Closeout Report

on the

DOE/NASA
Review Committee

on the

Technical, Cost, Schedule, and
Management Review

of the

Gamma-Ray Large Area Space Telescope

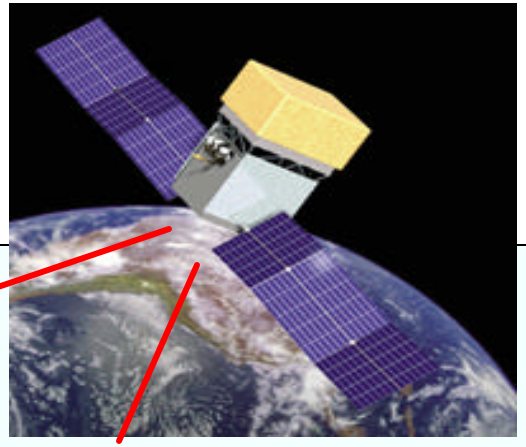
LARGE AREA TELESCOPE (LAT) PROJECT

August 1, 2002

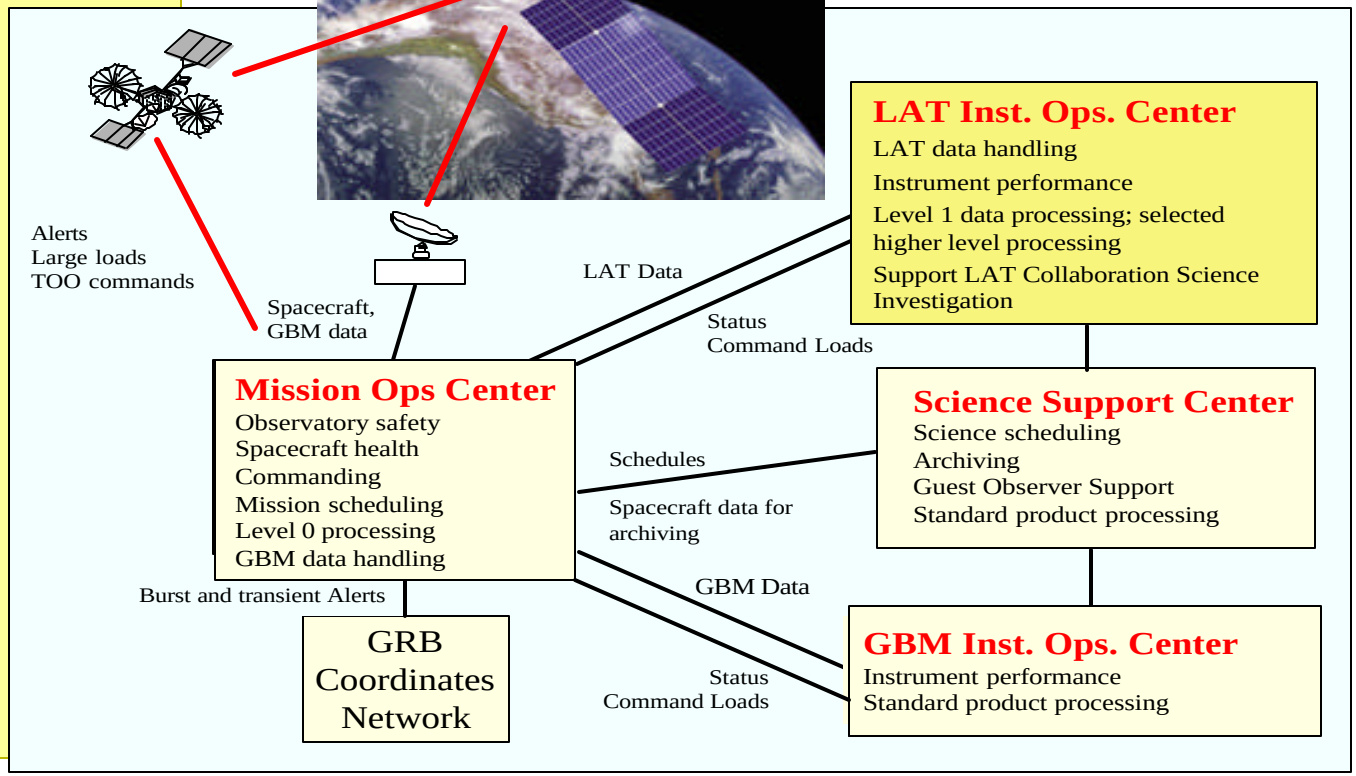
Gamma-ray Large Area Space Telescope

GLAST Mission

- high-energy gamma-ray observatory; 2 instruments
  - Large Area Telescope (LAT)
  - Gamma-ray Burst Monitor (GBM)
- launch (Sept 2006): Delta 2 class
- orbit: 550 km, 28.5° inclination
- mission operations
- science
  - LAT Collaboration
  - GBM Collaboration
  - Guest Observers
- lifetime: 5 years (minimum)

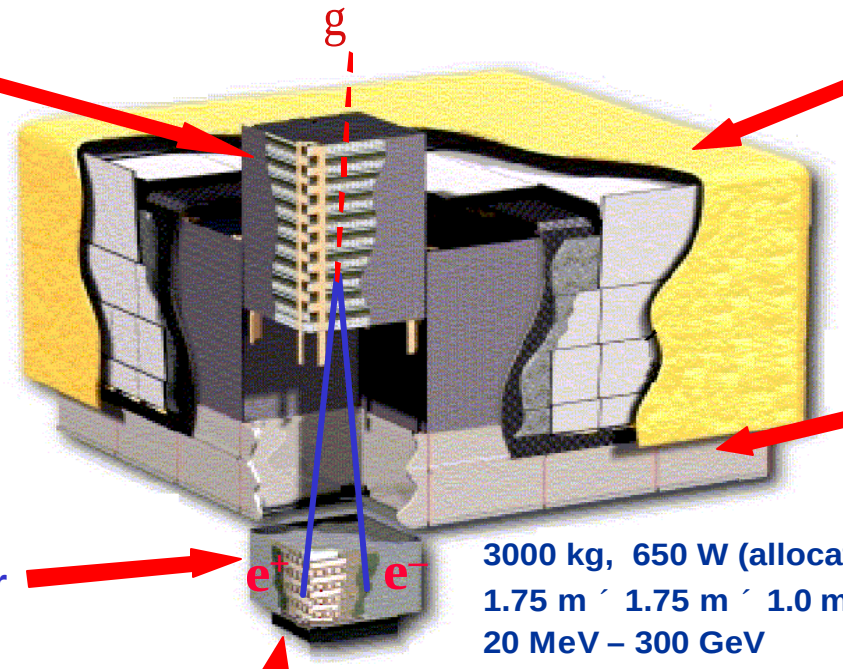


GLAST Observatory
- spacecraft
- LAT
- GBM



Instrument Design: 4x4 modular array

Si Tracker
pitch = 228 µm
8.8 10^5 channels
12 layers × 2.8% X_0
+ 4 layers × 19% X_0
+ 2 layers



ACD
Segmented scintillator tiles
0.9997 efficiency
Þ minimize self-veto

Mechanical Sys. (inc. Grid & Thermal Radiators)
3000 kg, 650 W (allocation)
1.75 m ´ 1.75 m ´ 1.0 m
20 MeV – 300 GeV

CsI Calorimeter
Hodoscopic array
8.4 X_0 8 × 12 bars
2.0 × 2.7 × 32.6 cm
⇒ cosmic-ray rejection
⇒ shower leakage correction

Electronics, Data Acquisition, & Flight Software

Flight Hardware
16 Tracker Flight Modules
16 Calorimeter Modules
1 Flight Anticoincidence Detector
Data Acquisition Electronics + Flight Software

National Aeronautics and Space Administration
and
U.S. Department of Energy

JOINT OVERSIGHT GROUP

TO: Mr. David Betz, NASA/Goddard Space Flight Center; and

Mr. Daniel Lehman, Director, Construction Management Support Division, SC-81

Date:

RE: Request to Conduct a "Delta" Preliminary Design and Baseline Review of the Large Area Telescope Project

The Department of Energy (DOE) and the National Aeronautics and Space Administration (NASA) Joint Oversight Group (JOG) for the Large Area Telescope (LAT) project on the Gamma-ray Large Area Space Telescope (GLAST) Mission requests that a follow –on "Delta" Preliminary Design and Baseline Review be conducted on July 30 - August 1, 2002, at the Stanford Linear Accelerator Center (SLAC). The LAT is the principal scientific instrument to be flown on the NASA GLAST mission, scheduled for launch in 2006.

This review follows the joint DOE/NASA Preliminary Design Review (PDR) and Baseline Review of the LAT project at SLAC in January 2002. Four subsystems (Calorimeter, Anti-Coincidence Detector, Mechanical/Thermal, and Integration and Test) were deemed not ready for the DOE baselining status of the technical design, cost, schedule, and management structure in this review. Only one subsystem (Mechanical/Thermal) did not pass for technical issues. All subsystems except Mechanical/Thermal passed the NASA/PDR part of the review, which focuses on the technical design of each subsystem and the integrated instrument in addition to being concerned with its cost, schedule, and management structure.

The purpose of the review is to carry out an integrated examination of each of the four subsystems that did not pass the January review. This should cover cost, schedule and management aspects of these subsystems as well as technical aspects of the Mechanical/Thermal subsystem. There have been changes to the overall project since January and the committee should evaluate the cost, schedule and management of the entire project, keeping in mind the issues highlighted from past reviews.

In performance of a general assessment of progress, current status, and the identification of potential issues, the committee should address the following specific items:

1. Overall Project: Identify any changes made to the project plans (technical, cost, schedule, management) since the January 2002 review and comment on their impact.

2. Technical Progress: Review the technical progress of the subsystems that did not pass the January review, with special concentration on the Mechanical/Thermal subsystem, which still had technical issues at that time. Review the proposed design and associated implementation approach and resources and comment on whether they adequately satisfy the performance requirements.

3. Cost: Is the cost estimate consistent with the plan to deliver the LAT with the stated technical performance?

4. Risk: Assess the project's risk analysis, which should address technical, cost, and schedule risks. How effective is the project's management of these risks? Are the contingency funds and schedule float adequate and being utilized at an appropriate rate?

5. International Contributions: What is the status of the international contributions, and what is the schedule for finalizing these commitments? Are these consistent with the schedule?

6. Schedule: Is the proposed schedule reasonable and appropriate in view of the technical tasks and projected funding profiles? Have the various subsystem schedules been incorporated in a well-understood way, relative to product flow, critical paths, and linkage between various activities?

7. Management: Evaluate the management structure, including the relationships to the GLAST Mission organization and relationships with foreign entities, as to its adequacy to deliver the LAT within specifications, budget, and schedule.

Liz Citrin is the project manager for the GLAST Mission at NASA and will serve as the NASA contact person for the review. Kathleen Turner is the program manager for the LAT project at DOE and will serve as the DOE contact person for the review.

We appreciate your assistance in this matter. As you know, these reviews are an important element of the NASA/DOE joint oversight of the GLAST/LAT Project. They help to ensure that the U.S. astro-particle physics program remains robust and meets its commitments on cost and schedule.

You are asked to submit a formal report by October 1, 2002.

Paul Hertz	John R. O'Fallon
NASA Co-Chair	DOE Co-Chair
Office of Space Science	Division of High Energy Physics
NASA Headquarters	U.S. Department of Energy
Washington, DC 20546	Germantown, MD 20874

cc:
P. Rosen, DOE
K. Turner, DOE
A. Byon-Wagner, DOE

Department of Energy/National Aeronautics and Space Administration Review
of the
GLAST Large Area Telescope (LAT) Project
July 30-August 1, 2002

Daniel R. Lehman, DOE Co-Chairperson David Betz, NASA Co-Chairperson*

SC1 Tracker (WBS 4.1.4)	SC2 Calorimeter (WBS 4.1.5)	SC3 Anti-Coincidence Detector (WBS 4.1.6)	SC4 Electronics, DAQ, Elec. Sys. & Flight S/W (WBS 4.1.7)	SC5 Mechanical Systems (WBS 4.1.8)
Helmuth Spieler, LBNL	* Ron Ray, Fermilab	* Pawel De Barbaro, Rochester	* Fred Huegel, NASA/GSFC	* James Ryan, NASA/GSFC
Gary Sneiderman, NASA/GSFC	Mike Crisler, Fermilab		Chris Bebek, LBNL	Dick DiGennaro, LBNL
			Ron Zellar, NASA/GSFC	Dennis Hewitt, NASA/GSFC
				Tom McCarthy, NASA/GSFC
				Russ Wells, LBNL

SC6 Systems Engineering (WBS 4.1.2)	SC7 Integration and Testing Performance/Safety Assure. (WBS 4.1.9 and WBS 4.1.A)	SC8 Ground Systems/Analysis (WBS 4.1.B and 4.1.D)	SC9 Cost, Schedule and Funding (WBS 4.1.1)	SC10 Project Management (WBS 4.1.1 and 4.1.C)
Steve Scott, NASA/GSFC	* Bill Craig, LLNL	* Rob Kutschke, Fermilab	* Mark Reichanadter, Fermilab	* Jay Marx, LBNL
Joe Bolek, NASA/GSFC	Rich Stanek, Fermilab		Steve Tkaczyk, DOE/SC	Pepin Carolan, DOE/Fermilab
				Marty Davis, NASA/GSFC
				Mark Goans, NASA/GSFC

OBSERVERS

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G. Ousley, Jupiter (DOE/EIR)	J. Deily, NASA/GSFC	
J. Cullen, Jupiter (DOE/EIR)	T. DiVenti NASA/GSFC	

LEGEND

SC Subcommittee
* Chairperson
[ ] Part-time Subcom. Member

Count: 26 (excluding observers)

7/31/02:q:sc-81:sns:0010rev:revcmglast.xls

Department of Energy/National Aeronautics and Space Administration Review
of the
GLAST Large Area Telescope (LAT) Project

REPORT OUTLINE/WRITING ASSIGNMENTS

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      2.1.2 Comments
      2.1.3 Recommendations **[Reference Request for Action (RFA) Numbers]**
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   2.3 Anti-Coincidence Detector (WBS 4.1.6) ..... De Barbaro/SC 3
   2.4 Electronics, Data Acquisition, Flight Software (WBS 4.1.7) ..... Huegel/SC 4
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   2.6 Mechanical Systems (WBS 4.1.8) ..... Ryan/SC 5
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E. Schedule Charts
F. Funding Tables
G. Action Items

* Denotes lead for writing assignment
SC Subcommittee

2.1 Tracker (WBS 4.1.4)

Reviewers: Helmuth Spieler (Lawrence Berkeley National Laboratory) and Gary Sneiderman (Goddard Space Flight Center)

2.1.1 Findings

- As noted in past reviews, this is a well thought out design that can be completed within the required time.
- The bottoms-up cost estimate yields a total subsystem cost of $9.9M with a contingency of 25%. Both are reasonable.
- The design uses mature and well-tested technologies, so the technical risk is low, provided the procedures for design and verification developed by the Project are followed.
- Issues from last review:
  - Contingency:
    - Has been increased from 11% to 25%
  - Schedule float:
    - Schedule float is still marginal.
  - Verification plans and test procedures:
    - Test plans and procedures are now at, or beyond, the level expected for PDR.
- Substantial progress has been made in the mechanical design
  - Many of the assembly details have been worked out.
  - Mechanical tests have been performed and have provided valuable technical feedback for the design.
- The Italian groups are fully integrated into the subsystem efforts and are making good progress.
- Both the digital and front-end integrated circuits that had been

submitted at the time of the last review are not usable for full pre-production system tests. Nevertheless, partial tests were possible and have led to circuit improvements. Four new chips, two digital chips and two front-end chips, have been submitted for fabrication and are due on August 21, 2002.

  - If these chips are acceptable as pre-production prototypes, the current schedule leaves sufficient time for system testing prior to commencement of full integrated circuit production on December 6, 2002.
  - If only minor modifications are necessary, a two-stage production schedule could preserve the planned production start with acceptable risk.

- Two key electronic components are not flight qualified, high voltage chip capacitors and poly-switches. The capacitor vendor has assumed responsibility for flight qualification, however, the project must ensure that the poly-switches are acceptable for flight by January 2003.
- A full analysis of the required number of spare components has not been completed.

2.1.2 Recommendations

1) Baseline the Tracker Subsystem.
2) Ensure thorough and stringent testing, coupled with critical evaluation, of tower electronics at least to the multi-ladder level before releasing the designs for full production.
3) Verify crack remediation and new side panel design prior to the Engineering Model mechanical test.
4) Compile data and conduct necessary tests to allow decision on poly-switches by the end of this year.
5) Review schedule and milestones when full testing of the current round of integrated circuits has been completed to ensure adequate schedule contingency.
6) Develop a spares plan by the time of CDR.

2.2

Calorimeter

M. Crisler
R. Ray
August 1, 2002

Findings and comments relevant to final recommendations

- The organizational changes proposed at the last review have been implemented with some success.
- MOA with IN2P3 has been signed. The MOA with Saclay has not been signed due to financial negotiations between Saclay and CNES.
- Representatives from Saclay and SLAC management assure us that an agreement is close.
- Work has progressed at Saclay to characterize PIN diodes and to develop procedures for assembling CDEs.
- The committee feels that the reorganized calorimeter system can now successfully meet its goals.

- Small cracks have been observed in the epoxy windows of PIN diodes after temperature cycling down to –30° C.
- The cracks develop because of different temp coefficients for the silicon, ceramic carrier and the epoxy.
- It is not clear what impact cracks have on performance.
- Discussions with Hamamatsu are in progress to understand if process changes can alleviate the problem. Other solutions are to keep the calorimeter temp above –20° C at all times by modifying the on-board thermal control system or to accept the risk and seek a waiver.
- 2 months to solve problem to avoid schedule delays.
- The committee is confident this problem can be solved.

- The schedule for the production of flight modules is now sensible and credible and has a more appropriate amount of float as a result of 6 month extension.

- The schedule for the production of CDEs at Saclay for the engineering model is very tight. It is important that CDEs produced according to the final agreed upon procedures be included in the engineering model.

- Critical path for the calorimeter system is electronics

- The cost of the US contribution to the calorimeter has increased due to increased scope as a result of reorganized responsibilities. The costs are primarily associated with module integration activities at NRL. The US has also taken responsibility for part of the PIN diode procurement as a result of budgetary limitations in France.

- These extra costs have all been included in the current cost estimate.

- The committee is comfortable with the base cost of the calorimeter. Appropriate procedures were used to arrive at the 25% contingency which appears adequate.

Recommendations

1. Baseline the cost, schedule and technical design of the calorimeter system.

2. Continue to work with Saclay to finalize the MOA and optimize the schedule in coordination with the French partners.

3. NRL and Saclay should continue to work closely on procedures for CDE assembly allowing Saclay to contribute completed CDEs to the engineering model.

2.3
Anticoincidence Detector (ACD)
WBS 4.1.6

Reviewer: Pawel de Barbaro, U. of Rochester

1. Findings and Comments

Overall Project

Subsystem managers have done a very good job of getting the ACD ready for this review. All the recommendations from the January 2002 review were addressed. In particular, a new bottoms-up Work Breakdown Structure (WBS) was created, contingency and critical path analyses were performed, documentation for Basis of Estimate (BoE) was provided.

Technical Progress

Technical progress has been made on three fronts:

a) Research and Development (R&D) was continued to finalize layout of the scintillator tile geometry,
b) New data was collected during test-beam at CERN to measure backsplash effect (self-veto of gamma events)
c) Full size mock-up of ACD was built at GSFC to work out details of fiber routing

Cost

Present cost of ACD is $10.3M, an increase of $250K with respect to the January 2002 cost. The increase is solely due to the 6-month extension in the project schedule. Material costs are $2.7M. Labor costs are $7.4M.

Total labor required to built and test ACD is 70 Full Time Equivalents (FTEs). 35 FTEs are civil servants. For civil servants, the project pays Multi-program support (MPS), approximately $35K/year. The remaining 35 FTEs are fully paid contractors. In this case, contractor costs and MPS is paid by the project.

To the date (June 2002), the subsystem has spent $2.7M. The remaining effort has the average contingency of 25%. Based on the maturity of the ACD design, this level of contingency seems appropriate.

Risk

ACD faces no unusual risks. In order to reduce a possibility of High Voltage (HV) failure, a second (redundant) High Voltage Bias Supply (HVBS) has been requested by the subsystem managers. This change would introduce a $60K cost increase of the subsystem. If HVBS fails and only a single photomultiplier is used to read out a tile, charged particle rejection efficiency drops from the required 0.9997 to 0.999.

International Contributions

No international contributions are used for this subsystem. ACD fully funded by DoE/NASA.

Schedule

With the recent half-year extension of the project , the present ACD schedule is credible.

Major milestones are:

d) October 2002: Critical Design Review (CDR). At that time, all of the R&D, design work has to be completed, drawings ready for approval by LAT management, and subsystem ready to begin fabrication.
e) February 2004: Complete assembly of ACD, begin integration and testing at Goddard.
f) June 2004: Deliver ACD to SLAC. Ready for I&T with LAT. 15 weeks float time (needed by Nov-2004)

Production of analog ASICs in on critical path. Scheduled ACD completion is 15 weeks ahead of the LAT integration need date. Some of this time could be used to extend testing of the 2nd submission of ASICs, if needed.

Management

Subsystem Management is well structured. The managers are supported by staff in Project Control (WBS, Primavera), Scheduling and Procurement. Engineering team (approximately 10 people) has been put together, with vast experience in previous satellite projects.

2. Recommendations

Committee finds the ACD subsystem ready to be baselined.

a) Develop detailed specifications for the readout fibers (light yield, attenuation length, batch-to-batch variations) prior to the bid process and purchase of materials

b) ensure that the second generation of the analog ASIC, (to be delivered in August 02) is well evaluated before third generation is sent off to production

c) continue to develop calibration plan for ACD for the Integration and Testing phase

2.4 and 2.5 - Electronics, Data Acquisition, Flight Software and Electrical Systems

Subcommittee members:

Fred Huegel GSFC
Chris Bebek, LBNL
Ron Zellar, GSFC

Recommendations:

- Electronics Baselined at PDR
- Work with GSFC parts branch to qualify polyswitches for use in the LAT electronics. Polyswitches will need to be ordered in Jan2003 for the Tracker Electronics

Recommendations for LAT Electronics

- Ensure that FPGA design practices adhere to Goddard guidelines and recommendations for spaceflight applications
- Determine the need date for processor downselect based on software design impacts
- Finalize the Flight Software Test Plan and the Flight Software Management Plan
- Identify solution path to replace the functionality that would have been provided by Spacecraft Command Language (SCL) COTS tool in flight software. Coordinate with I&T and Mission Operations.

Jim Ryan, Chair (NASA/GSFC)
Dennis Hewitt (NASA/GSFC)
Tom McCarthy (NASA/GSFC)
Russ Wells (LBNL)
Dick DiGennaro (LBNL)

2.6 Mechanical Systems (WBS 4.1.8)

Findings

Significant technical progress has been made since the January PDR. Both the mechanical and thermal designs presented were consistent with preliminary design maturity and were supported by an appropriate level of analyses that predict adequate design margins.

A spacecraft vendor still has not been selected although this is expected to happen later this summer. Upon selection, the thermal/mechanical interfaces with the spacecraft will have to be worked intensely to finalize interface documentation and reach mutually acceptable designs while maintaining schedule. It was felt that the subsystem team had done a very good job providing flexibility to their design so that this interface work can progress without major impacts to the current LAT thermal/mechanical designs.

Significant changes since January include the repackaging of the thermal radiators to fit inside the Launch Vehicle fairing and not interfere with S/C and Payload Attach Fitting (PAF) stay clear zones. The radiators were both widened and shortened from the January design. Existing heat pipes were rerouted and additional pipes added, and other structural changes were made to accommodate the radiator changes. Also, tracker sidewall plate material changes were made to reduce thermal gradients from top to bottom of the tower.

Tracker tower design iterations are ongoing. Two unsuccessful vibration tests have been conducted on a mechanical test tower. The latest test ended with the composite lower tray developing cracks in the corners where the Titanium support flexures attach. This has necessitated the initiation of a failure review board. Current plans are to proceed directly to an engineering model test in November, without having conducted a successful mechanical model test.

A high fidelity LAT structural finite element model (over 115,000 nodes) was presented. Static and modal analyses with this model indicated positive margins for strength and minimum fundamental frequencies. All frequencies identified were 55Hz or higher with the Grid drum-head frequency (first major mode) at 57 to 60 Hz depending on the total mass of the instrument. These frequency predictions are in excess of the minimum 50 Hz requirement. It should be noted that these analyses were done with a fixed LAT to S/C interface. Primary load paths seemed to be well understood. Results from numerous static load cases were presented with, for the most part, resulting stresses and deformations within acceptable limits. There was some concern for the low margins presented for the calorimeter to grid interface fasteners. This friction joint interface uses

hundreds of relatively small diameter fasteners to secure the calorimeters and close out the grid structure.

More realistic loads can be developed for the LAT and its subsystems when the spacecraft vendor is on-board and a more representative coupled loads analysis is conducted.

There appears to be adequate mass margin, with the current mass estimated to be 2699 kg (compared to 2614 kg back in January) against an allocation of 3000 kg. Normally the committee would like to see 15 to 20% mass margin at PDR. However, a large percentage (over 40%) of the current mass estimate of the instrument was presented as *measured* mass from the Calorimeter subsystem due to the known mass of its many hundreds of CsI logs.

The thermal modeling techniques and the process used to achieve the thermal predictions are adequate for PDR level. In January, analyses assumed overly conservative, constant solar array temperature around the orbit (+100 C hot and –100C cold). Parametric transient analyses have since been performed of a more realistic solar array temperature profile. This resulted in much lower heat inputs to the radiators.

Several thermal tests were added to retire risks. A Grid box assembly will be subjected to protoflight thermal vacuum cycling. Also, a thermal balance test has been added that includes the flight radiators, flight X-LAT plates, and a LAT simulator.

The fundamental thermal control system architecture is sound, testable, and has demonstrated adequate analytical margins for PDR.

Three additional staff members have been added to the team since January and there are immediate plans to hire much needed additional staff (systems engineer, mechanical engineer, analyst, and designer).

With the 6 month extension in the overall LAT schedule, the revised mechanical systems schedule appears credible. The grid delivery is the critical path item for the mechanical systems and it currently has 3 ½ months of float. Again, it is important that staffing be increased as stated above or schedule problems will occur. Also, the final design of the grid cannot be finalized until the S/C vendor has been brought on board and ICDs can be finalized.

Much progress has been made towards finalizing thermal/mechanical interface control documents and requirements documents. Many had already been through several reviews/iterations and release was said to be imminent.

There was a significant increase in the overall cost of this subsystem since the January review. The largest portion of this increase ($3M +) is due to the changes in the thermal design (heat pipe additions and radiator modifications) as well as moving the overall LAT thermal subsystem to the Lockheed Martin (LM) subcontract. The overall subsystem cost is now projected to be $11.85M with 43% contingency on the costs to go of $10M. The LM projected cost is $7.3M or 62% of the mechanical budget. The

contract is not fixed price and is renegotiated each year. Care must be taken to manage this contract to prevent cost growth.

Comments

The formal responses to the recommendations/action items from the PDR were not made available to the review team and are still considered open. The responses had been generated by the subsystem team, but had not yet been reviewed but SLAC/Goddard Project management and passed along to the review team for their evaluation.

Planned new hires for the SLAC team need to be brought on board as soon as possible to meet their schedule commitments. Delays in bringing these additional members to the team would most likely affect the engineering model work in progress and preparations for the subsystem CDR scheduled for January, 2003.

Efforts must be maintained to complete interface and requirements documentation. These important documents must be signed off so that consistent and efficient designs will be produced.

Strength qualification plans of the grid must be better defined. The current plan of insert pull tests and static deflections does not appear adequate. The grid structure must be subjected to stresses 1.25 times the maximum predicted stresses.

Because of the mix of composite and aluminum structures for mass and stiffness considerations, flexures are incorporated in several locations to prevent large stresses/deformations due to the differing coefficients of thermal expansion. Concern was expressed over the lack of shear constraints at primary structural interfaces (calorimeter to grid, for instance) and critical alignment interfaces. Relying solely on friction to resist shear loads at bolted interfaces could present problems with qualification.

Due to the large LAT mass (3000kg), Observatory center of gravity height is pushing the ceiling for maximum bending moment capability of the DELTA 6915 payload attach fitting. This issue needs to be tracked very closely by the LAT team and future spacecraft contractor.

Recommendations

1. Baseline the mechanical/thermal subsystem.

2. Maintain access to the electronics during LAT thermal cycling at SLAC. In other words, the X-LAT plates should not be installed until completion of this test.

3. Review LAT mechanical interface details with a special emphasis towards ease of assembly/integration.

James Rose (for Steve Scott, Joe Bolic)

2.7 Systems Engineering (WBS 4.1.2)

2.7.1 Findings

The systems engineering activity continues to be adequate for baselining and has progressed well. The project schedule has been extended six months since the PDR in January 2002. The systems engineering budget has been extended by $600K to account for the schedule extension. The systems engineering WBS carries 5-6 FTEs throughout the project. The FTEs consist of 1.5 systems engineer equivalents while the rest support systems engineering functions like requirements management, centralization of test programs, Instrument Operations Center (IOC) support, ICD support, and software requirements tracking. Other subsystem functions are hidden under other WBSs. The LAT systems engineer noted that everyone understands that systems engineering functions are in these WBSs and that they will not be cut. The overall systems budget appears to be adequate under these guidelines.

The document maturity has substantially improved since the PDR. The LAT systems engineering team directly addressed the review team's PDR concerns about project metrics. The status of drawing, level 3 specifications, ICDs, subsystem requirements are now being tracked. Mass, power, alignment, C.G., and "stay-clear" restrictions are being monitored and budgets have been established that will be followed through LAT delivery. The performance verification plan caught up from nothing to normal PDR-level maturity or beyond. Software testing and verification has been enhanced. West Virginia Independent Verification and Validation (IV&V) will be present for the software verification testing.

The schedule for system engineering document preparation seems to be reasonable. The linkage between documents affecting different elements of the LAT are established.

2.7.2 Comments

The LAT systems engineering team is now in place and appears to be sufficient in skill, experience, and number to maintain control of the systems engineering functions and tasks.

The design of the LAT is such that making repairs after the instrument elements have been integrated will be difficult and a repair could conceivably lead to a schedule impact. Systems engineering understands this and the project has acknowledged the risk.

The review team discussed some Requests For Action (RFAs) generated at the January PDR. However, the team was reluctant to discuss all of the RFA responses in detail because the team did not want to circumvent the proper project procedures for

reviewing and approving RFAs. Since most of the responses were intended for discussion at the delta PDR, the team suggests that the discussions on the RFA responses be held as soon as soon as possible in order to be of benefit.

2.7.3 Recommendations

1. Systems engineering needs to monitor the development and coordinate utilization of simulators, emulators, breadboards, and engineering models for the LAT instrument. (Mission/System Critical Design Review (CDR))

2. The LAT sparing philosophy still needs to be formalized. (CDR – list as needed to effect procurements)

3. The risk management process should be continuous and not limited to quarterly reviews. In addition, risk status should be a regular agenda topic at the LAT project management status meeting. (ASAP)

4. The criteria for defining when a repair is necessary to the integrated LAT instrument should be established by CDR.

5. The event filtering software needs to be monitored for its effect on CPU utilization. (metrics by October)

6. The LAT teams needs to develop preliminary critical interface definitions for the IOC to reduce risk to spacecraft development due to late IOC start-up. (ASAP - Inst CDR at the latest)

Section 2.8

WBS Item 4.1.9 Instrument Integration and Test

Bill Craig (LLNL), Rich Stanek (Fermilab)

August 1, 2002

Key Findings:

- This subsystem has developed a new cost, WBS and schedule since the last review. The WBS is organized by function and is fully staffed at Level 4. <u>The cost, cost basis and contingency appear adequate.</u>
- The impact of delayed delivery of CAL units A&B on the beam test at End Station A, a significant risk identified in the January ’02 review, <u>has been mitigated by the strong support of SLAC management and their stated willingness to accommodate the GLAST schedule</u>.

Key Findings (continued)

•The primary risk to the I&T schedule is late sub-system delivery. A large I&T staff will be in place as integration activities are beginning and there are substantial standing army costs. Detailed milestones are in place and the PMCS is being used to track progress within the subsystem.

•The schedule is reasonable but is inherently high risk as it requires four subsystems, each with moderately high risk, to be ready on time.

•The 100,000 class cleanroom, LAT assembly area and subsystem integration area are in place . There is a 'wet' sprinkler system in place throughout the I&T area. Access systems and controls are planned but are not yet in place. Cleanroom technical issues which will be addressed before flight hardware arrives are marking of critical HVAC equipment, open vents to non controlled areas, and lack of crane oil drip protection in the LAT cleanroom.

•This subsystem management and team have made commendable progress since the January '02 review.

2.8 Recommendations for I&T subsystem

1. Baseline the I&T subsystem.
2. Develop contingency plans by CDR that account for late subsystem arrivals.
3. Work to ensure that the touch labor involved in integration has I&T experience in advance of handling LAT flight hardware.
4. Review the progress of design efforts in December ‘02 to ensure that sufficient effort is available to complete tasks by CDR.
5. Obtain project concurrence and include the airborne test and LAT thermal cycling at SLAC as part of the approved baseline schedule by December of 02.
6. Conduct a thorough review of cleanroom facility readiness by CDR and consider the replacement of the wet sprinkler system.

Section 2.9

WBS Item 4.1.A Performance and Safety Assurance

Bill Craig (LLNL), Rich Stanek (Fermilab)

Key Findings:

- The cost as presented is 2.18M$, with an additional 0.51M$ (35%) of contingency. The LAT Safety Engineer is contributed labor from SLAC at the 0.3 FTE/yr level. **This cost and contingency is adequate. The schedule as presented is reasonable and low risk.**
- The primary effort of the P&SA subsystem since the January review has been to write the LAT Contamination Control Plan and to review and propose revisions to the Mission Assurance Requirement document (MAR). The proposed revisions to the MAR are currently under review by project management. **Once the revised MAR is approved, there will be changes to a number of plans and procedures that will require considerable effort from this subsystem.**

2.9 P&SA Recommendations

1. Reaffirm the decision to baseline this subsystem.
2. Complete the GSFC Performance Assurance Audit in December 2002, before the Critical Design Review.
3. Ensure that the new quality assurance engineer (from GSFC) is in residence at SLAC by December of 2002.
4. Complete the Mission Assurance Requirement (MAR) revision negotiation as soon as possible and modify all dependent plans before the GSFC performance audit is performed.

2.10 Ground Software

2.10.1 Instrument Operations Center (IOC) (WBS 4.1.B)

2.10.2 Recon and Science Analysis Software (SAS) (WBS 4.1.D)

Committee: Rob Kutschke, Fermilab (chair)

Findings: IOC (WBS 4.1.B)

- Reaffirm main findings of Jan. 2002 review.
- Schedule stretch had little impact:
  - Most procurements and hiring occur late in Fabrication phase.
  - Will use staff freed up by completion of other LAT work.
- Some work had been scheduled post CD4.
  - Moved to commissioning phase:
  - Main driver for cost reduction: M$3.71 → M$2.55.
- Technical progress: defining interfaces with MOC, SAS.
- No international contribution.
- Cost and schedule: credible and low risk.
- Scope contingency still present.

Instrument Operations Center (WBS 4.1.B)

- Recommendations:
  - Ready to be baselined: cost, schedule, mgt.

Findings: SAS (WBS 4.1.D)

- Reaffirm main findings of Jan. 2002 review.
- Impact of schedule stretch:
  - Cost increase K$294 (staff costs); most staff is off project.
- Commend SAS team for:
  - Significant technical progress in all aspects: simulation, reconstruction, infrastructure, interfaces.
  - Well thought out QA/QC plan. Parts in place already.
- New S/W engineer: reduces load on the code architect.
- User Analysis Group: feedback from expert scientist users.
- International: lots of off-project labor. Already staffed.
- Cost and schedule: credible and low risk.
- Scope contingency still significant.

Recon and Science Analysis Software (WBS 4.1.D)

- Recommendations:
  - Ready to be baselined: cost, schedule and mgt.
  - Re-evaluate the efficiency spec for the tracker.
    - Improved tools now available.

3 COST ESTIMATE

Findings

The LAT management presented a LAT baseline cost estimate of $99.97M AY(actual-year dollars), with an overall contingency of $21.27M AY, which represents 28.9% of the cost-to-go. The LAT project is ~26% complete, and the cost estimate is comprised of ~60% labor, ~40% materials. The total project cost of $121.24M AY is based upon the May 2002 resource loaded bottoms-up cost estimate.

Overall, the LAT cost estimate has experienced ~6% cost growth from the January 2002 review. The major cost drivers were a six-month delay in the launch schedule ($3.8M), and the remaining increase was driven by an updated base cost estimate. The baseline cost estimate contained major WBS revisions to the Calorimeter (4.1.5), Anti-Coincidence Detector (4.1.6), Mechanical Systems (4.1.8), Instrument Integration & Test (4.1.9).

Definitions of the boundaries from the fabrication phase to the commissioning phase, and then to the operations phase were finalized, with the cost estimates adjusted to align with the definitions. The completion of the LAT fabrication phase is now defined as delivery and acceptance of the LAT to NASA for integration with the GLAST spacecraft. This resulted in shifting $8.5M of LAT costs from the fabrication phase to the commissioning phase.

LAT management has implemented a Project Management Control System (PMCS), and has been reporting cost and schedule performance using an earned value system since September 2001. The PMCS team utilizes Primavera P-3 as the schedule database tool, with COBRA selected for handling the actual costs for the LAT project and providing products for external output for NASA and DOE reporting. Costs are generally reported down to the 5th level. The LAT PMCS is modeled after the B-factory cost and schedule system, and complies with DOE and NASA Management requirements. Contingency on remaining work was estimated by subsystem management at the lowest task level using a risk/weight contingency matrix.

The PMCS team is currently comprised of two full-time SLAC employee supported by a team of 3.5 consultants from Applied Integration Management. There is one open position for a SLAC employee, which will replace one consultant. LAT management plans to continue this blended team throughout the fabrication phase of the LAT. The PMCS team may be further reduced as the integrated planning for LAT becomes more routine.

Comments

The committee was very impressed with LAT management and the PMCS group and the committee thanks them for their thorough presentation and frank discussion of the present status and future challenges of the LAT project.

With the restructuring of the four subsystems mentioned above the LAT cost estimate now appears mature. The LAT team is confident that the current WBS contains an integrated work plan against which progress and actual costs can be measured.

Contingency at the level of 29% with respect to cost-to-go, while not extravagant, should be adequate for the LAT team to deliver its baseline commitments. As there remain external risks to the cost and schedule of the LAT (i.e., delivery of foreign components, spacecraft boundary conditions, etc.) as well as the inherent uncertainties in ASIC's and Integration and Testing, LAT management should work to maintain a comparable level of contingency on cost-to-go over the life of the fabrication project.

Table X-1. LAT DOE & NASA Cost Estimate (Escalated K$)

Cost Estimate (Real-Year K$)				
WBS#	**Subsystem**	**Cost To Date**	**Cost To Go**	**Total Base Cost**
4.1.1	Instrument Management (SC9/10)	$4,456	$7,146	$11,602
4.1.2	System Engineering (SC6)	$1,761	$2,885	$4,647
4.1.4	Tracker (SC1)	$4,382	$5,494	$9,877
4.1.5	Calorimeter (SC2)	$4,383	$12,965	$17,348
4.1.6	Anti-Coincidence Detector (SC3)	$2,699	$7,582	$10,280
4.1.7	Electronics (SC4)	$2,941	$12,797	$15,738
4.1.8	Mechanical Systems (SC5)	$1,815	$10,035	$11,850
4.1.9	Instrument Integration & Test (SC6)	$434	$6,220	$6,654
4.1.A	Performance & Safety Assurance (SC7)	$719	$1,461	$2,180
4.1.B	Instrument Operations Center (SC8)	$283	$2,269	$2,552
4.1.C	Education & Public Outreach (SC10)	$469	$2,129	$2,598
4.1.D	Science Analysis Software (SC8)	$638	$2,690	$3,328
4.1.E	Suborbital Flight (Balloon) Test	$1,321	$0	$1,321
Subtotals		**$26,301**	**$73,673**	
LAT Estimated Base Cost				**$99,973**
LAT Total Project Cost				**$121,240**
Contingency				**$21,267**
Contingency on Cost-to-Go (%)				**29%**

Recommendations

1. Approve the LAT baseline cost.

3 SCHEDULE & FUNDING

Findings

The integrated cost/schedule baseline for LAT consists of ~8000 schedule activities, summing to $99.97M, contains 190 interface milestones consistent with a LAT delivery to NASA in September 2005. The DOE CD-4 date tied to the completion of the LAT fabrication is December 15, 2005. Schedule and milestone variances were essentially zero since the LAT team had recently rescheduled all activities to current work accomplished.

LAT management presented high-level critical path analyses for the overall LAT as well as for each LAT subsystems. The overall LAT schedule provides for 17 weeks of overall float. The critical path of the LAT is currently electronics module delivery (3 weeks float) followed by the overall Integration and Testing (I&T) of the LAT instrument, and then the final 14 weeks of float prior to delivery of the LAT.

Work scheduled for FY02 and FY03 nearly saturates available funding leaving little contingency funds remaining for solving problems and maintaining schedule.

Comments

The committee finds the integrated schedule for fabrication and delivery of the LAT is an ambitious though achievable schedule, with technical decisions made as soon as possible. Sufficient schedule slack has been introduced to provide against reasonable risk.

The success of the LAT project is dependent upon the delivery of the LAT within its baseline cost and schedule. With this in mind, LAT management is strongly urged to introduce flexibility into its cost and schedule work planning, particularly in FY04 and FY05, in order to maintain the baseline schedule.

The schedule is dependent upon achieving staffing levels according to the developed plans. However, LAT management should work to coordinate its resources and decouple its activities as much as possible, in order to reduce its exposure to 'marching army' costs.

Attempts to introduce descoping scenarios in order to provide cost and schedule flexibility are apparently not feasible without seriously impacting the scientific mission of the LAT.

If FY03 scheduled work saturates funding, LAT management should work with the funding agencies to ensure that timely cash flow management solutions can be found to maintain progress.

Table X-2. LAT DOE & NASA Funding Estimate (Escalated M$)

	FY00	FY01	FY02	FY03	FY04	FY05	Total
DOE	3.0	5.7	8.1	8.9	7.9	3.4	37.0
NASA	3.9	3.8	13.1	20.9	25.8	15.7	83.2
JAPAN	0.0	0.0	0.0	0.0	1.0	0.0	1.0
Total/FY	6.9	9.5	21.2	29.8	34.7	19.1	121.2

Recommendations

1. Approve the LAT baseline schedule.

2. Develop ‘work-around’ strategies to the LAT cost and schedule baseline, particularly in FY04 and FY05, to add flexibility and reduce the potential exposure to ‘marching army’ costs.

4.0 Management (WBS 4.1.1)

Jay Marx (chair, LBNL), Marty Davis (Goddard), Mark Goans (Goddard), Pepin Carolan (DOE Fermi Area Office)

Findings & Comments

Management

The LAT Project Management organization appears to be stable and well structured to produce the LAT instrument within specifications, budget and schedule.

SLAC Directorate oversight of the LAT Project has been significantly enhanced and is of great value to the LAT project.

The DOE-NASA Joint Oversight Group (JOG) has been active in overseeing the LAT project. The DOE-NASA Implementing Arrangement was finally signed in January '02, clearing the way for finalizing of important NASA International Agreements.

A major concern from the previous review with French management of calorimeter efforts has been resolved.

In a number of LAT subsystems there are concerns regarding project staffing needs -- for additional or more senior design and engineering staff-- was noted.

The LAT Project Management documentation is in good shape with some minor revision of the PEP and PMP documents is anticipated in support of seeking DOE "Critical Decision-2" (CD-2) approval.

The effectiveness of the management tools put in place by Project Management should be carefully monitored during the coming year to be sure they are the right tool-set and in each case add value.

The cost estimate for management of the project appears adequate.

Risk Management

Risk assessments have been conducted by the project that covers project level risks and system level technical risks. The risk identification and assessments, however, are not updated with adequate frequency. They should be updated periodically.

The LAT Project has formulated a written risk management plan that defines the process to be used in identifying and mitigating risks, but has not yet implemented a formal risk management process.

The plan should cover the full LAT instrument including those WBS elements that are the responsibility of non-US institutions and collaborators.

A continuous risk management approach should be implemented that is used throughout the life of the project.

Consideration should be made for providing guidance and training to the subsystem managers to gain their support.

International aspects

Agreements between NASA and relevant space agencies of international partners are either pending signatures or are in the drafting stage. There is continued risk to the project until these agreements are signed and so it is very important to secure formal approval of these agreements.

SLAC intends to establish an International Finance Committee to bring together representatives of the various agencies as a mechanism to assure that the project receives the support needed for its success. This is very important and should happen as soon as possible

Recommendations:

1. Implement a continuous risk management approach for use throughout the life of the project by the end of this calendar year.

2. Complete any necessary further revisions to the management documents (PEP and PMP) and other pre-requisites necessary to support DOE CD-2 approval.

3. Provide for staffing needs in areas of concern (Mechanical Systems, Systems Engineering, I&T, Instrument Operations Center and Technical Coordination).

4. Complete and obtain signatures for all remaining agreements with international agencies and with LAT collaborating institutions as soon as possible.

OVERALL PROJECT

The committee commends SLAC, the LAT Project Office, the LAT team, and the DOE & NASA for the important progress that the project has made in the past 6 months.

Since last review there has been major progress in critical management areas and changes in the schedule, the estimated cost and the contingency that have strengthened the project and give greatly increased confidence in the project's ultimate success.

The project is now in very good shape for this point in its development and ready to be fully baselined.

We find that the cost estimate is mature and reasonable, the success-oriented schedule is achievable and the level of risk is reasonable for a project of this scale and complexity.

We note that other than the Principal Investigator and Project Manager there is no single individual with overall responsibility for technical oversight of the entire instrument.

We encourage NASA and DOE to work together to reduce any unnecessary burdens to the Project due to the dual sponsorship; e.g by coordinating and minimizing the impact of reviews.

Recommendations

1. **Baseline the LAT project based on the proposed cost estimate and schedule.**

2. **Continue the current level of oversight and management attention by SLAC Management and rapidly proceed with plans for a LAT International Finance Committee.**

3. **Bring on board an experienced and qualified person to be responsible for the technical oversight of the whole instrument.**

4. **Coordinate and plan the DOE/NASA reviews to take place on an annual basis and to minimize impact on the project (so long as project progress and performance is reasonable).**

ACTION ITEMS

Resulting from the July 30 – Aug. 1, 2002
Department of Energy (DOE) and National Aeronautics and Space Administration (NASA)
Review of the Large Area Telescope (LAT) Project

	Action	Responsibility	Due Date
1.	Approve Critical Decision 2	DOE	November 2002
2.	Conduct a Mini-Review	DOE & LAT	January 2003
3.	Conduct a NASA Critical Design Review (CDR) and DOE CD-3 Review	DOE, NASA, LAT	May 2003

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