DOE/NASA
Review Committee Report

on the

Technical, Cost, Schedule, and
Management Review

of the

Gamma-ray Large Area Space Telescope

LARGE AREA TELESCOPE (LAT) PROJECT

January 2002

EXECUTIVE SUMMARY

On January 8-11, 2002, a Department of Energy (DOE) and National Aeronautics and Space Administration (NASA) joint committee conducted a review of the Large Area Telescope (LAT) project. The LAT is being jointly developed by DOE and NASA and is the principal scientific instrument on the NASA Gamma-ray Large Area Space Telescope (GLAST) mission, scheduled for launch in March 2006. The review was conducted at the Stanford Linear Accelerator Center (SLAC), the host laboratory for the project. At the request of the DOE/NASA Joint Oversight Group (JOG), the review committee was co-chaired by Mr. David Betz, System Review Manager, Office of System Safety and Mission Assurance, NASA/Goddard Space Flight Center and Mr. Daniel R. Lehman, Director of the Construction Management Support Division, DOE Office of Science. For DOE, this review served to determine if the project was ready for a baseline status of the technical design, cost, schedule, and management structure. For NASA, the review served as an instrument-level Preliminary Design Review (PDR). A PDR 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 charge to the committee was 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 was asked to evaluate all aspects of the project, keeping in mind the issues highlighted from past DOE/NASA reviews. In its general assessment of progress, current status, and identification of potential issues, the Committee addressed specific items in the areas of technical progress, cost estimates, international contributions, schedule, and management.

The scientific objectives of the LAT include the study of the mechanisms of particle acceleration in astrophysical environments and the resolution of unidentified galactic sources and diffuse emissions from cosmological sources using measurements of celestial gamma-rays. Among other topics of cosmological interest, these data will give information on extragalactic background light in the early universe and dark matter. The main components of the instrument, which will measure the energy and direction of gamma rays incident from space with energies at approximately 20 MeV to greater than 300 GeV, include a silicon-strip track detector, a Cesium-Iodide calorimeter, an anti-coincidence detector (ACD), and a data-acquisition system.

The Committee commended the LAT project for its hard work carried out since the February 2001 DOE/NASA review. Out of the 11 subsystems, all except the Mechanical subsystem were seen to be at the PDR stage and seven were seen to be ready for baselining by the Committee. Four of the systems were seen to need more work (calorimeter, ACD, mechanical, and integration and testing (I&T) subsystems) before baselining could be recommended. Details of the recommendations are included in the text of the report.

Overall project management for the LAT seemed to be strengthened in the last year, with additional personnel added and roles better defined. The overall schedule seemed tight for the planned March 2006 launch date. The total project cost of $115.8 million includes funding from DOE, NASA, and Japan and has a relatively low contingency level of 28 percent. The Committee identified a need for a critical path and high-level milestones. A major issue at the time of the review was the lack of a signed Implementing Arrangement (IA) between DOE and NASA. The Committee felt that cost and schedule impacts were resulting and recommended expediting signatures on these agreements. (Note: The IA was signed by NASA on January 15, 2002, and by DOE on January 18, 2002).

The technical design of the calorimeter was found to be sound. Current management problems between various French institutions involved in the calorimeter have yet to be fully resolved and place the project at considerable risk. A recent proposal by the French institutions addresses these issues by revising their responsibilities. The Committee supports this reorganization and is optimistic that it will mitigate many of the existing problems, although it is likely to increase the scope of the U.S. contribution. The Committee concluded that the calorimeter subsystem is at the PDR level but should not be baselined until the French commitments are finalized and changes in the scope of the U.S. contribution are fully understood.

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

The mechanical subsystem was found to be consistent and technically mature, except for the thermal design. The Committee concluded that the mechanical subsystem is not at the PDR level and recommended against baselining this subsystem until the thermal design changes and radiator repackaging requirements are understood.

The I&T subsystem's technical design was deemed to be mature. The management structure appeared to be strong and the budget and contingency appeared to be adequate. The Committee concluded that the I&T subsystem is at the PDR level but recommended against baselining this subsystem due to lack of a bottoms-up cost estimate and the newly reworked WBS.

The Committee concluded that all of the subsystems except for Mechanical Systems were at a PDR level of maturity. Four of the subsystems were not recommended for baselining by the Committee. As a result, the Committee recommended that DOE and NASA conduct a Delta (follow-on) baseline and PDR review in the April 2002 timeframe.

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CONTENTS

Executive Summary i
1. Introduction 1
2. Technical Systems Evaluations 5
   2.1 Tracker (WBS 4.1.4) 5
   2.2 Calorimeter (WBS 4.1.5) 7
   2.3 Anti-Coincidence Detector (WBS 4.1.6) 9
   2.4 Electronics, Data Acquisition, Flight Software (WBS 4.1.7) 12
   2.5 Mechanical Systems (WBS 4.1.8) 15
   2.6 Systems Engineering (WBS 4.1.2) 19
   2.7 Integration and Testing (WBS 4.1.9) 27
   2.8 Performance and Safety Assurance (WBS 4.1.A) 30
   2.9 Ground Systems and Analysis 32
      2.9.1 Instrument Operation Center (WBS 4.1.B) 32
      2.9.2 Reconstruction and Analysis Software (WBS 4.1.D) 34
3. Cost, Schedule and Funding (WBS 4.1.1) 37
   3.1 Cost Estimate 37
   3.2 Schedule and Funding 40
4. Project Management (WBS 4.1.1) 43

Appendices
A. Charge Memorandum
B. Review Participants
C. Review Agenda
D. Cost Tables
E. Schedule Charts
F. Funding Tables
G. DOE Action Items
H. NASA Requests for Action

1. INTRODUCTION

1.1 Background

The Large Area Telescope (LAT) will be the principal scientific instrument on the National Aeronautics and Space Administration (NASA) Gamma-ray Large Area Space Telescope (GLAST) Mission that is scheduled to be launched in 2006. The LAT is a joint project organized by Department of Energy (DOE) and NASA supported scientists and institutions and also involves teams from France, Italy, Japan, and Sweden. The LAT proposal was submitted to and accepted by NASA in response to the NASA Announcement of Opportunity (AO 99-OSS-03). The DOE-supported Stanford Linear Accelerator Center (SLAC) is the host laboratory for the project. Professor Peter Michelson, who holds a joint appointment at Stanford University and SLAC is the Instrument Principal Investigator.

The scientific objectives of the LAT are largely motivated by discoveries made by the EGRET experiment aboard the Compton Gamma Ray Satellite and, for energies above 300 GeV, by ground-based atmospheric Cerenkov telescopes. Measurements of celestial gamma-rays are used to achieve these objectives which include the study of the mechanisms of particle acceleration in astrophysical environments, active galactic nuclei, pulsars and supernova remnants; resolving unidentified galactic sources and diffuse emissions from cosmological sources; and determining the high-energy behavior of gamma-ray bursts and transients. Among other topics of cosmological interest, these data will give information on extragalactic background light in the early universe and dark matter. The main components of the instrument, which will measure the energy and direction of gamma rays incident from space with energies ~ 20 MeV to greater than 300 GeV, include a silicon-strip track detector, a calorimeter, an anti-coincidence detector and a data-acquisition system.

The LAT is a gamma-ray telescope based on conversion of the gamma rays to electron-positron pairs in a silicon strip-tracking detector which records the tracks of charged particles. The design for the tracker consists of a four-by-four array of tower modules, each with interleaved planes of silicon-strip detectors and tungsten converter sheets. Silicon-strip detectors are able to more precisely track the electron or positron produced from the initial gamma ray than other types of detectors. This is followed by a calorimeter, which has Thallium-doped Cesium Iodide (CsI) bars with photodiode readout, arranged in a segmented manner, to give both longitudinal and transverse information about particle energy deposition. An Anti-Coincidence Detector (ACD) provides background rejection of the large flux of charged cosmic rays. It consists of segmented plastic scintillator tiles, with wavelength shifting fiber/photomultiplier tube readout. The detector draws on the strengths of the high-energy physics community, typically supported by DOE, for the silicon and calorimeter technology and related physics analysis. Space qualification and telemetry are new dimensions for high energy physics, but well understood in astro-particle physics, typically supported by NASA, as well as the foreign collaborators.

NASA and DOE have formed a Joint Oversight Group at the Headquarters level to coordinate agency oversight of the project. The host laboratory under the leadership of the Instrument Principal Investigator supplies coordination and management of the project, including resource management and cost and schedule accountability and reporting. DOE/NASA relationships for the GLAST mission and the LAT project are formalized in an Implementing Arrangement (which was signed by both agencies in January 2002).

1.2 Charge to the DOE/NASA Review Committee

In a December 7, 2001 memorandum (Appendix A), the DOE/NASA Joint Oversight Group (JOG) requested that Mr. David Betz, System Review Manager, Office of System Safety and Mission Assurance,, NASA/Goddard Space Flight Center, and Mr. Daniel Lehman, Director of the DOE Construction Management Support Division conduct a Preliminary Design Review (PDR) and baseline review of the GLAST/LAT project on January 8-11, 2002. The LAT is being jointly developed by DOE and NASA and is the principal scientific instrument on the NASA Gamma-ray Large Area Space Telescope (GLAST) Mission, scheduled for launch in March 2006. The review was conducted at the Stanford Linear Accelerator Center (SLAC), the host laboratory for the project. For DOE, this review served to determine if the project was ready for a baseline status of the technical design, cost, schedule, and management structure. For NASA, the review served as an instrument-level Preliminary Design Review (PDR). A PDR focuses on the technical design of each subsystem and the integrated instrument in addition to being concerned with its cost, schedule and management structure. Requests for Actions (RFA) are written during the PDR review by the Committee members or others in attendance and forwarded to David Betz for coordination. The RFAs (Appendix H) are generated for specific items that are felt to need more explanation than was available at the time.

The charge to the Committee was 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 was asked to evaluate all aspects of the project, keeping in mind the issues highlighted from past reviews. In its general assessment of progress, current status, and identification of potential issues, the Committee addressed specific items in the areas of technical progress, cost estimates, international contributions, schedule and management.

1.3 Membership of the Committee

The committee was co-chaired by Mr. David Betz, NASA/Goddard Space Flight Center and Mr. Daniel R. Lehman, Director of the Division of Construction Management Support in the DOE Office of Science. The committee was organized into ten subcommittees with members drawn from universities, DOE National laboratories, and NASA Space Flight Centers. Committee membership and subcommittee structure are shown in Appendix B.

1.4 The Assessment Process

The review was the third DOE/NASA review of the LAT project of a combined series that fulfills the otherwise-separate requirements of the DOE and NASA management oversight processes.

The review took place on January 8-11, 2002 at SLAC. The first day's plenary sessions consisted of overview presentations by LAT project management and leaders of the detector subprojects. These presentations were based largely on detailed information developed in preparation for the baseline cost estimate and the PDR. On subsequent days, the members of each subcommittee met with their project counterparts to discuss the technical status and details of the scope, cost, schedule, and management of each subsystem. The presentations by the subsystems were well prepared and the discussions were very useful. The closeout with GLAST/LAT management took place on the morning of the fourth day. The complete agenda is included in Appendix C.

The primary method for assessing technical requirements, cost estimates, schedules, and adequacy of management structures was comparison with past experience. Relative to high energy physics detectors with which the DOE reviewers, were familiar, the LAT is a small and simple detector. The additional complications due to space qualification were familiar to the NASA reviewers. The cost and schedule basis was a new "bottoms-up" estimate.

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2. TECHNICAL SYSTEMS EVALUATIONS

2.1 Tracker (WBS 4.1.4)

2.1.1 Findings

The Large Area Telescope (LAT) Tracker has an experienced project team. The concept of the LAT Tracker is well matched to its science goals and utilizes mature technologies. The design is well thought out and can be implemented within the available time.

A strong consortium of groups in Italy have 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; and 1,400 have been delivered and tested in both Japan and Italy with excellent results.

The front-end integrated circuit 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 $9.7 million with 11 percent contingency for the portion of the project funded by the U.S. The overall estimate appears reasonable, but the contingency is low. 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. A detailed and comprehensive schedule has been developed. Schedule contingency is marginal.
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 percent appears appropriate.

Plans for verification and testing exist, but must be reworked for completeness and consistency. The front-end integrated circuits are the dominant critical path item.

2.1.2 Comments

The concept of the Tracker is well matched to its 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 Istituto Nazionale di Fisica Nucleare (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 1,400 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 six-inch wafers and the results are excellent. Detector leakage current is <500 nA over the full area of 9 x 9 square centimeters wafers with only 0.01 percent defective strips. This high quality has been maintained in the first four prototype ladders.

The front-end integrated circuit 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 integrated circuit 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 Multi-Chip-Modules (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 should be reviewed to ensure that they include setup information and complete tables of target values and allowable ranges. Digital integrated circuits are tested with test vectors derived from simulations. Wafer probing of the analog front-end integrated circuits is especially critical, as the reliability of this test greatly affects the yield of the MCMs, which require 24 functional chips.

This is an opportune time to review 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 integrated circuit is on the critical path. Assembly of towers has an approximate three-month schedule float, which is marginal. Potential production bottlenecks have been identified, but careful monitoring is necessary to avoid severe schedule problems. The Project Management Control 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 10,368 sensors, but an additional 1,000 sensors are required as contingency to cover fabrication losses, so the budget must accommodate up to 11,400 sensors. Japan is funding 5,000 sensors. Combined contributions from INFN and Agenzia Spaziale Italiana cover additional 5,000 sensors. The remaining sensors 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 integrated circuits thoroughly to ensure success of full production run.

3. Refine assembly and test procedures.

2.2 Calorimeter (WBS 4.1.5)

2.2.1 Findings and Comments

The technical design of the Calorimeter is sound. The managers of the Calorimeter project are sound, capable, and highly motivated.

Procurement of Cesium Iodide by the 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 recent proposal addresses 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.

Centre National d-Etudes Spatiales 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 U.S. contribution by moving Pre-Electronics Module assembly to the United States.

The cost of the scope increase was not provided by the project, but is estimated by the Committee to be $2-4 million. The benefits of the scope increase include the ability to do all integration at one site, more control for LAT management, and elimination of redundant testing that will save approximately five weeks.

The Cesium Iodide Detector Elements (CDE) 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. Ten modules will be in production before the first flight module is complete and verified. The current budget and schedule does not include the change in scope of the U.S. effort or the startup delays of the CDE assembly.

2.2.2 Recommendations

1. The calorimeter project should not be baselined until the French commitments are finalized and changes in the scope of the U.S. contribution are fully understood.

2. The French collaborators, LAT management, and the relevant agencies should quickly reach and implement a final agreement on the responsibilities of the French institutions.

3. The LAT calorimeter management team should establish a new budget and schedule reflecting the change in scope of the U.S. commitment and the delay in CDE assembly.

2.3 Anti-Coincidence Detector (WBS 4.1.6)

2.3.1 Findings

The goal of the Anti-Coincidence Detector (ACD) is to reject charged particles with efficiency of 0.9997. At the same time, the ACD has to maintain efficiency for high-energy gammas. The requirement is that for 300 GeV, the reduction of the detector effective area is no more than 20 percent.

Simulation of LAT detector and test beam results indicate that to achieve this goal one needs to use 0.3 minimum ionizing particle (mip) thresholds. In order to stay below $3x10^{-4}$ inefficiency for charged particle rejection, light yield requirement for scintillator tiles is 20 photo electrons/mip. Measurements indicate that tiles read out with two photomultiplier tubes meet the required efficiency. However, in case of a photomultiplier tube failure, light yield of a tile drops and its efficiency falls to 0.999.

Since the February 2001 DOE/NASA review, the ACD subsystem has been descoped. In particular, the number of tiles has been reduced to 89. The High Voltage Bias system has been simplified and its redundancy reduced. The reduced segmentation still allows achieving the low backsplash self-veto requirement.

The present cost estimate for the ACD subsystem is $10 million (nearly 60 percent associated with labor costs). The total labor required for the ACD completion is estimated at the level of 80 man-years (FY 2002 through FY 2006). A large fraction of the labor, approximately two-thirds, will be performed by Goddard Space Flight Center civil servants, for which DOE/NASA project funds pay a reduced "head tax." At the February 2001 review, the total labor estimate for the ACD was 50 man-years.

2.3.2 Comments

Since the February 2001 DOE/NASA review, significant technical progress has been achieved.

The design (fiber routing, connectors and clear fibers, and segmentation) of the ACD was optimized. Progress in the engineering effort was also significant (technical drawings for mounting of tiles, electronics, and photomultiplier tubes; and design of thermal shield). Certain technical issues still need to be settled; in particular the design of the lowest (fourth) row of tiles has not been finalized. A realistic plan for initial calibration of the ACD needs to be developed.

Closer review indicated discrepancies in the schedule for the Analog and Digital ASIC development. Testing of the flight analog Application Specific Integrated Circuit (ASIC) is shown on the schedule to begin about one month prior to receiving the packaged flight ASICs. Testing of these devices cannot start until the devices are available. The correction of this scheduling error will add about one month to the development of the flight analog ASIC. Packaging of the flight digital ASIC is shown to begin prior to the foundry build of the devices. The packaging sequence needs to be moved so that it starts after device fabrication. However, correction of this error should not add any time to the availability date of the flight digital ASICs since the schedule, as it currently exists, shows that testing begins at the appropriate time if the packaging sequence is moved to start after the foundry build. In addition, it should be noted that the time allotted for qualification and burn in of the ASIC devices is considered a minimum.

Presently, the subsystem management is working on implementing the bottoms-up estimate of the ACD costs into the Work Breakdown Structure (WBS) in the Primavera system. Lack of the cost estimate makes it hard to review the costs of the subproject. In particular, it is not possible to verify if the labor funding is adequate.

The structure of the present WBS is not streamlined; material and services costs are not separated from the labor and the management tasks, treatment of Multi-Program Support costs for off-project labor is not consistent. Labor costs do not use the actual costs of the personnel. Documentation for the Basis of Estimate and the Contingency Analysis are incomplete.

2.3.3 Recommendations

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

2. Perform light yield tests and muon detection efficiency measurement of the final optical

system (scintillator tiles; and fiber ribbons, connector, clear fibers, and photomultiplier tubes).

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

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

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

6. Prepare a plan for Quality Control (tile response uniformity and broken fibers) and initial calibration (ADC/minimum ionizing particle) of the ACD system prior to the delivery to the Stanford Linear Accelerator Center.

7. Additional time should be added to the ASIC production schedule to provide some schedule margin.

8. Complete the bottoms-up Work Breakdown Structure in the Primavera framework.

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

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

11. Due to lack of a verifiable Work Breakdown Structure (cost estimate) for the ACD, the subsystem is not ready to be baselined at the present time. Consider the following streamlining steps:

    - Separate materials and services from the labor tasks at lowest WBS level
    - Identify all the off-project labor costs at the lowest WBS level
    - Use the actual, fully loaded costs for technicians, specialists, engineers, etc., in all WBS labor estimates

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

2.4 Electronics, Data Acquisition, Flight Software (WBS 4.1.7)

2.4.1 Findings

The Electronics subsystem (WBS 4.1.7) of the GLAST/LAT project will produce the data flight electronics and software. Its budget is $20.1 million, including 28 percent contingency. Included in the Electronics subsystem WBS element are the Tower Electronics Modules (TEMS), the Event Processor Units (EPU) and associated software, the Spacecraft Interface Unit (SIU) and associated software, the Power Distribution Unit (PDU), the Global Trigger-ACD-Signal Distribution Unit (GASU), the Ground Support Equipment (GSE) and flight harness, the electrical GSE, and the electrical integration. This is a total of 27 electronics boxes (only five designs). SLAC is responsible for the development of all of the above. Electronics development also occurs under the Tracker (WBS 4.1.4), Calorimeter (WBS 4.1.5) and Anti-Coincidence Detector (WBS 4.1.6) WBS elements. In addition, parts screening and burn-in take place under the Performance and Safety Assurance WBS element (4.1.A).

There are a total of ten ASIC designs used in the LAT: SLAC is developing six, Goddard Space Flight Center is developing two, and the University of California, Santa Cruz and the Naval Research Laboratory are each developing one. The total number of ASICS parts used in the LAT is approximately 20,000. Of these about 14,000 are packaged into 800 Tracker Multi-Chip-Modules (MCM) and undergo screening and burn-in at the MCM level.

The total flight software effort involves an estimated 200,000 to 300,000 lines of code for the SIU and EPUs. There are five EPUs but the hardware design and embedded software in each is identical. The design of the hardware and software are well advanced and contributed to a successful balloon test flight in August 2001. The flight designs for the LAT will build on those used in the balloon flight. Prototype versions of all analog ASIC designs and some of the digital ASIC designs have been built and successfully tested.

The subsystem architecture is well planned and does not pose substantial technical risk. Extensive functional redundancy with cross strapping is used. The design falls within the power and mass constraints for this LAT subsystem and is sufficiently advanced so that there is not large cost or schedule risk, except as noted below.

The number of people working on flight software has been approximately doubled, to about 5.5 FTE, since the February 2001 DOE/NASA review. Liaisons to the software teams for the Instrument Operation Center (WBS 4.1.B) and Science Analysis (WBS 4.1.D) have been put in place.

The WBS and Project Management Control System have been developed in sufficient detail to make them useful for tracking subsystem progress and identifying potential problems.

2.4.2 Comments

The preferred flight CPU, the BAe RAD 750, has not been space qualified. The possibility of having to fall back to alternative CPUs poses some schedule and cost risk.

Some ASICs, for example the ACD digital ASIC, are on the LAT critical path. Because there is little contingency in the testing schedule for these devices, this presents some schedule risk.

There is heavy use of tantalum capacitors in the tracker electronics. This presents a reliability risk. If a single tantalum capacitor shorts in a tracker tower the entire tower would be lost. The SLAC engineers would like to mitigate this risk through the use of polyswitches to protect against a catastrophic short circuit. Fuses cannot be used due to space limitations. However, at present, polyswitches are not qualified for flight use and there are no plans by other projects to qualify them.

Until recently, France was responsible for the development of several power supplies used in the LAT electronics. This development has now been assigned to SLAC. It is not clear if adequate resources are available to complete the power supply development within schedule and budget.

The power supply designs being developed by Southwest Research Institute use optocouplers for isolation. Goddard Space Flight Center has noted problems with power supply designs using optocouplers. These problems are due to Single Event Upsets and total dose radiation.

Based on the estimate of 200-300 K lines of code for the flight software and the current support level of 5.5 FTEs, it appears that the development pace (about 15 K lines per FTE-year) will be comparable to the intensive effort on the balloon flight (about 20 K lines per FTE-year). With the added testing requirements for flight software the schedule could be very difficult to meet. (The embedded software industry average is about 2 K.)

The development of the LAT electronics and associated software is obviously a huge effort requiring coordination of the efforts of several organizations. Fortunately, as noted above, both the hardware and software designs are well advanced in several areas, well beyond the typical Preliminary Design Review level.

2.4.3 Recommendations

1. Work with Goddard Space Flight Center parts branch to study the feasibility of qualifying polyswitches for use in the tracker electronics.

2. Ensure that flight tantalum caps receive 100 percent surge current testing and conservative derating to provide for maximum protection against short circuit failures.

3. Review the schedule and budget for the power supply development to ensure adequate resources have been identified.

4. The LAT parts engineer should verify that the use of the optocouplers in the SWRI power supplies falls within Goddard Space Flight Center approved guidelines.

5. Continue close monitoring of RAD750 development and continue to investigate backup options. Evaluate schedule, cost, and technical impacts of candidate backups.

6. Review the schedule for the burn-in and screening of the flight ASICS. The time currently allotted appears to be a minimum.

7. Correct the discrepancies in the ACD flight ASIC schedules.

8. Consider the need for additional resources in the software development area.

9. Cost and schedule look reasonable with adequate margin. Technical maturity in most areas is beyond the PDR level. The electronics is recommended to be baselined.

2.5 Mechanical Systems (WBS 4.1.8)

2.5.1 Findings

The mechanical designs presented for the LAT subsystems were consistent with preliminary design maturity with the exception of the thermal subsystem, which was not at Preliminary Design Review (PDR) level due to a recently directed change to repackage the radiators to allow a maximum spacecraft diameter, and thus, the maximum number of potential spacecraft vendors to bid for the spacecraft contract. Several LAT subsystems could even be considered beyond preliminary design, having completed significant development work and having already environmentally tested portions of their designs. However, with the Critical Design Review (CDR) scheduled in August of this year and no spacecraft vendor under contract at this time, it will be very challenging to complete final designs in time.

The material presented in the LAT PDR package and subcommittee sessions was of sufficient level of detail to access the thermal design progress. The thermal design is not at PDR level due to the aforementioned repackaging of the radiators and the application of extremely conservative design assumptions. The design does not achieve acceptable temperature control of the trackers, calorimeters, and electronics with a margin expected at PDR.

The mechanical/thermal team acknowledged the thermal design shortcomings and presented a possible solution. These changes will affect mechanical configuration, weight, cost, and testing.

A relatively high fidelity finite element model for a preliminary design review was presented. Dynamic analyses with this model indicated fundamental frequencies (64.8 Hz first mode, Grid drum-head) well in excess of the minimum 50 Hz requirement. Primary load paths seemed to be well understood. Because of the mix of composite and aluminum structures for mass and stiffness considerations, flexures are incorporated in several locations to prevent large stresses or deformations due to the differing coefficients of thermal expansion. Concern was expressed over the lack of shear constraints (e.g., shear pins) at primary structural interfaces and critical alignment interfaces. Relying solely on friction to resist shear loads at bolted interfaces could present problems with qualification.

There appears to be adequate mass margin at PDR, with the current mass estimated to be 2614 kg against an allocation of 3000 kg. Normally the committee would like to see 15 to

20 percent mass margin at PDR. However, a large percentage (almost 50 percent) 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 Cesium-Iodide logs.

Due to the large LAT mass (3000 kg), 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.

Preliminary design is proceeding despite not having a spacecraft contract in place. 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.

The thermal modeling techniques and the process used to achieve the thermal predictions are adequate for PDR level. The analyses assumed constant solar array temperature around the orbit (+100 C hot and –100 C cold). This is overly conservative. Also, the maximum end of life temperature of the stack detectors appears to be too conservative.

The thermal analyses of the ACD, structural gradients and electronic component are adequate for a PDR level of maturity. The thermal radiator is not using optimum thermal control surface coatings.

There are no thermal vacuum or thermal cycling tests on the grid integrated with Constant Conductance Heat Pipes (CCHP's) to prove workmanship.

The thermal control design allows the Variable Conductance Heat Pipes (VCHP's) to freeze. No thaw scenario was presented. The electronics for the thermal control system (WBS 4.1.8.5) should be moved to the electrical systems WBS. This is a better fit for the Electrical Systems Team Manager.

A very impressive amount of detail was provided for both cost and schedule and no omissions were found. A total cost for Mechanical Systems was presented at $8.3 million, with 38 percent contingency ($2.7 million), for a total cost plus contingency of $11 million. This level of funding appears adequate to cover the cost for the redesign necessary to meet thermal requirements and radiator repackaging, but would most likely leave insufficient reserve for the remaining mechanical system.

It is imperative that another full-time mechanical engineer and designer (planned in the budget) be hired as soon as possible onto the team at SLAC. Although the Committee was very impressed with the LAT mechanical systems leadership, the existing team is clearly overburdened.

It is unlikely that the mechanical/thermal systems will be ready for the LAT CDR in August 2002 given the relocation of the radiators driven by the range of potential spacecraft interfaces. It is also necessary for a thermal/mechanical delta-PDR to be held in the near future to present a thermal control system that satisfies both the thermal and mechanical design requirements.

The grid delivery is the critical path item for the mechanical systems. Currently, there is ten weeks of float in jeopardy because the final design of the grid is dependant upon spacecraft vendor selection, and the finalizing of spacecraft-to-grid interfaces. It is recommended that a planning Procurement Request (PR) be initiated to get the grid structure fabricator on-board before the final design is complete, to minimize schedule delays.

Also, there is much work to be done on finalizing thermal/mechanical interface control documents. Delays in getting these released will impact CDR readiness and the critical path grid structure delivery.

2.5.2 Comments

The planned thermal and mechanical verification is a very impressive. However, some comments are provided below with respect to the LAT strength qualification and sine testing plans.

Strength qualification of the LAT instrument is fragmented. There is no instrument level strength test planned. A comprehensive document defining the strength qualification plans will be requested. This will ensure that all interfaces and subsystems will be adequately strength qualified.

It is well known that the Delta launch vehicle imparts a significant sine input to its payload. It was not clear if the LAT instrument and/or its subsystems were to be subjected to sine sweep testing, and several charts presented provided contradictory information about this—some subsystems were performing sine sweep tests, while others were not. A consistent test philosophy should be adopted that will adequately qualify the LAT instrument/subsystems for the predicted sine environment.

A concern exists over the amount of disassembly of the instrument that would be required if a Tracker tower had to be replaced. Nearly all of the major structural interfaces would have to be broken to remove a tower. The impacts of this potential replacement should be well understood by the project. All efforts should be made to ensure the integrity and redundancy of the Tracker towers prior to instrument integration.

It is felt that the proposed changes to the thermal deign presented in the subcommittee session are extremely complex and a simpler solution should be found. The final design should be testable at the LAT thermal balance level.

Before proceeding with analyses of possible changes to the mechanical/thermal design to meet requirements within margins appropriate for PDR, the LAT project must address several of the requirements and boundaries being used in the thermal analysis. These issues are presented in the recommendations.

2.5.3 Recommendations

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

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

3. Provide an initial, top-level estimate of the cost and 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:

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

5. Investigate using thermal coatings with higher emissivity (while maintaining a low absorptivity) for the radiator.

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

7. Determine configuration of survival heaters, i.e., spacecraft control or thermostats.

8. Ensure that the Rapid Spacecraft Development Office contractor is aware of the long time constant LAT instrument that 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 Constant and Variable Conductance Heat Pipes) due to Lockheed Martin facility relocation to Mississippi.

11. Internal mechanical/thermal Interface Control Documents 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 the year slip apparently mandated by the funding profile). This is a programmatic risk that should be avoided if possible.

13. The Mechanical Subsystem is not ready to be baselined at this time. Contingencies must be reassessed after impacts of thermal design changes and radiator repackaging are understood.

2.6 Systems Engineering (WBS 4.1.2)

2.6.1 Findings

According to WBS 4.1.2, GLAST/LAT Systems Engineering includes the following activities: Requirements Management and Design Integration; Requirements Development, Validation, and Verification; Design Integration; Systems Analysis; Qualification and Testing; Parts Qualification; Parts Tracking and Reporting; Risk and Reliability Analysis; Failure Analysis; Configuration Management and Document/Data Library; and Systems Engineering Management and Planning.

Not all of these activities were addressed in the GLAST/LAT PDR Systems Engineering presentation. Some of them were addressed in subsystem presentations (e.g., Parts, Reliability Analysis, etc.), but it was not clear what role Systems Engineering is taking in integrating and monitoring subsystem activities to ensure system quality and to verify that processes are applied uniformly across subsystems and that all subsystem elements are compatible.

The Instrument Systems Engineer manages the GLAST/LAT Systems Engineering effort and is directly responsible for all the LAT Systems Engineering activities. The relationships between the Instrument Systems Engineer and the Instrument Chief Electronics Engineer and Instrument Mechanical Systems Engineer were not well defined. The relationship was clarified in subcommittee discussions with the Instrument Systems Engineer. Both the Instrument Chief Electronics Engineer and the Instrument Mechanical Systems Engineer report regularly on systems issues to the Instrument Systems Engineer. The relationship of GLAST/LAT Systems Engineering to GLAST Mission Systems Engineering was not described in the presentations but was also clarified in splinter sessions. The Systems Engineers engage in constant dialog. The role of Systems Engineering in monitoring system-wide technical activities like Software Engineering and Reliability Analyses was also unclear. It was not clear that all the functions of the Systems Engineer, defined the Project Management Plan (Section 3.2), were being performed. However, it became obvious in the subcommittee sessions that the LAT Instrument Systems Engineer receives a wide variety of outstanding support from many areas of the project including the Instrument Scientist.

LAT Systems Engineering roles, responsibilities, and activities are described in the LAT Systems Engineering Management Plan (SEMP; LAT-MD-00066-01, January 23, 2001 Draft). The plan is reasonable and sufficiently detailed for a draft. Many of the activities described in the plan are just beginning. The GLAST Mission Systems Engineer should review the plan before it is signed.

A reasonable allocation of system to subsystem requirements has been performed. Systems Engineering reviews do not perform this allocation.

Systems Engineering will develop a full Requirements Verification Traceability Matrix (RVTM). Currently, the RVTM traces only Level 2, 3, and 4 requirements and linkages with test plans and procedures have not yet been made. It was not clear to what extent LAT Systems Engineering is performing Requirements Validation (i.e., determining whether the flowdown of requirements is consistent with system-level performance requirements and the maintenance of adequate margins) although the SEMP clearly says this will be performed.

The Science Systems Analysis support for technical trade studies and key technical budgets is excellent.

Risk Analysis has been performed rather informally to date but the LAT Systems Engineer is developing a more systematic and formal approach to doing this. A LAT Continuous Risk Management System with a periodically updated risk list does not yet exist but is planned. Risks are being tracked at the GLAST Mission Level.

Failure Mode and Effects Analyses, Fault Tree Analyses, and Worst Case Circuit Analyses have been and are being performed by LAT Systems Engineering, Reliability Engineering, and Subsystem Engineers. The Goddard Space Flight Center GLAST project is performing an integrated GLAST Probabilistic Risk Assessment using information provided by LAT engineers and other sources.

The Systems Engineering Peer Review Reports were not available in the PDR Data Package. All of the Action Items from the Systems Engineering Peer Reviews are still open. Instrument Systems Engineering was not addressed in the February 2001 DOE/NASA review Committee Report, so there is no baseline for assessing progress since that review.

LAT engineers provided a very thorough approach to ASIC development. Very extensive simulations have been performed. It is important that Systems Engineering monitor this process as a potentially high-risk area.

The LAT Mission Assurance Requirements document does not require a Formal Qualification (Acceptance) Test of the LAT Flight Software. Systems and Software Engineering need to ensure that the Flight Software is fully qualified (all requirements and functionality are verified) before LAT Integration and Testing.

The LAT Non-Conformance Reporting and Corrective Action (NRCA) Process is defined in the Performance Assurance Implementation Plan and several procedures. Formal NRCA starts with fabrication of flight hardware.

Detailed interface diagrams and block diagrams were not presented in the review but are part of the individual subsystem reports.

While harness responsibility is listed in the Instrument Systems Engineers job description, review and approval of harnesses has been delegated to the Instrument Chief Electronics Engineer. A harness mock-up is being constructed.

Science Data Quality Assurance is accomplished via the Science Analysis Software and Instrument Operations Center Calibration Plans and "community practice." There are some problems with the instrument that can only be detected and diagnosed by science data processing.

Not all items in the Systems Engineering Work Breakdown Structure are broken out in the Systems Engineering Cost and Commitment Profile (e.g., Requirements Development, Validation, and Verification, Design Integration, Parts Qualification, Parts Tracking and Reporting, Risk Analysis, etc.). Most of these activities have been costed under other WBS items; however, this does not fully address the role of Systems Engineering in these activities. It was not clear whether the lack of distinct funding in these areas under the Systems Engineering Cost and Commitment Profile implies no or minimal Systems Engineering involvement in these areas. It is not clear to what extent Systems Engineering is performing the integrating and monitoring of these activities. The LAT project should provide a description of how Systems Engineering is using support from other technical areas to monitor these activities.

In general, the Systems Engineering cost profile seems low from the middle of FY 2003 until the end of Mission Life. In many cases, the labor profile is less than a single FTE. However, most of the Systems Engineering labor is funded under Requirements Management and Design Integration whether that is what is being done or not. Areas that seem particularly low for the actual level of effort required include Systems Analysis, which does not appear to have enough funding for even a single work year; Qualification and Tracking, which seems grossly underfunded; and Configuration Management.

Underfunding in these areas may be very deceptive since many Systems Engineering activities are conducted and funded under other WBS areas. If this funding is eliminated under the other WBS items, then it is not clear the Systems Engineering work would get done.

The percentage of contingency funding of 12 percent seems appropriate if the baseline Systems Engineering Funding is correct. There were no Systems Engineering schedules to evaluate.

2.6.2 Comments

The relationship between GLAST Mission Systems Engineering and GLAST/LAT Systems Engineering needs to be better defined, strengthened, and improved. Systems Engineering efforts need to be integrated across the GLAST Project. Currently, regularly-schedule meetings are conducted between GLAST Mission and LAT Systems Engineers. Both Systems Engineering Working Group and Interface Control Working Group Meetings should be continued.

The lack of a clearly defined Spacecraft and Mission Operations Center greatly hampers the LAT Systems Engineering effort and represents potential design liens against the instrument.

The GLAST Minimum Science Mission Requirements and Descope Plan need to be clearly defined. The Science Requirements Document currently defines Nominal Science Requirements, Goals, and Minima, but this document needs to be finalized. The Descope Plan is described in the proposal and mainly involves omitting towers, but it has very little latitude for reduction or removal of hardware components or capabilities. Some spares are available. The project should develop a time-phased Descope Plan that is consistent with an approved minimum science mission configuration that would be acceptable at launch.

LAT Systems Engineering needs to ensure that all the constraints on the RSDO spacecraft resulting from the more mature LAT instrument are being identified. The RSDO spacecraft has not yet been selected, but the GLAST Project Office understands RSDO issues and is working on GLAST customization of the request for proposals. The GLAST project has already conducted two spacecraft accommodation studies. An Interface Requirements Document has been drafted and needs to be finalized before the spacecraft procurement decision is made. The basic RSDO contract and specification should be modified to ensure that GLAST Mission and LAT requirements are met with adequate margins.

Systems Engineering needs to perform more comprehensive monitoring of technical budgets and margins (e.g., alignments, processor resources, memory resources, downlink, thermal, etc.). Currently, they are only maintaining mass and power budgets.

LAT Systems Engineering needs to monitor and track the status of technical drawings.

Currently, this is not being done, but Systems Engineering plans to start this process. The status and schedule for LAT technical drawings should presented at Critical Design Review.

LAT instrument personnel need to clearly define repeatable aliveness, limited performance, and comprehensive performance tests. The Goddard Space Flight Center GLAST project should provide further clarification and definition of these tests.

The choice of Test Executive and Test and Operations Language has been very problematic on other projects where the Instruments and Spacecraft were using different systems in their respective I&T efforts, and Instrument Procedures needed to be converted for use in observatory-level testing. GLAST believes they have solved this through a judicious selection at the instrument-level and accommodations studies by the potential spacecraft contractors. LAT engineers rather than spacecraft engineers will perform any procedure translations required, although they believe no translations will be required. The GLAST project needs to ensure that appropriate accommodation requirements are incorporated in the RSDO contract and that any translation activities are properly scheduled and budgeted.

The GLAST/LAT Systems Engineering Team needs to make a systematic analysis of the sparing philosophy. Currently several subsystems have an approach to providing spares, but this area has not been looked at systematically across the instrument (and GLAST project).

The change control trigger did not address control of changes that would reduce subsystem margins (i.e., where an increase in budget or other technical resource was not requested).

2.6.3 Recommendations

1. 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.

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

3. 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.

4. Provide a list of key LAT technical budgets that are monitored regularly (e.g., mass, power, thermal, processing resources, alignments, etc) or will be.

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

6. 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.

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

8. Provide the Request for Action (Action Items) list from the Subsystem and System Engineering Peer Reviews and their closures.

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

10. 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 Integration and Testing to Observatory Operations. Provide the appropriate section of the Configuration Management Plan if it addresses this.

11. 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.

12. 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.

13. 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.

14. 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 (FMEA) have had on the design (e.g., list any design changes that have resulted from the FMEA's)?

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

16. 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 and accepted software continues to function properly after changes have been made or problems resolved.

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

18. 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.

19. Describe the software maintenance approach from delivery of the Instrument to observatory-level integration and testing through launch plus five years.

20. Conduct a peer review of the cabling and harnessing.

21. Re-examine the operational and survival temperature limits prior to the start of component quality testing. Consider whether it is feasible to establish survival limits that are 15 degrees beyond normal operational ranges, so that operational performance 10 degrees C beyond

the normal operational range can be verified without significant risk of exceeding survival limits.

22. Electro-magnetic Interference/Electro-magnetic Compatibility acceptance testing needs to be performed on all flight boxes except for the qualification unit (which receives quality level EMI/EMC testing). This needs to be included in the verification plans.

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

2.7 Integration and Testing (WBS 4.1.9)

2.7.1 Findings

The Integrating and Testing (I&T) management was changed to its current configuration in August 2001. The I&T subsystem is responsible for final assembly and testing of the LAT. This includes developing I&T plans and procedures, the mechanical ground support equipment and some elements of the electronics ground support equipment (EGSE). The I&T subsystem will functionally test the LAT using beam tests, an airborne functional test and extensive functional testing utilizing cosmic ray muons at SLAC. This subsystem is also responsible for environmental testing of the LAT instrument and will support observatory level integration and environmental test.

As presented the cost estimate for I&T activities is $7.3 million. There is a 40 percent contingency for a total of $10.15 million. There is $3 million of off-project staff support, as well as off-project support for part of the development of the integration facility. Resources from the subsystems are assumed to be present during the final assembly and test of the LAT.

The I&T subsystem manager, particle test manager, integration facility and test manager and science verification manager are contributed labor. Performance assurance, instrument operation coordination and EGSE material and supplies are supported in other Level 3 Work Breakdown Structure items but have a functional role in I&T. The "online" (or experiment control and data analysis) software lead is included full-time in this WBS but spends time elsewhere.

The I&T engineer, an engineer responsible for mechanical ground support equipment (MGSE) and associated designer, the facility lead technician, an environmental test manager (who resides at the Naval Research Laboratory), the science verification programmer, and two dedicated integration and test technicians are paid on this WBS.

I&T support during final assembly and LAT scale testing is assumed from the other subsystems. The organization chart is populated and personnel, except the MGSE mechanical engineer, are named.

The I&T group manages development of EGSE systems, although development of the hardware (and firmware) components of the EGSE are the responsibility of the Electronics Group. The following systems will be developed and/or tested as part of I&T scope:

EGSE Engineering Model 1 (EM1) 15 units	June 2002
Single Tower Unit (EM or EM 1)	August 2002
EGSE Engineering Model 2 (EM2)	September 2002
Calibration Unit (CU, comprised of CAL Units A&B and Flight Units 1 & 2))	August 2003. Beam test in January/February 2004
Flight LAT assembly	Start-January 2004, complete May 2004
Flight LAT functional testing	June - October 2004
Flight LAT environmental verification	Begins in November 2004

The SLAC MGSE setup is underway. Development of the mechanical equipment needs to start this year, but has been limited by the need to hire and identify a MGSE mechanical engineer. The EGSE hardware development and production are included in the Electronics group.

Instrument I&T (including final assembly, LAT functional and environmental testing) is scheduled for January-November 2004. Assembly is planned to be complete in June 2004. Environmental test is scheduled for August-November 2004. Environmental test is baselined to be performed at the Naval Research Laboratory with at least three viable alternative facilities that might be more attractive depending on the S/C vendor selection.

The I&T manager is most worried by delivery of Calorimeter units A and B and the subsequent impact on the schedule; in particular there is a large impact if the window for the Jan 2004 beam test at SLAC is missed.

The I&T Building is essentially complete. The 100,000-class cleanroom, LAT assembly area, subsystem integration area and the van de Graff used for energy calibration and tests exist. The I&T manager expects the subsystems to use the I&T Building for SLAC incoming inspections of completed sub-system modules.

The verification test requirements are to be generated by Systems Engineering using the Dynamic Object Oriented Requirements System. Outline of tests and test matrices exist and a large fraction of these matrices are populated.

The I&T manager and lead engineer are aware of the need for formal sign offs and control document requirements.

The proposed airplane flight to the Naval Research Laboratory (and back) will be used for instrument level systems level functional test. This test provides a count rate environment close to that on-orbit and is viewed by the I&T team as an important test of system level functionality.

The I&T manager has developed a new WBS structure, and is developing a revised cost estimate and distribution within this structure to reflect the new organizational structure and to account for the actual tasks necessary to accomplish I&T and science verification. The new structure was discussed at the review with the committee. A complete, bottoms-up, cost for the new WBS was not presented. The new cost allocations and WBS are in the process of being reviewed and implemented by LAT management.

Lack of a bottoms-up cost estimate makes it hard to review for adequate time and staff for tests; the I&T manager believes that he has sufficient resources to do the job.

Detailed milestone development is planned and will measure progress for this subsystem.

A weekly systems meeting is the forum for I&T to influence subsystem I&T activities; otherwise the subsystems operate their I&T activities independent of the I&T group. The systems engineering group is responsible for tracking what tests have been conducted on which item. At least one component, the Cesium Iodide crystals, can be impacted by excessive thermal cycling.

2.7.2 Comments

The Committee feels that the organization put in place since the August 2001 management change appears well-suited to the job. The budget and contingency appear to be adequate although the lack of a bottoms-up cost estimate and the newly reworked WBS make it difficult to assess the cost at this point.

The I&T task duration can be directly affected by a slip in any subsystem schedule.

The segregation of the electronic integration from primary I&T activities appears workable but could present management challenges later in the project as preparation for I&T competes with delivery of flight electronics.

2.7.3 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. Perform a 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. Revision 0 assembly traveler should be written and under configuration control before Qualification Unit A arrives.

2.8 Performance and Safety Assurance (WBS 4.1.A)

2.8.1 Findings

The Performance and Safety Assurance scope includes the SLAC/LAT Performance Assurance Manager; development of a Instrument Operations Center (ISO) 9000 compatible non-conformance reporting system; conducting ISO 9000 quality assurance audits by outside contractors during the course of the project; various quality assurance support contracts, such as contractor expertise used in the design and construction of the I&T Building clean room area; a training budget, most notably targeted for training of personnel to NASA work standards; LAT Safety Engineering; and support of the Electrical, Electronic, and Electromechanical parts program at the Naval Research Laboratory during FY 2002-2004.

The WBS as presented is $2.21 million, with an additional $0.3 million (16 percent) of contingency. Of the total, $1.8 million covers personnel, including the WBS manager at level of effort for the duration of the project and 4.4 man-years total at the Naval Research Laboratory. The LAT Safety Engineer, estimated by the committee at 1.2 man-years over the course of 2002-2004 (approximately $250 K), is contributed labor by SLAC.

Goddard surveyed the GLAST Performance Assurance System in April 2001, resulting in no findings, seven observations, and two recommendations. A follow up survey is planned for spring of 2002, before the Critical Design Review.

SLAC/LAT has implemented a system using distributed responsibility for execution of the quality assurance plan throughout the project. The WBS manager works closely with the other subsystem managers to set up and execute Quality and Performance Assurance procedures throughout the project. The subsystem managers are responsible for the execution of the plans pertinent to their respective systems.

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

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

2.8.2 Comments

For proper execution of the safety, quality, and performance plans, the Performance and Safety Assurance 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.

2.8.3 Recommendation

1. Complete the Goddard Performance Assurance Audit this spring, before the Critical Design

Review.

2.9 Ground Systems and Analysis

2.9.1 Instrument Operations Center (WBS 4.1.B)

2.9.1.1 Findings

Several significant aspects of the Instrument Operations Center (IOC) subproject are:

1. It is not a technically challenging project, yet it is vital to the successful operation of the instrument.
2. It has interfaces to almost every other Level 3 LAT WBS item.
3. Its costs are dominated by labor (80.6 percent), most of which is effort on software development, testing and integration.
4. The major work on the project starts in the second quarter of FY 2004 and continues at a constant effort and funding until the start of operations.

Because items 2-4 it is important that the interfaces with the rest of the LAT project be clearly defined before the end of FY 2003. The most important of these interfaces are those with the Mission Operations Center (MOC) and the Data Processing Facility (DPF). Although it would be natural to first define the interface with the MOC, the team who will plan and develop that center have yet to be chosen.

In the past year the IOC team participated in Integration and Testing (I&T) for and the operation of the balloon flight-test, which gave them important experience and contacts with many of the other subprojects. However no formal planning for interfaces to these groups for space flight operations has begun. While the IOC subproject manager is ready to define all of the IOC interfaces, his counterparts on other subprojects have not yet been able to schedule their end of this work.

There is a second consequence of the MOC team not yet being in place. The I&T subsystem, with IOC support, has done a trade study and chosen a spacecraft control language and, if this language proves to be different from that chosen by the MOC, doing the required translations may result in additional costs.

The manpower assigned to the project is sufficient to complete the project on time. Moreover there is a large scope contingency: while the program would benefit from having highly polished, user-friendly software at startup, some polishing could be delayed if unforeseen problems consume manpower.

In summary, the Committee believes that this is not a technically challenging project and that, if well managed, it will have neither significant schedule risk nor significant cost risk. Judging by the WBS documents and conversations with the project manager, the project manger understands the problems and potential pitfalls. The management risk also appears small.

2.9.1.2 Comments

The IOC project is entirely funded by NASA and no off-project effort is planned.

One risk for a project dominated by software development labor is schedule risk due to inattention to the critical path. It can be tempting to play with the coolest new tools to add bells and whistles instead of keeping focus on the less glamorous jobs that must be done. Another risk is mission creep. The IOC subproject management recognizes these dangers and has sought to mitigate them by planning early milestones to produce a working end-to-end system, which can evolve into the final system. The Committee looks forward to seeing additional details of this plan in the Conceptual Design Report. The project management should consider planning for remote monitoring and, perhaps, remote control. This would allow operators to be located, for example, at collaborating institutions in Europe and Japan thereby providing coverage during lights out at the IOC.

2.9.1.3 Recommendations

1. Recommends baseline approval for technical, cost, schedule, and management.

2. Put in place a minimal MOC team as soon as possible so that the IOC team can plan their interfaces together. It is also important that the other LAT subprojects teams begin to plan their interfaces with the IOC.

2.9.2 Reconstruction and Analysis Software (WBS 4.1.D)

2.9.2.1 Findings

Due to the small data rate, detector simplicity, and expected low occupancy, the ground-based software and computing tasks are modest compared to those in large high-energy physics experiments currently running. Certainly the basic computing problem will be easily managed by the time the experiment is operational. Nevertheless, there will be a large user community to support and high quality software is required.

The plan to base the Data Production Facility (DPF) at SLAC simplifies the management of the project, saves money, and assures that facility will perform well. The project has a good plan to fully automate Level 1 production and to have analysis and testing results ready soon after data are transmitted from the spacecraft.

Simulation and reconstruction software has been under development for several years now. It has been demonstrated that the current software already meets the requirements of the experiment. Very significant technical progress has been achieved in the last year. Integration into a high quality software framework has been achieved. Migration from a Gismo based simulation to one based on GEANT4 has also been technically achieved, however, testing of GEANT4 will continue for some time. The LAT group has made significant steps in planning for the testing and calibration of the detectors and calibration software is under development. The formation of the LAT Integration and Testing (I&T) group has been beneficial to the organization of calibration effort.

A great deal of progress had been made in the planning and cost estimate for the analysis software. The largest component of the manpower is off-project and this has now been included in the planning. Given that the basic software is already in good shape, we are convinced that the project has enough resources to complete the vital parts of the software and production facility provided the level of off-project manpower is not decreased. The program will benefit from having highly polished, user-friendly software at startup, but some polishing could be delayed if unforeseen problems consume manpower. There is also the opportunity to improve software performance beyond the required levels, improving resolution and background rejection and increasing the effective area of the instrument. The Committee believes that, if necessary, the scope of the software project can be adjusted to assure that it remains within budget by delaying desirable improvements that are not vital to the baseline performance of the instrument. The overall contingency of 37 percent seems high given this scope flexibility.

At this time, the project is already at the planned peak level for off-project manpower, if the area of Science Analysis Tools is excluded. Since the off-project software effort is larger than the planned on-project effort, the outlook for having sufficient manpower to complete the project as desired is very good. Nevertheless, the project supports key and indispensable elements of the software effort. In particular, user support has been descoped from the project for FY 2002 and should not be further delayed.

Planning for the Science Analysis Tools is somewhat delayed compared to the schedule. As with most software projects, planning more than a few years into the future cannot be too detailed. The group will have to contend with changes in some of the outside software products they are using. The Science Analysis Tools development is planned to take place mainly later in the project and will be done in conjunction with the staff of the NASA Science Support Center based at Goddard. Its clear that not all the off-project manpower needed for this has been found. This is estimated to be three to four FTEs given the Science Support Center contribution.

The schedule for the next few years is well planned and can be met. Again, since the current software already meets performance goals, this task should not delay the LAT project.

The software group, although dispersed over a wide area has been working together well through the use of modern collaboration tools. International collaborators in Italy and France are playing an important role, currently contributing 5.5 man-years to the project. Growth in that number is likely but not required.

The project management is in place, very competent, and highly motivated. Morale in the group is very high. It is particularly impressive that the management has been able to recruit a large amount of off-project manpower and to get that manpower to work on the high priority tasks. The management has clearly put a lot of work into the planning over the last year. The Committee commends management for setting up a widely dispersed group that works well together using inexpensive tools.

2.9.2.2 Comments

The project currently has a single software architect who does much of the coding for the software framework. This is both a risk to the project and a possible source of delay. Similarly, although the project currently has the right number of FTEs, software engineers to help produce the core software are in short supply.

The one-year delay in the on-project user support position was a reasonable descoping of the project but further delay should be avoided.

In understanding the project, it is useful to note that all the NASA effort is on project and all the DOE effort is off. The Committee understands that there is no formal agreement for SLAC to provide computing for the Data Production Facility free of charge. Since the computing requirements are relatively small, this is likely not to be a problem.

2.9.2.3 Recommendations

1. Recommends baseline approval for technical, cost, schedule, and management.

2. The collaboration should at least maintain the current level of software effort that is not directly funded by the project.

3. The collaboration should move forward with the planning and early implementation of Science Analysis Tools. Some official planning is required soon. The three to four off-project full-time equivalents should be identified to begin implementation.

4. The collaboration should continue to recruit talented manpower for the software project. In particular, a second person competent to serve as a software architect and additional core software engineers should be identified.

5. The user support position should be filled as soon as possible in FY 2003.

3. COST, SCHEDULE AND FUNDING (WBS 4.1.1)

3.1 Cost Estimate

3.1.1 Findings

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

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

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

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 DOE/NASA reporting. Costs are generally reported down to the fifth level. The LAT PMCS is modeled after the SLAC B-factory project 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 five consultants from Applied Integration Management. The resource-loaded plan calls for a transition from the current plan to a more blended team of three full-time SLAC employees with two consultants. The team may be reduced further as the integrated planning for LAT becomes routine.

3.1.2 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 sub-orbital 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 ($1.32 million) required 65 percent contingency over its February 2001 cost estimate. The major cost drivers to the increase of the sub-orbital 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 greatly improved from the February 2001 review, however the cost estimate is not completely ready for baseline. For example, Instrument Integration and Test (WBS 4.1.9), 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 Anti-Coincidence Detector 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 might 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 3-1. 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	Sub-Orbital 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 (%) (based on Cost To Go)				**28%**

3.1.3 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 (Anti-Coincidence Detector, Integration and Testing) and supporting documentation related to the cost estimate should be available. A revised contingency analysis at the lowest WBS project based upon the latest baseline cost estimate, should also be performed, and explicitly

detailed.

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

3.2 Schedule and Funding

3.2.1 Findings

The integrated cost and schedule baseline for LAT consists of approximately 6,000 scheduled activities, summing to $94.4 million, and contains a set of milestones consistent with a launch date of March 2006.

In February 2001, the integrated LAT cost and schedule baseline estimate was made up of approximately 4,000 tasks summing to $80.7 million. Now, in January 2002, the LAT baseline is comprised of approximately 6,000 tasks for the total cost estimate of $94.4 million.

The baseline schedule contains a set of milestones consistent with a launch date of March 2006. This includes a three-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 U.S. collaborating institutions.

Currently, the LAT schedule contains a significant number of milestones at the Instrument Project Office, Level 3, that are monitored by LAT management. On average, the milestones are approximately one-week apart in time. However, at the GLAST Project Office, 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.

3.2.2 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 Total Project Cost 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 percent). Additionally, LAT management should look to decouple the subsystems schedules, and the overall LAT schedule, as much as possible, to allow each to go as fast as possible, and minimize the "marching army" effect.

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 $5.8 million 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 FY 2002 and FY 2003 nearly matches budget authority, which limits available contingency to solve problems. Details of the late FY 2002 tasks are not candidates for deferring until FY 2003 without risk to the schedule.

The shifting of deliverables from foreign to U.S. 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 U.S. responsibility.

The Level 3 milestone list is comprehensive and monitoring by LAT management is commendable. At Level 2, the milestones should be spaced at intervals of three to four months. 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 3-2. LAT DOE/NASA Funding Estimate (Escalated K$)

	FY00	FY01	FY02	FY03	FY04	FY05	FY06	Total
DOE	$3,000	$5,700	$8,200	$9,000	$5,900	$3,200	$0	$35,000
NASA	$3,863	$3,847	$13,170	$20,917	$25,803	$9,317	$2,869	$79,786
JAPAN	$0	$0	$0	$0	$1,000	$0	$0	$1000
Total	$6,863	$9,547	$21,370	$29,917	$32,703	$12,517	$2869	$115,786

3.3 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 Project Management Control System baseline. These schedules should be monitored closely, particularly in FY 2002 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.

4. PROJECT MANAGEMENT (WBS 4.1.1)

4.1 Findings

The Committee would like to commend the LAT Instrument Project Office and LAT Team 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 and 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 (PMP), 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 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 percent in August 2001 to 28 percent currently.

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

4.2 Comments

In particular the lack of a NASA/ Centre National d-Etudes Spatiales International 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 that Naval Research Laboratory.

If the NASA/ Centre National d-Etudes Spatiales 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 Critical Decision 1, Approve Preliminary Baseline Range, by the end of January 2002.

There is an area of concern regarding technical direction and communications on the Anti-Coincidence Detector subsystem, given the proximity of the Goddard Anti-Coincidence Detector 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 percent 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. The Committee thinks 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.

4.3 Recommendations

1. Sign the DOE/NASA Implementing Arrangement.

2. Expedite NASA/ Centre National d-Etudes Spatiales and NASA/Agenzia Spaziale Italiana International Agreements.

3. Consider DOE/NASA supplement to LAT project funding to offset cost increases resulting from lack of DOE/NASA Implementing Arrangement and supporting International Agreements.

4. Maintain awareness that the Anti-Coincidence Detector 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, 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.

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