Closeout Report

of 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

January 11, 2002

GLAST LAT Overview: Design

Si Tracker

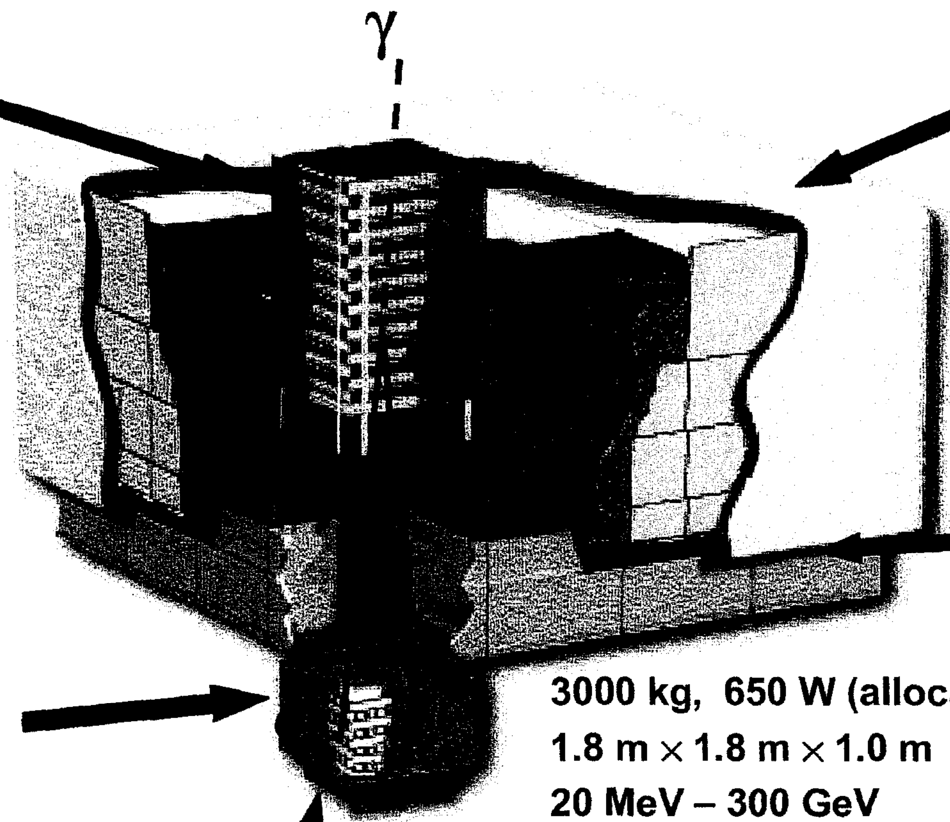
pitch = 228 µm

$8.8\ 10^5$ channels

12 layers × 2.8% X_0

+ 4 layers × 18% X_0

+ 2 layers



ACD

Segmented scintillator tiles

0.9997 efficiency

⇒ minimize self-veto

Grid (& Thermal Radiators)

3000 kg, 650 W (allocation)

1.8 m × 1.8 m × 1.0 m

20 MeV – 300 GeV

CsI Calorimeter

Hodoscopic array

8.4 X_0 8 × 12 bars

2.0 × 2.7 × 33.6 cm

⇒ cosmic-ray rejection

⇒ shower leakage correction

Data acquisition

Flight Hardware & Spares

16 Tracker Flight Modules + 2 spares

16 Calorimeter Modules + 2 spares

1 Flight Anticoincidence Detector

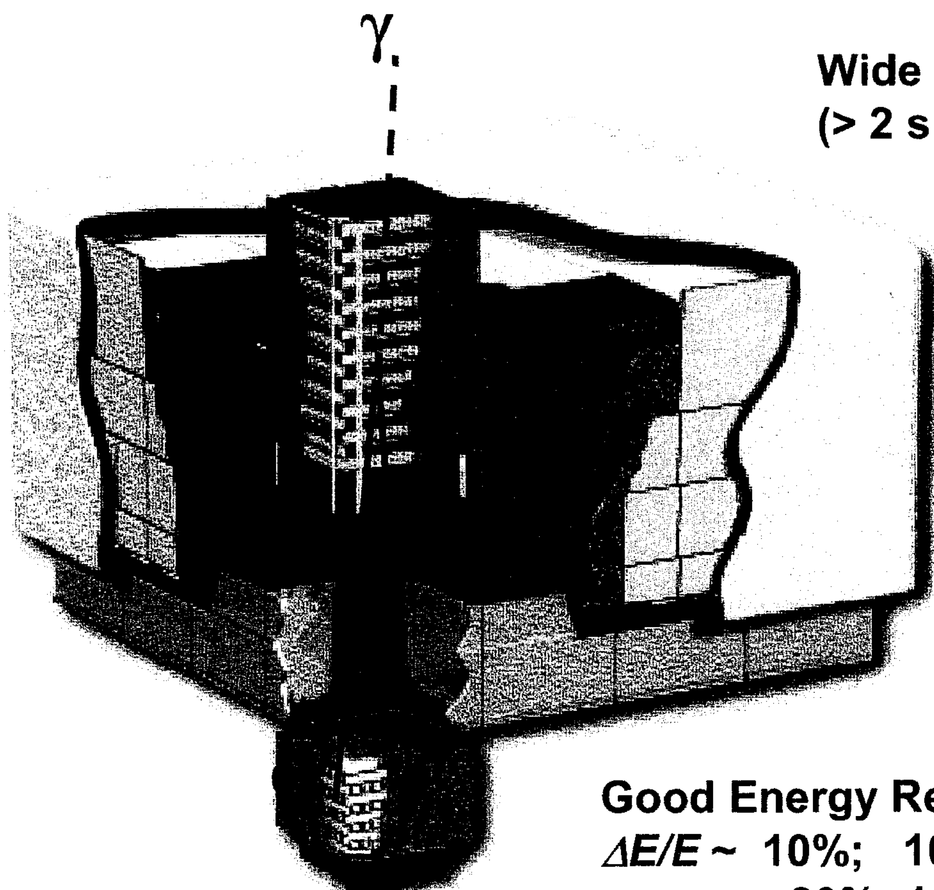
Data Acquisition Electronics + Flight Software

GLAST LAT Overview: Performance

Instrument performance meets or exceeds all requirements in 433-SRD-0001

Single Photon Angular Resolution
3.5° @ 100 MeV
0.15° @ 10 GeV

Wide Energy Range: 20 MeV - >300 GeV



Wide Field of View
(> 2 sr)

Point Source Sensitivity:
< 6 x 10^{-9} ph $cm^{-2}s^{-1}$
(est. performance:
< 3 x 10^{-9} ph $cm^{-2}s^{-1}$)

40 times EGRET's sensitivity

Low dead time:
< 100 µs/event

Source Localization:
0.3' – 1' (unid EGRET)

Large Effective Area
$(A_{eff})_{peak}$ > 8,000 cm^2

Good Energy Resolution
$\Delta E/E$ ~ 10%; 100 MeV – 10 GeV
~ < 20%; 10 GeV – 300 GeV

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

REPORT OUTLINE/WRITING ASSIGNMENTS

* Denotes lead for writing assignment
SC Subcommittee

Department of Energy/National Aeronautics and Space Administration Review
of the
GLAST Large Area Telescope (LAT) Project
January 8-10, 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, GSFC	* Jim Ryan, GSFC
			Bruce Meinhold, GSFC	Dennis Hewitt, GSFC
			Jon Thaler, U. of Illinois	Tom McCarthy, GSFC

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, GSFC	* Bill Craig, LLNL	* James Branson, UCSD	* Mark Reichanadter, Fermilab	* Sam Aronson, BNL
Cliff Jackson, GSFC	Jim Kerby, Fermilab	Rob Kutschke, Fermilab	Steve Tkaczyk, DOE/SC	Pepin Carolan, DOE/Fermilab
	Robert Vernier, GSFC			Martin Davis, GSFC

LEGEND

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

Count: 23 (excluding observers)

1/11/02:q:sc-81:sns:0010rev:revcmglast.xls

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: December 7, 2001

RE: Request to Conduct a Preliminary Design Review and Baseline Review of the GLAST LAT Project

The DOE/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 Preliminary Design Review and a Baseline Review be conducted on January 8-11, 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. It is being designed and built by an international collaboration. Professor Peter Michelson, who holds a joint appointment at Stanford University and SLAC, is the Spokesperson for the LAT Collaboration and Principal Investigator for the LAT project. He has overall responsibility for the technical, cost, and schedule management of the LAT. SLAC is the Host Laboratory for the LAT Project, providing technical and management support.

The purpose of the review is to carry out an integrated examination of each subsystem, the technical progress overall, and the cost, schedule and management planning of the GLAST/LAT project. The committee should evaluate all aspects of the 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. Technical Progress: Review the technical progress at the system and subsystem levels in order to assure that the proposed design and associated implementation approach satisfies the system and subsystem functional requirements. Review the LAT performance requirements and the adequacy of designs and resources allocated in order to meet the project's scientific goals.

2. Cost Estimates: Is the cost estimate consistent with the plan to deliver the LAT with the stated technical performance? Is the contingency adequate for the risk?

3. 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?

4. 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?

5. 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.

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 and help to ensure that the U.S. astroparticle physics program remains robust and meets its commitments on cost and schedule.

You are asked to submit a formal report by March 11, 2002. The committee members are asked to contribute draft sections of this report by the end of the closeout of the review, January 11, 2002.

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

2.1 LAT Tracker - WBS 4.1.4

Reviewer: Helmuth Spieler (LBNL)

2.1.1 Findings

- The concept of the LAT Tracker is well-matched to the science goals and utilizes mature technologies. The LAT Tracker has assembled an experienced team. The design is well thought out and can be implemented within the available time.

- A strong consortium of groups in Italy has taken responsibility for assembling and testing all ladders, trays and towers. This is a crucial contribution to the Tracker, which is being executed in very effective and competent manner.

- The silicon sensors are now in production. 1400 sensors have been delivered and tested in both Japan and Italy with excellent results.

- The front-end IC is relatively simple and can be implemented with mature processes. A preproduction prototype is now in fabrication.

- A bottoms up cost estimate by the subproject yields a total cost of $9.7M with 11% contingency for the portion of the project funded by the U.S. The overall estimate appears reasonable, but the contingency is low.

- A detailed and comprehensive schedule has been developed. Schedule contingency is marginal.

- Plans for verification and testing exist, but must be reworked for completeness and consistency.

- The front-end ICs are the dominant critical path item.

- The overall cost contingency is low because several major items have well-defined costs. However, contingency allocations for some remaining tasks are low and should be reviewed with a more realistic contingency model. Sensor losses during tray assembly were estimated but not fully covered in the budget.

- The Tracker has presented a mature design with a workable schedule. The technical design is ready for baseline approval, but an increased contingency of 20% appears appropriate.

2.1.2 Comments

The concept of the LAT Tracker is well-matched to the science goals. It utilizes a mature technology and builds on proven designs and extensive experience in high-energy physics.

A consortium of groups in Italy led by R. Bellazzini at INFN Pisa has taken on the responsibility for assembling the detector ladders, trays and towers. This is a crucial contribution to the project and the LAT is very fortunate to have secured the participation of this experienced and competent group.

T. Ohsugi at Hiroshima University is coordinating the sensor effort and brings extensive experience and expertise to the project. The first 1400 production sensors have been delivered and tested at the vendor, Hamamatsu Photonics, and in Italy. This is the first experiment to use a large number of sensors fabricated on 6" wafers and the results are excellent. Detector leakage current is <500 nA over the full area of 9 x 9 cm^2 wafers with only 0.01% defective strips. This high quality has been maintained in the first two prototype ladders.

The front-end IC builds on proven techniques from high-energy physics. Two versions of the front-end chip are currently in fabrication. One of these incorporates minor changes of the previous chip. The other has modified analog circuitry with the goal of improving the threshold uniformity. Both utilize elements from previous designs and qualify as pre-production prototypes.

The front-end IC schedule defines the critical path. Time for an additional fabrication run is not included in the schedule, so thorough evaluation of these chips is essential before going into production.

The design for the ladders, trays and towers is well-developed. Prototype ladders have been fabricated in Pisa using production tooling. A small-scale MCM with key elements of the full version has been designed and will be tested with the new chips.

Plans for verification and testing have been developed and reviewed. However, they must be reviewed to ensure that they include setup information and complete tables of target values and allowable ranges. Digital ICs are tested with test vectors derived from simulations, but analog parameters require more attention. Wafer probing of the analog front-end ICs is especially critical, as the reliability of this test greatly affects the yield of the MCMs, which require 16 functional chips. This is an opportune time to refine the wafer probe procedure, as the first pre-production chips are due in February. Tray and tower assembly procedures in Italy are being refined now with the experience gained with the first ladder assemblies.

A detailed and comprehensive schedule has been developed. As noted above the front-end IC is critical path. Assembly of towers has about 3 months schedule float, which is marginal. Potential production bottlenecks have been identified, but careful monitoring is necessary to avoid severe schedule problems. The PMCS system is difficult to use for monitoring technical progress with sufficient detail, but the Tracker is using additional tools to monitor progress and detect incipient critical path problems.

Cost contingencies tend to be low and should be reviewed and re-evaluated using a more realistic model. Contingency should also be increased to cover silicon sensor breakage during construction. Tower construction requires 10368 sensors, but an additional 1000 sensors are required as contingency to cover fabrication losses, so the budget must accommodate up to 11400 sensors. Japan is funding 5000 sensors. Combined contributions from INFN and ASI cover additional 5000 sensors. The remaining sensors must be covered by U.S. funding, but are only partially covered in the cost estimate. Since breakage will be gauged as tray assembly progresses, this can be covered by increased contingency.

2.1.3 Recommendations

1. Baseline the Tracker with increased contingency.

2. Evaluate pre-production ICs thoroughly to ensure success of full production run.

3. Refine assembly and test procedures.

R. Ray
Fermilab
1/11/02

2.2 Calorimeter

Findings and Comments Relevant to Final Recommendations

- The technical design of the CAL is sound.
- The managers of the CAL project are sound, capable and highly motivated.
- Procurement of CsI by Swedish collaborators is on schedule.
- Previously cited problems between various French institutions have yet to be fully resolved and place the project at considerable risk.
- A proposal has been recently made that finally address these issues by redefining the responsibilities of the French institutions. The Committee supports this reorganization and is optimistic that it will mitigate many of the existing problems.
- CNES is currently reviewing the funding of the French component of LAT within the context of this new proposal.
- Implementation of this proposal will likely increase the scope of the US contribution by moving PEM assembly to the US.

- The cost of this scope increase is $2M - $4M.
- The benefits of the scope increase include the ability to do all integration at one site; more control for LAT management; elimination of redundant testing that saves ~5 weeks.
- The CDEs will be assembled by industry under the direction of Saclay. Deliveries of CDEs for the engineering prototype have yet to commence and are several months behind schedule. The contract for assembly of the flight CDEs must be in place as soon as possible. This requires that an appropriate set of approved assembly and testing procedures are in place and transferred to the vendor performing the work.
- The first flight modules will be late. Production of subsequent modules are said to eat into a perceived slack that exists in the current schedule. The production schedule proceeds in parallel with many tasks taking place simultaneously. 10 modules will be in production before the first flight module is complete and verified.
- <u>The current budget and schedule does not include the change in scope of the US effort or the startup delays of the CDE assembly.</u>

Recommendations

1. The committee recommends that the calorimeter project not be baselined until the French commitments are finalized and changes in the scope of the US contribution are fully understood.
2. The committee encourages the French collaborators, LAT management and the relevant agencies to quickly reach and implement a final agreement on the responsibilities of the French institutions.
3. The committee recommends that the LAT calorimeter management team establish a new budget and schedule reflecting the change in scope of the US commitment and the delay in CDE assembly.

2.3

Anticoincidence Detector
WBS 4.1.6

Pawel de Barbaro,
U. Of Rochester

Technical Aspects

- We found that significant progress has been achieved since the last review, no major technical problems observed
- ACD subsystem was descoped, tile segmentation was reduced and the High Voltage system simplified
- descoped detector still meets physics requirements

Cost and Schedule

- Present cost estimate of ACD is $10M
- Approx. 60% of the cost is in labor
- Total labor estimate is 80 FTEs
- Large fraction of the labor to be performed by GSFC civil servants, off the project

Comments

- Subsystem management is working on implementing the bottoms-up cost estimate of the ACD
- Lack of the final WBS makes it hard to reliably review the costs of the project

Recommendations

- Significant technical progress on the ACD subsystem has been accomplished since the last review. Remaining issues can (and should) be settled within next few months.
- However, due to lack of a verifiable WBS, the subsystem is not ready to be baselined at the present time.
- The committee recommends a Subsystem Baseline Review as soon as the work on bottoms-up WBS in completed.

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

Subcommittee members:

Fred Huegel GSFC

Jonathan Thaler U. of Illinois

Bruce Meinhold GSFC

Recommendations:

- Minimize the risk of the loss of a tracker due to shorts in tantalum caps
  - ***Work with GSFC parts branch to study the feasibility of qualifying polyswitches for use in the tracker electronics***
  - ***Ensure that flight tantalum caps receive 100% surge current testing and conservative derating to provide for maximum protection against short circuit failures***

Recommendations for LAT Electronics

- Due to the recent reassignment of power supply development responsibilities the schedule and budget should be reviewed to ensure adequate resources have been identified.
- LAT parts engineer should verify that the use of the optocouplers in the SWRI power supplies falls within GSFC approved guidelines
- Continue close monitoring of RAD750 development and continue to investigate backup options. Evaluate schedule, cost and technical impacts of candidate backups
- Review the schedule for the burn-in and screening of the flight ASICS. The time currently allotted appears to be a minimum

Recommendations for LAT Electronics

- Correct the discrepancies in the ACD flight ASIC schedules
- Based on the upper level estimate of 300K lines of code for the flight software and the current support level of 5.5 FTEs it appears that the development pace will be comparable to the intensive effort on the balloon flight. With the added testing requirements for flight software the schedule could be very difficult to meet. It is recommended that the LAT project re-evaluate the need for additional resources in this area.
- Cost and schedule look reasonable with adequate margin. Technical maturity in most areas is beyond the PDR level. The electronics is recommended for baselining.

2.6
SC5
Mechanical Systems (WBS 4.1.8)

*Jim Ryan, GSFC
Dennis Hewitt, GSFC
Tom McCarthy, GSFC

The subcommittee was very impressed with the LAT mechanical systems leadership

Recommendations

1. Generate a comprehensive strength qualification plan for the LAT instrument.

2. Provide the sine test philosophy for the LAT instrument/subsystems.

3. Provide an initial, top-level estimate of the cost/schedule impact of replacing a Tracker tower after complete instrument assembly.

4. Evaluate modifying the requirements being used for thermal design analyses in the following areas:

   a) Temperature profile for solar arrays for hot, cold and survival cases.
   b) The EOL temperature margin that could be achieved by raising the allowable operating temperature of the tracker detectors.
   c) Evaluate increasing the survival heater power allocation.
   d) Evaluate the maximum power that the thermal system should reject.

5. Investigate using thermal coatings with higher emmissity for the radiator.

6. Perform TV cycling testing of the assembled grid with heat pipes (no other components) to evaluate workmanship.

7. Determine configuration of survival heaters, i.e., S/C control or thermostats.

8. Ensure that the RSDO contractor is aware of the long time constant LAT instrument which will effect the duration of performing 4 thermal vacuum cycling. Also consider the thermal time constant effect on the LAT thermal vacuum test.

9. Conduct a delta mechanical/thermal PDR to evaluate technical, cost and schedule impacts of the thermal changes necessary to meet requirements with margin.

10. Consider second sourcing thermal control components, such as VCHP's and CCHP's, due to LM facility relocation to Mississippi.

11. Internal mechanical/thermal ICD's need to be completed.

12. Pursue with the GLAST Project whether funding can be found to fabricate the radiators on the original schedule (rather than ther year slip apparently mandated by the funding profile). This is a programmatic risk that should be avoided if possible.

13. Mechanical system not ready to be baselined. Contingency must be reassessed based on thermal design changes/radiator repackaging.

2.7 LAT Baseline Review: Systems Engineering Summary (1/11/02)

Steve Scott (GSFC/Chair)
Cliff Jackson (GSFC)

1) The Systems Engineering (SE) effort on LAT is adequately well understood, as determined from the presentations, splinter sessions, and a review of the Systems Engineering Management Plan (SEMP).

2) The validation of key flowed-down requirements needs to be supported by technical budgets summarizing the allocations and margins.

3) The support available for the SE effort in key areas such as Electrical Systems, Mechanical Systems, and Science Systems Analysis is not clear, but is critical to SE success. Getting the full suite of SE activities underway will quickly verify the SS support available. This was the focus of many of the recommendations and the information requested there.

4) The SEMP needs to be signed off and approved by the Project, and the activities called for there implemented.

5) The full set of recommendations is included in the handout.

6) We recommend the SE effort for baselining, but recognize that there is significant cost risk uncertainty due to the distributed SE support.

Attachment: GLAST LAT Systems Engineering Recommendations

1. The following items fall into the category of information requests:

Provide a list of the Minimum Science Mission Requirements and a copy of the Descope Plan. A copy of the Science Requirements Document and Descope Plan from the proposal would be sufficient if they are still relevant.

Provide a copy of the (integrated) Requirements Verification Traceability Matrix. A plan for developing it would be acceptable for PDR.

Provide a copy of the current Risk List (that is full summary of risks to date) and the plan for updating it and using it on the project.

Provide a list of key LAT Technical Budgets that are monitored regularly (e.g., Mass, Power, Thermal, Processing Resources, Alignments, etc) or will be.

Provide a list of all open technical trade studies cutting across subsystems.

Provide a list of Spacecraft Requirements and Constraints derived from the unique Instrument requirements. Provide a list of the Instrument requirements and constraints derived from using an RSDO Spacecraft Bus for the GLAST Mission.

Provide a status of technical drawings and provide the plan for how they will be tracked.

Provide the list of RFA's (Action Items) from the Subsystem and System Engineering Peer Reviews and their closures.

Provide a list of cables and harnesses and who is responsible for designing and fabricating them.

Describe the (expected) transition of LAT Configuration Management and Problem Reporting and Corrective Action Processes from Instrument Integration and Testing to Observatory Integration and Testing and from Observatory I&T to Observatory Operations. Provide the appropriate section of the Configuration Management Plan if it addresses this.

2. Provide descriptions of the LAT Comprehensive Performance Test, Limited Performance Test, and Aliveness Test and determine where they will be conducted in the Instrument Integration and Test Flow and in the Observatory Integration and Test Flow.

3. Describe the LAT internal Alignment tests and where they will be conducted in the Instrument Test Flow. Describe the LAT Instrument to Spacecraft Alignment Requirements and how they will be measured and verified during the Observatory Integration and Test Flow. Determine whether an Alignment Test needs to be performed between LAT dynamics and Thermal Vacuum Testing. Determine whether a LAT to Spacecraft Alignment Test needs to be performed between Observatory Dynamics and Thermal Vacuum Testing. This could all be summarized in an Alignment Plan.

4. Provide a list of the Time Accuracy requirements allocated to and affecting the LAT Instrument and Instrument Operations Center. Describe the Instrument, Observatory, and Mission Time Management Approach and how it will be verified.

5. Describe how levels of redundancy were determined. Is redundancy based on the assumption that all components will survive five years and redundant units are simply present as back-ups, or are reserve units required to meet the five-year mission life? Is the number of redundant units based on statistical analysis or simply to prevent Single Point Failures? Describe the influence Failure Modes and Effects Analyses have had on the design (e.g., list any design changes that have resulted from the FMEA's)?

6. Develop/Provide a Logistics Support Plan and a list of all expected spares for the LAT Instrument, Ground Support Equipment, and Instrument Operations Center.

7. How will all the LAT Flight Software Requirements be verified before delivery to Instrument Integration and Testing? Describe the plans for Formal Qualification Testing (Acceptance Testing) of the Flight Software (a copy of the Software Test Plan or Software Development Plan containing this information would suffice). Describe any plans for a regression suite of software tests (subset of the full Software Qualification Test) to verify that previously qualified/accepted software continues to function properly after changes have been made or problems resolved.

8. Describe the role, if any, of the West Virginia Software Independent Verification and Validation Facility in the LAT Software development, verification, and validation program.

9. Describe how Electrical Ground Support Equipment Hardware and Software used to determine the correct functioning and performance of the LAT Instrument will be verified and validated.

10. Describe the Software Maintenance approach from delivery of the Instrument to Observatory-level Integration and Testing through Launch plus five years.

11. Conduct a Peer Review of the cabling and harnessing.

12. Re-examine the operational and survival temperature limits prior to the start of component qual testing. Consider whether it is feasible to establish survival limits that are 15 degrees beyond normal operational ranges, so that operational performance 10 C beyond the normal operational range can be verified without significant risk of exceeding survival limits.

13. EMI/EMC acceptance testing needs to be performed on all flight boxes except for the qualification unit (which receives qual level EMI/EMC testing). This needs to be included in the verification plans.

14. The Systems Engineering effort may be baselined (i.e., it is at Instrument PDR level).

2.8 SC-7 Integration and Test

Key Findings and Comments

- The I&T management was changed to its current configuration in August of 2001.

- The I&T manager has developed a new WBS dictionary, cost estimate and cost distribution to reflect the new organizational structure and to account for the actual tasks necessary to accomplish I&T and science verification. The cost and WBS structure as presented previously are being updated. A new WBS organization was presented during the review. Review of the new cost allocations and WBS by LAT management is in progress.

- The committee feels that the organization put in place since the August 2001 management change appears well-suited to the job.

- The subsystem manager and lead I&T engineer are cognizant of their responsibilities and have taken the appropriate steps to ensure that the team will be in compliance with project requirements.

Recommendations

1. Complete the reworked WBS with review and approval by project management by February 2002.

2. Complete the reworked cost and milestones with review and approval by project management by March 2002.

3. Recommend subsystem baseline review as soon as possible after the work on items 1 and 2 are complete.

4. Write the integration and electronics integration plans and get them under configuration management by March 2002.

5. Write a baseline level plan for the airborne test by March 2002 and ensure that any requirements on the subsystems levied by this test are flowed to subsystem managers.

6. Rev 0 assembly traveler should be written and under configuration control before Qualification Unit A arrives.

2.9 SC-7 Performance & Safety Assurance (P&SA)

Key Findings and Comments

- The safety program appears to be well formulated. Seismic safety has been explicitly addressed for the LAT integration facility.

- The QA manager has been actively involved with the LAT project for some time, and has a good working relationship with his colleagues.

- For proper execution of the safety, quality, and performance plans, the P&SA manager depends on a great deal of support from other subsystems, in particular the systems engineering group. The system engineering group is providing support for document and records management, configuration control, and quality engineering functions. Continued vigilance will be required to ensure that proper attention is maintained to complete these functions.

Recommendations

1. This subsystem is recommended for baselining.
2. Complete the GFSC Performance Assurance Audit this spring, before the CDR.

2.10

LAT Ground Systems Review

- Subsystem Managers
  - IOC(4.1.B): Scott Williams, SU-HEPL
  - SAS(4.1.D): Richard Dubois, SU-SLAC
- Reviewers:
  - Jim Branson, UCSD (chair)
  - Rob Kutschke, Fermilab

IOC Findings

1. Not a technically challenging project.
2. Interfaces to MOC plus almost all of LAT.
3. 80.6% labor: S/W development, testing and integration.
4. Major effort starts in FY04.

- Must define interfaces before FY04.
- Project has scope contingency.
- If well managed, should be small cost or schedule risk.
- Management understand risks and has plans to mitigate them.

IOC Recommendations

- Recommend Baseline Approval: Technical, Cost, Schedule, Management
- Subprojects which interface with the IOC should make people available soon to define interfaces.
- IOC needs a minimal MOC team in place.

SAS Findings

- Not a technically challenging project.
- Many elements demonstrated in balloon flight and beam test.
- Room to improve efficiencies, resolutions and background rejection. This effort is underway.
- The project has scope contingency.
- Management commended for strong planning, effectively using off-project labor and effectively running a dispersed collaboration.

SAS Recommendations

• Recommend Baseline Approval: Technical, Cost, Schedule, Management

•Maintain current S/W effort, including off-project people.

•With SSC, move forward with planning for implementation of Science Analysis Tools.

• Improve depth of organization at level of S/W architect and S/W engineers.

• Fill the user support position.

3 COST ESTIMATE

Findings

The LAT management presented a LAT baseline cost estimate of $94.4M (real-year dollars), with an overall contingency of $21.4M (then year dollars), which represents 27.6% of the remaining cost. The LAT project is ~18% complete, and the cost estimate is comprised of ~60% labor, ~40% materials. The total project cost of $115.8M RY is based upon the October 2001 resource loaded bottoms-up cost estimate.

The LAT cost estimate has experienced ~17% cost growth from the February 2001 review. The major cost drivers in this increase were a six-month delay in the launch schedule ($5.8M), and cost growth due to an improved base cost estimate ($10.8M).

On-project as well as contributed resources are included in the LAT integrated cost/schedule baseline. Major contributed resources to the LAT are SLAC (48.0FTE), and then the foreign collaborating groups from France (117.0FTE), Italy (44.1FTE), Sweden (16.6FTE), and Japan (9.2FTE)

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.

The PMCS team is currently comprised of one full-time SLAC employee supported by a team of 5 consultants from Applied Integration Management. The resource-loaded plan calls for a transition from the current plan to a more blended team of 3 full-time SLAC employees with 2 consultants. The team may be reduced further as the integrated planning for LAT becomes more routine.

Comments

LAT management and the PMCS group make a strong and capable team and the committee thanks them for their thorough presentation and frank discussion of the present status and the challenges that they see ahead for the LAT.

The suborbital flight test, being the first major subsystem to be completed, provides a valuable comparison between the cost estimate and the actual costs. The flight test actual cost ($1.321M) required 65% contingency over its February 2001 cost estimate. The major cost drivers to the increase of the suborbital flight test are a restructuring of the WBS, which added additional costs earlier captured elsewhere and a marching army effect due to a delay in the actual launch date (April to August).

The committee felt that the cost estimate is vastly improved from the February 2001 review, however the cost estimate is not fully mature. For example, WBS 4.1.9, Instrument Integration and Test, is in the process of reworking the WBS. At present, the rework is considered zero sum but there is additional risk to the schedule and cost. Also, the ACD does not consistently show a relationship between the WBS and the associated activities. Finally, LAT management has acknowledged that additional tasks for the LAT are expected in the coming months, which may make calls on available contingency.

The committee felt that the current percentage of contingency to work remaining may not be adequate to mitigate the current risk to the LAT project. This is partly due to the weighted matrix used to assess future contingency demand may not adequately capture the demands of some of the more risky items, or subsystems with a low design maturity. Additionally, contingency based upon current planning will not reflect any tasks that are missing from the current cost estimate. A new contingency assessment at the LAT management level may be necessary to incorporate missing tasks and address external risks to the LAT.

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 (SC10/11)	$2,683.0	$8,624.0	$11,307.0
4.1.2	System Engineering (SC6)	$948.0	$3,144.0	$4,092.0
4.1.4	Tracker (SC1)	$3,171.0	$6,510.0	$9,681.0
4.1.5	Calorimeter (SC2)	$2,614.0	$10,764.0	$13,378.0
4.1.6	Anti-Coincidence Detector (SC3)	$1,734.0	$8,226.0	$9,960.0
4.1.7	Electronics (SC4)	$1,902.0	$14,618.0	$16,520.0
4.1.8	Mechanical Systems (SC5)	$1,205.0	$7,083.0	$8,288.0
4.1.9	Instrument Integration & Test (SC7)	$109.0	$7,185.0	$7,294.0
4.1.A	Performance & Safety Assurance (SC8)	$289.0	$1,917.0	$2,206.0
4.1.B	Instrument Operations Center (SC9)	$141.0	$3,570.0	$3,711.0
4.1.C	Education & Public Outreach (SC10/11)	$308.0	$2,600.0	$2,908.0
4.1.D	Science Analysis Software (SC9)	$323.0	$3,377.0	$3,700.0
4.1.E	Suborbital Flight (Balloon) Test	$1,321.0	$0.0	$1,321.0
Subtotals		**$16,748.0**	**$77,618.0**	
LAT Estimated Base Cost				**$94,366.0**
LAT Total Project Cost				**$115,786.0**
Contingency				**$21,420.0**
Contingency (%)				**28%**

Recommendations

1. Complete a bottoms-up resource-loaded cost and schedule estimate for the LAT project to support a Baseline Review. The WBS should be trackable in the mentioned subsystems (ACD, I&T as examples) and supporting documentation related to the cost estimate should be available. A revised contingency analysis at the lowest WBS project should also be performed, and explicitly detailed.

2. Continue the transition of the PMCS (Project Management Control System) team from consultant support to the permanent PMCS team.

SCHEDULE & FUNDING

Findings

The integrated cost/schedule baseline for LAT consists of ~6000 schedule activities, summing to $94.4M, which can be and contains a set of milestones consistent with a launch date of March 2006.

In February 2001, the integrated LAT cost/schedule baseline estimate was made up of ~4000 tasks summing to $80.7M. Now, in January 2002, the LAT baseline is comprised of ~6000 tasks for the total cost estimate of $94.4M.

The baseline schedule contains a set of milestones consistent with a launch date of March 2006. This includes a 3-month period of explicit slack identified in the project. Contingency on remaining work was estimated by subsystem management at the lowest task level using a risk/weight contingency matrix.

Schedule and milestone variances were essentially zero since the LAT team had recently rebaseline their schedule. Most LAT subsystems are reporting positive cost variances that are primarily driven by large payment contracts and lag in reporting from US collaborating institutions.

Currently, the LAT schedule contains a significant number of milestones at the Instrument Project Office level (Level 3) that are monitored by LAT management. On average, the milestones are ~1 week apart in time. However, at the GLAST Project office level (Level 2), there are only seven future milestones with an average spacing of six months. At the DOE/NASA Headquarters level, there is only ONE milestone, i.e., Launch Instrument. The DOE Critical decision milestones are missing at this point.

Comments

Overall, LAT management should consider maintaining (or advancing) its schedule as its highest priority. Schedule variances to the baseline will result in cost growth due to the marching army effect. Additionally, attempts to stay within the TPC by descoping the LAT in the later stages of the project may not be possible due to the large labor component of the LAT (60%).

LAT management did not present high-level critical path analyses or total float for most LAT subsystems. Float, and total float are calculated by the PMCS, but it does not provide the traditional PERT chart with identified critical path.

The latest cost estimate includes a $5.8M launch delay that was driven by a decision taken by NASA. Contingency should be allocated to future schedule delays that may affect the overall LAT schedule, not contained within any specific LAT subsystem.

The LAT schedule is tight up to the launch date. LAT management should advance its work and procurements whenever possible to increase the schedule slack. In particular, planned work (BCWS) in FY02 and FY03 nearly matches budget authority, which limits available contingency to solve problems. Details of the late FY02 tasks are not candidates for deferring until FY03 without risk to the schedule.

The shifting of deliverables from foreign to US collaborators on the Calorimeter subsystem may have an effect on the overall LAT cost and schedule. A cost estimate and schedule impact assessment should be developed prior to accepting this as a US responsibility.

The Level 3 milestone list is comprehensive and the monitoring by LAT management is a commendable effort. At Level 2, the milestones should be spaced at intervals in the three to four month range. At Level 1, the interval should be approximately six months and should include the DOE Critical Decisions and any specific NASA high level milestones. The elevation of additional milestones to higher levels will provide those responsible with tools for monitoring of the project schedule by adding more schedule control to the LAT Change Control Thresholds as defined in the Project Management Plan.

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

	FY00	FY01	FY02	FY03	FY04	FY05	FY06	Total
DOE	$3,000.0	$5,700.0	$8,200.0	$9,000.0	$5,900.0	$3,200.0	$0.0	$35,000.0
NASA	$3,863.0	$3,847.0	$13,170.0	$20,917.0	$25,803.0	$9,317.0	$2,869.0	$79,786.0
JAPAN	$0.0	$0.0	$0.0	$0.0	$1,000.0	$0.0	$0.0	$1.0
Total	$6,863.0	$9,547.0	$21,370.0	$29,917.0	$32,703.0	$12,517.0	$2869.0	$115,786.0

Recommendations

1. Review the comprehensive list of Level 3 and 2 milestones and determine which dates should be elevated to higher levels at intervals suggested above. This review should be done by the responsible individuals at each level.

2. Define the DOE Critical decisions specific to this project and add them to the Level 1 Milestones. Additional NASA milestones may also be needed. The level 1 milestones and definitions should be included in the GLAST Project Execution Plan.

3. Continue to develop high-level, one page linked schedules for all of the LAT subsystems derived upon the PMCS baseline. These schedules should be monitored closely, particularly in FY02 to maintain the LAT within the available funding, and also used by subsystem managers to insure that sufficient slack exists in each of the individual subsystems.

SC10 Sub-Committee

Sam Aronson, BNL (chair)
Martin Davis, GSFC
Pepin Carolan, DOE-Fermilab

4 Project Management (WBS 4.1.1) (Draft Report)

FINDINGS

The committee would like to commend the LAT Instrument Project Office for all of the hard work carried out over the last year, as was evident from this review.

The DOE/NASA Implementing Arrangement (IA) has not yet been approved. It is NASA's position that NASA International Agreements will not be signed until the DOE/NASA IA is signed.

LAT Instrument project management has established good communication channels such as weekly meetings and status reports. Weekly meetings involve subsystem and international managers, project controls management and are open to the DOE LAT Project Manager. The LAT Instrument Project is developing integrated monthly reports that will satisfy requirements of both agencies.

The Instrument Project Office has done a good job in developing a draft Project Management Plan, as well as supporting management documentation such as Configuration Management, Risk Management and other plans. The latest draft PMP has incorporated needed change control thresholds, hierarchical Milestones, as well as the good practice of including French and Italian Project Managers on the Change Control Board. The Configuration Management Plan may need minor revision to be fully consistent with the PMP in the area of configuration control.

The source of perceived cost growth in the WBS 4.1.1 Project Management resulted from re-distribution of science support efforts, as well as addition of administrative and project management support personnel needed to implement the Project Management Control System (PMCS).

The overall LAT project contingency as a percentage of costs to go has increased from 23% in August '01 to 28% currently.

LAT Instrument project management has established a schedule that de-couples individual subsystem schedule activities from Integration &Test (I&T) schedule activities.

Project system engineering staff has been increased over the last year, including the recent addition of a Deputy Project Manager with an emphasis on technical system management.

COMMENTS

In particular the lack of a NASA/CNES Int'l Agreement has reduced GLAST and LAT Instrument Project management leverage on getting the French to live up to commitments on the Calorimeter. This has resulted in a new French organization and the probable move of the integration of the Calorimeter subsystem to the U.S., losing several months of schedule to date and significant cost increases that will result at NRL.

If the NASA/CNES International Agreement is not in place in the next few months, then the French team will not be able to initiate procurement of the Calorimeter PIN diodes, stopping this critical path subsystem.

The French team leaders on the Calorimeter system expressed a strong interest in participating in GLAST science and indicated particular areas where they could contribute resources to GLAST and LAT.

In our judgment there is good communications between the LAT Instrument project and program management, and between program management of both agencies, as well as between LAT Instrument and GLAST Mission Project management.

The DOE LAT Program Manager is new to the position, and still remains to establish the working relationship and expectations with the DOE LAT Project Manager. A DOE Project Execution Plan needs to be developed to support the DOE CD-1 process, by the end of January '02.

There is an area of concern regarding technical direction and communications on the ACD subsystem, given the proximity of the GSFC ACD management to GLAST Project Office, and sharing of personnel.

The project as a whole does have large management costs throughout the subsystems, but this appears warranted due to the nature of the collaboration and work distribution. The same is true of I&T cost estimates.

Contingency of 28% is not a comfortable number and presents significant challenges, particularly in the next two years. Project management is well equipped to address this situation. In particular the Instrument Project Manager should be commended for his emphasis on aggressive schedule management as the way to address this. The LAT Instrument Project Manager has opted for a direct control mechanism in addressing individual subsystem schedule delays with respect to I&T schedule delays. This control allows the Project Manager to prevent automatic propagation of schedule delays from one subsystem into others. LAT Instrument project management has also worked with SLAC and Stanford financial management to introduce flexibility in allocation of contingency. We think this is crucial to managing the LAT Instrument project effectively and commend this cooperation.

The LAT Instrument Project Manager also plans to add an additional senior system engineer to further strengthen system engineering. This should result in improved and faster response to systems engineering issues, and we agree that this action is appropriate.

RECOMMENDATIONS

1. Sign the DOE/NASA Implementing Arrangement.
2. Expedite NASA/CNES and NASA/ASI International Agreements.
3. Consider DOE/NASA supplement to LAT Project funding to offset cost increases resulting from lack of DOE/NASA IA and supporting International Agreements.
4. Maintain awareness that the ACD organization needs to respond to the LAT Instrument Project management, and not directly to the GLAST Project Office.
5. Work together to finalize and approve the Project Management Plan and complete a Project Execution Plan in a timely manner.
6. Inform the funding agencies when those WBS level 3 elements which are not now ready to be baselined are ready for a baseline review.

ACTION ITEMS

Resulting from the January 8-11, 2002
Department of Energy/NASA
Review of the Large Area Telescope (LAT) Project

	Action	Responsibility	Due Date
1.	Approve Implementing Agreement	DOE/NASA	ASAP
2.	Resolve Cost/Funding Issues	DOE/NASA Joint Oversight Group	February 2002
3.	Notify DOE/NASA when project will be ready for the Delta Baseline/PDR Review	LAT	Feb 2002
4.	Conduct a DOE/NASA Delta Baseline/PDR Review	DOE/NASA & LAT	Prior to April 2002
5.	Conduct a DOE/NASA CDR	DOE/NASA & LAT	September 2002

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