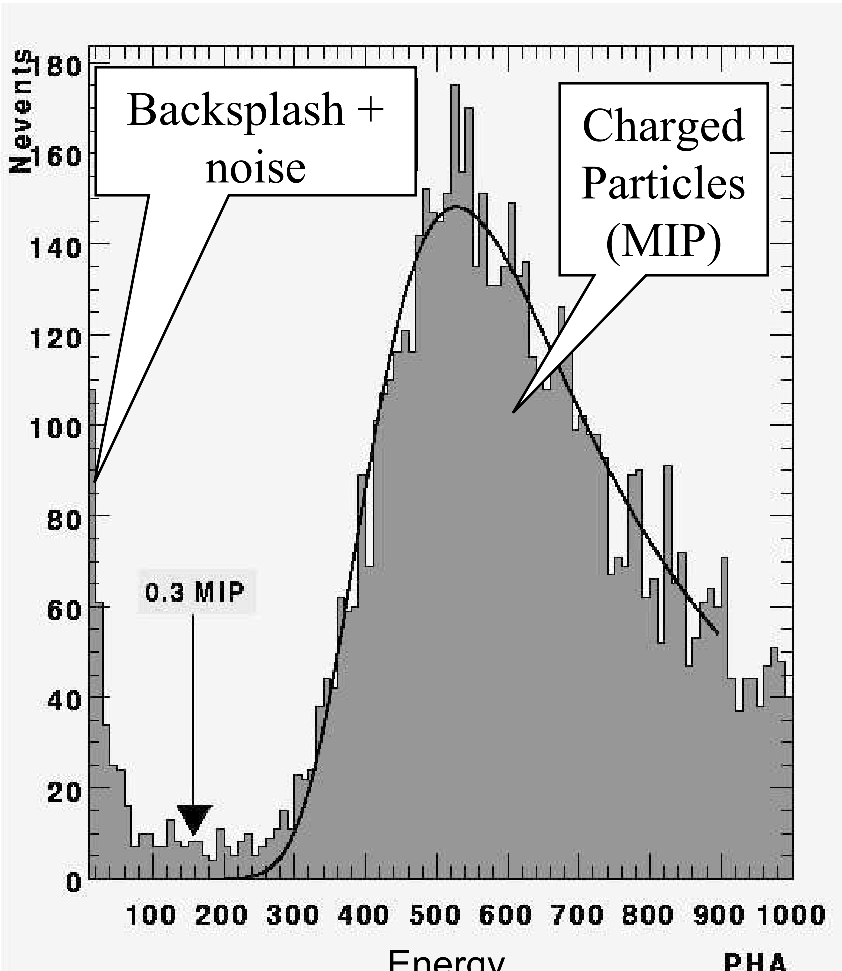


Charged Particle Detection vs. Backsplash



If the ACD were not segmented, we would lose the valuable high-energy gamma rays that produced a back-splash signal. This self-veto reduced the EGRET efficiency at high energies by more than 50%.

Meeting the Key Requirements



For high-efficiency MIP detection (0.9997), want a low energy threshold.

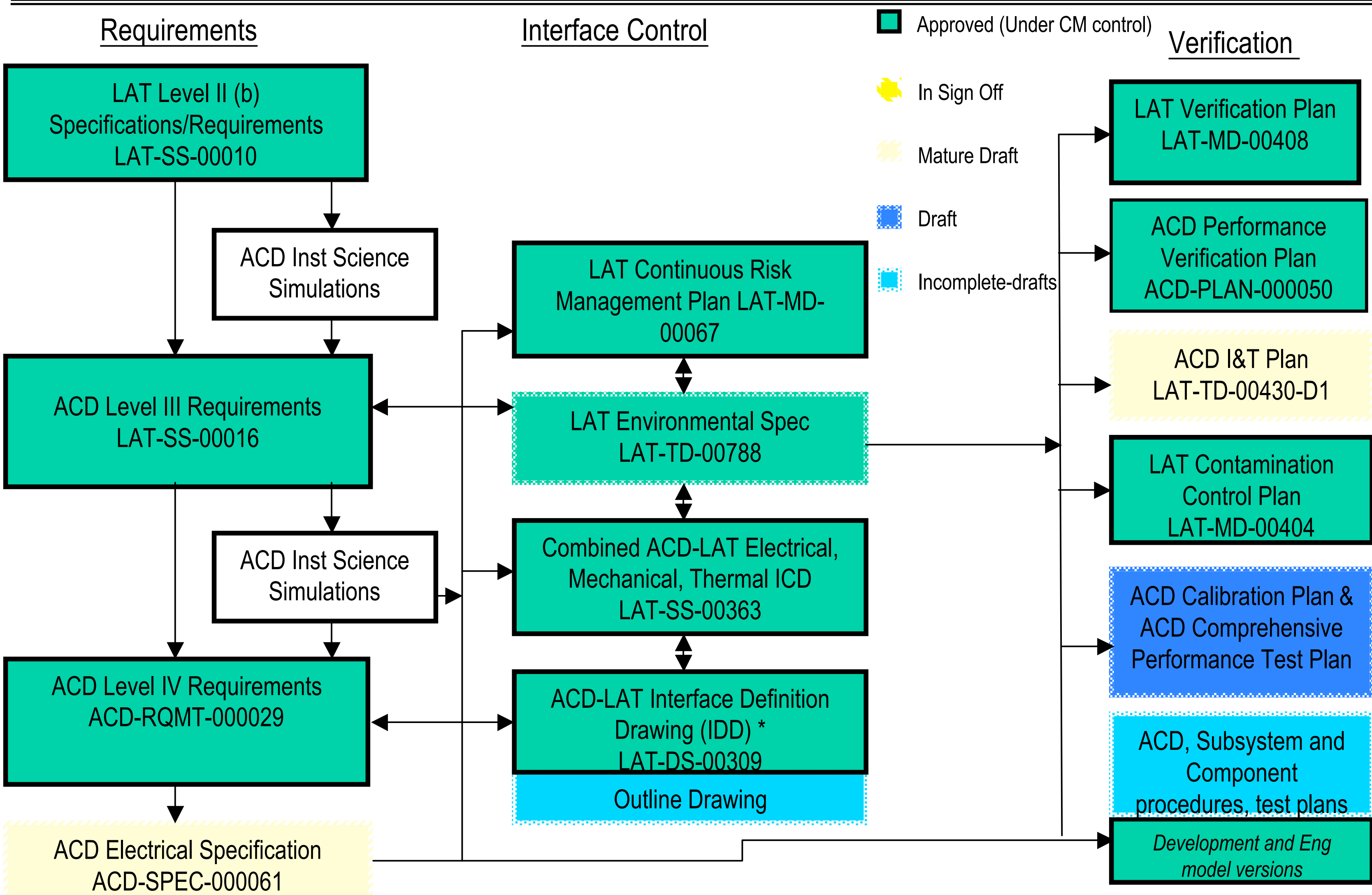
For good rejection of backsplash, want a high energy threshold.

A good balance between these requirements is about 0.3 of the MIP peak energy.

Level IV Requirements Outline

5.2 Charged Particle Detection
5.3 Adjustable Threshold on VETO Detection of Charged Particles
5.4 False VETO due to Electrical Noise
5.5 High-Threshold Detection
5.6 Adjustable High-Threshold
5.7 Level 1 Trigger Acknowledge (TACK)
5.8 Signals - (8 lower level requirements)
5.9 ACD Performance Monitoring - (10 lower level requirements)
5.10 High Voltage Bias Supply - (14 lower level requirements)
5.11 PMT - (6 lower level requirements)
5.12 Radiation Tolerance - (2 lower level requirements)
5.13 Reliability - (6 lower level requirements)
5.14 Commands - (10 lower level requirements)
5.15 Output Data Formats
5.16 Power Consumption
5.17 Total ACD Mass
5.18 Environmental Requirements - (11 lower level requirements)
5.19 Performance Life
5.20 Rate Requirement for Operation within Specification
5.21 Testability
5.22 Center of Mass
5.23 Volume
5.24 Instrument Coverage
5.25 LAT to ACD Gap.
5.26 Material interaction of gamma radiation (Gamma radiation due to ACD material interactions)
5.27 Thermal Blanket/ Micrometeoroid Shield Areal Mass Density
5.28 Gaps between scintillating tiles
5.29 Light Throughput

ACD System Documentation



ACD Requirements Database

- ACD uses our Requirements Database in DOORS to Track Requirements

ID	LAT ACD Subsystem Level III Requirements, LAT-SS-00016	Parent req Link Comments	Link Action Items
	other sources from which they derive are listed in the Requirements Table below.		
ACD3-15	**5.2 Detection of Charged Particles**		
ACD3-16	The ACD shall detect energy deposits with energies of above an adjustable threshold nominally at 0.3 MIP (minimum ionizing particle) (see 5.3 below) and produce VETO signals.		
ACD3-17	**5.3 Adjustable Threshold on Detecting Charged Particle**		
ACD3-18	The threshold for VETO detection of charged particles shall be adjustable from 0.1 to 2.0 MIP, with a step size of ≤0.05 MIP. (0.1 to 0.6 MIP would have been range if no degradation was expected)		
ACD3-19	**5.4 Detection Efficiency**		
ACD3-20	The average detection efficiency for minimum ionizing particles shall be at least 0.9997 over the entire area of the ACD (except for the bottom tiles on each side, for which the efficiency shall be at least .99 , simulation confirmation of this number is desired at some point).		Latest GAP analysis h been sent to Alex for e simulation update
ACD3-21	**5.5 Instrument Coverage**		
ACD3-22	The ACD shall cover the top and sides of the LAT tracker down to the top of the CsI. The top of all 4 sides of the ACD scintillator shall be extended upward so as to be at least as high as the highest point in		

ACD Level III Requirement Database (DOORS)

Active Links between Requirements

ACD-LAT ICD DOORS Database

Active Links between Requirements

ID	LAT ACD Subsystem Level IV Requirements and Verification Table, LAT-SS-00352	In-links at depth 1	Req Action item	Req
ACD4-89	**5.10.5 HVBS Input Power**			
ACD4-90	Each HVBS shall operate from a supply voltage of 28V ± 1V, with possible input ripple of 10 mV (frequency range 50 Hz to 50 MHz). The noise shall be less than 100 mV RMS from DC to 1.0 MHz.	ACD ICD LAT-SS-00363 ACDICD-45		
ACD4-91	**5.10.6 HVBS Line and Load Regulation**			
ACD4-92	The HVBS output voltage shall be regulated to ±0.5% for all combinations of input voltage and load current. (This produces ~5% change in PMT gain).	ACD Level III Requirements LAT-SS-00016 ACD3-18 ACD Level III Requirements LAT-SS-00016 ACD3-20		
ACD4-93	**5.10.7 HVBS Output Ripple**			
ACD4-94	The HVBS output voltage ripple shall be compatible with the ACD ASIC design. The HVBS output voltage ripple shall not exceed ±2 mV p-p over the frequency range 100 Hz to 50 MHz	ACD Level III Requirements LAT-SS-00016 ACD3-16		

ACD Level IV Requirement Database (DOORS)

Appendix B Fabrication (some duplication of main presentation for completeness)

ACD Fabrication Plan

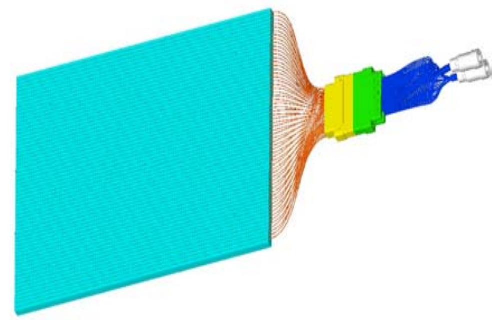
- Tile Detector Assemblies
  - FermiLab
- Scintillating fiber ribbons
  - Manufactured by Washington University, bent and assembled at GSFC.
- Composite Shell
  - Panel fabrication performed by outside vender, assembly and test in house
- Base Frame
  - In house fabrication, assembly and test
- Analog and Digital ASIC's
  - GSFC/SLAC Design, MOSIS fabrication, GSFC acceptance testing
- High Voltage Bias Supplies
  - In house design, fabrication by local vender, testing in house
- PMT/Resistor Network Assembly
  - Procure components and assemble and test in house
- Front End Electronic (FREE) Boards
  - Procure components and assemble and test in house
- Micrometeoroid Shield/Thermal Blanket
  - Shield designed by JSC, Blanket designed by GSFC, In house fabrication
- ACD Integration and Test
  - Building 7, 10, 15, & 29 complex

Qualification phototube in housing with resistor network.

Procurements

- Long lead procurements
  - Photomultiplier Tubes – Have received all 240 flight tubes
  - TSA Composite Support Shell – contract in place
  - Tile Detector Assemblies (with fibers) – fabrication started

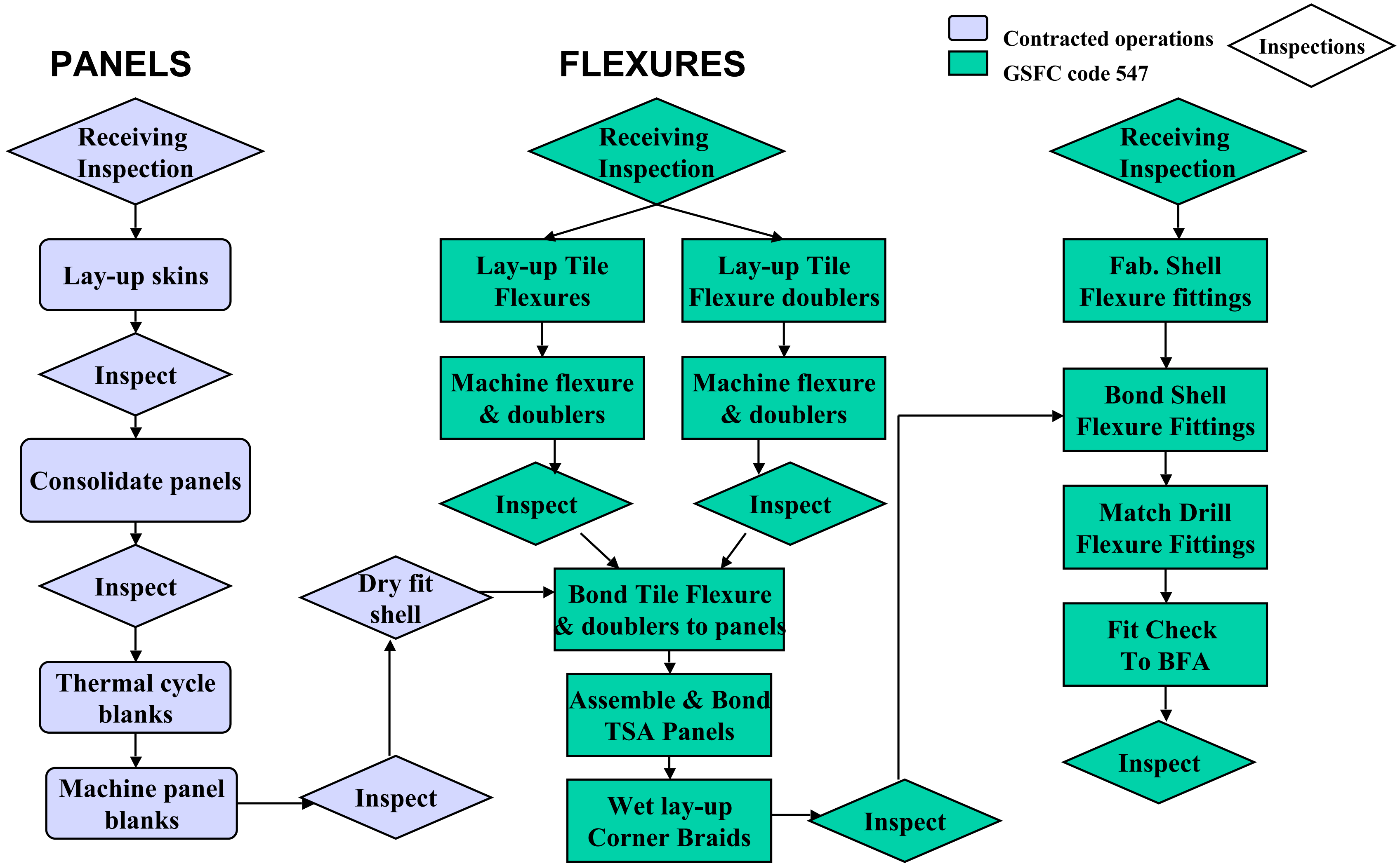
- Major upcoming procurements
  - Base Frame
  - Flight Analog and Digital ASICs
  - High Voltage Bias Supplies
  - PMT Assembly



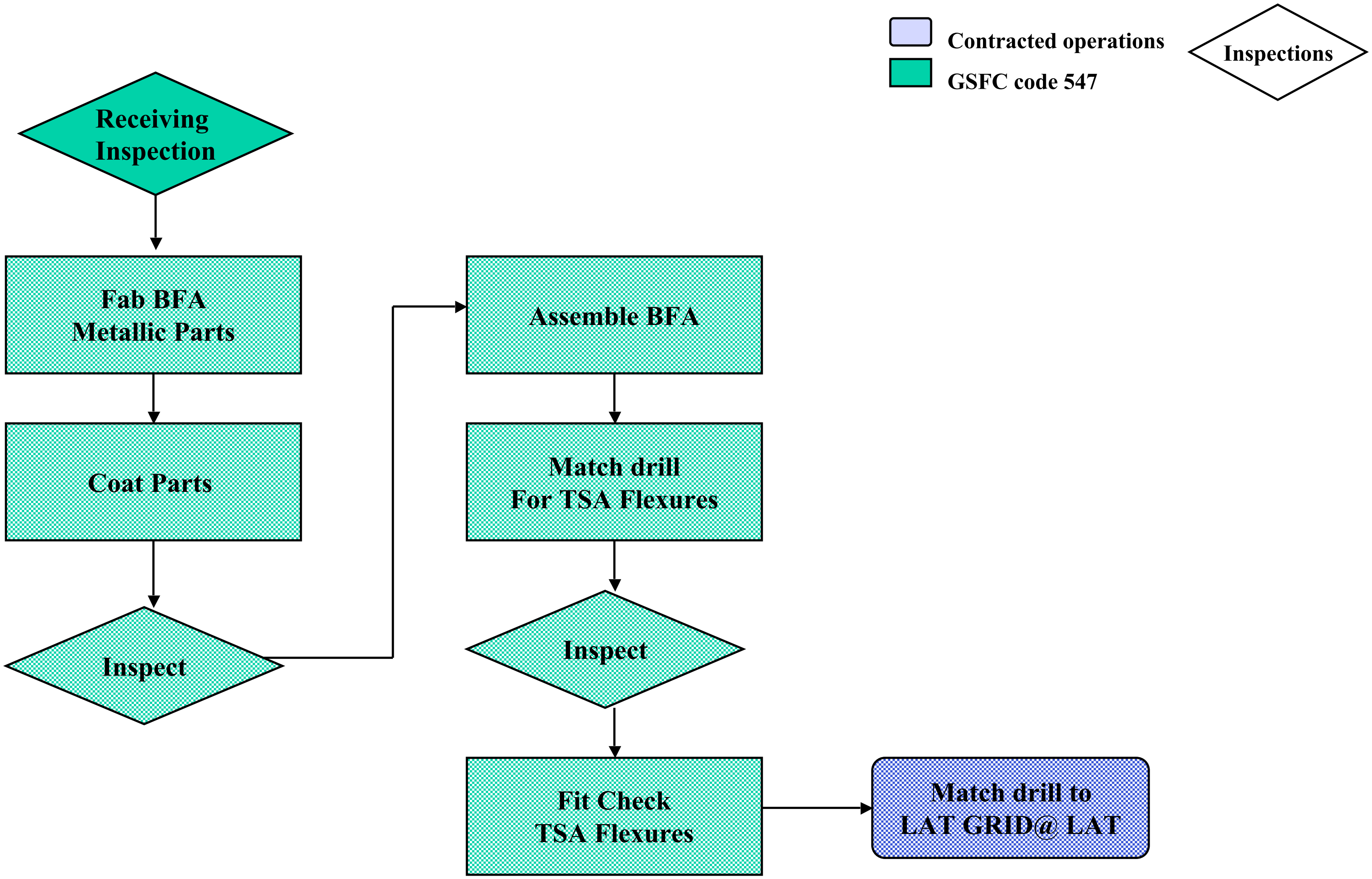
Tile Detector Assembly with
A clear fiber connector

- Smaller upcoming procurements
  - Electrical components
  - Tile Detector Assembly mounts

TSA Manufacturing Flow

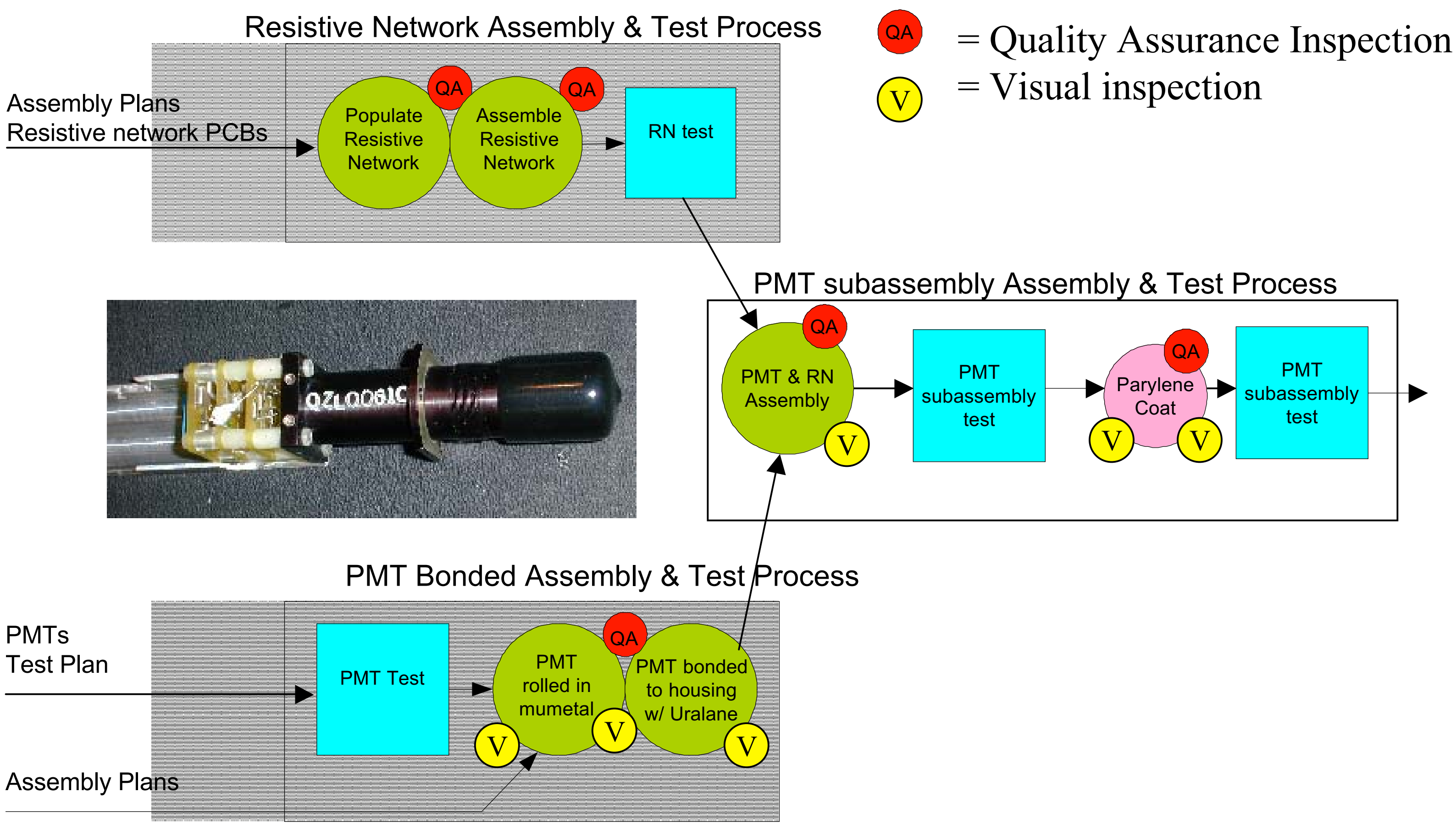


BFA Manufacturing Flow

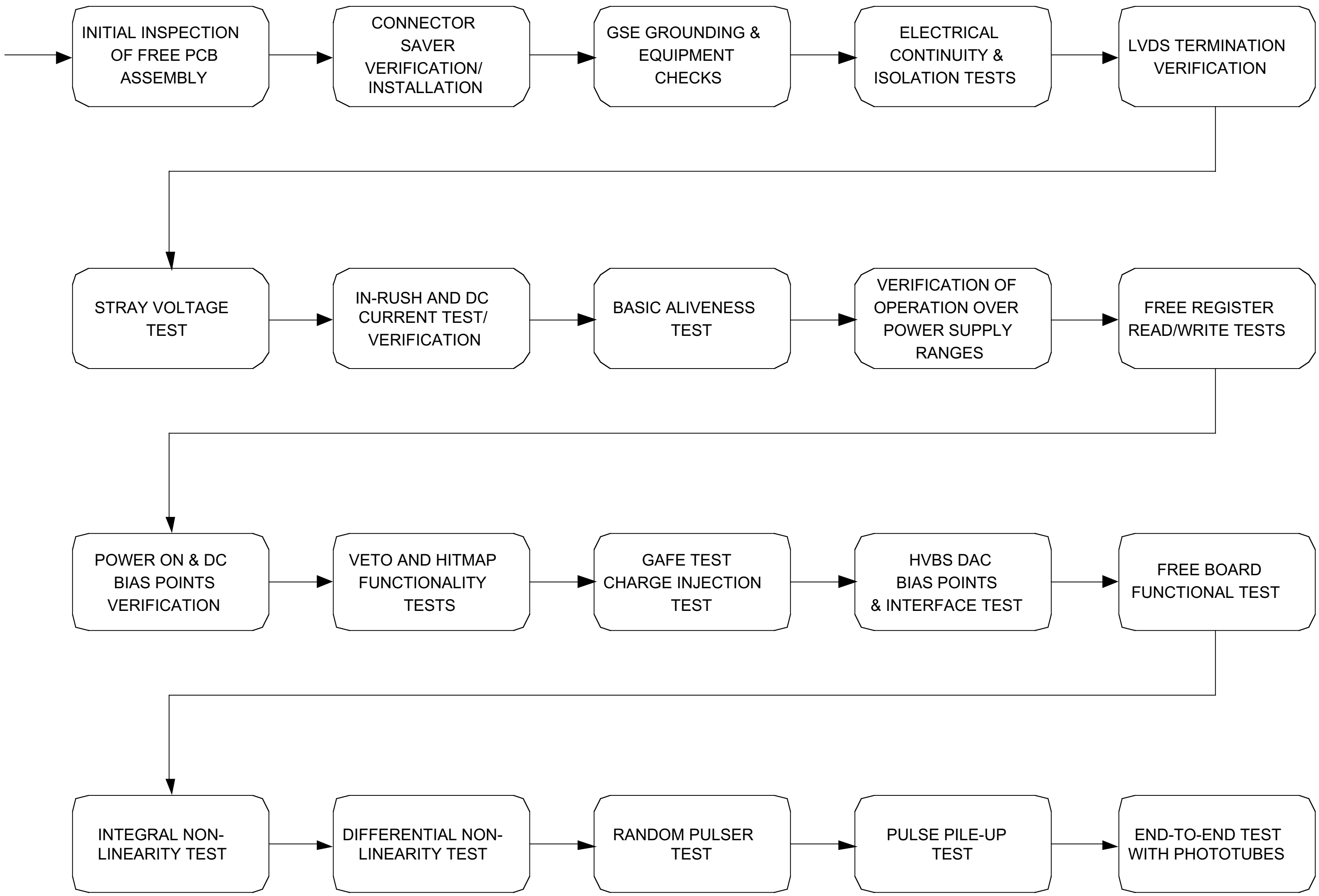


PMT Subassembly Assembly and Test Process

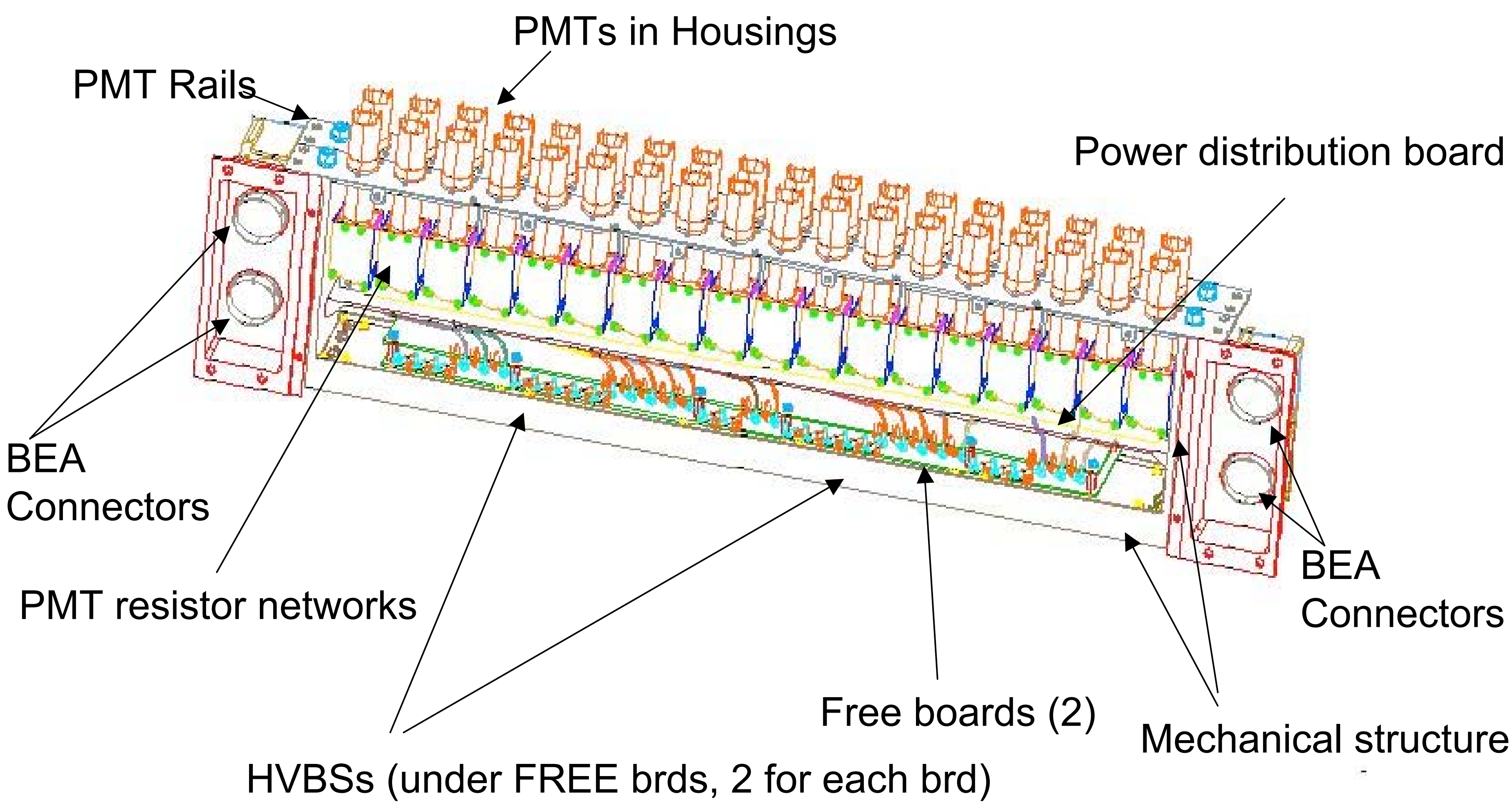
PMT Subassembly = PMT bonded assembly + PMT Resistive Network



FREE Assembly Integration and Test Flow

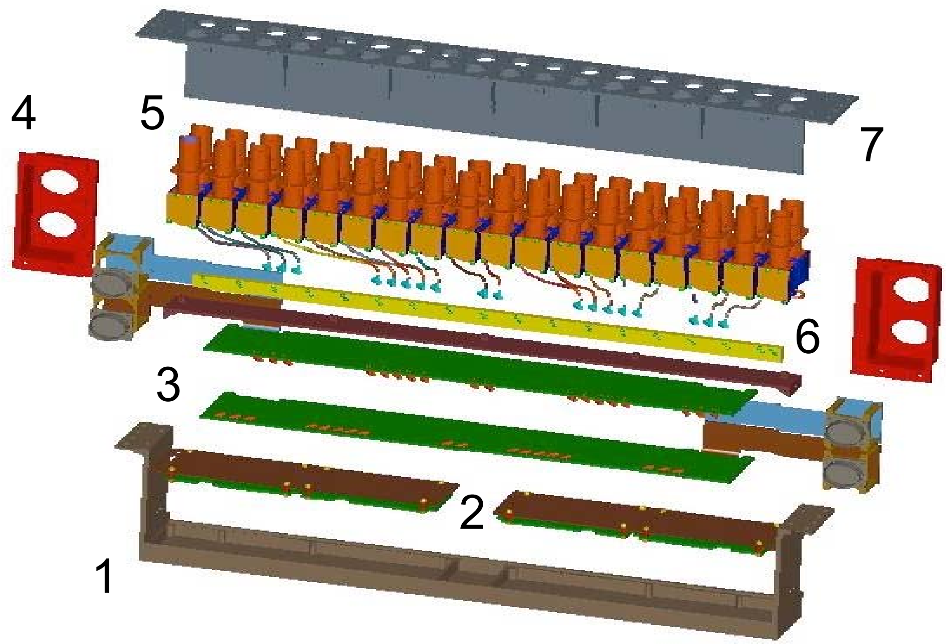


Electronics Chassis



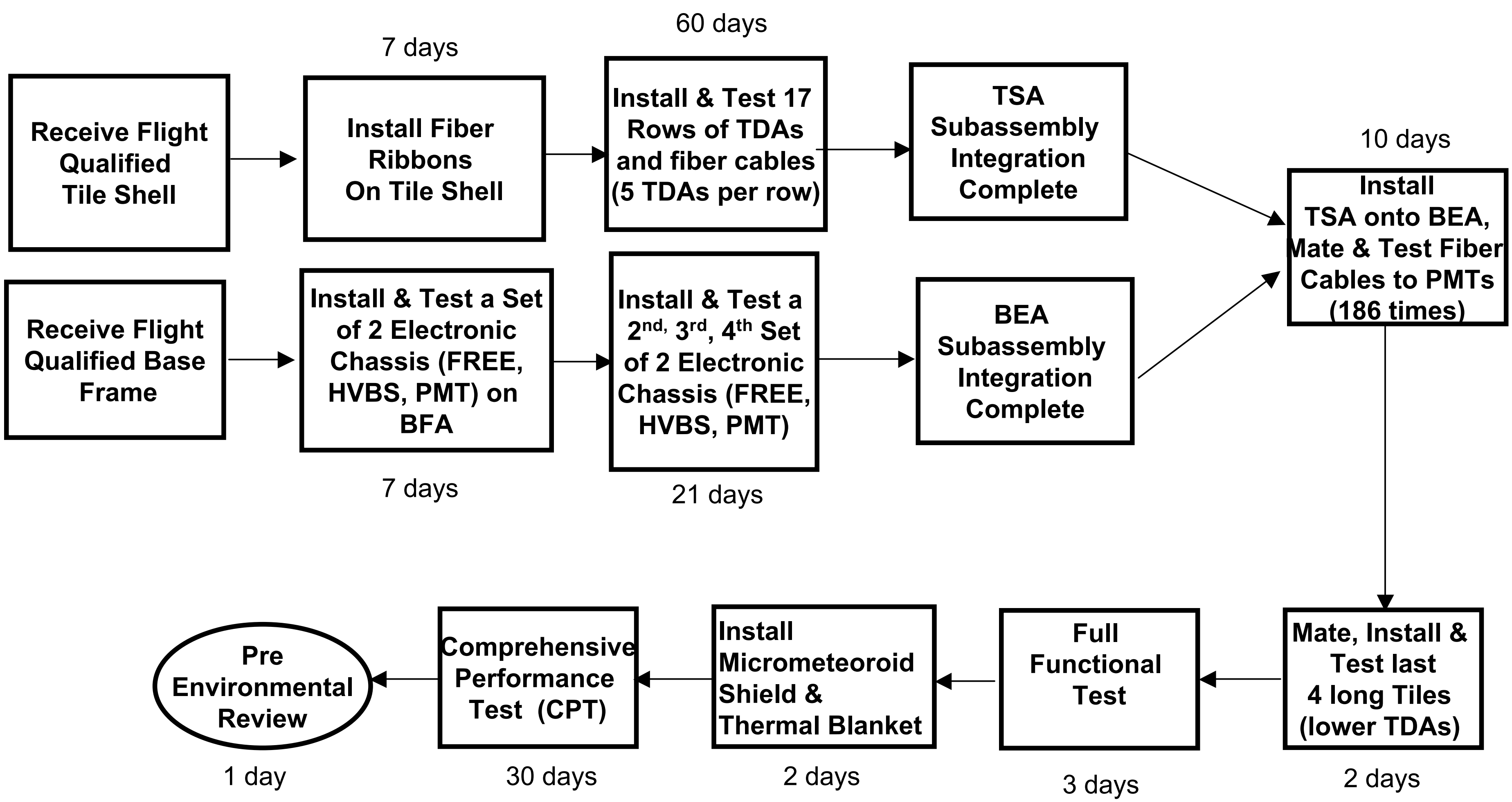
Electronics Chassis – Assembly Outline

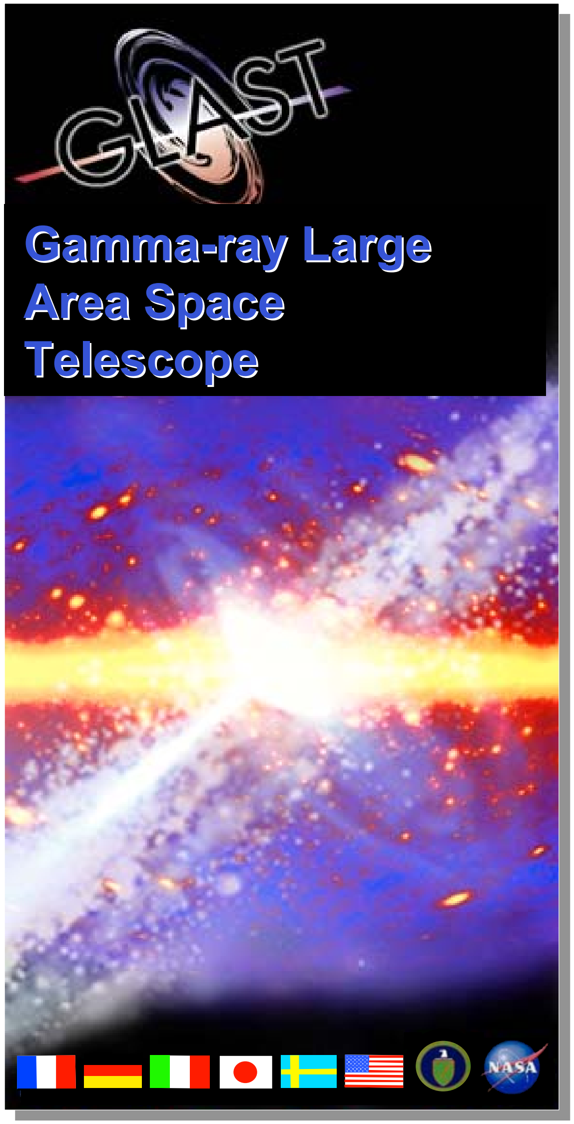
1. Start with mechanical support
2. Attach HVBS
3. Attach FREE cards
4. Attach connector supports
5. Attach phototubes to rail
6. Attach power distribution bus to rail
7. Attach rail to mechanical support
8. Make electrical connections
9. Mount Electronics Chassis in Base Frame
10. Close out mechanical structure



ACD I&T Assembly/Integration Flow

- **Major activities in I&T flow have been defined (LAT-TD-00430-D1)**





Appendix C

Peer Review RFAs

Peer Review RFAs

RFA #	Subsystem	Requestor	Owner	Request	Reason	Response	Status
1	ACD	Huegel	Thompson	Evaluate delivery date and completion readiness of ACD EGSE software delivery from Code 584 to Code 568 for I&T activities. If warranted, identify and provide experienced Code 584 personnel (civil servant and/or contractor) to assist present 584 ACD S/W engineer to assure timely delivery and completion of the ACD EGSE software. Identify the type of support, schedule, and deliverable items help that are needed. If a support contractor is identified to support this task, Code 584 and the ACD Project to coordinate in provide funding.	Concern was raised by Mr. Jim La, ACD I&T Lead from Code 568, on the timely EGSE software delivery to I&T from Code 584. In May 2002, 584 was tasked to provide to Code 568 (via SOW): 1. Design, develop, and deliver Python (was SCL)+ scripts and Qt (was Labview) Graphical User Interfaces (GUIs) to test the assembly of the ACD subsystem through ACD integration and test. 2. Assist Goddard personnel in writing ACD assembly test procedures. 3. Assist Stanford Linear Accelerator Center (SLAC) personnel in debugging their AEM simulator through the creation of test Python (was SCL) scripts. 4. Provide technical oversight on how the ACD EGSE works from an Python/Qt (SCL/Labview) perspective (including AEM database). This oversight is needed through both I&T and environmental testing. Because the complexity of the task, additional resources may be needed to assist the current 584 effort so that timely delivery and completion of the ACD EGSE S/W may be produced.	We expect a new EGSE hardware and software delivery from the LAT in April and another one in July. We have assembled a requirements document for the required EGSE software for these systems. Three milestones are identified: April 15 – Ability to handle GARC commands and readback (single FREE card with one GARC and one GAFE), exercise some test scripts, display simple pulse height histograms, and monitor some items for status and alarms. May 15 - Add full pulse height histograms and spectrum fitting. August 1 – Full functionality (not in final form) for full ACD. We are meeting regularly with Code 584 (John Donahue) and contractor software engineers with considerable EGSE experience (Greg Greer and Bruce Wendel). They are reviewing requirements and will develop an implementation plan by about March 1. We are considering sending the software engineers (at least one) to SLAC for several weeks to work with the new system before it is delivered to Goddard.	Closed
2	ACD	Horn	Amato	The ACD Reliability requirement is .96 at 5 years, current estimate is .92. ACD requested to review reliability analysis, assumptions and define key drivers with LAT System Engineering and Instrument Scientist to identify resolution. Note: A splinter was held 8 Jan 03. Three preliminary alternatives were discussed, the key driver is loss of single tile assumptions which appear to be overly conservative relative to the supporting science requirement at end of life. LAT Scientist, System Engineering and ACD Subsystem closure plan in work to verify science design margin and updated assumptions. It is expected that this review will result in ACD meeting their reliability requirement of .96	ACD subsystem reliability allocation is required to support overall LAT Mission requirements at 5 year life.	The ACD Reliability requirement is 0.96 at 5-years, but the current estimate is 0.92. The key driver to this estimate not meeting the reliability requirement is the fact that one penetration to the Micrometeoroid Shield (MMS) constitutes a failure to meet the ACD detection efficiency requirement of 0.9997. The ACD team will take the following steps to resolve this RFA. The changes described in this document shall be incorporated prior to LAT CDR in April 2003. 1) The LAT Instrument Scientist, Steve Ritz, has written a rationale of why two or more penetrations of the micrometeoroid shield constitute a failure to meet science requirements, rather than a single penetration. This document, LAT-TD-01591-01, has been placed into the Cyberdocs system and is attached to this response. The LAT mission objectives can still be met if the MMS has one penetration, rendering one tile nonfunctional, even though the overall ACD efficiency in this case would be less than 0.9997. 2) The ACD Reliability	Closed

Peer Review RFAs (Continued)

3	ACD	Ryan	T. Johnson	Demonstrate adequate venting of the tile detector assemblies and the micrometeoroid shield.	Tile detector assemblies are wrapped well to be light tight. Trapped air must be adequately vented to prevent damage to light tight covering during ascent. The micrometeoroid shield (MMS) venting scheme was not clear at CDR. Need to finalize the design and demonstrate that trapped air can adequately vent from under the MMS.	The TDA's are wrapped in two layers of black Tedlar for light protection. There are two separate vent paths for the TDA's. The first vent path is designed into the fiber connector and is simply a 1mm square serpentine path that requires multiple (>10) bounces for the light to pass through. The second vent path is achieved by leaving a 2-3 cm long length of seam on each layer of Tedlar to be left unsealed. This can be done since there are multiple layers of Tedlar and the seams are on opposite sides so it would take multiple bounces for a light leak to occur.The MMS materials are all self venting, in that they consist of woven fabric and open cell foam. However they do have to vent at the edges. Therefore the edges will not be sealed and the volume of the MMS enclosed by the thermal blanket will be vented at the bottom of the TDA's where there is a transition from having an MMS and Thermal Blanket to just having a Thermal Blanket. This is the same area in which the volume between the TDA's and shell will be vented. This approach is similar to the one used for EGRET, which had a similar shield.	Closed
4	ACD	Bolek	Amato	Delineate plans and procedures for preventing helium contamination of the photomultiplier tubes (PMT's) during ACD, LAT, and spacecraft integration. These should include:Sampling of purge gases to ensure no helium, Use of special purge lines (helium can pass through Tygon tubing). Actions to be taken if the helium detector alarm goes off. Plans for replacement detectors to be in place if the primary detector has to be removed.	The PMT's are sensitive to helium contamination. The sensitivity was noted to be at the 5 ppm level, which is near ambient conditions. Protecting the PMT's from contamination will be a challenge especially at the instrument and spacecraft level.	We have recently revised our Helium sensitivity calculations and produced a detailed helium exposure requirements curve. The new curve and some updated information on how to assess helium exposure on the PMTs are included in an updated version of the document LAT-TD-00720 – 'LAT ACD Phototube Helium Sensitivity'. Noticeable effects on the PMTs take quite some time near ambient and even at higher concentrations (over 10 weeks at double ambient helium levels). Because damage to the PMTs takes quite a bit if time we have decided we do not need continuous monitoring. Samples of purge gasses and of the room will be taken with a Helium monitor (the same one GLAS used) every 2 – 3 days and every time ACD or the PMTs are moved. Actions to be taken if Helium levels exceed the low threshold on the curve include increasing purge pressure (we will be purging with a dry nitrogen specified for low Helium levels and plan on using helium resistant purge lines), moving to constant monitoring and identifying the source. If the source can not be identified or is beyond our control and levels do not drop even with increased purge pressure,	Closed
						the PMTs and or ACD may have to be moved. Again the damage is quite slow, the requirement curve has quite a bit of margin in it (greater than a factor of 10) and we will have a running set of monitoring points to estimate total exposure to that point in I&T. Of course the urgency of the situation will depend on the accumulated exposure to that point (given our requirement and purging this is unlikely) which will be tracked using the monitor results. This information is currently in the process of being clarified on the ACD I&T plan. The requirements have been added to the latest draft of the Spacecraft IRD. It will be added to the GLAST LAT Contamination plan in its next update. We do not own a back up monitor but if the monitor becomes disabled we do have access to a Goddard sample collection service we used after the first PMTs arrived but before we had the monitor. The only disadvantage is that the results are delayed about a day. We are currently awaiting delivery of the Helium monitor that GLAS used. It is scheduled to be delivered to Building 2, Room 218 the first week of March. It does not come with an operating procedure, however we will generate one by March 28.	
						The procedure will include standard operating procedures for the monitor, data recording tables, and procedures for handling high levels of Helium.	

Peer Review RFAs (Continued)

5	ACD	Michalek	Scott	Provide the concept and details of how the various layers of the micrometeoroid shield will be electrically grounded to prevent static charge build up within and between the layers.	It's not obvious how this will be done since it seems to require a certain level of sheet electrical conductivity within each layer of the shield.	The micrometeoroid shield will be sandwiched between a grounded MLI Thermal Blanket and a grounded piece of aluminized Kapton. The MLI and aluminized Kapton will be grounded following standard Goddard procedures, using ground straps attached to the LAT instrument grid. The grounding procedure is that used for the EGRET instrument on the Compton Observatory, which had a similar shield.	Closed
6	ACD	Ryan	Amato	Environmental testing at the system level should be at "qualification" levels not "acceptance" levels. If strength qualification can be demonstrated by subsystem tests and analyses, reconsider a full ACD system "sine burst" test. Examine test predictions from protoflight level random vibration and acoustics tests to see if one of these tests dominates (eliminate one or the other test?).	The "protoflight" approach requires qualification test levels on the flight ACD assembly. A full up ETU qualification was eliminated from the verification approach (cost/schedule considerations). ETU qual would have allowed "acceptance" testing of the flight ACD assembly.	"Environmental testing at the system level should be at "qualification" levels not "acceptance" levels." We have since changed the levels planned for all environmental tests (including thermal vac) at the ACD full assembly level to 'protoflight' levels. These levels are defined as qualification levels which can be at reduced durations. One possible exception is mentioned below in response to your comment. "If strength qualification can be demonstrated by subsystem tests and analyses, reconsider a full ACD system "sine burst" test" We have reconsidered and will modify the ACD system sine burst test. Strength qualification tests have and will be performed on subsystem test components. The full mechanical structure will see a sine burst test to qualification levels prior to I&T. A sine burst test on the assembled ACD is not seen as necessary. "Examine test predictions from protoflight level random vibration and acoustics tests to see if one	Closed
						of these tests dominates (eliminate one or the other test?)." At the time of CDR the decision had already been made that random vibration tests would not be done at the full ACD assembly level because the acoustic loads dominate and in fact encompass our maximum launch loads. This approach has been discussed with LAT and has been agreed upon as an acceptable approach. Again, the ACD system level tests will be at protoflight levels.	
7	ACD	Ryan	T. Johnson	Although a web-based secure CM system (NGIN) was recently identified by the project, there was no mention of a CM document that defines the roles/responsibilities of personnel with respect to configuration management. Is there a requirement for a CM plan? If yes, does it exist?	Roles/responsibilities for CM did not appear to be documented.	Yes, there is a Configuration Management Plan for the ACD. It is ACD-PROC-000107, ACD Configuration Management Plan. We had experienced some previous difficulties with incorporating an ACD CM system with a system that the LAT Instrument Project Office wanted us to use. However it has been determined that we will use GSFC's on-site Instrument Systems and Technology Center configuration management system for all ACD work internal to GSFC (Level 4 and greater tasks). Interface documents between the LAT and ACD (Level 3) will reside on the LAT CM system. This approach has been agreed to by LAT project management and is a system that will meet the needs of the ACD.	Closed

Peer Review RFAs (Continued)

8	ACD	Michalek	Peters	Check to make sure that the thermal conduction from the BFA to the LAT grid is representative of the planned mechanical connection of the BFA to the LAT grid.	Since shims will be used to make the BFA to LAT grid mechanical joints, this may not give a good thermal conductive interface.	Parametric study has been performed on conductance value between BFA and Grid. The results show that radiation and not conduction is the primary mode of heat transfer between the BFA and Grid. Utilizing radiation only the ACD requirements are satisfied, conduction does provide additional thermal support.	Closed
9	ACD	Michalek	Segal	Mechanical analyses that consider extreme thermal loading conditions should consider a case or cases where one or more of the five sides of the TSA are at the extreme hot temperature while the remainder of the sides are at the cold temperature. Such asymmetrical thermal loading should also be applied to the BEA/BFA structural analysis.	Thus far, mechanical loading cases have considered all five sides either at hot or cold extreme. It is realistic on-orbit that 1 or 2 sides could be facing the sun while the remainder of sides will see a cold environment.	Asymmetric temperature loadings for the ACD were obtained from the ACD Thermal Engineer. Two cases were considered, hot case which is when the GRID and Tracker are in a hot case scenario and thermal hot case environmental parameters are applied and a cold case which is when the GRID and Tracker are in a cold case scenario and thermal cold case environmental parameters are applied. The cold case exhibited the highest temperature gradient across the TSA so the analysis was based on this case. The various temperatures were applied to the ACD FEM to produce the asymmetric thermal loading condition. The following tables show the results from the uniform temperature loading and the results from the asymmetric loading. (Data Provided)	Closed
10	ACD	Huegel	Unger	Complete the GAFE test procedure ASAP, and provide a copy.	New versions of the GAFE arrive almost monthly. A test procedure should be available for consistent testing from version to version.	GAFE test procedure development is occurring in two phases. The first phase was to develop a manual test procedure and the second is to develop an automated test procedure. The manual test proc (ACD-PROC-00067) was used as a basis for testing the first three generations of GAFEs (see the ACD Web site for the formal write-up on the GAFE2 testing, for example). The final version of the manual test proc is in review and is planned to be used for GAFEv4 testing around early March '03. Afterwards, the automated test proc will be updated and Labview coding will be performed. Then the automated test proc will be reviewed and tested with GAFEv4 around March/April '03. Some parts of the automated GAFE test procedure are already incorporated into the GARC Test procedure (ACD-PROC-000062) and the FREE board test procedure, which is largely complete. The current version of the GAFE manual test procedure is on the ACD website, and other versions of all procedures will be placed there as they are completed. Fred Huegel will be informed when that happens	Closed
11	ACD	Huegel	Unger	Ensure that the correct fabrication standard is used for the FREE printed circuit card.	In the electronics presentation, page 28, it is stated that the FREE PCB will be fabricated to the IPC-6012 standard. There is some question as to this being the correct standard.	Since this is a rigid-free board a standard Printed Circuit Board (PCB) specification does not exist. Therefore the ACD parts engineers are working on a specification for the FREE PCB. It is scheduled to be completed and released for review on March 14, 2004.	Submitted

Peer Review RFAs (Continued)

12	ACD	Ryan	Amato	Ref: I&T test flow, pg. 13, section 10. Two modal surveys are shown, one before vibration and one after acoustics. Typically a low-level sine sweep test is run before and after each vibration test axis. This checks for shifts in fundamental frequencies, but is not a true modal survey (more response accelerometers and data reduction required). Sine sweep testing for the flight Delta environment is required (0 – 50 Hz). Random vibration is required (unless acoustics testing envelopes this environment). Sine burst testing for strength may be required (unless subsystem test and analysis can show strength qual requirements have been met). Are two modal surveys planned (required)? Can the return to the vibe cell after acoustics testing be eliminated (reduce handling risks) by carefully looking at the acceleration response data from acoustics?		The modal surveys mentioned were defined (in the parenthetical comment) as low level sine sweeps. A full modal test is not planned or needed prior to integration with the LAT Grid. Low Level sine sweeps will be used for monitoring structural integrity. The post acoustic low level sine sweep will be replaced with a post acoustic test review of accelerometer data.	Closed
13	ACD	Scott	Kolecki	Describe in detail the problem reporting and corrective action system that will be used for ACD. When will formal problem reporting start? Describe the transition in problem reporting and corrective action systems (if any) after ACD delivery to LAT and LAT delivery to the observatory. Who will ensure that all ACD problems are tracked and closed out at all levels of integration?	This is an essential component of space flight mission assurance, overlooked in section 9, Safety and Mission Assurance. I'd prefer to see the actual ACD plans and procedures rather than just a requirement from the MAR.	All problem reporting will be documented using the GSFC Nonconformance reporting system as defined in GPG 5340.2C (Control of Nonconforming Product) and corrective action required will be documented using GPG 1710.1 (Corrective and Preventive Action). Formal reporting will begin post CDR with the start of procurement, fabrication and assembly and continue through final delivery of each subsystem to I&T. At this time, the LAT procedures are still under review, but it is expected that a similar, if not the GSFC on-line based system, will be used for observatory I&T also. The Product Development Lead will be responsible for initiating the NCR and QA will follow up on the corrective action. Configuration management and the SAM will be responsible for tracking the NCRs and coordinating dispositions with the PDL and the I&T lead. The SAM is currently developing an Assurance Implementation Plan for the ACD that will define how all the GLAST Mission Assurance Requirements will be met.	Submitted
14	ACD	Scott	Amato	Is there a logistical support plan or spares plan? Based on the calculated reliabilities, FMEA's, and mean times to repair, provide a full description of what spares will be provided. What spares accompany delivery to LAT and to the observatory?	A good spares plan (logistic support plan) will save time and money. Need to plan ahead. I'd like to see the list of spares and how you decided which ones to provide.	The ACD team has spent a lot of time during design of ACD determining the number of spares needed, however, we have not put all of this information in one document. The following Spares Plan will document the ACD spares plan. (Data Provided)	Closed

Peer Review RFAs (Continued)

15	ACD	Sneiderman	Segal	Evaluate changing the baseline bottom tile mount concept to one that does not rely on a slipping interface. Included in this evaluation, examine the consequence of one (or two) broken flexures if the concept is not changed. Add the evaluation of broken flexures to the project risk list if the concept is not changed.	The bottom tile slip/stick flexure must accommodate 8.4 mm of thermal expansion. Tests have shown that flexures fail at >6 mm displacement in the weak axis shear direction. This means that the last three flexures are at risk. There are numerous causes that could result in the non-slip of the slip interface. If the slip/stick feature does not work, flexures will fail. Since subtle features (workmanship/tolerances/friction properties/Belleville preload/contamination) of the slip interface are important in the proper function of the flexure, the low sample rate in the proposed qualification testing may not accurately simulate the flight condition and could provide a false positive result. There are 24 slip/stick fasteners that could cause a flexure failure (2 fasteners/flexure; 3 flexures/bottom tile with >6 mm displacement; 4 bottom tiles), yet the proposed qualification test only tests a sample of 8 fasteners.	The bottom tile flexure support design is a support flexure in the 'fixed/free' concept common to the other ACD tiles. This design does not rely on a 'slip stick' mechanism. The flexure design is a thinner composite laminate, .025 inch compared to .035 inch, than the baselined tile flexures. This thinner flexure design allows adequate compliance and has positive strength margins under thermal loading as well as launch loads (less severe of the two load cases). Testing plans include fabricating bottom tile flexures and testing them in strong and weak axis shear. Loading to failure in the weak axis will be performed after 12 load cycles to the maximum predicted deformation (based on survival temperature predictions). This approach will prove the design is capable to withstand repeated loading and maintain a margin after the repeated loading. Flexure failure is not deemed a risk on orbit. Even with three flexures in a row broken the tile would maintain its position as it is contrained by the Micrometeoriod Shield, the 4 flexures. No science impact would result.	Closed
16	ACD	Horn	Segal	Identify TDA's that will/may require the most disassembly to access or replace/repair. Suggest building "protective covers" to ensure that these TDA's will not be easily damaged. Recommendation is: Work with the LAT team to identify impacts and benefits (tech/cost/schedule) of building and integrating a hard cover to be installed from ACD assembly through launch prep. Include evaluation of ease of application/removal of the cover and potential of collateral damage from applying and removing the cover.	Probability of handling damage from ACD assembly through launch prep is a reality and must be assessed and mitigated where possible.	The TDA's that require the most disassembly to replace are the tiles on the top of ACD. Because the TDA's have a shingle overlap, to remove a top center row TDA, all of the TDA's in the same column as the TDA to be replaced would need to be removed. This means that a minimum of 6 TDA's would have to be removed to gain access to a top center row TDA. A soft protective cover will be designed and built to protect the ACD during integration, transportation and storage. A hard cover was considered, however the risk of damaging the ACD due to frequent installing and removing a large 'hard' cover that would need to be in close proximity to sensitive ACD surfaces is deemed too great. A soft cover can do an effective job protecting the ACD at a fraction of the design cost of a hardcover, therefore the softcover was selected. When the ACD is fully integrated it is fairly rugged. All fibers are shielded by 1 cm thick plastic scintillator and the ACD is covered with the thermal blanket and micrometeoroid shield (which has many layers of foam). The outer layer of the thermal blanket would be the most sensitive item at full assembly, and it is fairly rugged and can be easily repaired should th	Closed

Peer Review RFAs (Continued)

17	ACD	Goans	T. Johnson	The duration of the ACD integration is shown to start on 02/03/04 and finish on 04/22/04 on the top-level schedule. The integration flow up to the pre-environmental review was shown to take 115 days in the I&T presentation. Please provide an explanation for the discrepancy in the duration of the integration activity.	Time required for integration may not be accounted for in the project master schedule.	Semantics and task definitions have led to the confusion in this area. What is defined as "ACD Integration" (WBS 4.1.6.7.2 in the project schedule) on the top level schedule is integrating the TSA to the BEA. This task involves taking the fully integrated BEA and the nearly complete TSA and integrating them together. The following sub-tasks make up the overall "ACD Integration": Install the TSA on the BEA, Mate 186 fiber cables to PMTs, Integrate 4 bottom TDA's, Perform Functional Test, Install MMS/Thermal Blanket, and perform Performance/Efficiency Test. The Assembly/Integration Flow shown in the I&T section (Section 10 - page 7) starts with the integration of the BEA and the TSA. We defined these tasks as "ACD Subsystem Integration". Both the integration of the BEA and TSA begin in November, 2003. When the integration of the BEA and TSA are complete, we begin "ACD Integration". This accounts for a 67 day variance from November through February 3, 2004. An additional source of variance is that the I&T Assembly/Integration Flow represented in (Section 10 - page 7), displayed the days as "calendar" days, not "working days." This led to the additional discrepa	Closed
18	ACD	Klaisner	T. Johnson	Present a QA plan for the fabrication work at Fermilab of the scintillator tile assemblies. This plan should include the written procedures and the personnel involved, particularly the chain of command from the ACD management to the on-site personnel.	The manufacturing plan for these assemblies was not presented at this review. Fermilab has extensive experience in producing similar devices for high energy physics detectors. But, they have little experience with space programs. Based on a visit to Fermilab prior to this review, I am concerned about the process control. The ACD management should assure that the operators are adequately trained and that adequate inspection procedures and personnel are in place to assure quality units.	The ACD TDA's will be fabricated in accordance with ACD-PROC-00059, Fabrication and Assembly Procedure for the ACD Tile Detector Assembly (TDA). A Work Order Authorization shall be used as a traveler for all work performed on each TDA. There are Quality Inspection steps specified in ACD-PROC-00059 to verify that the TDA's meet or exceed all specifications and requirements prior to proceeding to the next step. As noted, Fermilab has a great deal of experience building similar detectors for ground based detectors. Fortunately, there is none to very little difference in the ACD TDA's and detectors used for ground based systems. The only potential differences would be in the selection of wrapping materials, tapes and adhesives and these are all specified. The primary components, namely the scintillator material, wave shifting fibers, clear fibers, and optical epoxy are the same for flight as for ground. These materials shall be qualified, tested, and controlled as specified in ACD-PROC-00059. The most important steps in the fabrication of the ACD TDA's are the machining of the scintillator, polishing the edges of the scintillator, fiber polishing (including conne	Closed
19	ACD	Dillman	Amato	Provide a risk management plan for ACD.	ACD has a risk list that they feed upwards to LAT. However, it was not clear how/when/by whom this list gets updated within the ACD subsystem. Need to clarify risk management roles/responsibilities.	As part of LAT, ACD risks and risk related issues (mitigation, flow, procedures etc) are captured in the LAT Continuous Risk Management Plan (LAT-MD-00067). Specific ACD risks and risk parameters are specifically identified in this document in ACD tables. New risks and risk updates will be actively asked for during the main leads and team meeting and by occasional e-mails containing the current ACD risk tables. Newly identified risks identified by anyone on the team are forwarded to the principal scientist and the systems engineers who discuss the issue. Newly identified risks are then entered into the LAT continuous risk management system by going to this web site (http://www-glast.slac.stanford.edu/systemengineering/lat_risk_management.htm) and entering required information on the on-line form	Closed