Quarterly Report

For the Period July 1 – 30 September 2000

Gamma Ray Large Area Space Telescope (GLAST) Project

GLAST Large Area Telescope (LAT)
Flight Investigation

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GLAST LAT Instrument Project Office
Stanford Linear Accelerator Center (SLAC)
Stanford University

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Participating Institutions:

California State University at Sonoma (SSU)

University of California at Santa Cruz - Santa Cruz Institute of Particle Physics (UCSC/SCIPP)

Centre National de la Recherche Scientifique / Institut National de Physique Nucléaire et de Physique des Particules (CNRS/IN2P3)

Commissariat à l'Energie Atomique / Direction des Sciences de la Matière/ Département d'Astrophysique, de physique des Particules, de physique Nucléaire et de l'Instrumentation Associée (CEA/DSM/DAPNIA)

Goddard Space Flight Center – Laboratory for High Energy Astrophysics (NASA/GSFC/LHEA)

Hiroshima University

Institute for Space and Astronautical Science (ISAS)

Istituto di Fisica Cosmica

Istituto Nazionale di Fisica Nucleare (INFN)

Naval Research Laboratory (NRL)

RIKEN

Royal Institute of Technology (KTH)

Stanford University – Hanson Experimental Physics Laboratory (SU-HEPL)

Stanford University - Stanford Linear Accelerator Center (SU-SLAC)

Stockholm University

Texas A&M University - Kingsville

Tokyo Institute of Technology

University of Washington

Table of Contents

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1 Introduction

The GLAST LAT Flight Investigation[1] was proposed by a collaboration of scientists and institutions led by Prof. Peter Michelson of Stanford University/SLAC. NASA selected it for the GLAST mission in February 2000. The LAT Instrument Project Office (IPO) is located at and supported by the Stanford Linear Accelerator Center (SLAC), a national laboratory supported by the U.S. Department of Energy. DOE, NASA and other domestic and foreign funding and resources are being applied to optimize the success of the LAT effort. The LAT instrument is planned to fly aboard the GLAST observatory (Fall 2005 launch). The GLAST mission is managed by NASA's Goddard Space Flight Center (GSFC).

Currently, the project team is carrying out the Formulation Phase, leading to a LAT Preliminary Design Review scheduled for August 2001.

Highlights of the reporting period:

- The LAT Project Controls Manager joined the Instrument Project Office.
- The LAT Tracker Engineer joined the project at SLAC.
- A trade study was initiated to review the distribution and thickness of converter material in the tracker and recommend a final design configuration.
- The System Requirements Review for both the LAT and the GLAST mission was conducted at GSFC on September 27-28.

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[1] *GLAST Large Area Telescope Flight Investigation: An Astro-Particle Physics Partnership Exploring the High-Energy Universe*, November 1999, Stanford University.

2 Recent Progress, Status, Work Planned Next Quarter

2.1 System Engineering

During this quarter, emphasis has been placed on compiling the LAT Instrument Performance Specification, drafting the LAT Subsystem Specifications, and drafting the System Engineering management plans and procedures.

An internal LAT Science Requirements Document was reviewed and approved. This document was also superseded upon the release of the LAT Instrument Performance Specification and the LAT Instrument Operation Center Performance Specification. These documents were review, approved, and placed under configuration control. These specifications were use as the basis of the LAT input to the Systems Requirements Review conducted in September.

The LAT Subsystem Specifications have been drafted and are currently undergoing the review, approval and configuration control process. The target date for completing the review and approval process is prior to the next project review scheduled for the February 2001.

Drafts of the LAT System Engineering Management Plan, LAT Configuration Management Plan, and The LAT Risk Management Plan have been prepared. The review and acceptance of these plans by the IPO is scheduled in the next quarter.

The LAT system requirements were presented at the System Requirements Review. The LAT team is addressing the one request for action assigned to the LAT instrument team.

The Instrument Design Team was formed and meetings formalized during this quarter. Meetings are held weekly via video-conference and telephone-conference. Decision/Action/Issue lists are generated and tracked through the meeting documentation and a database.

2.1.1 Mechanical Systems and Integration and Test

2.1.1.1 Current Design Status

2.1.1.1.1 Mechanical Design Integration

Progress during this quarter has continued to focus on requirements definition and subsystem design integration. System-level mechanical performance criteria have been developed and captured in the LAT Mechanical Performance Specification flowing down from requirements in the LAT Science Requirements Document, and LAT System Specification. A key aspect of this specification is to flow down environmental verification test requirements to the subsystem level.

A draft of the LAT Mechanical Performance Specification has been distributed to Subsystem Managers and lead engineers. We expect this to be completed and put under configuration control during the next quarter.

Design integration has continued to be a focus. A finite element analysis (FEA) model of the primary LAT structures has been completed, and was used extensively this quarter to refine the Calorimeter/Grid interface, and better understand and optimize the LAT stiffness. The current design of the interface represents the first tenable mounting concept for the Calorimeter, and results in an increased LAT stiffness such that the first-mode, drum-head natural frequency is 72 Hz, a nearly 50% margin over the GLAST Interface Requirement Document (see Figure 2.1-1).

The preliminary Calorimeter interface design is now with the Calorimeter subsystem engineers for more detailed analysis; we have changed our focus to the Anticoincidence detector interface. The Proposal design included a rigid connection of the Anticoincidence detector around the top perimeter of the Grid, and "snubbers" which supported the Anticoincidence detector off the top corners of the Tracker towers. Both of these mounting concepts are under review. First, it is becoming clear that Anticoincidence detector scintillator tiles need to overlap the top of the Calorimeter active volume, meaning that the Anticoincidence detector must extend down the side of

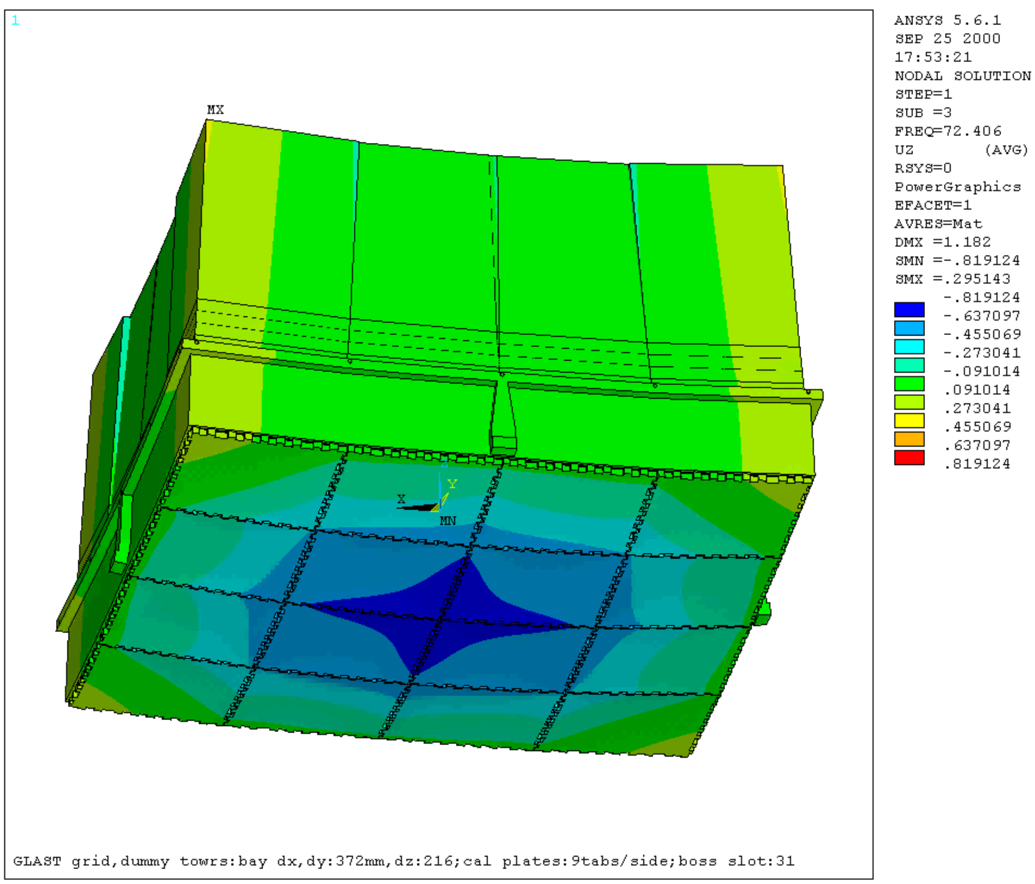

Figure 2.1-1 LAT First-Mode Natural Frequency Distorted Shape Plot

the Grid, and mount near the bottom. This puts it in direct competition for volume being used for heat pipe routing, spacecraft supports, and ground support equipment mounting. Over the past quarter we have identified the space needs in this area, and put together an Anticoincidence detector mounting concept.

A second Anticoincidence detector mechanical interface has been with the top of the Tracker towers. It is becoming clear that this mount greatly increases the complexity and risk of both subsystems. We are now steering away from this concept to a fully self-supporting Anticoincidence detector. Preliminary analysis of such a freestanding design shows that we would need to double the structural material to make this design work. Anticoincidence detector engineers are investigating this concept further, and the impact on physics, mass, and volume.

Finally, we have progressed in development of designs for the LAT support off the spacecraft and radiator mounting. The LAT support concept has been modified from an eight-point mount to a four-point support. The eight-point attachment was a concern of all spacecraft contractors during the last accommodation study. Also, as Figure 2.1-2 shows, we have developed a design concept for the radiator mount on the bottom of the Grid. This will be used to explore the interaction between the radiator mounts on the spacecraft and Grid, and the affect of relative motions between the spacecraft and LAT on the radiator structure.

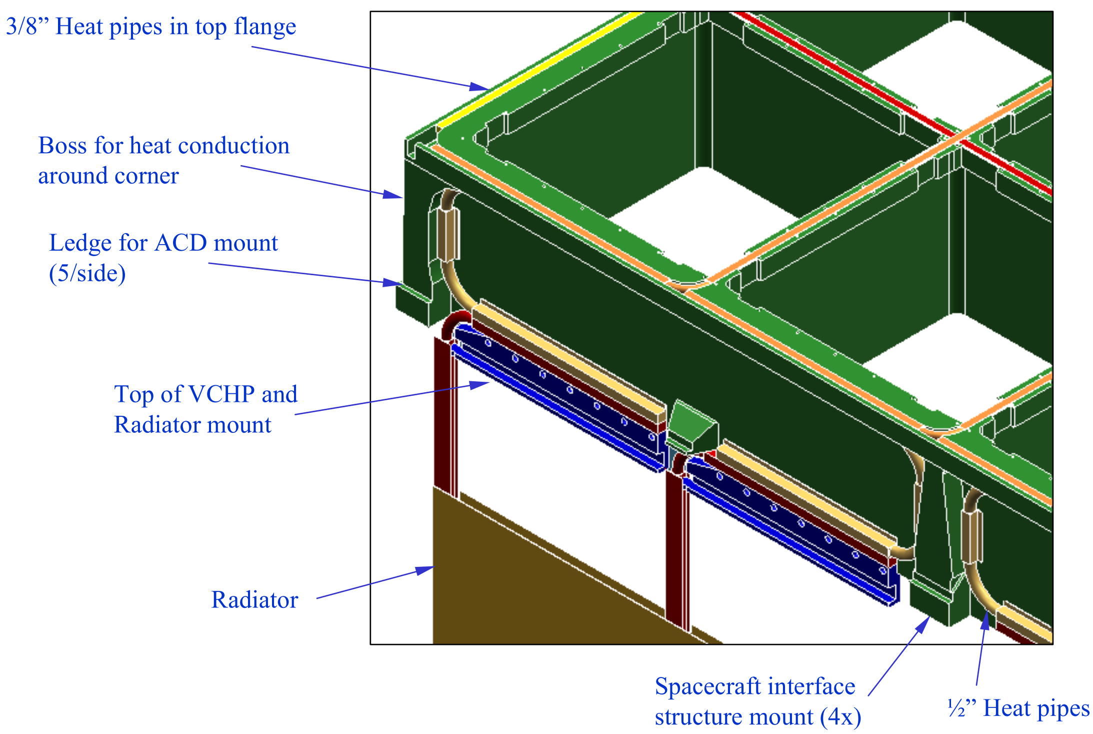

Figure 2.1-2 Grid corner detail, showing radiator and heat pipes

2.1.1.1.2 Thermal Engineering

An updated thermal radiation model of the LAT is nearly complete. This is a TSS finite-difference model, which will model the dynamic behavior of the LAT under changing on-orbit thermal environments. The Lockheed-Martin Advanced Technology Center (LM-ATC) is doing the model development. This work has been slowed as we have diverted their efforts to build a bottoms-up cost baseline, and because we have been slow in bringing them onto a new contract.

Thermal heating and LAT operations scenarios are also being defined, to be used to model the dynamic thermal behavior of the LAT. Specifically, we have been investigating the impact of the planned operations scenarios of zenith pointing, rocking, and pointed-observation on the performance of the radiators. A white paper on this was distributed for comment, and is currently being updated. This will serve as the starting point for radiator requirements development in the next quarter.

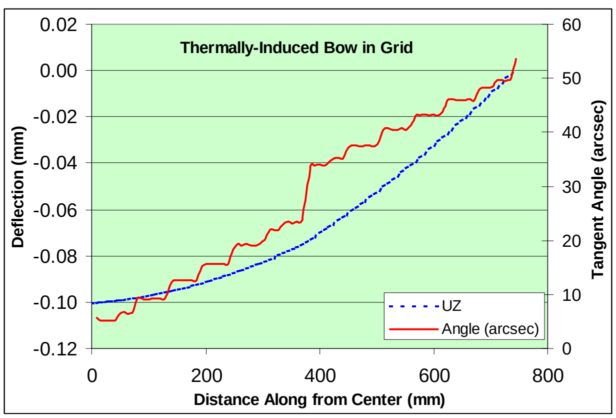

Figure 2.1-3 Thermally-induced bow in Grid, from center to edge of Grid

Finally, significant progress has been made in modeling the expected thermal distortion of the LAT due to temperature gradients in the Grid. The graph, Figure 2.1-3, shows the expected out-of-plane distortion along the centerline of the Grid. This shows that the maximum expected angular distortion of the Grid due to *steady-state* heat loads is 50 arc-seconds, which compares well with the requirement for *dynamic* changes of no more than 10 arc-seconds. The next step in this analysis is to use results of the on-orbit dynamic radiative analysis to model the dynamic distortions. We expect this to be on the order of 10% of the static, or 4-5 arc-seconds.

2.1.1.1.3 Grid Development

During the past quarter, we carried out a review of the aluminum and carbon-fiber composite (CFC) designs that we have been considering, and decided to halt development work on the CFC design and proceed with the aluminum design. This decision was based largely on two key risks of the CFC design. First, this design has lagged the aluminum design by 8-10 months, meaning that there are still significant unresolved technical issues with the CFC design. While there appear to be solutions to the problems, the added programmatic risk in waiting for the solutions to be validated was deemed to be unacceptable. Second, the technical merits of the CFC design did not appear to be compelling enough to warrant the increased risk. The two standard advantages of CFC designs: higher stiffness/mass ratio, and low coefficient of thermal expansion, did not appear to justify further development To fully work this out in a formal trade study would require at least six months, which was deemed unacceptable by the LAT IPO.

In other development work, the detailed design of the Grid structure has proceeded slowly, as most of the effort has been focused on interface development. With good progress having been made on the interfaces, we have now started the Grid work in earnest, proceeding on two fronts. First, we have produced manufacturing drawings for the Grid, to be used for manufacturability studies with in-house and sub-contractor machine shops. While we expect to machine this out of one monolithic piece of aluminum, we plan to investigate alternatives, as well.

Second, we have initiated prototyping the key interface bolted joints, to validate the Finite Element Analysis models we are using.

2.1.1.1.4 Integration and Test Planning

The new integration clean room facility at SLAC is taking shape. The 5-ton clean room crane has been installed, clean room floor treatment completed, and construction on the clean room is on-track to begin in early November. Preliminary safety and environmental reviews of the facility have taken place, and final reviews are being planned in conjunction with the start of construction of the facility.

We have developed preliminary environmental and performance test matrices, along with a more detailed verification test sequence for LAT subsystems and assemblies. This is the first step in producing a Verification Plan, but is serving well as a tool to check our preliminary assumptions, and assure we have adequate verification testing and calibration.

2.1.1.2 Key Accomplishments

- Aluminum Grid chosen as baseline. CFC development work stopped.
- LAT Finite Element Analysis model completed and in-use for refining interface designs and understanding thermal-mechanical behavior of LAT.
- Calorimeter/Grid preliminary interface details complete.
- Anticoincidence detector, Radiator interface concepts complete.
- I&T facility construction started.

2.1.1.3 Identified Risks and Mitigation Plans, Issues and Concerns

Risk: mass growth in Anticoincidence detector structure due to due support concept.

Mitigation Plan: work with Anticoincidence detector group in developing structure.

2.1.1.4 Work Planned Next Quarter

- Complete Mechanical Performance Specification and subsystem specification.
- Refine Anticoincidence detector, Tracker interfaces.
- Continue design, analysis of Grid, SC, and Radiator support concepts (with Project Office)
- Begin dynamic thermal analyses of LAT.
- Begin Grid prototype testing.
- Begin construction of Integration Facility clean room.

2.1.2 Electronics

2.1.2.1 Current Status and Accomplishments

The LAT electronics activities concentrated on the integration of the front-end systems including allocation of function blocks and interfaces. Tracker to tower electronics interfaces were finalized and Calorimeter to tower electronics interfaces are in progress. Other progress in electronics is reported under individual subsystem sections of this report.

2.1.2.2 Identified Risks and Mitigation Plans, Issues and Concerns

The main concern is the shortage of available manpower for the on-board software development. Management is aware of the issue and is working on a solution.

2.1.2.3 Work Planned Next quarter

The principal effort of the electronics team in the next quarter will be software effort for the balloon flight and design of the LAT electronics system. In addition, the work on the hardware for the balloon-flight will continue. Schedules and budgets for the PCMS will be created.

2.2 Tracker

2.2.1 Management

The Tracker management/engineering team was completed this quarter by the addition of Tom Borden at SLAC as lead Tracker mechanical engineer. Dave Nelson of SLAC is serving as lead electrical engineer. This team has nearly completed a detailed schedule for the remainder of the formulation-stage work and is also working on Tracker specifications and interfaces, particularly with the Grid on the mechanical side and the data acquisition system and power supplies on the electrical side.

2.2.2 Silicon Strip Detector Development and Procurement

During this quarter the detailed specifications of the silicon-strip detectors were completed and reviewed. Prototype silicon-strip detectors were tested from a second vendor (STM in Italy), and a prototype run for 40 detectors was initiated at the primary vendor (HPK in Japan). Furthermore, a prototype run at a third vendor (Micron in U.K.) is being prepared.

The availability of high-resistivity silicon for production was investigated and found to be good for our specification of 4 kΩ-cm resisitivity minimum. For the main production of flight detectors, a procurement plan was agreed upon that will phase in detector procurement by INFN groups during the next year. The Japanese groups will start earlier, and in fact, a tender went out from KEK to procure 400 detectors to the new specifications, as a preproduction run. Those detectors should be available in the spring of 2001.

2.2.3 Design and Specifications

The level-3 requirements for the Tracker were written and reviewed, and detailed requirements for the detectors and electronics exist. Documentation of the requirements on the mechanical/thermal side is in progress, as is documentation of the tracker interfaces.

A committee, “GLAST Team to Optimize Converter Configuration,” worked on optimizing the specifications for the Tracker converters and determined that the front-back asymmetry in the design should be maintained, but with somewhat thicker converters in the front (3.0% radiation length) and somewhat thinner converters in the back (18% radiation length).

2.2.4 Mechanical Structure

A major review of the engineering program for the Tracker mechanical/thermal structure was undertaken this quarter, and the design was simplified in order to bring both the engineering and fabrication costs better in line with the budget. Aluminum was seriously considered as a possible primary structural material that would be less expensive than carbon-fiber, but it was rejected for reasons of mass, radiation length, and thermal expansion. The design has settled around a machined carbon-carbon closeout that is almost twice the mass of the Hytec SBIR prototype but has more engineering margin, to reduce analysis and testing costs, and will be much less expensive to fabricate. Graphite-epoxy panels have been selected for the tray face sheets, and aluminum hex-cell has been selected for the cores. Both graphite-epoxy and carbon-carbon samples have been acquired to test for use in the Tracker walls. Materials for fabrication of prototype trays are on order.

The work plan for completion of the mechanical engineering was extensively reworked. The new plan relies much less on analysis and, instead, emphasizes early decisions on materials and a conservative design, followed by extensive testing of prototypes. This avoided a catastrophic overrun on the engineering costs and resulted in a schedule that is tight but should produce tested prototypes of the trays and walls by the time of the LAT Preliminary Design Review (PDR). Estimates of fabrication costs for the new tray design are well within the allocations in the budget of our NASA proposal.

A lot of work was done this quarter on understanding the interface between the silicon detectors and the tray mechanical structure. Analysis of the combination of carbon-fiber face sheet, converter foils, and detectors showed that in the case of the thin converters the stress in the silicon from thermal expansion or contraction of the assembly over our specified test range was far below danger levels, as determined from measurements made by breaking detector samples in 3-point bend tests. In the case of thick lead converters, however, the stress approached uncomfortably close to the safety limit. This led to a decision to use tungsten for the thick converters, with a compliant adhesive used between the detectors and the tungsten foils. The Pisa INFN group is responsible for further analysis and testing of this concept for the thick converters. SLAC has set up a thermal test system, with strain gauges, for verifying the thin-converter assembly concept, where probably either lead or tungsten could be used. Tungsten samples in both thicknesses are on order for these tests. Some preliminary tests have been completed, which indicate the coefficient of thermal expansion mismatch will not be a problem for at least the thin-converter trays, as long as the silicon is bonded securely to the tray over a large fraction of its area.

2.2.5 Tray Assembly

Responsibility for development of tray assembly procedures and tooling has been assigned to the collaborating institutes, and significant progress has been made during this quarter. The division of responsibility is as follows:

- SLAC:
    - Ladder assembly tooling and procedures, including fixtures for adhesive application to detectors, detector edge bonding, ladder storage, ladder transfer, and ladder wire bonding. An updated edge-bonding fixture has been prototyped and tested, and prototyping of an adhesive application fixture is in progress. A large number of dummy silicon wafers were acquired for this test work.

  - Tooling and procedures for encapsulation of wire bonds on ladders. An automated adhesive application machine is on order for this and other procedures.
  - Procedures and tooling for converter attachment. A study is in progress to look into incorporating the converter foils into a bias circuit made from aramid fibers.
  - Thermal testing of the thin-converter/detector assembly on carbon-fiber trays. The necessary equipment has been acquired and set up, and testing is beginning.
- INFN Pisa:
  - Tooling and procedures for alignment and assembly of ladders onto trays. Conceptual drawings of the tooling have been prepared.
  - Tooling and procedures for wire bonding between detector ladders and electronics, including encapsulation of wire bonds.
  - Design and production of the Kapton pitch adapter circuit to go between detectors and electronics (making the 90° bend). A prototype circuit was recently fabricated at CERN.
  - Analysis and thermal testing of the thick-converter/detector assembly on carbon-fiber trays, including analysis and verification of the strength needed for face sheets and core material in the thick-converter trays. FEM modeling of both mechanical strength and thermal stress is well in progress, with preliminary results available already.
- UCSC:
  - Tooling and procedures for installation of the corner radius and pitch-adapter circuit onto the printed circuit board of the front-end electronics multi-chip module.
  - Tooling and procedures for encapsulation of the multi-chip module.
  - Tooling for wire bonding and for storage of the multi-chip module.
  - Design of the mechanical interfaces between the electronics and the tray.

2.2.6 Tracker Front-end Electronics

During this quarter new specifications of the Tracker tower electronics interface were completed, and work began on redesigning the Tracker front-end electronics according to those specifications. We also began the task of redesigning all elements of the Tracker detector/electronics system to meet all relevant Institute of Printed Circuits (IPC) standards and to use only parts approved for space flight. During this quarter we researched the standards and began updating the specifications accordingly for each of the system components.

During this quarter a major effort was made in testing of the beam-test engineering model Tracker electronics to understand coupling between the digital readout and the amplifiers, which was causing problems with trigger noise. We found that the coupling could be reduced to a safe level by eliminating power transients caused by turn-on and turn-of of the clock to the front-end chips when the readout sequence begins and ends. In the new system design we are specifying a continuously running clock on the front-end multi-chip module and a continuously running clock within the front-end chip command decoder and readout register. This would result in increased system power, except that it is offset by decreases in power consumption within the redesigned amplifiers and discriminators. The drivers within the readout controller chip that drive the multi-chip module clock lines will be reduced in voltage swing, and the capacitance load in the multi-chip module will be decreased, to improve the noise performance. For the same reason, the drivers for the command and trigger busses will be changed to differential current mode (constant power) with low voltage swings.

During this quarter we also did a preliminary single event latchup test of the Tracker front-end application specific integrate circuit (ASIC), using an iron ion beam in Japan. Ions with LET as high as about 20 MeV-cm^2/mg were obtained, and no latchup was observed in a test chip containing the amplifiers and discriminators of the beam-test engineering model design implemented in the Hewlett Packard (HP) 0.5 μm process.

Completion of the ASIC design and prototyping is the critical path item in the Tracker schedule leading up to fabrication of the engineering model. Designs of both the front-end chip and the readout controller chip, originally done by UCSC for the beam-test engineering model, are being substantially modified by a collaborative UCSC/SLAC effort. Redesign of the readout controller chip, a purely digital chip, has been entirely moved to SLAC. The logic for that chip is a complete redesign, necessitated by the new set of specifications for the interface between the Tracker and the tower electronics. Other modifications are needed to make the configuration register safe from single event upsets (SEU) and to enhance the reliability of the off-chip data transmission.

The front-end chip design is being modified for a variety of reasons:

1. To use a new CMOS process. Both the HP 0.5 μm and Peregrine Silicon-on-Insulator processes are being targeted for prototypes.
2. To incorporate SEU-safe cells into the configuration register—design of a test chip with the new cells is nearly complete.
3. To insure that any possible errors in buffer pointers in the system will be detected and immediately corrected.
4. To improve the amplifiers and discriminators in terms of power consumption, noise, and threshold matching. Test chips were submitted this quarter to both the HP and Peregrine processes.
5. To limit the trigger dead time in case of a very large input signal, such as from a heavy ion.
6. To facilitate the tower electronics interface, the configuration register is being divided into 5 separate registers, each with non-destructive read capability.
7. To use low-voltage swings in the differential transmission of data from chip to chip.

8. To keep the main clock and the readout clocks running continuously, to eliminate power transients that were causing trigger noise problems in the beam-test engineering model system.

During this quarter the ASIC redesign was begun. The readout controller chip specifications were completed and implemented in a VHDL[2] model, and synthesis of the logic was tested by targeting a field programmable gate array. The Cadence design system was acquired by SLAC to begin synthesis of the logic for an ASIC, to be followed by automated place and route of standard cells. On the front-end chip side, we learned how to scale the old cells down to size for the new HP process (using the Tanner design system) we verified the functionality of a command decoder test chip made by automated place-and-route in Tanner, we redesigned the analog portion of the chip in Tanner and submitted prototypes, we nearly completed updating the digital schematic according to the new specifications, we designed an SEU-safe D flip-flop, and we began updating the layouts of various digital and I/O cells. Our goal is to complete the two chip designs for submission to the HP process by the beginning of February 2001.

2.2.7 Balloon-Flight Tracker Module

During this quarter we designed and fabricated tooling to disassemble the beam-test engineering model tower. Plans were made for repairs and modification of the tower for use in the balloon flight. The tower was then disassembled and the trays stored away in individual containers. To prepare them for the balloon flight, we will improve the bonding of the detector ladders to the trays and will repair components of the system that are known from the beam test not to be working (such as one non-functional redundant readout cable and one noisy ladder). The tower walls will be shortened, and then the trays will be stacked up without the thick-converter trays.

2.2.8 Identified Risks and Mitigation Plans, Issues and Concerns

- The extent of INFN resources for GLAST is unknown, so that planning for the Tracker fabrication cannot yet be completed. A meeting with Italian collaborators will take place at SLAC in November to prepare a plan to be presented to the Italian agencies in December.
- The Tracker mechanical engineering team needs to understand the loads that may be transferred into the Tracker from the Grid. Hytec is preparing an updated model of the tracker, to extract an interface model to be used in Grid design. The lead tracker engineer is working with the engineering teams at SLAC and Hytec to establish the specifications for the Tracker-Grid interface.

2.2.9 Work Planned Next Quarter

- Resource-load the Tracker schedule and refine the budget. Incorporate them into the GLAST project management system.

[2] Very high-speed integrated circuit (VHSIC) Hardware Description Language

- Complete the definition of the INFN role in the Tracker design and assembly work.
- Bring the redesign of the prototype ASICs nearly to completion.
- Complete testing of tower sidewall components and methods of surface coating for carbon-carbon structures.
- Begin fabrication of standard prototype trays according to the new carbon-fiber design.
- Select adhesives and complete preliminary thermal testing and analysis of the payload attachments schemes for both standard and thick-converter trays. Begin preparation of carbon-fiber tray mockups for conclusive payload attachment and thermal tests.
- Complete the new schematics for the multi-chip module printed circuit board and the flex cables. Begin and nearly complete the detailed layouts of those items.
- Begin testing of wire-bond encapsulations procedures for the detector ladders.
- Begin development of new ladder work/storage fixtures and complete development and testing of the adhesive application fixture.
- Develop new tooling for ladder transfers and probing.
- Begin prototyping of the precision ladder-placement jig and new work/storage holders for trays.
- Test detectors from the prototype runs.
- Complete the repairs and reassembly of the tracker module for the balloon flight.

  Continue installation of the clean-room facilities for Tracker assembly work at SLAC.

2.3 Calorimeter

2.3.1 Management

The project manager for the calorimeter efforts at NRL, Paolo Carosso of Swales, Inc., joined the group in late July. His immediate goal is the establishment of the baseline organization, schedule and cost for the calorimeter subsystem.

In France, the project manager for the French calorimeter effort resigned and no progress was made in the organization of the French activities for much of the quarter. Resource limitations at Saclay prevented progress on the development of the analog front end ASIC and the PIN photodiode.

In meetings with Per Carlson, the issues and test requirements for the specification of the CsI scintillation crystals were discussed. The Swedish team is developing a procurement specification for the CsI crystals to be reviewed next quarter.

In support of the GLAST balloon flight requirements review, we re-examined the schedule and costs associated with the preparation of the beam-test engineering model calorimeter for the balloon flight environment. The two key issues for the beam-test engineering model calorimeter are the temperature extremes expected during the flight and the mechanical shocks.

In support of the tracker optimization study, “GLAST Team to Optimize Converter Configuration,” we examined the low energy response of the LAT instrument and the impact of various converter configurations. We provided energy resolution measurements to the study team for the various simulations and indicated resolution impact of calorimeter readout zero suppression thresholds.

2.3.2 Cesium Iodide (CsI) Detector Module

The proposed calorimeter electronics design includes commercial off-the-shelf (COTS) analog to digital converters (ADCs). We also are considering plastic encapsulation of the ASICs required for the front end processing. We initiated discussions of the qualification and parts reliability issues with the GLAST project office at GSFC. The meeting with Peter Jones, GSFC, and the calorimeter parts expert, Nick Virmani of Swales, identified the issues that must be addressed.

2.3.3 Design and Verification

A review of Calorimeter ground software was held at SLAC on 22 September. Presentations were given by Eric Grove, outlining the whole of the Calorimeter ground processing and describing the requirements for ground data processing at a high level; Arache Djannati-Atai, summarizing the current status and plans for simulation and reconstruction; and Regis Terrier, comparing algorithms for energy reconstruction. The discussion was well received by the review committee – Toby Burnett (chair), Helmut Marsiske, Berrie Giebels, Joanne Bogart. Presentations and the review committee's comments can be found at the LAT website.

See http://www-sldnt.slac.stanford.edu/glast/Reviews/Calorimeter/

We analyzed SLAC beam test data and developed software for energy reconstruction for EM showers. We developed algorithms for profile fitting and shower leakage estimation.

2.3.3.1 Simulations

2.3.3.1.1 Converter configuration optimization study

In support of the tracker optimization study effort and in an attempt to better understand the LAT low energy response, we have installed the "simul-recon" version of GLASTSIM under Windows NT and are running simulations of incoming gammas at 100 MeV and below. To better understand the correlation of tracker hits and energy measured in the calorimeter, we decided to modify GLASTSIM to account for all energy depositions, even in passive material. These concepts will be implemented in future versions of the simulation code.

At IN2P3, a prototype iterative reconstruction method based on correlation between the lost energy and the number of hits in Tracker layers was developed. We applied this method to Monte Carlo simulated data and showed that the energy resolution below and at 100 MeV is around 25% to 30%, varying slightly with incident angle. Therefore the thickness of the back section of the tracker is not an issue as far as the energy resolution is concerned.

2.3.3.1.2 Optimization of the low energy response: photodiode size and thickness

The current photodiode design was reviewed in order to optimize its dimensions to get the best low energy response. As compared to maximum geometrical possibilities, the photodiode dimensions were previously limited due to concern about the degradation in performance of the Calorimeter by direct depositions in the photodiodes. In simulations, no dramatic effect was seen on the event-by-event reconstructed energy distribution caused by direct deposition.

2.3.3.1.3 Calorimeter software: energy reconstruction methods

Two different algorithms were implemented and compared to each other: profile fitting and an energy leakage correlation based method. It was shown that the latter gives slightly better performance for events for which the shower maximum is contained in the Calorimeter and hence a dependence on energy and incidence angle. The profile fitting remains the only effective method at high energies (over a few tens of GeV); it was shown that results depend on the definition of the errors: simple gaussian, double gaussian with a valley, or the exact covariance matrix (see September software review for details).

2.3.3.1.4 Beam test analysis

The beam-test engineering model (SLAC, 99-00) simulation code was tested and updated. Dedicated versions of the high-energy reconstruction algorithms discussed above were developed using the simulation tools. Data were analyzed in a first step to investigate the front-end electronics non-linearity and to correct and validate the calibration files. In a second step runs were compared to check data quality and to make a selection. Finally the beam-test engineering model performance at 20 GeV was evaluated using the two reconstruction methods. It was shown that the energy resolution was improved from 7% for raw data to 5% by profile fitting and to 4% by the correlation method. The results were gathered and summarized into the dedicated chapter in the beam-test engineering model paper.

The low energy performance is still under investigation. The work is in progress to include pedestal noise and other instrumental effects within the beam-test engineering model simulation code.

Results can be found in the paper and at http://cdfinfo.in2p3.fr/Experiences/GLAST.

2.3.3.1.5 Front- end electronics dynamic range: high energy limit study

Extensive simulations were used to study the high-energy range limit of the Calorimeter front-end electronics. An internal note referenced PCC-Calorimeter-001-Rev1.0 is available. The recommendation of lowering the limit from 100 GeV to 70 GeV seems a reasonable compromise.

Work is in progress to investigate possible correction methods at very high energies, over 1 TeV.

2.3.3.2 GSI Beam Test

During the month of July, we performed a beam test at GSI in Germany to test the calorimeter response to heavy ions. The beams available to us were carbon and nickel. The carbon beam was good to test the response to C-N-O ions in orbit; the nickel was a good simulation of Fe in orbit. The energies available to us were < 1 GeV per nucleon, which is less than the energies of the ion species in space, but the test was still a reasonable simulation of what to expect in space, except that the particle were not as penetrating. The experimental set up included the beam-test engineering model 99 calorimeter prototype, with its associated electronics. It also included plastic scintillators in front and behind the calorimeter. In addition there was a separate CsI array consisting of 2 layers of CsI with laboratory electronics. Figure 2.3-1 shows the beam-test engineering model 99 calorimeter

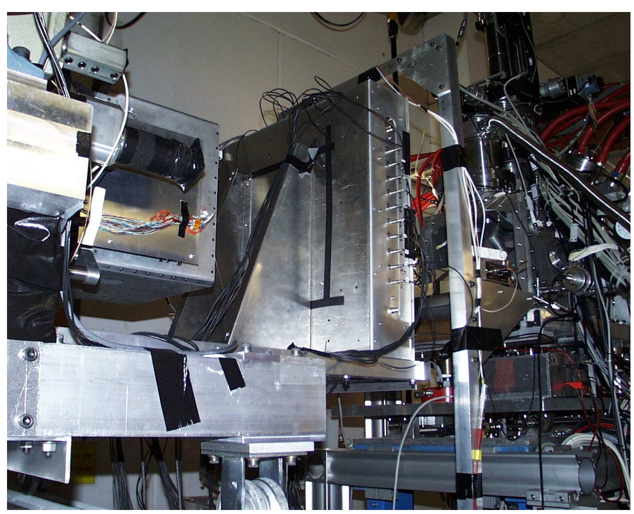

Figure 2.3-1. Prototype calorimeter on its translation and rotation drive (left). The CsI array with laboratory electronics is in the box with lemo connectors in the center of the picture. The beam line is visible on the right hand side of the picture.

(left) with the addition CsI array in a separate box (center). The beam is incident from the right in the view of Figure 2.3-1. Additional blocks of passive material were available to fragment the beam and add energy dispersion in front of the calorimeter.

The beam-test calorimeter was mounted on an assembly that allowed for two-dimensional translations perpendicular to the beam direction. There was also one degree of rotation along an axis perpendicular to the beam direction. The beam-test engineering model 99 calorimeter was read out using the tower electronics card from the beam test, whereas the other CsI array and plastic scintillation detectors were read out using a CAMAC crate in a separate data stream. The two data streams were merged off line.

The beam test ran over two weekends in July: The weekend of 8-9 July was dedicated to carbon runs, and the weekend of 15-16 July was dedicated to nickel runs. The setup was built, installed and operated by NRL, with assistance from scientists from IN2P3 and Bordeaux (France) in the second week.

A sample of the data from the beam test is shown in Figure 2.3-2. The figure shows a scatter plot of the energy measured in two successive layers of CsI for an incoming beam of 700 MeV per nucleon nickel. Approximately 5 cm of polyethylene was inserted in front of the detectors to produce nuclear fragmentation prior to the calorimeter. This amount of passive material is similar to the material above the calorimeter in the flight instrument (mostly the tracker). The nickel peak is dominant, but the peaks from the other elements are very distinct. Elements from nickel to scandium are fully contained within the first two layers, whereas elements below calcium have ranges beyond the second layer. This difference causes the change in slope seen in Figure 2.3-2.

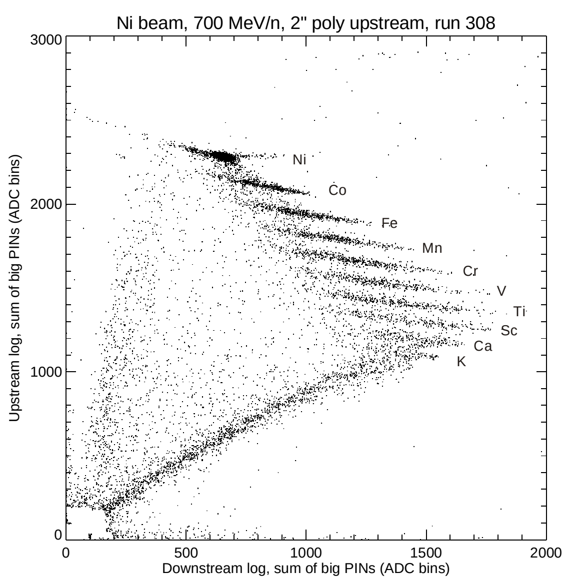

Figure 2.3-2. Scatter plot of energies in 2 CsI layers for 700 MeV per nucleon incident nickel, but with 5 cm of polyethylene inserted in front of the detectors.

To demonstrate why the distributions are as seen in Figure 2.3-2, we made calculations using nuclear interaction cross-sections and heavy ions energy loss coefficients. We simulated a nickel beam incident on silicon for a range of energies and the results are shown in Figure 2.3-3. The qualitative behavior of Figure 2.3-2 is clearly reproduced, although the energies are a little off.

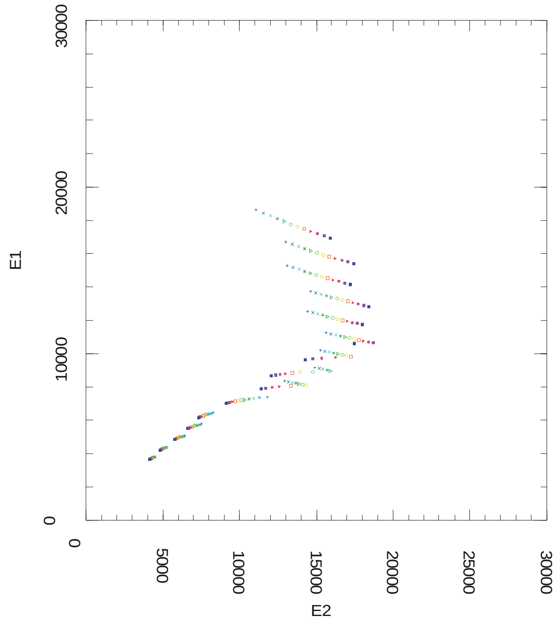

Figure 2.3-3. Calculation of nickel beam incident of a silicon target. The different traces show the different fragments produced. The different colors within a trace show different energies.

2.3.4 CsI Detector Elements

Photodiodes and optical coating

At IN2P3, the light yield was investigated for various diode sizes at the ends of the crystals, larger than the custom diode developed for NRL, and using a polished crystal received from CRISMATEC Company. The quest for an optimum reflective or diffusive material has continued and comparative measurements of light yield made.

2.3.5 Pre-electronics Module

2.3.5.1 Validation model 1 (VM1)

The first model of carbon composite cell mechanical structure has been completed by end June (VM0). It permitted validation of the tooling design and structure fabrication process, but has also revealed several flaws, mainly on the cells closeouts and electronics attachment aluminum parts. The fabrication of a new prototype (VM1) has started in July to address them. (See Figure 2.3-4).

Figure 2.3-4. VM1 carbon composite structure. Side posts support PCB mounting.

VM1 is a structural model designed to pass qualification load levels (static and vibrations). An optimization of the mechanical design has been made to bring a better compatibility with the electronic printed circuit boards. The attachment of the boards on the 4 sides of the Calorimeter modules is now

Figure 2.3-5. Insertion of dummy logs into VM1 carbon cell structure.

similar to the one designed for the compression concept. The amount of dead material has also been reduced (less aluminum), leading to a lighter structure.

The upgrade from VM0 to VM1 has required several modifications of the tooling used for cells production. A new complete carbon composite structure has been fabricated and a new set of adapted mechanical parts machined. To avoid compatibility problems between carbon composite and aluminum, inserts in the carbon cells are now used to attach all the aluminum parts (cell close-outs, top and bottom plates.) VM1 is produced by assembling 3 sub-structures, because the tooling allows the fabrication of a maximum of 3 layers of 12 cells. Precision problems have arisen during the assembly, delaying the completion of the model for the mechanical tests. They have been corrected.

2.3.5.2 Vibration test

The development of VM1 has required more work than expected and the completion of the model has not been possible before end September for a test in October as planned. Still, all the elements needed to assemble it are ready. Dummy steels logs have been fabricated to load the carbon cells. (See Figure 2.3-5.) Their section is defined so that they have the same mass as CsI logs. The overall inertia is equivalent to the one obtained with 96 crystal logs. The complete assembly of the prototype is planned for end October.

Although progress in the design of the Grid interface has been made, this point will not be addressed in VM1. A rigid frame will be used as an interface with the shaker for vibration testing. This results in a fixture somehow similar to the one foreseen for the interface with the Grid.

The test procedure has already been written and contacts have been taken with a company for a test date before end November.

2.3.5.3 Mechanical design

The mechanical drawings have been updated, following the reduction the overall instrument dimensions. Design studies are going on to optimize the electronic boards integration. The work on the Calorimeter bottom plate and Grid interface has lead to a design very similar to the one produced by SLAC engineering group, except for the number of fastening lugs. This particular point is strongly related to the number of connectors on the boards and the routing of the cables.

2.3.6 Analog Front End Electronics

In cooperation with the LAT IPO, design concepts have been developed for communications interfaces between the calorimeter subsystem and the trigger and data acquisition systems. Interface concepts and protocols are being considered that provide commonality among all LAT subsystems.

2.3.6.1 Progress on Analog to Digital Converter (ADC) selection.

We have made some progress on our evaluation of commercial ADCs for the flight GLAST Calorimeter. The requirements that we are searching in order of importance are:

1. Good Radiation Tolerance.
2. Good 12 bit Differential Non-linearity.
3. Low power.
4. Small PCB Footprint.
5. Conversion times about 10 us.
6. Serial data output.
7. +5 Volt operation.

We have performed a search of currently available devices following the construction of our prototype calorimeter that was built using two prospective devices. The search turned up two additional possible converters. The ADCs in consideration are:

Maxim MAX189	12-bit ADC, currently on calorimeter prototype.
Burr Brown ADS7816	12-bit ADC, currently on calorimeter prototype.
Burr Brown ADS8320	16 bit ADC
Maxim MAX194/195	14/16-bit ADC.

2.3.6.2 Differential Non-Linearity Testing.

A small sample of the four ADCs was tested for differential non-linearity (DNL) by applying a low frequency triangle wave to the ADC and sampling at a high rate. A computer histogrammed the data. ADCs with higher than 12-bit resolution were histogrammed using the 12 most significant bits. The DNL distribution for the MAX189 is shown in Figure 2.3-7. Its DNL is approximately three times better than the Burr-Brown ADS7816 and even better than the 14-bit MAX194 in 12-bit resolution.

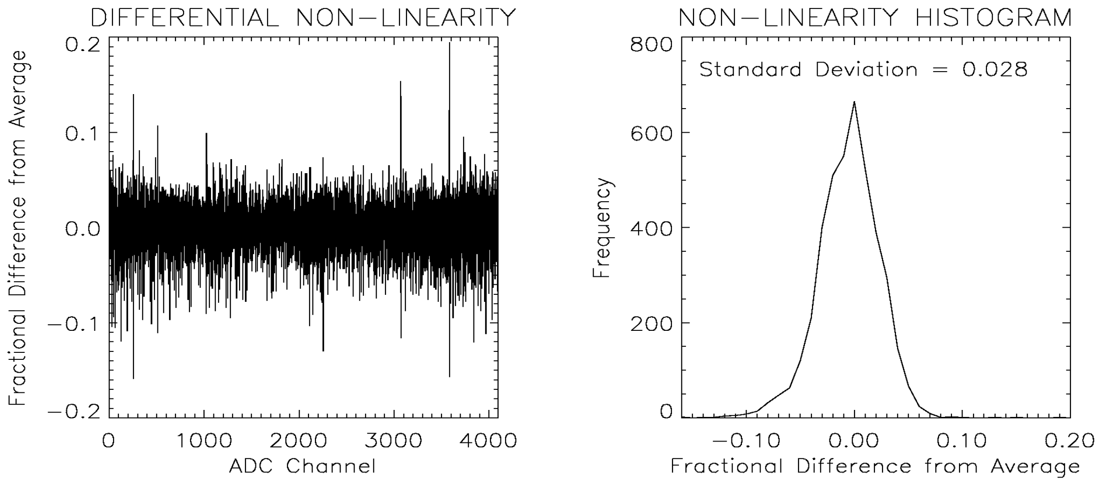

Figure 2.3-7. Maxim MAX189 12 Bit Differential Non-Linearity.

2.3.6.3 Radiation Testing.

Two ADCs were tested for latchup susceptibility at the NRL Radiation Test Laser Facility in June. The facility uses a 605 nm laser of focused spot size 1 µm which has a 1/e penetration depth of 1.8 µm. Figure 2.1-1 shows a picture of the test board used.

The board has three rows of sockets on the left section, one row for each type of ADC (Max189, ADS7816, and another ADC dropped from list). For the latchup testing, the board senses the voltage drop on a series 100 Ω power supply resistor. If the voltage drop across the resistor trips a comparator, then a dual n-channel p-channel power MOSFET both opens the power supply to the ADC while the ADC power pin is grounded. The power to the affected ADC is re-connected after half a second. The test board thus senses a destructive latchup condition, one that unabated could cause permanent failure of the device. As a side note, the radiation test board above also has additional circuitry to measure small changes in current draw and changes in non-linearity for possible future total dose radiation testing.

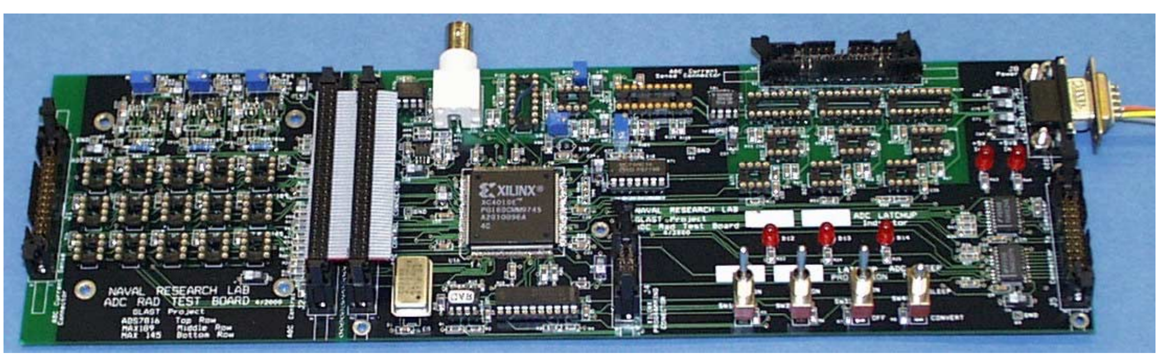

Figure 2.3-6. ADC Radiation test Board.

Chips tested at the Laser facility first had to be de-lidded to expose the silicon die. Figure 2.3-8 and Figure 2.3-9 show photos of the two die. The photos are shown to the same scale: the MAX189 die is much larger in size.

The results of scanning the laser over all areas of both die revealed that the digital areas of the chips are most sensitive. The digital areas are recognizable by the neat rows of standard cell devices and routing metalization between rows. The destructive latchup sensitivity measured was approximately a ratio of four between the two devices.

Table 2.3-1 ADC Laser Measured Latchup Sensivity

Device	LET Destructive Latchup Sensitivity
Maxim MAX189	Approx. 70 MeV * cm^2/ mg
Burr-Brown ADS7819	Between 15 and 20 MeV * cm^2/ mg

2.3.6.4 Discussion:

From the presented data on differential non-linearity and laser latchup testing of the ADCs, the most promising ADC to use on the flight calorimeter is the Maxim MAX189. Possible explanations of the better DNL performance of the MAX189 is that it uses an internal clock for conversion cycles and that the surface mount package has a separate analog and digital ground pin.

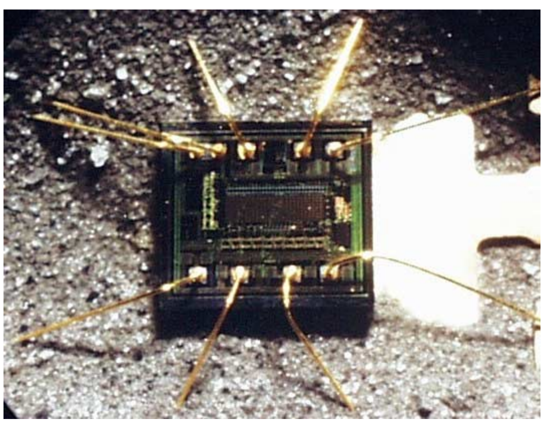

Figure 2.3-8 ADS7819 Die

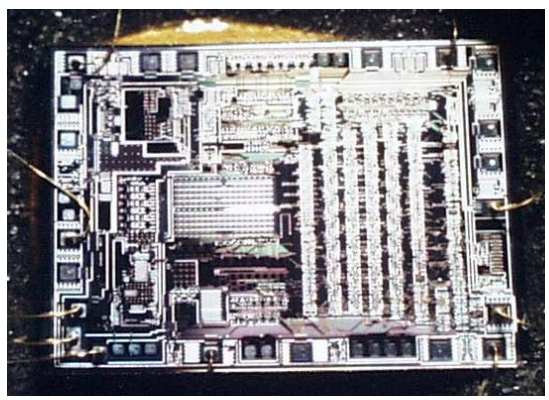

Figure 2.3-9 Max 189 Die

2.3.7 Balloon Flight Preparations

We distributed a memo to the Calorimeter team, *Americium calibration of electron yield in BTEM crystals* (NRL SEM 2000-01), by Grove and Sandora, dated 14 Sept 2000. This is a revised estimate of the scintillation light measured in the PIN diodes from muon passing through the CsI. The estimate is made by comparing the muon peak to the 60-keV Am241 peak observed in direct illumination of the photodiodes. The typical light yield in the 1 cm^2 photodiode, after 8 months of compression in the beam-test engineering model, is ~4200 e/MeV by this method. See NRL GLAST website: **electron_yield_in_BTEM_by_Am.pdf** .

We distributed a memo to the Calorimeter team, *Effect of Light Tapering on Light Yield* (NRL SEM 2000-02), by Grove, dated 20 Oct 2000. This summarized the effect on the average light yield in the beam-test engineering model CsI crystals from sanding the crystal surfaces to taper the light with distance from a crystal end face. The memo concluded that the modest sanding to give 65% tapering slightly increases the light yield in the center of the crystals. See NRL GLAST website: **Effect_of_Light_Tapering_on_Light_Yield.pdf**

We studied thermal stability of optical bonds between CsI and PIN diodes. We tested five spare beam-test engineering model CsI crystals with custom dual photodiodes on both ends. All 10 photodiodes were bonded with the hard Epotek 301 epoxy used on all beam-test engineering model crystals, and all 10 bonds were created in summer 1999 during the assembly of the beam-test engineering model Calorimeter. One of the 10 bonds began the testing already optically degraded, i.e. with roughly half the signal of the other photodiodes. We cycled the crystals one or more times between 40C and -20C, with temperature gradients always <10C per hour and typically <5C per hour. Approximately 1/3 of the bonds degraded during the hot cycle, and all of the bonds had degraded by 10C during the cold cycle. The first bond degradations occurred at ~35C during heating and ~20C during cooling. The bond that was degraded when the test began was essentially unchanged, and those that degraded sometime during the testing didn't decline further with additional cycling. Two of the 10 bonds mechanically failed, and in both cases the Epotek remained firmly attached to the PIN but cleanly, smoothly separated from the CsI. The remaining eight held their mechanical integrity. The signal measured in optically degraded but mechanically attached bonds is essentially the same as that in mechanically failed bonds; thus, the optical degradation is equivalent to an air gap, i.e. roughly half the signal from a good bond. Conclusions: (1) The safe storage temperature range for the beam-test engineering model is roughly 25C +- 5C; (2) Once bonds have optically degraded, further temperature cycling doesn't further degrade the light output; (3) The degraded signal is about half the signal from a good bond, as we have seen in the beam-test engineering model crystals.

Based on this thermal sensitivity, we have begun a program of thermal cycling of the beam-test engineering model calorimeter to stabilize all of the bonds at the degraded level. While this reduces the light output by half, it should ensure that the gain calibration remains stable throughout the balloon flight.

2.3.8 Identified Risks and Mitigation Plans, Issues and Concerns

- The resignation of the French program manager has created a significant delay in the organization and planning of the French efforts for the calorimeter. A new program manager has been identified by Saclay and he is expected to be on board in October. A new system engineer has also been identified who will be hired by IN2P3. He is expected to be on board by the first of next year.
- Resource limitations at Saclay have prevented the initiation of the analog front end ASIC design. Consequently, the current schedule does not provide prototype run results in time for PDR or provide sample parts for the engineering model construction prior to CDR.

2.3.9 Work Planned Next Quarter

2.3.9.1 Management

- Completion of the baseline calorimeter organization, schedule and cost estimation in support of the LAT PMCS system.
- Establishment of the French management team and development of responsibilities and schedules.

2.3.9.2 System Engineering

- Completion of the Calorimeter system requirements and specifications.
- Completion of the analog front end ASIC requirements specification.

2.3.9.3 Vibration test

Vibration test of VM1 is scheduled for November. The results will be used to update the finite element model so that an analytical model of the Calorimeter module can be provided in December to the instrument integration group, as required.

2.3.9.4 Optical reflector

Evaluation of optical coatings for the CsI logs will continue. A good candidate material is now available. The effort should be put mainly on characterization and acceptance tests. The ability of the material to support the fabrication process of the carbon cell structures needs to be checked (temperature and pressure during epoxy resin cure time). Investigation will start to evaluate the ability of the material to be used in space applications (outgassing measurements).

2.3.9.5 Crystal photodiode optical coupling

Several options are still foreseen to couple the CsI logs and the photodiodes. This remains the critical point for the completion of calorimeter design. A strong effort needs to be made to get to a final solution. The studies that have already been performed should allow quickly choosing a baseline solution and concentrating on the development, test and validation of it. A backup solution could also be investigated.

2.3.9.6 Optical validation model OVM

The OVM fabrication is conditioned by the developments made on optical coatings and crystal to photodiode coupling. A three layer composite structure with optical walls will be fabricated, but only one layer should be equipped (reduced number of CsI logs). The two others are needed for cell closeouts attachments.

2.3.9.7 Analog Front End ASIC

Design of the analog front-end ASIC will begin.

2.3.9.8 ADC Radiation Testing

Completion the ADC Radiation Board programmable logic and associated computer software to fully run and test the chips during radiation exposure. Testing at the Brookhaven heavy ion accelerator in December will more precisely determine the radiation threshold for Single Event Upsets (incorrect data output) and the threshold for Destructive Latchup (permanent circuit failure).

2.3.9.9 Balloon Flight Preparations

- Completion of the beam-test engineering model calorimeter thermal cycling
- Repair/replacement of damaged PIN photodiode bonds.
- Transfer of CsI crystals to balloon flight compression cell.
- Beam-test engineering model calorimeter calibration. Delivery to SLAC is scheduled for January, 2001.

2.4 Anticoincidence Detector

2.4.1 Current Status and Accomplishments

- Considerable work has been done to improve the beam-test engineering model Anticoincidence detector electronics in preparation for the GLAST balloon flight, including an interface test with the revised electronics.
- Modeling to optimize the Anticoincidence detector segmentation, particularly for the bottom side rows, is ongoing.
- Studies of the flight electronics have begun, including an informal review conducted by the SLAC team.
- The top-level requirements document for the Anticoincidence detector was refined.
- Design work on the front-end ASIC has begun.
- Plans are being started for procurement of the photomultiplier tubes and high voltage power supplies for the flight unit.

2.4.2 Identified Risks and Mitigation Plans, Issues and Concerns

- The mass has increased relative to the proposal. Mitigation will be in a more complete mechanical design and if necessary request for additional mass.
- An item of concern is that the light being collected from the Anticoincidence detector tiles may have inadequate margin to meet the needed efficiency while maintaining redundancy through the life of GLAST. Mitigation will include testing and improving aspects of the light collection.
- A small risk has been identified in finding a source for the high voltage power supplies, since Hamamatsu has not built low-power, flight-qualified high voltage supplies before. Mitigation includes working with Hamamatsu and contacting other vendors, as well as a possible in-house GSFC design.
- The Anticoincidence detector staffing must reach steady state. The new mechanical systems engineer Sharon Siepel has both Anticoincidence detector subsystem and GLAST project responsibilities and may need to concentrate primarily on the GLAST Project effort. This necessitates additional mechanical support for the Anticoincidence detector. The Anticoincidence detector also needs instrument management and system engineering support. These positions are expected to be filled early in the next quarter.

2.4.3 Work Planned Next Quarter

The principal efforts of the Anticoincidence detector team in the next quarter will be

- Preparation of the balloon flight instrument Anticoincidence detector. This work will include completion of the Anticoincidence detector electronics modifications, replacement of several of the scintillator tiles to reduce gaps, and re-work of all mechanical aspects of the Anticoincidence detector.

- Planning for the Anticoincidence detector flight mechanical design. Regular meetings of the scientists and engineers have begun to define the design and identify potential issues. A retreat including the LAT mechanical designers will be held during November to specify interfaces.

- Planning for the Anticoincidence detector flight electrical design. Work on the preliminary ASICs will continue. Better definitions of the "trigger primitives" for the Anticoincidence detector will be used to help define the specific electronics constraints.

2.5 Beam Test Data Analysis

An engineering model corresponding to 1 out of the 16 towers for the GLAST LAT detector was built and installed in a beam test of positrons, protons and tagged photons during December 1999 and January 2000 at the fixed target area at SLAC. More than 400 Gbytes of data have been collected and analyzed.

The paper on the beam test analysis is already in its last draft and will be published as a SLAC report (SLAC-PUB-8662) early next quarter. After that, it will be submitted to publication in a referred journal (NIM A). The next paragraphs summarize the accomplishments of this beam test.

- We have demonstrated the feasibility of an integrated data acquisition scheme with self-triggering and developed a data processing scheme that uses a file format that adheres to the object-oriented paradigm thereby reducing the complexity of reading and writing event data. We have also proven that low energy neutrons interacting in the hydrogen within the plastic scintillator of the Anticoincidence detector are not a significant source of backsplash false signals. We have developed a novel method to measure the energy resolution in the calorimeter, which uses the correlation between the escaping energy and the energy deposited in the last layer of the calorimeter. The results from this beam test suggest that this method is comparable to that of profile fitting provided the shower maximum is contained in the calorimeter. We have used the hadron beam to align the silicon tracker ladders in a plane to within 18 micrometers. We have further improved our Monte Carlo simulations and validated the distribution of number of hits in the tracker (front and back sections) for on-axis and off-axis incidence. This is very important since the energy lost in the tracker can be estimated from the total number of hits. We have shown that the Time-over-Threshold from the tracker is a promising tool as a photon conversion finder and can be used as an additional handle on the charged background rejection. We have also measured the point-spread function for both sections of the tracker. For normal incidence and 68% containment the results between Monte Carlo and data agree well for photon energies from 100 MeV up to 5 GeV. Among the most important achievements of this beam test has been to complete a full tower system integration, further developing our data processing path and to validate the performance of the back section of the tracker. We have also acquired invaluable experience towards the construction of the full scale flight instrument.

2.6 Balloon Flight

Although the time scale for the GLAST Balloon Flight Engineering Model (BFEM) is short, good progress has been made in pulling together plans for a balloon flight in June 2001. The basic concept is to use an upgrade of the beam-test engineering model along with existing balloon hardware available from GSFC projects.

2.6.1 Current Status and Accomplishments

During this quarter, efforts have focused on detailed planning and first steps toward testing improved balloon flight electronics.

The following documents have been prepared:

- *Report on the GLAST LAT Balloon Test Flight Objectives*, July 12, 2000
- GLAST-BFRD-1, *LAT Balloon Flight Requirements Document*, August 8, 2000
- *Balloon Flight Objectives and Constraints*, June 10, 2000
- *Balloon Flight Budget*, September 11, 2000
- *Balloon Power Systems and Packaging Concepts*, Sept 14, 2000
- *Draft Mass and Power Budget*, Aug 10, 2000

In addition, a combined document, ***GLAST Balloon Flight Engineering Model - Plan for Balloon Flight,*** is nearly complete. This document will be made available to the entire GLAST collaboration for review and comment.

An improved version of the balloon flight electronics has been built, and interface tests have been conducted with the Tracker, the Calorimeter, and the Anticoincidence detector subsystems. A second iteration of the electronics is currently undergoing similar interface tests. The tower electronics cards used are modified versions of the cards used in the Test-Beam effort. The tower electronics cards require a few additional modifications, which will be done next quarter. A VME board for housekeeping was selected and obtained. All power-supplies were received. Two Motorola 603 power-PC boards supporting SCSI disks were selected, ordered, and received. Progress was made on the balloon-interface unit.

A prototype version of the external targets has been built and delivered to GSFC for testing using the Anticoincidence detector electronics.

2.6.2 Identified Risks and Mitigation Plans, Issues and Concerns

A preliminary risk assessment was performed during the first quarter. The principal risk mitigation activity was the development of a detailed balloon flight plan including mission concept, WBS, schedule, and budget. In addition, a potential risk involved in modification and testing of the suggested pressure vessel has been relieved by obtaining a flight-tested pressure vessel of the right size from a previous GSFC balloon experiment. A photo of that vessel is shown in Figure 2.6-1.

Figure 2.6-1 Pressure vessel to be used for GLAST balloon flight. This vessel was previously used for balloon flights by Bob Hartman, who has given GLAST permission to modify it as needed.

The schedule is tight. Opportunities for a balloon flight are limited to the April-October time frame, and both ends of this window have conflicts with other projects. In addition, the Preliminary Design Review scheduled for August 2001 requires support from many of the same people involved in balloon planning. The departure of Roger Williamson may negatively impact the DAQ development.

2.6.3 Work Planned Next quarter

Between now and the end of 2000, all the principal subsystems - DAQ, tracker, calorimeter, anticoincidence detector, balloon interface unit, and pressure vessel - should be assembled and tested in preparation for the integration to take place at SLAC in January.

2.7 Instrument Operations Center (IOC)

2.7.1 Current Status and Accomplishments

The LAT IOC is dedicated to LAT instrument operations and data analysis. The LAT IOC consists of two subsystems, the LAT Operations Facility (LOF) and the Science Analysis Software (SAS). The LOF will monitor LAT health & safety, acquire LAT telemetry, maintain LAT flight software and configuration control, generate LAT command uploads, and support the rapid alert capability. The SAS is responsible for performing production data processing to generate level 1 data products, generate the point source catalog, and to interface with and distribute data to the LAT science team and the SSC. Progress on the SAS is reported in a separate section.

2.7.2 Current Status and Accomplishments

The IOC Integrated Product Team (IPT) continued to support review of IOC functions, requirements, and interfaces. The IPT developed and validated the Level II requirements in the LAT IOC specification and initiated the decomposition of those requirements into the LAT Operations Facility level III requirements. The IPT also reviewed other level II documentation for the mission Systems Requirements Review (SRR) including the Mission Operations Center (MOC) Requirements Document, Science Support Center (SSC) Requirements Document, Operations Concept Document, Mission System Specification, and a draft Ground System Interface Requirements Document.

2.7.3 Issues and Concerns

A concern is the very small allocation of resources to support early IOC requirements and mission concept development during the formulation phase. A further concern is that the delay in selecting contractors for implementing the MOC function may impede the ability to use common commanding tools and prevent detailed development of IOC/MOC interface requirements in a timely fashion.

2.7.4 Plans for next quarter

- Support resolution of any Requests for Action (RFA) from the SRR.
- Develop the LAT Operations Facility performance specification.
- Produce a draft plan for LOF development.
- Begin trade studies on hardware and software to support the LOF plan.
- Participate in the development of EGSE for the balloon flight
- Support the balloon flight as a means of prototyping LOF processes and procedures.

2.8 Science Analysis Software

2.8.1 Current Status and Accomplishments

Our efforts during this quarter were mostly directed towards

- preparing the code development environment
- starting the code architecture upgrade
- identifying our manpower needs, including estimates for the higher level tools
- preparing a detailed schedule of activities
- starting balloon flight support planning

In the process we ran two general workshops and a two-week working meeting.

2.8.1.1 Code Development Environment

We have adopted the Orsay product, CMT (Code Management Tool) to set up our environment. It supports our 3 approved operating systems, providing Makefiles on UNIX and MS Developer Studio project files on NT.

We have moved the cvs code repository from Stanford campus up to SLAC. This now provides a secure 24x7 supported environment. Web browsing was an issue with SLAC computing security, so we have set up a read-only mirror on campus and point the cvsweb browsing tool there. Anonymous checkout is also available from the mirror. We took the opportunity to clean up the repository, only moving active projects.

We have fully documented the new environment.

2.8.1.2 Code Evolution and Architecture Migration

The Calorimeter group is producing a requirements document for the expected evolution of their simulation, reconstructions and calibration needs. This latter topic was pointed out in the detailed review of the Calorimeter in our September workshop.

We decided in the previous quarter that we would adopt the GAUDI code architecture, developed by the LHCb experiment at CERN and now also adopted by ATLAS. Our initial work has been to understand how the architecture functions and how to apply it to our needs.

We have demonstrated the first usage, which is to take the existing GlastSim IRF file (Instrument Response Format) as input and fill the in-memory classes for the Anticoincidence detector tiles using the facilities provided by the GAUDI framework.

This work was kicked off during a two-week workshop at SLAC in August. It was attended by the core software team and was augmented with a developer each from Italy and Japan.

2.8.1.3 Manpower Needs

During the workshop we estimated the manpower profile for the core software needs. We believe the subsystem software areas to be adequately staffed. We estimated that we need 10-12 FTEs to support the project. We counted up 4 FTEs available. Since then we have added 1 FTE and are in the process of hiring another. We are now engaged in canvassing the collaboration for graduate students and post-docs to fill the remaining areas.

2.8.1.4 Preparing schedules

We are preparing detailed schedules for the effort. This includes subsystem as well as core activities. We are folding in the high-level science tools that have been identified by the Science Analysis Tools working group and that will be need effort after FY2002 starts. We are investigating a web-based project management system (MS Project Central) that will allow us to distribute responsibility for the various subsections of the project. We have a server running at SLAC that, so far, allows team members to view the schedule. We are learning how to allow them to submit updates and modifications.

2.8.1.5 Balloon Flight Support

Since we are undergoing a major rework of the simulation/reconstruction chain, we cannot guarantee that it will be ready in time for the balloon flight. Our conservative fallback position is to reuse as much of the 1999-2000 test-beam (TB99) code and tools as possible.

In this model, the Hiroshima group, which is spearheading a GEANT4 simulation of the balloon and gondola, will provide an interface between the simulation output and the Root classes that were defined for TB99. We will make modest changes to those classes to reflect improvements we found we needed during the analysis this summer. Mostly this will be improved information on the Monte Carlo particle parentage.

We will reuse the reconstruction package, tb_recon, which was developed for TB99. We will also adapt the web bookkeeping and batch scripts that were used to process the data and keep track of the details. We plan to have an end-to-end test of the system in April 2001.

We believe we have a secure fallback position for the balloon support. Given the good recent progress in the mainline architecture upgrades, we are actively investigating whether we can provide the support under the umbrella of the mainline activities. This would be preferable and is looking promising.

2.8.2 Identified Risks and Mitigation Plans, Issues and Concerns

- there is some risk in attempting to support the balloon flight in the mainstream effort. We will evaluate the work involved and set a drop-dead date for reverting to our fallback position.
- Our manpower levels are too low. We must work with the collaboration to acquire more people. Presumably this will be in the form of graduate students and post-docs.

2.8.3 Work Planned Next Quarter

We expect to

- have implemented the bulk of the code framework
- have most of the balloon support code in place for simulation. Reconstruction will happen in the following quarter.
- created a detailed schedule for our activities for FY2001 and a less detailed schedule for out years
- continue to extract additional manpower from the collaboration to cover our needs
- bring online the new people taking over support of the Tracker software
- hold a working meeting of the core group for one week at SLAC in early December
- hold the next general workshop in mid-January. The workshop will feature detailed reviews of the Tracker and GAUDI code, and presentation of the Calorimeter requirements.

The Science Support Center has been assigned to GSFC. We will be working with the SSC to understand the division of labor and the required components that the SSC and LIOC need.

2.9 Performance Assurance and Safety

LAT Project Management has provided feedback and comments to the GSFC Project Office on the latest revision of the GLAST LAT Mission Assurance Requirements (MAR) document. Clarification on the MAR Recommended Documentation (RD's) concept has been provided by the GSFC Project Office along with relief on the Destructive Physical Analysis (DPA) requirement (these will be performed by the GSFC Project). The GSFC Project Office is currently addressing the remaining issue regarding the requirement for Software Metric Reports. The completion and approval of the LAT Performance Assurance Implementation Plan (PAIP) will occur after the formal release of the MAR document.

A draft Systems Safety Program Plan (SSPP) has developed. The SSPP describes in detail the tasks and activities of system safety management and engineering required to identify, evaluate, and eliminate and control hazards, or reduce the associated risk to an level acceptable to NASA Range Safety throughout the system life cycle. In addition, the plan accounts for all contractually required task and responsibilities on an item-by-item basis. The draft SSPP has been submitted to GSFC Project Office systems safety personnel for initial discussions on the LAT Systems Safety Program.

2.10 Education and Public Outreach (EPO)

2.10.1 Current Status

The Sonoma State University (SSU) subcontract from Stanford University for the LAT program was effective June 1, 2000. Most of the effort during this quarter was expended on creating a new plan, schedule and budget that expands the EPO effort to include the entire GLAST project. A draft of the plan, including the schedule and budget was circulated to interested individuals and management in mid-August. A presentation on the status of the LAT EPO program and plans for this expanded program was given at the GLAST Science Working Group (SWG) meeting on September 23, 2000. The presentation can be found through the September 2000 GLAST EPO links at: http://perry.sonoma.edu/materials.

Statements of work for both GSFC and SSU were generated, with accompanying budgets for FY01. The SOWs for GSFC were sent to Jerry Bonnell for input, and we are awaiting his feedback. The budget for next year was approved by Scott Lambros for both SSU and GSFC. Since the project cannot support the entire proposed E/PO effort for GLAST during phase C, feedback was solicited about priorities for new projects, from members of the SWG at the September 23, 2000 meeting. A planned meeting at NASA headquarters could not be held, due to the unexpected unavailability of headquarters personnel.

Approval was received for the design and purchase of an exhibit booth for GLAST. The order was placed with Joan Carol Design Group, and the booth will be shipped directly to the High Energy Astrophysics Division meeting in Honolulu in early November. Two original graphics are being created for this exhibit booth, as part of the design effort. We solicited comments on the small GLAST graphic from the allglast e-mailing list. As a result of these comments, the graphic was redesigned. The graphic that will appear on the podium of the exhibit booth can be viewed at:

http://www-glast.sonoma.edu/GLASTsmall.jpg.

We have continued to work on revamping the GLAST outreach web site. Inputs have been solicited from the four interdisciplinary scientists. Work has begun on the solar flare science section. The main banner is being redesigned to include the DoE logo, as well as the new GLAST small graphic.

We placed an advertisement in the AAS job register and subsequently hired Dr. Philip Plait to work on content and web support for the GLAST EPO effort. Dr. Plait is the author of the popular Bad Astronomy web site (www.badastronomy.com) and has considerable experience in astronomy outreach. He will start at SSU as of December 1, 2000.

The Quest chats started on September 27, 2000, with Kevin Hurley (who is on the Swift team. Swift and GLAST team members are sharing the Chat responsibilities.) Although only one person showed up to chat, we expect to be able to build an audience for future chats, and we are going to advertise on the Imagine the Universe! website, as well as our own Swift and GLAST sites.

An abstract describing the GLAST Ambassador program was submitted for a poster paper to be given in January, at the joint AAPT/AAS meeting in San Diego. This meeting will have many high school teachers in attendance, and is a good place to spread the word about the Ambassador program.

2.10.2 Plans for Next Quarter

We are planning to begin the process of publicizing the GLAST Ambassador program. Notices will be drafted in preparation for the national teacher's conferences, which will be held in the following quarter. We have established contact with Rick Shope of JPL, who is the head of similar Ambassador projects for Stardust and Galileo. During the next quarter, we expect to continue our conversations with him, to discuss possible linkages with other Ambassador programs.

The GLAST booth will be finished by Joan Carol Design, including the large GLAST graphic. It will then travel to both the HEAD meeting in Honolulu in November and the AAS meeting in San Diego in January. Although officially a function of GLAST PR, E/PO personnel will participate in staffing the booth. The poster about the GLAST Ambassador program will be presented at this meeting, but will be created during the next quarter.

The upgrades to the GLAST website should be in place by the end of the quarter. These include the new sections on the Interdisciplinary scientists, the solar flare science section, Quest Chats and the new GLAST banner and sidebar.

Quest Chats will be held on October 25 and November 22, featuring GLAST personnel. The October chat will feature Elliott Bloom (SLAC) and will discuss Dark Matter. The November chat will feature David Thompson (NASA/GSFC) and will discuss gamma-rays from pulsars. The new Quest page will be on line and linked to the Swift, GLAST and Imagine sites, to try to increase participation. SSU personnel will also assist in the reconfiguration of the project web site, at http://glast.gsfc.nasa.gov.

We expect that GSFC will sign off on their statement of work for FY01, and that funds for FY01 will appear at Sonoma State. Subsequent to this signoff, we expect that GSFC personnel will begin work on the GLAST video subcontract and the materials for the teacher's workshop, to be held in April. We also anticipate the rescheduling of the meeting with NASA headquarters Education personnel, to present the expanded E/PO plan. Discussions will continue with TOPS and Thomas Lucas in regards to future sub-contracts that will be issued.

3 Technical Resources

3.1 System Engineering

3.1.1 Mass Summary

A mass accounting of LAT subsystems was completed early in the quarter, in conjunction with finalizing the footprint and silicon size. This was formalized for the SRR in September, and is being put under configuration control now. Total reserves have actually increased somewhat, from 15.5% to 16.3%. Figure 3.1-1 shows these past trends of the mass budget, starting with the Proposal mass and reserve budget. Table 2.3-1 shows details of the current mass budget, broken down to subsystem component type. Reserve shown in this figure represent the reserved budgeted at that level, not that which is apportioned to the subsystem. Currently, the mass reserve allocation method is being developed.

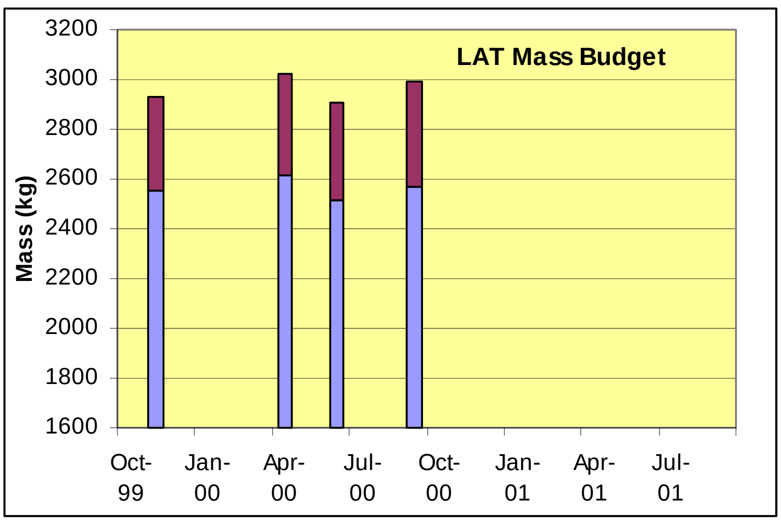

Figure 3.1-1 LAT Mass Budget History (blue = estimate, red = reserve)

Table 3.1-1 LAT Subsystem Mass Breakdown

GLAST LAT Instrument Mass	Mass	Reserve	Reserve	Total
	kg	%	kg	kg
INSTRUMENT TOTALS	**2590.548**	**16.4%**	**425.775**	**3016.323**
Tracker	**522.701**	**20.0%**	**104.361**	**627.061**
Thermal & Mechanical Structures	212.759	35%	74.466	287.225
Silicon detectors	68.803	3%	2.064	70.867
Lead Converters	164.855	3%	4.946	169.801
Electronics, Cabling, and Others	76.284	30%	22.885	99.169
Calorimeter	**1482.064**	**6.9%**	**101.840**	**1583.904**
Mechanical Structures	169.911	30%	50.973	220.884
Cesium Iodide	1260.854	2%	25.217	1286.071
Electronics & Cabling	31.648	50%	15.824	47.472
Others (wrapping, etc)	19.651	50%	9.826	29.477
Anticoincidence Detector	**171.310**	**30.7%**	**52.539**	**223.849**
Detectors	99.710	24.4%	24.329	124.039
Fibers, wrapping, foam spacers, etc				
Phototubes, HV power, and wiring	21.000	50%	10.500	31.500
Mechanical Structures	50.600	35%	17.710	68.310
Electronics				
Grid	**234.225**	**39.2%**	**91.833**	**326.058**
Grid Structure	130.858	35.0%	45.800	176.659
Heat Pipes and mounts	28.264	50.0%	14.132	42.397
Radiators (w/o mounts)	46.848	50.0%	23.424	70.272
Thermal Blankets	28.254	30.0%	8.476	36.731
Data Acquisition Electronics	**180.248**	**41.7%**	**75.202**	**255.450**
Tower electronics Modules	74.611	30.0%	22.383	96.995
SIU Modules	13.629	50.0%	6.814	20.443
Anticoincidence detector Modules	34.000	50.0%	17.000	51.000
Cable Plant	39.456	50.0%	19.728	59.183
SC ESN	16.000	50.0%	8.000	24.000
Others (cable ties, bolts, etc)	2.553	50.0%	1.276	3.829
Other	**0.000**	**0%**	**0.000**	**0.000**

Potential mass increases: Anticoincidence detector electronics mass may need to be increased, to accommodate boards which were omitted from past accounting. Also, the Anticoincidence detector structure mass budget may need to be increased to cover the new structural design concept. These proposed increases will be weighed against the system-level benefits for the design changes.

Potential decreases: preliminary indications of the Calorimeter structural design show that the CFC structure is lighter than the baseline design, and that it may require the CsI crystals to get incrementally shorter (~1 mm). This will reduce the Calorimeter mass somewhat. As a result of moving to the CFC design, the Grid will actually get shallower, which will lighten it, as well.

3.2 Tracker

3.2.1 Mass

The mass of the Tracker is better known now that the mechanical design is more mature and the dimensions are fixed. Compared with our NASA proposal, the tower size is slightly reduced, and the total amount of converter is reduced (and most likely changed from lead to tungsten). On the other hand, the tray closeout is more massive than assumed in the proposal. The net result is a reduction in estimated mass by 31 kg, or 6%, as shown in Table 3.2-1.

Table 3.2-1 Mass estimate of the Tracker, compared with the estimates in the proposal.

Mass Estimate, kg				
Item	**1 Module**	**16 Modules**	**Proposal**	**Delta**
Mechanical Structures	12.4	199.0	191	+8.0
Silicon Detectors	4.3	68.8	73	-4.2
W Converters	9.1	145.7	(Pb) 173	-27.3
Electronics, cabling, other	4.8	76.3	84	-7.7
Total	30.6	490	521	-31

3.2.2 Power

The tracker power has been reevaluated in light of considerable design changes. The amplifier-discriminator power has decreased significantly, due to design improvements and the new lower-voltage process. On the other hand, we have found it necessary to increase power in some line drivers, to give a more conservative system design, and to keep all of the readout clocking going full time, to avoid problems with noise from power transients. Furthermore, we have reviewed the power-supply requirements and decided that the efficiencies assumed in our original NASA proposal were not realistic. We now are assuming 75% efficiency for the 3.3 V supplies and 69% efficiency for the 1.5 V supply. The net result is an estimated average power requirement of 210 W plus a 57 W reserve, which is an improvement over our NASA proposal (partially due to the 15% descope of the Tracker channel count, as reported last quarter).

3.3 Calorimeter

No changes to report.

3.4 Anticoincidence Detector

Continued updates of power estimates indicate no major deviation from those in the proposal. It was found that the mass for the Anticoincidence detector electronics modules had been significantly underestimated in the proposal, by about 43 kg including allocated contingency. The revised mass estimate has been forwarded to the IPO system engineering activity.

4 Cost/Schedule Status

A Project Control Manager has been hired, and started in the last week of September. A team of consultants has been engaged to create the Project Management Control System (PMCS), based on the system successfully developed and implemented by SLAC's B-Factory project. It is anticipated that the PMCS will be operable in time for the joint DOE/NASA review planned for February 2001. Due to delays in establishing commitments from collaborators in Italy and France, the system may not accurately reflect French and Italian contributions to the project until these situations are resolved.

4.1 System Engineering

Progress on the system engineering effort is progressing toward the establishment of requirements for the LAT Preliminary Design Review.   The system engineering cost and work breakdown structure is being updated and integrated in to the PMCS system for LAT.

The system engineering events leading to the PDR and CDR are being identified and scheduled. The system and subsystem requirements are scheduled for completion before the first project review in February of 2001.

4.1.1 Mechanical Systems and Integration and Test

A new ground-up budget and schedule for the Mechanical Systems element of the LAT budget is partially complete. This is being absorbed into the LAT PMCS system, although the LM-ATC budget has not been folded into this, yet.

The I&T budget and schedule is under review, but not yet ready for the PMCS system.

4.1.2 Electronics

The schedule and budget for the electronics is being developed for the PCMS to enable status reporting and tracking. No variances compared to the proposal are apparent at this time.

4.2 Tracker

Problems with budgeting the carbon-fiber Tracker mechanical structure have been resolved by simplifying the design and the development plan. This work is on a tight schedule to complete the design, prototyping and test work in time to begin the engineering model assembly shortly after PDR. Slippage of the schedule could result from problems with procuring materials on time. Other Tracker development work is on schedule, with the most critical item during the coming year being the ASIC design. Submission of complete prototypes needs to occur by February 2001 to allow time for two prototyping cycles before fabrication of the engineering model. Work on formal drafting of detailed requirements and interface control documents is behind schedule, with respect to the actual engineering work in progress, but more effort is now being placed in that area.

Detail for the formulation phase is still being filled into the schedule on both the mechanical and electrical sides, but it is nearly ready for input into the project management system. The budget numbers need to be updated, although that cannot be completed for the implementation phase until more is known about the availability of INFN resources. Tools are not yet in place to track in detail whether the spending rate matches the planning.

4.3 Calorimeter

4.4 Anticoincidence Detector

The Anticoincidence detector group has been asked to support the LAT Preliminary Design Review in August 2001. This accelerates the schedule compared to that driven by the post-proposal understanding of funding availability. An update of FY'01 manpower and cost for the work at GSFC, including the Anticoincidence detector and the balloon flight work, is being submitted with an over-guide for the accelerated effort to meet an August PDR. The Anticoincidence detector WBS, schedules, and costs are also being reviewed.

Short-term schedule:

September	System Requirements Review
October-December	Complete balloon Anticoincidence detector Continue ASIC and flight electronics design Continue flight mechanical design (Nov. design retreat) Testing of light collection Continued modeling in support of overall LAT design
January	Ship balloon Anticoincidence detector to SLAC.
August, 2001	Support Preliminary Design Review (by request)

4.5 Balloon Flight

Labor for the BFEM development has been largely identified in the Balloon Flight Working Group. Software development has been identified as an area of concern. Most of the hardware for the balloon flight has been borrowed, purchased, or ordered.

Some funding for the necessary mechanical, electrical, and software development was included in the budget. A review of the budget for the balloon flight shows that it can be done for close to the costs anticipated in the original response to the NASA AO (exceeds budget by $75K out of $1M). Efforts will continue to refine the budget and manpower requirements.

Schedule

August	BF requirements review
September	BFEM design review
October-November	Electrical integration tests at GSFC, NRL and UCSC for Anticoincidence detector, Calorimeter, BIU, Tracker, and gondola electronics. Begin gondola assembly at GSFC
December	BF pre-integration review
January	Ship subsystems to SLAC. Receiving and bench tests.
February	Mechanical/Electrical integration including active targets
March	Software integration
April	Ship to GSFC, Gondola integration
May	Ship to Texas
June	Flight
July-August	Data analysis and preliminary performance report

4.6 Instrument Operations Center

Current IOC activity is on schedule and budget.