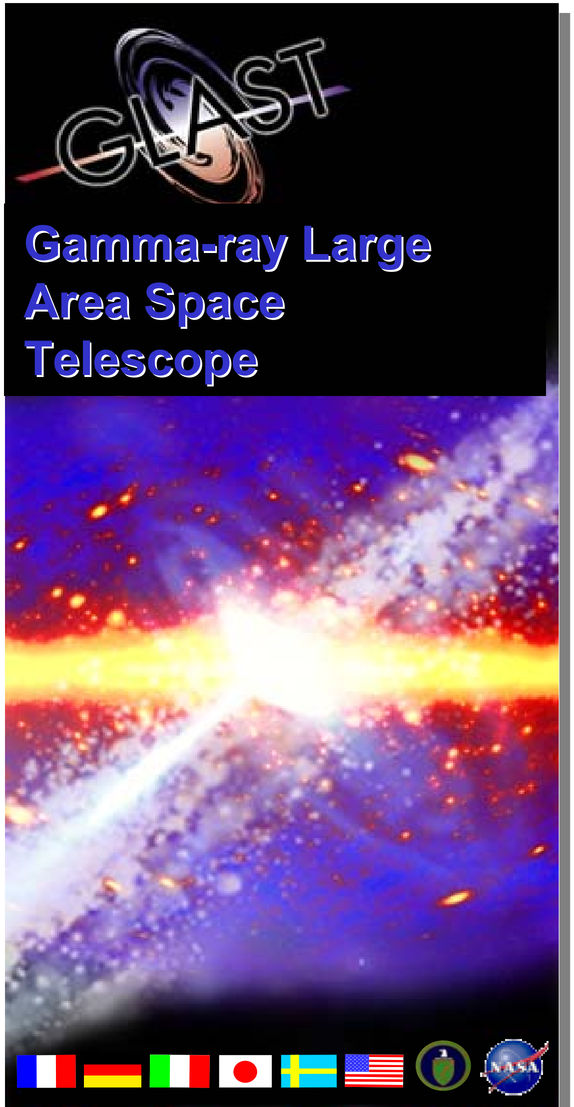


GLAST Large Area Telescope:

AntiCoincidence Detector (ACD) WBS 4.1.6

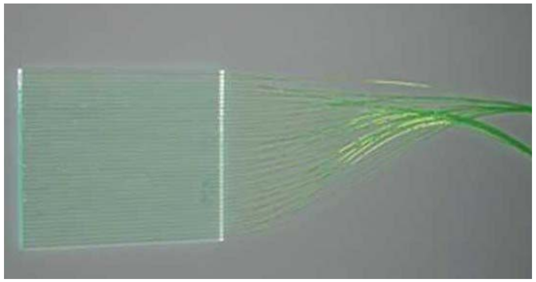
David J. Thompson, Subsystem Manager
Thomas E. Johnson, ACD Manager
NASA Goddard Space Flight Center
djt@egret.gsfc.nasa.gov (301) 286-8168
tjohnson@mscmail.gsfc.nasa.gov (301) 286-1284

Outline - ACD

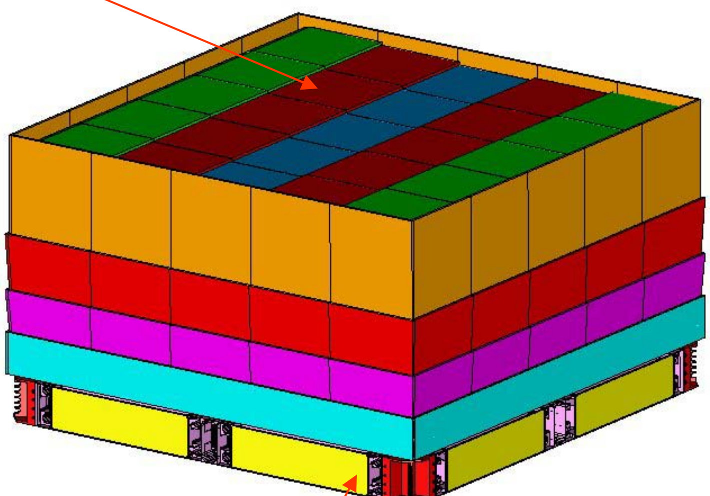
- Overview
- Results from January PDR/Baseline review
  - Findings and recommendations
  - Actions since the review
- Schedule and Budget
- Issues
- Summary

Anticoincidence Detector Overview

Prototype ACD tile read out with Wavelength Shifting Fiber



Tile Shell Assembly (TSA)



Base Electronics Assembly (BEA)

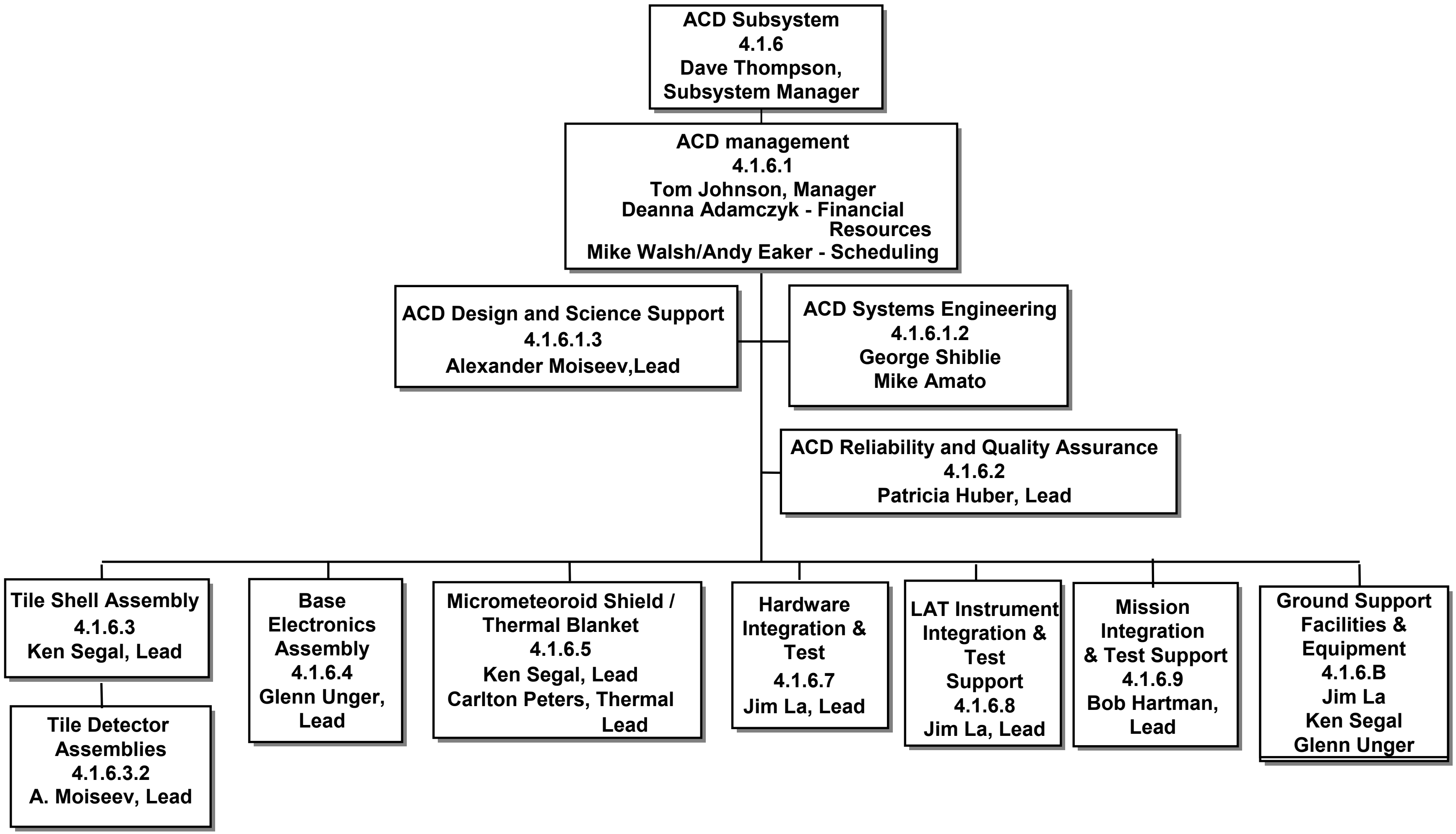
- **TILE SHELL ASSEMBLY**
  - 89 Plastic scintillator tiles
  - Waveshifting fiber light collection (with clear fiber light guides for long runs)
  - Two sets of fibers for each tile
  - Tiles overlap in one dimension
  - 8 scintillating fiber ribbons cover gaps in other dimension (not shown)
  - Supported on self-standing composite shell
  - 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. High voltage power supply on each board.

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 (less for bottom row of tiles)**	**≥0.9997** **≥0.99 (bottom tiles)**	**Test and Analysis**
Fast VETO signal	Logic signal 50-700 nsec after passage of charged particle	50-700 nsec	Test
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**	**< 20%**	**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	Test and Analysis
Size	Outside: 1796 x1796 x 1015 mm Inside Grid: 1574 x 1574 x 204.7 mm Inside TKR: 1515.5 x 1515.5 x 650 mm	1796 x1796 x 1015 1574 x 1574 x 204.7 1515.5 x 1515.5 x 650	Test
Mass	≤ 235 kg (228 + 7 allocated)	228	Test
Power	< 31 Watts (conditioned)	14	Test
Instrument Lifetime	Minimum 5 yrs	> 5 yr.	Analysis

ACD Organization Chart



ACD Team Space Flight Experience

- Science
  - Dave Thompson - SAS-2, EGRET
  - Bob Hartman - SAS-2, EGRET
  - Alex Moiseev - GAMMA-1
- Engineering
  - Tom Johnson - BBXRT, COBE, EUVE, SAMPEX, TRMM, HST
  - George Shiblie - FUSE, MAP
  - Mike Amato - Spartan 201, STIS (HST), Stereo COR1
  - Ken Segal - TRMM, HST, POES, EOS
  - Glenn Unger - MOLA, XTE, MAP
  - Dave Sheppard - BBXRT, XTE, TGRS, POEMS, GRS, Swift
  - Satpal Singh - EPACT and TGRS on WIND, Swift
  - Art Ruitberg - EGRET, COBE, POLAR, WIND, CASSINI, Triana
  - Bob Baker - HEAO, SMM, EGRET, BBXRT, XRS, XTE, Swift
  - Jim La - TDRS, POES, VCL/MBLA, Spartan, ROMPS, SLA, SEM
  - Carlton Peters - VCL, CATSAT, MAP, Triana

Summary of January Review

"The Committee found that there has been significant technical progress in terms of descoping and fully optimizing the ACD, while still meeting performance requirements. A schedule and a critical path analysis needs to be done for the ACD along with a revised bottoms-up estimate of the costs. The Committee concluded that the ACD subsystem is at the PDR level but was not ready for baselining at this time."

- ACD cost estimate and schedule have been revised and integrated with the LAT PMCS. Detailed Basis of Estimate, critical path analysis and contingency analysis have been prepared.
- Other (technical) recommendations from the January review are being addressed.

Status of January Review Recommendations

1. Finalize the design and generate the engineering drawings for the tile and fiber layout, including the lowest row of the ACD.

   – Designs for the 12 types of tile have been analyzed for thermal and vibration tolerances. Results are being used to generate engineering drawings.
   – Design for the lowest tile row is waiting for test results from two prototypes with different fiber layouts being made at Fermilab.
   – Preliminary drawings have been made for the routing of the fibers from the tiles to the phototubes. The routing is being checked using a mock-up of the ACD (about 80% complete). Final routing and drawings depend on the final tile designs.

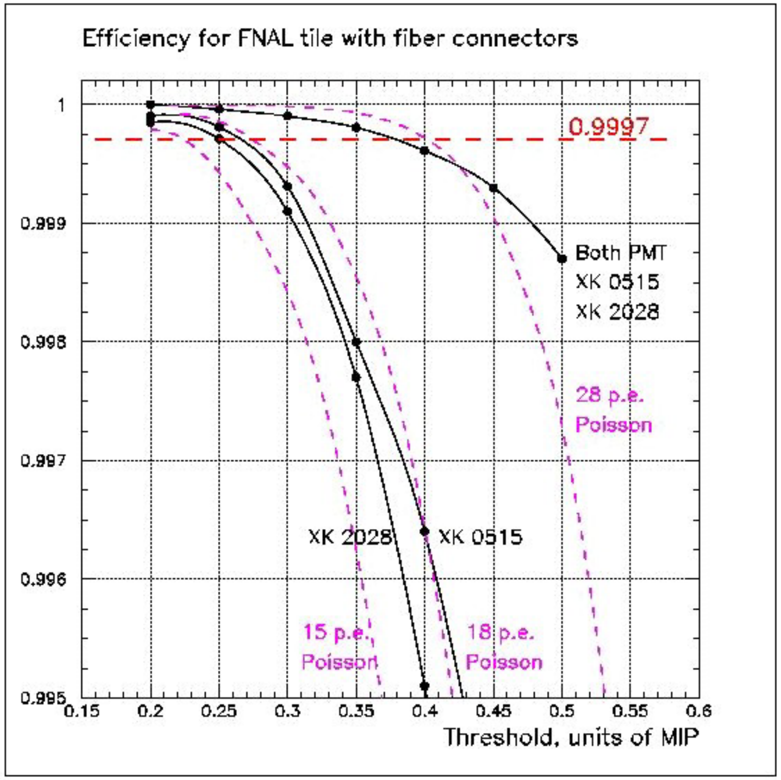
Status of January Review Recommendations

2. **Perform light yield tests and muon detection efficiency measurement of the final optical system (scintillator tiles; and fiber ribbons, connector, clear fibers, and photomultiplier tubes).**

Complete – results are similar to those shown in January: with two phototubes, 0.9997 efficiency is met; with one phototube, efficiency is ~ 0.999

Light output of Fermilab tiles is good. Light losses in the optical connector and clear fibers are higher than expected. Further tests will be done to identify and improve the light loss.

LAT-TD-00843-D1, Design Qualification Tests for ACD TDA and Phototubes



Performance of a full end-to-end TDA

Status of January Review Recommendations

3. Demonstrate that electronic noise of the system is low enough not to affect the muon rejection efficiency and efficiency for gammas by more than one percent.

Bench tests of the first analog ASIC show no noise problem. Tests on a full electronics card are planned for October.

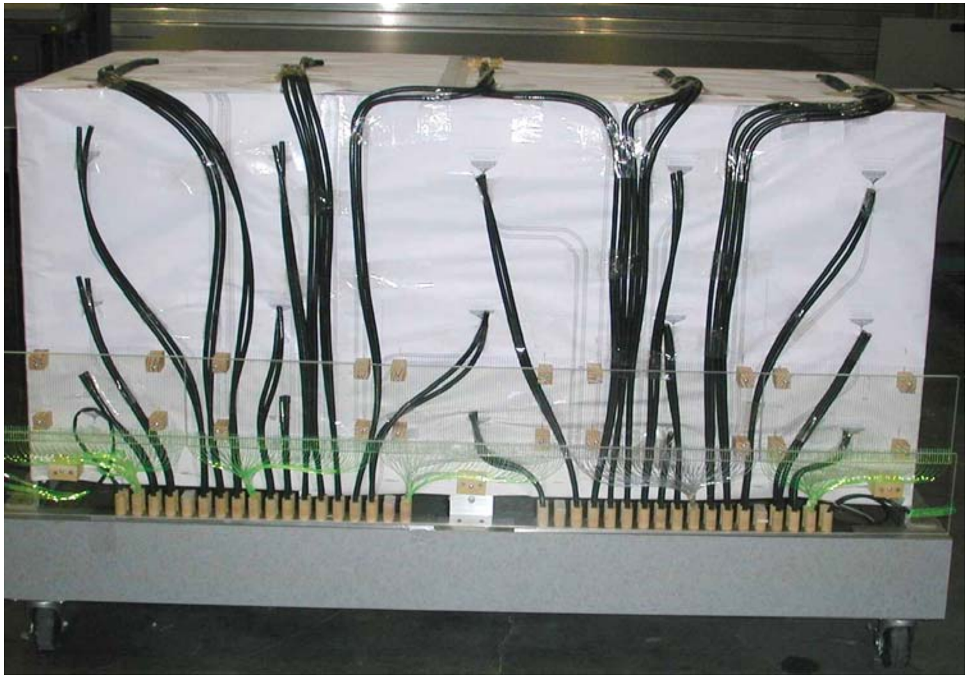
The ACD electronics noise is required to be < 0.2 X threshold. The early calculations show that the noise at the lowest threshold setting of 0.1 MIP is approximately 50% lower than the requirement.

The ACD team along with the LAT Electronics Systems Engineers have designed a grounding and shielding scheme to keep noise to a minimum.

Status of January Review Recommendations

4. **Complete full mockup of ACD, including clear fiber layout to photomultiplier tubes.**

The mockup has been built and many (~80%) of the tile and fiber routing placements have been completed.



Full-scale mock-up of ACD being used for tile placement and fiber routing from tiles to phototubes. Two bottom tile rows have been included.

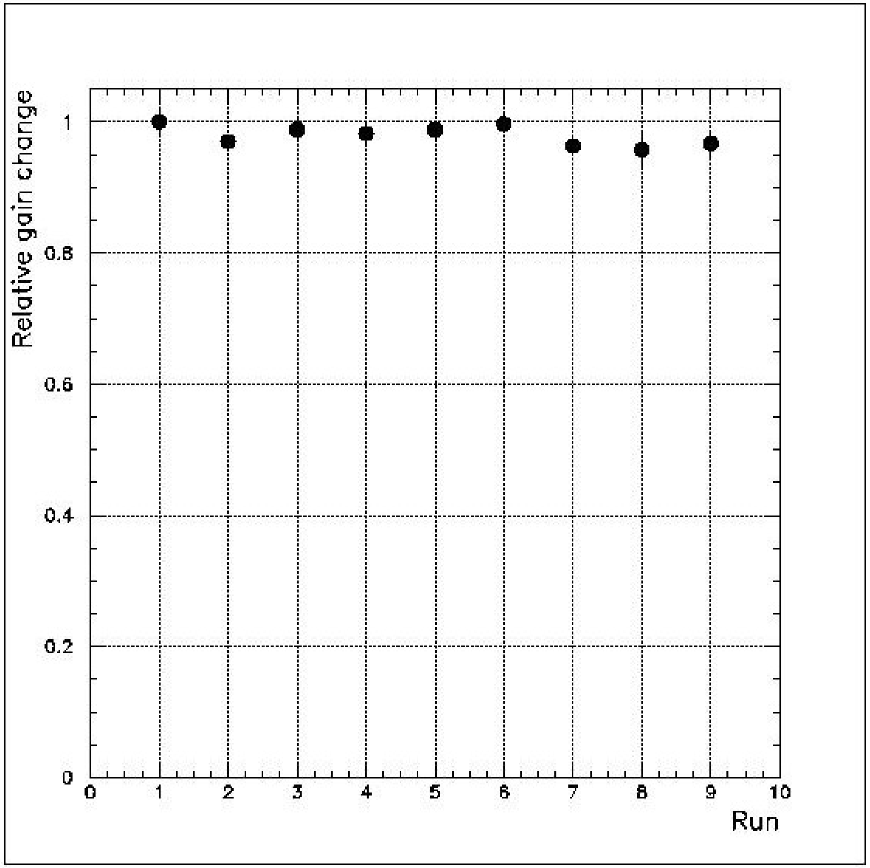
Details of mock-up.

Status of January Review Recommendations

5. **Perform thermal cycle of fully assembled tiles and ribbons. Verify that no damage to tile/fiber assemblies takes place and light yield is not decreased.**

- Thermal cycle was -65 C to +45 C.
- Performance was measured using a muon telescope for Minimum Ionizing Particles.
- After 340 cycles, the loss of performance was less than 5%.

LAT-TD-00858-D1, ACD TDA Thermal Cycling Test



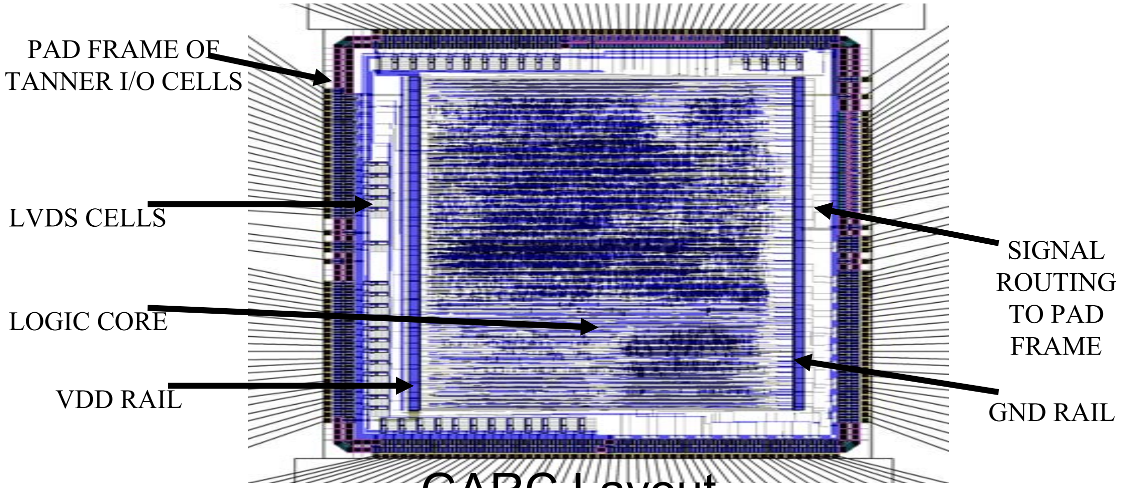
Light yield of Tile/fiber assembly during thermal cycling.

Status of January Review Recommendations

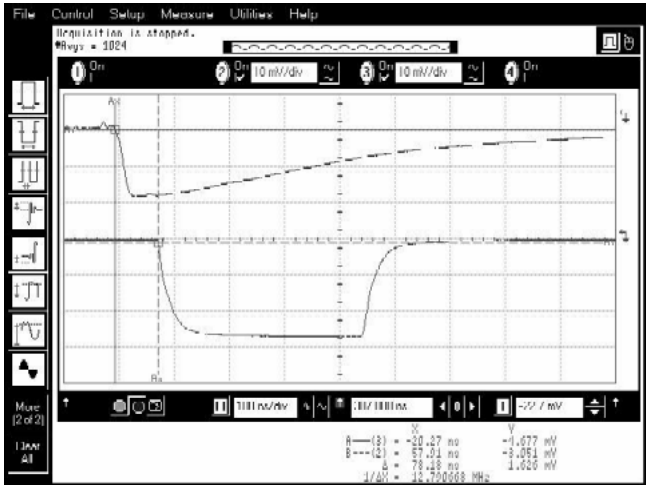
6. Prepare a plan for Quality Control (tile response uniformity and broken fibers) and initial calibration (ADC/minimum ionizing particle) of the ACD system prior to the delivery to the Stanford Linear Accelerator Center.
   - Quality Control is covered by the general ACD Quality Plan (ACD-QA-8001). Specific guidelines for handling of the TDAs will be written as an addendum to this document.
   - The methods for determining tile response uniformity and detecting broken fibers are documented in “Light Collection/Optical Performance Tests” (LAT-TD-00438-D2). Performance is measured using a muon telescope for Minimum Ionizing Particles.
   - A plan for calibrating the ACD using a muon telescope for mapping reference efficiency and then using internal triggers for PHA distributions is described in “ACD Gain Calibration Test with Cosmic Ray Muons” (LAT-TD-00844-D1). This approach was tested using the balloon flight ACD.

Status of January Review Recommendations

7. **Additional time should be added to the ASIC production schedule to provide some schedule margin.**
   - The current LAT extended schedule incorporates an additional month for ASIC development and additional testing time.
   - The GSFC Program management approved qualification and screening process for the ASICs is now shorter than the original one.
   - The scheduled ACD completion is now 15 weeks before the LAT integration need date.



GARC Layout



GAFE Veto Generation – 1 MIP

Status of January Review Recommendations

8. Complete the bottoms-up Work Breakdown Structure in the Primavera framework.
   - The WBS has been completed and has 10 major elements:
   - 4.1.6.1 Project Management/Systems Engineering/Science
   - 4.1.6.2 Safety and Mission Assurance
   - 4.1.6.3 Tile Shell Assembly
   - 4.1.6.4 Base Electronics Assembly
   - 4.1.6.5 Micrometeoroid Shield/Thermal Blanket Assembly
   - 4.1.6.6 Mechanical Qualification and Calibration Unit
   - 4.1.6.7 Integration and Test
   - 4.1.6.8 LAT Integration and Test Support
   - 4.1.6.9 Mission Integration and Test Support
   - 4.1.6.B Ground Support Equipment and Facilities

Status of January Review Recommendations

9. **Perform the critical path schedule analysis for the entire subsystem. Provide detailed documentation (at the lowest level of WBS) for the Basis of Estimate of the costs, in particular the on-project and off-project labor costs.**

One critical path has been identified (details in a later slide):

- ASIC development and testing. Three iterations of the ASICs are scheduled. Turnaround time from submittal to delivery is typically at least 12 weeks. Adding testing time means that one iteration can take at least four months. Shortened time for the screening testing helps. Scheduled ACD completion is 15 weeks before the LAT integration need date.
- Photomultiplier tube delivery had been a critical path. The 6-month schedule extension alleviated that pressure.

A detailed Basis of Estimate is available. Summaries in later slides.

Status of January Review Recommendations

10. Perform the contingency analysis of the subsystem. In particular, assess contingency for the off-project labor tasks.

A detailed contingency analysis, including all aspects of the ACD, has been carried out and incorporated into the PMCS. Some examples of contingency are shown in later slides.

Status of January Review Recommendations

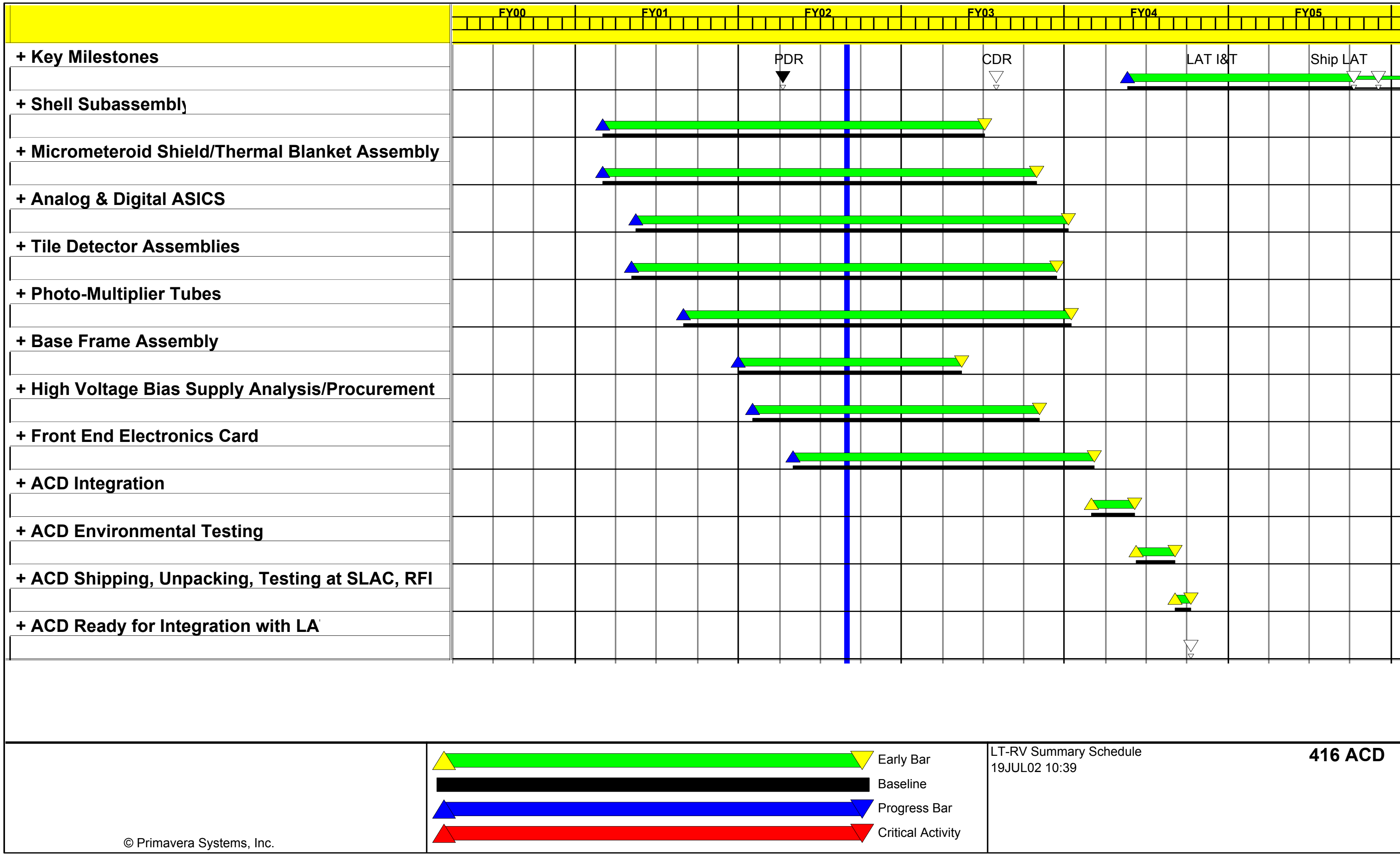
11. Due to lack of a verifiable Work Breakdown Structure (cost estimate) for the ACD, the subsystem is not ready to be baselined at the present time. Consider the following streamlining steps:
    - Separate materials and services from the labor tasks at lowest WBS level
    - Identify all the off-project labor costs at the lowest WBS level
    - Use the actual, fully loaded costs for technicians, specialists, engineers, etc., in all WBS labor estimates

- The PMCS contains most of this detailed information. Each resource is identified. Summaries are presented in later slides.
- Because the Goddard tax system is based on estimates rather than actuals, the labor costs are not fully loaded.

12. Conduct a Subsystem Baseline Review as soon as the work on the subsystem Work Breakdown Structure is completed.

    This is that review.

Summary Schedule



Key Level 3 Milestones

Activity Description	AV: Early Finish	Float	Baseline Finish
4.1.6 ACD			
Test/Screening Board w/ASIC for EM1 -ACD to Elec	09/20/02	0	09/20/02
High Voltage Power Supply (Bd & Prts)-ACD toElec	08/26/02	58	11/15/02
Doc defining Backsplash Test Model (ACD to I&T)	01/03/03	0	01/03/03
(11) FREE Bds & ASICS, (1) Fully Tested Bd - EM2	03/04/03	4	03/10/03
ACD Calibration Test Unit at SLAC, Tested & RFI	10/31/03	66	02/17/04
ACD Test Scripts (from ACD to I&T)	03/05/04	104	08/02/04
ACD Flight Unit at SLAC, Tested/Inspected & RFI	07/09/04	75	10/25/04

FY02: Q4 | FY03: Q1 Q2 Q3 Q4 | FY04: Q1 Q2 Q3 Q4 | FY05: Q1 Q2 Q3 Q4

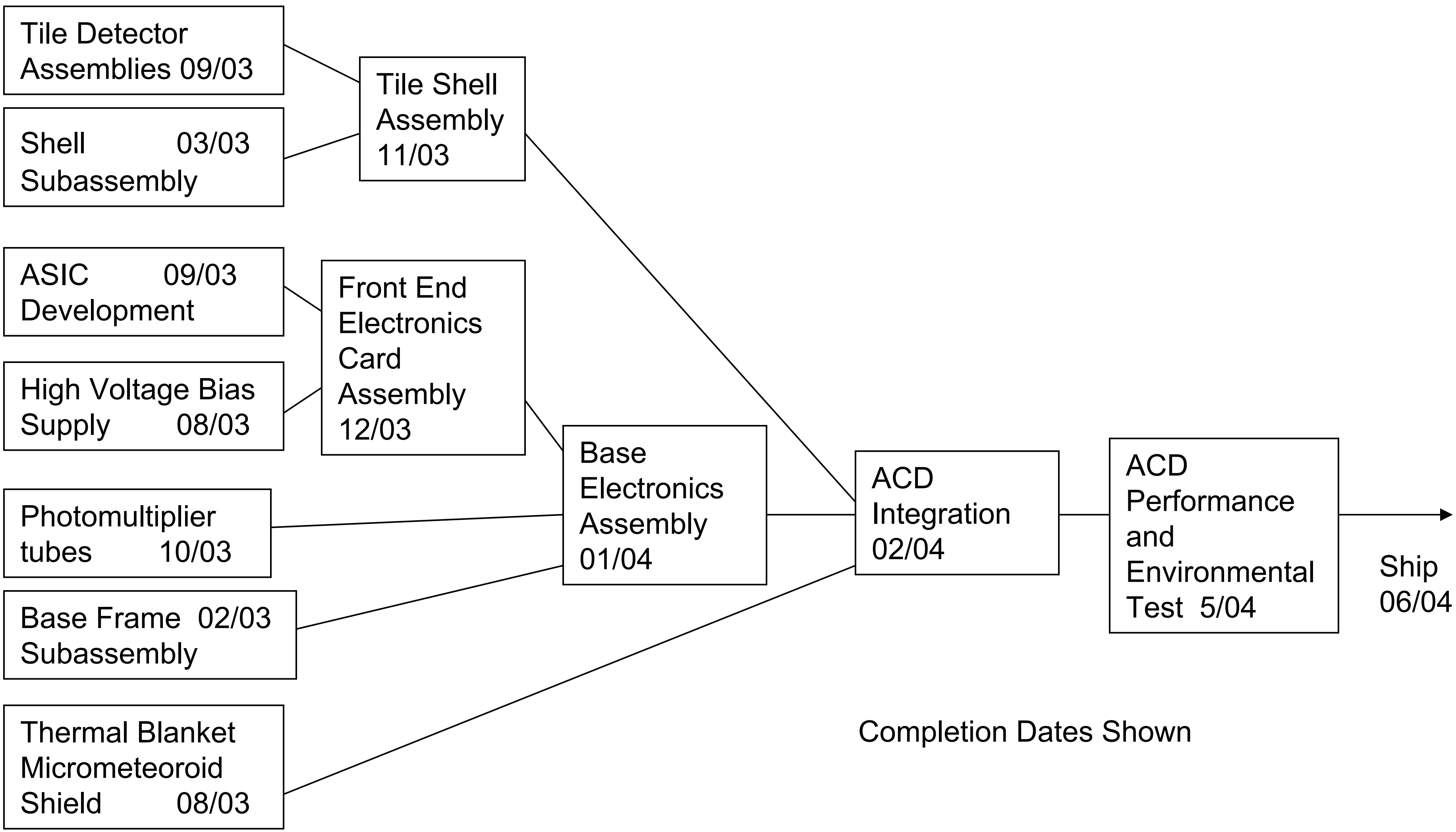
Run Date 07/19/02 10:53
Data Date 06/01/02

GLAST LAT PROJECT
Key Milestones

LAT3
LT-D4: Key Milestones
FL-D4: Key Milestones

Sheet 3

ACD Work Flow Overview



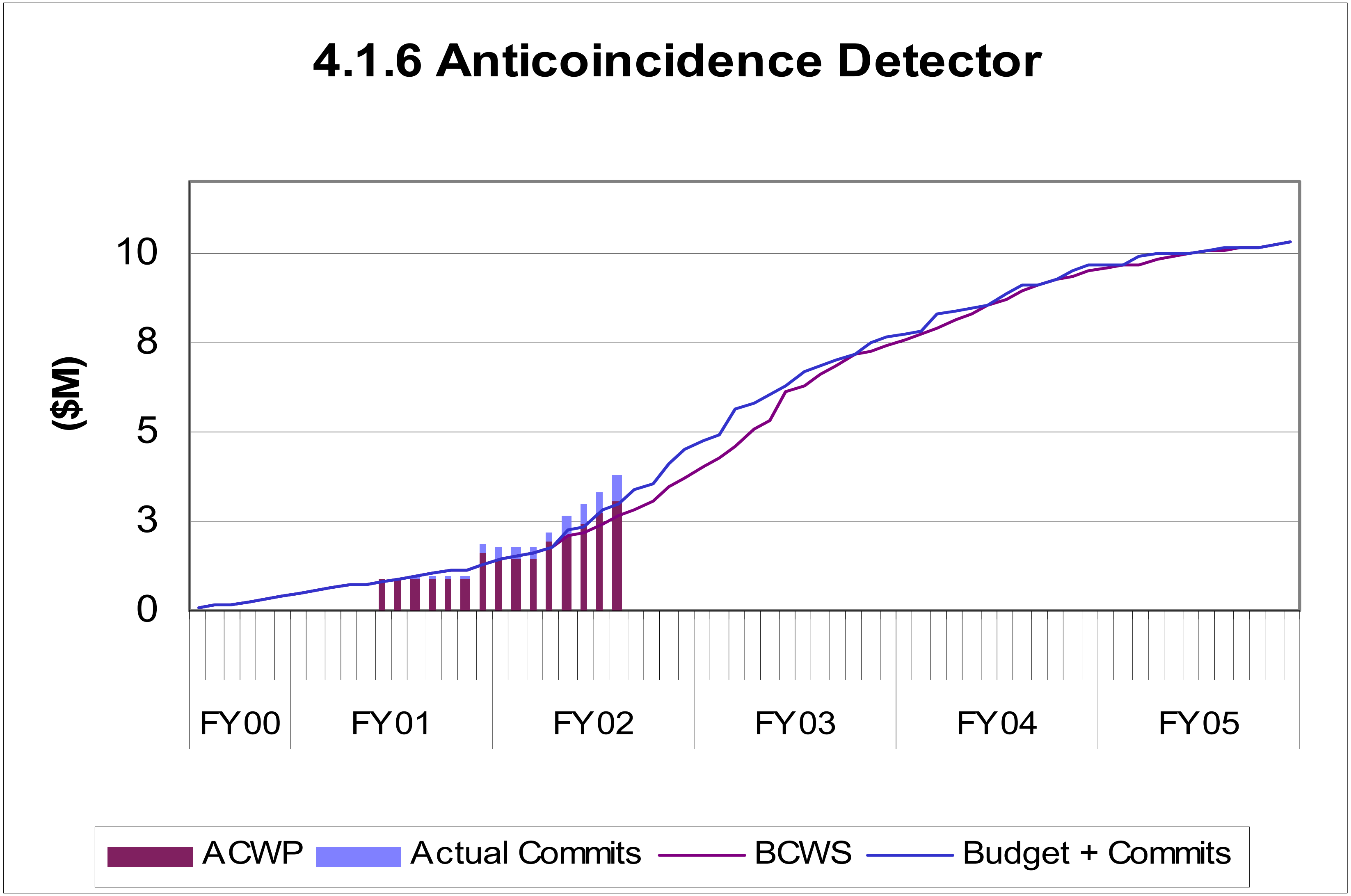
ACD Critical Path – Flight Analog ASIC

Activity	Dates
Second generation analog ASIC testing and flight analog ASIC design	9/12/02 – 2/28/03
Fabricate Flight Analog ASIC	3/3/03 - 5/27/03
Slice Die for Flight Analog ASIC	5/28/03 - 6/25/03
Package and Inspect Flight Analog ASIC	6/26/03 - 8/8/03
Testing Services for Flight Analog ASIC	8/11/03 - 10/8/03
Populate FREE Boards with Flt Analog ASIC	10/9/03 - 10/15/03
Populate FREE Boards with Flt, ADC, & DAC	10/16/03 - 10/29/03
Populate FREE Boards with Flt Digital ASIC	10/30/03 - 11/5/03
Populate FREE Boards with Flt PMT's & Inspect	11/6/03 - 11/19/03
Flight FREE Board Validation Tests	11/20/03 - 12/4/03
Install & Test FREE Boards, HVBS, & PMT's	12/5/03 - 1/12/04
Install & Test TDA	1/13/04 - 1/29/04
Complete ACD Integration	1/30/04 - 2/5/04
Performance Efficiency Verification Test	2/6/04 - 3/5/04
ACD Environmental Tests	3/8/04 - 6/2/04
Shipping Prep	6/3/04 - 6/4/04
Ship to SLAC, Test, & RFI	6/7/04 - 7/9/04

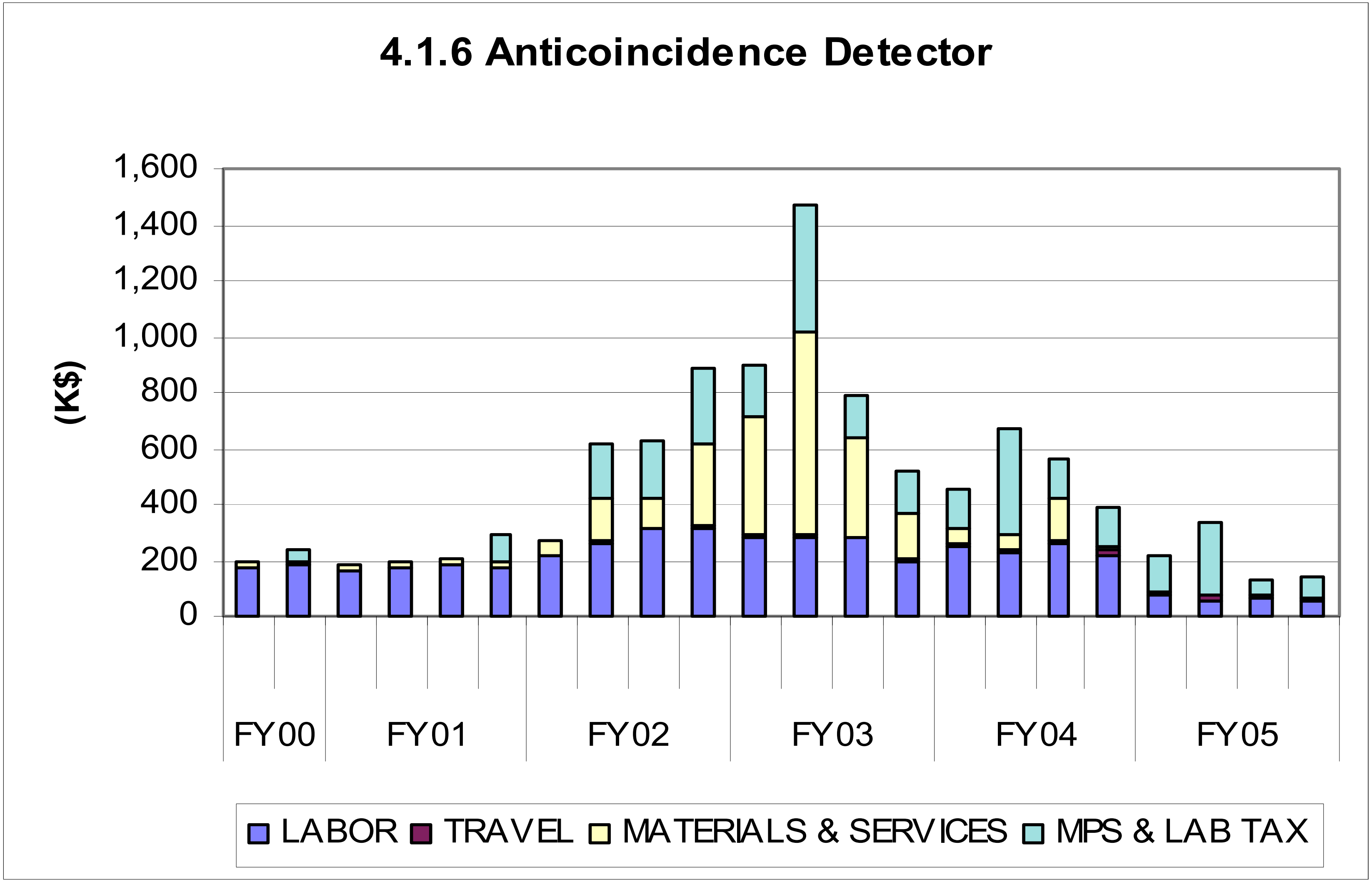
Goddard Costing

- Labor
  - Civil Service - We do not pay salary for Civil Servants, but we do pay Multi-Program Support (MPS, see below)
  - Contractor - We pay contractor costs plus MPS
- Taxes
  - MPS - This tax pays for Goddard overhead and is charged for flight projects at a flat rate of $35K per on-site FTE, based on the estimated manpower usage.
  - Lab Tax - This tax pays for local services such as computer systems support, publications, and office supplies. It is charged at a rate of 4% of the total cost of the project.
- Procurements
  - Ordinary - Purchase Requests are issued. Large items are required to be competed unless justified as sole source.
  - Shop - Fabrication purchases made through the Goddard shops may be done in-house or sent to contractors. Costs are estimated by Goddard staff, but they get bids to determine actual cost.

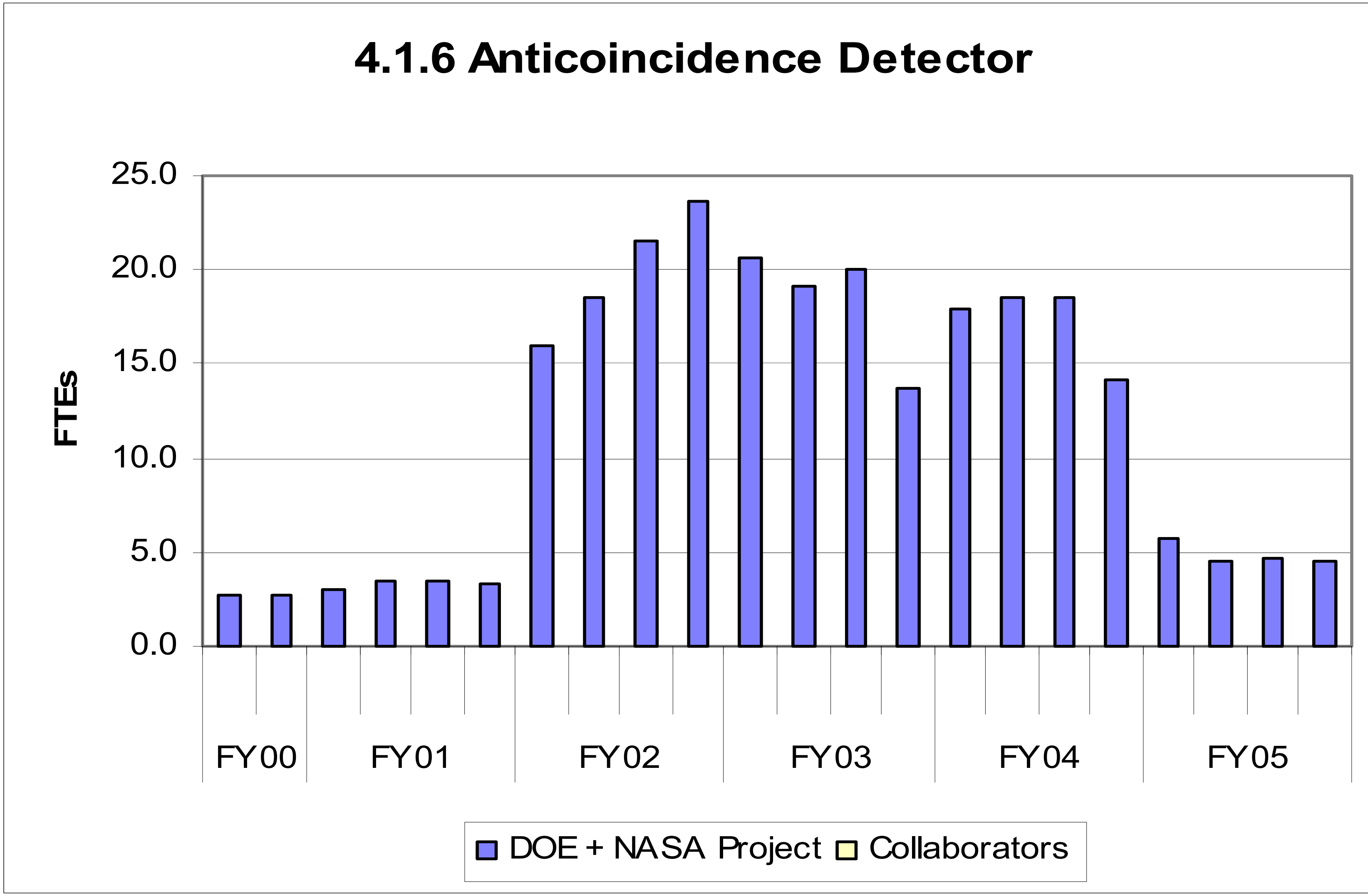
Cost & Commitments



Cost Profile



Manpower Plan



Cost/Manpower Overview by Fiscal Year

FY	Cost ($M) + Commit	FTE	Activities
2000	0.4	3.0	Planning, test
2001	0.9	6.5	Planning, test, design
2002	3.2	19.9	Complete design, start fabrication
2003	3.1	18.4	Fabrication, assembly, test
2004	2.0	17.3	Integration, test, delivery, LAT support
2005	0.7	4.9	LAT support
TOTAL	10.3	70.0	

FTE $\equiv$ 1976 hours

Cost/Manpower Overview by Task

WBS Element	Total Cost	M&S	Labor	Travel	Taxes	Contract FTE	CS FTE
4.1.6.1 Management/Systems Eng/Science Support	4,827,823	125,504	1,594,222	56,902	3,051,195	12.6	19.2
4.1.6.2 Safety & Mission Assurance	576,428	0	576,428	0		5	0
4.1.6.3 Tile Shell Assembly	1,620,559	1,022,724	578,833	19,001		3.7	2.2
4.1.6.4 Base Electronics Assembly	1,784,995	898,520	879,994	6,481		6.3	3.6
4.1.6.5 Micrometeoroid Shield/Thermal Blanket	150,096	121,051	29,045	0		0.3	0.3
4.1.6.6 Mechanical Qual & Calibration Unit	202,434	102,183	94,243	6,008		0.8	0.4
4.1.6.7 Integration & Test	627,978	182,005	420,973	25,000		3.8	7.8
4.1.6.8 LAT Integration & Test Support	35,630	0	0	35,630		0	0
4.1.6.9 Mission Integration & Test	1,380	1,162	217	0		0	0
4.1.6.B GSE	453,094	229,005	224,089	0		2.1	1.9
Total	10,280,416	2,682,154	4,398,044	149,023	3,051,195	34.6	35.4

Civil Service personnel salaries are paid by Goddard, not the LAT.

Taxes: Goddard overhead, charged on the basis of on-site FTE and total cost.

Manpower Skill Mix by Fiscal Year

RESOURCE	2002	2003	2004	2005
GSFC CS Clerical	0.04	0.04	0.02	0
GSFC CS Engineer	6.5	5.0	5.3	1.0
GSFC CS Prof Admin	1.0	1.0	0.9	0.6
GSFC CS R&D Supervisory	0.6	0.7	0.7	0.4
GSFC CS Scientist	0.9	0.9	0.9	0.9
GSFC CS Technician	1.0	1.2	1.0	0.1
GSFC Contractor I&T Engineer	0.1	0.1	0.0	0.0
GSFC Quality Assurance	1.6	1.9	1.5	0.0
GSFC Contractor On-Site Admin	0.6	0.6	0.5	0.5
GSFC Contractor On-Site Clerical	0.5	0.5	0.5	0.1
GSFC Contractor Sr Engineer	4.4	1.9	2.1	0.3
GSFC Contractor Jr Engineer	0.8	1.6	1.3	0.1
GSFC Contractor Sr Technician	0.9	2.1	1.7	0.1
GSFC Sr Scientist	0.9	0.9	0.9	0.9
TOTAL	**19.8**	**18.4**	**17.3**	**5.0**

ACD - Largest Procurements

Item	Cost	Supplier	Basis of Estimate	Contingency
Flight shell (composite)	$360,000	Composite vendor	3 vendor quotes	28%
Flight phototubes	330,000	Hamamatsu	Vendor quote	10%
Flight tile detector assemblies	195,000	Fermilab	Quote	32%
Micrometeoroid shield design/test	100,000	JSC	Fixed quote	21%
Clear fiber bundles/connectors	97,000	GSFC	Eng. Estimate, prev. exper.	38%
Digital ASIC (2 runs)	88,300	MOSIS	Catalog price	10%
Thermal Vac Cables	62,166	GSFC	Previous experience	32%
Tile detector tiedown hardware	61,500	Composite vendor	Vendor quote	32%
Flt. Spare tile detector assmbl.	61,000	Fermilab	Quote	32%
Test shell fab and assembly	42,000	Composite vendor	Eng. Estimate, prev. exper.	24%
HV bias supplies fabrication	40,000	SAIC	Vendor quote	38%
Test tile detector assemblies	30,000	Fermilab	Quote	32%
COTS phototubes	30,000	Hamamatsu	Fixed price, catalog	10%
Base frame handling dolly fab	30,000	GSFC	Mech. Branch estimate	32%
Tile shell handling dolly fab	25,999	GSFC	Mech. Branch estimate	32%
Shipping container fab	25,999	GSFC	Mech. Branch estimate	32%
Tile detector development	25,000	Fermilab	Quote	32%
Fiber ribbon flight unit fab	22,000	Wash. U.	Vendor quote	32%
Turnover/assembly dolly fab	21,999	GSFC	Mech. Branch estimate	32%

ACD – Costs of Major Tests

Item	Cost	Supplier	Basis of Estimate	Contingency
ACD Thermal Bal/Vac (24/7)	$193,460	GSFC	Test Branch estimate, LOE	28%
ASIC Testing Services	80,000	GSFC	Parts branch estimate	31%
Mech. Subsys. Thermal tests	35,899	GSFC	Test Branch estimate, LOE	32%
Mech. Subsys. Vibe tests	32,817	GSFC	Test Branch estimate, LOE	32%
ACD vibe test	43,055	GSFC	Test Branch estimate, LOE	28%
EMI/EMC test	36,576	GSFC	Test Branch estimate, LOE	28%
Test unit tile shell vibe test	19,505	GSFC	Test Branch estimate, LOE	28%
ACD acoustics test	27,956	GSFC	Test Branch estimate, LOE	28%
Mech. Subsys. acoustics test	17,413	GSFC	Test Branch estimate, LOE	28%
Mech. Subsys. Mass prop. test	14,563	GSFC	Test Branch estimate, LOE	28%
Test unit base frame vibe test	14,376	GSFC	Test Branch estimate, LOE	28%
ACD Mass prop. test	19,098	GSFC	Test Branch estimate, LOE	28%

Some ACD Risks - Not Likely, But Possible

Risk Description	Probability	Cost Impact	Schedule Impact	Technical Impact without mitigation/ Description	Mitigation Plan/Results	Contigency Plan
Design flaw in flight ASIC	Medium	Medium	High	2 - lose effective area, lower background rejection, no diffuse measurement	Three foundry runs, comprehensive test program, and peer reviews	Replace with newly designed ASICs
Tile Assy. (Tiles, ribbons & PMT) fail efficiency test in ACD Qualification	Medium	Medium	Medium	2R - Lose ability to measure difuse radiation	Early testing, detailed simulations	Thicker tiles
Corona in Thermal Vac around HV	Low	Medium	High	2 - if systematic, lose effective area, lower background rejection, no diffuse measurement 3 - Lower efficiency if workmanship failure	Early testing and qualification of subassembly	Analyze and redesign the PMT assembly process for systematic failure. Re-pot PMT assembly for workmanship failure.
PMT Fails in test	Low	Medium	High	3 - Lower efficiency	PMT qualification program and burn-in	Replace with spares
Light Leak in the detector system channel	Medium	Low	Medium	2R - Lose ability to measure difuse radiation	Early testing and qualification of subassembly	
Mechanical interference problem found during assembly	Low	Low	Medium	1 - cannot fly without ACD or something above	Design checks and early Fit checks	Modify BEA
Waveshifting fibers break in environmental testing	Low	Low	High	3 - Lower efficiency	Subassembly test, careful tiedown. If you had a failure in a later environmental test, the cost will increase.	Re-design the fiber cable tie-downs
Tile comes loose in acoustics	Low	Low/Med <100k	High	3 - Lower efficiency	Conservative design, analysis, mechanical qualification program	Analyze failure, repair or redesign
EMI/EMC produces noisey signals	Low	Low	Medium	3 - Lower efficiency	Careful design, early subassembly tests	
HVBS fails in test	Low	Medium	High	2R - Lose ability to measure difuse radiation	HVBS qualification program and burn-in	Replace with spares
Structural Failure (I.e. lamenant failure, bond failure, etc)	Low	Low/Med	Medium	3 - Lower efficiency	Conservative design, analysis, mech. qual program	Analyze failure, repair or redesign
Other BEA electronics subassembly failure	Low	Low	High	2R	Early testing and qualification of	Replace with spares
QA finds problem in part (ie GIDEP alert)	Low	Low/Med	Medium	3 - Lower efficiency	None	Replace w/ different
Civil Servant test conductors pulled off for another project	Medium	Medium	Medium	4 - only schedule impact	High visibility with GSFC management	Hire and Train test conductors

Summary

- The ACD continues to make technical progress. Most of the technical recommendations from the January review have been resolved. Additional test planning is still needed.
- The ACD has developed a coherent, verifiable cost and schedule plan. Basis of Estimate, critical path analysis and contingency have been clarified.
- The schedule has three months of float at the end.
- The ACD faces no unusual risks. The risks are those experienced by any space flight instrument.

Backup material

Second Quarter FY03 Cost Spike

Costs show a peak in FY03 Q 2 – total of	$1.5 M
Manpower is about the same as other Q	0.3 M
Extra MPS and lab taxes are costed this Q	0.5 M
Several major hardware purchases this Q	
•Flight TDAs	0.2 M
•Flight fiber cables	0.1 M
•PMT housing assembly	0.1 M
•Mechanical GSE	0.09 M
•Thermal Vac cables	0.085 M

Level 3 Key Milestones

ACD Subsystem Requirements Review	03/20/01
Anticoincidence Detector PDR	07/25/01
Prototype Electronics Module (Elec to ACD)	04/15/02
EGSE Workstation / Software #1 (I&T to ACD)	04/15/02
Test/Screening Board for EM1 - ACD to Elec	09/20/02
Anticoincidence Detector CDR	10/07/02
High Voltage Power Supply (Bd & Prts)-ACD toElec	11/15/02
Doc. Defining Calibration Model - ACD to I&T	01/03/03
(11) FREE Bds & ASICS, (1) Fully Tested Bd - EM2	03/10/03
Flight Grid Ready for ACD Fit Test-(Mech to ACD)	05/08/03
ACD Calibration Test Unit at SLAC, Tested & RFI	02/17/04
ACD Test Scripts (from ACD to I&T)	08/02/04
ACD Flight Unit at SLAC, Tested/Inspected & RFI	**10/25/04**

Contractor FTE's - Details (1)

ACT ID	DESC	TOTAL	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005
4.1.6.1 ACD PROJECT MANAGEMENT/SUBSYSTEM ENG.								
DGL$	GSFC Labor (fully loaded)	1.07	0.36	0.70				
DGLHA	GSFC On-Site Administrative	2.11			0.54	0.54	0.54	0.49
DGLHC	GSFC On-Site Clerical	1.42			0.45	0.45	0.45	0.07
DGLHE	GSFC H Engineer	2.70			0.90	0.90	0.68	0.23
DGLHJ	GSFC H Jr Engineer	1.71			0.47	0.90	0.34	
DGLUS	GSFC U Sr. Scientist	3.61			0.90	0.90	0.90	0.90
TOTAL	**61**	**12.61**	**0.36**	**0.70**	**3.26**	**3.69**	**2.91**	**1.68**
4.1.6.2 SAFETY & MISSION ASSURANCE								
DGL$	GSFC Labor (fully loaded)	0.36	0.12	0.23				
DGLEQ	GSFC Quality Assurance	4.70			1.58	1.69	1.43	
TOTAL	**62**	**5.06**	**0.12**	**0.23**	**1.58**	**1.69**	**1.43**	
4.1.6.3 TILE SHELL ASSEMBLY (TSA)								
DGL$	GSFC Labor (fully loaded)	1.56	0.53	1.03				
DGLEI	GSFC I&T Engineer	0.09			0.07	0.02		
DGLEQ	GSFC Quality Assurance	0.10			0.04	0.07		
DGLHA	GSFC On-Site Administrative	0.06			0.04	0.02		
DGLHE	GSFC H Engineer	1.27		0.00	1.25	0.02		
DGLHJ	GSFC H Jr Engineer	0.17		0.00	0.14	0.03		
DGLHT	GSFC H Sr Technician	0.47			0.30	0.17		
TOTAL	**63**	**3.73**	**0.53**	**1.03**	**1.84**	**0.33**		
4.1.6.4 BASE ELECTRONICS ASSEMBLY (BEA)								
DGL$	GSFC Labor (fully loaded)	1.96	0.67	1.30				
DGLEQ	GSFC Quality Assurance	0.16			0.00	0.14	0.02	
DGLHE	GSFC H Engineer	1.98			1.70	0.28		
DGLHJ	GSFC H Jr Engineer	0.06			0.06	0.00		
DGLHT	GSFC H Sr Technician	2.15			0.28	1.37	0.49	
TOTAL	**64**	**6.31**	**0.67**	**1.30**	**2.04**	**1.79**	**0.52**	
4.1.6.5 MICROMETEOROID SHIELD/THERMAL BLANKET								
DGLEQ	GSFC Quality Assurance	0.00				0.00		
DGLHA	GSFC On-Site Administrative	0.03			0.01	0.02		
DGLHE	GSFC H Engineer	0.10			0.01	0.08		
DGLHJ	GSFC H Jr Engineer	0.13			0.02	0.12		
TOTAL	**65**	**0.26**			**0.04**	**0.22**		

Contractor FTE's - Details (2)

ACT ID	DESC	TOTAL	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005
4.1.6.6 ACD MECHANICAL QUALIFICATION & CALIBRAT								
DGLEI	GSFC I&T Engineer	0.03			0.02	0.01		
DGLEQ	GSFC Quality Assurance	0.02				0.02		
DGLHE	GSFC H Engineer	0.30			0.03	0.28		
DGLHJ	GSFC H Jr Engineer	0.46			0.10	0.36		
TOTAL	**66**	**0.81**			**0.15**	**0.66**		
4.1.6.7 ACD INTEGRATION & TEST								
DGLHE	GSFC H Engineer	1.48				0.04	1.38	0.06
DGLHJ	GSFC H Jr Engineer	0.95					0.89	0.06
DGLHT	GSFC H Sr Technician	1.33				0.06	1.21	0.06
TOTAL	**67**	**3.76**				**0.09**	**3.48**	**0.19**
4.1.6.9 MISSION INTEGRATION & TEST SUPPORT								
DGLHE	GSFC H Engineer	0.00						0.00
TOTAL	**69**	**0.00**						**0.00**
4.1.6.B GROUND SUPPORT FACILITIES & EQUIPMENT								
DGLEI	GSFC I&T Engineer	0.08				0.08	0.00	
DGLEQ	GSFC Quality Assurance	0.01				0.01	0.00	
DGLHA	GSFC On-Site Administrative	0.01			0.01			
DGLHE	GSFC H Engineer	0.85		0.00	0.53	0.28	0.03	
DGLHJ	GSFC H Jr Engineer	0.22			0.00	0.15	0.06	
DGLHT	GSFC H Sr Technician	0.90			0.35	0.55		
TOTAL	**6B**	**2.07**		**0.00**	**0.89**	**1.07**	**0.10**	
	REPORT TOTAL	**34.62**	**1.68**	**3.27**	**9.81**	**9.55**	**8.44**	**1.87**

Civil Service FTE's – Details (1)

ACT ID	DESC	TOTAL	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005
4.1.6.1 ACD PROJECT MANAGEMENT/SUBSYSTEM ENG.								
DGLCC	GSFC CS Clerical	0.11			0.04	0.04	0.02	
DGLCE	GSFC CS Engineer	7.19	0.69	1.35	1.51	1.53	1.20	0.90
DGLCP	GSFC CS Prof Admin	4.59	0.37	0.72	0.95	1.04	0.89	0.63
DGLCR	GLRD CS R&D Supervisory	3.02	0.05	0.54	0.63	0.72	0.72	0.36
DGLCS	GSFC CS Scientist	4.29	0.23	0.45	0.90	0.90	0.90	0.90
TOTAL	**61**	**19.19**	**1.34**	**3.06**	**4.03**	**4.23**	**3.73**	**2.80**
4.1.6.3 TILE SHELL ASSEMBLY (TSA)								
DGLCE	GSFC CS Engineer	1.62		0.00	1.34	0.28		
DGLCP	GSFC CS Prof Admin	0.02			0.01	0.01		
DGLCT	GSFC CS Technician	0.54		0.00	0.33	0.21		
TOTAL	**63**	**2.18**		**0.00**	**1.68**	**0.50**		
4.1.6.4 BASE ELECTRONICS ASSEMBLY (BEA)								
DGLCE	GSFC CS Engineer	2.17			1.21	0.96		
DGLCT	GSFC CS Technician	1.40			0.56	0.82	0.03	
TOTAL	**64**	**3.57**			**1.77**	**1.78**	**0.03**	
4.1.6.5 MICROMETEOROID SHIELD/THERMAL BLANKET								
DGLCE	GSFC CS Engineer	0.27		0.10	0.11	0.06		
TOTAL	**65**	**0.27**		**0.10**	**0.11**	**0.06**		
4.1.6.6 ACD MECHANICAL QUALIFICATION & CALIBRAT								
DGLCE	GSFC CS Engineer	0.31			0.04	0.26		
DGLCT	GSFC CS Technician	0.09			0.04	0.05		
TOTAL	**66**	**0.40**			**0.08**	**0.32**		
4.1.6.7 ACD INTEGRATION & TEST								
DGLCE	GSFC CS Engineer	6.68			1.13	1.40	4.02	0.13
DGLCT	GSFC CS Technician	1.17				0.07	1.03	0.06
TOTAL	**67**	**7.84**			**1.13**	**1.46**	**5.06**	**0.19**

Civil Service FTE's – Details (2)

ACT ID	DESC	TOTAL	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005
4.1.6.9 MISSION INTEGRATION & TEST SUPPORT								
DGLCE	GSFC CS Engineer	0.00						0.00
TOTAL	**69**	**0.00**						**0.00**
4.1.6.B GROUND SUPPORT FACILITIES & EQUIPMENT								
DGLCE	GSFC CS Engineer	1.80		0.14	1.15	0.47	0.04	
DGLCT	GSFC CS Technician	0.14			0.12	0.03		
TOTAL	**6B**	**1.94**		**0.14**	**1.27**	**0.50**	**0.04**	
	REPORT TOTAL	**35.41**	**1.34**	**3.30**	**10.08**	**8.84**	**8.85**	**2.99**

Total Cost + Commitments – Details (1)

ACT ID	DESC	TOTAL	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005
4.1.6.1 ACD PROJECT MANAGEMENT/SUBSYSTEM ENG.								
DGCI	GSFC In PO Commitment	2803194			1047156	652243	765045	338750
DGCO	GSFC Out PO Commitment	-2803194			-559308	-943188	-797633	-503065
DGL$	GSFC Labor (fully loaded)	227999	77422	150577				
DGLCC	GSFC CS Clerical							
DGLCE	GSFC CS Engineer							
DGLCP	GSFC CS Prof Admin							
DGLCR	GLRD CS R&D Supervisory							
DGLCS	GSFC CS Scientist							
DGLHA	GSFC On-Site Administrative	165932			40814	41956	43304	39858
DGLHC	GSFC On-Site Clerical	61716			18984	19518	20142	3072
DGLHE	GSFC H Engineer	339520			109656	112715	87249	29900
DGLHJ	GSFC H Jr Engineer	185994			49582	98346	38067	
DGLUS	GSFC U Sr. Scientist	613060			146682	150773	155615	159990
DGO	GSFC M&S (fully loaded) no travel	125504	7131	13869	21501	23001	45001	15001
DGT	GSFC Travel (fully loaded)	56902			20000	20000	16901	
DGX	GSFC MPS & Lab Tax	3051195	43000	100001	664307	943189	797634	503066
TOTAL	**61**	**4827823**	**127553**	**264447**	**1559375**	**1118552**	**1171325**	**586571**
4.1.6.2 SAFETY & MISSION ASSURANCE								
DGL$	GSFC Labor (fully loaded)	76000	25807	50192				
DGLEQ	GSFC Quality Assurance	500428			164009	179574	156845	
TOTAL	**62**	**576428**	**25807**	**50192**	**164009**	**179574**	**156845**	
4.1.6.3 TILE SHELL ASSEMBLY (TSA)								
DGCI	GSFC In PO Commitment	421500			61500	360000		
DGCO	GSFC Out PO Commitment	-421500				-421500		
DGL$	GSFC Labor (fully loaded)	333000	113077	219922				
DGLCE	GSFC CS Engineer							
DGLCP	GSFC CS Prof Admin							
DGLCT	GSFC CS Technician							
DGLEI	GSFC I&T Engineer	15074			11521	3553		
DGLEQ	GSFC Quality Assurance	10965			3887	7079		
DGLHA	GSFC On-Site Administrative	4407			3030	1377		
DGLHE	GSFC H Engineer	154945		77	152130	2738		

Total Cost + Commitments – Details (2)

ACT ID	DESC	TOTAL	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005
4.1.6.3 TILE SHELL ASSEMBLY (TSA)								
DGLHJ	GSFC H Jr Engineer	18690		25	15082	3583		
DGLHT	GSFC H Sr Technician	41752			26639	15113		
DGO	GSFC M&S (fully loaded) no travel	1022724	7470	16072	182998	808183	8001	
DGT	GSFC Travel (fully loaded)	19001			5001	8000	6001	
TOTAL	**63**	**1620559**	**120548**	**236096**	**461788**	**788126**	**14001**	
4.1.6.4 BASE ELECTRONICS ASSEMBLY (BEA)								
DGCI	GSFC In PO Commitment	785400			430850	354550		
DGCO	GSFC Out PO Commitment	-785400			-156075	-589325	-40000	
DGL$	GSFC Labor (fully loaded)	420000	142620	277380				
DGLCE	GSFC CS Engineer							
DGLCT	GSFC CS Technician							
DGLEQ	GSFC Quality Assurance	17509			377	14739	2392	
DGLHE	GSFC H Engineer	241675			206623	35052		
DGLHJ	GSFC H Jr Engineer	6596			6198	398		
DGLHT	GSFC H Sr Technician	194215			24769	123657	45788	
DGO	GSFC M&S (fully loaded) no travel	898520	26147	50853	188039	592360	41120	
DGT	GSFC Travel (fully loaded)	6481			1400	4115	966	
TOTAL	**64**	**1784995**	**168768**	**328233**	**702181**	**535546**	**50267**	
4.1.6.5 MICROMETEOROID SHIELD/THERMAL BLANKET								
DGCI	GSFC In PO Commitment	50000			50000			
DGCO	GSFC Out PO Commitment	-50000			-50000			
DGLCE	GSFC CS Engineer							
DGLEQ	GSFC Quality Assurance	194				194		
DGLHA	GSFC On-Site Administrative	2314			995	1319		
DGLHE	GSFC H Engineer	12069			1674	10395		
DGLHJ	GSFC H Jr Engineer	14468			1627	12841		
DGO	GSFC M&S (fully loaded) no travel	121051			107567	13483		
TOTAL	**65**	**150096**			**111863**	**38233**		

Total Cost + Commitments – Details (3)

ACT ID	DESC	TOTAL	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005
4.1.6.6 ACD MECHANICAL QUALIFICATION & CALIBRAT								
DGLCE	GSFC CS Engineer							
DGLCT	GSFC CS Technician							
DGLEI	GSFC I&T Engineer	4345			3473	871		
DGLEQ	GSFC Quality Assurance	1745				1745		
DGLHE	GSFC H Engineer	37789			3134	34656		
DGLHJ	GSFC H Jr Engineer	50363			10869	39495		
DGO	GSFC M&S (fully loaded) no travel	102183			5494	96690		
DGT	GSFC Travel (fully loaded)	6008			2101	3907		
TOTAL	**66**	**202434**			**25071**	**177364**		
4.1.6.7 ACD INTEGRATION & TEST								
DGLCE	GSFC CS Engineer							
DGLCT	GSFC CS Technician							
DGLHE	GSFC H Engineer	190657				4810	177717	8130
DGLHJ	GSFC H Jr Engineer	107439					100345	7094
DGLHT	GSFC H Sr Technician	122877				5105	111918	5854
DGO	GSFC M&S (fully loaded) no travel	182005					182005	
DGT	GSFC Travel (fully loaded)	25000					25000	
TOTAL	**67**	**627978**				**9915**	**596986**	**21078**
4.1.6.8 LAT INTEGRATION & TEST SUPPORT								
DGT	GSFC Travel (fully loaded)	35630						35630
TOTAL	**68**	**35630**						**35630**

Total Cost + Commitments – Details (4)

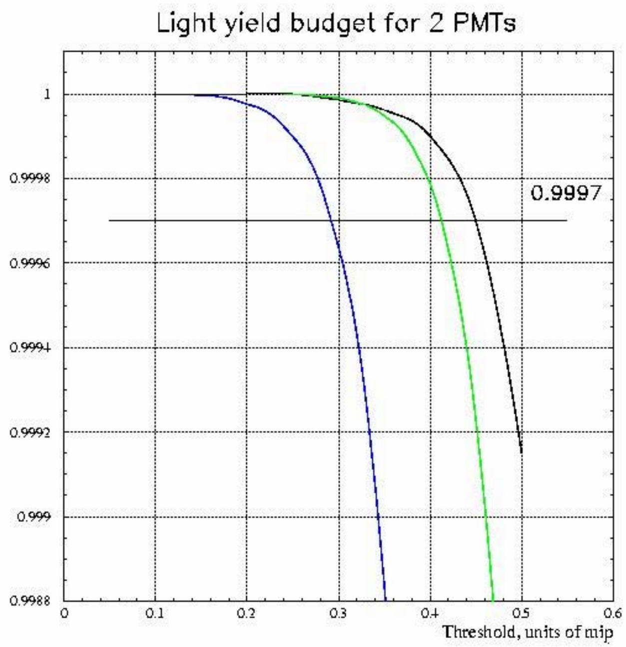
ACT ID	DESC	TOTAL	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005
4.1.6.9 MISSION INTEGRATION & TEST SUPPORT								
DGLCE	GSFC CS Engineer							
DGLHE	GSFC H Engineer	217						217
DGO	GSFC M&S (fully loaded) no travel	1162						1162
TOTAL	**69**	**1380**						**1380**
4.1.6.B GROUND SUPPORT FACILITIES & EQUIPMENT								
DGCI	GSFC In PO Commitment	21000			21000			
DGCO	GSFC Out PO Commitment	-21000			-21000			
DGLCE	GSFC CS Engineer							
DGLCT	GSFC CS Technician							
DGLEI	GSFC I&T Engineer	13487				12879	609	
DGLEQ	GSFC Quality Assurance	1169				970	199	
4.1.6.B GROUND SUPPORT FACILITIES & EQUIPMENT								
DGLHA	GSFC On-Site Administrative	552			552			
DGLHE	GSFC H Engineer	104317		32	65271	34558	4456	
DGLHJ	GSFC H Jr Engineer	23944			465	16623	6856	
DGLHT	GSFC H Sr Technician	80620			30760	49859		
DGO	GSFC M&S (fully loaded) no travel	229005			96060	129313	3631	
TOTAL	**6B**	**453094**		**32**	**193109**	**244202**	**15752**	
	REPORT TOTAL	**10280416**	**442676**	**879000**	**3217395**	**3091511**	**2005176**	**644658**

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 - similar ASIC's (same designer) used on the BFEM. 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.

Meeting the Level III Key Requirements

Detection Efficiency 0.9997

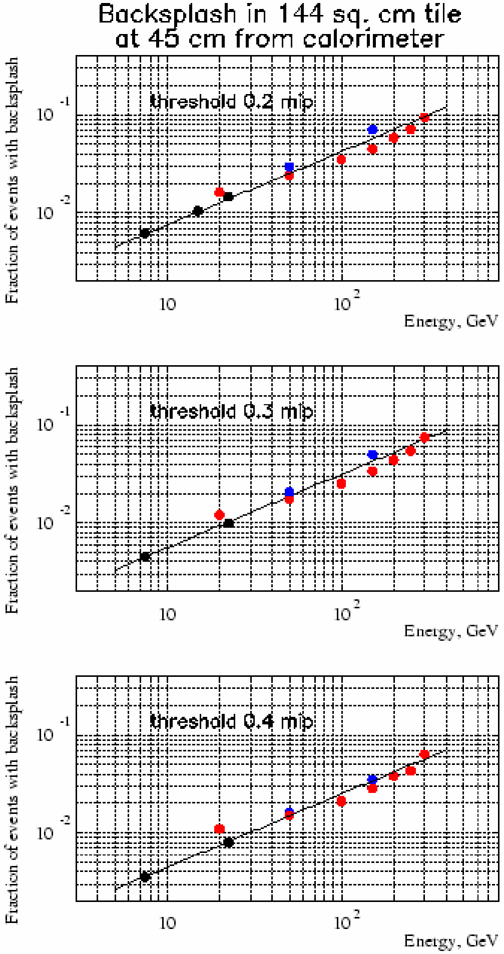


Black line: measured efficiency

Green line: efficiency with 15% loss

Blue line: efficiency with 40% loss

Backsplash Loss <20% at 300 GeV

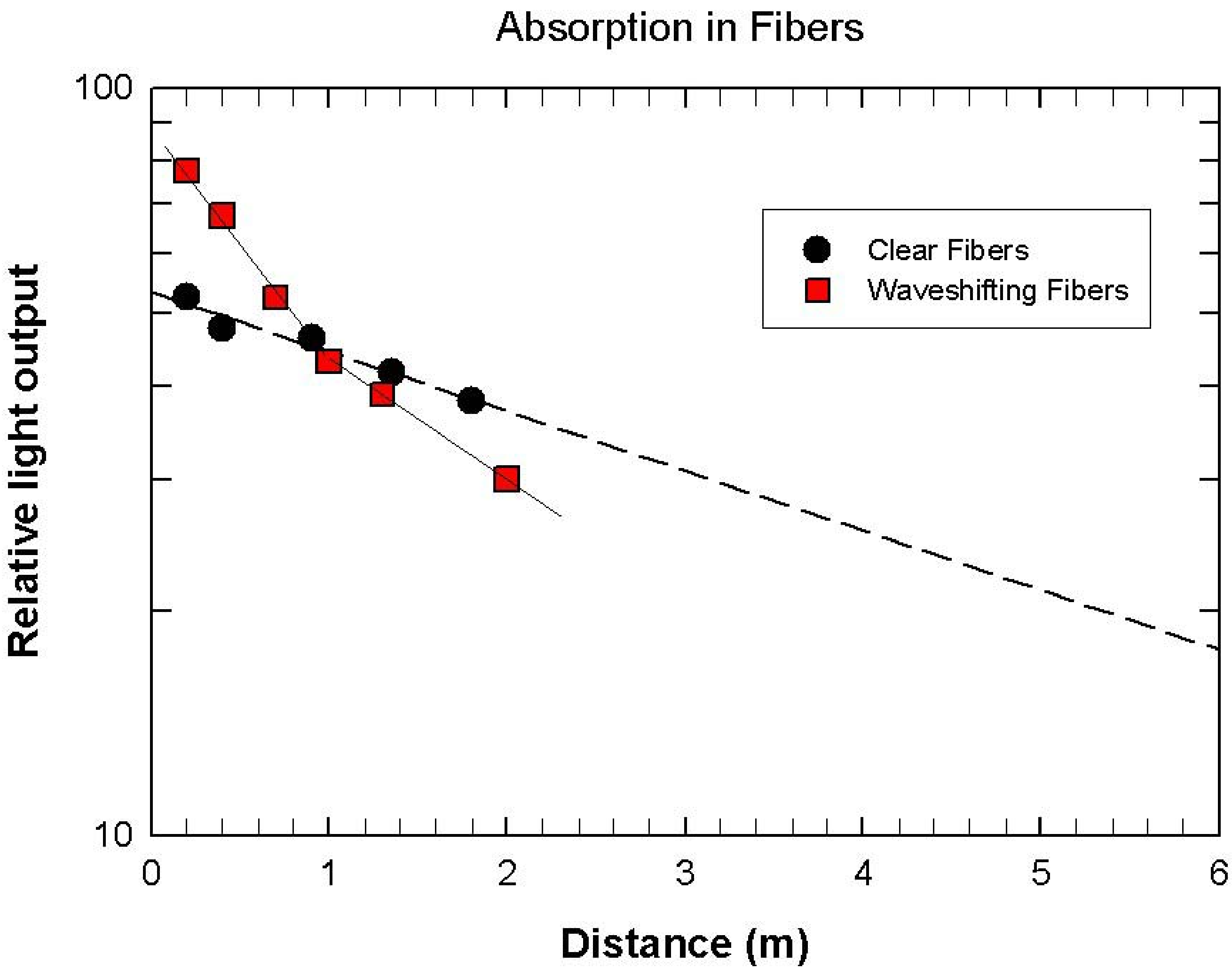


Measurements at SLAC and CERN

Light Absorption in Fibers – an Issue

Absorption in the waveshifting fibers is substantial.

Absorption in the clear fibers is not negligible, and appears higher than advertised by the vendor.



Flowdown - Requirements to Design

Parameter	Requirement	Constraints	Characteristics Needed	Design
Detection of Charged Particles	≥ 0.9997 average detection efficiency over entire area of ACD (less for bottom row of tiles)	Mass Power Size Lifetime Low backsplash sensitivity Minimize inert material outside active detector	**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	< 20% false VETO's due to calorimeter backsplash at 300 GeV	Mass Power Size Lifetime High charged particle detection efficiency	**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** **Low-noise electronics** **Threshold well below MIP peak but above most of backsplash**

ACD Optimization - Summary

- **Light Collection** - optimized with 5 mm fiber spacing, TETRATEC wrapping material, aluminized fiber ends, multiclad fibers. Scintillator manufacturer does not matter. Two sets of interleaved fibers for redundant readout.
- **Absolute Efficiency** - using the light collection described above, a single phototube meets the 0.9997 efficiency requirement at 0.3 MIP threshold if there are no appreciable light losses. With two tubes operating, there is ample margin. Light losses in long waveshifting fibers or connector to clear fibers makes the single tube marginal.
- **Broken Fibers** - the ACD could meet its requirements with up to two broken fibers on up to three tiles.
- **Segmentation** - the 89-tile design meets the backsplash requirements.
- **Hermeticity** - a double layer of square 1.5 mm fibers with offset centers provides adequate sealing of the gaps between tiles.
- REFERENCE: LAT-TD-00438-D2

End-to-end efficiency and light yield measurement

Tested detectors:

Sample 1. 32cm by 32 cm tile with two (short) bundles of WSF fibers - flight prototype

Sample 2. similar tile, but with fiber-to-fiber optical connector and 115 cm long clear fiber bundles

Sample 3. similar tile, but with thermally spliced 65 cm long clear fibers

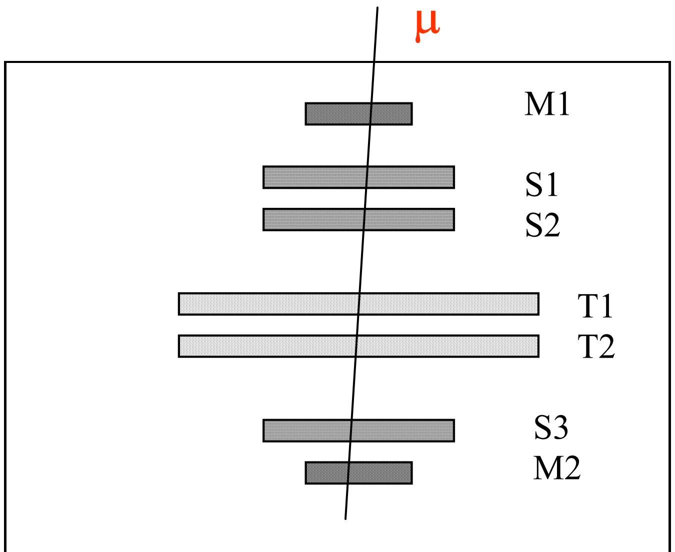
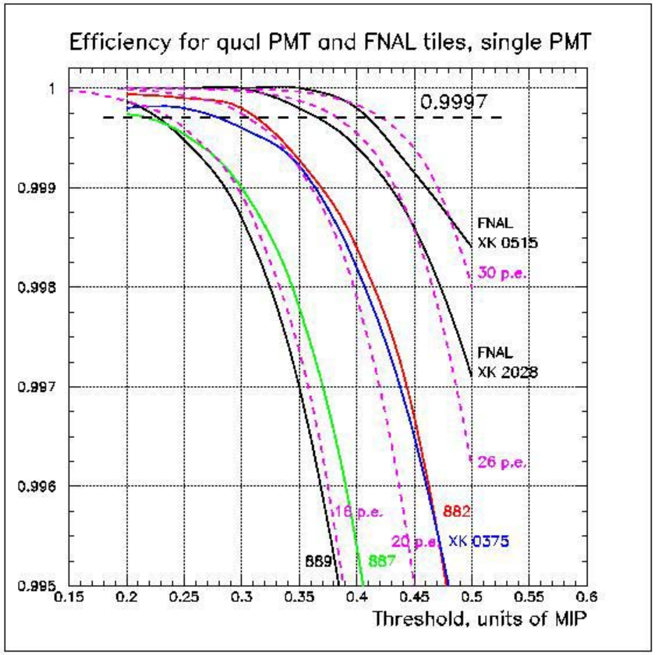


Fig.1 Principal Scheme of the tests

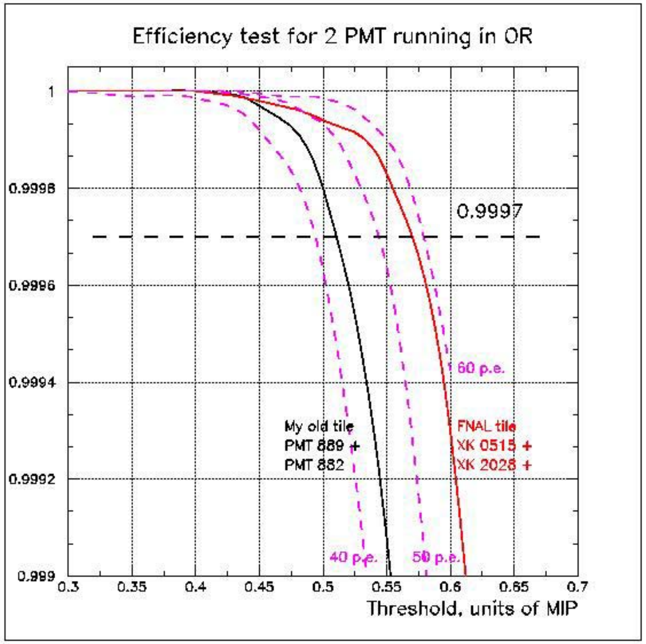
Tests were performed with cosmic muons according to the scheme shown in Fig.1 (M1, M2, S1, S2, S3 - triggering detectors, T1 and T2 - tiles being tested)

End-to-end efficiency and light yield measurement (cont.)

Results for sample 1



Single PMT running; black lines show measured efficiency for each of 2 PMTs

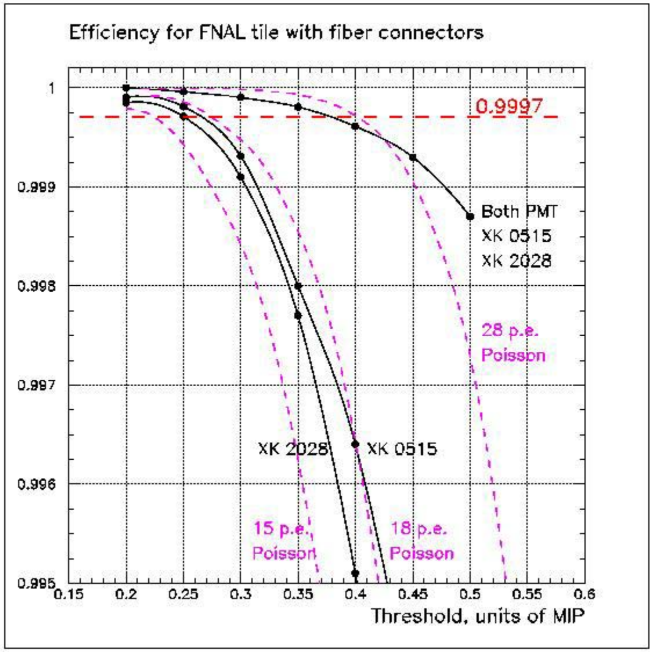


Both PMTs running in "OR". Red line shows measured efficiency for sample 1

Perform end-to-end efficiency and light yield measurement (cont.)

Results for sample 2

• Tests with sample 3 (thermally spliced fibers) demonstrated similar performance as sample 2



For more details see notes "Design qualification tests for ACD TDA", A.Moiseev, 05/28/02

Conclusion.

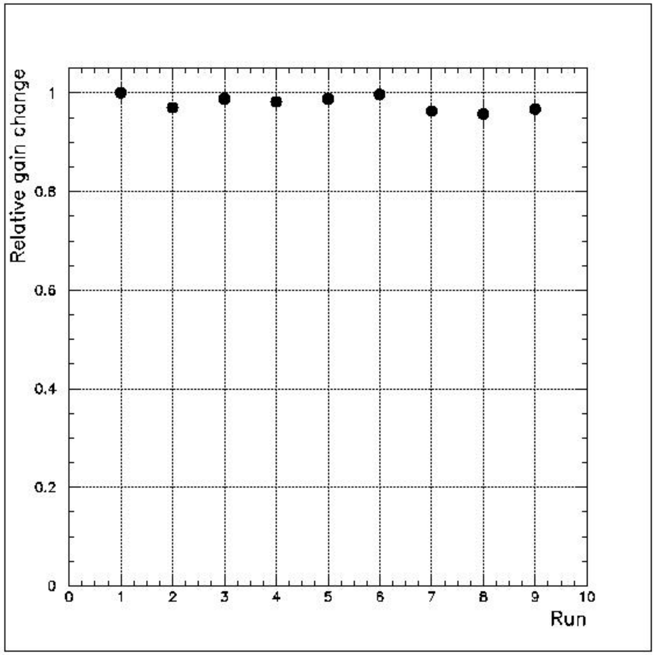
1. Tile performance depends on the Q.E. of the phototube; we will have all tubes with the minimum Q.E. lying between that which were used here (XK 2082 and XK 0515). We can expect efficiency of around 0.999 for single PMT and nominal threshold.

2. We see significant light loss in sample 2 with respect to sample 1 (around 50%). We have an indication that about half of it is lost in the connector, and another half in clear fibers

3. Currently we are repeating these tests for more confidence

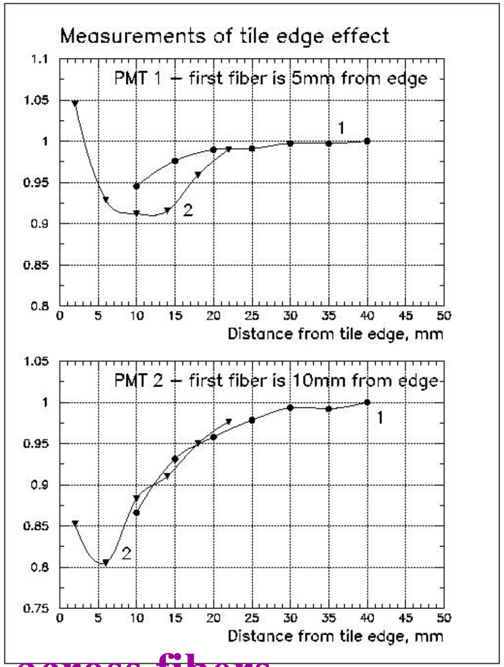
Perform thermal cycling for the tile

- Thermal cycling was performed from -65C to +45C.
- There were 8 sets of cycles. The test tile and a reference tile were tested after each set.
- The tested parameter was the response to single MIP (cosmic muons) looking for decrease of the tile light yield which would be revealed by the shift of the MIP peak position
- The results are shown in a figure, there the last point (9) corresponds to 340 thermal cycles in total
- We see that the tile degradation is under 5%

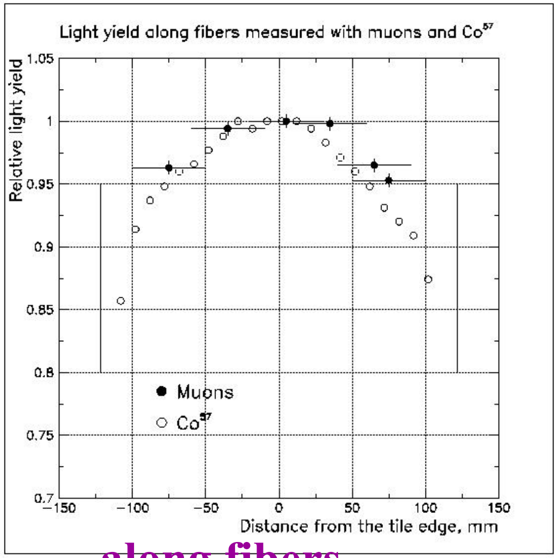


Light yield dependence along fibers in TDA

- Light yield uniformity for TDA was measured by using cosmic muons and fiber hodoscope
- For the measurements across the fibers the collimated radioactive source was also used



across fibers



along fibers

Fiber ribbon design

- The design is complete (two layers of fibers with eight 1.5 mm square fibers in the first and 9 the same fibers - in the second)
- The prototype fiber ribbon made at Washington U. was tested and bent to the shape
- The fixture for the bending of flight ribbons is being designed and built
- 7 more sets of ribbons are made at Washington U
- The first flight prototype ribbon will be bent in mid-August