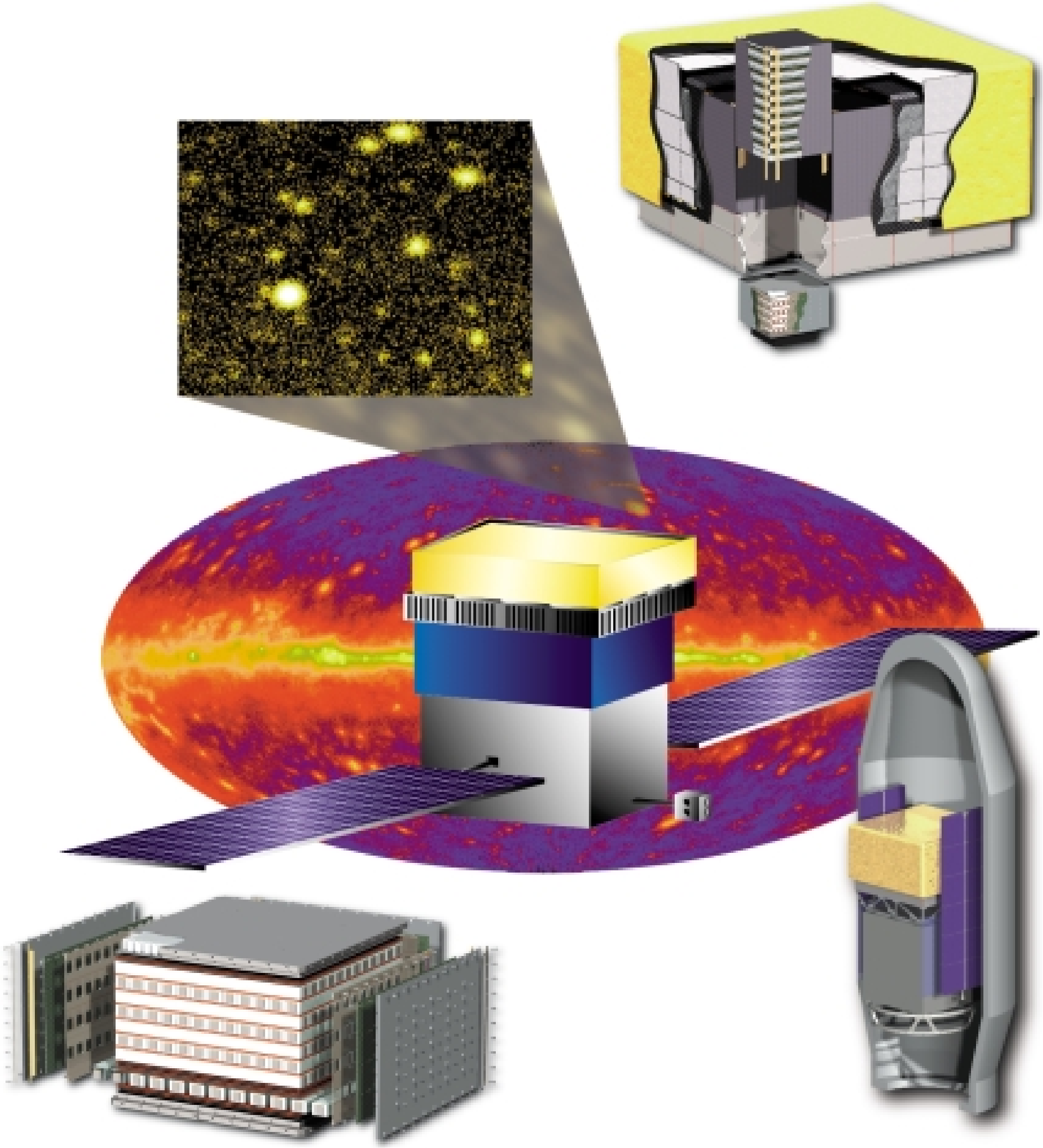
**Response to AO 99-OSS-03**

# GLAST LARGE AREA TELESCOPE

# Flight Investigation:

## *An Astro-Particle Physics Partnership Exploring the High-Energy Universe*

### Volume 2: Cost and Management Plan



**November 1999**
**Stanford University**

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AO-99-OSS-008

## Proposal Cover Page

## AO 99-OSS-03 – Gamma Ray Large Area Space Telescope (GLAST) Flight Investigations

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**Institution Authorization**

Name of Authorizing Official: Lillie Ryans-Culclager

Title: Senior Contracts Officer, Office of Sponsored Research

Institution: Leland Stanford Jr. University

Signature and Date:

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**Full Title**
GLAST Large Area Telescope Flight Investigation: A Particle-Astrophysics Partnership To Explore the High-Energy Universe

**Short Title:** GLAST LAT Flight Investigation

**Funding Data**

Cost to NASA: $65,900,000

Total Cost: $181,900,000

Education/Outreach Budget: $1,288,000

**NASA Grant or Contract Number of any current NASA award that the PI holds that is a logical predecessor of the newly proposed work**
NAS5-98039

**Type of Proposing Institution:** Educational institution

**Themes**
**Theme 1:** SEU
**Theme 2:** ASO
**Theme 3:** SEC
**Theme 4:**

**Proposal Type:** IPI

**Type of Instrument(s):**
Large Area Telescope

**New Technologies Employed:**
NONE

**Principal Investigator:**

| | |
|---|---|
| Prof. Peter F. Michelson | Stanford University |

**Co-Investigators:**

| | | | |
|---|---|---|---|
| Prof. Isabelle Grenier | CEA-Saclay | Dr. W. Neil Johnson | NRL |
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| Prof. Tadashi Kifune | UCRR, U. Tokyo | Prof. Tuneyoshi Kamae | U. Tokyo |
| Dr. Patrizia Caraveo | IFC, CNR | Prof. Robert Johnson | UCSC |
| Prof. Guido Barbiellini | INFN | Prof. Hartmut Sadrozinski | UCSC |
| Dr. Tadayuki Takahashi | ISAS | Prof. Terry Schalk | UCSC |
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**Asociate Scientists:**

| | | | |
|---|---|---|---|
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| Prof. Marc Kamionkowski | Caltech | Dr. Masanobu Ozaki | ISAS |
| Dr. Ann Wehrle | Caltech | Dr. Tom Francke | KTH-Stockholm |
| Prof. Mark Oreglia | U. Chicago | Dr. H. Mayer-Hasselwander | MPE |
| Prof. Rene A. Ong | U. Chicago | Dr. Gottfried Kanbach | MPE |
| Dr. J. T. Bonnell | GSFC | Dr. Andrew Strong | MPE |
| Dr. Stanley D. Hunter | GSFC | Dr. Jeffrey D. Scargle | NASA Ames |
| Dr. Alice K. Harding | GSFC | Dr. Charles D. Dermer | NRL |
| Dr. Floyd W. Stecker | GSFC | Prof. Roger Romani | Stanford U. |
| Dr. Matthew G. Baring | GSFC/USRA | Prof. Vahe Petrosian | Stanford U. |
| Dr. Katsuichi Yoshida | Hiroshima U. | Dr. Paul Kunz | SU-SLAC |
| Prof. Masaki Mori | ICRR, U. Tokyo | Dr. E. do Couto e Silva | SU-SLAC |
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| Dr. Piergiorgio Picozza | INFN | Dr. Yasushi Fukazawa | U. Tokyo |
| Dr. Annalisa Celotti | Int. School Adv. St. | Prof. Joel R. Primack | UCSC |
| Dr. J. P. Dezalay | CESR Toulouse | Prof. Stanford E. Woosley | UCSC |
| Dr. F. Lebrun | CEA-Saclay | Prof. Brenda Dingus | U. Wisconsin |

**E/PO Objectives:**
Gamma-ray astronomy is an exciting field for the public as well as the researcher. Both young and old can be engaged by the exotic concepts of black holes and violent explosions seen across the Universe. Thus, we believe that the GLAST E/PO program is well suited to promote inquiry into the origin and structure of the Universe and the relationship between energy and matter, concepts included in the Physical Science Content Standards A,B, & D for grades 9-12. Therefore in the GLAST LAT E/PO program we will focus on the specific educational goal of utilizing the observations and scientific discoveries of the GLAST mission to improve understanding and utilization of physical science and mathematics concepts for grades 9-12. Results obtained from the program will be evaluated against well-defined metrics.

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**Proposal Summary/Abstract**

Our understanding of the Universe has experienced a revolution in the last several years with breakthrough observations of many new phenomena that have changed our view of the high-energy Universe and raised many new questions. The GLAST mission stands poised to open enormous opportunities for answering these questions and advancing knowledge in astrophysics and particle physics. A Large Area high-energy gamma-ray Telescope (LAT), based on pair conversion, is proposed, by an international team, that will meet all of the GLAST mission requirements with large performance margins for critical telescope characteristics. The telescope consists of (i) a precision tracker, based on proven Silicon-strip detector technology, (ii) a finely segmented CsI calorimeter for energy measurement, and (iii) a segmented anticoincidence shield that covers the tracker. The instrument will support a broad scientific investigation. In particular, the LAT will (i) provide rapid notification of high-energy transients, (ii) provide an extensive catalog of several thousand high-energy sources obtained from an all-sky survey, (iii) measure spectra from 20 MeV to more than 50 GeV for several hundred sources, (iv) localize point sources to 0.3 – 2 arcmin, (v) map and obtain spectra of extended sources such as SNRs, molecular clouds, and nearby galaxies, and (vi) measure the diffuse isotropic gamma-ray background up to TeV energies.

**Certification of Compliance with Applicable Executive Orders and U.S. Code**

**By signing and submitting the proposal identified in this Cover Sheet/Proposal Summary, the Authorizing Official of the proposing institution, as identified above (or the individual proposer if there is no proposing institution);**

1. **certifies that the statements made in this proposal are true and complete to the best of his/her knowledge;**
2. **agrees t oaccept the obligations to comply with NASA award terms and conditions if an award is made as a result of this proposal;**
3. **provides certification to the following that are reproduced in their entirety in this NRA: (i) Certification Regarding Debarment, Suspension, and Other Responsibility Matters; (ii) Certification Regarding Lobbying, and (iii) Certification of Compliance with the NASA Regulations Pursuant to Nondiscrimination in Federally Assisted Programs.**

AO-99-03-OSS-008

# Volume 2 - Management and Cost Plan

## *Table of Contents*

## Appendices

# 1.0 MANAGEMENT PLAN

The GLAST LAT Management Plan is built upon the organization shown in Figure 1.1.1. The LAT team is led by the Instrument Principal Investigator (IPI), Peter Michelson, who has overall responsibility for all aspects of the LAT Instrument Project. Key elements of the Management Plan are as follows:

- The Instrument Project Office (IPO) at the Stanford Linear Accelerator Center, Stanford University (SU-SLAC), is directly coupled to both SLAC's and the team's technical infrastructure and supports the IPI in the management of the project. The core of the IPO is composed of the IPI, the Instrument Project Manager (IPM), William Althouse, and the Instrument Technical Manager (ITM), Tuneyoshi Kamae. Clear lines of authority and reporting, as described in Section 1.1, are established.
- Direct accountability for all aspects of the project to the IPO central management is supported by a proven Project Management Control System (PMCS) provided by SU-SLAC. Good communication is a key focus for maintaining effective managerial guidance and strongly performing subsystem teams. The SLAC laboratory management pro-actively supports the IPO.
- A work breakdown structure (WBS) has been developed in concert with all of the instrument team member institutions and is the primary tool for delineating the details of the tasks.
- Adequate technical and programmatic reserves have been budgeted and baselined. Their allocation will be centrally managed by the IPO and formally distributed under a Configuration Control Plan, described in Section 1.2.
- The IPO (IPI, IPM, and ITM) meets weekly with SLAC management—the laboratory director and the research director—as part of the project review process. These meetings will facilitate the laboratory's role of technical support and will serve as an "early warning" system in detecting and resolving emerging problems.
- Finally, the Management Plan is built upon the dedication and personal commitment of each team member, with the full support of his/her institution. These team characteristics have already been demonstrated throughout the GLAST Mission Concept phase, and during the technology development and demonstration phase preceding this proposal. The Instrument team co-investigators are identified in Table 1.0.1.

Each LAT institution and individual has recent experience in their areas of responsibility. They bring a combination of experience with flight systems, and with the technologies relevant to this flight instrument. The Stanford University-Stanford Linear Accelerator Center (SU-SLAC), lead organization and responsible institution for managing the Instrument Project, brings extensive experience in successfully managing multi-institutional, multinational projects, of a scale similar to the GLAST LAT. This includes a 25-year history in the management, development, and installation of eight facility-class particle detectors, all on a scale larger than GLAST. This has recently culminated in the management and installation of the BABAR detector—a $110 million international project. Relevant experience in the management of space-flight hardware projects is brought to the project by the W. W. Hanson Experimental Physics Laboratory (SU-HEPL), at Stanford University.

The multi-institutional LAT team organization is built upon the existing foundation of an effective organization developed and managed by Stanford University's SLAC and HEPL laboratories. This organization was developed during the technology development and demonstration phase that preceeded this proposal. There has also been significant previous experience with all major foreign partners.

## 1.1 MANAGEMENT ORGANIZATION

### *1.1.1 Organizational Structure*

The GLAST LAT management organization captures the strengths of an international, multidisciplinary team and also addresses potential risks associated with the management of multi-institutional instrument subsystems. The structure is

**Table 1.0.1:** Science Team Co-Investigators

| Science Team Member | Institution | Role/Responsibility |
|---|---|---|
| P. Michelson*^ | SU-HEPL/SLAC | Principal Investigator |
| S. Ritz | GSFC | Instrument Scientist |
| T. Kamae*^ | SU-SLAC, JGC(Tokyo) | IDT Lead,<br>Lead Japanese Scientist |
| N. Gehrels* | GSFC | SSAC Chair |
| R. Johnson* | UCSC | TKR Manager |
| H. Sadrozinski* | UCSC | TKR detectors – US Lead |
| G. Godfrey | SU-SLAC | TKR Assembly |
| T. Kifune | JGC(ICRR) | TKR |
| T. Ohsugi | JGC (Hiroshima) | TKR Detectors – Japan Lead |
| E. Bloom*^ | SU-SLAC | TKR Integration |
| G. Barbiellini*^ | INFN | TKR Production –<br>Italian Lead Scientist |
| N. Johnson*^ | NRL | CAL Manager |
| E. Grove | NRL | CAL Integration |
| B. Phlips | NRL/USRA | CAL Detectors - US |
| I. Grenier*^ | CEA-Saclay | CAL, French Lead Scientist |
| P. Fleury* | IN2P3 (Ecole Polytechnique) | CAL, Dep. French Lead |
| J. Paul | CEA-Saclay | CAL |
| A. Djannati-Atai | IN2P3 (College de France) | CAL Simulations |
| P. Goret | CEA-Saclay | CAL – xtal readout |
| T. Reposeur | IN2P3(Bordeaux) | CAL – GSE/testing |
| P. Carlson* | RIT, Sweden | CAL – CsI procurement |
| J. Ormes* | GSFC | ACD Manager |
| D. Thompson*^ | GSFC | ACD Design, Multi-wavelength Coordinator |
| A. Moiseev | GSFC/USRA | ACD Assembly & Integration |
| R. Williamson* | SU-HEPL | DAQ Manager |
| K. Wood* | NRL | DAQ Processors |
| M. Lovellette | NRL | DAQ Interfaces |
| R. Dubois | SU-SLAC | Software System Mgr. |
| J.J. Russell | SU-SLAC | Inst. Flight Software Lead |
| S. Williams | SU-HEPL | Inst. Ops. Mgr. |
| T. Burnett | UW | Inst. Simulations Lead |
| T. Schalk | UCSC | Track Reconstruction Software |
| S. Digel | GSFC/USRA | Science Analysis Software |
| J. Norris | GSFC | Instrument Simulation, Data Analysis |
| Y. C. Lin | SU-HEPL | Data Analysis |
| P.L. Nolan | SU-HEPL | Data Analysis |
| D. Suson | UT-Kingsville | Instrument Simulation |
| R. Svensson | Stockholm Obs. | Data Analysis |
| P. Caraveo* | IFC/CNR | Malindi Ground Station, Dep. Italian Lead |
| L. Cominsky | SSU | E/PO Lead |

** Senior Scientist Advisory Committee*

*^ Member of SWG*

based on the WBS for the instrument. This unequivocally defines the flow-down of roles and responsibilities to all subsystems and team member organizations within the subsystem. Table 1.1.1 shows the alignment of the top-level WBS for the instrument with the responsible organizations. Team institution names and acronyms are shown in Table 1.1.2, and a comprehensive acronym list is given in Appendix E.

**Table 1.1.1:** Work Breakdown Structure and Institutional Responsibility Alignment

| WBS # | Description |
|---|---|
| **4.1.1** | **Instrument Management** |
|  | Lead: SU-SLAC |
|  | SU-HEPL |
| **4.1.2** | **Systems Engineering** |
|  | Lead: SU-SLAC |
| **4.1.3** | **Science Support*** |
|  | Lead: SU-HEPL |
|  | SU-SLAC |
|  | Team* |
| **4.1.4** | **Tracker** |
|  | Lead: UCSC |
|  | SU-SLAC |
|  | JGC |
|  | INFN |
| **4.1.5** | **Calorimeter** |
|  | Lead: NRL |
|  | French Team |
| **4.1.6** | **Anti-Coincidence Detector** |
|  | Lead: GSFC |
| **4.1.7** | **Data Acquisition System** |
|  | Lead: SU-HEPL |
|  | NRL |
|  | SU-SLAC |
| **4.1.8** | **Grid** |
|  | Lead: SU-SLAC |
| **4.1.9** | **Integration and Testing** |
|  | Lead: SU-SLAC |
|  | SU-HEPL |
|  | GSFC (balloon flight) |
| **4.1.10** | **Performance Assurance** |
|  | Lead: SU-SLAC |
| **4.1.11** | **Instrument Operations Center** |
|  | Lead: SU-HEPL |
|  | SU-SLAC |
| **4.1.12** | **Education & Public Outreach** |
|  | Lead: SSU |

* *For budget purposes, science support and Operations Phase MO&DA support for subsystem teams are tracked in the appropriate subsystem WBS element*

**Table 1.1.2:** Team Institutions and Acronyms

| Acronym | Institution Name |
|---|---|
| **Domestic Team Instituitions** | |
| SU | Stanford University |
| SU-HEPL | Hanson Experimental Physics Laboratory |
| SU-SLAC | Stanford Linear Accelerator Center |
| GSFC | NASA Goddard Space Flight Center |
| NRL | Naval Research Laboratory |
| UCSC | University of California at Santa Cruz |
| SSU | Sonoma State University |
| UW | University of Washington |
| TAMUK | Texas A&M University—Kingsville |
| **Japanese Team Institutions** | |
| JGC | Japan GLAST Collaboration |
| Tokyo | University of Tokyo |
| ICRR | Institute for Cosmic-Ray Research |
| ISAS | Institute for Space and Astronautical Science |
| Hiroshima | Hiroshima University |
| **Italian Team Institutions** | |
| INFN | Instituto Nazionale di Fisica Nucleare |
| ASI | Italian Space Agency |
| IFC/CNR | Istituto di Fisica, Cosmica, CNR |
| **French Team Institutions** | |
| CEA/DAPNIA | Commissariat à l'Energie Atomique, Département d'Astrophysique, de physique des Particules, de physique Nucléaire et de l'Instrumentation Associée |
| IN2P3 | Institut National de Physique Nucléaire et de Physique des Particules |
| IN2P3/LPNHE-X | Laboratoire de Physique Nucléaire des Hautes Energies de l'Ecole Polytechnique |
| IN2P3/PCC | Laboratoire de Physique Corpusculaire et Cosmologie, College de France |
| IN2P3/CENBG | Centre d'études nucléaires de Bordeaux Gradignan |
| **Swedish Team Institutions** | |
| KTH | Royal Institute of Technology |
| Stockholm | Stockholms Universitet |

This plan is strongly focussed on the subsystem elements, as opposed to the team institutions, to provide clear oversight and analysis of subsystem performance through the life of the project. The following section discusses the general method for implementation of this plan.

### 1.1.2 Organizational Responsibilities

Figure 1.1.1 shows the GLAST LAT organization chart. The Instrument Principal Investigator (IPI) is the ultimate authority within the LAT team for all decisions concerning the instrument development. The IPI manages the development of the instrument by way of the IPO, and coordinates efforts of the collaboration science team. Advice concerning the scientific direction of the project is provided to the IPI by the Senior Scientist Advisory Committee (SSAC) composed of members of the Collaboration Science Team. Decision-making authority flows from the IPI to the Instrument Project Manager (IPM) by delegation of all day-to-day decision-making and authority with regard to management of technical, cost, and schedule issues. The IPM manages the engineering development and delivery of the instrument, and ensures compliance to cost, schedule, and technical performance. The education and Public Outreach Coordinator (E/PO) also reports directly to the IPI, and excecutes the E/PO program of the GLAST instrument project.

Instrument technical development is the responsibility of the Instrument Technical Manager (ITM), through the Instrument Design Team (IDT),which the ITM chairs. The IDT is responsible for controlling the coordinated design, development, fabrication, integration, testing, and support of the instrument and its subsystems. Its membership includes all subsystem managers and key system engineering personnel.

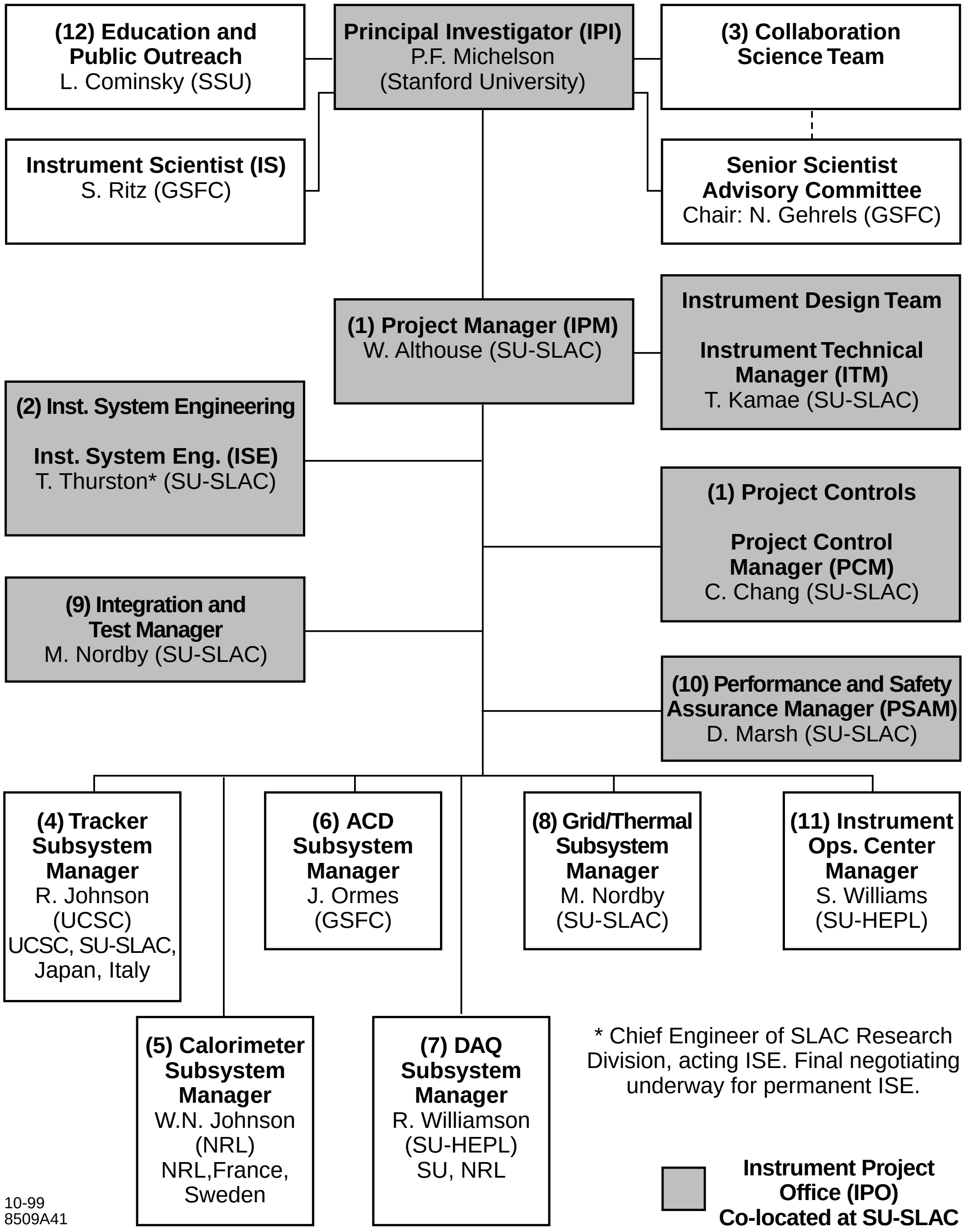
The IPI, IPM, and ITM comprise the core of the IPO management team. The IPM will serve as the prime contact point in the IPO.

The Instrument System Engineer (ISE) establishes and maintains performance specifications, verification and test plans, interface documents, and technical metrics and reserves. The ISE also allocates and maintains these budgets by instrument subsystem elements: Tracker (TKR), Calorimeter (CAL), Data Acquisition (DAQ), Anticoincidence Detector (ACD), Instrument Grid, and Instrument Operations Center (IOC).

The Project Control Manager (PCM) manages the budget and reserve control system for cost, schedule and technical performance, executing the change-control management of all performance parameters for the project. The PCM is also the primary financial interface in the IPO for all team member institutions.

The subsystem managers (for TKR, CAL, ACD, DAQ, and Grid) direct the development of each of the instrument subsystems. Subsystem managers maintain authority over team members with regard to subsystem work, and report to the IPM, particularly on matters of engineering development, technical performance, cost, and schedule.

**Figure: 1.1.1:** GLAST LAT Organization Chart



The Instrument Integration and Test Manager (I&T Manager) develops and maintains procedures and schedules for the instrument I&T phase in accordance with the plans established by the ISE. The I&T Manager will also review the I&T schedules for each instrument subsystem that are developed by the subsystem managers, and will be responsible for maintaining the overall I&T schedule. The I&T Manager reports to the IPM.

The Instrument Scientist (IS) monitors the overall flight instrument design and construction to ensure that the instrument meets the science performance requirements. The IS reports directly to the IPI.

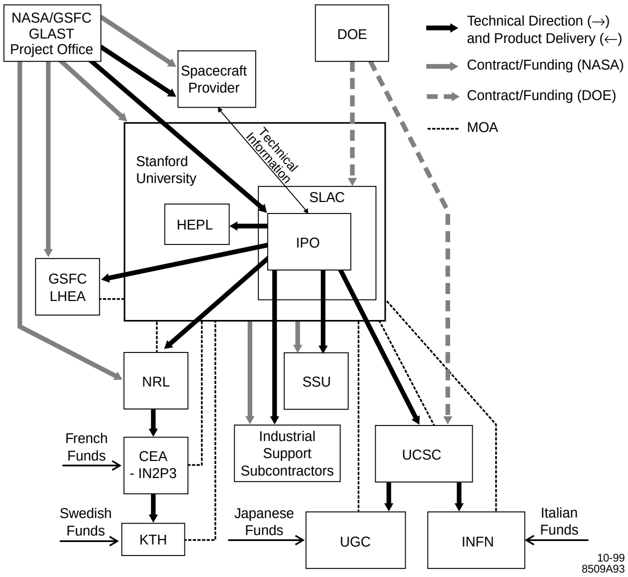
The Performance and Safety Assurance Manager (PSAM) reports to the IPM, and is responsible for the development and execution of all quality assurance, safety, and environment and health activities for the project. Toward that end, the PSAM works closely with the ISE, and with subsystem managers and quality assurance personnel to assure appropriate and consistent quality measures are implemented.

The IPO consists of the IPI, IPM, ITM, ISE, I&T Manager, PCM, and PSAM.

### *1.1.3 Relationships Between Institutions and Organizations*

The LAT project captures the strengths of multiple government- and university-based technical organizations, and two US and four foreign funding agencies. The relationships between these organizations is illustrated in Figure 1.1.2, while the details of the roles and responsibilities of each team organization are provided in the sections below. The figure illustrates the flow of technical direction from the Goddard Space Flight Center (GSFC) Project Office to the IPO, and from the IPO to all supporting organizations.The figure also shows the flow of product deliveries along the technical direction paths (but in the opposite direction), and the flow of both NASA and Department of Energy (DOE) funds.

**Figure: 1.1.2:** Relations Between Team Institutions and Organizations



Where direct contracting mechanisms are inappropriate, the team institutions are linked by Memoranda of Agreement (MOAs). An Interagency Agreement between NASA and DoD will provide the funding vehicle for NRL, while funds to the GSFC LHEA will be transferred internally at GSFC. In both instances, the GSFC Project Office would authorize these funding transfers only upon request of the GLAST LAT IPO.

A particular advantage of the arrangement shown in the figure is that NASA funding authority will be processed and accounted for by the SU-HEPL business system, which is familiar with NASA procedures and requirements. DOE funds will be processed and accounted for by the SU-SLAC business system, which is similarly familiar with DOE procedures and requirements. The separation ensures that the integrity and tracking of funds is maintained for both agencies. However, all funding, commitment and expenditure transactions will be controlled by the PCM captured by the IPO's Integrated Project Management Control System (see Sect. 1.2.3 below). This will ensure reporting, tracking, and visibility of all project expenditures in a coherent manner.

### *1.1.4 Subsystem Teaming Arrangements*

Each LAT team member institution has demonstrated experience to perform their responsibilities. The team institutions bring a combination of flight instrument experience on a scale similar to the GLAST LAT effort, extensive experience with the technologies relevant to the LAT, and recent experience with successful implementation of large, complex projects that are both multi-institutional and international in scope. Collectively, the institutions bring a considerable history of successful collaboration.

The collaboration began as a relatively loose-knit team of institutions, sharing a common set of scientific goals, and a strong interest in developing the GLAST science and instrument. As the collaboration has evolved, a strong organization has developed. Today, the WBS and subsystem responsibilities and teaming arrangements have been firmly established, and formal agreements are nearing ratification. The teaming arrangements for the various subsystems are discussed below, along with the key personnel for each subsystem team.

### 1.1.4.1 Management, System Engineering, Science, and Performance Assurance

SU-SLAC is responsible for management of the GLAST LAT instrument development and implementation, providing systems instrument engineering guidance, and Performance and Safety Assurance oversight to the project. The IPO at SU-SLAC is responsible for managing finances, accounting, contracts, schedule, and technical performance of the GLAST instrument.

The GLAST management plan recognizes and addresses the oversight and financial accountability requirements of the two U.S. agencies providing funds for the project: NASA and DOE. These will be accomplished by the IPO through the use of a centralized Project Management Control System (PMCS), and by leveraging the existing infrastructure at both SU-SLAC and SU-HEPL. The IPO will provide integrated project management oversight for all U.S. funding sources. It will also manage project progress across all institutions through implementation of an earned value system.

GSFC LHEA is responsible for monitoring the flight instrument science requirements to insure that the instrument meets the mission science requirements, and for the coordination of multiwavelength observations in support of science objectives.

The instrument team science investigation will be carried out by all members of the instrument science team under the direction of the IPI.

***Key Positions:***

- *Instrument Principal Investigator (IPI)(SU-SLAC/HEPL)*: Responsible for the overall development and delivery of the GLAST LAT, the quality of the scientific investigation, and the dissemination of results; timely delivery of required documentation, software, and data within budget limitations; and the final performance and calibration of the instrument. Requirements of the position are a strong scientific background in astrophysics, demonstrated ability to scientifically plan and organize a space science investigation, and the ability to communicate effectively.
- *Instrument Project Manager (IPM)(SU-SLAC):* Responsible for the day-to-day management of the GLAST LAT project. Requirements of the position are a demonstrated ability to plan, organize, integrate, and control a complex space instrument development and implementation project with major contributions from several organizations; ability to communicate effectively.
- *Instrument Technical Manager (ITM)(SU-SLAC):* Responsible for technical management of the development and construction of the instrument, to ensure fulfillment of scientific objectives. Chairs the IDT. Requirements for the position are a demonstrated knowledge of high-energy particle detector technology; the ability to design instrumentation utilizing these technologies; a strong scientific background in experimental high-energy physics or astrophysics, and demonstrated skills in managing such projects; ability to communicate effectively.
- *Instrument System Engineer (ISE)(SU-SLAC):* Responsible for providing technical leadership, and directing the work of the subsystem development teams through the development and tracking of requirements, reserves, interface control documents, performance, and verification specifications. Assures that all subsystem elements are compatible and meet overall objectives. Oversees, from the instrument side, all aspects of the S/C-instrument interfaces. Member of the IDT. Requirements for the position are a demonstrated knowledge of scientific and engineering disciplines involved in space-flight instrumentation; comprehensive knowledge of scientific system and subsystem designs and operations; ability to identify problems, formulate and recommend solutions; systems engineering understanding of all the mission requirements; ability to communicate effectively.

- *Instrument Electrical Systems Engineer (SU-SLAC)*: Responsible for providing technical leadership and directing the work of the subsystem electronics development teams through the development and tracking of requirements, reserves (particularly power), interface control documents, performance and verification specifications; assures that all subsystem electronics elements are compatible and meet overall objectives and that all spacecraft electrical interfaces are defined; is member of the IDT. Requirements for the position are a demonstrated knowledge of electrical engineering disciplines involved in complex instrumentation with several subsystems; comprehensive knowledge of scientific system and subsystem designs and operations; ability to identify problems, formulate and recommend solutions; electronics systems engineering understanding of all the mission requirements; ability to communicate effectively.
- *Software System Manager (SU-SLAC)*: Responsible for the overall direction of software development activities among several institutions; development of the Software Quality Assurance (SQA) plan including software configuration management. Requirements for the position are a demonstrated knowledge of effective SQA practice; understanding of mission software requirements; ability to communicate effectively.
- *Project Control Manager (PCM)(SU-SLAC):* Manages budgets and reserves for cost, schedule and technical performance, executes the change-control management of all performance parameters for the project. The PCM is also the primary financial interface for all team member institutions. Requirements for the position include demonstrated background in the management and control of large, multi-institutional projects. Experience in tracking and analyzing project performance using computer software tools and analysis techniques.
- *Performance and Safety Assurance Manager (PSAM)(SU-SLAC):* Responsible for the development and execution of all quality assurance activities for the project. Toward that end, the PSAM works closely with the ISE, and with subsystem managers and quality assurance personnel to assure appropriate and consistent quality measures are implemented. Requirements for the position include a demonstrated background and knowledge of modern quality assurance techniques, with specific emphasis on the ISO 9001 quality program, and space flight quality assurance practices.
- *Instrument Scientist (IS)(*GSFC*):* Responsible for monitoring the flight instrument design and construction; coordinating the necessary instrument and science simulations to support these activities; advises the IPI on all matters that affect the scientific performance of the instrument; is member of IDT and SSAC. Requirements for the position are a demonstrated knowledge of high-energy particle detector technology; the ability to evaluate the expected performance of instrument designs with computer modeling; the ability to communicate effectively.

### 1.1.4.2 Tracker

UCSC is responsible for the overall management of the GLAST Tracker subsystem, and for the development of the silicon tracker readout electronics.

SU-SLAC is responsible for the Tracker mechanical development, and for fabrication, assembly, and integration of the Tracker modules. This effort also receives mechanical engineering design support from Hytec, Inc., located in Los Alamos, New Mexico. Hytec specializes in precision engineering of composite structures. They bring relevant experience to the project, having provided the key mechanical engineering design work for the very large-scale GEM and SDC silicon tracking detectors that were planned for the Superconducting Super Collider. Hytec performed much of the TKR and instrument design engineering during the Concept Phase.

The University of Tokyo is responsible for the specification and procurement of silicon strip-detectors for the flight instrument. Hiroshima University is responsible for the detailed specifications and design of the silicon-strip detectors for the Tracker subsystem and for participation in the procurement and acceptance testing of detectors for the flight instrument.

INFN, Italy is responsible for the fabrication, assembly, and testing of silicon-strip detector ladders and trays for eight (TBR) of the sixteen tracker modules.

***Key Positions:***

- *Tracker Subsystem Manager (UCSC)*: Responsible for the development and delivery of the instrument tracker subsystem in accordance with the subsystem performance specifications and within schedule and resource commitments; serves as a member of the SSAC; is member of IDT. Requirements for the position are a broad knowledge of high-energy particle physics instrumentation with particular expertise in particle-tracking technology and instrumentation; ability to plan, organize, implement, and integrate a complex technical project; ability to communicate effectively.
- *Italian Lead Scientist (INFN)*: prime point of contact between the Tracker Subsystem Manager and the Italian GLAST team, and is responsible for the scientific oversight of the technical development work in Italy and for the delivery of components of the GLAST Tracker. The Lead Scientist is a member of the SSAC and the SWG. Requirements of the position are a strong scientific and technical background in high-energy physics or astrophysics, with a broad knowledge of high-energy particle detector technology.
- *Italian Project Manager (INFN)*: Responsible for the day-to-day management of TKR tasks in Italy, as delegated by the Italian Lead Scientist. Requirements of the position are a demonstrated ability to plan, organize, integrate, and control a space instrument development project in collaboration with international partners.
- *Japanese Lead Scientist (University of Tokyo)*: Prime point of contact between the Tracker Subsystem Manager and the Japanese GLAST team, and is responsible for the scientific oversight of the technical development work in Japan and for the delivery of the silicon strip detector components for the Tracker. The Lead Scientist is a member of the SSAC and SWG. Requirements of the position are a strong scientific background in astrophysics, demonstrated ability to scientifically plan and organize a space science investigation; ability to communicate effectively.
- *Tracker Detector Scientist (Hiroshima University)*: Responsible for the day-to-day technical oversight of silicon detector development and production in Japan. Requirements for this position are broad knowledge of particle-tracking technology and instrumentation with particular emphasis on expert knowledge of silicon-strip detectors; ability to plan and organize a scientific project effectively.

### 1.1.4.3 Calorimeter

NRL is responsible for managing the development of the calorimeter subsystem. They will also plan and execute the calorimeter electronics integration and calorimeter flight unit testing, including environmental testing, and calibration.

CEA/DAPNIA is responsible for the overall management of the French contributions to the GLAST LAT, including contributions from the IN2P3 organizations. The CEA technical responsibilities include the design, prototyping, fabrication, and testing of the GLAST calorimeter front-end analog readout ASIC. CEA scientists are also members of the instrument science team and will contribute to the analysis software development effort.

IN2P3/LPNHE-X is responsible for the mechanical design and qualification of the calorimeter module structural support system and the mechanical integration of the CsI crystals into the module structural support. IN2P3 scientists are also members of the instrument science team and will contribute to the analysis software development.

IN2P3/PCC is responsible for calorimeter and instrument-level simulation efforts and IN2P3/CENBG is responsible for the GSE in support of ASIC testing.

The Swedish groups are responsible for the procurement and acceptance testing of the CsI crystals for the calorimeter subsystem.

***Key Positions:***

- *Calorimeter Subsystem Manager (NRL)*: Responsible for the development and delivery of the instrument calorimeter subsystem in accordance with the subsystem specifications and within schedule and resource commitments. Serves as a member of the SSAC, SWG and IDT. Requirements for the position are comprehensive technical knowledge of calorimetry; ability to plan, organize, implement, and integrate a complex technical project; ability to communicate effectively.
- *French Lead Scientist (CEA)*: Prime point of contact between the Calorimeter subsystem manager and the French GLAST team. Responsible for the delivery of components of the GLAST calorimeter as specified in the MOA and SOWs pertaining to the calorimeter. The Lead Scientist is a member of the SSAC and SWG. Requirements of the position are a strong scientific background in astrophysics, demonstrated ability to scientifically plan and organize a space science investigation; ability to communicate effectively.
- *French Deputy Lead Scientist (IN2P3/ LPNHE-X):* Responsible for the scientific oversight of the technical development work in France. The Deputy Lead Scientist is a member of the SSAC. Requirements for the position are a strong scientific and technical background in high-energy physics or astrophysics, with a broad knowledge of high-energy particle detector technology.
- *French Project Manager (CEA)*: responsible for the day-to-day management of the GLAST LAT calorimeter tasks in France. Requirements of the position are a demonstrated ability to plan, organize, implement, integrate, and control a space instrument development project in collaboration with international partners.
- *Swedish Lead Scientist (KTH)*: prime point of contact with the Calorimeter subsystem manager for the Swedish GLAST team and is responsible for the procurement of the CsI crystals for the calorimeter. The lead scientist is a member of SSAC.

#### 1.1.4.4 Anticoincidence Detector (ACD)

GSFC will develop, fabricate, test, and deliver the ACD subsystem of the instrument.

***Key Positions:***

- *ACD Subsystem Manager (GSFC)*: Responsible for managing the development and delivery of the instrument ACD subsystem in accordance with the subsystem specifications and within schedule and resource commitments. Serves as a member of the SSAC and IDT. Requirements for the position are broad knowledge of technologies needed for scientific flight instruments; ability to plan, organize, and integrate a complex technical project; ability to communicate effectively.

#### 1.1.4.5 Data Aquisition (DAQ)

SU-HEPL is responsible for managing and engineering the data acquisition system for the instrument. NRL will develop the DAQ CPU, and lead development of the data switch FPGA (DSF) and the Spacecraft Interface Unit (SIU). SU-SLAC will lead the development of the flight data acquisition software.

***Key Positions:***

- *DAQ Subsystem Manager (SU-HEPL)*: Responsible for the development and delivery of the instrument data acquisition system in accordance with the subsystem specifications and within schedule and resource commitments. Serves as a member of the SSAC and the IDT. Requirements for the position are comprehensive technical knowledge of data acquisition systems for scientific flight instruments; ability to plan, organize, implement, and integrate a complex technical project; ability to communicate effectively.
- *NRL DAQ Task Manager:* At NRL, the Task Manager has overall responsibility for NRL tasks relating to the DAQ subsystem.
- *NRL DAQ Engineer:* Will assure the day-to-day engineering coordination of the NRL tasks and will report to the NRL DAQ Task Manager.

#### 1.1.4.6 Grid, Integration and Test

SU-SLAC is responsible for the planning, managing, and implementation of the Integration and Test plans for the flight instrument. Grid responsibilities include managing all engineering subcontracts with Lockheed-Martin Advanced

Technology Center (LM-ATC), and working with the System Engineering team to provide design integration function for the instrument. Integration responsibilities include development and fabrication of all Mechanical Ground Support Equipment (MGSE) for integration.

SU-HEPL will develop the detailed functional test protocols and Electrical Ground Support Equipment (EGSE) for the flight instrument. Working in conjunction with the Electrical Systems Engineer and the DAQ subsystem manager, the electrical test engineering team will develop and execute acceptance functional test procedures that will verify all requirements.

GSFC will manage and coordinate all instrument integration for the suborbital flight.

***Key Positions:***

- *I&T Manager (SU-SLAC)*: Responsible for developing and maintaining procedures and schedules for the instrument I&T phase. This includes electrical and mechanical integration and the instrument environmental test program. Reviews the I&T schedules for each instrument subsystem that are developed by the subsystem managers. Works with the GSFC Project Office and S/C contractor to develop the test program for the combined instrument and S/C. Develops MGSE and EGSE requirements. Requirements for the position are a demonstrated experience in integrating and testing a complex instrument, an ability to plan and organize multiple disciplines, and a systems engineering understanding of the mission requirements.

#### 1.1.4.7 Instrument Operations Center (IOC)

SU-HEPL is responsible for managing the development and operation of the IOC, as well as developing requirements and testing IOC software.

SU-SLAC is responsible for developing and testing level-1 data processing software, and for providing the physical facilities for the IOC, and computer and network infrastructure and support personnel to install, operate, and maintain it.

***Key Positions:***

- *Instrument Operations Center Manager (SU-HEPL)*: Work with the I&T Manager in the development of all I&T software and functional test protocols. Develop operations software, and establish IOC. Requirements for the position include familiarity and experience with spacecraft operating principles, and a background in on-orbit instrument or mission operations.

#### 1.1.4.8 Education and Public Outreach

Sonoma State University (SSU) is responsible for managing and implementing the Education and Public Outreach Program.

***Key Positions:***

- *Education and Public Outreach Coordinator (SSU)*: Responsible for the execution of the Education and Public Outreach Program (E/PO) of the GLAST LAT program. Requirements for this position are experience in the education of the public, particularly students, in the world of physics and space science and the ability to communicate clearly.

### *1.1.5 Experience and Capabilities of Team Member Organizations*

Table 1.1.3 summarizes the responsibilities and relevant experience of each team member institution with instrument hardware or software responsibilities.

#### 1.1.5.1 Stanford University

Stanford University is a world-renowned research university located in Stanford, California. It has conducted research in high-energy particle physics for more than 40 years, beginning with pioneering research by W. W. Hansen that led to the development of the first linear accelerator. In 1967, a two-mile electron linear accelerator was completed on the Stanford campus, and the Stanford Linear Accelerator Center (SU-SLAC), a national laboratory facility, was commissioned. Since its inception, SU-SLAC has been managed by Stanford University for the Department of Energy. SLAC has conducted research at the forefront of high-energy physics, with three Nobel Prizes in Physics awarded to SLAC scientists for their work. Recently, SLAC completed the PEP-II B-Factory, a new Asymmetric electron-positron collider, and a large particle detector known as BABAR, for conducting research on weak decays of heavy quarks. Both PEP-II and BABAR are large international projects that were successfully managed and are currently operated by SLAC.

**Table 1.1.3:** Institutional Responsibilities

| Institution(s) | Areas of Responsibility | Relevant Experience |
|---|---|---|
| SU-SLAC | Management of GLAST LAT project<br>Instrument systems engineering, electrical systems engineering<br>Tracker subsystem mechanical design, construction, testing, integration<br>Software management<br>Grid development<br>Instrument integration and test<br>Level-1 data processing<br>Performance and Safety Assurance<br>DAQ engineering support | Management and construction of many large particle physics accelerators and experiments; most recently PEP II, BABAR, SLD<br>USA/ARGOS |
| SU-HEPL | DAQ Subsystem development; Inst. Ops. Ctr. | EGRET, GP-B, CHeX, SOHO/MDI |
| | | |
| SSU | Education and Public Outreach Program | EUVE, GSFC LHEA E/PO, Swift |
| | | |
| GSFC | ACD Subsystem; thermal blanket/ micrometeorite shield;<br>Instrument Scientist | EGRET, RXTE, BBXRT, SWIFT, ACE, ZEUS |
| | | |
| NRL | DAQ/CPU, DAQ/DSF, S/C Interface Unit; calorimeter digital electronics; calorimeter integration and test | OSSE, USA, SOHO/LASCO, YOHKOH/BCS |
| | | |
| FRANCE<br>*CEA/DAPNIA* | Calorimeter analog front-end photo-diodes and electronics readout; management of French effort | INTEGRAL, Sigma-GRANAT, COS-B, Gamma-1, ISO, XMM, LHC/CMS |
| *IN2P3/France* | Calorimeter module mechanical design and assembly; calorimeter & inst. simulation | LHC/CMS, CAT, Celeste, BABAR |
| | | |
| KTH, Stockholm University | Calorimeter CsI crystals | AMANDA, CAPRICE |
| | | |
| UCSC | Tracker Subsystem: electronics, mechanical design, assembly, testing | SLD, BABAR, ATLAS, ZEUS, Milagro |
| | | |
| JGC, Japan: | Tracker: Silicon-strip detectors | ASCA, Astro-E<br>CANGAROO<br>CDF, SSC-SCD<br>GINGA, ASCA, YOKOH, Astro-E |
| | | |
| INFN, Italy | Tracker: Silicon-strip ladders and tracker tray assembly | AMS, BABAR, ALEPH, DELPHI, SLD, CMS |

SU-SLAC also helped in the development of the Unconventional Stellar Array (USA) X-ray telescope, and is currently involved in the data analysis.

SU-SLAC has also been strongly involved in DOE’s education and outreach programs, pioneering science teacher training and hands-on summer workshops, as well as ongoing development of both virtual and physical visitor outreach centers.

The SU-HEPL located on the Stanford campus, has managed and/or built several flight instruments during the past 20 years. The calorimeter for the Energetic Gamma-Ray Experiment Telescope (EGRET) was built at SU-HEPL. The EGRET instrument was calibrated, before integration with the CGRO S/C, at SLAC. Several members of the EGRET Instrument team at Stanford University, including the IPI on this proposal, are members of the GLAST LAT team. Furthermore, SU-HEPL was involved with both the Michelson-Doppler Imager (MDI) instrument on SOHO, and the Confined Helium Experiment (CHEX) recently flown on the Space Shuttle.

### 1.1.5.2 Sonoma State University (SSU)

Sonoma State University brings strong experience in NASA education and public outreach programs. This includes participating in outreach programs for GSFC's LHEA, and involvement in the SWIFT E/PO program.

### 1.1.5.3 Goddard Space Flight Center (GSFC)

Goddard Space Flight Center's (GSFC) Laboratory for High Energy Astrophysics (LHEA) has had extensive experience designing and building successful X-ray, gamma-ray, and cosmic-ray telescopes for space flight applications. In LHEA, a broad program of experimental and theoretical research is conducted in all phases of astrophysics associated with high-energy particle and quanta produced in the interactions with their environments. Experiments are designed, built, tested and flown on balloons, rockets, Earth satellites and deep space probes. The resulting data are analyzed and interpreted by Laboratory scientists and their associates in the larger high-energy astrophysics community. Laboratory scientists have developed a broad range of instrumentation including quantum calorimeters and thin-foil grazing incidence optics for X-ray spectroscopy, imaging detectors for high-energy gamma-rays, CdZnTe and isotropically enriched germanium detectors for gamma-ray line spectroscopy, and superconducting magnet spectrometers for energetic particle studies.

Of particular relevance to the GLAST mission, LHEA was the lead organization for the EGRET experiment on CGRO and the project lead for the CGRO mission. LHEA scientists designed the particle-tracking detector (spark chamber) for EGRET and have led the EGRET instrument operations team that included scientists from Stanford University. This breadth of experience is available to the GLAST LAT team. These programs are particularly relevant to the GLAST LAT development program in that they represent the capabilities of the LHEA that will design and produce the ACD subsystem for the GLAST LAT and will coordinate the multi-wavelength observations that the LAT science program requires.

### 1.1.5.4 Naval Research Laboratory (NRL)

The Naval Research Laboratory is the Navy's corporate laboratory. NRL conducts a broadly-based multidisciplinary program of scientific research and advanced technological development directed toward maritime applications of new and improved materials, techniques, equipment, system, and ocean, atmospheric, and space sciences and related technologies. NRL was commissioned in 1923 by Congress for the Department of the Navy. Today it is a field command under the Chief of Naval Research and has approximately 3,300 personnel (over 1900 research staff—nearly half of these PhD's) who address basic research issues concerning the Navy's environment of sea, sky, and space.

NRL has conducted basic research and development in the space sciences for over five decades. The Space Science Division (SSD) was formed in the 1960s and has executed pioneering space experiments in the areas of upper atmospheric, solar, and astronomical research for NASA, DoD, and other agencies. Currently, NRL's SSD designed and operates the Oriented Scintillation Spectrometer Experiment (OSSE) for NASA's Compton Gamma Ray Observatory (CGRO), LASCO on the SOHO mission, BCS for the YOHKOH mission, and supports the Solar Ultraviolet Spectral Irradiance Monitor (SUSIM) for NASA's Upper Atmospheric Research Satellite (UARS) and the Atmospheric Laboratory for Application and Science (ATLAS) missions. SSD developed three experiments, each produced at very low cost, for the Advanced Research and Geophysical Observation Satellite (ARGOS), launched in February 1999 by the U.S. Air Force Space Test Program (STP). One of these experiments, the NRL-801 (USA) Experiment contains the DOD's first testbed for comparison of hardware and software techniques for computing in space. The techniques applied in the testbed are directly applicable to the GLAST data acquisition system. NRL operates the Background Data Center (BDC) maintaining background phenomenology data collected by DoD programs. The Space Science Division is also supported by NRL's Naval Center for Space Technology that built and launched the CLEMENTINE spacecraft in less than 25 months, demonstrating a successful implementation of the fast and inexpensive paradigm for small- and medium-sized missions. These past programs demonstrate the technical expertise, management skills and array of resources available within the GLAST team at NRL's Space Science Division, to fulfill its leadership responsibilities in the development and fabrication of the GLAST calorimeter subsystem and its key responsibilities in the development of hardware and software for the GLAST data acquisition subsystem.

#### 1.1.5.5 Service d' Astrophysique, Laboratorie du Commissariat a l'Energie Atomique(CEA)

The Département d'Astrophysique, de Physique des Particules, de Physique Nucléaire et d'Instrumentation Associée (DAPNIA) of the Commissariat à l'Energie Atomique (CEA) at Saclay conducts a broad program of experimental and theoretical research in astrophysics, particle physics, and nuclear physics. Inside DAPNIA, the Service d'Astrophysique (SAp) is a renowned space astrophysics laboratory. Its research interests cover high-energy astrophysics and compact objects, star formation and evolution, large-scale structures and cosmology, with a particular emphasis for several years on a multi-wavelength interpretation of the sources. The discovery of micro-quasars illustrates the success of this approach. SAp has long been engaged in space-based and ground-based instrumentation. Its successful contributions to high-energy satellites (e.g. HEAO3-C2, COS-B, GAMMA-1, GRANAT-SIGMA, Ulysses, XMM, INTEGRAL) and telescopes (ASGAT, CAT), to infrared space detectors (ISO-ISOCAM, CASSINI-CIRS) and telescopes (VLT-VIZIR), to SOHO-GOLF, has largely contributed to the laboratory international image. This breadth of experience is available to the LAT team. SAp has adopted FIRST and GLAST as its highest priority programs for the near future. The laboratory receives strong support from the large technical groups of DAPNIA. The detector development group (SED), who designed and built many high-energy particle detectors and calorimeters, will be part of the LAT effort, as well as the microelectronics group (SEI) who have developed DMILL technology and have long designed full custom ASIC's for experimental physics and space applications. The instrumentation developments take advantage of a long-established and close collaboration between scientists and engineers, as well as across the three disciplines of DAPNIA.

#### 1.1.5.6 Ecole Polytechnique, Saclay France

Inside the Centre National de la Recherche Scientifique (CNRS), the Institut de Physique Nucléaire et de Physique des Particules (IN2P3) has 16 laboratories in high-energy physics among which three are part of the LAT effort, namely, Laboratoire de Physique Nucléaire des Hautes Energies at Ecole Polytechnique (LPNHE-X), Physique Corpusculaire et Cosmologie (PCC) at Collège de France, and Centre d'Etudes Nucléaires de Bordeaux Gradignan (CENBG) at the University of Bordeaux. These laboratories have had a major impact on the CERN activities since the sixties. Famous results were obtained on hadrons with the hydrogen bubble chamber of B. Gregory and on Weak Currents with the Gargamelle heavy liquid chamber. In recent years, their activities covered Quark-Gluon search with NA-38 at CERN-SPS, e-p collisions on H1 at DESY, e+-e- collisions at LEP (ALEPH & DELPHI). They currently participate to the BaBAR experiment at SLAC and to construction work for LHC, in particular for the lead-tungstate crystal calorimeter of CMS. Non-accelerator activities include the construction of the underground Fréjus laboratory to run a proton lifetime experiment and, presently, a neutrino experiment, NEMO. More directly related to the GLAST mission, the three laboratories have recently developed and are now operating two atmospheric Cherenkov telescopes, CAT and CELESTE, at Thémis, in the French Pyrénées. They were joined in this effort by colleagues from CEA/DAPNIA. The camera of CAT has achieved unprecedented performance and CELESTE has opened a new window between 60 GeV and 200 GeV.

#### 1.1.5.7 Royal Institute of Technology, Stockholm Observatory, & Stockholm University, Stockholm, Sweden

There are three groups in the Stockholm area participating in the LAT collaboration. They are the Stockholm Observatory group (the University's astronomy department) under Prof Roland Svensson, the Stockholm University group under Prof Lars Bergström and the Royal Institute of Technology group under Prof Per Carlson. The three groups will geographically join at the new Stockholm Physics Center and there form a very cohesive team. These groups are involved in high-energy astrophysics with a current activity in gamma ray bursts, both observationally and theoretically. They are involved in the Integral satellite mission, in close connection with experimental groups, in particular with the AMANDA neutrino experiment. Current activities include estimating the contribution of dark matter supersymmetric particles to the gamma-ray flux and estimates of detection possibilities with GLAST. The group of Per Carlson is an experimental group strong in instrumentation. The group has designed, constructed and implemented a variety of Ring Imaging Cherenkov detectors in cosmic-ray magnetic spectrometers, including the first charge-one sensitive RICH used in cosmic ray research. They are the main analysis point of the CAPRICE experiments with recent results on atmospheric muons.

#### 1.1.5.8 University of California at Santa Cruz, Santa Cruz Institute for Particle Physics (UCSC)

The Santa Cruz Institute for Particle Physics (SCIPP) at the University of California at Santa Cruz (UCSC) has extensive experience with large-scale, silicon-strip detector based particle-tracking detectors, and has collaborated closely with SU-SLAC on several projects, the most recent being the BABAR detector.

SCIPP is one of the ORU's (Organized Research Units) funded by the University of California. It is housed on the UC campus in Santa Cruz, California, close to its sister institution, Lick Observatory, which allows close scientific and technical interactions between the two institutions. In its 20 years of operation, SCIPP has contributed significantly to scientific and technical progress, not only in accelerator-based elementary particle physics, but also in particle astrophysics theory and experiment (SCIPP provides the largest group participating in the large air-shower detector, Milagro, at Los Alamos). SCIPP has built a reputation for its expertise in instrumentation. In addition, SCIPP personnel have held important managerial positions in a number of large scientific construction projects.

UCSC's involvement with silicon microstrip detectors began in the 1980's with major contributions to the construction of the first silicon-strip detector system used in a colliding beam experiment. Since then, SCIPP has introduced many novel technologies into the field of silicon-strip detector systems, especially low-power, low-noise and radiation-hard ASICs. In all cases, the ASICs and electronics modules have been designed and tested in the SCIPP Microelectronics Laboratory and then delivered to the experiment. This includes the Zeus project at DESY in Hamburg, the BABAR project at SLAC and the ATLAS project at CERN, as well as the development of the silicon-strip readout electronics for the GLAST LAT.

UCSC's personnel have contributed to software development and management in several large collaborations. Expertise exists in tracking code development (Mark3, Mark2, SLD, Zeus, BABAR) and the overall organization of a large computing effort (SLD, BABAR).

UCSC also has an active education and outreach program for teachers and undergraduates from groups under-represented in science.

#### 1.1.5.9 Instituto Nazionale di Fisica Nucleare (INFN), Italy

The Italian Institute for Nuclear Physics (INFN) has several laboratories which are world renowned for their expertise in instrument design, fabrication and testing. They have been especially active in the development of large-scale silicon microstrip detector systems, for example in the ALEPH and L3 experiments in collaboration with CERN, in the BABAR experiment in collaboration with SU-SLAC, and on the AMS mission recently flown on the shuttle.

#### 1.1.5.10 University of Tokyo, Institute for Cosmic-Ray Research (ICRR), Institute for Space and Astronautical Science, and Hiroshima University

The University of Tokyo is the leading research university in Japan. It has conducted research in all fields of science since its establishment in the mid 19th century. Many world-class research laboratories in particle, nuclear, space, and astrophysical sciences were first founded by its faculty on one of its several campuses. The National Accelerator Lab. (KEK), Inst. for Space and Astron. Sci. (ISAS), National Astronomical Observatory (NAO), Institute of Cosmic Ray Research (ICRR) with Kamioka Neutrino Facility are among them. The Physics Department now leads many ambitious R/D projects in Japan, US, and Europe. ICRR hosts two large international projects, the Super-Kamiokande neutrino experiment and the CANGAROO gamma-ray telescope array in Australia. ISAS has been a world research center in satellite-based science research and has successfully hosted international scientific missions such as GINGA, ASCA, and YOKOH. The Institute is about to launch its next international mission, Astro-E.

Hiroshima University was established as one of the two elite "Ecole Normals" in Japan. Its Physics Department has played a leading role in silicon strip detector development for accelerator experiments in the US and Europe

## 1.1.6 Commitment and Experience of Key Personnel

### 1.1.6.1 Key Positions

- *Instrument Principal Investigator:* Prof. Peter Michelson of Stanford University has the overall responsibility for the proposed investigation and has the decision-making authority for the proper conduct of the GLAST LAT investigation. GLAST is Prof. Michelson’s principal responsibility and interest and has his full attention for the research portion of his time (67% of full-time; the remaining time is divided between teaching responsibilities, including supervision of graduate students who will work on the GLAST program, and university & departmental responsibilities). Prof. Michelson has more than 10 years of experience in space science, including the past 9 years as a co-investigator and the Stanford University lead on the EGRET instrument team. He has a Ph.D. in Physics from Stanford University (1979) and currently holds faculty appointments at both the Physics Department, Stanford University and at SLAC.
- *Instrument Project Manager:* William Althouse is responsible for the day-to-day execution of the GLAST LAT design, construction, testing, and delivery. Authority of the IPM is delegated from the IPI. Mr. Althouse will be responsible for maintaining development of the GLAST LAT within the cost and schedule plan baselined in this proposal and as modified during the Formulation Phase. Mr. Althouse served as Project Manager or Deputy Project Manager for science instruments on the International Solar Polar Mission, Voyager, International Sun-Earth Explorer 3, and Interplanetary Monitoring Platforms 7 and 8; he also served as Chief Engineer for the Laser Interferometer Gravitational- Wave Observatory Project during the concept and formulation phases, responsible for management, control and accountability of LIGO configuration, schedule, cost, quality assurance and safety. Mr. Althouse will be dedicated 100% time to this project.
- *Instrument Technical Manager:* Prof. Tuneyoshi Kamae is responsible for coordinating the technical development of the LAT instrument, and he chairs the Instrument Design Teams that report to the IPM. His authority is delegated from the IPM. Prof. Kamae has more than 25 years of experience in experimental elementary particle physics and 10 years of experience in high-energy astrophysics. He is the Principal Investigator of the hard X-ray experiment soon to be launched on Astro E. Professor Kamae is currently Professor of Physics at the University of Tokyo and will be Professor at SLAC, beginning April 1, 2000. During the entire development of the GLAST LAT, Kamae will spend 100% time on the project, with most of the time at SU-SLAC. While at SU-SLAC he will devote 50% of his time in the role of ITM, and 50% time in the management of the GLAST science research functional group. He will also be the Lead Japanese Scientist on the project until April 2000, at which time Prof. Ohsugi will become the principal contact in Japan. Prof. Kamae has a Ph.D.

degree in Physics from Princeton University (1968).

### 1.1.6.2 Key Personnel at Stanford University

- ***Instrument System Engineer.*** Tim Thurston is the acting system engineer. He reports to the IPM and is responsible for the overall flow-down of requirements to the subsystem level for the instrument; for tracking of requirements and margins; and for establishing performance specifications, verification and test plans, and interface documents. The ISE will be 100% time on the GLAST project. Thurston is the SLAC Research Division Chief Engineer, and has more than 25 years of project experience in both high-energy physics and space systems, including work at the Kennedy Space Center, in the SDC experiment at the SSC, and in aerospace and nuclear testing support systems. He received a NASA Team Achievement Award in 1997. An offer has already been made to a highly qualified individual to join SLAC staff to serve as the full-time, permanent GLAST Instrument System Engineer.
- ***Electronics System Engineer.*** Dr. Gunther Haller reports to the ISE and is responsible for the flow down of requirements concerning electronics, power distribution, and EMI, to the subsystem level for the instrument; for tracking of requirements and margins in these areas; establishing electronics performance specifications, verification and test plans, and electronics interface documents Dr. Haller was electrical systems engineer for the SLD and BABAR high-energy physics particle detectors. Dr. Haller will devote 100% of his time to the project.
- ***Software System Manager.*** Dr. Richard Dubois reports to the ISE and is responsible for the overall coordination of software development activities and for the development and execution of the SQA plan including software configuration management. Dr. Dubois will devote 100% of his time to the project.
- ***Integration & Test Manager / Grid Manager.*** Mr. Martin Nordby reports to the IPM and is responsible for developing and maintaining procedures and schedules for the instrument I&T phase including electrical and mechanical integration and the instrument environmental test program. Mr. Nordby is also the manager of the instrument grid development. He brings 15 years of experience in the development of mechanical systems for high-energy physics detectors and accelerators, including cryogenics and ultra-high vacuum technologies. He recently completed management of the construction and installation of the PEP-II interaction region, and integration of the PEP-II collider with the BABAR detector. Mr. Nordby will devote 100% of his time to the project.
- ***Instrument Operations Center Manager.*** Dr. Scott Williams reports to the IPM and is responsible for the development and delivery of the Instrument Operations Center and for supporting instrument operations and data acquistion during integration, test and flight. Dr. Williams has 14 years of experience with spacecraft operations, was a Co-Investigator and Operations Director for the Shuttle Electrodynamic Tether System experiment on STS-46 and STS-75, developed the Mission Operations Plan for the Michelson Doppler Imager on SOHO, and managed MDI launch and on-orbit commissioning from the SOHO Experiment Operations Facility at GSFC. Dr. Williams will devote 100% of his time to the project.
- ***Data Acquisition System (DAQ) Manager***. Dr. Roger Williamson reports to the IPM and is responsible for the development and delivery of the LAT instrument data acquisition system. Dr. Williamson has 30 years of experience in space flight related work including Spacelab 1 and 2, and, most recently, he has been manager of electronics and the DAQ for the Confined Helium Experiment (CheX) that was launched in November 1997 on the shuttle. Dr. Williamson will be 100% time on the GLAST LAT project. Dr. Williamson has been the DAQ technology development manager during the technology development program.

### 1.1.6.3 Key Personnel at Sonoma State University

- ***Education and Public Outreach Coordinator.*** Prof. Lynn Cominsky reports to the IPI and is responsible for the GLAST/LAT E/PO program. Dr. Cominsky is Professor of Physics and Astronomy at Sonoma State University (SSU), and has served as Chair of the Public Affairs Working Group for the NASA GLAST Facility Science Team for the past two years. As part of this work, (and with the help of SSU undergraduate physics student Tim Graves) she created the GLAST outreach Web site: http://www-glast.sonoma.edu. She is also a member of the E/PO team for Swift, a gamma-ray burst MIDEX mission that will be launched in 2003. An author of over 45 research papers in high-energy astronomy, in 1993 Prof. Cominsky was named the Outstanding Professor at Sonoma State University and the California Professor of the Year by the Council for Advancement and Support of Education. Cominsky is also Deputy Press Officer for the American Astronomical Society, Press Officer for the AAS High Energy Astrophysics Division, and the PI on SSU's successful "Space Mysteries" NASA LEARNERS proposal (developed with Dr. Laura Whitlock.) Prior to joining the SSU faculty, Cominsky managed various parts of NASA's Extreme Ultra-Violet Explorer satellite project at the University of California Berkeley's Space Sciences Laboratory, serving as Software, Operations and Data Analysis group Administrator and the Science Payload Development Manager. In this latter position, she supervised over 70 engineers, technicians, scientists and programmers, and controlled a multi-million dollar yearly budget. Prof. Cominsky will devote 50% of her time to the project.

### 1.1.6.4 Key Personnel at Goddard Space Flight Center

- ***Instrument Scientist*.** Dr. Steven Ritz, Laboratory for High Energy Astrophysics at Goddard Space Flight Center, reports directly to the IPI and is responsible for monitoring the flight instrument design and construction; for coordinating the necessary instrument and science simulations to support these activities. Dr. Ritz will advise the IPI on all matters that affect the scientific performance of the instrument. Dr. Ritz will devote 100% time to the GLAST project. Dr. Ritz received a Ph.D. degree in Physics from the University of Wisconsin-Madison (1988) and was Associate Professor of Physics at Columbia University from 1990 to 1998. Dr. Ritz has extensive experience with high-energy particle physics detectors. He was responsible for the design, development, and production of major elements of the readout and DAQ system for the ZEUS experiment at HERA, the world’s only lepton-hadron collider. He also has extensive experience with data analysis in a wide variety of science topics.
- ***Anticoincidence Detector (ACD) Manager.*** Dr. Jonathan Ormes, Laboratory for High Energy Astrophysics at Goddard Space Flight Center, reports to the IPM and is responsible for the development and delivery of the instrument ACD subsystem. Dr. Ormes will devote 60% of his time to the project. Dr. Ormes is currently the Project Scientist for the Advanced Composition Explorer (ACE) mission.

### 1.1.6.5 Key Personnel at the Naval Research Laboratory

- ***Calorimeter Manager.*** Dr. W. Neil Johnson reports to the IPM and is responsible for the development and delivery of the instrument calorimeter subsystem. Dr. Johnson has been the manager of calorimeter technology development. For matters concerning the calorimeter, he is the principal technical interface to the calorimeter effort in France. Dr. Johnson has over 30 years of experience in design, fabrication, and operation of gamma-ray experiments for space-based platforms. As project scientist, he was responsible for the design, implementation, and operation of the OSSE experiment on CGRO. Dr. Johnson received a Ph.D. degree in Physics from Rice University (1973). Dr. Johnson will devote 65% of his time to the project.

- ***NRL DAQ Task Manager.*** Dr. Kent S. Wood reports to the DAQ Subsystem Manager and is resonsible for the NRL DAQ tasks. Dr. Wood has been responsible for the NRL development of the DAQ CPU during the technology development and demonstration phase. He is currently the PI on the USA Experiment flying on the ARGOS satellite. This experiment includes the first DOD testbed for space computing. Dr. Wood will devote 65% of his time to the LAT project.
- ***NRL DAQ Engineer.*** Dr. Michael Lovellette oversees the day-to-day engineering coordination of the NRL DAQ tasks and reports to Dr. Wood. Dr. Lovellette will devote 80% of his time to the LAT project.

### 1.1.6.6 Key Personnel in France

- ***French Lead Scientist.*** Prof. Isabelle Grenier, CEA/DAPNIA and University of Paris, is the prime point of contact between the IPM and Calorimeter subsystem manager, and the French GLAST team, and has overall responsibility for the delivery of components of the GLAST calorimeter as specified in the MOA and SOWs pertaining to the calorimeter. Prof. Grenier will also serve on the GLAST SWG and is a member of the Senior Scientist Advisory Committee. Prof. Grenier will devote 80% of her time to the project.
- ***French Deputy Lead Scientist.*** Prof. Patrick Fleury, IN2P3/Ecole Polytechnique, is responsible for the scientific oversight of the technical development work in France. Prof. Fleury is a member of the Senior Scientist Advisory Committee. Prof. Fleury has more than 30 years experience in experimental particle physics. He started both the CAT and CELESTE projects in Europe and is the former director of the LPNHE laboratory at the Ecole Polytechnique. Prof. Fleury will devote 80% of his time to the project.
- ***French Project Manager***. Dr. Philippe Lavocat, CEA-Saclay, is responsible for the day-to-day management of the GLAST LAT calorimeter tasks in France. He reports to Prof. Grenier and to the Calorimeter Manager on matters concerning the calorimeter development. Dr. Lavocat will devote 100% of his time to the project.

### 1.1.6.7 Key Personnel in Sweden

- ***Lead Swedish Scientist.*** Prof. Per Carlson, Royal Institute of Technology, is the prime point of contact between the IPM and Calorimeter subsystem manager and the Swedish GLAST team. Prof. Carlson is responsible for the procurement of the CsI crystals for the calorimeter subsystem. Prof. Carlson will devote the remaining 25% of his time to the project.

### 1.1.6.8 Key Personnel at the University of California at Santa Cruz

- ***Tracker Manager.*** Prof. Robert Johnson reports to the IPM and is responsible for the development and delivery of the instrument tracker subsystem. Prof. Johnson has been the tracker technology development manager. Prof. Johnson has more than 10 years of experience working on large particle physics experiments. In 1986 he worked on the design and construction of the large time-projection chamber for the ALEPH experiment at CERN. More recently, he played a critical role in the development of the readout electronics ASIC for the silicon-strip vertex detector of the BABAR experiment, collaborating with Lawrence Berkeley National Lab and INFN, Italy. Prof. Johnson received a Ph.D. degree in Physics from Stanford University (1986). Prof. Johnson will devote 75% of his time to the project, with the remaining 25% time devoted to teaching.

### 1.1.6.9 Key Personnel in Italy

***Italian Lead Scientist.*** Prof. Guido Barbiellini is the prime point of contact between the IPM and Tracker subsystem manager and the Italian GLAST team, and has overall responsibility and scientific oversight of the technical development work in Italy and for delivery of components of the GLAST tracker as specified in the MOA and SOWs pertaining to the tracker. Prof. Barbiellini will also serve on the Senior Scientist Advisory Committee and will devote 50% time to the GLAST project.

***Italian Project Manager.*** Responsible for the day-to-day management of the GLAST LAT tracker tasks in Italy, and reports to the Tracker

**Table 1.1.4:** *Financial and Contractual Relationships*

| Organization | Contractual Relationship(s) | Assumed Start Date | Comments |
|---|---|---|---|
| Stanford University | Contract from NASA<br>Contract from DOE | April 1, 2000<br>April 1, 2000 | As specified in NASA AO<br>DOE participation governed by Stanford/ SLAC contract with DOE |
| Sonoma State University | Subcontract from SU | April 1, 2000 | |
| Goddard Space Flight Center | MOA with SU | April 1, 2000 | Draft MOA exists defining reporting requirements |
| Naval Research Laboratory | MOA with SU | April 1, 2000 | Draft MOA exists defining reporting requirements; funding of effort through NASA Defense Purchase Request (Economy Act Order) |
| CEA/DAPNIA-(Saclay) & IN2P3 | MOA with SU-SLAC | May 15, 2000 | Draft MOA exists; will be finalized within 6 weeks of selection |
| Royal Institute of Technology, Stockholm University, and Stockholm Observatory | MOA with SU-SLAC | May 15, 2000 | Draft MOA exists; will be finalized within 6 weeks of selection |
| University of California at Santa Cruz | MOA with SU-SLAC | April 1, 2000 | Draft MOA exists; will be finalized within 6 weeks of selection |
| University of Tokyo, Institute for Cosmic-Ray Research, Hiroshima University, & Institute for Space and Astronautical Research | MOA with SU-SLAC | May 15, 2000 | Draft MOA exists; will be finalized within 6 weeks of selection |
| INFN and ASI | MOA with SU-SLAC | May 15, 2000 | Draft MOA exists; will be finalized within 6 weeks of selection |
| Lockheed-Martin ATC | Subcontract from SU-SLAC | May 15, 2000 | |

Manager. Pending award of contract, a project manager will be appointed.

### 1.1.6.10 Key Personnel in Japan

- ***Japanese Lead Scientist***. Prof. Tuneyoshi Kamae, currently represents the Japanese GLAST collaboration (JGC) and is the prime point of contact between the IPM and Tracker subsystem manager and the JGC. He is responsible for the scientific oversight of the technical development work in Japan and for the delivery of detector components of the GLAST tracker as specified in the MOAs and SOWs pertaining to the tracker. Beginning April, 2000, Prof. Kamae will also be the Instrument Technical Manager and holds a Professor position at SU-SLAC. At that time, Professor Ohsugi will become the prime point of contact with the JGC.
- ***Tracker Detector Scientist.*** Prof. Takahashi Ohsugi, Hiroshima University, is responsible for the day-to-day technical oversight of silicon detector development and production in Japan. Prof. Ohsugi was the subsystem manager for the DAQ and trigger system for the TRISTAN-VENUS experiment at KEK and was deputy manager of the SDC silicon central tracking system for the SSC. Recently, he was in-charge of the development and production of silicon-strip detectors for the FermiLab CDF experiment vertex detector upgrade. He will devote 50% time to the GLAST project.

## 1.1.7 Financial and Contractual Relationships

The financial and contractual relationships among the GLAST LAT team organizations and contractors are summarized in Table 1.1.4 Relationships with team institutions are largely governed by MOAs. These have served past projects well by establishing concise statements of work and scope of responsibility for each team institution, along with budget and management authorities. SU-SLAC has recent experience in establishing such MOAs on other projects with all of the GLAST team institutions.

## 1.1.8 International Exchange of Information and Materials

The development, fabrication, and operation of the LAT instrument and science investigation as defined by this proposal will adhere to all applicable U.S. laws and regulations concerning the import and export of technical information and materials. Compliance with all applicable laws and regulations is written into all MOAs with foreign collaboration members.

## 1.2 MANAGEMENT PROCESSES AND PLANS

The GLAST Instrument Project is managed by way of a heirarchical WBS, with all work package budgets and schedules captured in an integrated project schedule (IPS). System and subsystem technical requirements and parameters are baselined and managed, with configuration control handled by a change control board (CCB). The CCB reviews and controls all proposed changes of scope, requirements, design, and cost and schedule, and authorizes implementation of these changes in the Project Management Control System (PMCS).

These management processes are detailed in the following sections.

### 1.2.1 Decision-Making Processes

The WBS and organization structure define the limits of individual authority and responsibility relative to cost, schedule, and technical requirements. At the top level, the Instrument Principal Investigator, Instrument Project Manager, and the Instrument Technical Manager jointly establish overall project goals including budget allocations, program master schedules and the top-level program technical requirements. The IPI is the final authority regarding changes that affect project scope while the IPM is the final authority on the allocation of overall resources, schedules and requirements among the second level WBS elements. System and subsystem specifications, Interface Control Documents, program master schedules and WBS budgets define the scope of each second level function. The subsystem manager has the authority to establish and maintain cost, schedule and requirements flow-downs within the second level function so long as they do not impact the master schedule critical path, increase budgeted expenditure requirements above budget limits, or impact requirements established in the Specifications. The subsystem manager establishes and controls the scope of all third level WBS elements within the second level WBS.

End item configuration, WBS master schedules and WBS budgets define the scope of each third level function. The WBS third level task manager has the authority to establish and maintain cost, schedule, and requirements flowdowns within the third level function so long as they do not impact the master schedule critical path, increase budgeted expenditure requirements above the budget limits or impact requirements established in the associated configuration end item specification. The third level Task Manager establishes and controls the scope of all fourth level WBS's within the third level WBS. As the program progresses, it is recognized that revisions to requirements, schedules and budgets will be necessary. As long as changes are within a particular WBS manager's scope of responsibility, and externally imposed constraints (requirements, interfaces, schedule milestones, or the program critical path) are not impacted, no approval is required of any "higher authority." Coordination and feedback are assured as all changes are recorded by the central PMCS and identified at periodic program reviews.

The central theme of decision making in the LAT Project is that each key individual listed above understands the roles and responsibilities of all other key individuals and has the necessary knowledge, commitment and experience to coordinate appropriately with all other key individuals on the program as necessary. This allows decisions to be made at the proper level with the minimum of unnecessary control. Responsiveness of the program is thus improved and the costs associated with formal approval processes are minimized.

Key decisions made by the LAT IPO will be regularly reviewed by the SLAC director and director of research as part of regularly scheduled weekly meetings with the IPO (IPI, IPM, and ITM).

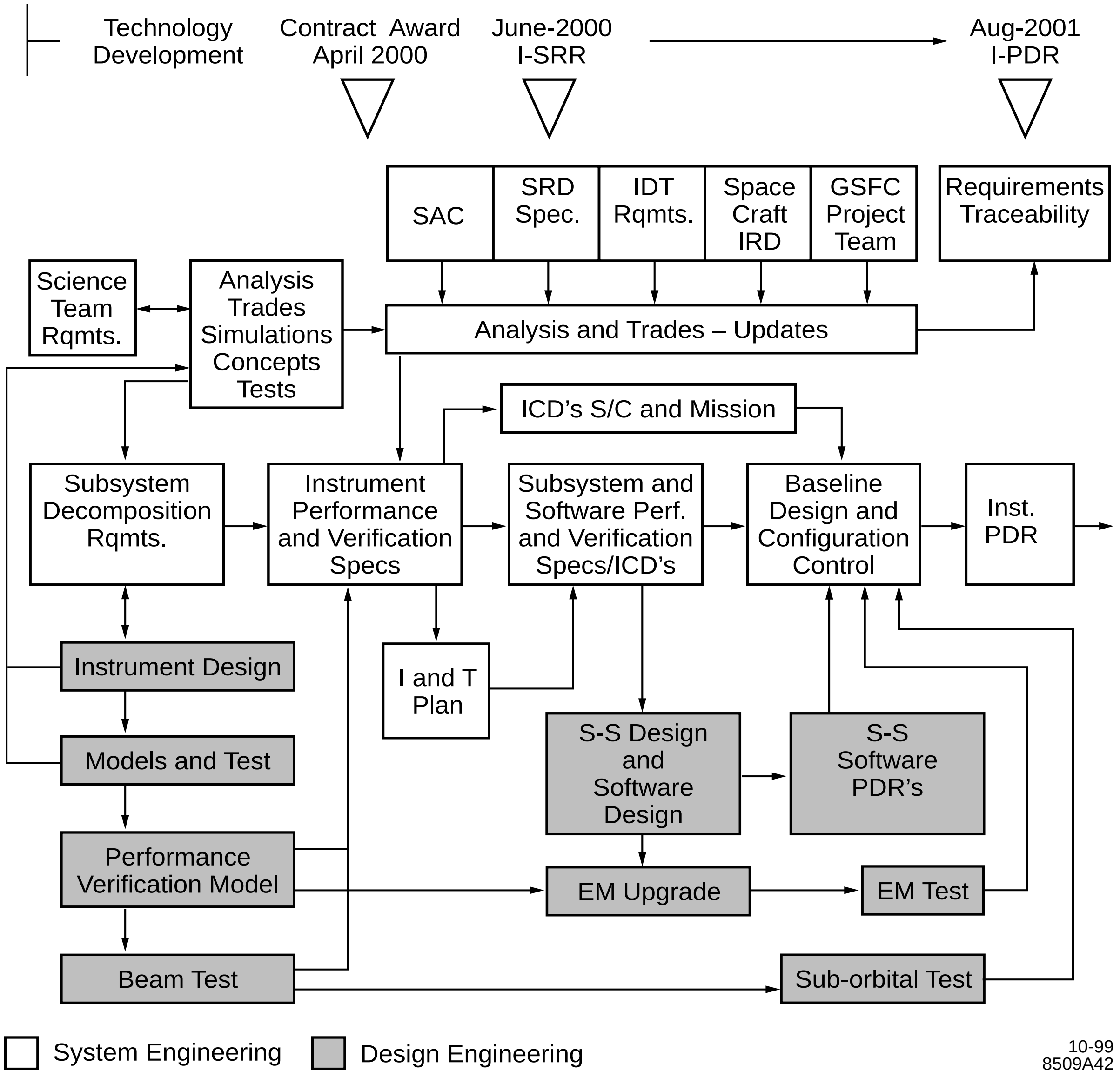
Soon after contract award, a GLAST project management workshop will be held with emphasis on the formulation-phase execution and preparation for rigorous planning of the implementation phase.

All WBS Level 3 managers and the IPM and project controls will participate. The GSFC project manager is encouraged to attend.

### 1.2.2 System Engineering & Integration

The LAT management process for instrument development uses an intensive System Engineer-

**Figure: 1.2.1:** System Engineering Process through PDR



ing activity to complete the Formulation Phase (Phase B) as depicted in Figure 1.2.1.The development approach utilizes all applicable design criteria, analysis, support, test precedents, lessons learned, environment and safety procedures and a distributed collaborative engineering methodology. The emphasis during Formulation Phase is to maximize the science benefit in the further development of the instrument, to formalize the products and processes needed to deliver the instrument and place them under configuration control, and to design to cost.

The ISE is responsible for performing the system trades, decomposition of requirements, developing GLAST Instrument System Specifications and, in conjunction with subsystem engineering staffs, developing the subsystem specifications and design verification plans and ICDs between subsystems. All requirements will be formalized, documented, traced, and verified with a requirements traceability software tool. This will provide a flexible, responsive, easy-to-use capability that will assure that all requirements are met and are traceable through the life of the mission.

The ISE is also responsible for performing the design integration function. The ISE and his team will assure that when the complete instrument is integrated, it will perform all the functions required of the entire system. This design integration function includes defining all connectors and wiring harnesses, and flex cables which interconnect the subsystems, and connect the instrument to the spacecraft. The ISE will also define and control the telemetry and command functions for the instrument. Operational modes with corresponding duty cycles and power usage models will be developed.

The ISE will also develop and control the ICDs between the instrument and spacecraft and instrument and ground systems and mission operations. As such, the ISE is the principle interface during physical integration and test activities.

Furthermore, the ISE has the primary responsibility for establishing technical interchanges with the spacecraft supplier after award of the spacecraft bus contract. In the early stages of the program we will assist the spacecraft supplier in understanding bus/telescope interface requirements and developing the required Interface Control Documents. This contact will also initiate the technical relationships needed during spacecraft integration and launch operations.

The instrument system engineering and management teams will participate in spacecraft design reviews to further ensure the correct flow of information and invite representatives from the spacecraft team to our reviews. Adjustments to requirements and schedules resulting from the review process will be made in full-cooperation with the spacecraft supplier and GSFC Project Team.

We will support mission simulation tests with the integrated spacecraft from both the supplier facility and SU-SLAC. The relationships developed with the spacecraft supplier during integration and test will contribute to successful collaboration during launch vehicle integration activities at the launch site, launch operations, and on-orbit checkout.

The IDT, chaired by the ITM, provides critical support to the system engineering effort. This team, composed of all subsystem and system-level managers with direct hardware, software, or integration responsibilities, will be responsible for assuring closure of all technical and implementation issues. It will also serve as the primary means by which conflicting requirements or subsystem problems and issues are identified and resolved. The IDT will meet weekly (via video conference) during Formulation and Implementation Phases of the instrument project. Action items from these meetings will be recorded, maintained, and circulated by the ISE.

The System Engineering activities during Implementation Phase are depicted in Figure 1.2.2. In support of the IPM, the ISE will also strive to control overall instrument development and implementation cost. The methods to be used by the ISE include:Value engineering

- Capping the design effort, and designing to cost
- Emphasizing validation testing during process development
- Minimizing the use of engineering models
- Reducing new technologies in the design.

The use of a distributed collaborative engineering process will play a key role in reducing the cost and risk associated with implementing an instrument such as GLAST. This process will draw on the past management experience of SU-SLAC, by using video-conferencing, strong project-based management, and selective team meetings to connect the geographically dispersed teams.

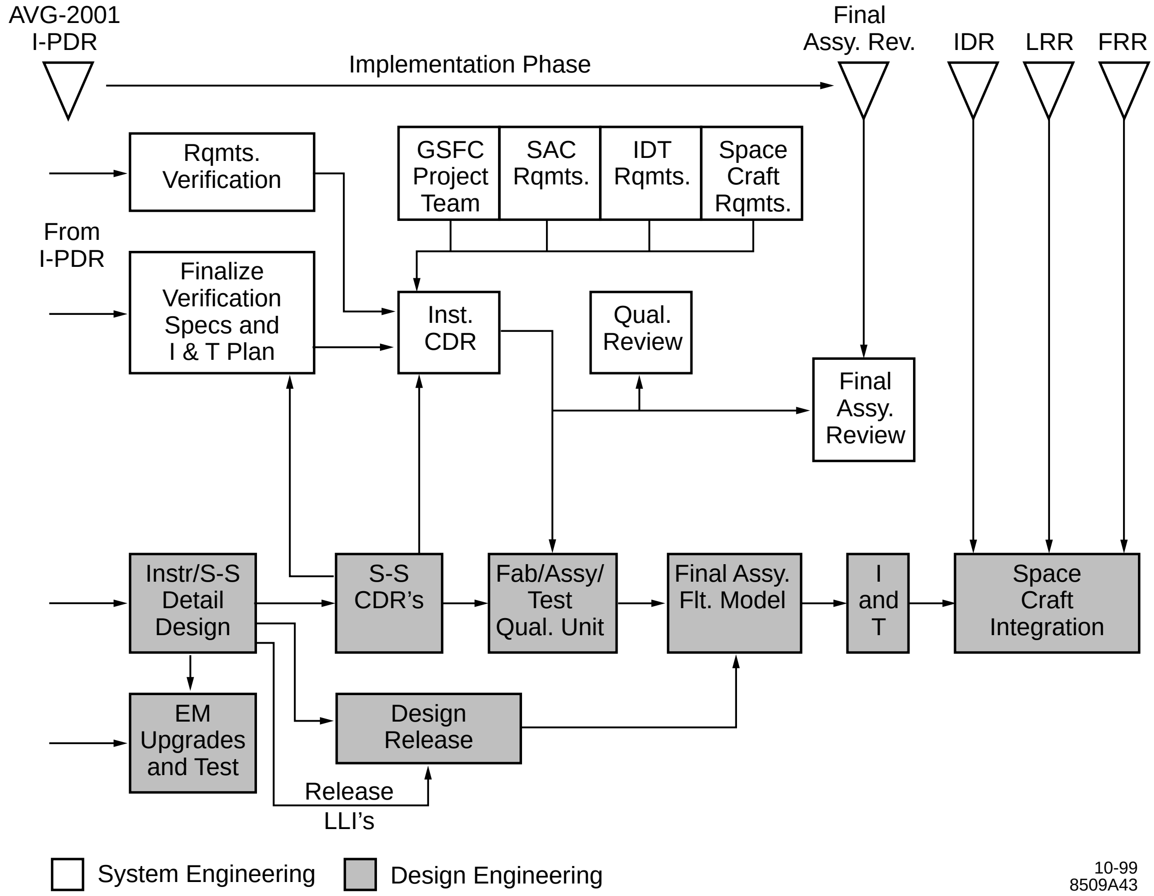
### 1.2.2.1 Requirements Development

The primary sources for GLAST instrument requirements are:

- AO Flight Investigation and SRD requirements
- GLAST Facility Science Definition Team requirements
- Science Working Group requirements
- Instrument Design Team requirements
- Space Craft Interface Requirements Document
- GSFC Project Team Requirements
- Derived Requirements by each subsystem

The ISE is responsible for assuring that all requirements are: 1) accurately defined (complete and unambiguous); 2) appropriately allo-

**Figure: 1.2.2:** System Engineering Process through Implementation Phase



cated to the GLAST subsystem elements; 3) verified, thoroughly documented, and rigidly controlled by configuration management techniques.

All requirements will be documented online, allowing for rapid access throughout the geographically distributed engineering team, for the life of the mission. They will be stated in clear operational terms, allowing maximum flexibility to meet mission objectives. Throughout the life of the mission, changes to this document must adhere to the configuration management process approved by the IPM & IPI (outlined in Sect. 1.2.2.3).

To facilitate management of the system engineering requirements, the IPO is currently evaluating six requirements management software tools. Prior to contract start, the assessment will be completed and a recommendation made to the GSFC project office, so that compatibility with the GLAST mission requirements management tool is assured.

The Formulation Phase system engineering process, as depicted in Figure 1.2.1, shows the flow of requirements decomposition leading to the GLAST instrument Performance Specification and Verification Plan, the subsystem and software performance specifications, and ICDs. Specifications will be developed which accurately define the minimum acceptable performance, allowing subsystem and element engineering to develop design solutions.

### 1.2.2.2 Technical Performance Metrics

The IDT will establish technical performance metrics for instrument development during the Formulation Phase. These critical parameters will be reviewed at the SRR (June 2000) and formalized and placed under configuration control by the I-PDR (August 2001). These parameters, either directly measurable or derivable from modeling of the instrument design, represent the key performance requirements which must be met to ensure that the mission objectives are met.

The criteria for selection of a parameter for the metrics list is that, if it exceeds a critical value, it will result in impact to science, cost or schedule, requiring the implementation of a descope option, an increase to mission cost, or a slip in schedule to accommodate the variance.

The critical parameters are quantified to define the seriousness of the problem. These parameters along with cost and schedule parameters, will be monitored at a monthly project control meeting. At the time of submission of this proposal, the critical Technical Performance Parameters are those shown in Table 1.2.1. The current value of the metric is shown along with the peak or threshold requirements value for the metric. The “Trigger Point” is that point which, if exceeded, triggers an automatic review of the entire system by the IPM.

These system-level metrics are flowed down and budgeted to the subsystems by the IDT. All subsystem metric budgets are analyzed at the project control meeting, to ensure that any subsystem problems are quickly identified and appropriate corrective actions are developed with the subsystem manager.

**Table 1.2.1:** Critical Technical Performance Metrics at Proposal Submission

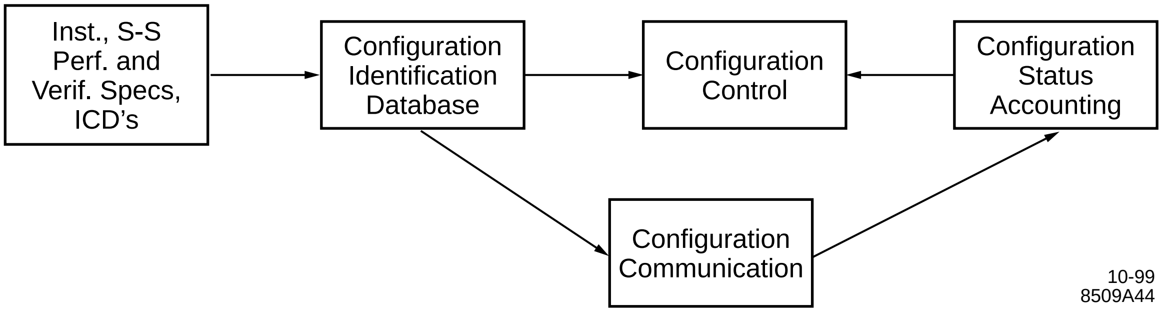
| Metric | Flight Instrument | Requirement or Constraint | Trigger Point |
|---|---|---|---|
| Instrument Mass, kg | 2556 | 3000 | 2700 |
| | | | |
| Electrical Power, W | 564 | 650 | 590 |
| Center of Gravity Offset from Instrument. Interface Plane, cm | 23.2 | 25* | 25* |
| Horizontal Dimension, m | 1.73 | 1.8 | 1.76 |
| Instrument Dead Time, µs | 20 | 100 | 40 |
| Background Rejection | $3 \times 10^5$:1 | $10^5$:1 | $10^5$:1 |
| Field of View, sr | 2.3 | 2 | 2.2 |
| Ratio of Single Photon Angular Resolutions, 95%/68% | 2.3 | 3 | 2.8 |
| Single Photon Angular Resolution (68%) @ 1 GeV, deg | 0.37 | 0.5 | 0.45 |
| Peak Effective Area, cm$^2$ | 12,000 | 8,000 | 9,000 |
| Energy Resolution @ 1 GeV, % | 7 | 10 | 9 |

** Depends on the details of instrument-interface plane definition*

### 1.2.2.3 Configuration Management

Configuration Management (CM) is the process through which the GLAST LAT Project documents the instrument’s functional and physical characteristics during its lifecycle, controls changes to those characteristics, and provides information on the state of change action. Figure 1.2.3 shows the configuration management flow to be implemented for the instrument projects. Configuration management provides the current state and description and allows traceability to all previous configurations as well as the rationale for the changes. Our process allows all engineers to design to the same set of requirements, provides visibility into the design interfaces, and supports the production of a design that meets the requirements.

**Figure: 1.2.3:** Key Elements of Configuration Management



The IPO plans to start placing requirements and design documents under configuration management shortly after the SRR. Initially, the top-level instrument requirements and key instrument design parameters will be baselined. This will then flow down to subsystem requirements, and interface design within the instrument. Early establishment and subsequent control of the product baseline will minimize program costs and contribute to schedule control through:

- Systematic and documented approach to change control.
- Careful evaluations and timely disposition of proposed changes.
- Immediate communication of change disposition to all affected personnel.
- Establishment of consistent program documentation. The project control group will operate and maintain an instrument database, which will provide a central point for control of all documentation for hardware and software. This internet-accessible database will ensure that these documents are properly recorded, controlled and distributed to the team. The database will also serve as an archive of all program documentation, furnishing the IPO with readily accessible and reliable information. Included in this database will be the status record and history of the GLAST Data Requirements List (DRL) and action items.
- This method of electronic databasing and configuration management has been successfully used in the management of both the PEP-II B-Factory project and BABAR experimental program at SU-SLAC. These projects were more complex than GLAST, with BABAR having a similarly distributed engineering and science team.
- Once baseline configuration items are established, the Change Control Board (CCB) will manage requests for changes to system-level designs and interfaces, as well as proposed draw-downs on instrument cost and technical reserves. The CCB, chaired by the IPM, reviews each engineering change request to determine its effect on the project. The CCB consists of:.
    - Instrument Project Manager
    - Instrument Technical Manager
    - Instrument Scientist
    - Instrument System Engineer
    - Subsystem representatives
    - Project Control Manager
    - I&T Manager
    - Performance and Safety Assurance Manager

The ISE will coordinate all activities pertaining to a proposed change, to ensure that the material is complete to make a decision. Changes will be classified as shown in Table 1.2.2, and changes managed as appropriate for the class, Changes approved by the CCB will result in modifications to the instrument baseline. This will be implemented by the PMCS, with all subsequent performance measured against the new baseline.This streamlined change processing system has a single-tier change review and approval system, which will avoid protracted and expensive change processing. This will assure that needed changes are managed efficiently, while all changes still fall under the configuration management process. As discussed in Sect. 1.2.4, all CCB actions will be reviewed with the SU-SLAC Director and Associate Director of Research, and reported to the GSFC Project Office.

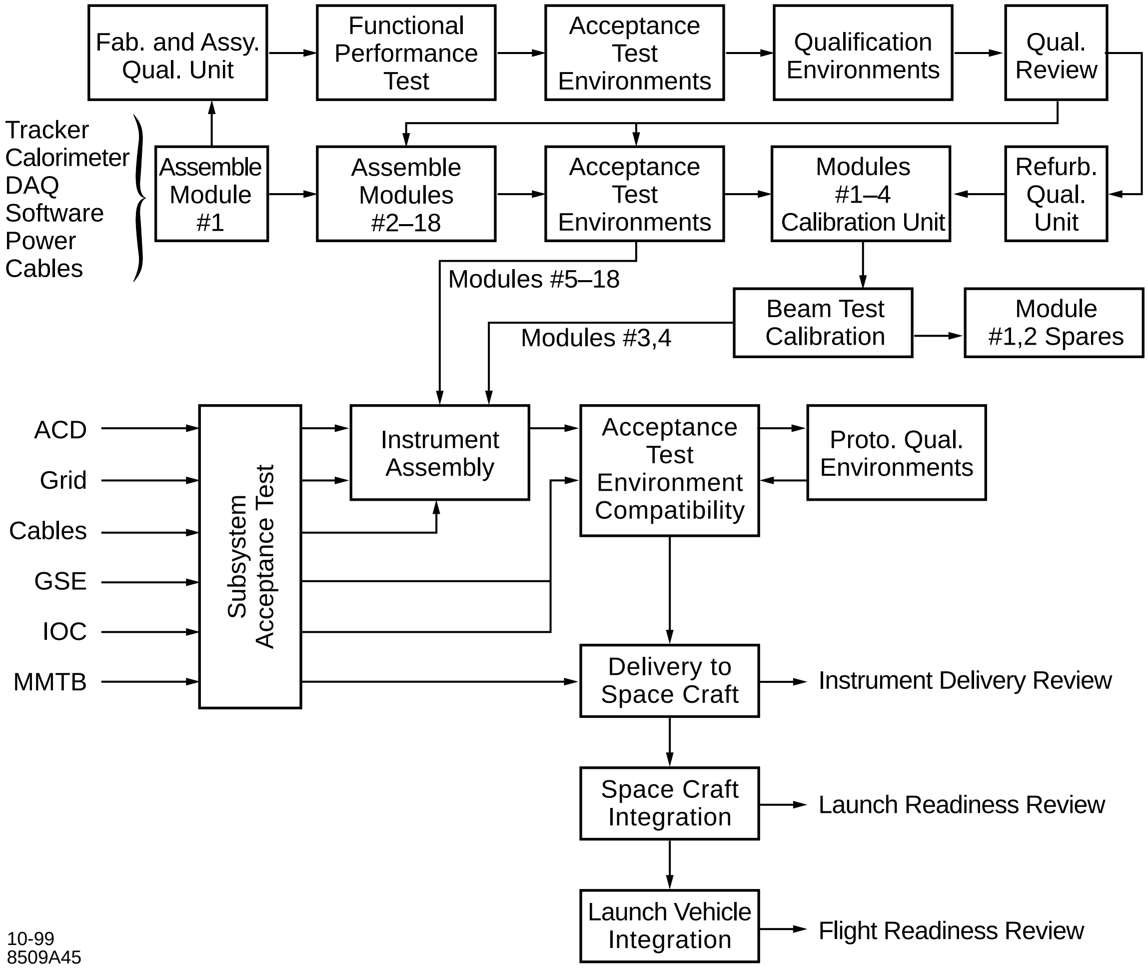
**Table 1.2.2:** Change Classifications

| Change Class | Description | Change Process |
|---|---|---|
| Class I | Affects form, fit, or function | Requires PI approval |
| Class II | Affects subsystem interfaces | Requires CCB approval, |
| Class III | Affects subsystem design | Managed at subsystem level, with CM implemented to track changes |

### 1.2.2.4 Integration, Verification, and Qualification

The IPO will implement a thorough integration and test plan, based on requirements established in the System Specification Verification Plan and subsystem Specification Plans. While the formal plan will be developed during the Formulation and early Implementation Phases, key elements of it are already understood. This

**Figure: 1.2.4:** Integration and Testing Flow



expected flow of integration and testing is depicted in Figure 1.2.4

First, GLAST instrument testing will begin at the lowest level of assembly, namely elements and subsystems. These tests will demonstrate functional performance at acceptance environment test levels, assuring that all sub-assemblies, when delivered for instrument integration, meet their requirements. Because of the modular nature of the instrument design, this testing will significantly mitigate technical and schedule risks of subsequent qualification and acceptance testing on the flight instrument.

Prior to production assembly of the flight instrument modules, one module will be assembled and tested at qualification test levels. The qualification data will be reviewed by the IDT and, when deemed acceptable, will trigger the start of assembly of modules 2 through 18. These modules will be tested at acceptance levels, to verify workmanship. The 16-module flight instrument will then be assembled and tested at proto-flight environment levels, which is an acceptable and customary approach for scientific instrument single-development models. The 18th unit after assembly and environmental test will be used as a spare, and the 1st unit, which was subjected to qualification environment tests, will be refurbished and re-tested at acceptance environments and made available as the 2nd spare. Test parameters will be derived from the GSFC GEVS-SE Specification, Revision A (June, 1996).

The I&T Manager will assemble an I&T team to lead the test effort. Representatives from each of the instrument subsystems will be present during the I&T effort to assure timely resolution of anomalies and discrepancies. The instrument environmental test will be performed at an environmental test facility to be competitively selected at the start of Implementation Phase. Upon successful completion of all tests, an Instrument Pre-Ship Review, conducted by the IPM, will trigger delivery for spacecraft integration.

Throughout the integration and test process, the I&T Manager will be responsible to record all test data with the PSAM, and deliver verification results to the ISE. The ISE will determine that requirements have been verified for all system- and subsystem-level requirements.

### *1.2.3 Integrated Project Management Control System (PMCS)*

To monitor and assure compliance with cost and schedule baselines, the IPO will implement a proven Project Management Control System (PMCS) supporting the IPM. The PMCS will be implemented by an experienced PCM who is responsible for schedule, cost, contract, financial and data management, variance analysis, configuration management and monthly program contract reporting.

The PMCS will:

- Establish and maintain an integrated cost and schedule baseline
- Provide for the orderly and systematic authorization of work and project budget
- Develop and publish timely management reports which display cost, funding and schedule status to baseline plans
- Measure actual and forecasted cost and schedule status against the performance measurement baseline to determine the current and forecast future performance
- Maintain a clearly documented audit trail of all changes to the performance measurement baseline through the work breakdown structure
- Identify potential problem areas in sufficient time to implement the proper management actions

This PMCS has recently been successfully used on two large projects managed by SU-SLAC. The PEP-II *B*-Factory Collider project was a five year construction project, with a total cost of $200M, involving three national laboratories, and managed at SU-SLAC, using this PMCS system. The BABAR Detector is a $110M experimental physics detector, designed and fabricated over the past five years, by an international collaboration of 80 institutions, from nine countries. BABAR was recently assembled at the SU-SLAC facility, and is now in operation in conjunction with the PEP-II B-Factory, staffed around the clock by the collaboration and support personnel at SU-SLAC.

The WBS ensures that project management control flows down from the PCM to all subsystem managers. They are the Control Account Managers for their subsystem and, as such, will be under the direct authority of the IPM and are required to report monthly to the PCM on cost, schedule, and performance measurement. The details of this control flow-down and reporting are outlined below.

#### 1.2.3.1 Resource Management

The PMCS system formally maintains the project's cost and schedule baselines, while providing for the development and generation of timely performance measurement data and reports. This data, and the corresponding reports, provide the IPM with the necessary visibility to analyze progress and identify any significant problems and issues in order to establish and implement corrective action.

#### 1.2.3.2 Baseline Development Process

The baseline for the GLAST project is defined in a series of documents which detail the project scope, establish the baseline estimate of project cost and schedule, and contain the plan for completing the project, as depicted in the AO response.

The performance measurement baseline development process integrates the cost, schedule, and technical baselines to ensure that defined project objectives are achieved. Hence, the performance measurement baseline is the only baseline against which all cost, schedule and technical progress is measured. This is used to develop all data for internal project management, as well as for reporting to the GLAST Project Office at GSFC, and to other funding agencies.

### 1.2.3.3 Cost Estimating

The Project Control group is responsible for maintaining a project cost estimate by incorporating all approved configuration management plan actions.

The WBS provides the framework by which all contract effort is planned, authorized, scheduled, budgeted, measured, and reported for performance measurement purposes. The WBS is used to organize and subdivide the instrument project effort into manageable work elements. The WBS dictionary and budget estimate then provide a synopsis of the technical work and associated cost for each fourth level WBS element. The WBS is the organizational structure which is integrated to establish a Responsibility Assignment Matrix and to identify Control Accounts.

The objective of the Responsibility Assignment Matrix is to assure that each Control Account is assigned to one organizational entity, which is responsible for the management of the work. The cost accumulation structure, associated work order numbers, and Control Accounts are employed to plan all project activities and subsequently to collect the actual costs incurred for all project efforts.

### 1.2.3.4 Schedule Management

The scheduling process ensures that the project schedules are integrated with the project's cost estimate and authorized budgets. The IPS contains all project requirements and constraints which affect the cost, schedule and technical baselines on the Project. This schedule incorporates the major project milestones, key decision points, logic relationships, and interdependencies into an integrated hierarchy of schedules that establish and maintain vertical and horizontal relationships between and among all systems and subsystems. The IPS displays all constraints and interface points, as well as the critical path for the Project.

For team member institutions which will be providing in-kind contributions of equipment and hardware for the instrument project, the IPS forms the nucleus of the performance tracking system. For these institutions, performance analysis is done using earned-value and schedule variance techniques. Past experience has shown that simply monitoring work progress towards a distant earned-value milestone does not provide the level of detail and immediacy needed to track such a complex project. However, monitoring performance variances against expected performance at the work package and task level yields far more accurate valuation data, and provides the IPM with more useable metrics to identify and address any under-performing aspect of the project.

The IPM will use the Primavera scheduling software to manage the IPS. This has been successfully used in past projects at SU-SLAC, not to simply track schedule progress, but to proactively manage subsystem performance, identify potential variances, and plan corrective action. Using this modern management tool has helped in the on-time completion of both major projects completed in the past year at SU-SLAC.

### 1.2.3.5 Performance Analysis

The performance baselining process ensures that the cost, schedule and technical parameters of the project are integrated into a single performance measurement baseline, to enable timely and valid performance data reporting throughout the lifetime of the project. The performance baseline is hierarchical in nature; the baseline exists within each of the systems and Control Accounts as well as at the total Project level.

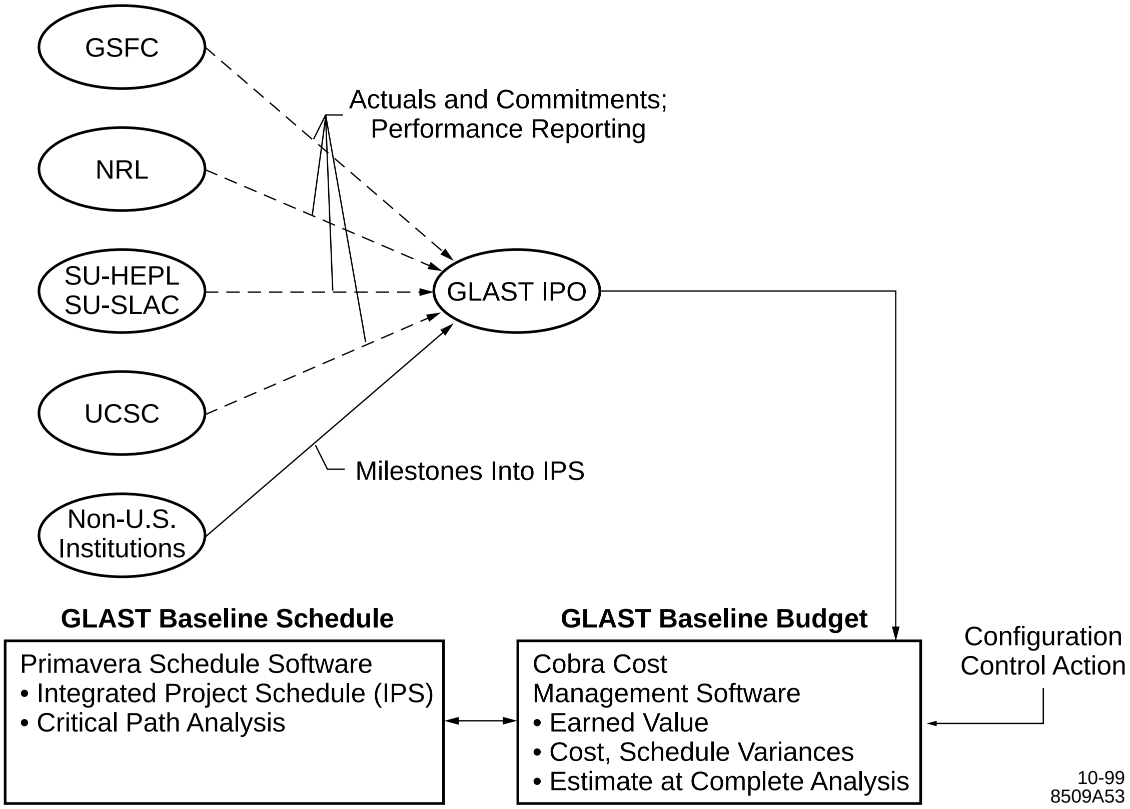
The Project Control group is responsible for administering formal change control procedures to maintain the integrity of the baseline. Control Account and work package planning guidance and procedures exist to assure that this integrity is maintained at the performing level as well.

The process further helps to assure that the total cost does not exceed the approved project budget base. The performance baseline is one of the data elements used to ensure that the near-term budget expenditure profile plus planned commitments and termination liability, conforms to the authorized funding profile.

### 1.2.3.6 Status Reporting and Data Collection

As the Project progresses, the baseline plans developed during the baseline development phase will have their status reported. Performance data will be gathered, work performance assessed, and forecasts of future performance are made on a monthly basis.

**Figure: 1.2.5:** Project management Control System Monthly Process



Internal and external reports will be provided to the IPO and corrective action plans developed as needed to arrest or minimize potential cost and schedule problems. Figure 1.2.5 shows the flow of data in this collection and reporting process.

Key tools for project status reporting are the Control Account detailed schedules. These are updated monthly with estimated levels of schedule and cost performance, and are combined within the Integrated Project Schedule. The performance reported on the various schedules is the basis for determining earned value, cost, and schedule variances for all project effort on a monthly basis. Comparing performance with the associated budget and the corresponding actual costs for each Control Account and WBS element, provides insights that enable Control Account Managers and the PCM to analyze cost and schedule variances, and focus resources to rectify and/or mitigate cost and schedule problems.

The COBRA software tool will be used to implement this status reporting and analysis. This tool has been employed by SU-SLAC since the start of the PEP-II project, and has proved invaluable in aiding accurate reporting and analysis of performance data.

### 1.2.3.7 Account Management

To facilitate accurate and timely reporting of all actual cost data, all costs will be reported to the PCM, organized by Control Account and WBS element. Work orders and accounts will be established at all member institutions, and will be linked with the appropriate control accounts. This ensures that project performance is tracked equally well for all subsystems, independent of the institutions involved. To effectively manage the reporting of all actual costs, the PCM will work with contacts in accounting departments at all team institutions.

### 1.2.3.8 Performance Reports

Monthly performance reports will be generated by the PCM, for dissemination within the project. These will be the primary tool used to analyze status and variances of instrument subsystems. Monthly summary Cost/Schedule Status Reports (CSSR) will also be generated, for distribution to the GSFC Project Office, to the DOE-SLAC site office, and to any other funding agencies requiring this information.

#### 1.2.3.9 Performance Analysis and Forecasting

The PMCS process provides for a consistent and objective means to analyze the work accomplished. The analysis forms the basis for the development of forecasts of future performance and the supporting rationale for estimate-to complete studies.

#### 1.2.3.10 Performance Measurement Baseline Maintenance

As the project progresses, there will likely be events and conditions that necessitate changes be made to the cost, schedule and technical baselines. This will be accomplished in compliance with the project configuration control plan. Revisions to the performance measurement baseline are classified into one of three categories, with differing levels of change control required. These are listed in Table 1.2.3.

**Table 1.2.3:** Levels of Change Control

| Change Type | Approving Agent |
|---|---|
| Routine replanning | Control Account Manager |
| Internal replanning | Project Control Manager |
| CCB changes | CCB and IPM |

### *1.2.4 Reporting and Reviews*

#### 1.2.4.1 Programmatic Reviews

As described in Sect. 1.2.3, the Integrated Project Management Control System will electronically generate monthly and quarterly reports. The PCM will maintain these electronically accessible databases of the cost, schedule and performance baselines. The GSFC GLAST Project Office and DOE-SLAC site office will receive formal written monthly cost and schedule reports. On a quarterly basis, the IPI and the IPO will hold a project review with the GSFC Project Office that encompasses programmatic and technical progress, including accomplishment narratives, budgets, schedules, and issues, as well as configuration changes that have been approved/disapproved by the GLAST IPO.

In addition to these formal programmatic reviews, the SU-SLAC directorate will support the instrument management team through weekly status reviews. These reviews between the IPI, IPM, and ITM, and the SU-SLAC Director and Associate Director for Research have proven very effective in past projects both to provide guidance, and to resolve any intra- or inter-institutional issues regarding the project.

Within the instrument project, the IPM will convene monthly project control reviews, to assess performance analyses for cost, schedule, and technical performance of each subsystem, and of the system as a whole. Finally, the IPM will convene informal weekly status updates, to keep abreast of development progress, and guide tactical decision-making at the subsystem level.

#### 1.2.4.2 Technical Reviews

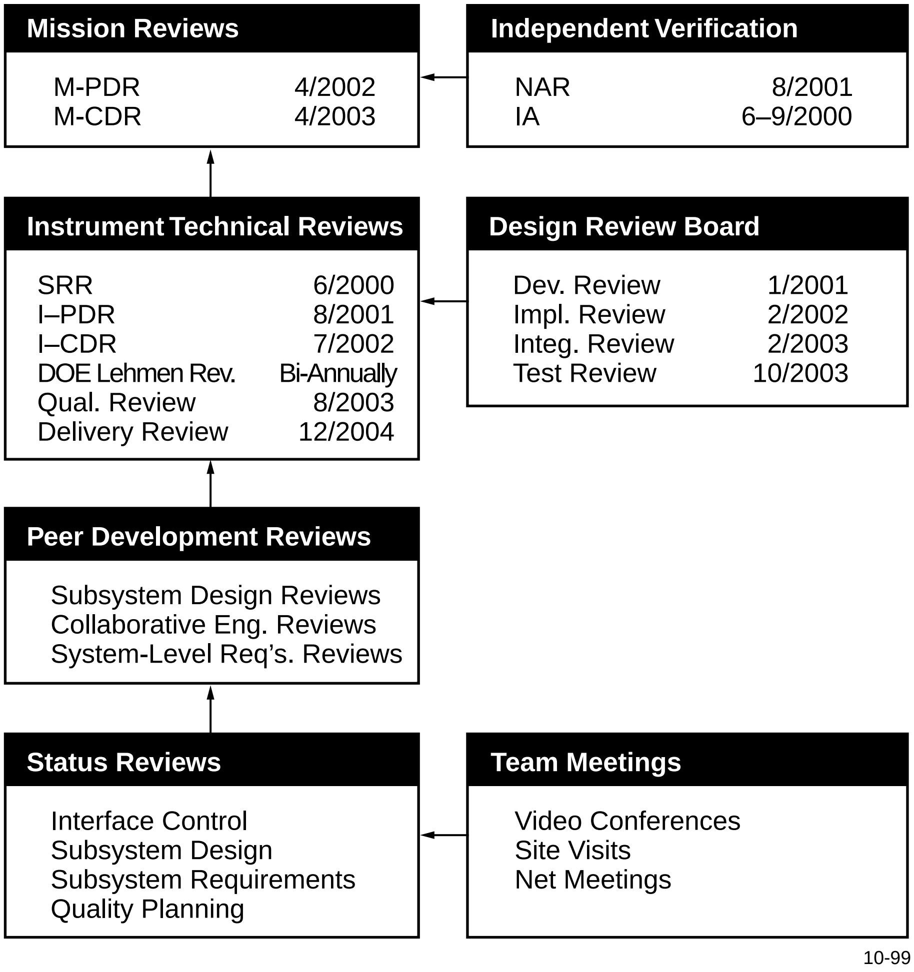
The IPO will institute a multi-tiered system of technical reviews for the project. This is shown graphically in Figure 1.2.6. First, the IPO will support NASA Mission-level reviews, including the M-PDR and M-CDR, with status reporting on the instrument technical and programmatic progress.

The next tier of reviews focuses specifically on the instrument. This process starts with the System Requirement Review, which will be a formal review to finalize the mission requirements. Its purpose is to assure the mission team that the goals and objectives of the mission are being accomplished by the requirements and the flow down that has been established by the GLAST IPO.

Furthermore, at project start, semi-annual (every six months) DOE Lehman reviews will be initiated. These will evaluate the status of the entire GLAST project from programmatic and technical perspectives. This formal review process has been used during the implementation of past projects at SU-SLAC, both as a tool for DOE to manage the project, and as a consistent formal feedback mechanism for project management at SU-SLAC.

The IPI proposes that these on-going DOE reviews also be used as a mechanism for both the NASA GSFC project office and the DOE to be formally updated on both LAT instrument and mission status.

**Figure: 1.2.6:** GLAST Instrument Technical Reviews



For all instrument-level reviews, the GLAST IPO will present designs, test plans, and verification plans. The review team will develop specific recommendations, actions, and concerns to the Project. These actions will be tracked to resolution by the IPM, to ensure closure, then presented to the same team at the next review.

To supplement the formal instrument review process, the IPI & SLAC directorate will convene a standing Design Review Board (DRB) to review the instrument project at least once a year, and evaluate the instrument implementation as the project evolves. The DRB will be comprised of a standing group of world-class scientists and engineers drawn from institutions internationally. Their technical and managerial experience will provide a valuable calibration source for instrument progress, against which the IPI and SU-SLAC directorate can guage overall performance of the instrument. Similar standing review committees have been convened for past projects at SU-SLAC, and they have been valuable in providing guidance to the management team.

The third tier of technical reviews planned for the project is comprised of, incremental "peer reviews" at the subsystem level. These occur on an *ad hoc* basis, convened and managed by the ISE as part of the process leading up to the formal reviews. For these reviews, technical experts from within the instrument subsystems will be called upon to engage in informal round table reviews of plans, designs, and implementations at key development stages. Formal notes and action items will be taken at these peer reviews and will be presented at the program review. We have already made extensive use of peer reviews during the technology development phase and have found them to be very effective. These reviews are listed in Table 1.2.4

Finally, the last tier of reviews are scheduled IDT meetings, chaired by the ITM, which will be conducted throughout the development, fabrication, test, and integration processes. These meetings are meant to provide an iterative process to refine the project, while considering the impacts of technical cost and schedule issues..

**Table 1.2.4:** Peer Reviews

| Review | Date |
|---|---|
| Instrumentation Software Status | 6/99 |
| DAQ Design | 4/99 |
| ACD Design | 1/99 |
| Calorimeter Electronics Design | 6/98 |
| Tracker Electronics Design | 11/97 |
| Tracker Silicon-strip Detectors | 6/97 |

### 1.2.5 Team Member Coordination and Communications

As discussed above, there will be varying tiers of reviews and coordination meetings to provide status reporting and guidance within the GLAST instrument team. These will provide the formal structure of coordination within the team. Both the monthly Project Control review, and the weekly IDT meeting will be video-conferences, to ensure that all team members are included. Video-conferencing has been used extensively during the development phase, with the necessary infrastructure already in place at all member institutions.

Communication within the instrument team is now being handled using all media available. Specifically, the instrument already has in place an extensive array of web sites at most member institutions. These will be expanded significantly at project start. The IPO, in particular, will expand its web presence to include the latest schedule and cost data, as well as all documented and configuration-controlled requirements and design parameters. Action item lists will also be posted on the site along with the status and full explanation as to the resolution of the item. Events will be posted to keep the entire team informed as to the latest status. This will be an important tool to keep the entire team, especially our international partners, informed on all of the latest developments of the project.

Using these advanced communication and coordination tools will help ensure strong team coordination and cohesion. They will also help minimize the need for time consuming written formal reports, and for excessive travelling. However, monthly site visits by IPO representatives have been planned and budgeted, to assess and guide progress in person at all subsystem home institutions. Whenever possible, these onsite visits will be timed with milestone events to minimize travel.

### 1.2.6 Multi-Institutional Management

Sections 1.2.2 through 1.2.4, above, have described the processes by which the IPO will proactively guide the instrument project. These processes have been tailored to fit the international, dispersed project team, by relying heavily on the project work breakdown structure for clear definition of projects, and on modern media for tight links between geographically diverse parts of the project. Past experience at SU-SLAC and other of the team institutions has proven that these tools can, when applied by a strong and proactive Instrument Project Office, yield a stable and dynamic team.

There are two significant aspects to successfully managing such a dynamic project team. First, roles and responsibilities of all team members must be well defined. This will be accomplished through a well-applied WBS structure, and statements of work for all team member groups and institutions. This empowers individuals and groups to excel in their work, while still maintaining clear accountability and management oversight for the project. Such a well-defined structure also works to minimize competition between organizations.

Another critical aspect of successful management of such an international project is clear communication between team member institutions. At the project level, this will be provided by the tiered review and reporting system planned. At the institutional level, this requires strong commitment and eclectic communications between institutions, to ensure that the project maintains visibility. This director-level communication is strongly endorsed by the leadership at Stanford University, and has proven to be very effective in keeping open lines of communication between organizations. The LAT instrument project has long since initiated and sustained such institutional ties. The Memoranda of Agreement will serve to formalize these ties, and subsequent communications will help maintain strong project support at all team member organizations.

## 1.3 HARDWARE AND SOFTWARE ACQUISITION STRATEGY

The GLAST hardware and software acquisition strategy is depicted in Table 1.3.1 through Table 1.3.5. For each subsystem the following data is provided:

- Description of the product to be acquired, and quantities needed
- Design status of the current design, indicating the level of design work needed to achieve flight design status
- Responsible institution or key sub-contractor handling the acquisition
- End item use category for each product, discussed below

The Use category identifies the end item assemblies in which the product is used. The Beam Test Engineering Model (BTEM) currently exists, and will be used for electron-beam calibration studies in the Fall of 1999. This includes a full-scale Tracker tower, Calorimeter module, and ACD model, to validate the technologies involved.

The Engineering Model (EM), is the update to the BTEM, comprised of flight-configuration hardware and processes. EM models will include a Tracker tower, Calorimeter module, ACD, and DAQ. These serve to validate all processes planned for the flight implementation.

The Qualification Unit (Qual. Unit) is the first flight unit that is built and subjected to qualification environmental levels. The Flight Units are the 16 modules to be delivered and integrated into the flight instrument. The Spares listed are only the flight-tested spare assemblies, which will be placed in storage, to be used in the event of a part or subassembly failure. Additional flight-tested spare components will be available as-needed, during the assembly and testing of all subassemblies. As shown in the tables, almost all of the critical acquisitions have been identified, and we have either already initiated communications with possible subcontractors or vendors, or have actually procured prototypes or hardware for the BTEM. Given the relatively conservative technology choices, none of the acquisitions is expected to pose large technical risk. The only long-lead acquisition needed is for the silicon-strip detectors for the Tracker. Section 2.2 of Volume 1 details the extensive prototyping and validation planning that has already been undertaken for the silicon strip detectors.

**Table 1.3.1:** GLAST Acquisition Strategy - Tracker

| Description | Design Status | Responsibility | Use Quantity | | | | |
|---|---|---|---|---|---|---|---|
| | | | BTEM | EM | Qual. | Flight | Spare |
| Tower | Existing | SU-SLAC, UCSC, & INFN | Existing | 1 | 1 | 16 | 1 |
| Silicon-Strip Detector | Existing | Hamamatsu Photonics<br>Commercial Purchase | 130 Ladders Existing | — | 144 Ladders | 2304 Ladders | 144 Ladders |
| Front-End Electronics | Existing<br>New Mfg. Process | Design – UCSC<br>Fab–HP | 34 Existing | — | 38 | 608 | 38 |
| ASICs | Existing | Design-UCSC<br>Fab-U.S. Vendor | 800 | --- | 1008 | 16128 | 1008 |
| Tray Sandwich Structure | Existing | Design – SU-SLAC /Hytec<br>Fab – U.S. Vendor | 17 Existing | 10 | 19 | 304 | 19 |
| Kapton Flex Circuits | Existing | Design-UCSC<br>Fab-INFN, Italy | 40 | 26 | 44 | 704 | 44 |

**Table 1.3.2:** GLAST Acquisition Strategy - Calorimeter

| Description | Design Status | Responsibility | Use Quantity | | | | |
|---|---|---|---|---|---|---|---|
| | | | BTEM | EM | Qual. | Flight | Spare |
| Calorimeter | Existing | NRL, France & Sweden | Existing | 1 | 1 | 16 | 1 |
| CsI Crystal | Existing | KTH (Stockholm, Sweden)<br>BTEM qualified two vendors: Crismatec & Amcrys H | Existing | 96 | 96 | 1536 | 96 |
| PIN Photodiode | Existing | French and NRL,<br>Vendor: Hamamstu Photonics | Existing | 192 | 192 | 3072 | 192 |
| ASIC | Mod-Existing | CEA/DAPNIA/SEI (France), DMILL process | Existing | 192 | 192 | 3072 | 192 |
| Electronics | Existing | NRL | Existing | 4 | 4 | 64 | 4 |
| Mechanical Structure | Existing | Design: IN2P3/LPNHE-H-X (France & Hytec)<br>Fab: IN2P3/LPNHE-H-X | Existing | 1 | 1 | 16 | 1 |

**Table 1.3.3:** GLAST Acquisition Strategy - ACD

| Description | Design Status | Responsibility | Use Quantity | | | | |
|---|---|---|---|---|---|---|---|
| | | | BTEM | EM | Qual. | Flight | Spare |
| Anticoincidence Detector | Design | GSFC | Existing | —— | 1 | 1 | — |
| Sensor Plastic Scintillator Tiles | Existing | GSFC | Existing | — | 12 | 145 | 15 |
| Light Collection Wave Shifting Fibers | Existing | Bicron -<br>Commercial Purchase<br>GSFC assembly | Existing | — | 24 | 290 sets | 30 sets |
| Readout Phototubes | Mod - Existing | Hamamatsu - Japan<br>Commercial Purchase | Existing | — | 1 | 2 | — |
| HV supplies | Mod - Existing | Design: GSFC<br>Fab: US vendor | Existing | 1 | 1 set | 2 sets | 1 set |
| ASIC | Design | Design: GSFC<br>Fab: US vendor | — | 12 | 24 | 290 | 30 |
| Electronics | Mod – Existing | Design: GSFC<br>Fab: US vendor | Existing | 1 | 1 | 32 | 2 |
| Mechanical Support | Mod – Existing | Design: GSFC<br>Fab: US vendor | Existing | 1 | 1 | 1 | — |

## 1.4 SCHEDULES

### *1.4.1 Development and Implementation Schedule*

#### 1.4.1.1 Instrument System Schedule

A schedule has been developed which shows how the instrument project will proceed from the BTEM and project start, through final instrument development to a second-generation engineering model which uses the flight design. Finally, flight hardware will be designed, procured, and assembled by subsystem, before final integration at SU-SLAC.

Scheduling of subsystem activities was done in conjunction with work and budget estimating. Particular attention was paid to the personnel loading relating to the parallel productions lines for the Tracker and Calorimeter. Also, because of the difficult funding profile from NASA, formulation-phase loading and unloading was checked. This ensured that work

**Table 1.3.4:** GLAST Acquisition Strategy - DAQ

| Description | Design Status | Responsibility | Use Quantity | | | | |
|---|---|---|---|---|---|---|---|
| | | | BTEM | EM* | Qual. | Fight | Spare |
| TEM (TCPU, DSF) | Mod – Existing | NRL | Existing | 24 | 3 | 20 | 3 |
| CAL-TKR-IO | Mod – Existing | SU-HEPL | Existing | 19 | 1 | 16 | 1 |
| ACD-IO | Mod – Existing | SU-HEPL | Existing | 3 | 1 | 2 | 1 |
| SIU-IO | Mod – Existing | NRL/SU-HEPL | NR | 2 | 1 | 2 | 1 |
| SIU-Power Switching | Mod – Existing | NRL | NR | 2 | 1 | 2 | 1 |
| Power System | Mod – Existing | SU-HEPL/ Power Supply Vendor | COTS | 3 ACD<br>2 SIU<br>19 CAL<br>19 TKR<br>24 TEM | 1 ACD<br>1 SIU<br>1 CAL<br>1 TKR<br>3 TEM | 2 ACD<br>2 SIU<br>16 CAL<br>16 TKR<br>20 TEM | 2 ACD<br>2 SIU<br>2 CAL<br>2 TKR<br>3 TEM |
| Cable Harness | Mod – Existing | SU-HEPL/ Cable Vendor | Existing | — | partial set | 1 set | 2 each unique cable type |
| Enclosures | Mod – Existing | SU-HEPL | NR | — | 1 | 1 | — |
| Flight Software<br>IOC Software | Mod – Existing | SU/SLAC/NRL | | | | | |
| | Mod – Existing | SLAC/U. Washington | Existing | — | — | — | — |
| | | GFSC/NRL | | | | | |
| | New | SLAC/NRL | — | — | — | 1 | — |
| | New | SLAC/SU (HEPL) | — | — | — | 1 | — |
| IOC Hardware | Mod – Existing | SLAC | Existing | — | — | Existing | — |

**Table 1.3.5:** GLAST Acquisition Strategy - GRID

| Description | Design Status | Responsibility | Use Quantity | | | | |
|---|---|---|---|---|---|---|---|
| | | | BTEM | EM | Qual. | Flt | Spare |
| Grid | New | SU-SLAC/LM-ATC | — | 1 | 1 | 1 | — |
| Heat Pipes | New | SU-SLAC/LM-ATC | — | — | 4 | 20 | — |
| Radiators | New | SU-SLAC/LM-ATC | — | — | — | 2 | — |
| Thermal Blanket | Mod - Existing | GSFC | --- | — | — | 1 | — |

packages could be accomplished on schedule and within the tight budget constraints.

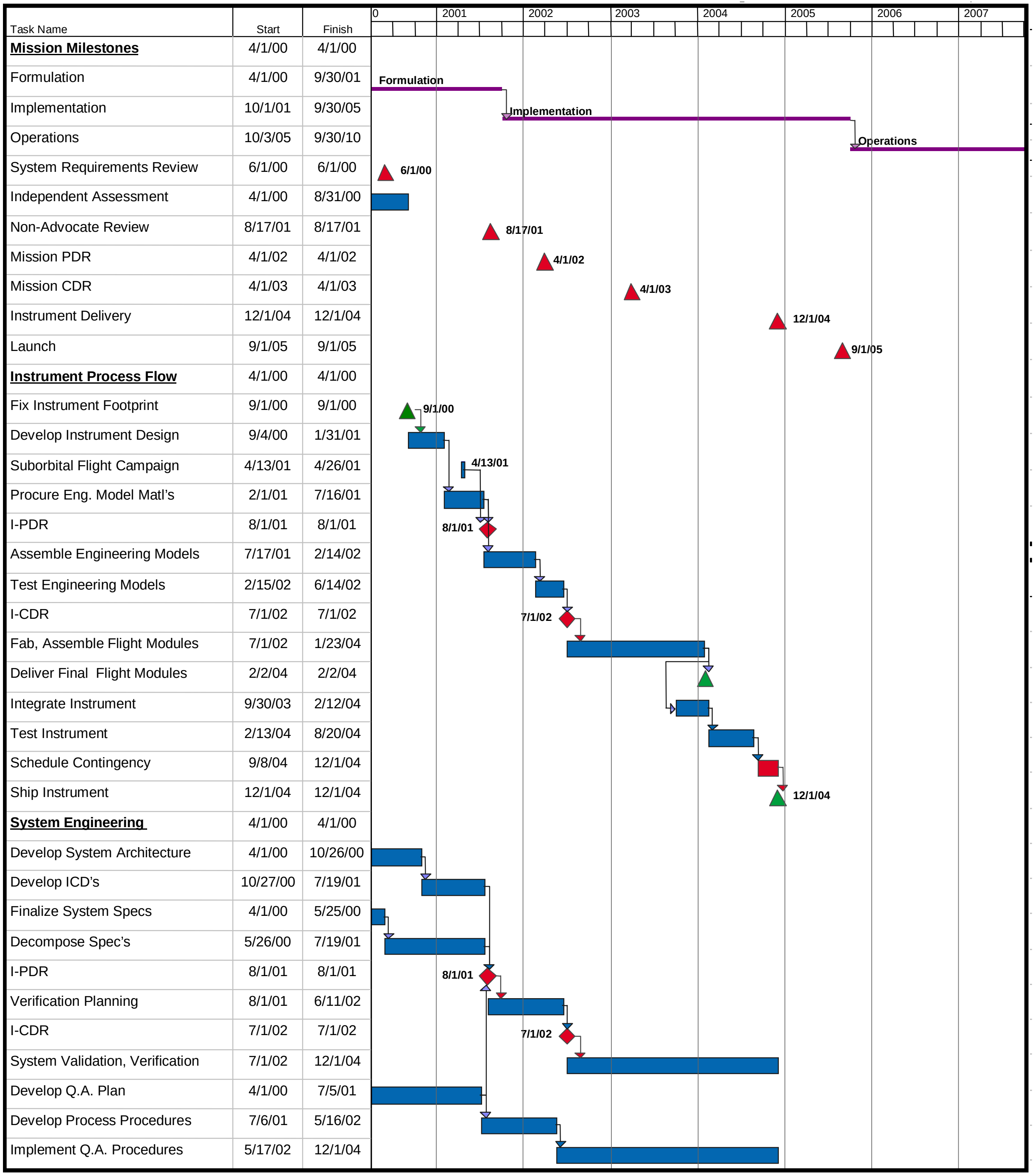
A strongly mitigating factor in the schedule risk introduced by the funding profile is the deep base of experienced personel at almost all of the team institutions. Staff can, if necessary, be brought on to the project for finite time periods or tasks, to ensure schedules are met, then reassigned to other projects as necessary,

Figure 1.4.1 shows the top-level mission and instrument milestones, along with the flow of development activities which support them. This is a summary of detailed subsystem schedules which have been developed.

Mission-level milestones are shown on top, with supporting instrument milestones detailed on the bottom. Planned dates for the instrument PDR is August 1, 2001, and for the CDR is July 1, 2002. The I-PDR is scheduled to occur near the mission NAR, just before the start of Phase C/D, and the development of flight-design engineering models. The I-CDR is scheduled just after the mission PDR and completion of engineering model testing, but soon enough to be able to start production lines for flight hardware.

Also shown in the schedule are system engineering planning and verification phases. These show the schedule for the process sequences

**Figure: 1.4.1:** Top-Level Mission and Instrument Milestones



| Task Name | Start | Finish |
|---|---|---|
| **Mission Milestones** | 4/1/00 | 4/1/00 |
| Formulation | 4/1/00 | 9/30/01 |
| Implementation | 10/1/01 | 9/30/05 |
| Operations | 10/3/05 | 9/30/10 |
| System Requirements Review | 6/1/00 | 6/1/00 |
| Independent Assessment | 4/1/00 | 8/31/00 |
| Non-Advocate Review | 8/17/01 | 8/17/01 |
| Mission PDR | 4/1/02 | 4/1/02 |
| Mission CDR | 4/1/03 | 4/1/03 |
| Instrument Delivery | 12/1/04 | 12/1/04 |
| Launch | 9/1/05 | 9/1/05 |
| **Instrument Process Flow** | 4/1/00 | 4/1/00 |
| Fix Instrument Footprint | 9/1/00 | 9/1/00 |
| Develop Instrument Design | 9/4/00 | 1/31/01 |
| Suborbital Flight Campaign | 4/13/01 | 4/26/01 |
| Procure Eng. Model Matl's | 2/1/01 | 7/16/01 |
| I-PDR | 8/1/01 | 8/1/01 |
| Assemble Engineering Models | 7/17/01 | 2/14/02 |
| Test Engineering Models | 2/15/02 | 6/14/02 |
| I-CDR | 7/1/02 | 7/1/02 |
| Fab, Assemble Flight Modules | 7/1/02 | 1/23/04 |
| Deliver Final Flight Modules | 2/2/04 | 2/2/04 |
| Integrate Instrument | 9/30/03 | 2/12/04 |
| Test Instrument | 2/13/04 | 8/20/04 |
| Schedule Contingency | 9/8/04 | 12/1/04 |
| Ship Instrument | 12/1/04 | 12/1/04 |
| **System Engineering** | 4/1/00 | 4/1/00 |
| Develop System Architecture | 4/1/00 | 10/26/00 |
| Develop ICD's | 10/27/00 | 7/19/01 |
| Finalize System Specs | 4/1/00 | 5/25/00 |
| Decompose Spec's | 5/26/00 | 7/19/01 |
| I-PDR | 8/1/01 | 8/1/01 |
| Verification Planning | 8/1/01 | 6/11/02 |
| I-CDR | 7/1/02 | 7/1/02 |
| System Validation, Verification | 7/1/02 | 12/1/04 |
| Develop Q.A. Plan | 4/1/00 | 7/5/01 |
| Develop Process Procedures | 7/6/01 | 5/16/02 |
| Implement Q.A. Procedures | 5/17/02 | 12/1/04 |

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which were shown in Figures 1.2.1 and 1.2.2. This starts with establishing the system-level architecture, then flowing requirements down to the subsystem level, and establishing spacecraft ICD's. Verification planning then begins, followed by execution of the test and verification procedures. This cycle is duplicated for the quality assurance planning and implementation.

The schedule shown is driven by the funding profile for the instrument. This back-end heavy profile introduces some additional schedule risk, since production, assembly and testing of the Tracker and Calorimeter modules must wait for funding, then proceed very rapidly. Our detailed scheduling shows that this is mitigated by parallel production lines, and by the modular design of the instrument.

#### 1.4.1.2 Subsystem Schedules

Figure 1.4.2 shows the schedule for implementation and includes work tasks for the key subsystems. This only shows a summary of subsystem activities. The detailed subsystem schedules include a full listing and logical linking of work packages and tasks. The scheduled time to integrate the instrument is fairly short—18 weeks for integration and preliminary functional testing. This reflects the modular design, since individual sub-assemblies will mechanically integrate very quickly. Electrical integration will follow identical procedures and test protocols used for module testing after assembly. The flight DAQ system will be fully tested using signal generators before final integration so this, too, should integrate smoothly with the instrument.

On the other hand, we have scheduled 26 weeks of testing on the integrated instrument. This will be used for a full array of EMI/EMC tests, cosmic ray and electron beam calibration testing, and thermal and structural testing. This testing is followed by a three month, fully-funded schedule contingency, which almost doubles the available integration time, if needed. Experience with similarly complex high-energy physics detectors has shown that this long test, check-out, and calibration cycle is crucial for a complete understanding of the behavior of the instrument during operation.

#### 1.4.1.3 Critical Path

The critical path for the instrument development and implementation runs through the Tracker subsystem. It is set by the final development and prototyping of the Tracker carbon-fiber composite (CFC) Tray structure. Following the I-PDR, a structural engineering model of the Tracker will be built, to qualify the design and assembly method. Then, following the I-CDR, the flight CFC tray structures will be fabricated and assembled, in support of the flight tray production effort.

The silicon-strip detector fabrication falls almost ten months off this critical path, even given the relatively slow delivery rate planned. Likewise, schedule risk for other key elements of the instrument is relatively low. This includes the CsI logs for the Calorimeter, and the custom ASIC's for both the TEM's and the Calorimeter.

### *1.4.2 Long-Lead Procurements*

A long-lead procurement is defined as any hardware procurement that needs to be placed before the start of the Implementation phase. The instrument has only one such long-lead item, the silicon-strip detectors for the Tracker subsystem. As discussed in Volume 1, an aggressive development program has been undertaken to fully characterize the requirements and performance of these detectors. This program is nearing completion, and the design and performance of the detectors will be baselined early in the Formulation Phase. Procurement will begin during the Formulation Phase in early FY 2001, to ensure that delivery of these poses a low schedule risk. Funds for procuring the detectors will be supplied by funding agencies in Japan and Italy.

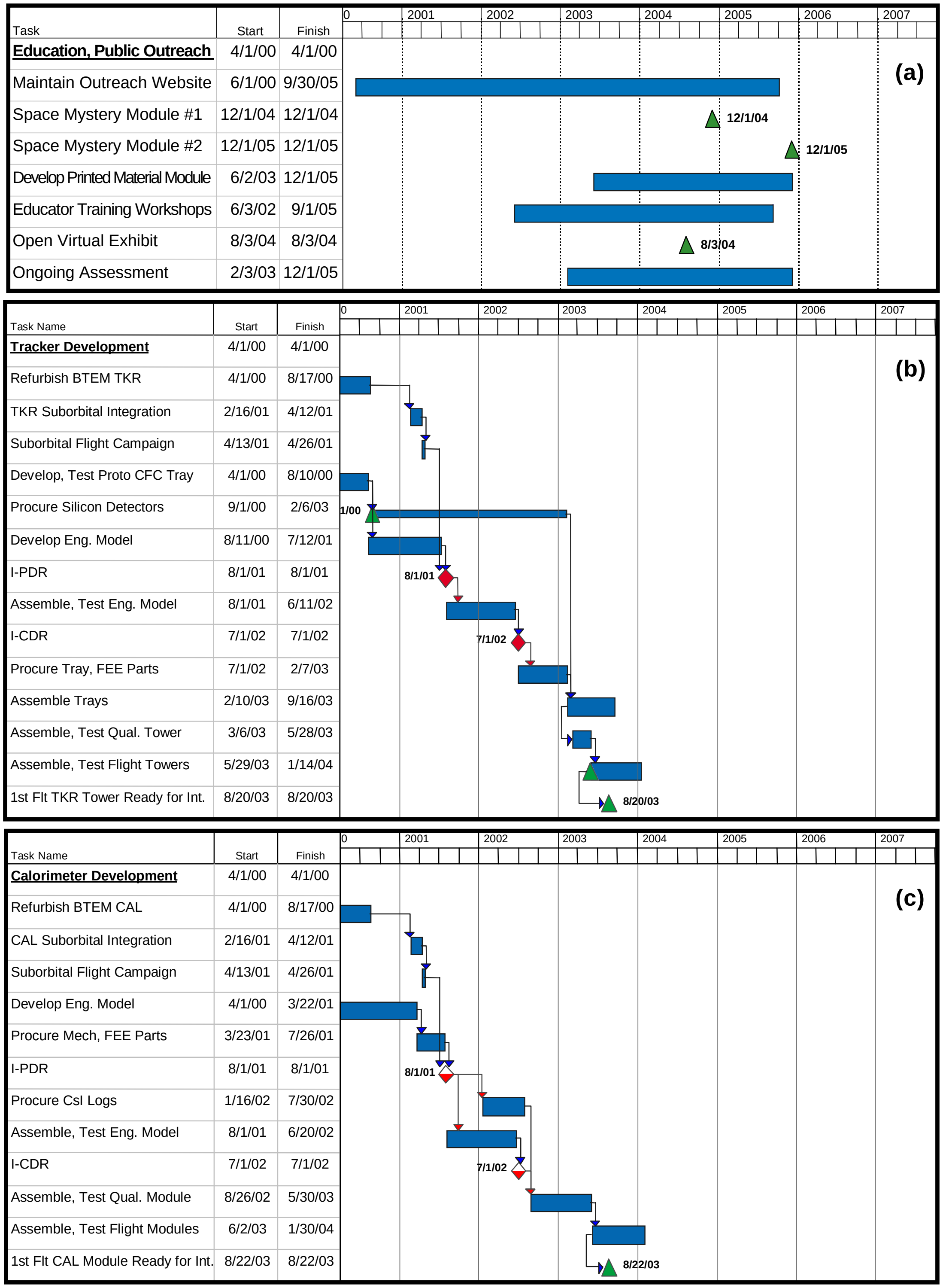
## 1.5 RISK MANAGEMENT PLAN

Establishment and implementation of a Risk Management Plan, based on a thorough identification and analysis of implementation and product risks is key to successful risk management.

The GLAST team has been careful in the Phase A Concept Study to develop an implementation approach that is low risk and modular in design. This allows selective flexibility for implementation of changes and de-scope options, if necessary. It is possible, however, that unanticipated events may occur that will introduce risk areas during the project evolution. The IPM will implement an ongoing process that will allow--in fact encourage--each individual on the project to bring to management's attention any perceived or actual risks at their first occurrence.

Table 1.5.1 shows a hierarchical approach to how risk will be managed for the GLAST instrument. This describes a descending order decision path for mitigating risk. The first level to resolve risk is by the allocation of technical resources and margins. If that is an insufficient or inappropriate solution, then cost and schedule

**Figure: 1.4.2:** Subsystem Schedule Summary



(a)

| Task | Start | Finish |
|---|---|---|
| **Education, Public Outreach** | 4/1/00 | 4/1/00 |
| Maintain Outreach Website | 6/1/00 | 9/30/05 |
| Space Mystery Module #1 | 12/1/04 | 12/1/04 |
| Space Mystery Module #2 | 12/1/05 | 12/1/05 |
| Develop Printed Material Module | 6/2/03 | 12/1/05 |
| Educator Training Workshops | 6/3/02 | 9/1/05 |
| Open Virtual Exhibit | 8/3/04 | 8/3/04 |
| Ongoing Assessment | 2/3/03 | 12/1/05 |

(b)

| Task Name | Start | Finish |
|---|---|---|
| **Tracker Development** | 4/1/00 | 4/1/00 |
| Refurbish BTEM TKR | 4/1/00 | 8/17/00 |
| TKR Suborbital Integration | 2/16/01 | 4/12/01 |
| Suborbital Flight Campaign | 4/13/01 | 4/26/01 |
| Develop, Test Proto CFC Tray | 4/1/00 | 8/10/00 |
| Procure Silicon Detectors | 9/1/00 | 2/6/03 |
| Develop Eng. Model | 8/11/00 | 7/12/01 |
| I-PDR | 8/1/01 | 8/1/01 |
| Assemble, Test Eng. Model | 8/1/01 | 6/11/02 |
| I-CDR | 7/1/02 | 7/1/02 |
| Procure Tray, FEE Parts | 7/1/02 | 2/7/03 |
| Assemble Trays | 2/10/03 | 9/16/03 |
| Assemble, Test Qual. Tower | 3/6/03 | 5/28/03 |
| Assemble, Test Flight Towers | 5/29/03 | 1/14/04 |
| 1st Flt TKR Tower Ready for Int. | 8/20/03 | 8/20/03 |

(c)

| Task Name | Start | Finish |
|---|---|---|
| **Calorimeter Development** | 4/1/00 | 4/1/00 |
| Refurbish BTEM CAL | 4/1/00 | 8/17/00 |
| CAL Suborbital Integration | 2/16/01 | 4/12/01 |
| Suborbital Flight Campaign | 4/13/01 | 4/26/01 |
| Develop Eng. Model | 4/1/00 | 3/22/01 |
| Procure Mech, FEE Parts | 3/23/01 | 7/26/01 |
| I-PDR | 8/1/01 | 8/1/01 |
| Procure CsI Logs | 1/16/02 | 7/30/02 |
| Assemble, Test Eng. Model | 8/1/01 | 6/20/02 |
| I-CDR | 7/1/02 | 7/1/02 |
| Assemble, Test Qual. Module | 8/26/02 | 5/30/03 |
| Assemble, Test Flight Modules | 6/2/03 | 1/30/04 |
| 1st Flt CAL Module Ready for Int. | 8/22/03 | 8/22/03 |

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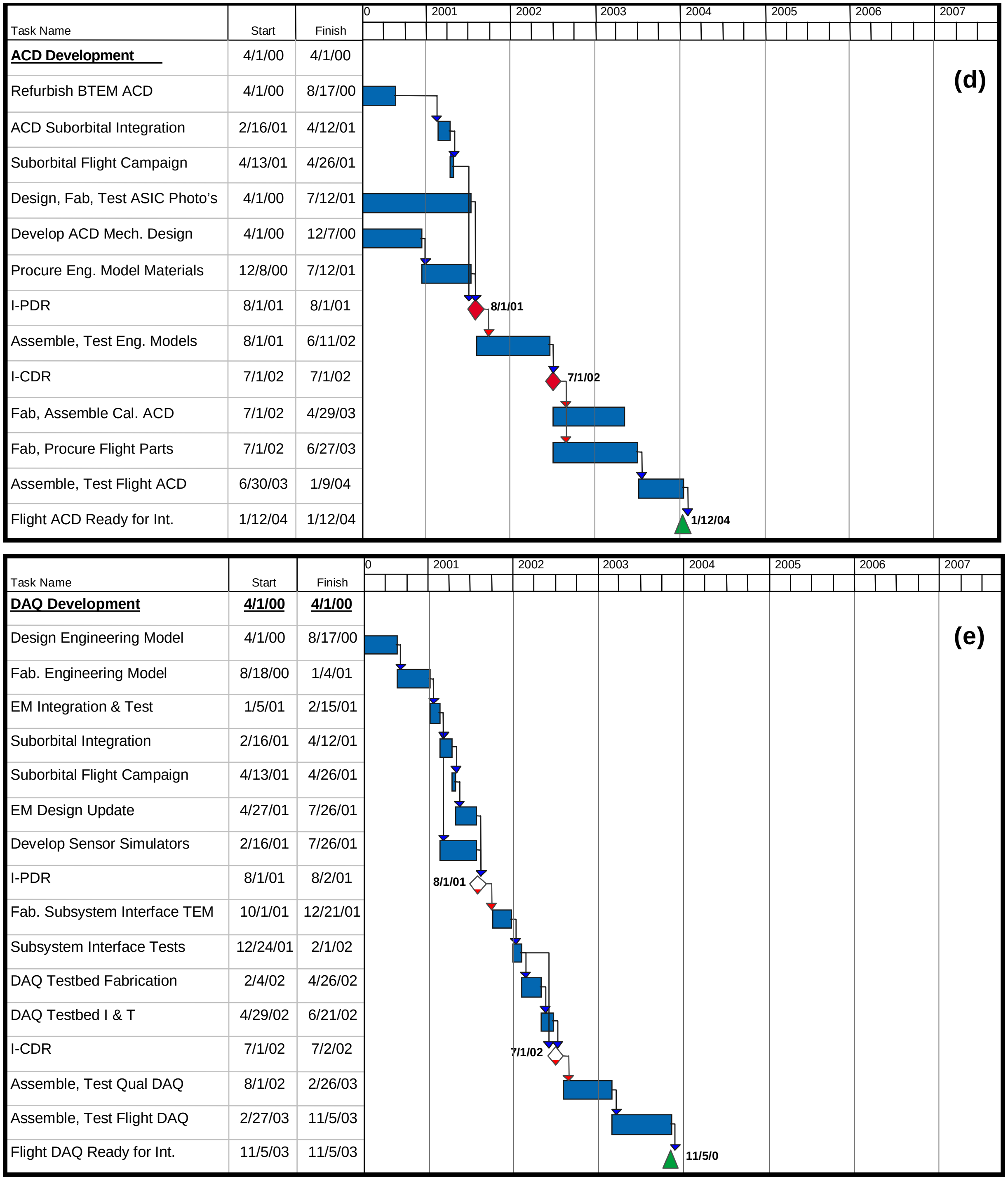
**Figure: 1.4.2:** Subsystem Schedule Summary



| Task Name | Start | Finish |
|---|---|---|
| **ACD Development** | 4/1/00 | 4/1/00 |
| Refurbish BTEM ACD | 4/1/00 | 8/17/00 |
| ACD Suborbital Integration | 2/16/01 | 4/12/01 |
| Suborbital Flight Campaign | 4/13/01 | 4/26/01 |
| Design, Fab, Test ASIC Photo's | 4/1/00 | 7/12/01 |
| Develop ACD Mech. Design | 4/1/00 | 12/7/00 |
| Procure Eng. Model Materials | 12/8/00 | 7/12/01 |
| I-PDR | 8/1/01 | 8/1/01 |
| Assemble, Test Eng. Models | 8/1/01 | 6/11/02 |
| I-CDR | 7/1/02 | 7/1/02 |
| Fab, Assemble Cal. ACD | 7/1/02 | 4/29/03 |
| Fab, Procure Flight Parts | 7/1/02 | 6/27/03 |
| Assemble, Test Flight ACD | 6/30/03 | 1/9/04 |
| Flight ACD Ready for Int. | 1/12/04 | 1/12/04 |

| Task Name | Start | Finish |
|---|---|---|
| **DAQ Development** | **4/1/00** | **4/1/00** |
| Design Engineering Model | 4/1/00 | 8/17/00 |
| Fab. Engineering Model | 8/18/00 | 1/4/01 |
| EM Integration & Test | 1/5/01 | 2/15/01 |
| Suborbital Integration | 2/16/01 | 4/12/01 |
| Suborbital Flight Campaign | 4/13/01 | 4/26/01 |
| EM Design Update | 4/27/01 | 7/26/01 |
| Develop Sensor Simulators | 2/16/01 | 7/26/01 |
| I-PDR | 8/1/01 | 8/2/01 |
| Fab. Subsystem Interface TEM | 10/1/01 | 12/21/01 |
| Subsystem Interface Tests | 12/24/01 | 2/1/02 |
| DAQ Testbed Fabrication | 2/4/02 | 4/26/02 |
| DAQ Testbed I & T | 4/29/02 | 6/21/02 |
| I-CDR | 7/1/02 | 7/2/02 |
| Assemble, Test Qual DAQ | 8/1/02 | 2/26/03 |
| Assemble, Test Flight DAQ | 2/27/03 | 11/5/03 |
| Flight DAQ Ready for Int. | 11/5/03 | 11/5/03 |

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reserves will be used. Finally, descoping is a last resort and, if used, will be coordinated with the GSFC Project Office.

**Figure: 1.5.1:** Risk Management Process

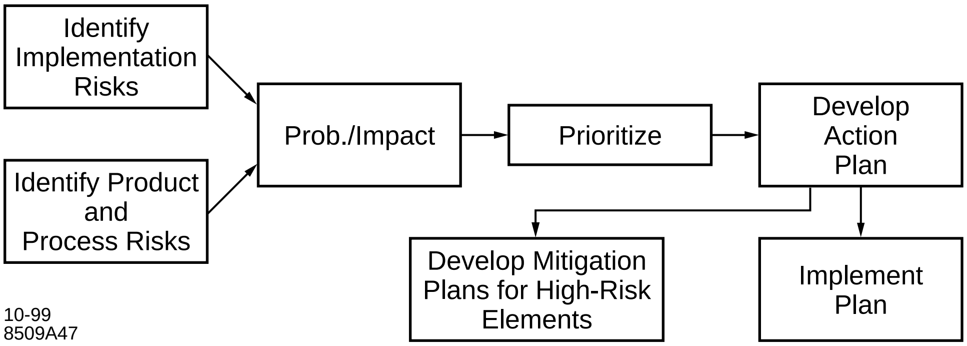


**Table 1.5.1:** Risk Mitigation Approach

| Risk Level | Risk Mitigation Approach | Phase |
|---|---|---|
| 1 | Design low risk into instrument<br>*-Use only proven technologies*<br>*-Favor lower risk approach in system trades* | Form. |
| 2 | Maintain adequate technical reserves, and manage allocation closely | Impl. |
| 3 | Carry cost and schedule reserves and allocate at the subsystem and system level | Impl. |
| 4 | Implement planned descope options, in coordination with GSFC Project Office | Impl. |

### 1.5.1 Overall Plan

Near the end of the GLAST Concept study phase, an ongoing risk management process was begun. This is depicted in Figure 1.5.1.

The first step has been to identify project risks, including both implementation and product risks. Since the GLAST instrument is based on proven technology, where development models have been built and tested and an engineering model will be tested prior to contract start, the elements of risk are primarily implementation and program risks.

Each subsystem was assessed considering the following factors:

- Technology Readiness Level
- Performance
- Materials
- Parts/Processes
- Redundancy
- Mass
- Power
- Schedule
- Cost
- Team Commitment

A summary of the resultant data is shown in Table 1.5.2. This also shows the baseline approach for reducing the risk to acceptable levels (Low Probability/Low Impact). This risk assessment data will be formalized and expanded on at the project start, and will form the nucleus of the risk management database.

With all key risk elements identified, their potential impact on the program was analyzed, based on the probability of incident, and impact on the mission. Analysis allows the risks to be prioritized, and action plans developed. Action plans include a mitigation strategy and implementation protocol. For all risks determined by the team to have a high probability of occurrence and a serious impact on the project a mitigation plan will be developed that will include two potential solutions. The first will be a process to alleviate the risk using the planned implementation and the second will be an alternate solution that would minimize program impact and would include established review and implementation dates.

### 1.5.2 Top Four Programmatic Risks

Using the preliminary risk analysis and mitigation table, reduction of risk elements were incorporated into the baseline approach for all risks. The top four risks associated with this baseline are summarized in Table 1.5.3.

***Risk 1:*** The IPO has firm commitments from our European and Japanese collaborators. Their funding authorities have guaranteed the hardware and have allocated funding for scientific involvement. Nevertheless, we carry a significant contingency during the Implementation Phase, to deal with unexpected changes in foreign funding. Although this contingency cannot fully replace all activity which the foreign partners supply, we would be able to proceed while alternate solutions are established or issues resolved.

***Risk 2:*** As the GLAST Instrument is being integrated and tested, problems are bound to occur. We have anticipated that such problems might occur even though we will strive to minimize them by extensive testing at the subsystem level, interface verification and performance verification prior to delivery of the subsystem. To deal with these events we are holding a 50% contingency during the I&T fiscal year, in addition to a three-month fully funded schedule reserve.

***Risk 3:*** The IPO has firm commitments and agreements with our European and Japanese team institutions, and our relationship is based upon the demonstrated dedication of each institution and the personal commitment of each individual member. We have demonstrated effective communication throughout the concept studies that preceded this proposal, and have a long track record on past projects showing exemplary performance from all team institutions This has been due both to their dedication, and to a pro-active management method with all team members throughout the project. This will be implemented in the GLAST project, as well, as described in Sect. 1.2.6 on Multi-Institutional Management.

***Risk 4:*** The largest single procurement item is the silicon strip detectors. The GLAST team has been working on the procurement strategy from the beginning of the R&D phase. Based on our long experience in ground-based applications, we conducted several trade studies of the detector design, and in all cases the more conservative, simpler solution has been chosen. For example, while AMS has flown the more advanced, but more complicated, double-sided detectors, GLAST has selected the more robust and economical single-sided configuration, which afford much larger margins in operations and reliability. The market was surveyed early, and we found that the capacity of qualified vendors exceeds the needs of GLAST by a factor of eight, with no known competition for resources from other experiments. We now have prototyped detectors with three established companies. Our foreign team institutions will procure the detectors, under direct control of the Tracker subsystem manager. Together with SU-SLAC, they have funded an aggressive prototyping program in the last years, and their funding profile will allow early procurement of the detectors. To establish high visibility of this effort, the Tracker subsystem manager has appointed a Detector Coordinator, to directly manage all efforts relating to the detector development and procurement.

### 1.5.3 Management Strategies for Reserves and Margins

This proposal represents the GLAST Baseline which will be put under configuration control soon after submission. Cost, schedule and performance reserves are under the control of the Instrument Project Manager. Subsystem allocations and re-allocations may be made within the resources of the subsystem with the knowledge of the IPM and Project Control Manager. Changes that affect other interfaces must be formally documented, requested and approved by the Configuration Control Board. See Sect. 1.2.2.3 on Configuration Management.

Any changes that affect science or programmatic requirements require the knowledge and concurrence of the IPI. When actions impacting science, such as de-scoping, are implemented, the IPI must have the concurrence of the GSFC Project Office. The allocation and release of all resources will be under configuration control and are monitored by, and require concurrence of, the Instrument Project Manager. Cost reserves are held by the IPO and not pre-allocated.

Figure 1.5.2 shows the planned allocation of program resources. We expect that approximately 25% of the technical reserves will be allocated by the time of the PDR. Schedule contingency and cost reserve allocations should be minimal at PDR. An additional 25% of the technical reserve and approximately 15-25% of the cost reserves and very little schedule contingency should be allocated by CDR. From CDR through launch, the remaining assets would be

**Table 1.5.2:** Identified Instrument Risks

| Subsystem | Concern | Baseline Mitigation Approach |
|---|---|---|
| **TKR** | Silicon availability | Long lead item developed on advanced schedule |
| | Silicon fab process sensitivity | Multiple suppliers pre-qualified for order |
| | Tight assembly schedule | Parallel tray assembly lines at SU-SLAC, INFN |
| **CAL** | Tight assembly schedule | Parallel assembly lines at NRL, CEA |
| | CsI fab. process sensitivity | Two suppliers pre-qualified for order |
| **ACD** | Puncture light-tight seal by micrometeorite in flight | Optical isolation of individual tiles |
| **DAQ** | L3T processing requires more MIPs than available in SIU | Utilize Tower CPUs for L3T processing (up to ~300 MIPs available) |
| **Grid** | Complex fabrication process | Perform trade study on CFC vs. aluminum, and fab techniques early in Formulation Phase |
| **Software** | Meeting schedule and cost plans | Development Plan during Formulation Phase |
| **System Level** | Multiple Interfaces | Strong, proactive Instrument Project Office; cultivate good subsystem teamwork |
| | Hardware/Software Integration | Pro-active System Engineering approach; implement through I&T plan |
| | Single Point Failures | Perform FMEA analysis before I-PDR & I-CDR |
| | Supplier Performance | Develop dual sources for critical items |
| | Domestic, international funding availability | Pro-active cost/funding analysis and strong team involvement to keep project sold |

**Table 1.5.3:** Top Four Programmatic Risks

| | Risk | Effect | Mitigation |
|---|---|---|---|
| 1 | Foreign team institution withdraws from investigation | Loss of funding source and personnel to accomplish work. | Draw down contingency to mitigate loss of funding source. Redistribute effort within project. |
| 2 | Problems or delays during Instrument I&T | Integration cost and schedule variances | Holding a 50% cost reserve during I&T, with a fully funded three-month schedule reserve |
| 3 | Under-performing team institution | Cost and schedule variances eat up reserve | Maintain 35% reserve during Implementation Phase, and manage subsystems pro-actively during life of project |
| 4 | Late delivery of Silicon Strip Detectors | Schedule delay in Tracker assembly | Start SSD development before project start. Procure SSD's starting in Formulation Phase (long lead). Develop multiple suppliers for SSD's |

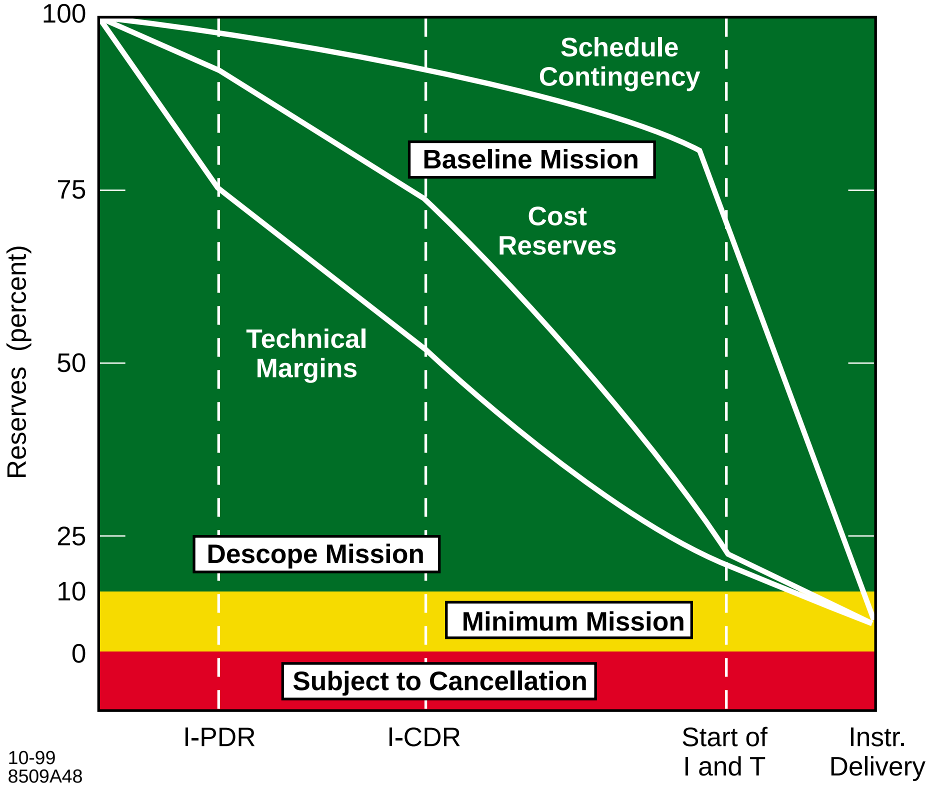
allocated on an as-needed basis determined at the monthly program status reviews. A plot of the planned distributions with an up-to-date actual distribution will be maintained and used as a tool to evaluate progress regarding the ability to implement the baseline mission versus the need to implement a descope option.

## *1.5.4 Performance Reserves*

### 1.5.4.1 Mass Reserves

Of paramount importance is the control of instrument mass. The early prototyping and testing of a variety of subsystems of the GLAST instrument has helped us get an early understanding of the mass of most of the key elements of the instrument. Using this as a starting point, we have characterized all instrument subsystems

**Figure: 1.5.2:** Planned Allocation of Resources



to fully detail the instrument mass. Table 1.5.4 shows a summary of these subsystem masses, along with two component-level reserve analyses.

Class defines the fabrication history of the component:

I. A new design which is one-of-a-kind or a first generation device.

II. A generational design that follows a previously developed concept and expands complexity or capabilty within an established design envelope, including new hardware applications to meet new requirements.

III. A production level development based on an existing design for which multiple units are planned, and a significant amount of standardization exists.

Level defines the maturity of the design:

*Bid:* Concept proposal, RFP response, or a baseline design for future development.

*CDR:* Conceptual design review level.

Despite the relatively advanced state of the subsystem designs, the instrument still carries a conservative mass reserve. This reserve was computed using two techniques. First, an industry-standard specification, the "Guide for Estimating and Budgeting Weight and Power Contingencies for Spacecraft Systems," (ANSI/AIAA-G-020-1992), was used to best map technology and maturity of the instrument components to standard industry-adopted reserves. This analysis shows that, for our estimated mass of 2557 kg, we need a 15.6% reserves, bringing the total mass, with reserve, to 2957 kg and below the mass ceiling of 3000 kg.

In the second reserve analysis, differing levels of reserve were assigned to different types of mass. GLAST contains a considerable amount of material used expressly for scientific signal production, and the exact quantity, volume, and density of this material have been measured and understood for quite some time. These materials are the lead converters and silicon detectors for the Tracker subsystem, the scintillators for the Anticoincidence Detector, and the CsI for the

**Table 1.5.4:** Subsystem Reserve and Mass Analyses

| | | | Reserve Approach 1 | | | | Reserve Approach 2 | |
|---|---|---|---|---|---|---|---|---|
| **Component Type** | **Mass Estimate (kg)** | **Class** | **Level** | **Cat** | **% Reserve** | **Mass Budget (kg)** | **% Reserve** | **Mass Budget (kg)** |
| **TRACKER** | | | | | | | | |
| *Thermal & Mechanical Structures* | 191.416 | I | Bid | BW | 35.0 | 258.411 | 42.0 | 271.810 |
| *Silicon detectors* | 73.011 | II | CoDR | BW | 20.0 | 87.614 | 4.0 | 75.932 |
| *Lead Converters* | 173.285 | III | CoDR | BW | 3.0 | 178.484 | 4.0 | 180.217 |
| *Electronics, Cabling, and Others* | 84.123 | I | CoDR | BW | 30.0 | 109.360 | 42.0 | 119.455 |
| **Subtotal Tracker** | 521.836 | | | | 21.5 | 633.869 | 24.1 | 647.414 |
| **CALORIMETER** | | | | | | | | |
| *Mechanical Structures* | 161.597 | I | CoDR | BW | 30.0 | 210.075 | 42.0 | 229.467 |
| *Cesium Iodide* | 1338.302 | III | Bid | CW | 2.0 | 1365.068 | 4.0 | 1391.834 |
| *Electronics & Cabling* | 31.653 | I | Bid | AW | 50.0 | 47.479 | 42.0 | 44.947 |
| *Others (wrapping, etc)* | 17.956 | I | Bid | AW | 50.0 | 26.935 | 42.0 | 25.498 |
| **Subtotal Calorimeter** | 1549.508 | | | | 6.5 | 1649.558 | 9.2 | 1691.747 |
| **ACD** | | | | | | | | |
| *Mechanical Structures* | 50.781 | I | Bid | BW | 35.0 | 68.554 | 42.0 | 72.109 |
| *Scintillators* | 84.550 | II | Bid | BW | 25.0 | 105.688 | 4.0 | 87.932 |
| *Phototubes, HV power, and wiring* | 23.800 | I | Bid | AW | 50.0 | 35.700 | 42.0 | 33.796 |
| *Fibers, wrapping, foam spacers, etc* | 14.500 | I | Bid | AW | 50.0 | 21.750 | 42.0 | 20.590 |
| **Subtotal ACD** | 173.631 | | | | 33.4 | 231.692 | 23.5 | 214.427 |
| **GRID** | | | | | | | | |
| *Grid Structure* | 142.979 | I | Bid | BW | 35.0 | 193.021 | 42.0 | 203.029 |
| **Subtotal Grid** | 142.979 | | | | 35.0 | 193.021 | 42.0 | 203.029 |
| **DATA ACQUISITION (DAQ)** | | | | | | | | |
| *TEM Modules* | 32.000 | I | Bid | AW | 50.0 | 48.000 | 42.0 | 45.440 |
| *SIU Modules* | 15.000 | I | Bid | AW | 50.0 | 22.500 | 42.0 | 21.300 |
| *ACD Modules* | 5.000 | I | Bid | AW | 50.0 | 7.500 | 42.0 | 7.100 |
| *Cable Plant* | 40.000 | I | Bid | AW | 50.0 | 60.000 | 42.0 | 56.800 |
| **Subtotal DAQ** | 92.000 | | | | 50.0 | 138.000 | 42.0 | 130.640 |
| **OTHER** | | | | | | | | |
| *Thermal Blankets* | 27.265 | II | Bid | AW | 30.0 | 35.445 | 42.0 | 38.717 |
| *Heat Pipes and radiators* | 50.000 | I | Bid | AW | 50.0 | 75.000 | 42.0 | 71.000 |
| **Subtotal Other** | 77.265 | | | | 42.9 | 110.445 | 42.0 | 109.717 |
| **INSTRUMENT TOTALS** | **2557.218** | | | | **15.6%** | **2956.584** | **17.2%** | **2996.974** |

Calorimeter. These four materials were assigned a mass reserve of 4% (equivalent to changing the length and width of one tower by 8 mm). We consider this an adequate reserve for these well-understood materials.

For the remainder of the material, the less well-defined mass which represents the instrument structure, electronics, and cable plant, a 42% reserve was assigned. This results in a total instrument mass, including reserve, of 2997 kg, right at the instrument budget of 3000 kg. Using this method, the average reserve for all mass is 17.2%, above that recommend by method #1, using the AIAA standard. The two reserve analyses are in good agreement, giving us confidence that the mass budget can be met.

### 1.5.4.2 Power Reserves

The instrument power reserves are also calculated using the guidelines of ANSI/AIAA-G-020-1992 for Category AP subsystems at the proposal stage. The Class assignment of each subsystem along with the applicable reserve and required power is shown in Table 1.5.5.

**Table 1.5.5:** Power Budget and Reserve by Instrument Subsystem

| Element | Class | Power (W) | Reserve | Power with Reserve |
|---|---|---|---|---|
| TKR | III | 273 | 13% | 308 |
| CAL | III | 118 | 13% | 134 |
| TEM | II | 88 | 40% | 123 |
| ACD | I | 29 | 90% | 55 |
| SIU | I | 10 | 90% | 19 |
| **TOTAL** | | **518** | | **639** |

The Tracker power is determined by the two types of ASICs which have been built and tested during the ATD phase. The Tracker is assigned Class 3 because the complete electronics consist of only two device types which have been prototyped and measured, including a small activity dependence. In the production cycle, we plan to utilize wafer level probing to verify that the device power is acceptable.

The Calorimeter is also Class 3 since the power for one module has been measured during the ATD phase. However, along with the prototype FE analog ASICS, the Calorimeter power measurements were made using some discrete parts; the flight unit will utilize ASICs, with more control functionality, to decrease the parts count and the power. An alternative approach to calculating the Calorimeter power reserve is to estimate the power of the flight design and apply Class 1 contingency of 90%. The Class 3 choice is the more conservative.

The ACD was prototyped during the ATD phase using commercial parts. The flight unit power estimate is based on an ASIC similar to the one already developed for the CAL BTEM, with other electronics similar to the prototype. Because the ASIC is a new design, we assign a Class 1 contingency level.

The Tower Electronic Module (TEM) processor and read out boards have been prototyped using commercial parts and the power measured, including the activity dependence of the processor. Because the TEM was not tested in flight configuration and the activity dependence is a significant portion of the power requirement, we have assigned Class 2 contingency to this subsystem component. Changes in the TEM processor were identified during the ATD phase testing which will decrease the power requirement, but this has not been accounted for in the power tabulation.

The SIU was not prototyped during the ATD phase by the GLAST program, but it is based on existing devices and circuits developed for other programs which provide power estimates. A major portion of the SIU is the processor circuit which is identical to the TEM processor.

With reserves applied, we have no margin with respect to the IRD allocation of 650 watts orbit averaged. The orbit dependence of power with reserve applied is 12.4 watts per kHz of the Level One Trigger. The power margin is calculated using an orbit average Level One Trigger of 5.5 kHz with the veto disabled. With the veto enabled, the orbit average power decreases by 43 watts and the gross power margin increases by 7%. All powers shown include allowance for typical power supply efficiencies in the range of 69% to 87% depending on voltage output.

### 1.5.4.3 Cost Reserve

Budget reserve has been rolled-up to the instrument level, and is shown in Table 1.5.6, below. Reserve has been allocated both to fit the tight funding profile, and to reflect the level of maturity of the design in different phases, and the level of risk associated with the phase of the project

Both NASA and the major domestic contributor, the Department of Energy (DOE), carry their own reserve, and all other domestic contributors are bringing in level-of-effort salaries of individuals, where no reserve is needed.

**Table 1.5.6:** Budget Reserve by Funding Source

| | FY00 | FY01 | FY02 | FY03 | FY04 | FY05 | Total |
|---|---|---|---|---|---|---|---|
| NASA Costs w/out Reserve | $3,289 | $3,595 | $12,024 | $13,960 | $10,633 | $3,673 | $47,174 |
| Budget Reserve % | 5.00% | 0.00% | 22.00% | 25.00% | 50.00% | 24.00% | 26.49% |
| Budget Reserve $ | $164 | $0 | $2,645 | $3,490 | $5,317 | $882 | $12,498 |
| | | | | | | | |
| DOE Costs w/out Reserve | $3,435 | $6,298 | $5,454 | $6,709 | $3,645 | $2,323 | $27,864 |
| Budget Reserve % | 10.00% | 15.40% | 26.10% | 27.50% | 40.00% | 38.00% | 25.52% |
| Budget Reserve $ | $347 | $982 | $1,483 | $1,879 | $1,536 | $883 | $7,110 |
| | | | | | | | |
| Total Other Costs | $3,174 | $9,695 | $12,006 | $5,642 | $3,349 | $3,273 | $37,139 |

Budget reserves for both NASA and DOE contributions are just over 25%, which we consider to be adequate for the project. Reserve during Formulation Phase is relatively low, given the advanced state of design for a number of the subsystems, and the negative annualized funding profile for the NASA-funded institutions in FY 2001. For NASA-funded work, we plan to remain relatively lean until the I-PDR, when NASA funding can better support the advanced development and implementation work.

During Implementation Phase, through integration and testing, reserves grows with the increased risk of negative cost variances. In addition to the 50% NASA reserve, and 40% DOE reserve held during FY 2004, the main integration and test year, the Integration and Test budget plan includes a funded schedule contingency of three months.

### 1.5.4.4 Schedule Reserve

As noted in Sect. 1.4 and above, the instrument schedule carries a three month funded contingency following the integration and test phase. The schedule will be managed aggressively over the project to maintain that margin. Nonetheless, the schedule includes contingency from three additional sources. First, for the three subsystems with the most schedule risk: the Tracker, Calorimeter, and DAQ, the subsystem modularity provides a level of fabrication and integration flexibility which can provide significant schedule relief. This flexibility includes being able to add extra shifts or additional production lines, if needed.

Second, schedule risk can be mitigated by drawing on the strengths of the institutions involved in the instrument production. All bring long and relevant experiences in high-energy physics detectors and flight instrumentation assembly and integration. This can be drawn on to mitigate schedule risks by bringing additional resources to bear on at-risk subsystems, production processes, or even component-level design and production.

Finally, the modular nature of the instrument provides additional schedule risk mitigation, by allowing for selective de-scoping, if needed, to mitigate schedule risk. This is only possible because of the modular design, and the relatively soft effect on science performance of mild descoping.

### *1.5.5 Descope Plan*

Our descope strategy is an integral part of the Risk Management Plan. Descope is the action of last resort in the hierarchical approach to risk mitigation. The descope plan addresses mitigation of risk to four principal resources: cost, schedule, mass and power. In Section 2.2.10 of Vol.1, the performance floor is defined to be ¾ of the effective area of the baseline LAT. If that reduction is accomplished by eliminating 4 of 16 towers, then the effective area and FOV that remain still satisfy the SRD requirements. Table 2.2.18 of Vol.1 shows how the science reach depends upon the effective area.

The simplest way to descope the effective area is to reduce the number of towers, as is discussed in Section 2.2.10 of Vol.1. In that case all of the performance metrics presented in Table

2.2.1 and in Foldout B (5a-5d) are unchanged, except for the effective area and, to a much lesser extent, the FOV. Other viable descope options exist and may be preferred in some circumstances. Table 1.5.7 lists several options that we have considered and consider to be acceptable, together with their impact on resources. Table 1.5.8 shows how the descope options could fit into the mission phases.

***Mass.*** An effective descope of the LAT mass requires a reduction in the CAL volume. That can be accomplished in the Formulation Phase (A/B) by rescoping the module sizes. A reduction in tower lateral size would have to be accomplished very early in the design process because of its impact on fundamental dimensions such as the SSD size. The CAL depth could be adjusted much later in the design process. In fact, even after design, CsI layers could be replaced by lower-density mechanical frames, allowing such a mass descope to be taken even during the Implementation Phase (C/D). Descoping entire towers could occur well into the Implementation Phase and would, of course, result in substantial mass reduction.

***Power.*** Early in the Formulation Phase the power could be reduced by increasing the strip pitch of the TKR detectors at the cost of some reduction in performance for high-energy photons. The power could be reduced by about 50 W in this way without running into problems with increased strip capacitance. The number of TKR planes could be descoped later in the design process, but that would result in a loss of effective area. TKR planes could be descoped even in the Implementation Phase for power purposes by building some TKR trays without converters, detectors, and readout chips. Some power savings could be achieved by reducing the number of TCPU cards, which could be done even in the Implementation Phase. That would result in a loss of level two trigger processing power, which may be needed at the highest rate conditions. Descoping entire towers would, of course, result in substantial power reduction.

***Cost.*** The modularity of the LAT design provides a straightforward cost descope option, by elimination of entire towers. This option could be exercised even during the Implementation Phase to save both schedule time and cost in materials and assembly. Elimination of two towers is more than sufficient to cover the loss of \$2.5M of NASA LAT funding that would occur if a secondary instrument were funded.[1] In that circumstance the full baseline instrument could still be flown with no loss of capability, assuming that the qualification tower modules were refurbished to serve as a flight tower. That would add some risk, however, since there would be no spare modules. Beam tests, unless eliminated entirely, would have to be carried out with one or two flight towers and would have to be scheduled so as not to delay I&T. Also, the I&T schedule would become slightly more complex in order to accommodate the refurbished towers. The refurbished towers and any towers used in beam tests would be the last ones to be integrated onto the flight grid.

Some limited descope options are presented in Tables 1.5.7 and 1.5.8, such as reducing the ACD segmentation, that could be invoked to resolve small budget problems. However, to save 10% of NASA costs would require elimination of 4 towers. In an optimistic scenario, in that circumstance the flight spare tower and refurbished qualification tower could be installed and flown, resulting in minimal loss of capability. However, if there is a schedule problem in addition to the cost descope, then it might be necessary to fly a 4×3 array of towers, which would put the LAT at the performance floor. The maximum possible descope would be elimination of 6 towers. That carries a very high risk, however, of falling below the performance floor, since it would require flying the qualification tower with no spare towers available. Note that if the number of towers is reduced sufficiently early, then the power reduction would allow the use of less expensive power supplies, saving an additional \$0.6M.

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[1] Another \$2.5M of NASA instrument funding already is not included in our budgeting.

**Table 1.5.7:** Descoping Options and Impact

| ACTION | | Performance Loss | Risk | Science Impact | Resource Impact | | |
|---|---|---|---|---|---|---|---|
| | | | | | Mass | Power | Cost |
| Larger, fewer ACD tiles<br>Form. Phase | | Reduced ε @ E > 30 GeV | No additional | Line Search Goal and decreased high E efficiency | 0 | -12W | -$0.3M |
| 3 fewer front and 1 fewer back Tracker x,y planes<br>Form. Phase | | Loss of ≈ 20% of effective area | No additional | Decreased sensitivity at all energies | -110kg | -75W | -$2.8M |
| 2 fewer CAL layers<br>Form./Impl. Phases | | Reduced energy resolution | No additional | Reduced energy reach | -350kg | -18W | -0.25M |
| Reduce number of TCPU boards<br>Impl. Phase | | Decreased peak-rate capability | Decreased redundancy, margins;<br>Increased S/W complexity | Loss of effective area in high-background conditions | -8kg | -13W | -$0.4M |
| Reduce TEM testbed to 4 units<br>Impl. Phase | | None | Testing inadequate to represent flight hardware | None | 0 | 0 | -$0.4M |
| Cheaper, less efficient power supplies<br>Form Phase | | Increased dead time at high rate (power α rate) | Increased heat dissipation and lower power margin | None | 0 | +122W | -$0.6M |
| Increase TKR pitch<br>Form. Phase | 235 µm | Worse PSF at high energy | No additional | Decreased sensitivity at high energy | 0 | -24W | Negligible |
| | 282 µm | | | | | -48W | |
| Stop assembly of up to 6 towers<br>Impl. Phase | 2 | 0% of $A_{eff}$ | Moderate | None | 0 | 0 | -$0.1M |
| | 4 | 12% of $A_{eff}$ | High | Decreased sensitivity at all energies | -263kg | -70W | -$0.2M |
| | 6 | 25% of $A_{eff}$ | Very High | | -526kg | -140W | -$0.3M |
| Omit up to 6 towers<br>Form. Phase | 2 | 0% of $A_{eff}$ | Moderate | None | 0 | 0 | -$3.35M |
| | 4 | 12% of $A_{eff}$ | High | Decreased sensitivity at all energies | -263kg | -70W | -$6.7M |
| | 6 | 25% of $A_{eff}$ | Very High | | -526kg | -140W | -$10.1M |

As indicated in Tables 1.5.7 and 1.5.8, assembly of up to 6 towers could be halted during the implementation phase. However, Table 1.5.7 shows that the cost savings would be negligible, assuming that all parts were already purchased. Therefore, such a descope would make sense only if required in order to resolve a schedule problem. If this involved omission of towers from the flight instrument, then the resulting configuration would be non-optimal, since the Grid and the ACD will have already been designed and built for the full configuration of towers.

None of these descope options include reductions in engineering costs. This is why a part-count reduction of 25% only leads to a 10% reduction in overall costs. But parts, fabrication, testing and integration costs do scale nearly proportional to the number of towers. Since the budget is severely restricted during the first years of the program, and costs during this phase are dominated by engineering, it would be difficult to use this plan to compensate for significant cuts in the funding for work scheduled during the early years (FY 2000 and 2001).

Funding of tower components is derived from several sources, including non-NASA contributions. Therefore, in attributing the descope savings to NASA costs, we are assuming that a descope of the number of towers will require renegotiations of responsibilities between collaborating institutions and movement of resources from one subsystem to another. We are confident that there is sufficient flexibility in our management plan and sufficient commitment from our collaborators that this can be accomplished in any of the scenarios presented here.

## 1.6 PERFORMANCE AND SAFETY ASSURANCE

### *1.6.1 Overview of the Performance and Safety Assurance Plan*

The scope of the GLAST Performance and Safety Assurance includes quality assurance,

**Table 1.5.8:** Mission phased descope for risk mitigation

| Phase | Resource Issue | Mitigation | Science Impact | Resource Comment |
|---|---|---|---|---|
| **Form.** | Mass | Rescope tower module size | Effective Area | Save mass & power |
| | | Rescope # tracker layers | Effective Area | Save mass & power |
| | | Rescope calorimeter depth | Energy reach, energy resolution | |
| | Power | Reduce DAQ TCPU cards | Reliability, orbit average deadtime | Save materials, assembly and I&T costs |
| | | Increase SSD strip pitch | Hi Energy angular resolution | No cost savings |
| | | Rescope # of tracker layers | Effective Area | |
| | Schedule Cost | Delete fabrication and test of two towers | Increased Risk: Fly qualification unit, no spare module | Save materials, assembly, and test costs |
| | | Delete Flight towers (max 4) | Effective Area | Save materials, assembly, test, and I&T costs; compress I&T schedule. |
| | Cost | Reduce DAQ TCPU cards | Reliability, orbit average deadtime | Would complicate flight software |
| | | Reduce Segmentation of ACD | Loss of high energy effective area from backsplash veto | Save on electronics channels, assembly, and test costs |
| | | Reduce number of tracker layers | Effective Area | Materials, assembly, test costs |
| | | Cheaper power supplies | Lower power margin, increased heat | |
| **Impl.** | Mass | Remove Cal CsI layers | Energy reach, energy resolution | Replace with mechanical frames; saves some power |
| | Power | Reduce DAQ TCPU boards | Reliability, orbit average deadtime | Save assembly costs |
| | | Reduce # of tracker layers | Effective Area | Save assembly costs |
| | | Reduce # of towers | Effective Area | Save assembly costs |
| | Schedule Cost | Delete beam test of two towers | Increased Risk: Calibration, performance uncertainty | Compress I&T schedule & associated costs |
| | | Delete fabrication and test of two towers | Increased Risk: Fly qualification unit, no spare module | Save assembly, test, and I&T costs. |
| | | Remove up to 4 Flight towers | Effective Area | Save assembly, test, and I&T costs; compress I&T schedule. |

material and parts selection and control, inspection, problem failure reporting, reliability, software validation, and safety. The predominant assurance objective is that GLAST will operate in a safe and environmentally sound manner, and will meet the science objectives and corresponding measurement requirements specified in the GLAST *Science Requirements Document*. To achieve these top-level objectives, the project will establish formal programs to address the process for achieving safety and mission success.

## 1.6.2 1.6.2 Quality Assurance

### 1.6.2.1 Quality Assurance Program

The GLAST Quality Assurance Program provides guidelines for the quality system of the instrument project to ensure quality consistency for all activities. Instrument quality assurance will be planned, implemented, and managed consistent with the requirements of ANSI/ISO/ASQC Q9001-1994, “Standard for Quality Systems – Model for Quality Assurance in Design, Development, Production, Installation, and Servicing.” Ultimately, the instrument quality assurance program will contain elements that:

- Define a fully integrated and functioning quality organization at all levels of the instrument organization
- Assure quality requirements are identified and implemented through all phases of instrument formulation and implementation
- Provide practical guidance on implementing a quality plan for critical activities on the project as well as support to core group/service organizations

- Facilitate the implementation of project-wide quality measures with emphasis on problem prevention
- Integrate all subsystem and team member institution assurance activities

Quality engineers will be members of the IDT, and product development teams beginning at the formulation phase, and will continue their involvement through implementation, test, and delivery. These teams will develop the manufacturing processes, test procedures, and verification requirements to assure producibility, testability, inspectability and verifiability.

Furthermore, the product development teams will determine the critical products and processes within their product scope which require design review, parts control, inspection and problem resolution protocols. The quality engineer on the team will assure that GLAST Quality Assurance Program guidelines are met, and the appropriate implementing procedures are developed for the subsystem or product element. These procedures will be in accordance with the programs outlined in the following subsections. Figure 1.6.1 shows this quality assurance process development flow.

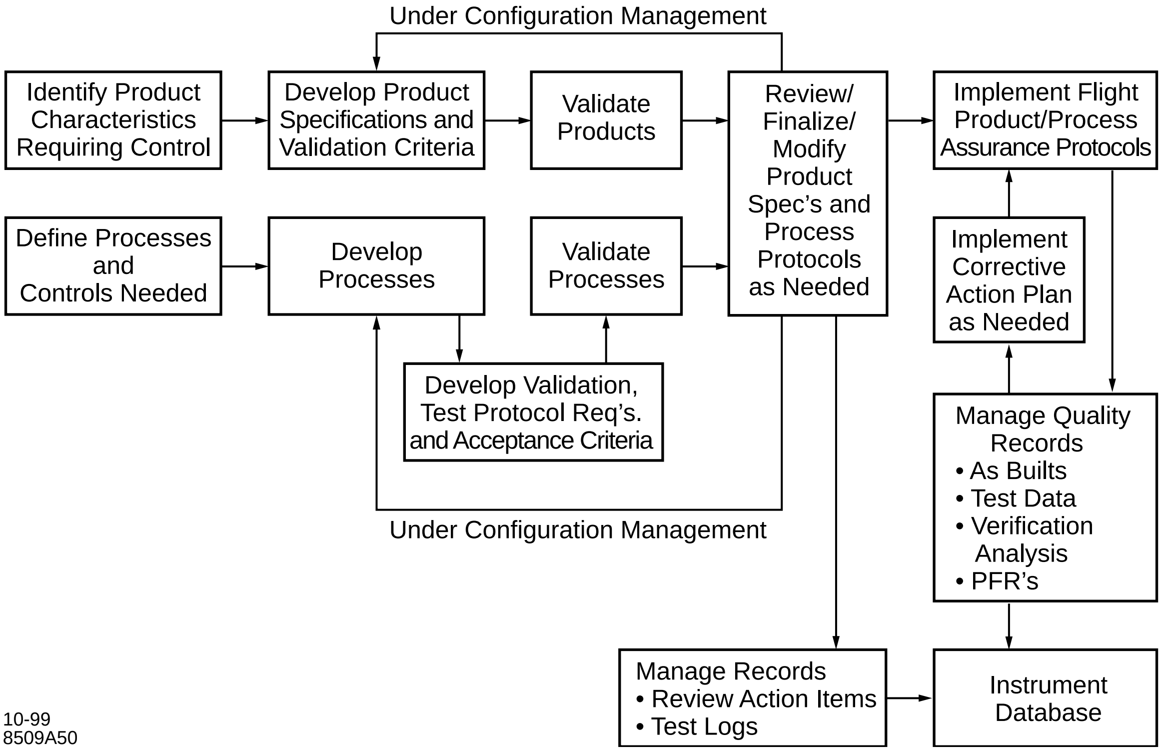
The quality assurance team will also oversee the engineering redline process, in accordance with the configuration management plan, and will maintain the database of all quality records, as defined by ISO 9001 procedures. These include copies of peer review data packages, validation and qualification test logs, as-built drawings, and other quality records.

### 1.6.2.2 Reviews

The PSAM will support a series of comprehensive system-level design reviews that will be conducted by the GSFC Project Office, as discussed in Sect. 1.2.5. The reviews cover all aspects of flight and ground hardware, software, and operations for which the IPO has responsibility.

The IPO will also implement a program of peer reviews at the component and subsystem levels. The review teams will be composed of both knowledgeable experts to evaluate the functional aspect of the element being reviewed, as well as the ISE, PSAM and I&T manager to evaluate the system-level issues.

**Figure: 1.6.1:** Quality Assurance Process Flow



These reviews will serve two functions. First, they will be used to evaluate the ability of the component or subsystem to successfully perform its function under operating and environmental conditions during both qualification testing and flight. Second, they will be used to assess the quality assurance plans, and verification test plans for the component or subsystem.

While the functional aspect of the review will serve as a gate through which the development process must pass, the quality function of the review will provide the means by which formal quality procedures and processes are implemented for the reviewed element. Action items will be maintained by the ISE, and the PSAM will ensure that quality issues are resolved.

### 1.6.2.3 Parts Selection and Control

An Electrical, Electronic, and Electromechanical (EEE) Parts Control Program will be implemented to assure that all parts selected for use in flight hardware meet mission objectives for quality and reliability. This program will be developed as part of the larger Quality Assurance Program prior to I-PDR, and will facilitate the management, selection, standardization, and control of parts and associated documentation. The primary mechanism to accomplish this will be the Program Approved Parts List (PAPL). This will be developed and maintained to assure that only parts whose performance and reliability have been proven, or that have demonstrated acceptance for the application, are used. Custom or advanced technology devices such as custom hybrid microcircuits, detectors, ASIC's, and Multi-Chip Modules (MCM) will also be subject to parts control appropriate for the individual technology.

The foundation for the Parts Control Program will be GSFC 311-INST-001, "Instructions for EEE Parts Selection, Screening and Qualification." For each EEE part which is a candidate for the PAPL, an appropriate parts quality level (as defined in 311-INST-001) will be assigned, based on system redundancy or criticality. Parts selected from the PPL, or NASA EEE Parts Selection List (NPSL) are considered to have met all criteria of 311-INST-001, and will be considered for approval for the PAPL.

For custom microcircuits, hybrid microcircuits, MCM's, and ASIC's, the Parts Control Program will prescribe a thorough qualification process. This will include complying with the applicable requirements of 311-INST-001, as well as implementing a design review process which will address derating of elements, element reliability assurance, the assembly process and materials, and methods for assuring adequate thermal matching of materials

### 1.6.2.4 Inspections

Flight products, components, piece parts, and material or any item that directly interfaces with flight products will be subject to receiving inspection, in-process inspection, and final acceptance inspection, as determined by the Product Design Team. Inspection procedures and criteria, and approval/rejection protocols will be developed and placed under configuration control concurrent with the product design. Given the redundant nature of many elements of the instrument, selective inspection methods will be implemented for some processes.

These documented instructions/procedures will be used for the inspection of quality characteristics during the processing of a product. All such procedures, travelers, and inspection results will be logged in the quality records database.

### 1.6.2.5 Workmanship

Workmanship standards and procedures will be developed concurrent with inspection procedures. For EEE parts and assemblies, the instrument Quality Assurance Program will rely heavily on proven NASA and industry standards, and implement them as needed. These standards include:

- *NASA-STD-8739-3:* Workmanship Standards for Soldered Electrical Connections
- *NASA-STD-8739-5:* Technical Standard for Fiber Optic Terminations, Cable Assemblies, and Installation
- *NAS 5300.4 (3J-1):* Workmanship Standards for Staking and Conformal Coating of Printed Wiring Boards and Assemblies
- IPC-2221: Generic Standard on Printed Board Design,
- *IPC-6011:* Generic Performance Specification for Printed Boards

- *NASA-STD-8739-4:* Technical Standard for Crimping, Interconnecting Cables, Harnesses, and Wiring
- *NASA-STD-8739-7:* Technical Standard for Electrostatic Discharge Control
- *NAS 5300.4 (3M):* Workmanship Standard for Surface Mount Technology
- *IPC-2222:* Sectional Standard on Rigid PWB Design
- *IPC-6012:* Qualification and Performance Specification for Rigid Printed Boards

For non-EEE parts, NASA and industry workmanship standards will be used when possible. For custom processes, new standards will be developed, documented, and implemented as needed. These will be subject to design review, as part of the overall product and process review procedure (detailed in 1.6.2.2).

#### 1.6.2.6 Problem/Failure Resolution

Problems or failures occurring during ground test of any flight hardware or software will be identified, documented, assessed, tracked and corrected in an approved and controlled manner. The process to assure closure of all such incidents is the Problem/Failure Report (PFR) system. This will be formalized concurrent with the Quality Assurance Program, prior to I-PDR. PFR's will be invoked at failure of any in-process test or inspection procedure, or in the event of any anomaly or problem while performing any procedure on flight hardware or software. The PFR will be monitored by the PSAM, through a process of data collection, disposition determination, and corrective action planning. Final approval of corrective actions will be given by the ISE, at the recommendation of the PSAM. A PFR is considered for closure when the ISE determines that appropriate and sufficient investigation of the cause of the problem or failure has been completed, and that commensurate corrective action has been implemented.

For hardware, the PFR system becomes effective with the first application of power at the component or subsystem level, or first test usage of a mechanical item. For software, PFR protocols begin with the first test use of the software with a flight hardware item at the component level or higher.

### 1.6.3 Reliability

GLAST Performance and Safety Assurance will plan and implement a reliability program that interacts effectively with other project disciplines, including safety, systems engineering, hardware design, and performance assurance. The program will be tailored according to the risk level in order to:

- Assure that adequate consideration is given to reliability during the design and development of hardware.
- Demonstrate that redundant functions, are independent to the extent practicable. This includes alternative paths and work-arounds.
- Identify single-point failure items, their effect on the attainment of mission objectives, and possible safety degradation. We will minimize these to the extent possible, and our modular design mitigates against the risk of such single points of failure.
- Demonstrate that stress applied to parts is not excessive; follow the PAPL derating guidelines.
- Show that reliability design is in keeping with mission design life and that it is consistent among systems, subsystems, instruments and components.

During the Formulation Phase, reliability analysis will be performed at the system and subsystem level, to identify potential problem areas. At a minimum, a Failure Mode and Effect Analysis will be performed to a sufficient depth so that mission critical failures are identified and dealt with effectively.

The reliability analysis will use GIDEP (Government-Industry Data Exchange Program) failure rate, failure mode and replacement rate data. This will leverage existing reliability information to improve the quality and reliability of parts, components, and subsystems in the insturment. In addition, the NASA Lessons Learned Information System (LLIS) will be used to apply the knowledge gained from past experience to avoid the repetition of past failures and mishaps.

### 1.6.4 Software Verification and Validation

Early in the R&D phase of the instrument, the GLAST LAT collaboration developed a computer simulation of the GLAST design. This simulation included essential details of the instrument design, including an accurate representation of the detector elements, material dead space, and the DAQ triggering method. As the R&D phase has proceeded, we have made this simulation progressively truer to our design in all details including an approximation of the spacecraft, which is important when considering background processes. The performance of the early simulations was verified during the 1997 electron beam test, and the more detailed simulations will be further verified during the 1999 beam test at SLAC. We have used these simulations to develop event reconstruction algorithms and to test them conceptually. These algorithms are being moved to the LAT Beam Test Engineering Model tower we now have in hand (which will also be used as a development platform and test-bed) for the real-time flight software implementations. Beam tests of this tower will also be used to validate our flight software. As the construction of the instrument develops, we plan to produce a four by four flight tower assembly that will also be used in extensive bench and beam tests to verify our flight software algorithms. Finally, the GLAST LAT project test plan also has provision for a beam test of the full GLAST instrument in a beam that will give further verification of our final flight software. Using these various test beds, the project will achieve realistic verifications of both the flight software and the simulations & reconstruction algorithms. These test procedures are being prototyped and implemented well ahead of the I&T phase.

In general, verification and validation (V & V) activities will be performed to ensure that GLAST software will satisfy its functional, performance and quality requirements. The Software System Manager is responsible for thorough testing of the code, from unit testing, through integration, to acceptance testing. The role of V & V is to perform analyses throughout the development process, to detect problems as early as possible, preferably before they show up in testing. As mentioned above, varied levels of software tests, ranging from unit or element testing through integration testing and performance testing, up to software system and acceptance tests for the completed instrument will be performed.

### 1.6.5 Safety and Hazard Mitigation

The IPO will plan and implement a system safety program that identifies and controls hazards to personnel, facilities, support equipment, and the flight system during all stages of the instrument development. System safety requirements will be derived from EWR 127-1, “Eastern and Western Range Safety Requirements,” as well as applicable safety standards of the institutions in the instrument team.

During the Formulation Phase, the Instrument Safety Officer will perform a hazard analysis. This will be a subsystem and system-level qualitative analysis that identifies all potential hazards, develops specific mitigation plans, and assures their resolution. All hazards which are deemed potentially critical will be further listed in the Project Safety Plan. As part of the hazard analysis process, the Instrument Safety Officer will work with product design teams to implement hazard controls in the design of hardware and in the development of process procedures.

Throughout the Implementation Phase, listed hazard risks will be jointly resolved between the responsible functional element and the Safety Officer. Resolution of each listed hazard is accomplished by a safety review of all appropriate test reports, engineering drawings and analyses, procedures and task flow. Analyses developed by other disciplines (FMEA, trade studies, reliability analyses) will provide input to support the safety analysis of failure points that present an hazard risk.

## 1.7 EDUCATION AND PUBLIC OUTREACH MANAGEMENT PLAN

### 1.7.1 E/PO Program Outline

The Education & Public Outreach (E/PO) program to accompany the LAT Flight Instrument development is designed to exhibit gamma-ray astronomy as an exciting field for the public as well as the researcher. Both young and old can be engaged by the exotic concepts of black holes and violent explosions seen across the Universe. Thus, the GLAST E/PO program is well suited to promote inquiry into the origin and structure of the Universe and the fundamental relationship between energy and matter, concepts which are included in the Physical Science Content Standards A, B, & D for grades 9-12.

Therefore, this Flight Instrument E/PO proposal, focuses on the following specific educational goal:

> *We will utilize the observations and scientific discoveries of the GLAST mission to improve the understanding and utilization of physical science and mathematics concepts for grades 9-12.*

We will at all times base our educational materials on the National Mathematics and Science Standards (with major emphasis on Physical Science Content Standards A, B, & D), and work within the established OSS Education ecosystem of the SEU Forum and the Regional Broker/ Facilitators to maximize our program returns.

Prof. Lynn Cominsky of California State University at Sonoma (SSU) will serve as the E/PO coordinator. In this capacity, she will work directly with and report to the IPI. She will supervise the work of Dr. Laura Whitlock and of the student assistant, and direct efforts for all E/PO WBS elements. Prof. Cominsky will be responsible for achieving the overall goals, as well as managing the budget and schedule for the GLAST E/PO program. She will ensure that all curricular products are aligned with national standards and are independently and comprehensively evaluated. Cominsky will also coordinate the participation by science team members in the E/PO program activities, and moderate the Quest Space Science Chats that include science team members. Cominsky's GLAST activities are funded at 25% time through the GLAST E/PO budget, and are cost-shared for an additional 25% time with SLAC, where she has been a visiting scientist for the past seven years.

Dr. Laura Whitlock has three main areas of responsibility: developing curricular content for the Web-based educational projects produced with E/PO partner Videodiscovery, developing specific curriculum products with E/PO partner and curriculum development specialists TOPS, and overseeing and managing the GLAST Ambassadors program. As part of the Ambassadors program, Whitlock will develop teacher workshops and will ensure that the workshops are presented at a wide variety of national, state and local conferences.

Dr. Helen Quinn (SU-SLAC) will supervise the creation of an interactive gamma-ray detector exhibit as part of the SLAC Virtual Visitors Center. She will also participate with Drs. Whitlock and Hartmut Sadrozinski (UCSC) in training the GLAST Ambassadors, and in developing curriculum content for the TOPS modules.

Videodiscovery Inc. will provide the software, graphics, videos, and other electronic media components required to create two Space Mysteries Series modules and the associated Web site.

TOPS Learning Systems will develop 3 specific curriculum modules which incorporate physical science and mathematics concepts for grades 9-12, derived from the GLAST E/PO educational goal which emphasizes Physical Sciences Content Standards A, B & D. TOPS will field-test these modules in classrooms before release.

WestEd, Inc. will provide both formative and summative assessment of the GLAST E/PO curriculum products developed in partnership with Videodiscovery and TOPS. Assessment tools and metrics will be developed and utilized for the Web-based Space Mystery modules from Videodiscovery (during FY 2004 and 2005), and for the more traditional print-based curriculum modules from TOPS (during 2003-2005). These metrics will also assess the training of the GLAST Ambassadors and the training by the GLAST Ambassadors of subsequent generations of teachers, as well as the content, use in the classroom and learning by the students.

### 1.7.2 E/PO Partners

The E/PO Coordinator has enlisted a number of partnering individuals and institutions in developing the E/PO program for the instrument. These are listed below.

***Sonoma State University***

*Dr. Lynn R. Cominsky* is Professor of Physics and Astronomy at Sonoma State University (SSU), and has served as Chair of the Public Affairs Working Group for the NASA GLAST Facility Science Team for the past two years. As part of this work, (and with the help of SSU undergraduate physics student Tim Graves) she created the GLAST outreach Web site: http://www-glast.sonoma.edu. She is also a member of the E/PO team for Swift, a gamma-ray burst MIDEX mission that will be launched in 2003. An author of over 45 research papers in high-energy astronomy, in 1993 Prof. Cominsky was named the Outstanding Professor at Sonoma State University and the California Professor of the Year by the Council for Advancement and Support of Education. Cominsky is also Deputy Press Officer for the American Astronomical Society, Press Officer for the AAS High Energy Astrophysics Division, and the PI on SSU's successful "Space Mysteries" NASA LEARNERS proposal (developed with Dr. Laura Whitlock.) Prior to joining the SSU faculty, Cominsky managed various parts of NASA's Extreme Ultra-Violet Explorer satellite project at the University of California Berkeley's Space Sciences Laboratory, serving as Software, Operations and Data Analysis group Administrator and the Science Payload Development Manager. In this latter position, she supervised over 70 engineers, technicians, scientists and programmers, and controlled a multi-million dollar yearly budget.

Dr. Laura Whitlock, has recently relocated to SSU to work full time on developing multimedia educational products that use NASA mission data. She was formerly the Education/Outreach Projects Coordinator at NASA Goddard's LHEA, where she created, developed, and promoted multi-media education and outreach materials, emphasizing the effective use of the World Wide Web. Her activities have focused on the field of high-energy astrophysics, notably on neutron stars, pulsars, black holes, quasars, and other eruptive cosmic sources, bringing these subjects to a level where K - 12 students and teachers can appreciate them. In addition to overseeing, assisting, and coordinating the E/PO efforts of the many missions in LHEA, she is the creator, designer, and project leader for the award-winning *Imagine the Universe!* and *StarChild* World Wide Web sites (http://imagine.gsfc.nasa.gov and http://starchild.gsfc.nasa.gov). She has written and published many teachers' guides and educational posters on astronomy and space exploration, and produced several CD-ROMs used to distribute NASA space science education material. In addition, Dr. Whitlock routinely creates and presents training workshops to educators at local, state, and national education meetings, including the National Science Teachers Association and the National Council of Teachers of Mathematics. These workshops use high-energy astronomy data (including X-ray and gamma-ray observations) to teach national standards in the physical sciences and mathematics. Dr. Whitlock holds the title of Honorary Master Teacher from the National Teacher Training Institute and is a member of the Association for Supervision and Curriculum Development. She is the Co-PI on SSU's LEARNERS grant, and a member of the Swift MIDEX E/PO team.

### *Videodiscovery, Inc.*

Videodiscovery is a leading publisher and distributor of quality, innovative multimedia products for educators and families. Renowned for its award-winning laserdiscs and CD-ROMs for the K - 12 and college market, Videodiscovery is an established new media industry leader. The company has consistently defined the cutting edge in multimedia education, responding to learning trends and students' needs with innovative, engaging applications of interactive media. Based in Seattle, the 15 year-old company specializes in science and math education.

Key personnel from Videodiscovery, Inc. that will participate in the GLAST E/PO program include CEO D. Joseph Clark and Vice President of Product Development Shaun Taylor. Dr. Clark founded Videodiscovery in 1983, after spending nine years as Director of the Center for Instructional Development and Research at the University of Washington, (in Seattle) and four years as an Assistant Professor at the University of British Columbia. He has a Ph. D. in microbiology from UC Davis, and was an NIH post-doctoral fellow at both UC Berkeley and the University of Copenhagen. Dr. Clark will ensure that the employees of Videodiscovery provide the necessary tools, drivers, scripts and video production footage needed to complete two modules of the Space Mystery Series. Shaun Taylor has been employed at Videodiscovery in his current position since 1986, after receiving the M. Ed. Degree in secondary education with an emphasis on science teaching and computers, and endorsements in physics and chemistry from Montana State University. At Videodiscovery, Taylor has produced 36 interactive videodiscs, and 26 CD-ROMs, and has been responsible for the major content preparation for over $4.2 million in grants and contracts from government agencies. He has also conducted numerous teacher training workshops for interactive programming and has made many presentations at national educational conferences. For GLAST, Taylor will direct the project and participate in the design meetings.

Some of the awards won by Videodiscovery products in the past 5 years include: Newsweek Magazine Editors' Choice Award; 1996 (Science Sleuths CD-ROM); Technology & Learning Magazine Software Excellence Award; 1995 (Science Sleuths CD-ROM); New Media Magazine Invision Awards Silver Medal; 1995 (Science Sleuths CD-ROM); National Parenting Center Seal of Approval; 1995 (Science Sleuths CD-ROM); Curriculum Administrator, Districts' Choice Award; June 1995 (Understanding Earth laserdisc); National Educational Film and Video Festival, Bronze medal; 1993 (Science Sleuths laserdisc)

In February 1997, Videodiscovery was awarded a grant by the National Science Foundation for the development and evaluation of an innovative approach to performance-based assessment using advanced technology. This methodology, and other proprietary software developed by Videodiscovery will be licensed at no cost to the GLAST project, for use in the development of at least two GLAST-inspired Space Mysteries (web-based inquiry-driven explorations targeted at grades 9-12, and which teach mathematics and physical science standards.) Videodiscovery is already working with Dr. Cominsky and Whitlock to develop three Space Mystery modules as part of NASA's LEARNERS Cooperative Agreement Notice, and a fourth module as part of the Swift MIDEX mission.

***TOPS Learning Systems***

TOPS Learning Systems is a leader in developing high quality curriculum that is aligned with the National Science and Mathematics standards. They have extensive experience in crafting attractive, ready-to-teach lessons that teachers can use in the classroom with a minimum of preparation, and which use simple, inexpensive materials. As a result, TOPS lessons are actually used by teachers, and don't just sit on the shelf. TOPS has created many lessons in physical sciences and astronomy for grade level 9-12. TOPS material is extensively field-tested in classrooms before release to the general education community.

The key person from TOPS is President and chief curriculum developer Ron Marson. Marson has been designing and marketing quality educational materials in science and math for over 20 years. Marson is a graduate of Seattle Pacific University (B.S. in Chemistry) and Harvard University (M.A.T. in Science Education). As founder and president of TOPS Learning Systems, a nonprofit educational corporation, he has developed the curriculum for the entire TOPS catalog of over 40 modules of activities, which include more than 900 different lessons.

***SU-SLAC***

Dr. Helen Quinn is a theoretical particle physicist at the Stanford Linear Accelerator Center. She is a fellow of the American Physical Society and an elected member of the American Academy of Arts and Sciences. She has extensive experience in the area of education, both as Assistant to the Director responsible for pre-college and undergraduate education programs at SLAC and as a member of collaborative projects aimed at improving science teaching in local school districts.

***UCSC***

Dr. Hartmut Sadrozinski is Adjunct Professor of Physics in the Institute for Particle Physics at the University of California at Santa Cruz. He is an experimental particle physicist and a specialist in instrumentation. He has used this expertise and the resources of a modern laboratory to promote scientific methods and thought in groups under-represented in science, through both Research Experience for Undergraduates (REU) and for Research Experience for Teachers (RET) programs.

***Quest***

The Quest project is a service of NASA's Education Program. Quest is located at Ames Research Center and is managed by NASA's Learning Technologies Project (LTP) of the High Performance Computing and Communications (HPCC) Program. The Space Scientists Online program explores a rich variety of topics with exciting spacecraft like Mars Pathfinder and Hubble Space Telescope, and includes archives from a half-dozen previous projects (e.g., Mars Team Online). This project provides live events on the Internet (both chats and audio/video programs) on diverse topics within NASA's Office of Space Science.

***WestEd***

WestEd is a non-profit research, development and service agency dedicated to improving education and other opportunities for children, youth and adults. WestEd was created in 1995 to unite and enhance the capacity of Far West Laboratory and Southwest Regional Laboratory, two of the nation's original education laboratories created by Congress in 1966. In addition to its work across the nation, WestEd serves as the regional education laboratory for Arizona, California, Nevada and Utah.

The key person from WestEd that will direct the GLAST assessment effort is Program Director for Science and Mathematics, Dr. Steven A. Schneider. Dr. Schneider holds a Ph.D. from Stanford University in Design and Evaluation of Educational Programs, a bachelor's degree in Biology from UC Berkeley, and a California Life Teaching Credential. He has extensive experience in the area of program evaluation, research, and teaching in the areas of science, mathematics, and technology. A few of the programs which Dr. Schneider has evaluated or directed include: the High School Science Teacher Assessment for the National Board for Professional Teaching Standards (NSF); the National Hewlett-Packard Company Hands-On Science Program and the $5.7 million Local Systemic Change Project (NSF and HP); the California Mathematics Implementation Study; and the California's State Systemic Initiative (SSI) (NSF). Dr. Schneider is currently a member of the U.S. Department of Education's Expert Panel in Mathematics and Science focusing on developing criteria for identification of exemplary and promising programs. Dr. Schneider's evaluation, research, teaching, and leadership expertise and experience makes him extremely qualified to be the lead project evaluator for the GLAST E/PO program.

### 1.7.3 GLAST Mission E/PO Program

The E/PO funds available through the Flight Instrument AO represent only a small fraction (~20%) of the total E/PO funding for the GLAST mission. We propose that the Flight Instrument team be given the resources and responsibility for the entire mission E/PO effort. NASA policies require a serious commitment of effort to the E/PO effort by the Science team - only the IPI team can provide this commitment. The following lists several additional activities which we have considered, and for which we have committed partners but that we cannot pursue within the scope of the budget offered by the Flight Instrument AO. These activities include, but are not limited to:

***GLAST Webcast Projects: Live@The Exploratorium and NASA QUEST.***

The world-renowned Exploratorium proposes to develop and host a series of on-line World Wide Web resources for the GLAST mission. Together with the staff at the Exploratorium, we propose to host a series of two-hour Internet webcasts over the duration of the project highlighting the GLAST mission. Each of the webcasts will feature discussions of research, presentation of recent discoveries, and interaction with the GLAST Science Team. These webcasts will be done through the "Live@The Exploratorium" program and will be archived to support viewing by students and the public at a later date. In support of these webcasts, the Exploratorium will design an accompanying multimedia website and other educational materials (see attached letter.)

The NASA/Ames Quest project also has offered to sponsor webcasts featuring GLAST science team members, and to host on-line teacher training workshops (see attached letter of commitment.)

***PBS television special***

We have explored working on a one or two hour television show to be shown on PBS. We have considered either an episode of NOVA or an independent special produced by Thomas Lucas, the award-winning producer of the recent PBS shows Voyage to the Milky Way and Mysteries of Deep Space (see attached letter of commitment.)

***Additional Space Mystery modules and GEMS guides.***

Within the financial constraints of the Flight Instrument AO, we can produce two Space Mystery modules. We have successfully competed in the NASA LEARNERS program, and have received funding for an initial three modules. An additional module is planned for the Swift gamma-ray burst MIDEX E/PO program (to be developed by Cominsky and Whitlock, who are also members of the Swift E/PO team.) This latter module will be developed in collaboration with personnel at the Lawrence Hall of Science, creators of the Great Explorations in Math and Science (GEMS) guides. We are interested in using GLAST E/PO project funding to develop at least two additional Space Mystery modules, as well at least one additional GEMs guide (see attached letter of commitment.)

## 1.8 MAJOR FACILITIES AND EQUIPMENT

### 1.8.1 Management, System Engineering, and Performance Assurance

#### 1.8.1.1 SU-SLAC

The IPI and LAT IPO will be located at Stanford University, Stanford Linear Accelerator Center. The LAT R&D effort at SU-SLAC has been housed in existing office and lab space in Building 084 on the SU-SLAC campus. Additional office and lab space has been identified in Building 084 to house the IPO as it grows in size. This co-location of the entire instrument staff at SU-SLAC will help to ensure good communication and teamwork within the organization.

Facilities available on the SU-SLAC campus for the Instrument Project Office include significant computing infrastructure and support staff, already in place, supporting the high-energy physics experimental programs. Videoconferencing rooms, high-speed internet access, and technical publications and graphic design support will further support the needs of the IPO. The Business Services Division has demonstrated the capability to support the management of large, international instrument teams, such as the BABAR particle physics detector.

The system engineering and performance assurance functions will similarly be supported by experienced departments, familiar with the management of complex systems and processes. Experience in working in the regulatory environment of a Department of Energy National Laboratory will prove worthwhile in developing engineering and quality assurance infrastructure for the GLAST instrument project.

### 1.8.2 Tracker

#### 1.8.2.1 UCSC

The Santa Cruz Institute for Particle Physics (SCIPP), at the University of California, Santa Cruz brings many years of experience in high-energy physics to the team. SCIPP is housed in the Natural Sciences Building on the UCSC campus. These facilities include office, lab, and clean room space for the full staffing complement for the GLAST effort. The facilities include computerized design and test equipment for the development of complex integrated circuits.

#### 1.8.2.2 SU-SLAC

The Tracker development effort has been ongoing since 1994 in the Research Division at SU-SLAC. This has formed the physical and organizational nucleus of the IPO, housed in Building 084 on the SU-SLAC campus. This includes office and lab space sufficient for the entire Tracker team, located downstairs from the expected headquarters of the IPO.

Given that the Tracker will be partially assembled, and fully integrated at SLAC, the currently available clean room facilities will soon be augmented. Facilities have been identified for the Tracker effort, and they will be re-configured for this effort, once project approval is given. SLAC’s long experience in the development of ultra-high vacuum systems will aid in the staffing of these facilities.

#### 1.8.2.3 INFN

The laboratories of the Italian Institute for Nuclear Physics (INFN) are well equipped for design, assembly, and testing of large-scale silicon strip detector systems. Large clean room facilities house several precision assembly stations and several automated wire bonding machines. Moreover the trained staff has developed expertise in recent projects and are ready to start the GLAST LAT effort. Testing facilities are integrated into the clean rooms, such that the planned assembly of a large part of the tracker modules can be supported, starting from the silicon wafers and ending with tested trays.

#### 1.8.2.4 Hiroshima University

Hiroshima University has high quality clean rooms and test equipment to support the inspection and testing of silicon microstrip detectors. They will work closely with Hamamatsu Photonics, our major supplier of silicon sensors, during the fabrication cycle on the control of the quality and performance of the silicon detectors. Hiroshima personnel have a long-standing reputation in the design and testing of high quality detectors, and they will interface with the factory on a regular basis on QA issues. Hiroshima will perform detailed performance checks (including radiation testing) on the Tracker silicon detectors.

### *1.8.3 Calorimeter*

#### 1.8.3.1 NRL

NRL's primary contribution to the GLAST program is centered in NRL's Space Science Division. The SSD has a number of commitments for space experiments aboard NASA, DoD, and other space projects that include mission operations and data analysis facilities for the OSSE experiment on NASA's Compton Observatory and the LASCO experiment on the NASA/ESA Solar-Heliospheric Observatory. The Division maintains facilities to design, construct, assemble, and calibrate space experiments.

The design, analysis, fabrication and test of the GLAST Calorimeter subsystem and the GLAST DAQ subsystem components will be performed in the SSD facilities. NRL's Naval Center for Space Technology (NCST) will be utilized for environmental testing of the subsystems. NCST's Design, Test and Processing Branch provides facilities for spacecraft vibration test, thermal high-vacuum testing, and acoustic reverberation testing. The Systems Analysis Branch provides facilities for electronics thermal control analysis, modal survey testing and static loads testing.

#### 1.8.3.2 CEA

The Service d'Astrophysique (Sap) of the Commissariat a l'Energie Atomique is a major space astrophysics laboratory with a long history of high-energy astrophysics and multilength approach to cosmic rays, compact objects, stellar formation and evolution, interstellar medium, and large-scale structures in the Universe. The staff of Sap of ~100 includes astrophysicists and an engineering group for space instrumentation. Sap is part of a department, DAPNIA, which has brought together, since 1991, research groups in astrophysics, nuclear and particle physics, along with strong technical support groups. DAPNIA gathers over 400 scientists and engineers, and 300 technical and administrative staff. The design, fabrication, and integration activities for the LAT calorimeter will benefit from the unique expertise and solid experience available inside DAPNIA in space instrumentation, high-energy calorimetry, radiation-hard analog and digital microelectronics, light detectors, data acquisition and processing systems, and instrument simulations. This experience is drawn from 40 years of development of accelerator and space instrumentation, and the related scientific analyses. DAPNIA is equipped with many clean rooms (up to class 100), assembly halls, thermal vacuum test equipment, as well as manufacturing and testing equipment. The group takes advantage of a long tradition in the management of international ground-based programs and space missions sponsored by CNES, ESA, and NASA.

#### 1.8.3.3 Ecole Polytechnique

The Institut de Physique Nucleaire et de Physique des Particules (IN2P3) runs 16 nuclear and particle physics laboratories inside the Centre National de la Recherche Scientifique (CNRS). Three are involved in the LAT proposal, Namely Physique Nucleaire des Hautres Energies (LPNHE), at Ecole Polytechnique; Physic que Corpusculaire et Cosmologie (PCC) at College-de-France; and Centre d'Etudes Nucelaires de Bordeaux Gradignan at the University of Bordeaux. The three laboratories are run jointly by IN2P3 and the institutions which host them. They represent a total of 120 physicists and 140 engineering and administrative staff. These groups have had a major impact on the CERN activities since the sixties on hadronic physics and weak currents. In recent years, their activities covered quark-gluon search with NA-38 at CERN-SPS, e-p collision on H1 at DESY, e+e- collisions at LEP (ALEPH & DELPHI), on BABAR at SLAC (presently running), and construction work for the future LHC. In particular, the mechanical engineering group at LPNHE is involved in the design and fabrication of the mechanical structure of the WPb04 crystal calorimeter of the CMS experiment for LHC, using carbon-fiber cells in a focusing geometry.

In the last decade, the three groups have developed activities in high-energy astrophysics. They designed, built, and are now operating CAT and CELESTE, which represent major successes in ground-based gamma-ray telescopes. These laboratories have large technical groups, well trained on international scale projects. In particular, the mechanical group of 19 engineers and technicians at LPNHE, have complete capabilities from design (7 CAD stations) to integration. The workshop is equipped with modern fabrication and testing equipment. A clean room and assembly hall will be available for LAT activities. The electronics group at CENBG and PCC represent 20 engineers and technicians, fully equipped with CAD stations for electronics and electrical engineering, and test equipment to develop the ground support equipment for the Front-end ASIC and acceptance tests. Calorimeter tests and calibrations will benefit from strong presence at CERN, with a team member residing there.

## 1.8.4 Anticoincidence Detector

### 1.8.4.1 GSFC

The ACD development effort will take place at GSFC. GSFC possesses a full range of state-of-the-art facilities for developing, manufacturing, and testing of flight hardware. GSFC has all the required office and laboratory space in buildings 2, 5, 7, and 23 necessary for the development of the flight ACD. The center has the necessary thermal vacuum chambers, electromagnetic compatibility (EMC) test facilities, vibration, and acoustic test facilities needed to fully qualify and test the flight ACD. No major new facilities or equipment are required.

## 1.8.5 Data Acquisition System

### 1.8.5.1 SU-HEPL

Based on the W.W. Hanson Experimental Physics Laboratory (HEPL), Stanford University has developed a comprehensive and effective infrastructure that supports space science programs, including current projects such as Gravity Probe B (GPB), the Mini Satellite Test of the Equivalence Principle (STEP), the Solar Oscillations Investigation (SOI), the Lambda Point Experiment (LPE), the Confined Helium Experiment (CHeX), and the Energetic Gamma Ray Experiment Telescope (EGRET). The infrastructure provides access to services and personnel experienced in program management, procuremnent, production reliability, design, quality assurance, and certified handling of flight hardware. Facilities that support research in HEPL include four 250-1300 SF class 10,000 clean rooms, one 2,500 SF class 100,000 hi-bay with overhead cranes with up to 40-ton capacity, numerous electronics laboratories with ESD-protected laminar-flow benches, meeting rooms, and office space. Within or in close proximity to HEPL, we have access to a number of technical services such as machine shops, a microfabrication laboratory, welding srevices, electrical and plumbing shops, in-house emergency generators, secure shipping and receiving capability, and bonded storage. All HEPL facilities are part of a 100MB local-area computer network. HEPL is host to the GP-B Mission Operations Center (GMOC). The GMOC is on the NASA IONET and will operate GPB spacecraft after launch in 2001 using a suite of software tools including Dataviews, Satellite Tool Kit (STK), RTworks, and Operations and Science Instrument Support (OASIS). HEPL has an established safety program tied to the University's Environmental Health and Safety Office. Also, ONR currently maintains a quality assurance representative at Stanford for government review of space flight programs. Within HEPL, the GLAST Integrated Instrument Demonstration and Development project presently occupies 12 offices, one controlled access electronics laboratory with ESD-protected lab benches, and one data processing/meeting room. Additional facilities will be made available as required to support the GLAST program in the implementation phase.

### *1.8.6 Grid, Integration and Test*

#### 1.8.6.1 SU-SLAC

SU-SLAC will house the integration and functional testing of the flight instrument. Integration clean rooms will form part of the complex of clean rooms, used also for the Tracker assembly and testing. SU-SLAC's extensive experience in the assembly and operation of large ultra-high vacuum, cryogenic, and high-powered microwave assemblies has yielded a large knowledge base and physical infrastructure to support the GLAST integration facilities.

The SLAC linear accelerator will provide high-energy electron beams for test and calibration of engineering models and the flight calibration unit and flight instrument. The End Station A facilities have been configured for performance testing of the GLAST modules. This facility will be used throughout the instrument development and implementation for calibration and test of instrument subassemblies.

### *1.8.7 Plans for New Facilities*

#### 1.8.7.1 SU-SLAC

Instrument processing, assembly and test areas will be reconfigured to accommodate the unique requirements of the GLAST instrument. The Light Assembly Building, Building 33, will be reconfigured to include clean rooms for Tracker equipment assembly and test, as well as integration of the flight instrument. This facility has been used recently for the assembly of the BABAR Drift Chamber detector subsystem.

## 1.9 WORK BREAKDOWN STRUCTURE

As detailed in previous sections, the WBS provides the framework around which the management organization and plans are built. Cost and schedule control is delegated to subsystem managers, and reporting of all subsystem performance from lower levels of the WBS flow through them.

The WBS also defines all work categories and packages for the project. It has been used for all budgeting and scheduling shown in this proposal, as well as to define the Statement of Work in Appendix F. The WBS is organized into three groupings, which are outlined in Table 1.9.1.

**Table 1.9.1:** Work Breakdown Structure

| |
|---|
| **Instrument Project Office and System-Level Science** |
| *4.1.1 Instrument Management* |
| *4.1.2 System Engineering* |
| *4.1.3 Science* |
| **Hardware Subsystems** |
| *4.1.4 Tracker* |
| *4.1.5 Calorimeter* |
| *4.1.6 Anticoincidence Detector* |
| *4.1.7 Data Acquisition* |
| *4.1.8 Grid* |
| **Instrument-Level Functional Groups** |
| *4.1.9 Integration and Test* |
| *4.1.10 Performance and Safety Assurance* |
| *4.1.11 Instrument Operations Center* |
| *4.1.12 Education and Public Outreach* |

Following this in Table 1.9.2 is the Work Breakdown Structure, expanded to the fourth level. WBS levels are defined, assuming the Mission is level 1, Mission Instruments are level 2, and Instrument Subsystems are level 3 elements. WBS level 4, therefore, delineate top-level work packages for each of the instrument subsystems.

These fourth level elements have been standardized as much as possible across all subsystems and third level functional elements, to aid future performance tracking and analysis. Elements common to most subsystems are management, reliability and quality assurance, suborbital I&T, instrument I&T, mission I&T support, and mission operations and data analysis (MODA) support. Other fourth-level elements are unique to the subsystem. All elements are described in detail in the Statement of Work in Appendix F. Below the fourth level which is shown, all subsystems have developed expanded and detailed work package and task breakdowns to level six and seven. These were used for budget estimating and scheduling purposes, and are shown in Appendix H, “Detailed Subsystem Budget Estimates.”

## **Table 1.9.2:** WBS by Fourth Level

- **4.1.1 Instrument Management**
  - *4.1.1.1 Project Management at Stanford*
  - *4.1.1.2 Project Management at SLAC*
  - *4.1.1.3 Cost & Schedule Control*
  - *4.1.1.4 Project Database Management*
  - *4.1.1.5 Administrative Support*
  - *4.1.1.6 Travel*
  - *4.1.1.7 Special Studies*

- **4.1.2 System Engineering**
  - *4.1.2.1 Requirements Management and Design Integration*
  - *4.1.2.2 Test and Verification Planning*
  - *4.1.2.3 Systems Analysis*
  - *4.1.2.4 Qualification & Tracking*

- **4.1.3 Science**
  - *4.1.3.1 Management*
  - *4.1.3.2 Science Simulations*
  - *4.1.3.3 Calibration Requirements & Planning*
  - *4.1.3.4 Science Data Processing*
  - *4.1.3.5 Instrument Integration & Test*
  - *4.1.3.6 Mission Systems Integration & Test*
  - *4.1.3.7 Mission Operations & Data Analysis*

- **4.1.4 Tracker**
  - *4.1.4.1 Tracker Management*
  - *4.1.4.2 Reliability & Quality Assurance*
  - *4.1.4.3 Tray Subassembly*
  - *4.1.4.4 Tower Structure & Assembly*
  - *4.1.4.5 Tracker Test & Calibration*
  - *4.1.4.6 Suborbital Integration & Test*
  - *4.1.4.7 Instrument Integration & Test Support*
  - *4.1.4.8 Mission Integration & Test Support*
  - *4.1.4.9 Mission Operation & Data Analysis*

- **4.1.5 Calorimeter**
  - *1.4.5.1 Management*
  - *4.1.5.2 Reliability & Quality Assurance*
  - *4.1.5.3 CsI Detector Module*
  - *4.1.5.4 Analog Front End Electronics*
  - *4.1.5.5 Structural Support*
  - *4.1.5.6 Calorimeter Tower Controller*
  - *4.1.5.7 Calorimeter Assembly*
  - *4.1.5.8 Test & Calibration*
  - *4.1.5.9 Design & Verification*
  - *4.1.5.10 Suborbital Integration & Test*
  - *4.1.5.11 Instrument Integration & Test Support*
  - *4.1.5.12 Mission Integration & Test Support*
  - *4.1.5.13 Mission Operation & Data Analysis*

- **4.1.6 Anticoincidence Detector (ACD)**
  - *4.1.6.1 ACD Management*
  - *4.1.6.2 Reliability & Quality Assurance*
  - *4.1.6.3 ACD Detectors*
  - *4.1.6.4 Electronics*
  - *4.1.6.5 Mechanical Components*
  - *4.1.6.6 Flight Software*
  - *4.1.6.7 Suborbital Integration & Test*
  - *4.1.6.8 Instrument Integration & Test*
  - *4.1.6.9 Mission Integration & Test Support*
  - *4.1.6.10 Mission Operation & Data Analysis*

## **Table 1.9.2:** WBS by Fourth Level (Cont.)

- **4.1.7 Data Acquisition**
  - *4.1.7.1 DAQ Management*
  - *4.1.7.2 Reliability & Quality Assurance*
  - *4.1.7.3 Tower Electronics Module*
  - *4.1.7.4 Instrument Data Bus*
  - *4.1.7.5 Spacecraft Interface Unit*
  - *4.1.7.6 Power Conditioning*
  - *4.1.7.7 Enclosures*
  - *4.1.7.8 Cable Harness*
  - *4.1.7.9 Flight Software*
  - *4.1.7.10 Ground Support Equipment*
  - *4.1.7.11 Suborbital Flight Support*
  - *4.1.7.12 Instrument Integration & Test*
  - *4.1.7.13 Mission Systems Integration & Test*

- **4.1.8 Grid**
  - *4.1.8.1 Grid Management*
  - *4.1.8.2 Reliability & Quality Assurance*
  - *4.1.8.3 Mechanical Interface*
  - *4.1.8.4 Structural Analysis & Simulation*
  - *4.1.8.5 Mechanical Design*
  - *4.1.8.6 Thermal Design & Analysis*
  - *4.1.8.7 Manufacturing/Fabrication - Grid*
  - *4.1.8.8 Manufacturing/Fabrication - Heat Pipes/Radiations*
  - *4.1.8.9 Thermal Blanket/Shield*
  - *4.1.8.10 Instrument Integration & Test*
  - *4.1.8.11 Mission Integration & Test*
  - *4.1.8.12 Mission Operations & Data Analysis*

- **4.1.9 Integration and Test**
  - *4.1.9.1 Integration & Test Management*
  - *4.1.9.2 Reliability & Quality Assurance*
  - *4.1.9.3 Integration Facilities*
  - *4.1.9.4 Ground Support Equipment*
  - *4.1.9.5 Suborbital Integration & Support*
  - *4.1.9.6 Instrument Integration & Testing*
  - *4.1.9.7 Mission Integration & Testing*

- **4.1.10 Performance and Safety Assurance**
  - *4.1.10.1 Performance Assurance Management*
  - *4.1.10.2 Quality Assurance*
  - *4.1.10.3 Training*
  - *4.1.10.4 Records Management*
  - *4.1.10.5 Safety & Environmental Control*

- **4.1.11 Instrument Operations Center**
  - *4.1.11.1 IOC Management*
  - *4.1.11.2 Performance Assurance*
  - *4.1.11.3 Mission & Operations Planning*
  - *4.1.11.4 Instrument Operations Center*
  - *4.1.11.5 Data Processing Facility*
  - *4.1.11.6 Suborbital Flight Support*
  - *4.1.11.7 Instrument Integration & Test*
  - *4.1.11.8 Mission Systems Integration & Test*

- **4.1.12 Education and Public Outreach**
  - *4.1.12.1 Management*
  - *4.1.12.2 Reliability & Quality Assurance (Assessment)*
  - *4.1.12.3 Website*
  - *4.1.12.4 Teacher Training*
  - *4.1.12.5 Curriculum Development/PR*
  - *4.1.12.6 Exhibits*

# 2.0 Cost Plan

Cost budgets and breakdowns are presented in this section, followed in Appendix H by the detailed budget estimates for each instrument subsystem. The total instrument cost for Formulation and Implementation of this investigation is $140.6M in FY99 dollars, including a reserve of 25.1%. This budget is comprised of $59.0M of NASA-funded activity, and $81.6M of contributions from both the Department of Energy (DOE) and other domestic and foreign institutions. Figure 2.0.1 shows the cost profile for the Instrument project.

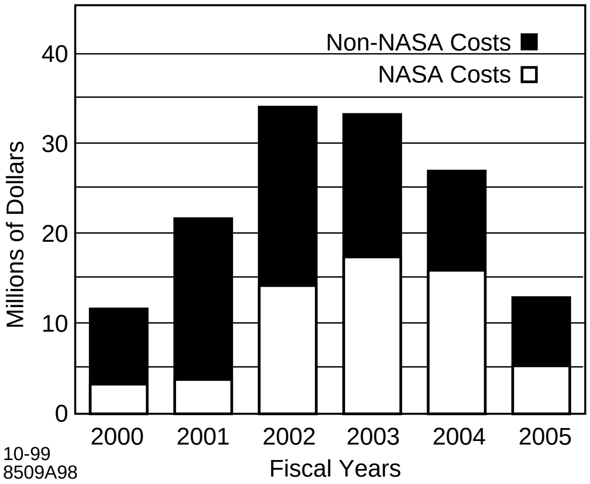


**Figure 2.0.1:** GLAST Instrument Funding Profile (M$)

For a facility-class instrument project such as GLAST, the NASA funding resources are seriously constrained in both quantity and profile. We have mitigated the risk which is inherent in the NASA funding plan by assembling a collaboration which will contribute more than 50% of the cost of the LAT. These contributions are phased in order to change the funding profile and provide the resources necessary to begin procurement of critical long lead items and advance technology readiness in preparation for the I-CDR. The integrated cost plan (NASA plus contributions) allows us to maintain healthy budget reserves averaging 25.1% during development and reaching 50% on the NASA costs during integration and testing.

Figure 1.1.2, in Section 1.1.3, illustrates the flow of funds, responsibilities, and technical direction within the instrument collaboration and with respect to NASA and the other funding sources.The arrangement shown is advantageous in that NASA funding will be directed to institutions which have had past involvment with NASA. Thus, processing and accounting of these funds will be familiar to them. Likewise, DOE funds will be managed by institutions with past DOE involvment.

Nonetheless, funding and cost activities associated with the instrument will be authorized and managed by the IPO at SU-SLAC. It will maintain control of cost and schedule of all contributions with the integrated Project Management Control System discussed in Section 1.2.3.

## 2.1 COST ESTIMATING METHODOLOGY

### *2.1.1 Grass-Roots Cost Estimate*

Budget estimates were developed for each WBS sub-system and functional group. These estimates are consistent with the work breakdown structure, and collect all costs and work associated with the Formulation, Implementation, and Operations Phases of the instrument development.

To improve accuracy of the estimates, work packages were typically broken down to level five or six of the subsystem WBS. Work packages and item procurements were costed individually, then costs rolled-up to higher WBS levels. Costs were estimated using four estimation techniques:

1. Vendor quotes: quotes for items or services.
2. Catalog prices: standard prices for components with flight qualification.
3. Related experience: estimates based on experience with similar work packages from previous projects, or extrapolated from known costs of similar items.
4. Engineering estimates: for less well-defined work packages, budget estimates may be based on level-of-effort work plans, or extrapolated from past work that is similar in expected work content, if not in specific tasks.

Given the relatively advanced state of the instrument design for many of the subsystems, estimates of work packages have typically been based on quotes, purchase prices, and related experience. This is especially the case for significant cost items.

The estimating process was iterative. Initial subsystem cost estimates were judged for their completeness, level of detail, and perceived quality of estimating. This also gave the IPO a first look at the total budget. Following the initial estimates, subsystem budgets and plans were checked for double-counted elements, overlapping areas of responsibility, and "hidden" reserve. This coincided with a firming up of the WBS structure for the instrument, and resulted in scope adjustments for several of the subsystems.

Subsystem managers and engineers evaluated these scope adjustments, and also firmed up participation of team institutions in the collaboration. This led to a second set of detailed budgets, with much cleaner WBS organization and better assignment of responsibilities. While the focus was to ensure the budget was not too high, this also resulted in increasing budgets for some subsystems.

Finally, with solid subsystem budgets in-hand, the subsystem managers and the IPO met for a week to complete a second round of detailed checking, and to ensure that adequate reserve was included in the subsystem budgets. These totals have now been used to secure commitments from all team institutions, and comprise the budgets which follow.

### 2.1.2 Cost Estimating Assumptions

Fiscal year 1999 dollars have been used for all cost estimates. Inflation rates were applied to generate real-year dollar estimates. All institutions used the inflation rates as defined in the GLAST AO, with no other rates used. Rates used are shown in Table 2.1.1

**Table 2.1.1** Inflation Rates Used for Budget Estimating

| | FY99 | FY00 | FY01 | FY02 | FY03 | FY04 | FY05 |
|---|---|---|---|---|---|---|---|
| Inflation Rate | 0% | 4.1% | 3.9% | 3.9% | 3.9% | 3.9% | 3.9% |
| Cumulative Inflation Index | 1.0 | 1.041 | 1.082 | 1.124 | 1.168 | 1.213 | 1.260 |

Beyond FY2005, an annual inflation rate of 3.9% was used. All values shown in this Cost Plan are shown in FY99 values, in thousands of dollars (K$), unless specifically stated otherwise.

For contributions from foreign institutions, the exchange rate for October 1, 1999 was used to determine the dollar value of the contribution. Since all foreign institutions are providing in-kind contributions of personnel and equipment, fluctuations in the exchange rate in future years will not affect the total work effort of the foreign institution. Furthermore, all major procurements expected to be made in foreign countries will be funded by foreign institutions, usually within the country. This will also shield the project from possible negative effects of unforeseen changes in exchange rate.

For the budget estimation process, components and processes were costed assuming a two-year mission life. The instrument design is robust and redundant, and there are no expendables or consumables that could limit the lifetime. We have attempted to make design choices to ensure that if parts fail or lose sensitivity the instrument would degrade gracefully. We can find no rationale for carrying the burden of five-year class parts, and we expect the instrument to be working well, even ten years after launch. Furthermore, we estimate that using five-year class parts would increase total instrument cost by $15M, which would unacceptably increase the total mission cost. Thus, using two-year life parts is a technically and financially conservative choice. It is cost-effective, and does not introduce significant additional mission risk.

### 2.1.3 Budgeting Bases of Estimates

Budget estimates were generated at the subsystem level, with input from all team institutions involved with the subsystem. Below is a description of the detailed estimating process that was used by the subsystems.

#### *Management, System Engineering, and Performance and Safety Assurance*

Budgets for Instrument Project Office (IPO) staffing were developed using input and guidance from a number of sources. First, as the Management Plan described in this volume evolved, specific task and duty assignments were made to the specific WBS elements within the IPO. This, in turn, yielded a list of IPO staff needed to accomplish the tasks to be completed.

In establishing this staffing plan, experience at SU-SLAC with PEP-II and BABAR, two recent large international projects, was used to calibrate all estimates. For the Management team, specifically, experience from these projects was directly applicable to GLAST management. Staffing levels, and ramp-up and ramp-down profiles were drawn from this history.

System Engineering staffing and budgets were similarly budgeted from past experience. However, we enlisted a consultant with past flight-project experience to ensure that all system engineering tasks were covered, and that the staffing plan could adequately support the system engineering activities needed for the GLAST flight instrument.

Performance and Safety Assurance budgets were developed using two techniques. First, each subsystem has included quality assurance and reliability analysis in their budgets, to ensure that all local, subsystem-level quality assurance needs are costed.

Second, instrument-level Performance and Safety Assurance budgets were estimated using past experience with DOE and DOD programs. The work effort budgets were further calibrated by drawing from the flight project experience of our team institutions. The resultant budget includes adequate staffing and consulting services to ensure that suitable performance assurance oversight is implemented in the project.

***Science***

The science cost basis is composed of past experience in supporting similar space science experiments. The basis applicable depends on the particular WBS element which include science team coordination, instrument operations planning, instrument performance modeling and simulation, science data processing development, and instrument calibration planning and analysis. Costs were estimated from a detailed WBS at levels 5 and 6. Costs for the Instrument Scientist (IS), science team coordination, and support of science operations and planning are scaled from previous space science programs such as CGRO/EGRET and SOHO/SOI at SU-HEPL and GSFC, and from large physics experiments such as SLD at SU-SLAC. During the Formulation Phase, the test-validated Monte Carlo simulation software, GLASTSIM, will be used to calculate technical performance measures and to evaluate instrument configuration trade studies. GLASTSIM will continue to be used during the implementation and MO&DA phases to support instrument calibration and data analysis. Cost estimates for these activities are scaled from the current level of effort on the instrument technology development. Substantial contributions of labor for supporting GLASTSIM from UCSC and UW serve to reduce NASA's costs for this activity. Labor estimates for the development of science analysis software are scaled from experience at GSFC and SU-HEPL on programs of similar size and complexity, including CGRO/EGRET and SOHO/SOI. Efficiency in the science analysis software development is obtained through leveraging existing FTOOLS software and data analysis expertise developed and maintained at GSFC for EGRET. Labor estimates for planning instrument calibration are scaled from SU-SLAC experience with the two beam tests during the instrument technology development phase, from SU-HEPL experience with calibration of the EGRET, MDI, and SETS instruments, and GSFC experience with many calibration programs for space science instruments including EGRET.

Travel costs, salaries, indirect costs, fringe benefits, and telecommunications and reproduction for SU-HEPL personnel are based on the same estimation basis as described for SU-HEPL management costs.

***Tracker***

Work tasks and products were budgeted at WBS level seven, or the individual part level. The budgeted cost for the silicon strip detector costs was the procurement cost for SSDs for the BTEM. We have been assured lower unit costs for our production run, but felt it conservative to use the actual cost paid for past orders. ASIC procurement costs were similarly based on our direct experience with the BTEM. Custom structural parts for the Tracker tray and tower assemblies were estimated by Hytec, our engineering consultants, based on their experience with fabrication of carbon-carbon composite structures of similar complexitiy. Our experience with the BTEM provided a useful calibration of these estimates.

Engineering design and development times and costs were estimated using three techniques. First, for engineering of the structural components, bids from Hytec were checked, then used in the budget. These are based on their experience in the design of composite structures and, specifically, in their recent work in developing and fabricating prototype Tracker structures, and structures for the BTEM.

The second estimating method parsed the development work into discrete packages of analysis and drafting. Using models developed from past work at SU-SLAC, time and cost estimates were assigned to these packages. The final estimation method used for engineering work was scaling from past projects. Development of the Front-End Electronics, and some of the integration and test facility was budgeted based on similar development work done for the BaBar Silicon Vertex Tracker.

Production and assembly costs for SSD inspection, assembly, and verification testing were estimated from detailed work-flow analysis of the production work. Individual work tasks and stations were detailed, then time estimates assigned independently by separate groups to calibrate the estimating process. These production times were based on directly applicable experience with the BABAR Silicon Vertex Tracker at SU-SLAC, and on the OPAL and NOMAD silicon detector assemblies at CERN. These silicon trackers used double-sided technology with on-board electronics, making them much more complex than the GLAST Tracker design. Thus, they served as conservative bases for our time estimates.

The individual work package estimates were rolled up into production line through-put rates by scaling by quantity, introducing latency and “dead” time rates averaging 25%, and establishing the number of parallel production lines needed to accomplish the work. This resulted both in a realistic estimate of the total production job, as well as an estimate of the number and complexity of the production fixturing. Fixturing and equipment costs were derived from catalog prices and quotes for standard equipment, such as wire bonders and probe stations, and from actual fixturing fabrication costs for BTEM fixtures.

Finally, as the BTEM has been completed this past summer, these estimates were modified to reflect the lessons learned from assembling SSDs and trays.

### *Calorimeter*

The calorimeter subsystem design and fabrication is a collaboration among the Naval Research Laboratory (NRL), Commissariat à l'Energie Atomique/ Département d'Astrophysique, de physique des Particules, de physique Nucléaire et de l'Instrumentation Associée (CEA/ DAPNIA), Institut National de Physique Nucléaire et de Physique des Particules (IN2P3) in France, and the Royal Institute of Technology (KTH) and Stockholm University in Stockholm, Sweden. These institutions have designed and built many experiments for space flight on NASA, DOD, ESA and other French missions as well as complex experiments for high energy particle physics.

The calorimeter subsystem basis for costs derive from one or more of the three following sources:

1. Grassroots estimation based on WBS Dictionary description work packages and deliverables to level 5 or 6.
2. Actual designs, procedures, and costs associated with the fabrication and test of the Beam Test Engineering Model (BTEM) calorimeter module which has been completed as part of the technology development program.
3. Relevant experience at NRL and CEA on space missions of comparable complexity and technology. Examples of such missions are CGRO/OSSE (NRL, NASA) and INTEGRAL (CEA, ESA).

Volume 2, Appendix H contains supporting detail for the NASA costs for the calorimeter subsystem. Description and cost basis for materials and equipment are also included. Table 2.1.2 shows the cost basis for the various elements in the calorimeter subsystem WBS.

### *ACD*

The ACD cost was determined from a grassroots estimate based on a detailed WBS. Estimates were determined down to WBS level five, and in some cases down to level six, especially where hardware/software component development was involved. Staffing levels were estimated by labor classifications. Material and subcontracts were estimated for each of the WBS sub-levels by taking into account make-or-buy decisions, long-lead procurements, and risk factors.

The engineering design, development duration, staffing levels and associated costs were based on similar flight hardware assemblies that

GSFC has worked on in the past. The development costs associated with the assembly and integration of the detector sub-assembly (plastic scintillator tiles, wave-shifting fibers, and PMTs) are based on previous flight experience with similar detectors done on EGRET and on prototype work done on the BTEM during this past summer. Analog ASIC development duration, staffing levels and costs were based on GSFC's previous experience developing the analog ASICs for the Calorimeter BTEM. Development costs associated with the flight Printed Circuit Boards (PCBs) are based on similar development costs for boards of similar size that have been developed at GSFC for the Cassini/Composite Infrared Spectrometer (CIRS) flight instrument electronics and Microwave Anisotropy Probe (MAP) flight instrument electronics.

In the case where the actual flight component to be used was known, the current price of the component was used in the cost estimate. Price quotes were obtained for key components that are used in large quantities, such as the Actel FPGA and the Hamamatsu PMTs (R1635 and R5900). The costs of the plastic scintillator tiles and the waveshifting fibers were based on procurement costs associated with the BTEM unit.

The full cost accounting estimates for the GSFC portion of this proposal have been developed in accordance with GSFC's guidelines for developing proposals using full cost principles. NASA's approach to full cost assigns all agency costs, including Civil Service personnel and travel costs, to major programs or activities.

### *DAQ*

The DAQ cost basis is composed of past experience in building similar subsystems for space flight and vendor quotations for parts and services. The basis applicable depends on the particular WBS element.

***Parts and Materials.*** For each element, where applicable, parts and materials were estimated from either previous purchases of parts for other projects or from new vendor quotations. The TCPU board has been prototyped using commercial parts and flight equivalents have been identified. The cost of these flight parts was established on another program (NEMO) and is in accord with our experience for similar parts purchases on previous programs (e.g. USA/ARGOS processor boards). An itemized list of TCPU parts with costs for flight versions of each part was used to estimate the cost basis for the TCPU boards. Fabrication, assembly, and test costing follows experience on these and other previous space flight programs together with vendor estimates for the flight version of prototype boards. The IO boards which provide Level 1 Trigger and Read Out functions consist primarily of FPGA and LVDS devices. New vendor quotations for flight parts were received for these devices--which contribute the primary portion of the parts cost of these boards. The DAQ costs include the purchase of all FPGAs to be used in the Instrument as well as all of the Power Supplies. The joint purchase of common parts is designed as a cost saving measure and is one of the "Lessons Learned" from previous projects.

***Power Supplies.***The cost of power supplies is a significant item within the DAQ budget. The DAQ provides all power supplies for the Instrument and we will utilize a common purchase of these units. The costing is based on quotations and discussions with 2 different vendors and catalog prices from a third vendor. During the Formulation Phase, we will select one vendor and cost will be a major criteria.

***Flight Harness.*** The flight harness cost estimate is based on a count of the number of signals, cables, and connectors required to support the Instrument. The cable harness concept was developed to facilitate manufacturing of the cable harness with cost as a factor. The simplified design of the cables permits easy assembly and testing with a minimum amount of NRE. Allowance is made in the Cable Harness WBS for all aspects of the cable harness acquisition cost including requirements, specifications, vendor selection, and testing.

***Spacecraft Interface Unit***. The two Spacecraft Interface Units will include TCPU boards identical to those in the other Instrument modules and are costed under the TCPU WBS. The power switching, 1553B, and SSR interface portions of the SIU are based on previously developed interfaces on the NEMO project and will be designed and built by the same vendor. The cost for the SIU is based on vendor estimates using this prior experience.

**Table 2.1.2** Cost Basis for Calorimeter Subsystem by WBS Element

| WBS Element | Cost Basis |
|---|---|
| **4.1.5.1<br>Management** | Mgmt Labor (NASA, French)- Level of Effort based on previous NASA programs of equivalent or larger magnitude, eg. CGRO/OSSE<br>Travel (NASA, French,Swedish)– Based on planning for 6 formal reviews, quarterly team mtgs, quarterly Calorimeter team mtgs, and quarterly status reviews. Reviews/mtgs alternate east coast – west coast. Cal mtgs alternate US – France. |
| **4.1.5.2<br>R&QA** | Labor (NASA, French, Swedish)- Level of Effort based on previous NASA programs of equivalent or larger magnitude, eg. CGRO/OSSE |
| **4.1.5.3<br>CsI Detector Module** | Labor (Swedish, French Cost)– Based on actual labor hours from fabrication of BTEM module scaled for 20% increase in flt module size and factor for R&QA procedures.<br>CsI crystals (Swedish cost) – based on actual cost of BTEM crystals and results of acceptance testing for rejection. Quotes from two vendors (Crismatec and Amcrys-H) were obtained for the size, quantity and delivery schedule for flight.<br>PIN Photodiodes (French cost) ) – based on actual cost of BTEM photodiodes and results of acceptance testing for rejection. Quote from Hamamatsu Photonics was obtained for the size, quantity and delivery schedule for flight<br>Acceptance Test Equip (Swedish, French Costs) – based on actual cost of assembly of equipment and procedures for BTEM acceptance testing. |
| **4.1.5.4<br>Analog Front End Electronics** | ASIC design and fab (French Cost) – based on considerable experience with other flight ASIC programs (eg. INTEGRAL/ISGRE)<br>Front End Boards (NASA)– based on actual costs of design and fab of BTEM boards scaled for parts quality and R&QA procedures. Considerable experience with design, fab, and test of similar boards at NRL applies as well. |
| **4.1.5.5<br>Compression Cell** | (French Cost) Based on actual details for design and fabrication of BTEM compression cells which has successfully completed qualification level vibration testing. Costs considered and adapted to the French design and fabrication methodology. |
| **4.1.5.6<br>Cal Controller** | (NASA)– based on actual costs of design and fab of BTEM controller scaled for parts quality and R&QA procedures. Considerable experience with design, fab, and test of similar boards at NRL applies as well |
| **4.1.5.7<br>Assembly** | Labor (NASA)– Based on procedures and actual labor hours from assembly of BTEM module scaled for 20% increase in flt module size and factor for R&QA procedures.<br>GSE (NASA) – based on equipment assembled for BTEM assembly testing. Quantities based on parallel operations in manufacturing plan. |
| **4.1.5.8<br>Test & Calibration** | Labor (NASA)– Based on procedures and actual labor hours from test of BTEM module.<br>EGSE (NASA) – based on equipment assembled for BTEM testing and previous beam test experiments.<br>MGSE (NASA) – based on actual costs of fixtures and shipping containers fabricated for BTEM support. |
| **4.1.5.9<br>Design & Verification** | Simulations Labor (NASA, France) – level of effort support<br>System Engineering (NASA, France) – based on experience from previous flight programs at NRL and CEA/DAPNIA (France)<br>Beam Tests (NASA) – based on costs and test plans from three previous beam tests and planning for BTEM tests. |
| **4.1.5.10<br>SubOrbital Flight I&T** | Labor (NASA) – based on level of effort and duration of support from typical balloon flight experience at NRL and GSFC.<br>Travel (NASA) – based on number of people and duration in field for CONUS balloon flight. |
| **4.1.5.11<br>Instrument I&T** | Labor (NASA) – based on level of effort and duration for cal subsystem science and engineering support of integration and test. Staffing plan includes continuous on-site support as well as multi-shift support for environmental testing.<br>Travel (NASA) - on-site support of I&T plan, includes over 135 man-weeks of per diem and associated flights NRL – Stanford. |
| **4.1.5.12<br>Mission I&T** | Labor (NASA) – based on level of effort and mission I&T duration. Cal subsystem science and engineering support present for all major functional and environmental testing. |
| | |

***EM Units.*** The cost basis for EM units was obtained in a similar way to the flight units but with non-flight parts and reduced screening and testing requirements. The cost of the Test Bed and simulators is based on similar VME boards developed during the ATD phase.

***Data Switch FPGA.*** The DSF is composed of the Data Switch FPGA and associated links. A preliminary version was developed and tested during the ATD phase to read out the detector subsystems. Integration of the functions required for the flight version of the DSF will proceed during the Formulation phase with the NRL vendor who is an expert in this area. Costing is based on an estimate from the NRL vendor.

***Travel***. Travel costs are based on estimating the number of trips, persons, and duration for each location using projected costs for airfare, car rental, and per diem.

***Labor***. Labor costs are based on current salaries and expected duration for each task.

***Software***. Software costs are extrapolated from the current cost of licenses (including the Tornado II development environment suite, VxWorks, Cadence, IDL, and other general purpose packages) and estimates for some additional software at later phases.

***Grid***

The Grid support structure, thermal blanket, and radiator costs were estimated by Lockheed-Martin Advanced Technology Center. Work packages were estimated down to the lowest level of work, or parts fabrication, where applicable. LM-ATC experience with composite structures and satellite thermal management was brought to bear in estimating design and development times for the Grid carbon-fiber composite (CFC) structure, as well as for the thermal analysis and sizing of the heat pipes and radiators.

Fabrication costs for the Grid were estimated from engineering drawings of the engineering model, by personnel with direct fabrication experience in flight composite structures.

The detailed budget estimate of this subcontracted work is proprietary, and not included in this Cost Plan. However, information regarding the estimate can be requested from the Defense Contract Audit Agency, Ronald Hop, Resident Auditor; Phone: 408-742-5991.

***Integration and Test***

Integration and Test estimates have been based on a detailed level six and seven breakdown of all work packages to the detailed part and process level. This ensures that all aspects of the I&T process are included.

Sub-orbital flight integration was estimated by GSFC personnel, based on their experience in mounting similar balloon campaigns for numerous other flight instruments. This was done with the aid of the GSFC LHEA, a team institution.

Ground Support Equipment development, fabrication, and testing was budgeted by SU-SLAC. This was done at the individual component level, based on experience from integration of similarly complex instruments for the BABAR high-energy physics detector and the PEP-II ultra-high vacuum beam transport system. While these were not space flight systems, their level of complexity, cleanliness, fragility, and fault-tolerance closely matches that of the LAT instrument.

The estimate for environmental testing is a high average of budgetary quotes from Lockheed-Martin Missiles and Space, and TRW. While these are not formal quotes, they have been based on conservative test specifications for the instrument.

Functional testing for the integrated instrument has been budgeted two ways. First all testing specific to a subsystem has been budgeted in the subsystem budget. This includes pre- and post-integration testing, and support for functional testing at the environmental test facility. Instrument-level testing is included in the I&T element, and has been budgeted by developing work tasks for an instrument test team, then budgeting for this team through the entire integration and test cycle.

***Instrument Operations Center***

The cost estimate for the IOC is based on scaling from the experience of SU-HEPL and GSFC for similar flight instrument programs, and from the experience of SU-SLAC for data processing of similar scale physics experiments. The Solar Oscillations Investigation (SOI), based in SU-HEPL, operates the Michelson Doppler Imager (MDI) on the SOHO spacecraft. MDI produces approximately the same data rate as GLAST and the MDI portion of the SOHO operations environment has the same architecture and interfaces as that planned for GLAST. The MDI instrument is operated from a SU-HEPL managed facility in the SOHO EOF at GSFC and performs most of the same functions anticipated for the GLAST IOC under WBS 4.1.11.4. The SOI Science Support Center (SSSC), located in SU-HEPL, performs the level 1 and 2 data processing for MDI, similar in scope as planned for the LAT DPF under WBS 4.1.11.5. The same interfaces exist between the MDI EOF, SSSC, and the SOHO Science Operations Center (SOC) and Mission Operations Center (MOC) as will exist between the GLAST IOC, DPF, SOC and MOC. SU-HEPL managed the mission operations planning and instrument integration and test support for MDI. The MDI integration and test effort was supported by the operations team in much the same manner as envisioned for LAT. Labor levels specified for the LAT IOC are consistent with those of SOI for similar activities. Computer equipment expenses are based on current procurement costs for equivalent workstations, peripherals and servers.

The detailed costing of the LAT data processing facility is based upon the experience of the SU-SLAC SLD experiment which had similar data rates and volumes to what is expected for GLAST. The major elements of the facility are shown in Table 2.1.3, along with an effort estimate.

**Table 2.1.3** Labor Estimates for Significant Data Processing Facility Activities

| Item | FTE's |
|---|---|
| Fully automated data processing server | 1 |
| Multi-pass filters for Level 1 data | 0.5 |
| Relational database for the processing state | 0.5 |
| Experiment monitoring and feedback | 3 |
| Remote data mirror | 1 |
| Fully automated Monte Carlo server | 1 |
| **Total** | 7 |

The server estimates are based on projections made by the author of the SLD processing server when SLD was planning on rewriting its server for a new platform. The MC server would be closely related to the data server. Extra effort is assigned for the MC server for actually running it during the Formulation and Implementation Phase period for instrument studies. Labor estimates for the DPF are consistent with the experience of SU-HEPL on SOI.

Travel costs, salaries, indirect costs, fringe benefits, and telecommunications and reproduction for SU-HEPL personnel are based on the same estimation basis as described for SU-HEPL management costs.

***Education and Public Outreach***

Materials costs were budgeted based on similar quantities and types of materials (CDs, brochures, posters, teacher's guides) printed at the GSFC LHEA. LHEA experience was also used to estimate the costs of attending educator conferences, and for developing the exhibit for such conferences. SSU salaries were budgeted based on the level of effort expected from past experience at LHEA in developing similar educational products and website development and maintenance.

Travel costs were budgeted based on current airfare and per diem rates for trips to the East Coast; this is a conservative estimate, as not all trips will be cross-country. Teacher stipends were budgeted based on the standard amount of summer salary requested by high-school teachers that we surveyed.

Sub-contracts to VideoDiscovery and TOPS Learning Systems were comparable in cost per module developed and were taken from written bids for this work. We received two bids for assessment activities; that from WestEd, although more expensive, included work that was considerably more comprehensive and therefore better matched to the NASA E/PO criteria.

### 2.1.4 Parametric Cost Estimate

At our request, the Goddard Resources Analysis Office (RAO) undertook a parametric cost study of the LAT instrument. Although we believe our design approach should help keep this mission below the historical cost curve, the parametric costing is valuable to confirm the validity of our grass-roots cost. The parametric costs were generated using the Multivariable Instrument Cost Model (MICM), whose fundamental input parameters are mass, power, data rate, and technology readiness level. These parameters were given separately for the Tracker, Calorimeter, Data Acquisition System, Anti-Coincidence Detector and mechanical support Grid, along with a description of the category, heritage and complexity of the various subsystem technologies. To obtain the basic instrument cost, the model was first used to estimate costs of the first tower of modular components (Tracker, Calorimeter, Data Acquisition System). Then costs were estimated for the remaining 15 towers, which do not carry non-recurring engineering costs, and, finally, the cost of the ACD and Grid, which are not modular.

The project construction duration was assumed to be 39 months, and the costs were generated as an out-of-house build, relative to GSFC. The mission class was 1.301 (two-year class), in line with our overall goal of maximizing the scientific capabilities of the instrument under the constraint of the cost cap (as discussed in 2.1.2, above).

According to the model, the instrument cost is $124M, in FY99 dollars. Generic costs for Integration and Test (20%), Fee (5%), and Contingency (35%) were included. The instrument cost for a five year mission life was estimated to be $139M .

Costs are for Formulation and Implementation Phases and are based on the technology readiness levels attained from the seven-year multi-agency $10 million technology development program for this instrument. Overall, we consider the grass-roots cost to be adequately confirmed by the parametric study.

Details of the RAO parametric estimate are included in Appendix H.

## 2.2 BUDGET RESERVE STRATEGY

Budget reserves have been rolled-up to the instrument level, and are shown in Table 2.1.4. Reserve has been allocated both to fit the tight funding profile, and to reflect the level of maturity of the design in different phases, and the level of risk associated with the phase of the project.

**Table 2.1.4** Budget Reserve (FY99 K$)

| | FY00 | FY01 | FY02 | FY03 | FY04 | FY05 | Total |
|---|---|---|---|---|---|---|---|
| **NASA Costs w/out Reserve** | **$3,288** | **$3,596** | **$12,022** | **$13,976** | **$10,382** | **$3,458** | **$46,722** |
| Budget Reserve % | 5.00% | 0.00% | 14.70% | 24.30% | 50.00% | 50.00% | 26.21% |
| Budget Reserve $ | $164 | $0 | $1,767 | $3,396 | $5,191 | $1,729 | $12,248 |
| DOE Costs w/out Reserve | $3,337 | $6,389 | $5,577 | $6,886 | $4,018 | $2,496 | $28,703 |
| Budget Reserve % | 10.00% | 15.00% | 20.00% | 25.00% | 45.00% | 30.00% | 23.29% |
| Budget Reserve $ | $334 | $958 | $1,115 | $1,721 | $1,808 | $749 | $6,686 |

As shown in the table, both NASA and DOE costs carry an average reserve of 25.1%. All other domestic contributors are bringing in level-of-effort salaries of individuals, where no reserve is needed. Additionally, every foreign contribution is either guaranteed by the contributing institution, or carries its own reserve.

Reserve during Formulation Phase is relatively low, given the advanced state of design for a number of the subsystems, and the negative annualized funding profile for the NASA-funded institutions in FY 2001.

During Implementation Phase, through integration and testing, reserves grow with the increased risk of negative cost variances. In addition to the 50% NASA reserve, and 45% DOE reserve held during FY 2004, the main integration and test year, the Integration and Test budget plan includes a funded schedule reserve of three months. This reserve represents 20% of the integration budget.

As discussed in Section 1.2.3, the Integrated Project Management System to be implemented for the LAT will track cost and schedule actual costs and variances for all subsystems. These variances will be used to provide monthly updates of instrument cost and variances, which will be compared with the phased budget. For foreign team institutions, earned-value performance metrics will be used to characterize work progress towards pre-established milestones.

This process recognizes that it is not possible to remain within the initial cost objectives for every subsystem. The responsibility for managing the variances lies with each subsystem manager. However, if cost or schedule variances for the subsystem deviate from the budget baseline, the Configuration Control methodology discussed in Section 1.2.2.3 will ensure that overall instrument technical and budget reserves are managed.

This method of controlling variances and managing reserves will allow the IPM flexibility in allocating reserve, by holding all reserve at the instrument project level, and not pre-allocating it to subsystems. The reporting and correction planning will also ensure that reserve is used sparingly, as part of the overall risk mitigation plan discussed, and not simply as a stopgap measure.

## 2.3 FORMULATION PHASE COST PROPOSAL

### *2.3.1 Contract Pricing Proposal Cover Sheet SF1411*

The Contract Pricing Proposal Cover Sheet, SF1411, is included as Appendix G.

### *2.3.2 Workforce Staffing Plan*

A summary of staffing for the Formulation Phase effort is shown in Table 2.3.1. A detailed breakdown of staff by subsystem, showing key personnel for the instrument project and for each subsystem is given in Table 2.3.2. These tables include all personnel working directly on

**Table 2.3.1** Staffing Summary for Formulation Phase (staff-yr)

| WBS | LaborTotal | FY2000 | FY2001 | Total |
|---|---|---|---|---|
| 4.1.1 | Management | 3.37 | 9.04 | 12.41 |
| 4.1.2 | System Engineering | 2.13 | 7.79 | 9.92 |
| 4.1.3 | Science Support | 5.35 | 8.53 | 13.87 |
| 4.1.4 | Tracker | 12.02 | 25.30 | 37.32 |
| 4.1.5 | Calorimeter | 30.94 | 36.09 | 67.04 |
| 4.1.6 | Anticoindence Detector | 5.12 | 8.23 | 13.36 |
| 4.1.7 | Data Acquisition System | 6.42 | 10.14 | 16.56 |
| 4.1.8 | Grid | 1.12 | 3.62 | 4.74 |
| 4.1.9 | Integration and Test | 0.41 | 2.86 | 3.27 |
| 4.1.10 | Perf., Safety Assurance | 0.83 | 3.33 | 4.17 |
| 4.1.11 | Instrument Operations Center | 0.91 | 0.48 | 1.39 |
| 4.1.12 | Education, Public Outreach | 0.64 | 0.89 | 1.53 |
| | **Total Staffing** | **69.26** | **116.31** | **185.57** |

the instrument, at all of the institutions involved. Staffing values are shown in staff-years.

The staffing plans shown were developed during the budget estimating process, from bottoms-up estimates of work tasks and work packages. Costing for the staffing shown is reflected in the cost tables which follow. Labor and other rates for staff are tabulated in Section 2.7 “Institutional Bases of Estimates.”

There are three trends in the staffing plan to note. First, since the project is expected to begin half way through FY2000, the staffing levels, in staff-years, for FY2000 represent essentially twice the number shown in actual personnel on the project.

Second, and related to this, the Calorimeter shows fairly high staffing, compared to other subsystems, with no characteristic slow start due to the half fiscal year in FY2000. This is due almost entirely to the French contribution to the Calorimeter. Their project funding began in October, 1999, so they have already staffed up for their involvement in GLAST. Thus, their FY2000 staffing is for nearly the entire fiscal year. Also, their contribution includes significant science contributions in the simulation of the Calorimeter. Finally, their effort includes a relatively large management staff to monitor the efforts of the various French team institutions.

The third trend in staffing is apparent in the detailed staffing numbers. While Science and System Engineering are identified and staffed as separate cost elements, with discrete system-level statements of work, each hardware subsystem carries scientists and engineers, as well. Their efforts include science simulations and system engineering activities, but are focussed

**Table 2.3.2** Staffing Breakdown for Formulation Phase (staff-yr)

| WBS | Labor Total | FY2000 | FY2001 | Total |
|---|---|---|---|---|
| **4.1.1** | **Management** | **3.37** | **9.04** | **12.41** |
| | Prinicpal Investigator | 0.31 | 0.63 | 0.94 |
| | Instrument Technical Manager | 0.25 | 0.50 | 0.75 |
| | Instrument Project Manager | 0.50 | 1.00 | 1.50 |
| | Management Staff | 1.24 | 4.67 | 5.91 |
| | Science and Engineering Staff | 1.06 | 2.25 | 3.31 |
| | Technicians and Others | 0.00 | 0.00 | 0.00 |
| **4.1.2** | **System Engineering** | **2.13** | **7.79** | **9.92** |
| | Instrument System Engineer | 0.50 | 1.00 | 1.50 |
| | Management Staff | 0.50 | 1.00 | 1.50 |
| | Science and Engineering Staff | 1.13 | 5.54 | 6.67 |
| | Technicians and Others | 0.00 | 0.25 | 0.25 |
| **4.1.3** | **Science Support** | **5.35** | **8.53** | **13.87** |
| | Instrument Scientist | 0.40 | 0.80 | 1.20 |
| | Management Staff | 0.25 | 0.40 | 0.65 |
| | Science and Engineering Staff | 3.95 | 6.83 | 10.77 |
| | Technicians and Others | 0.75 | 0.50 | 1.25 |
| **4.1.4** | **Tracker** | **12.02** | **25.30** | **37.32** |
| | Tkr Subsystem Manager | 0.61 | 1.23 | 1.84 |
| | Tkr Subsystem Engineer | 0.51 | 1.03 | 1.54 |
| | Management Staff | 2.00 | 4.00 | 6.00 |
| | Science and Engineering Staff | 7.77 | 13.44 | 21.20 |
| | Technicians and Others | 1.13 | 5.61 | 6.73 |
| **4.1.5** | **Calorimeter** | **30.94** | **36.09** | **67.04** |
| | Cal Subsystem Manager | 0.82 | 0.54 | 1.36 |
| | Cal Subsystem Engineer | 0.75 | 1.00 | 1.75 |
| | Management Staff | 3.67 | 5.06 | 8.73 |
| | Science and Engineering Staff | 15.57 | 18.42 | 33.98 |
| | Technicians and Others | 10.14 | 11.08 | 21.22 |
| **4.1.6** | **Anticoindence Detector** | **5.12** | **8.23** | **13.36** |
| | ACD Subsystem Manager | 0.45 | 0.60 | 1.05 |
| | Management Staff | 0.77 | 1.43 | 2.21 |
| | Science & Engineering Staff | 3.45 | 5.60 | 9.05 |
| | Technicians & Others | 0.45 | 0.60 | 1.05 |
| **4.1.7** | **Data Acquisition System** | **6.42** | **10.14** | **16.56** |
| | DAQ Subsystem Manager | 0.37 | 0.65 | 1.02 |
| | Management Staff | 0.45 | 0.75 | 1.20 |
| | Science and Engineering Staff | 4.78 | 7.39 | 12.17 |
| | Technicians and Others | 0.83 | 1.35 | 2.18 |
| **4.1.8** | **Grid** | **1.12** | **3.62** | **4.74** |
| | Grid Subsystem Manager | 0.19 | 0.62 | 0.81 |
| | Management Staff | 0.00 | 0.13 | 0.13 |
| | Science and Engineering Staff | 0.80 | 2.06 | 2.86 |
| | Technicians and Others | 0.13 | 0.81 | 0.93 |
| **4.1.9** | **Integration and Test** | **0.41** | **2.86** | **3.27** |
| | Integration and Test Manager | 0.00 | 1.04 | 1.04 |
| | Management Staff | 0.00 | 0.00 | 0.00 |
| | Science and Engineering Staff | 0.35 | 0.78 | 1.12 |
| | Technicians and Others | 0.07 | 1.04 | 1.11 |
| **4.1.10** | **Perf., Safety Assurance** | **0.83** | **3.33** | **4.17** |
| | Performance Assurance Manager | 0.50 | 1.00 | 1.50 |
| | Management Staff | 0.00 | 0.00 | 0.00 |
| | Science and Engineering Staff | 0.33 | 2.33 | 2.67 |
| | Technicians and Others | 0.00 | 0.00 | 0.00 |
| **4.1.11** | **Instrument Operations Center** | **0.91** | **0.48** | **1.39** |
| | IOC Manager | 0.09 | 0.03 | 0.12 |
| | Management Staff | 0.03 | 0.05 | 0.08 |
| | Science and Engineering Staff | 0.80 | 0.40 | 1.20 |
| | Technicians and Others | 0.00 | 0.00 | 0.00 |
| **4.1.12** | **Education, Public Outreach** | **0.64** | **0.89** | **1.53** |
| | EPO Coordinator | 0.20 | 0.20 | 0.40 |
| | Management Staff | 0.00 | 0.25 | 0.25 |
| | Science and Engineering Staff | 0.00 | 0.00 | 0.00 |
| | Technicians and Others | 0.44 | 0.44 | 0.88 |
| | **Total Staffing** | **69.26** | **116.31** | **185.57** |

on the subsystem element. This is especially true in the Formulation Phase, when overall system requirements and interfaces are being flowed down to the subsystems. These subsystem personnel are the conduits for this flowdown and run the simulations and provide data to develop the interface requirements for their subsystem.

### 2.3.3 Formulation Phase Time-Phased Cost Summary

Costs for the Formulation Phase are shown in the sections to follow. To simplify the layout, and facilitate direct comparison of tables, all page-length tables have been collected in Section 2.3.3.4. These full-page tables are:

**Table 2.3.3** List of Formulation Phase Cost Tables

| Table | Title |
|---|---|
| **2.3.5 (a)** | Cost Breakdown by Cost Type for Formulation Phase |
| **2.3.5 (b)** | Contributed Costs for Formulation Phase |
| **2.3.5 (c)** | Total Cost for Formulation Phase |
| **2.3.6 (a)** | Cost Breakdown by Cost Type with Full-Cost Accounting for NASA Institutions |
| **2.3.6 (b)** | Total Cost with Full-Cost Accounting for NASA Institutions |

#### 2.3.3.1 Total Formulation Phase Cost

Table 2.3.4 summarizes costs for the instrument by WBS element. These are total costs for the element, independent of funding source, and are rolled up from significantly more detailed budget breakdowns for each subsystem. Unless specifically stated, all costs shown here and elsewhere in this section are in FY 1999 thousands of dollars (FY99k$), with no inflation, and assuming no full-cost accounting for NASA institutions. Tables and budgets including inflation and/or NASA full cost accounting will be so labeled.

Two trends are apparent in these rolled-up summaries. First, since the project starts in quarter three of FY2000, the budget for FY2000 only covers six months. Thus, the budgeted monthly rate of expenditure for the Formulation Phase is actually flat, approximately $1.85M per month. This flat spending profile results from the significant and early contributions of resources from other domestic and foreign institutions. The allocated monthly funds provided by NASA actually drop by 50% from FY 2000 to FY 2001. Without the other contributions, this would have introduced a significant schedule risk very early in the project, where personnel are needed to aggressively continue the development of instrument technologies, and put into place the System Engineering and Management infrastructure for the remainder of the project.

**Table 2.3.4** Total Formulation Phase Costs by WBS Element (FY99 K$)

| WBS | Subsystem | FY00 | FY01 | Total |
|---|---|---|---|---|
| **4.1** | **Instrument Total** | **$11,608** | **$21,956** | **$33,564** |
| 4.1.1 | Instrument Management | $552 | $1,270 | $1,822 |
| 4.1.2 | Systems Engineering | $524 | $1,294 | $1,817 |
| 4.1.3 | Science | $611 | $936 | $1,546 |
| 4.1.4 | Tracker | $3,234 | $7,613 | $10,847 |
| 4.1.5 | Calorimeter | $4,130 | $6,560 | $10,690 |
| 4.1.6 | Anticoindence Detector | $529 | $624 | $1,153 |
| 4.1.7 | Data Acquisition System | $1,357 | $1,630 | $2,987 |
| 4.1.8 | Grid | $251 | $779 | $1,030 |
| 4.1.9 | Integration and Testing | $93 | $446 | $539 |
| 4.1.10 | Performance Assurance | $135 | $629 | $765 |
| 4.1.11 | Instrument Operations Ctr | $156 | $91 | $248 |
| 4.1.12 | Education & Outreach | $36 | $84 | $120 |

The second important trend is that Management, System Engineering, and Performance Assurance, show a sharp increase in funding during the Formulation Phase to support the Instrument Project Office (IPO), which is vital to guiding this project through to successful implementation. As can be seen in the following section, nearly the entire IPO is funded from Department of Energy (DOE) funds, through SU-SLAC.

A complete summary and further analysis of the total instrument cost is provided in Section 2.6.

#### 2.3.3.2 Cost Breakdown by Cost Type

Table 2.3.5(a) shows costs, divided by cost type. For NASA costs, the table shows costs categorized by Labor (both Civil Servant and Contractor), Material and Equipment, Sub-Contracts, and Reserves for each subsystem receiving NASA funds. Costs are shown for Formulation Phase only, with FY99 kilo-dollars on the left, and Real Year kilo-dollars on the right. These categories include the following:

***Labor.*** All direct labor budgeted for work at team institutions. This includes civil servants of the federal government at GSFC and NRL, as well as contractor labor. Institutions considered contractors are SU-HEPL, SU-SLAC, UCSC, SSU, and all foreign institutions. Labor rates and overheads are shown in Section 2.7. "Institutional Bases of Estimates."

***Material and Equipment, and Other Directs.*** This includes costs for all purchased material and equipment. Also included are costs for travel and other purchased components or equipment. Costs have been estimated extrapolating from actual costs from past experience, catalog costs, and quotes. When these were unavailable, engineering estimates from past work were used.

***Subcontracts***. All subcontracts to companies are totaled by subsystem. This includes all subcontracts for work on-site at a team institution, or to provide engineering or other types of service. Subcontracts also include any consulting services. Key subcontracts and consulting contracts for the Formulation Phase are delineated in Section 2.3.3.5, below.

Table 2.3.5(b) lists contributing institutions, showing the amount and phasing of the contribution. For all foreign institutions, these contributions are in in-kind equipment and sub-assembly delivery. For the SU-SLAC contribution, funding is provided by the DOE. All other domestic contributions are in the form of salaries for full time faculty or staff involved with the LAT instrument at the institution.

For the Formulation Phase, funding from other contributors is $26.51M.

#### 2.3.3.3 Full-Cost Accounting for NASA Institutions

Tabulated costs using full-cost accounting for NASA institutions follow in Table 2.3.6. All contributions from non-NASA sources are identical, and are not repeated. Total costs for all sources are shown at the bottom of the table, and reflect both the full-cost accounted NASA costs, and the contributed costs.

#### 2.3.3.4 Formulation Phase Cost Tables

The Formulation Phase Cost Tables follow on the next pages.

**Table 2.3.5 (a)** Cost Breakdown by Cost Type for Formulation Phase (FY 99 K$ and RY K$)

| | **Contract Costs to NASA** | | **FY99 K$** | | | **RY K$** | |
|---|---|---|---|---|---|---|---|
| **WBS** | **Instrument Subsystem** | **FY 2000** | **FY 2001** | **Total** | **FY 2000** | **FY 2001** | **Total** |
| | **Total Contract Cost** | **$3,452** | **$3,596** | **$7,048** | **$3,594** | **$3,891** | **$7,485** |
| | **Labor** | **$2,457** | **$2,956** | **$5,413** | **$2,558** | **$3,198** | **$5,756** |
| 4.1.1 | Instrument Management | $49 | $93 | $143 | $51 | $101 | $152 |
| 4.1.2 | Systems Engineering | $0 | $0 | $0 | $0 | $0 | $0 |
| 4.1.3 | Science | $294 | $412 | $706 | $306 | $446 | $752 |
| 4.1.4 | Tracker | $0 | $0 | $0 | $0 | $0 | $0 |
| 4.1.5 | Calorimeter | $1,039 | $923 | $1,961 | $1,081 | $999 | $2,080 |
| 4.1.6 | Anticoindence Detector | $388 | $519 | $907 | $404 | $561 | $965 |
| 4.1.7 | Data Acquisition System | $650 | $882 | $1,532 | $677 | $955 | $1,631 |
| 4.1.8 | Grid | $0 | $8 | $8 | $0 | $9 | $9 |
| 4.1.9 | Integration and Testing | $4 | $37 | $41 | $4 | $40 | $44 |
| 4.1.10 | Performance Assurance | $0 | $0 | $0 | $0 | $0 | $0 |
| 4.1.11 | Instrument Operations Center | $17 | $13 | $30 | $18 | $14 | $32 |
| 4.1.12 | Education & Outreach | $17 | $68 | $85 | $17 | $74 | $91 |
| | **Mat'l & Equip, Other Directs** | **$806** | **$640** | **$1,446** | **$839** | **$693** | **$1,531** |
| 4.1.1 | Instrument Management | $12 | $20 | $32 | $12 | $22 | $35 |
| 4.1.2 | Systems Engineering | $0 | $0 | $0 | $0 | $0 | $0 |
| 4.1.3 | Science | $69 | $60 | $129 | $72 | $65 | $137 |
| 4.1.4 | Tracker | $0 | $0 | $0 | $0 | $0 | $0 |
| 4.1.5 | Calorimeter | $136 | $177 | $314 | $142 | $192 | $334 |
| 4.1.6 | Anticoindence Detector | $116 | $105 | $221 | $121 | $113 | $234 |
| 4.1.7 | Data Acquisition System | $401 | $218 | $618 | $417 | $235 | $653 |
| 4.1.8 | Grid | $0 | $0 | $0 | $0 | $0 | $0 |
| 4.1.9 | Integration and Testing | $46 | $32 | $78 | $48 | $35 | $83 |
| 4.1.10 | Performance Assurance | $0 | $0 | $0 | $0 | $0 | $0 |
| 4.1.11 | Instrument Operations Center | $7 | $12 | $19 | $8 | $13 | $21 |
| 4.1.12 | Education & Outreach | $18 | $16 | $34 | $18 | $17 | $36 |
| | **Subcontracts** | **$25** | **$0** | **$25** | **$26** | **$0** | **$26** |
| 4.1.1 | Instrument Management | $0 | $0 | $0 | $0 | $0 | $0 |
| 4.1.2 | Systems Engineering | $0 | $0 | $0 | $0 | $0 | $0 |
| 4.1.3 | Science | $0 | $0 | $0 | $0 | $0 | $0 |
| 4.1.4 | Tracker | $0 | $0 | $0 | $0 | $0 | $0 |
| 4.1.5 | Calorimeter | $25 | $0 | $25 | $26 | $0 | $26 |
| 4.1.6 | Anticoindence Detector | $0 | $0 | $0 | $0 | $0 | $0 |
| 4.1.7 | Data Acquisition System | $0 | $0 | $0 | $0 | $0 | $0 |
| 4.1.8 | Grid | $0 | $0 | $0 | $0 | $0 | $0 |
| 4.1.9 | Integration and Testing | $0 | $0 | $0 | $0 | $0 | $0 |
| 4.1.10 | Performance Assurance | $0 | $0 | $0 | $0 | $0 | $0 |
| 4.1.11 | Instrument Operations Center | $0 | $0 | $0 | $0 | $0 | $0 |
| 4.1.12 | Education & Outreach | $0 | $0 | $0 | $0 | $0 | $0 |
| | **Reserves** | **$164** | **$0** | **$164** | **$171** | **$0** | **$171** |
| 4.1.1 | Instrument Management | $3 | $0 | $3 | $3 | $0 | $3 |
| 4.1.2 | Systems Engineering | $0 | $0 | $0 | $0 | $0 | $0 |
| 4.1.3 | Science | $18 | $0 | $18 | $19 | $0 | $19 |
| 4.1.4 | Tracker | $0 | $0 | $0 | $0 | $0 | $0 |
| 4.1.5 | Calorimeter | $60 | $0 | $60 | $62 | $0 | $62 |
| 4.1.6 | Anticoindence Detector | $25 | $0 | $25 | $26 | $0 | $26 |
| 4.1.7 | Data Acquisition System | $53 | $0 | $53 | $55 | $0 | $55 |
| 4.1.8 | Grid | $0 | $0 | $0 | $0 | $0 | $0 |
| 4.1.9 | Integration and Testing | $2 | $0 | $2 | $3 | $0 | $3 |
| 4.1.10 | Performance Assurance | $0 | $0 | $0 | $0 | $0 | $0 |
| 4.1.11 | Instrument Operations Center | $1 | $0 | $1 | $1 | $0 | $1 |
| 4.1.12 | Education & Outreach | $2 | $0 | $2 | $2 | $0 | $2 |

**Table 2.3.5 (b)** Contributed Costs for Formulation Phase (FY 99 K$ and RY K)$

| | Contributions | FY99 K$ | | | RY K$ | | |
|---|---|---|---|---|---|---|---|
| **WBS** | **Instrument Subsystem** | **FY 2000** | **FY 2001** | **Total** | **FY 2000** | **FY 2001** | **Total** |
| | **Total Contributions** | **$8,156** | **$18,360** | **$26,516** | **$8,490** | **$19,865** | **$28,356** |
| | **SU-SLAC** | **$3,671** | **$7,348** | **$11,019** | **$3,822** | **$7,950** | **$11,772** |
| 4.1.1 | Instrument Management | $449 | $1,079 | $1,528 | $467 | $1,167 | $1,635 |
| 4.1.2 | Systems Engineering | $524 | $1,294 | $1,817 | $545 | $1,400 | $1,945 |
| 4.1.3 | Science | $65 | $135 | $200 | $67 | $147 | $214 |
| 4.1.4 | Tracker | $1,822 | $2,466 | $4,289 | $1,897 | $2,669 | $4,566 |
| 4.1.7 | Data Acquisition System | $253 | $530 | $783 | $264 | $573 | $837 |
| 4.1.8 | Grid | $251 | $771 | $1,022 | $261 | $834 | $1,095 |
| 4.1.9 | Integration and Testing | $41 | $377 | $418 | $43 | $408 | $451 |
| 4.1.10 | Performance Assurance | $135 | $629 | $765 | $141 | $681 | $822 |
| 4.1.11 | Instrument Operations Center | $131 | $66 | $197 | $136 | $72 | $208 |
| | **SU-Cost Share** | **$39** | **$78** | **$116** | **$40** | **$84** | **$124** |
| 4.1.1 | Instrument Management | $39 | $78 | $116 | $40 | $84 | $124 |
| | **UCSC** | **$233** | **$467** | **$700** | **$243** | **$505** | **$748** |
| 4.1.3 | Science | $132 | $263 | $395 | $137 | $285 | $422 |
| 4.1.4 | Tracker | $102 | $204 | $305 | $106 | $220 | $326 |
| | **CNES/CEA/IN2P3** | **$2,470** | **$3,760** | **$6,230** | **$2,571** | **$4,068** | **$6,640** |
| 4.1.5 | Calorimeter | $2,470 | $3,760 | $6,230 | $2,571 | $4,068 | $6,640 |
| | **INFN/ASI** | **$570** | **$3,288** | **$3,858** | **$593** | **$3,558** | **$4,151** |
| 4.1.4 | Tracker | $570 | $3,288 | $3,858 | $593 | $3,558 | $4,151 |
| | **JGC** | **$740** | **$1,655** | **$2,395** | **$770** | **$1,790** | **$2,561** |
| 4.1.4 | Tracker | $740 | $1,655 | $2,395 | $770 | $1,790 | $2,561 |
| | **Sweden** | **$400** | **$1,700** | **$2,100** | **$416** | **$1,839** | **$2,256** |
| 4.1.5 | Calorimeter | $400 | $1,700 | $2,100 | $416 | $1,839 | $2,256 |
| | **UW** | **$32** | **$65** | **$97** | **$34** | **$70** | **$104** |
| 4.1.3 | Science | $32 | $65 | $97 | $34 | $70 | $104 |

**Table 2.3.5(c)** Total Cost for Formulation Phase (FY 99 K$ and RY K$)

| | Total Cost for Time Phase | FY99 K$ | | | RY K$ | | |
|---|---|---|---|---|---|---|---|
| **WBS** | **Instrument Subsystem** | **FY 2000** | **FY 2001** | **Total** | **FY 2000** | **FY 2001** | **Total** |
| | **Total Cost for Time Phase** | $11,608 | $21,956 | $33,564 | $12,084 | $23,756 | $35,840 |

### **Table 2.3.6 (a)** Cost Breakdown by Cost Type with Full-Cost Accounting for NASA Institutions FY 99 K$ and RY K$

| | **Contract Costs to NASA** | | **FY99 K$** | | | **RY K$** | |
|---|---|---|---|---|---|---|---|
| **WBS** | **Instrument Subsystem** | **FY 2000** | **FY 2001** | **Total** | **FY 2000** | **FY 2001** | **Total** |
| | **Total Contract Cost** | **$3,918** | **$4,471** | **$8,389** | **$4,079** | **$4,837** | **$8,916** |
| | **Labor** | **$2,890** | **$3,814** | **$6,705** | **$3,009** | **$4,127** | **$7,136** |
| 4.1.1 | Instrument Management | $49 | $93 | $143 | $51 | $101 | $152 |
| 4.1.2 | Systems Engineering | $0 | $0 | $0 | $0 | $0 | $0 |
| 4.1.3 | Science | $427 | $669 | $1,096 | $444 | $724 | $1,168 |
| 4.1.4 | Tracker | $0 | $0 | $0 | $0 | $0 | $0 |
| 4.1.5 | Calorimeter | $1,039 | $923 | $1,961 | $1,081 | $999 | $2,080 |
| 4.1.6 | Anticoindence Detector | $677 | $1,075 | $1,751 | $704 | $1,163 | $1,867 |
| 4.1.7 | Data Acquisition System | $650 | $882 | $1,532 | $677 | $955 | $1,631 |
| 4.1.8 | Grid | $0 | $30 | $30 | $0 | $33 | $33 |
| 4.1.9 | Integration and Testing | $16 | $60 | $76 | $16 | $65 | $82 |
| 4.1.10 | Performance Assurance | $0 | $0 | $0 | $0 | $0 | $0 |
| 4.1.11 | Instrument Operations Center | $17 | $13 | $30 | $18 | $14 | $32 |
| 4.1.12 | Education & Outreach | $17 | $68 | $85 | $17 | $74 | $91 |
| | **Mat'l & Equip, Other Directs** | **$817** | **$656** | **$1,473** | **$850** | **$710** | **$1,560** |
| 4.1.1 | Instrument Management | $12 | $20 | $32 | $12 | $22 | $35 |
| 4.1.2 | Systems Engineering | $0 | $0 | $0 | $0 | $0 | $0 |
| 4.1.3 | Science | $80 | $71 | $151 | $84 | $77 | $161 |
| 4.1.4 | Tracker | $0 | $0 | $0 | $0 | $0 | $0 |
| 4.1.5 | Calorimeter | $136 | $177 | $314 | $142 | $192 | $334 |
| 4.1.6 | Anticoindence Detector | $116 | $105 | $221 | $121 | $113 | $234 |
| 4.1.7 | Data Acquisition System | $401 | $218 | $618 | $417 | $235 | $653 |
| 4.1.8 | Grid | $0 | $0 | $0 | $0 | $0 | $0 |
| 4.1.9 | Integration and Testing | $46 | $37 | $83 | $48 | $40 | $88 |
| 4.1.10 | Performance Assurance | $0 | $0 | $0 | $0 | $0 | $0 |
| 4.1.11 | Instrument Operations Center | $7 | $12 | $19 | $8 | $13 | $21 |
| 4.1.12 | Education & Outreach | $18 | $16 | $34 | $18 | $17 | $36 |
| | **Subcontracts** | **$25** | **$0** | **$25** | **$26** | **$0** | **$26** |
| 4.1.1 | Instrument Management | $0 | $0 | $0 | $0 | $0 | $0 |
| 4.1.2 | Systems Engineering | $0 | $0 | $0 | $0 | $0 | $0 |
| 4.1.3 | Science | $0 | $0 | $0 | $0 | $0 | $0 |
| 4.1.4 | Tracker | $0 | $0 | $0 | $0 | $0 | $0 |
| 4.1.5 | Calorimeter | $25 | $0 | $25 | $26 | $0 | $26 |
| 4.1.6 | Anticoindence Detector | $0 | $0 | $0 | $0 | $0 | $0 |
| 4.1.7 | Data Acquisition System | $0 | $0 | $0 | $0 | $0 | $0 |
| 4.1.8 | Grid | $0 | $0 | $0 | $0 | $0 | $0 |
| 4.1.9 | Integration and Testing | $0 | $0 | $0 | $0 | $0 | $0 |
| 4.1.10 | Performance Assurance | $0 | $0 | $0 | $0 | $0 | $0 |
| 4.1.11 | Instrument Operations Center | $0 | $0 | $0 | $0 | $0 | $0 |
| 4.1.12 | Education & Outreach | $0 | $0 | $0 | $0 | $0 | $0 |
| | **Reserves** | **$187** | **$0** | **$187** | **$194** | **$0** | **$194** |
| 4.1.1 | Instrument Management | $3 | $0 | $3 | $3 | $0 | $3 |
| 4.1.2 | Systems Engineering | $0 | $0 | $0 | $0 | $0 | $0 |
| 4.1.3 | Science | $25 | $0 | $25 | $26 | $0 | $26 |
| 4.1.4 | Tracker | $0 | $0 | $0 | $0 | $0 | $0 |
| 4.1.5 | Calorimeter | $60 | $0 | $60 | $62 | $0 | $62 |
| 4.1.6 | Anticoindence Detector | $40 | $0 | $40 | $41 | $0 | $41 |
| 4.1.7 | Data Acquisition System | $53 | $0 | $53 | $55 | $0 | $55 |
| 4.1.8 | Grid | $0 | $0 | $0 | $0 | $0 | $0 |
| 4.1.9 | Integration and Testing | $3 | $0 | $3 | $3 | $0 | $3 |
| 4.1.10 | Performance Assurance | $0 | $0 | $0 | $0 | $0 | $0 |
| 4.1.11 | Instrument Operations Center | $1 | $0 | $1 | $1 | $0 | $1 |
| 4.1.12 | Education & Outreach | $2 | $0 | $2 | $2 | $0 | $2 |

### **Table 2.3.6 (b)** Total Cost with Full-Cost Accounting for NASA Institutions FY 99 K$ and RY K$

| | **Total Cost for Time Phase** | | **FY99 K$** | | | **RY K$** | |
|---|---|---|---|---|---|---|---|
| **WBS** | **Instrument Subsystem** | **FY 2000** | **FY 2001** | **Total** | **FY 2000** | **FY 2001** | **Total** |
| | Total Cost for Time Phase | $12,074 | $22,831 | $34,905 | $12,569 | $24,703 | $37,272 |

### 2.3.3.5 Key Cost Elements

Key cost elements for the Formulation Phase are shown in Tables 2.3.7, 2.3.8, and 2.3.9. Note that all costs are in FY99 dollars, and are for the complete instrument, regardless of funding source.

Travel costs are summarized in Table 2.3.7, and include all instrument-related travel for the domestic team institutions in the project. Foreign team member travel is budgeted by the foreign team institutions, and not carried or shown in the budgets presented here.

Computer costs include budgets for all computer hardware and software for domestic team institutions. This covers all standard computers needed for the project, including office and lab computers, and standard and specialized software for the computers. However, this does not include any specialized computing or electronic equipment needed to perform specific production or testing functions, or that is included as part of equipment which performs these functions. For example, the computer built into a wire-bonding machine for the silicon Tracker is not included in this summary. All such specialized computers have been budgeted as equipment, and their costs are rolled up in the "materials and equipment" cost type shown in Section 2.3.3.2.

Key subcontracts include all subcontracts and consulting to institutions or companies outside of the immediate team institutions shown in the budgets in Section 2.3.3.2.

### **Table 2.3.7** Travel Costs for Formulation Phase (FY 99$)

| **Travel** | **Budget** |
|---|---:|
| Instrument Management* | $290,343 |
| Systems Engineering* | $0 |
| Science | $67,448 |
| Tracker | $111,480 |
| Calorimeter | $68,850 |
| Anticoindence Detector | $46,000 |
| Data Acquisition System | $62,145 |
| Grid | $21,148 |
| Integration and Testing** | $28,408 |
| Performance Assurance | $60,500 |
| Instrument Operations Center | $21,448 |
| Education & Outreach | $11,784 |
| **Total** | **$789,554** |

(*) Travel for Management and Systems Engineering included under Management budget.

(**) Travel for sub-orbital flight support included under I&T budget.

### **Table 2.3.8** Computer Costs for Formulation Phase (FY 99$)

| **Computers** | **Budget** |
|---|---:|
| Instrument Management* | $11,053 |
| Systems Engineering* | $0 |
| Science | $20,000 |
| Tracker | $6,900 |
| Calorimeter | $50,000 |
| Anticoindence Detector | $12,000 |
| Data Acquisition System | $10,000 |
| Grid | $0 |
| Integration and Testing | $2,040 |
| Performance Assurance | $4,500 |
| Instrument Operations Center | $22,000 |
| Education & Outreach | $20,499 |
| **Total** | **$158,992** |

(*) All computers for Management and Systems Engineering budgeted under Management

### **Table 2.3.9** Sub-Contract and Consulting Costs for Formulation Phase (FY 99$)

| **Key Sub-Contracts** | **Budget** | **Description** |
|---|---|---|
| **Management** | $0 | |
| System Engineering | | |
| Instrument structural and thermal analysis | $658,000 | Structural and dynamic response analysis; on-orbit thermal analysis, performed by Lockheed-Martin Advanced Technology Center |
| Reliability engineering | $80,000 | System-level reliability engineering, and working with sub-system reliability engineers |
| Structural analysis | $380,000 | Structural analysis to support design integration function, performed by Hytec, Inc. |
| **Science** | $0 | |
| Tracker | | |
| Tracker tower structural design, analysis, and testing | $410,000 | Hytec, Inc. will provide engineering and testing support for tower structural and thermal design |
| Tray mechanical design | $347,000 | Hytec, Inc. will engineer, fabricate, and test the carbon-fiber tray structural members |
| Calorimeter | $0 | |
| Anticoindence Detector | $0 | |
| Data Acquisition System | $0 | |
| Grid | | |
| Design and analysis of Grid engineering model | $898,313 | Detailed design, and thermal and structural analysis of the Grid will be sub-contracted to Lockheed-Martin Advanced Technology Center |
| **Integration and Test** | $0 | |
| Performance and Safety Assurance | | |
| ISO 9000 quality audit | $15,000 | Perform audit of SLAC ISO 9000 plans and procedures |
| ISO 9000 qualification planning | $20,000 | Aid SLAC Q.A. personnel in preparing for ISO 9000 qualification |
| Contamination control auditing service | $40,000 | Audit instrument project’s contamination control procedures and implementation |
| **Instrument Operations Center** | $0 | |
| Education and Public Outreach | | |
| Web curriculum development | $100,000 | To be contracted to VideoDiscovery |
| Printed curriculum development | $150,000 | To be contracted TOPS Learning Systems |
| Assessment | $120,000 | Independent assessment of curriculum. To be contracted to WestEd |
| **Total Sub-Contracts** | **$3,253,313** | |

## 2.4 IMPLEMENTATION PHASE COST ESTIMATE

### *2.4.1 Workforce Staffing Plan*

A summary of staffing for the Implementation Phase effort is shown in Table 2.4.1. Following this is a detailed breakdown of staff, by subsystem, showing key personnel for the instrument project and for each subsystem. These tables include all personnel working directly on the instrument, at all of the institutions involved.

The single significant trend in this staffing profile is that it peaks in FY 2003. This corresponds with the peak spending year for non-NASA funds. Following I-CDR in July 2002, we plan to move aggressively in the construction of all subsystem flight components. This is especially true for the Tracker and parts of the DAQ, which receive significant DOE funds.

**Table 2.4.1** Staffing Summary for Implementation Phase (staff-yr)

| WBS | LaborTotal | FY2002 | FY2003 | FY2004 | FY2005 | Total |
|---|---|---|---|---|---|---|
| 4.1.1 | Management | 9.85 | 9.86 | 9.86 | 7.18 | 36.74 |
| 4.1.2 | System Engineering | 8.68 | 7.73 | 7.41 | 2.00 | 25.81 |
| 4.1.3 | Science Support | 14.10 | 14.30 | 13.33 | 12.31 | 54.04 |
| 4.1.4 | Tracker | 25.55 | 32.98 | 24.67 | 16.36 | 99.56 |
| 4.1.5 | Calorimeter | 46.11 | 46.74 | 33.03 | 28.13 | 154.02 |
| 4.1.6 | Anticoindence Detector | 14.01 | 14.34 | 11.29 | 3.83 | 43.46 |
| 4.1.7 | Data Acquisition System | 19.90 | 19.72 | 15.15 | 5.50 | 60.26 |
| 4.1.8 | Grid | 5.11 | 4.14 | 2.37 | 0.29 | 11.91 |
| 4.1.9 | Integration and Test | 3.83 | 6.09 | 4.98 | 2.54 | 17.43 |
| 4.1.10 | Perf., Safety Assurance | 3.35 | 3.36 | 3.33 | 0.83 | 10.87 |
| 4.1.11 | Instrument Operations Center | 1.32 | 3.44 | 6.72 | 5.64 | 17.12 |
| 4.1.12 | Education, Public Outreach | 1.14 | 1.14 | 1.14 | 1.14 | 4.56 |
|  | **Total Staffing** | **152.94** | **163.83** | **133.27** | **85.74** | **535.79** |

## **Table 2.4.2** Staffing Breakdown for Implementation Phase(staff-yr)

| WBS | Labor Total | FY2002 | FY2003 | FY2004 | FY2005 | Total |
|---|---|---|---|---|---|---|
| **4.1.1** | **Management** | **9.85** | **9.86** | **9.86** | **7.18** | **36.74** |
| | Prinicpal Investigator | 0.63 | 0.63 | 0.63 | 0.63 | 2.50 |
| | Instrument Technical Manager | 0.50 | 0.50 | 0.50 | 0.50 | 2.00 |
| | Instrument Project Manager | 1.00 | 1.00 | 1.00 | 1.00 | 4.00 |
| | Management Staff | 5.47 | 5.48 | 5.48 | 3.50 | 19.93 |
| | Science and Engineering Staff | 2.25 | 2.25 | 2.25 | 1.56 | 8.31 |
| | Technicians and Others | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **4.1.2** | **System Engineering** | **8.68** | **7.73** | **7.41** | **2.00** | **25.81** |
| | Instrument System Engineer | 1.00 | 1.00 | 1.00 | 1.00 | 4.00 |
| | Management Staff | 1.00 | 1.00 | 1.00 | 0.25 | 3.25 |
| | Science and Engineering Staff | 6.18 | 5.23 | 5.16 | 0.75 | 17.31 |
| | Technicians and Others | 0.50 | 0.50 | 0.25 | 0.00 | 1.25 |
| **4.1.3** | **Science Support** | **14.10** | **14.30** | **13.33** | **12.31** | **54.04** |
| | Instrument Scientist | 0.80 | 0.80 | 0.90 | 0.90 | 3.40 |
| | Management Staff | 0.40 | 0.40 | 0.40 | 0.40 | 1.60 |
| | Science and Engineering Staff | 9.60 | 9.80 | 8.58 | 7.56 | 35.54 |
| | Technicians and Others | 3.30 | 3.30 | 3.45 | 3.45 | 13.50 |
| **4.1.4** | **Tracker** | **25.55** | **32.98** | **24.67** | **16.36** | **99.56** |
| | Tkr Subsystem Manager | 1.23 | 1.23 | 1.24 | 1.01 | 4.71 |
| | Tkr Subsystem Engineer | 1.03 | 1.03 | 1.04 | 0.34 | 3.44 |
| | Management Staff | 4.00 | 4.00 | 4.00 | 3.00 | 15.00 |
| | Science and Engineering Staff | 17.71 | 16.84 | 16.62 | 11.73 | 62.90 |
| | Technicians and Others | 1.58 | 9.88 | 1.78 | 0.27 | 13.50 |
| **4.1.5** | **Calorimeter** | **46.11** | **46.74** | **33.03** | **28.13** | **154.02** |
| | Cal Subsystem Manager | 0.54 | 0.73 | 0.31 | 0.25 | 1.83 |
| | Cal Subsystem Engineer | 1.00 | 1.00 | 0.60 | 0.19 | 2.79 |
| | Management Staff | 5.44 | 4.44 | 3.94 | 1.84 | 15.66 |
| | Science and Engineering Staff | 25.51 | 23.91 | 18.32 | 19.10 | 86.84 |
| | Technicians and Others | 13.62 | 16.67 | 9.87 | 6.75 | 46.91 |
| **4.1.6** | **Anticoindence Detector** | **14.01** | **14.34** | **11.29** | **3.83** | **43.46** |
| | ACD Subsystem Manager | 0.20 | 0.20 | 0.20 | 0.20 | 0.80 |
| | Management Staff | 1.71 | 1.74 | 1.44 | 0.23 | 5.11 |
| | Science & Engineering Staff | 8.15 | 7.75 | 6.00 | 2.40 | 24.30 |
| | Technicians & Others | 3.95 | 4.65 | 3.65 | 1.00 | 13.25 |
| **4.1.7** | **Data Acquisition System** | **19.90** | **19.72** | **15.15** | **5.50** | **60.26** |
| | DAQ Subsystem Manager | 1.00 | 1.00 | 1.00 | 0.44 | 3.44 |
| | Management Staff | 1.70 | 1.70 | 1.70 | 0.60 | 5.70 |
| | Science and Engineering Staff | 13.55 | 13.32 | 8.75 | 4.46 | 40.07 |
| | Technicians and Others | 3.65 | 3.70 | 3.70 | 0.00 | 11.05 |
| **4.1.8** | **Grid** | **5.11** | **4.14** | **2.37** | **0.29** | **11.91** |
| | Grid Subsystem Manager | 0.68 | 0.44 | 0.43 | 0.03 | 1.58 |
| | Management Staff | 0.13 | 0.14 | 0.14 | 0.00 | 0.41 |
| | Science and Engineering Staff | 3.73 | 2.96 | 1.10 | 0.24 | 8.03 |
| | Technicians and Others | 0.57 | 0.60 | 0.70 | 0.02 | 1.88 |
| **4.1.9** | **Integration and Test** | **3.83** | **6.09** | **4.98** | **2.54** | **17.43** |
| | Integration and Test Manager | 1.04 | 1.04 | 1.05 | 0.82 | 3.96 |
| | Management Staff | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | Science and Engineering Staff | 2.42 | 3.38 | 1.32 | 0.73 | 7.86 |
| | Technicians and Others | 0.36 | 1.67 | 2.61 | 0.98 | 5.62 |
| **4.1.10** | **Perf., Safety Assurance** | **3.35** | **3.36** | **3.33** | **0.83** | **10.87** |
| | Performance Assurance Manager | 1.00 | 1.00 | 1.00 | 0.50 | 3.50 |
| | Management Staff | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | Science and Engineering Staff | 2.33 | 2.33 | 2.33 | 0.33 | 7.33 |
| | Technicians and Others | 0.01 | 0.03 | 0.00 | 0.00 | 0.04 |
| **4.1.11** | **Instrument Operations Center** | **1.32** | **3.44** | **6.72** | **5.64** | **17.12** |
| | IOC Manager | 0.55 | 1.00 | 1.00 | 0.78 | 3.33 |
| | Management Staff | 0.17 | 0.17 | 0.17 | 0.15 | 0.66 |
| | Science and Engineering Staff | 0.60 | 2.27 | 4.55 | 3.71 | 11.13 |
| | Technicians and Others | 0.00 | 0.00 | 1.00 | 1.00 | 2.00 |
| **4.1.12** | **Education, Public Outreach** | **1.14** | **1.14** | **1.14** | **1.14** | **4.56** |
| | EPO Coordinator | 0.20 | 0.20 | 0.20 | 0.20 | 0.80 |
| | Management Staff | 0.50 | 0.50 | 0.50 | 0.50 | 2.00 |
| | Science and Engineering Staff | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | Technicians and Others | 0.44 | 0.44 | 0.44 | 0.44 | 1.76 |
| | **Total Staffing** | **152.94** | **163.83** | **133.27** | **85.74** | **535.79** |

### *2.4.2 Implementation Phase Time-Phased Cost Summary*

Costs for the Implementation Phase are shown in the sections to follow. To simplify the layout, and facilitate direct comparison of tables, all page-length tables have been collected in Section 2.4.2.4. These full-page tables are:

**Table 2.4.3** List of Implementation Phase Cost Tables

| Table | Title |
|---|---|
| **2.4.5 (a)** | Cost Breakdown by Cost Type for Implementation Phase (FY99 K$) |
| **2.4.5 (b)** | Contributed Costs for Implementation Phase (FY99 K$) |
| **2.4.5 (c)** | Total Cost for Implementation Phase (FY99 K$) |
| **2.4.6 (a)** | Cost Breakdown by Cost Type for Implementation Phase (RY K$) |
| **2.4.6 (b)** | Contributed Costs for Implementation Phase (RY K$) |
| **2.4.6 (c)** | Total Cost for Implementation Phase (RY K$) |
| **2.4.7 (a)** | Cost Breakdown by Cost Type with Full-Cost Accounting for NASA Institutions (FY99 K$) |
| **2.4.7 (b)** | Total Cost with Full-Cost Accounting for NASA Institutions (FY99 K$) |
| **2.4.8 (a)** | Cost Breakdown by Cost Type with Full-Cost Accounting for NASA Institutions (RY K$) |
| **2.4.8 (b)** | Total Cost with Full-Cost Accounting for NASA Institutions (RY K$) |

#### 2.4.2.1 Total Implementation Phase Cost

Table 2.4.4 summarizes costs for the instrument by WBS element. These are total costs for the element, independent of funding source, and are rolled up from more detailed budget breakdowns for each subsystem. A summary and discussion of the total instrument cost is provided in section 2.6.

#### 2.4.2.2 Cost Breakdown by Cost Type

Tables 2.4.5(a) shows NASA costs by cost type, Table 2.4.5(b) shows contributed costs, and Table 2.4.5 (c) shows total cost. For NASA costs, the table shows costs categorized by Labor (both Civil Servant and Contractor), Material and Equipment, Sub-Contracts, and Reserves for each subsystem receiving NASA funds. Tables 2.4.6 (a)-(c) give the same information in RY$.

#### 2.4.2.3 Full-Cost Accounting for NASA Institutions

Tables 2.4.7 and 2.4.8 show costs using full-cost accounting for NASA institutions in FY99$ and RY$ respectively. All contributions from non-NASA sources are identical to Tables 2.4.5(b) and 2.4.6(b), and are not repeated. Total costs for all sources are shown in Tables 2.4.7(b) and 2.4.8(b),including both the full-cost accounted NASA costs, and the contributed costs.

#### 2.4.2.4 Implementation Phase Cost Tables

The Implementation Phase Cost Tables are presented on the following pages.

**Table 2.4.4** Implementation Phase Costs by WBS Element(FY99 K$)

| WBS | Subsystem | FY 2002 | FY 2003 | FY 2004 | FY 2005 | Total |
|---|---|---:|---:|---:|---:|---:|
| **4.1** | **Instrument Total** | **$34,265** | **$33,318** | **$26,600** | **$12,846** | **$107,029** |
| **4.1.1** | Instrument Management | $1,401 | $1,469 | $1,701 | $1,191 | $5,761 |
| **4.1.2** | Systems Engineering | $1,499 | $1,271 | $1,444 | $345 | $4,559 |
| **4.1.3** | Science | $1,656 | $1,796 | $1,888 | $1,641 | $6,981 |
| **4.1.4** | Tracker | $8,755 | $6,338 | $3,240 | $1,989 | $20,321 |
| **4.1.5** | Calorimeter | $10,105 | $7,998 | $4,990 | $3,481 | $26,574 |
| **4.1.6** | Anticoindence Detector | $3,077 | $3,268 | $2,272 | $465 | $9,082 |
| **4.1.7** | Data Acquisition System | $4,711 | $6,564 | $5,547 | $1,455 | $18,276 |
| **4.1.8** | Grid | $1,240 | $1,276 | $617 | $113 | $3,244 |
| **4.1.9** | Integration and Testing | $639 | $1,712 | $2,137 | $511 | $4,999 |
| **4.1.10** | Performance Assurance | $622 | $616 | $642 | $157 | $2,037 |
| **4.1.11** | Instrument Operations Center | $299 | $691 | $1,471 | $1,152 | $3,614 |
| **4.1.12** | Education & Outreach | $263 | $319 | $651 | $347 | $1,580 |

**Table 2.4.5(a)** Cost Breakdown by Cost Type for Implementation Phase (FY 99 K$)

| | **Contract Costs to NASA** | | | **FY99 K$** | | |
|---|---|---|---|---|---|---|
| **WBS** | **Instrument Subsystem** | **FY 2002** | **FY 2003** | **FY 2004** | **FY 2005** | **Total** |
| | **Total Contract Cost** | **$13,789** | **$17,372** | **$15,573** | **$5,187** | **$51,922** |
| | **Labor** | **$7,271** | **$8,294** | **$6,382** | **$2,679** | **$24,627** |
| 4.1.1 | Instrument Management | $186 | $188 | $188 | $90 | $653 |
| 4.1.2 | Systems Engineering | $0 | $0 | $0 | $0 | $0 |
| 4.1.3 | Science | $903 | $926 | $787 | $668 | $3,284 |
| 4.1.4 | Tracker | $0 | $0 | $0 | $0 | $0 |
| 4.1.5 | Calorimeter | $1,720 | $2,407 | $1,285 | $451 | $5,862 |
| 4.1.6 | Anticoindence Detector | $1,038 | $1,062 | $899 | $226 | $3,225 |
| 4.1.7 | Data Acquisition System | $2,225 | $2,235 | $1,794 | $555 | $6,809 |
| 4.1.8 | Grid | $959 | $769 | $393 | $75 | $2,196 |
| 4.1.9 | Integration and Testing | $0 | $368 | $376 | $129 | $873 |
| 4.1.10 | Performance Assurance | $0 | $0 | $0 | $0 | $0 |
| 4.1.11 | Instrument Operations Center | $141 | $242 | $560 | $386 | $1,330 |
| 4.1.12 | Education & Outreach | $99 | $99 | $99 | $99 | $395 |
| | **Mat'l & Equip, Other Directs** | **$4,472** | **$5,207** | **$2,895** | **$739** | **$13,314** |
| 4.1.1 | Instrument Management | $24 | $22 | $22 | $40 | $107 |
| 4.1.2 | Systems Engineering | $0 | $0 | $0 | $0 | $0 |
| 4.1.3 | Science | $131 | $136 | $140 | $105 | $512 |
| 4.1.4 | Tracker | $0 | $0 | $0 | $0 | $0 |
| 4.1.5 | Calorimeter | $1,240 | $536 | $215 | $70 | $2,061 |
| 4.1.6 | Anticoindence Detector | $1,416 | $1,257 | $476 | $83 | $3,233 |
| 4.1.7 | Data Acquisition System | $1,400 | $2,629 | $1,666 | $202 | $5,898 |
| 4.1.8 | Grid | $122 | $258 | $18 | $0 | $397 |
| 4.1.9 | Integration and Testing | $0 | $243 | $99 | $32 | $374 |
| 4.1.10 | Performance Assurance | $0 | $0 | $0 | $0 | $0 |
| 4.1.11 | Instrument Operations Center | $58 | $57 | $140 | $114 | $369 |
| 4.1.12 | Education & Outreach | $81 | $68 | $121 | $92 | $362 |
| | **Subcontracts** | **$279** | **$475** | **$1,105** | **$40** | **$1,898** |
| 4.1.1 | Instrument Management | $0 | $0 | $0 | $0 | $0 |
| 4.1.2 | Systems Engineering | $0 | $0 | $0 | $0 | $0 |
| 4.1.3 | Science | $0 | $0 | $0 | $0 | $0 |
| 4.1.4 | Tracker | $0 | $0 | $0 | $0 | $0 |
| 4.1.5 | Calorimeter | $0 | $0 | $0 | $0 | $0 |
| 4.1.6 | Anticoindence Detector | $229 | $310 | $140 | $0 | $678 |
| 4.1.7 | Data Acquisition System | $0 | $0 | $0 | $0 | $0 |
| 4.1.8 | Grid | $0 | $0 | $0 | $0 | $0 |
| 4.1.9 | Integration and Testing | $0 | $75 | $750 | $0 | $825 |
| 4.1.10 | Performance Assurance | $0 | $0 | $0 | $0 | $0 |
| 4.1.11 | Instrument Operations Center | $0 | $0 | $0 | $0 | $0 |
| 4.1.12 | Education & Outreach | $50 | $90 | $215 | $40 | $395 |
| | **Reserves** | **$1,767** | **$3,396** | **$5,191** | **$1,729** | **$12,084** |
| 4.1.1 | Instrument Management | $31 | $51 | $105 | $65 | $252 |
| 4.1.2 | Systems Engineering | $0 | $0 | $0 | $0 | $0 |
| 4.1.3 | Science | $152 | $258 | $463 | $387 | $1,260 |
| 4.1.4 | Tracker | $0 | $0 | $0 | $0 | $0 |
| 4.1.5 | Calorimeter | $435 | $715 | $750 | $260 | $2,161 |
| 4.1.6 | Anticoindence Detector | $394 | $639 | $757 | $155 | $1,945 |
| 4.1.7 | Data Acquisition System | $533 | $1,182 | $1,730 | $379 | $3,824 |
| 4.1.8 | Grid | $159 | $249 | $206 | $38 | $651 |
| 4.1.9 | Integration and Testing | $0 | $167 | $612 | $81 | $860 |
| 4.1.10 | Performance Assurance | $0 | $0 | $0 | $0 | $0 |
| 4.1.11 | Instrument Operations Center | $29 | $73 | $350 | $250 | $702 |
| 4.1.12 | Education & Outreach | $34 | $62 | $217 | $116 | $429 |

### **Table 2.4.5 (b)** Contributed Costs for Implementation Phase (FY 99 K$)

| | **Contributions** | | | **FY99 K$** | | |
|---|---|---|---|---|---|---|
| **WBS** | **Instrument Subsystem** | **FY 2002** | **FY 2003** | **FY 2004** | **FY 2005** | **Total** |
| | **Total Contributions** | **$20,476** | **$15,945** | **$11,027** | **$7,659** | **$55,107** |
| | **SU-SLAC** | **$6,692** | **$8,607** | **$5,826** | **$3,244** | **$24,370** |
| 4.1.1 | Instrument Management | $1,082 | $1,131 | $1,308 | $918 | $4,439 |
| 4.1.2 | Systems Engineering | $1,499 | $1,271 | $1,444 | $345 | $4,559 |
| 4.1.3 | Science | $141 | $147 | $171 | $153 | $612 |
| 4.1.4 | Tracker | $2,087 | $3,745 | $1,185 | $680 | $7,698 |
| 4.1.7 | Data Acquisition System | $553 | $518 | $356 | $319 | $1,746 |
| 4.1.8 | Grid | $0 | $0 | $0 | $0 | $0 |
| 4.1.9 | Integration and Testing | $639 | $858 | $300 | $269 | $2,066 |
| 4.1.10 | Performance Assurance | $622 | $616 | $642 | $157 | $2,037 |
| 4.1.11 | Instrument Operations Center | $70 | $320 | $420 | $403 | $1,213 |
| | **SU-Cost Share** | **$78** | **$78** | **$78** | **$78** | **$311** |
| 4.1.1 | Instrument Management | $78 | $78 | $78 | $78 | $311 |
| | **UCSC** | **$468** | **$468** | **$468** | **$432** | **$1,835** |
| 4.1.3 | Science | $263 | $263 | $263 | $263 | $1,053 |
| 4.1.4 | Tracker | $204 | $204 | $205 | $168 | $782 |
| | **CNES/CEA/IN2P3** | **$4,810** | **$3,440** | **$1,890** | **$1,500** | **$11,640** |
| 4.1.5 | Calorimeter | $4,810 | $3,440 | $1,890 | $1,500 | $11,640 |
| | **INFN/ASI** | **$3,548** | **$1,994** | **$1,570** | **$1,140** | **$8,252** |
| 4.1.4 | Tracker | $3,548 | $1,994 | $1,570 | $1,140 | $8,252 |
| | **JGC** | **$2,916** | **$394** | **$280** | **$0** | **$3,590** |
| 4.1.4 | Tracker | $2,916 | $394 | $280 | $0 | $3,590 |
| | **Sweden** | **$1,900** | **$900** | **$850** | **$1,200** | **$4,850** |
| 4.1.5 | Calorimeter | $1,900 | $900 | $850 | $1,200 | $4,850 |
| | **UW** | **$65** | **$65** | **$65** | **$65** | **$260** |
| 4.1.3 | Science | $65 | $65 | $65 | $65 | $260 |

### **Table 2.4.5(c)** Total Cost for Implementation Phase (FY99 K$)

| | **Total Cost for Time Phase** | | | **FY99 K$** | | |
|---|---|---|---|---|---|---|
| **WBS** | **Instrument Subsystem** | **FY 2002** | **FY 2003** | **FY 2004** | **FY 2005** | **Total** |
| | Total Cost for Time Phase | $34,265 | $33,318 | $26,600 | $12,846 | $107,029 |

## **Table 2.4.6(a)** Cost Breakdown by Cost Type for Implementation Phase(RY K$)

| | **Contract Costs to NASA** | | | **RY k$** | | |
|---|---|---|---|---|---|---|
| **WBS** | **Instrument Subsystem** | **FY 2002** | **FY 2003** | **FY 2004** | **FY 2005** | **Total** |
| | **Total Contract Cost** | **$15,499** | **$20,291** | **$18,890** | **$6,536** | **$61,216** |
| | **Labor** | **$8,173** | **$9,688** | **$7,741** | **$3,376** | **$28,978** |
| 4.1.1 | Instrument Management | $210 | $220 | $228 | $113 | $771 |
| 4.1.2 | Systems Engineering | $0 | $0 | $0 | $0 | $0 |
| 4.1.3 | Science | $1,015 | $1,082 | $954 | $842 | $3,893 |
| 4.1.4 | Tracker | $0 | $0 | $0 | $0 | $0 |
| 4.1.5 | Calorimeter | $1,933 | $2,811 | $1,559 | $568 | $6,871 |
| 4.1.6 | Anticoindence Detector | $1,167 | $1,240 | $1,090 | $285 | $3,782 |
| 4.1.7 | Data Acquisition System | $2,501 | $2,610 | $2,177 | $699 | $7,987 |
| 4.1.8 | Grid | $1,077 | $898 | $477 | $95 | $2,547 |
| 4.1.9 | Integration and Testing | $0 | $430 | $456 | $162 | $1,049 |
| 4.1.10 | Performance Assurance | $0 | $0 | $0 | $0 | $0 |
| 4.1.11 | Instrument Operations Center | $159 | $282 | $680 | $487 | $1,608 |
| 4.1.12 | Education & Outreach | $111 | $115 | $120 | $124 | $470 |
| | **Mat’l & Equip, Other Directs** | **$5,027** | **$6,082** | **$3,512** | **$931** | **$15,552** |
| 4.1.1 | Instrument Management | $27 | $25 | $26 | $51 | $129 |
| 4.1.2 | Systems Engineering | $0 | $0 | $0 | $0 | $0 |
| 4.1.3 | Science | $148 | $159 | $169 | $133 | $608 |
| 4.1.4 | Tracker | $0 | $0 | $0 | $0 | $0 |
| 4.1.5 | Calorimeter | $1,394 | $626 | $260 | $88 | $2,369 |
| 4.1.6 | Anticoindence Detector | $1,592 | $1,469 | $577 | $105 | $3,743 |
| 4.1.7 | Data Acquisition System | $1,573 | $3,071 | $2,021 | $255 | $6,920 |
| 4.1.8 | Grid | $137 | $301 | $21 | $0 | $459 |
| 4.1.9 | Integration and Testing | $0 | $284 | $120 | $41 | $445 |
| 4.1.10 | Performance Assurance | $0 | $0 | $0 | $0 | $0 |
| 4.1.11 | Instrument Operations Center | $66 | $67 | $170 | $143 | $446 |
| 4.1.12 | Education & Outreach | $91 | $79 | $146 | $116 | $433 |
| | **Subcontracts** | **$313** | **$555** | **$1,340** | **$50** | **$2,258** |
| 4.1.1 | Instrument Management | $0 | $0 | $0 | $0 | $0 |
| 4.1.2 | Systems Engineering | $0 | $0 | $0 | $0 | $0 |
| 4.1.3 | Science | $0 | $0 | $0 | $0 | $0 |
| 4.1.4 | Tracker | $0 | $0 | $0 | $0 | $0 |
| 4.1.5 | Calorimeter | $0 | $0 | $0 | $0 | $0 |
| 4.1.6 | Anticoindence Detector | $257 | $362 | $170 | $0 | $789 |
| 4.1.7 | Data Acquisition System | $0 | $0 | $0 | $0 | $0 |
| 4.1.8 | Grid | $0 | $0 | $0 | $0 | $0 |
| 4.1.9 | Integration and Testing | $0 | $88 | $910 | $0 | $997 |
| 4.1.10 | Performance Assurance | $0 | $0 | $0 | $0 | $0 |
| 4.1.11 | Instrument Operations Center | $0 | $0 | $0 | $0 | $0 |
| 4.1.12 | Education & Outreach | $56 | $105 | $261 | $50 | $473 |
| | **Reserves** | **$1,986** | **$3,967** | **$6,297** | **$2,179** | **$14,429** |
| 4.1.1 | Instrument Management | $35 | $60 | $127 | $82 | $304 |
| 4.1.2 | Systems Engineering | $0 | $0 | $0 | $0 | $0 |
| 4.1.3 | Science | $171 | $301 | $562 | $487 | $1,521 |
| 4.1.4 | Tracker | $0 | $0 | $0 | $0 | $0 |
| 4.1.5 | Calorimeter | $489 | $835 | $910 | $328 | $2,562 |
| 4.1.6 | Anticoindence Detector | $443 | $746 | $919 | $195 | $2,303 |
| 4.1.7 | Data Acquisition System | $599 | $1,381 | $2,099 | $477 | $4,555 |
| 4.1.8 | Grid | $179 | $291 | $249 | $47 | $766 |
| 4.1.9 | Integration and Testing | $0 | $195 | $743 | $102 | $1,039 |
| 4.1.10 | Performance Assurance | $0 | $0 | $0 | $0 | $0 |
| 4.1.11 | Instrument Operations Center | $33 | $85 | $425 | $315 | $858 |
| 4.1.12 | Education & Outreach | $38 | $73 | $263 | $146 | $520 |

### **Table 2.4.6(b)** Contributed Costs for Implementation Phase(RY K$)

| WBS | Contributions Instrument Subsystem | FY 2002 | FY 2003 | RY K$ FY 2004 | FY 2005 | Total |
|---|---|---|---|---|---|---|
| | **Total Contributions** | **$23,015** | **$18,624** | **$13,376** | **$9,650** | **$64,665** |
| | **SU-SLAC** | **$7,522** | **$10,053** | **$7,067** | **$4,088** | **$28,730** |
| 4.1.1 | Instrument Management | $1,216 | $1,321 | $1,587 | $1,156 | $5,280 |
| 4.1.2 | Systems Engineering | $1,685 | $1,485 | $1,751 | $435 | $5,356 |
| 4.1.3 | Science | $159 | $172 | $207 | $193 | $731 |
| 4.1.4 | Tracker | $2,346 | $4,375 | $1,437 | $857 | $9,015 |
| 4.1.7 | Data Acquisition System | $622 | $605 | $432 | $402 | $2,060 |
| 4.1.8 | Grid | $0 | $0 | $0 | $0 | $0 |
| 4.1.9 | Integration and Testing | $718 | $1,003 | $364 | $339 | $2,424 |
| 4.1.10 | Performance Assurance | $699 | $720 | $779 | $198 | $2,395 |
| 4.1.11 | Instrument Operations Center | $79 | $373 | $509 | $507 | $1,469 |
| | **SU-Cost Share** | **$87** | **$91** | **$94** | **$98** | **$370** |
| 4.1.1 | Instrument Management | $87 | $91 | $94 | $98 | $370 |
| | **UCSC** | **$526** | **$546** | **$568** | **$544** | **$2,184** |
| 4.1.3 | Science | $296 | $307 | $319 | $332 | $1,254 |
| 4.1.4 | Tracker | $230 | $239 | $249 | $212 | $929 |
| | **CNES/CEA/IN2P3** | **$5,406** | **$4,018** | **$2,293** | **$1,890** | **$13,607** |
| 4.1.5 | Calorimeter | $5,406 | $4,018 | $2,293 | $1,890 | $13,607 |
| | **INFN/ASI** | **$3,988** | **$2,330** | **$1,904** | **$1,436** | **$9,658** |
| 4.1.4 | Tracker | $3,988 | $2,330 | $1,904 | $1,436 | $9,658 |
| | **JGC** | **$3,278** | **$460** | **$340** | **$0** | **$4,077** |
| 4.1.4 | Tracker | $3,278 | $460 | $340 | $0 | $4,077 |
| | **Sweden** | **$2,136** | **$1,051** | **$1,031** | **$1,512** | **$5,730** |
| 4.1.5 | Calorimeter | $2,136 | $1,051 | $1,031 | $1,512 | $5,730 |
| | **UW** | **$73** | **$76** | **$79** | **$82** | **$309** |
| 4.1.3 | Science | $73 | $76 | $79 | $82 | $309 |

### **Table 2.4.6(c)** Total Costs for Implementation Phase(RY K$)

| WBS | Total Cost for Time Phase Instrument Subsystem | FY 2002 | FY 2003 | RY K$ FY 2004 | FY 2005 | Total |
|---|---|---|---|---|---|---|
| | Total Cost for Time Phase | $38,514 | $38,915 | $32,266 | $16,186 | $125,881 |

**Table 2.4.7(a)** Cost Breakdown by Cost Type, with Full-Cost Accounting for Implementation Phase (FY99 K$)

| | **Contract Costs to NASA** | | | **FY99 K$** | | |
|---|---|---|---|---|---|---|
| **WBS** | **Instrument Subsystem** | **FY 2002** | **FY 2003** | **FY 2004** | **FY 2005** | **Total** |
| | **Total Contract Cost** | **$14,861** | **$18,559** | **$16,922** | **$6,056** | **$56,397** |
| | **Labor** | **$8,195** | **$9,238** | **$7,339** | **$3,316** | **$28,088** |
| 4.1.1 | Instrument Management | $186 | $188 | $188 | $90 | $653 |
| 4.1.2 | Systems Engineering | $0 | $0 | $0 | $0 | $0 |
| 4.1.3 | Science | $1,150 | $1,172 | $1,044 | $914 | $4,280 |
| 4.1.4 | Tracker | $0 | $0 | $0 | $0 | $0 |
| 4.1.5 | Calorimeter | $1,720 | $2,407 | $1,285 | $451 | $5,862 |
| 4.1.6 | Anticoindence Detector | $1,693 | $1,726 | $1,359 | $410 | $5,187 |
| 4.1.7 | Data Acquisition System | $2,225 | $2,235 | $1,794 | $555 | $6,809 |
| 4.1.8 | Grid | $981 | $802 | $427 | $75 | $2,284 |
| 4.1.9 | Integration and Testing | $0 | $368 | $583 | $336 | $1,287 |
| 4.1.10 | Performance Assurance | $0 | $0 | $0 | $0 | $0 |
| 4.1.11 | Instrument Operations Center | $141 | $242 | $560 | $386 | $1,330 |
| 4.1.12 | Education & Outreach | $99 | $99 | $99 | $99 | $395 |
| | **Mat'l & Equip, Other Directs** | **$4,483** | **$5,218** | **$2,906** | **$750** | **$13,358** |
| 4.1.1 | Instrument Management | $24 | $22 | $22 | $40 | $107 |
| 4.1.2 | Systems Engineering | $0 | $0 | $0 | $0 | $0 |
| 4.1.3 | Science | $142 | $147 | $151 | $116 | $556 |
| 4.1.4 | Tracker | $0 | $0 | $0 | $0 | $0 |
| 4.1.5 | Calorimeter | $1,240 | $536 | $215 | $70 | $2,061 |
| 4.1.6 | Anticoindence Detector | $1,416 | $1,257 | $476 | $83 | $3,233 |
| 4.1.7 | Data Acquisition System | $1,400 | $2,629 | $1,666 | $202 | $5,898 |
| 4.1.8 | Grid | $122 | $258 | $18 | $0 | $397 |
| 4.1.9 | Integration and Testing | $0 | $243 | $99 | $32 | $374 |
| 4.1.10 | Performance Assurance | $0 | $0 | $0 | $0 | $0 |
| 4.1.11 | Instrument Operations Center | $58 | $57 | $140 | $114 | $369 |
| 4.1.12 | Education & Outreach | $81 | $68 | $121 | $92 | $362 |
| | **Subcontracts** | **$279** | **$475** | **$1,105** | **$40** | **$1,898** |
| 4.1.1 | Instrument Management | $0 | $0 | $0 | $0 | $0 |
| 4.1.2 | Systems Engineering | $0 | $0 | $0 | $0 | $0 |
| 4.1.3 | Science | $0 | $0 | $0 | $0 | $0 |
| 4.1.4 | Tracker | $0 | $0 | $0 | $0 | $0 |
| 4.1.5 | Calorimeter | $0 | $0 | $0 | $0 | $0 |
| 4.1.6 | Anticoindence Detector | $229 | $310 | $140 | $0 | $678 |
| 4.1.7 | Data Acquisition System | $0 | $0 | $0 | $0 | $0 |
| 4.1.8 | Grid | $0 | $0 | $0 | $0 | $0 |
| 4.1.9 | Integration and Testing | $0 | $75 | $750 | $0 | $825 |
| 4.1.10 | Performance Assurance | $0 | $0 | $0 | $0 | $0 |
| 4.1.11 | Instrument Operations Center | $0 | $0 | $0 | $0 | $0 |
| 4.1.12 | Education & Outreach | $50 | $90 | $215 | $40 | $395 |
| | **Reserves** | **$1,905** | **$3,628** | **$5,572** | **$1,950** | **$13,054** |
| 4.1.1 | Instrument Management | $31 | $51 | $105 | $65 | $252 |
| 4.1.2 | Systems Engineering | $0 | $0 | $0 | $0 | $0 |
| 4.1.3 | Science | $190 | $321 | $597 | $515 | $1,623 |
| 4.1.4 | Tracker | $0 | $0 | $0 | $0 | $0 |
| 4.1.5 | Calorimeter | $435 | $715 | $750 | $260 | $2,161 |
| 4.1.6 | Anticoindence Detector | $491 | $800 | $987 | $247 | $2,525 |
| 4.1.7 | Data Acquisition System | $533 | $1,182 | $1,730 | $379 | $3,824 |
| 4.1.8 | Grid | $162 | $257 | $222 | $38 | $679 |
| 4.1.9 | Integration and Testing | $0 | $167 | $612 | $81 | $860 |
| 4.1.10 | Performance Assurance | $0 | $0 | $0 | $0 | $0 |
| 4.1.11 | Instrument Operations Center | $29 | $73 | $350 | $250 | $702 |
| **4.1.12** | **Education & Outreach** | $34 | $62 | $217 | $116 | $429 |

**Table 2.4.7(b)** Total Costs, with Full-Cost Accounting for Implementation Phase (FY99 K$)

| | **Total Cost for Time Phase** | | | **FY99 K$** | | |
|---|---|---|---|---|---|---|
| **WBS** | **Instrument Subsystem** | **FY 2002** | **FY 2003** | **FY 2004** | **FY 2005** | **Total** |
| | Total Cost for Time Phase | $35,337 | $34,504 | $27,949 | $13,714 | $111,504 |

**Table 2.4.8(a)** Cost Breakdown by Cost Type, with Full-Cost Accounting for Implementation Phase (RY K$)

| | **Contract Costs to NASA** | | | **RY K$** | | |
|---|---|---|---|---|---|---|
| **WBS** | **Instrument Subsystem** | **FY 2002** | **FY 2003** | **FY 2004** | **FY 2005** | **Total** |
| | **Total Contract Cost** | **$16,704** | **$21,676** | **$20,526** | **$7,630** | **$66,537** |
| | **Labor** | **$9,211** | **$10,790** | **$8,903** | **$4,178** | **$33,081** |
| 4.1.1 | Instrument Management | $210 | $220 | $228 | $113 | $771 |
| 4.1.2 | Systems Engineering | $0 | $0 | $0 | $0 | $0 |
| 4.1.3 | Science | $1,292 | $1,369 | $1,266 | $1,152 | $5,080 |
| 4.1.4 | Tracker | $0 | $0 | $0 | $0 | $0 |
| 4.1.5 | Calorimeter | $1,933 | $2,811 | $1,559 | $568 | $6,871 |
| 4.1.6 | Anticoindence Detector | $1,903 | $2,015 | $1,648 | $516 | $6,083 |
| 4.1.7 | Data Acquisition System | $2,501 | $2,610 | $2,177 | $699 | $7,987 |
| 4.1.8 | Grid | $1,103 | $936 | $518 | $95 | $2,651 |
| 4.1.9 | Integration and Testing | $0 | $430 | $707 | $423 | $1,561 |
| 4.1.10 | Performance Assurance | $0 | $0 | $0 | $0 | $0 |
| 4.1.11 | Instrument Operations Center | $159 | $282 | $680 | $487 | $1,608 |
| 4.1.12 | Education & Outreach | $111 | $115 | $120 | $124 | $470 |
| | **Mat'l & Equip, Other Directs** | **$5,039** | **$6,094** | **$3,525** | **$945** | **$15,604** |
| 4.1.1 | Instrument Management | $27 | $25 | $26 | $51 | $129 |
| 4.1.2 | Systems Engineering | $0 | $0 | $0 | $0 | $0 |
| 4.1.3 | Science | $160 | $172 | $183 | $146 | $661 |
| 4.1.4 | Tracker | $0 | $0 | $0 | $0 | $0 |
| 4.1.5 | Calorimeter | $1,394 | $626 | $260 | $88 | $2,369 |
| 4.1.6 | Anticoindence Detector | $1,592 | $1,469 | $577 | $105 | $3,743 |
| 4.1.7 | Data Acquisition System | $1,573 | $3,071 | $2,021 | $255 | $6,920 |
| 4.1.8 | Grid | $137 | $301 | $21 | $0 | $459 |
| 4.1.9 | Integration and Testing | $0 | $284 | $120 | $41 | $445 |
| 4.1.10 | Performance Assurance | $0 | $0 | $0 | $0 | $0 |
| 4.1.11 | Instrument Operations Center | $66 | $67 | $170 | $143 | $446 |
| 4.1.12 | Education & Outreach | $91 | $79 | $146 | $116 | $433 |
| | **Subcontracts** | **$313** | **$555** | **$1,340** | **$50** | **$2,258** |
| 4.1.1 | Instrument Management | $0 | $0 | $0 | $0 | $0 |
| 4.1.2 | Systems Engineering | $0 | $0 | $0 | $0 | $0 |
| 4.1.3 | Science | $0 | $0 | $0 | $0 | $0 |
| 4.1.4 | Tracker | $0 | $0 | $0 | $0 | $0 |
| 4.1.5 | Calorimeter | $0 | $0 | $0 | $0 | $0 |
| 4.1.6 | Anticoindence Detector | $257 | $362 | $170 | $0 | $789 |
| 4.1.7 | Data Acquisition System | $0 | $0 | $0 | $0 | $0 |
| 4.1.8 | Grid | $0 | $0 | $0 | $0 | $0 |
| 4.1.9 | Integration and Testing | $0 | $88 | $910 | $0 | $997 |
| 4.1.10 | Performance Assurance | $0 | $0 | $0 | $0 | $0 |
| 4.1.11 | Instrument Operations Center | $0 | $0 | $0 | $0 | $0 |
| 4.1.12 | Education & Outreach | $56 | $105 | $261 | $50 | $473 |
| | **Reserves** | **$2,141** | **$4,238** | **$6,758** | **$2,456** | **$15,593** |
| 4.1.1 | Instrument Management | $35 | $60 | $127 | $82 | $304 |
| 4.1.2 | Systems Engineering | $0 | $0 | $0 | $0 | $0 |
| 4.1.3 | Science | $213 | $375 | $724 | $649 | $1,962 |
| 4.1.4 | Tracker | $0 | $0 | $0 | $0 | $0 |
| 4.1.5 | Calorimeter | $489 | $835 | $910 | $328 | $2,562 |
| 4.1.6 | Anticoindence Detector | $551 | $935 | $1,198 | $311 | $2,994 |
| 4.1.7 | Data Acquisition System | $599 | $1,381 | $2,099 | $477 | $4,555 |
| 4.1.8 | Grid | $182 | $301 | $269 | $47 | $800 |
| 4.1.9 | Integration and Testing | $0 | $195 | $743 | $102 | $1,039 |
| 4.1.10 | Performance Assurance | $0 | $0 | $0 | $0 | $0 |
| 4.1.11 | Instrument Operations Center | $33 | $85 | $425 | $315 | $858 |
| 4.1.12 | Education & Outreach | $38 | $73 | $263 | $146 | $520 |

**Table 2.4.8(b)** Total Cost, with Full-Cost Accounting for Implementation Phase (RY K$)

| | **Total Cost for Time Phase** | | | **RY K$** | | |
|---|---|---|---|---|---|---|
| **WBS** | **Instrument Subsystem** | **FY 2002** | **FY 2003** | **FY 2004** | **FY 2005** | **Total** |
| | Total Cost for Time Phase | $39,719 | $40,301 | $33,902 | $17,280 | $131,202 |

## 2.5 OPERATIONS AND DATA ANALYSIS COST ESTIMATE

### *2.5.1 Operations Phase Time-Phased Cost Summary*

#### 2.5.1.1 Total Operations Phase Cost

Table 2.5.1 summarizes costs for the instrument by subsystem for the Operations and Data Analysis Phase. Costs shown are for all domestic team institutions. Note that scientific data analysis has been budgeted under subsystem WBS elements, along with subsystem support for the instrument. For instance, funding shown for the Calorimeter covers not just the Calorimeter subsystem operations support, but also data analysis of Calorimeter and instrument data by scientists affiliated with the Calorimeter subsystem.

Foreign institution funding is not shown for this phase. However, all foreign institutions will support their co-Investigators during this phase.

#### 2.5.1.2 Cost Breakdowns

Tables 2.5.2 and 2.5.3 show cost breakdowns for the Operations Phase in FY99$ and RY$ respectively. Level-of-effort budgeting has produced the budgets shown. Detailed costing by cost elements will be part of the Formulation Phase effort , so divisions showing labor, materials and equipment, and subcontracts have yet to be determined. As with the Formulation and Implementation Phases, a significant contribution in operations funds from the DOE will ensure that the Instrument Operations Center is well-staffed, and that the instrument is well-supported.

#### 2.5.1.3 Full Cost Accounting for NASA Institutions

Tables 2.5.4 and 2.5.5 show cost breakdowns for the Operations Phase, with NASA full-cost accounting, in FY99$ and RY$, respectively,

**Table 2.5.1** Total Operations Phase Costs by WBS Element (FY99 K$)

| WBS | Subsystem | FY06 | FY07 | FY08 | FY09 | FY10 | Total |
|---|---|---:|---:|---:|---:|---:|---:|
| 4.1 | **Instrument Total** | **$10,606** | **$8,367** | **$7,651** | **$7,412** | **$7,256** | **$41,291** |
| 4.1.1 | Instrument Management | $344 | $317 | $292 | $276 | $272 | $1,500 |
| 4.1.2 | Systems Engineering | $130 | $130 | $130 | $130 | $130 | $650 |
| 4.1.3 | Science | $2,424 | $2,469 | $2,432 | $2,364 | $2,351 | $12,040 |
| 4.1.4 | Tracker | $378 | $378 | $338 | $338 | $338 | $1,770 |
| 4.1.5 | Calorimeter | $744 | $600 | $500 | $420 | $345 | $2,609 |
| 4.1.6 | Anticoindence Detector | $175 | $145 | $91 | $69 | $61 | $542 |
| 4.1.7 | Data Acquisition System | $153 | $152 | $123 | $118 | $100 | $646 |
| 4.1.8 | Grid | $0 | $0 | $0 | $0 | $0 | $0 |
| 4.1.9 | Integration and Testing | $0 | $0 | $0 | $0 | $0 | $0 |
| 4.1.10 | Performance Assurance | $50 | $50 | $40 | $40 | $40 | $220 |
| 4.1.11 | Instrument Operations Center | $6,159 | $4,075 | $3,660 | $3,616 | $3,579 | $21,089 |
| 4.1.12 | Education & Outreach | $50 | $50 | $45 | $40 | $40 | $225 |

**Table 2.5.2** Operations Phase Costs by Institution (FY99 K$)

| WBS | Subsystem | FY06 | FY07 | FY08 | FY09 | FY10 | Total |
|---|---|---:|---:|---:|---:|---:|---:|
| | **NASA Funds** | | | | | | |
| 4.1.1 | Instrument Management | $0 | $0 | $0 | $0 | $0 | $0 |
| 4.1.2 | Systems Engineering | $0 | $0 | $0 | $0 | $0 | $0 |
| 4.1.3 | Science | $596 | $541 | $404 | $336 | $323 | $2,200 |
| 4.1.4 | Tracker | $0 | $0 | $0 | $0 | $0 | $0 |
| 4.1.5 | Calorimeter | $744 | $600 | $500 | $420 | $345 | $2,609 |
| 4.1.6 | Anticoindence Detector | $175 | $145 | $91 | $69 | $61 | $542 |
| 4.1.7 | Data Acquisition System | $28 | $27 | $23 | $18 | $0 | $96 |
| 4.1.8 | Grid | $0 | $0 | $0 | $0 | $0 | $0 |
| 4.1.9 | Integration and Testing | $0 | $0 | $0 | $0 | $0 | $0 |
| 4.1.10 | Performance Assurance | $0 | $0 | $0 | $0 | $0 | $0 |
| 4.1.11 | Instrument Operations Center | $259 | $175 | $160 | $116 | $79 | $789 |
| 4.1.12 | Education & Outreach | $50 | $50 | $45 | $40 | $40 | $225 |
| **Total** | **NASA Contract Costs** | **$1,852** | **$1,539** | **$1,223** | **$999** | **$848** | **$6,461** |
| | | | | | | | |
| **Total** | **Contributions** | **$8,614** | **$6,714** | **$6,314** | **$6,314** | **$6,314** | **$34,268** |
| | **SU-SLAC** | **$8,040** | **$6,140** | **$5,740** | **$5,740** | **$5,740** | **$31,400** |
| 4.1.1 | Instrument Management | $125 | $125 | $100 | $100 | $100 | $550 |
| 4.1.2 | Systems Engineering | $130 | $130 | $130 | $130 | $130 | $650 |
| 4.1.3 | Science | $1,500 | $1,600 | $1,700 | $1,700 | $1,700 | $8,200 |
| 4.1.4 | Tracker | $210 | $210 | $170 | $170 | $170 | $930 |
| 4.1.7 | Data Acquisition System | $125 | $125 | $100 | $100 | $100 | $550 |
| 4.1.8 | Grid | $0 | $0 | $0 | $0 | $0 | $0 |
| 4.1.9 | Integration and Testing | $0 | $0 | $0 | $0 | $0 | $0 |
| 4.1.10 | Performance Assurance | $50 | $50 | $40 | $40 | $40 | $220 |
| 4.1.11 | Instrument Operations Center | $5,900 | $3,900 | $3,500 | $3,500 | $3,500 | $20,300 |
| | **SU-Cost Share** | **$78** | **$78** | **$78** | **$78** | **$78** | **$388** |
| 4.1.1 | Instrument Management | $78 | $78 | $78 | $78 | $78 | $388 |
| | **UCSC** | $431 | $431 | $431 | $431 | $431 | $2,155 |
| 4.1.3 | Science | $263 | $263 | $263 | $263 | $263 | $1,315 |
| 4.1.4 | Tracker | $168 | $168 | $168 | $168 | $168 | $840 |
| | **UW** | **$65** | **$65** | **$65** | **$65** | **$65** | **$325** |
| 4.1.3 | Science | $65 | $65 | $65 | $65 | $65 | $325 |
| | | | | | | | |
| | **Total Cost for Time Phase** | **$10,465** | **$8,252** | **$7,537** | **$7,313** | **$7,162** | **$40,729** |

## Table 2.5.3 Operations Phase Costs by Institution (RY K$)

| WBS | Subsystem | FY06 | FY07 | FY08 | FY09 | FY10 | Total |
|---|---|---|---|---|---|---|---|
| | **NASA Funds** | | | | | | |
| 4.1.1 | Instrument Management | $0 | $0 | $0 | $0 | $0 | $0 |
| 4.1.2 | Systems Engineering | $0 | $0 | $0 | $0 | $0 | $0 |
| 4.1.3 | Science | $780 | $736 | $571 | $494 | $493 | $3,073 |
| 4.1.4 | Tracker | $0 | $0 | $0 | $0 | $0 | $0 |
| 4.1.5 | Calorimeter | $974 | $816 | $707 | $617 | $526 | $3,640 |
| 4.1.6 | Anticoindence Detector | $230 | $197 | $129 | $101 | $94 | $750 |
| 4.1.7 | Data Acquisition System | $36 | $37 | $33 | $27 | $0 | $133 |
| 4.1.8 | Grid | $0 | $0 | $0 | $0 | $0 | $0 |
| 4.1.9 | Integration and Testing | $0 | $0 | $0 | $0 | $0 | $0 |
| 4.1.10 | Performance Assurance | $0 | $0 | $0 | $0 | $0 | $0 |
| 4.1.11 | Instrument Operations Center | $339 | $238 | $227 | $171 | $120 | $1,095 |
| 4.1.12 | Education & Outreach | $65 | $68 | $64 | $59 | $61 | $317 |
| **Total** | **NASA Contract Costs** | **$2,424** | **$2,093** | **$1,729** | **$1,467** | **$1,294** | **$9,007** |
| | | | | | | | |
| **Total** | **Contributions** | **$11,276** | **$9,132** | **$8,923** | **$9,271** | **$9,632** | **$48,234** |
| | **SU-SLAC** | **$10,525** | **$8,352** | **$8,112** | **$8,428** | **$8,757** | **$44,175** |
| 4.1.1 | Instrument Management | $164 | $170 | $141 | $147 | $153 | $774 |
| 4.1.2 | Systems Engineering | $170 | $177 | $184 | $191 | $198 | $920 |
| 4.1.3 | Science | $1,964 | $2,176 | $2,403 | $2,496 | $2,594 | $11,632 |
| 4.1.4 | Tracker | $275 | $286 | $240 | $250 | $259 | $1,310 |
| 4.1.7 | Data Acquisition System | $164 | $170 | $141 | $147 | $153 | $774 |
| 4.1.8 | Grid | $0 | $0 | $0 | $0 | $0 | $0 |
| 4.1.9 | Integration and Testing | $0 | $0 | $0 | $0 | $0 | $0 |
| 4.1.10 | Performance Assurance | $65 | $68 | $57 | $59 | $61 | $310 |
| 4.1.11 | Instrument Operations Center | $7,724 | $5,305 | $4,946 | $5,139 | $5,340 | $28,454 |
| | **SU-Cost Share** | **$102** | **$106** | **$110** | **$114** | **$118** | **$549** |
| 4.1.1 | Instrument Management | $102 | $106 | $110 | $114 | $118 | $549 |
| | **UCSC** | **$564** | **$586** | **$609** | **$633** | **$658** | **$3,050** |
| 4.1.3 | Science | $344 | $358 | $372 | $386 | $401 | $1,861 |
| 4.1.4 | Tracker | $220 | $229 | $237 | $247 | $256 | $1,189 |
| | **UW** | **$85** | **$88** | **$92** | **$95** | **$99** | **$460** |
| 4.1.3 | Science | $85 | $88 | $92 | $95 | $99 | $460 |
| | | | | | | | |
| | **Total Cost for Time Phase** | **$13,701** | **$11,225** | **$10,652** | **$10,738** | **$10,926** | **$57,241** |

**Table 2.5.4** Operations Phase Costs, with Full-Cost Accounting by Institution (FY99 K$)

| WBS | Subsystem | FY06 | FY07 | FY08 | FY09 | FY10 | Total |
|---|---|---|---|---|---|---|---|
| | **NASA Funds** | | | | | | |
| 4.1.1 | Instrument Management | $0 | $0 | $0 | $0 | $0 | $0 |
| 4.1.2 | Systems Engineering | $0 | $0 | $0 | $0 | $0 | $0 |
| 4.1.3 | Science | $865 | $798 | $637 | $557 | $544 | $3,401 |
| 4.1.4 | Tracker | $0 | $0 | $0 | $0 | $0 | $0 |
| 4.1.5 | Calorimeter | $744 | $600 | $500 | $420 | $345 | $2,609 |
| 4.1.6 | Anticoindence Detector | $303 | $225 | $160 | $126 | $107 | $920 |
| 4.1.7 | Data Acquisition System | $28 | $27 | $23 | $18 | $0 | $96 |
| 4.1.8 | Grid | $0 | $0 | $0 | $0 | $0 | $0 |
| 4.1.9 | Integration and Testing | $0 | $0 | $0 | $0 | $0 | $0 |
| 4.1.10 | Performance Assurance | $0 | $0 | $0 | $0 | $0 | $0 |
| 4.1.11 | Instrument Operations Center | $259 | $175 | $160 | $116 | $79 | $789 |
| 4.1.12 | Education & Outreach | $50 | $50 | $45 | $40 | $40 | $225 |
| **Total** | **NASA Contract Costs** | **$2,248** | **$1,876** | **$1,525** | **$1,277** | **$1,114** | **$8,040** |
| | | | | | | | |
| **Total** | **Contributions** | **$8,614** | **$6,714** | **$6,314** | **$6,314** | **$6,314** | **$34,268** |
| | **SU-SLAC** | **$8,040** | **$6,140** | **$5,740** | **$5,740** | **$5,740** | **$31,400** |
| 4.1.1 | Instrument Management | $125 | $125 | $100 | $100 | $100 | $550 |
| 4.1.2 | Systems Engineering | $130 | $130 | $130 | $130 | $130 | $650 |
| 4.1.3 | Science | $1,500 | $1,600 | $1,700 | $1,700 | $1,700 | $8,200 |
| 4.1.4 | Tracker | $210 | $210 | $170 | $170 | $170 | $930 |
| 4.1.7 | Data Acquisition System | $125 | $125 | $100 | $100 | $100 | $550 |
| 4.1.8 | Grid | $0 | $0 | $0 | $0 | $0 | $0 |
| 4.1.9 | Integration and Testing | $0 | $0 | $0 | $0 | $0 | $0 |
| 4.1.10 | Performance Assurance | $50 | $50 | $40 | $40 | $40 | $220 |
| 4.1.11 | Instrument Operations Center | $5,900 | $3,900 | $3,500 | $3,500 | $3,500 | $20,300 |
| | **SU-Cost Share** | **$78** | **$78** | **$78** | **$78** | **$78** | **$388** |
| 4.1.1 | Instrument Management | $78 | $78 | $78 | $78 | $78 | $388 |
| | **UCSC** | **$431** | **$431** | **$431** | **$431** | **$431** | **$2,155** |
| 4.1.3 | Science | $263 | $263 | $263 | $263 | $263 | $1,315 |
| 4.1.4 | Tracker | $168 | $168 | $168 | $168 | $168 | $840 |
| | **UW** | **$65** | **$65** | **$65** | **$65** | **$65** | **$325** |
| **4.1.3** | **Science** | $65 | $65 | $65 | $65 | $65 | $325 |
| | | | | | | | |
| | **Total Cost for Time Phase** | **$10,862** | **$8,590** | **$7,838** | **$7,591** | **$7,428** | **$42,309** |

## **Table 2.5.5** Operations Phase Costs, with Full-Cost Accounting by Institution (RY K$)

| WBS | Subsystem | FY06 | FY07 | FY08 | FY09 | FY10 | Total |
|---|---|---|---|---|---|---|---|
| | **NASA Funds** | | | | | | |
| 4.1.1 | Instrument Management | $0 | $0 | $0 | $0 | $0 | $0 |
| 4.1.2 | Systems Engineering | $0 | $0 | $0 | $0 | $0 | $0 |
| 4.1.3 | Science | $1,132 | $1,086 | $900 | $818 | $830 | $4,766 |
| 4.1.4 | Tracker | $0 | $0 | $0 | $0 | $0 | $0 |
| 4.1.5 | Calorimeter | $974 | $816 | $707 | $617 | $526 | $3,640 |
| 4.1.6 | Anticoindence Detector | $396 | $307 | $226 | $185 | $163 | $1,276 |
| 4.1.7 | Data Acquisition System | $36 | $37 | $33 | $27 | $0 | $133 |
| 4.1.8 | Grid | $0 | $0 | $0 | $0 | $0 | $0 |
| 4.1.9 | Integration and Testing | $0 | $0 | $0 | $0 | $0 | $0 |
| 4.1.10 | Performance Assurance | $0 | $0 | $0 | $0 | $0 | $0 |
| 4.1.11 | Instrument Operations Center | $339 | $238 | $227 | $171 | $120 | $1,095 |
| 4.1.12 | Education & Outreach | $65 | $68 | $64 | $59 | $61 | $317 |
| **Total** | **NASA Contract Costs** | **$2,943** | **$2,552** | **$2,155** | **$1,876** | **$1,700** | **$11,225** |
| | | | | | | | |
| **Total** | **Contributions** | **$11,276** | **$9,132** | **$8,923** | **$9,271** | **$9,632** | **$48,234** |
| | **SU-SLAC** | **$10,525** | **$8,352** | **$8,112** | **$8,428** | **$8,757** | **$44,175** |
| 4.1.1 | Instrument Management | $164 | $170 | $141 | $147 | $153 | $774 |
| 4.1.2 | Systems Engineering | $170 | $177 | $184 | $191 | $198 | $920 |
| 4.1.3 | Science | $1,964 | $2,176 | $2,403 | $2,496 | $2,594 | $11,632 |
| 4.1.4 | Tracker | $275 | $286 | $240 | $250 | $259 | $1,310 |
| 4.1.7 | Data Acquisition System | $164 | $170 | $141 | $147 | $153 | $774 |
| 4.1.8 | Grid | $0 | $0 | $0 | $0 | $0 | $0 |
| 4.1.9 | Integration and Testing | $0 | $0 | $0 | $0 | $0 | $0 |
| 4.1.10 | Performance Assurance | $65 | $68 | $57 | $59 | $61 | $310 |
| 4.1.11 | Instrument Operations Center | $7,724 | $5,305 | $4,946 | $5,139 | $5,340 | $28,454 |
| | **SU-Cost Share** | **$102** | **$106** | **$110** | **$114** | **$118** | **$549** |
| 4.1.1 | Instrument Management | $102 | $106 | $110 | $114 | $118 | $549 |
| | **UCSC** | **$564** | **$586** | **$609** | **$633** | **$658** | **$3,050** |
| 4.1.3 | Science | $344 | $358 | $372 | $386 | $401 | $1,861 |
| 4.1.4 | Tracker | $220 | $229 | $237 | $247 | $256 | $1,189 |
| | **UW** | **$85** | **$88** | **$92** | **$95** | **$99** | **$460** |
| 4.1.3 | Science | $85 | $88 | $92 | $95 | $99 | $460 |
| | | | | | | | |
| | **Total Cost for Time Phase** | **$14,219** | **$11,684** | **$11,077** | **$11,146** | **$11,332** | **$59,459** |

# 2.6 TOTAL COST ESTIMATE

## *2.6.1 Total Cost Funding Profile*

### 2.6.1.1 Total Cost Funding Profile by Institution

Total instrument costs are shown in Table 2.6.1. This is divided by Phase, and by institution. Totals for NASA contract costs are shown at the top of the table, for all institutions receiving NASA funds. All other contributions from domestic and foreign institutions are shown at the bottom of the table, also divided by Phase. Table 2.6.2 is organized identically, but shows all costs in real year dollars.

### 2.6.1.2 Full Cost Accounting for NASA Institutions

Table 2.6.3 and 2.6.4 show total costs for the project, including full-cost accounting for NASA institutions, in FY99$ and RY$, respectively.

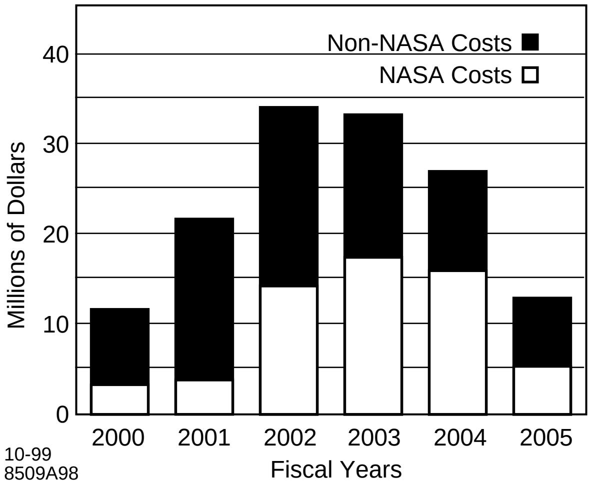
### 2.6.1.3 Total Cost Funding Analysis

The above tables reflect the strong involvement of the non-NASA team institutions. The support of other funding agencies, both domestic and international, provide for over half of the total funding for the instrument, in all phases of the project. Also significant to the success of the project, the non-NASA contributions serve to mitigate the schedule risk introduced by the challenging NASA profile.

Figure 2.6.1 shows the effect of these outside contributions. The graph shows that the funding ramps up much more quickly for the total project than for NASA funds, and that the peak of the total funding profile occurs one year earlier than the NASA profile. The early ramp-up of other funding sources will help us continue our aggressive development effort, and establish a strong Management and System Engineering infrastructure for the project.

The funding profile will ensure a quick transition from I-PDR in August, 2001, to fabrication and testing of the flight-configured engineering model, prior to the I-CDR in August, 2002. This profile allows the early ordering of the long-lead silicon detectors for the Tracker subsystem and the transition in FY 2003 from the I-CDR to flight production of all instrument subsystems.

**Figure** 2.6.1 Total Cost (FY99$)



Another feature shown in the total cost tables is the continued support of the DOE through the Operations Phase. DOE and other contributions exceed the NASA funding, allowing for adequate staffing of the IOC and timely delivery of data products. Finally, during Operations Phase, foreign Co-Investigators will be supported by their institutions. These contributed costs are not shown here.

### 2.6.1.4 Total Cost Tables

## *2.6.2 Total Cost Funding Profile by WBS*

### 2.6.2.1 Funding Profile by WBS

Table 2.6.5 shows total funding for the Formulation and Implementation Phases of the instrument project, divided by WBS subsystem element, then further by institution. Costs shown are for all team institutions, and include reserves. As is evident in the other cost tables, NASA funds will be used only at four institutions: SU-HEPL, GSFC, NRL, and SSU. All other institutions are fully funded from other sources.

Notable in Table 2.6.5 is that most of the Instrument Project Office (IPO), all of the Tracker, and a significant portion of almost all other subsystems show strong involvement of other team institutions. This serves three purposes. First, the strengths of the personnel and facilities of the team institutions are being maximally utilized in the project. Second, the work is being spread out among multiple institutions, reducing the schedule risk introduced by a single under-performing institution. Finally, both the funding and other resources brought to the project by team institutions can be used to mitigate potential funding problems with any given institution.

### 2.6.2.2 Funding Profile by Cost Type

The Funding Profile by Cost Type follows in Table 2.6.6.

**Table 2.6.1** Summary of Total Cost by Phase and Institution (FY99 K$)

| Phase/Institution | FY00 | FY01 | FY02 | FY03 | FY04 | FY05 | FY06 | FY07 | FY08 | FY09 | FY10 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Formulation** | **$3,452** | **$3,596** | | | | | | | | | | **$7,048** |
| SU-HEPL | $783 | $933 | | | | | | | | | | $1,716 |
| GSFC | $843 | $1,004 | | | | | | | | | | $1,847 |
| NRL | $1,791 | $1,575 | | | | | | | | | | $3,365 |
| SSU | $36 | $84 | | | | | | | | | | $120 |
| **Implementation** | | | **$13,789** | **$17,372** | **$15,573** | **$5,187** | | | | | | **$51,922** |
| SU-HEPL | | | $4,761 | $7,624 | $7,659 | $2,692 | | | | | | $22,736 |
| GSFC | | | $3,666 | $3,988 | $2,966 | $846 | | | | | | $11,466 |
| NRL | | | $5,099 | $5,441 | $4,297 | $1,302 | | | | | | $16,139 |
| SSU | | | $263 | $319 | $651 | $347 | | | | | | $1,580 |
| **Operations** | | | | | | | **$1,993** | **$1,653** | **$1,337** | **$1,098** | **$942** | **$7,023** |
| SU-HEPL | | | | | | | $684 | $573 | $485 | $395 | $322 | $2,459 |
| GSFC | | | | | | | $515 | $430 | $307 | $243 | $235 | $1,730 |
| NRL | | | | | | | $744 | $600 | $500 | $420 | $345 | $2,609 |
| SSU | | | | | | | $50 | $50 | $45 | $40 | $40 | $225 |
| **Cost to NASA** | **$3,452** | **$3,596** | **$13,789** | **$17,372** | **$15,573** | **$5,187** | **$1,993** | **$1,653** | **$1,337** | **$1,098** | **$942** | **$65,993** |
| | | | | | | | | | | | | |
| **Formulation** | **$8,156** | **$18,360** | | | | | | | | | | **$26,516** |
| SU-SLAC | $3,671 | $7,348 | | | | | | | | | | $11,019 |
| SU-Cost Share | $39 | $78 | | | | | | | | | | $116 |
| UCSC | $233 | $467 | | | | | | | | | | $700 |
| CNES/CEA/IN2P3 | $2,470 | $3,760 | | | | | | | | | | $6,230 |
| INFN/ASI | $570 | $3,288 | | | | | | | | | | $3,858 |
| JGC | $740 | $1,655 | | | | | | | | | | $2,395 |
| Sweden | $400 | $1,700 | | | | | | | | | | $2,100 |
| UW | $32 | $65 | | | | | | | | | | $97 |
| **Implementation** | | | **$20,476** | **$15,945** | **$11,027** | **$7,659** | | | | | | **$55,107** |
| SU-SLAC | | | $6,692 | $8,607 | $5,826 | $3,244 | | | | | | $24,370 |
| SU-Cost Share | | | $78 | $78 | $78 | $78 | | | | | | $311 |
| UCSC | | | $468 | $468 | $468 | $432 | | | | | | $1,835 |
| CNES/CEA/IN2P3 | | | $4,810 | $3,440 | $1,890 | $1,500 | | | | | | $11,640 |
| INFN/ASI | | | $3,548 | $1,994 | $1,570 | $1,140 | | | | | | $8,252 |
| JGC | | | $2,916 | $394 | $280 | $0 | | | | | | $3,590 |
| Sweden | | | $1,900 | $900 | $850 | $1,200 | | | | | | $4,850 |
| UW | | | $65 | $65 | $65 | $65 | | | | | | $260 |
| **Operations** | | | | | | | **$8,614** | **$6,714** | **$6,314** | **$6,314** | **$6,314** | **$34,268** |
| SU-SLAC | | | | | | | $8,040 | $6,140 | $5,740 | $5,740 | $5,740 | $31,400 |
| SU-Cost Share | | | | | | | $78 | $78 | $78 | $78 | $78 | $388 |
| UCSC | | | | | | | $431 | $431 | $431 | $431 | $431 | $2,155 |
| CNES/CEA/IN2P3 | | | | | | | $0 | $0 | $0 | $0 | $0 | $0 |
| INFN/ASI | | | | | | | $0 | $0 | $0 | $0 | $0 | $0 |
| JGC | | | | | | | $0 | $0 | $0 | $0 | $0 | $0 |
| Sweden | | | | | | | $0 | $0 | $0 | $0 | $0 | $0 |
| UW | | | | | | | $65 | $65 | $65 | $65 | $65 | $325 |
| **Contributed Costs** | **$8,156** | **$18,360** | **$20,476** | **$15,945** | **$11,027** | **$7,659** | **$8,614** | **$6,714** | **$6,314** | **$6,314** | **$6,314** | **$115,891** |
| **Grand Total Costs** | **$11,608** | **$21,956** | **$34,266** | **$33,318** | **$26,600** | **$12,846** | **$10,606** | **$8,367** | **$7,651** | **$7,412** | **$7,256** | **$181,884** |

**Table 2.6.2** Summary of Total Cost by Phase and Institution (RY K$)

| Phase/Institution | FY00 | FY01 | FY02 | FY03 | FY04 | FY05 | FY06 | FY07 | FY08 | FY09 | FY10 | Total |
|---|---:|---:|---:|---:|---:|---:|---:|---:|---:|---:|---:|---:|
| **Formulation** | **$3,594** | **$3,891** | | | | | | | | | | **$7,485** |
| SU-HEPL | $815 | $1,010 | | | | | | | | | | $1,825 |
| GSFC | $877 | $1,086 | | | | | | | | | | $1,963 |
| NRL | $1,864 | $1,704 | | | | | | | | | | $3,568 |
| SSU | $38 | $91 | | | | | | | | | | $129 |
| **Implementation** | | | **$15,499** | **$20,291** | **$18,890** | **$6,536** | | | | | | **$61,216** |
| SU-HEPL | | | $5,352 | $8,905 | $9,290 | $3,392 | | | | | | $26,939 |
| GSFC | | | $4,120 | $4,658 | $3,597 | $1,066 | | | | | | $13,442 |
| NRL | | | $5,731 | $6,355 | $5,213 | $1,641 | | | | | | $18,940 |
| SSU | | | $296 | $373 | $790 | $437 | | | | | | $1,895 |
| **Operations** | | | | | | | **$2,609** | **$2,248** | **$1,890** | **$1,612** | **$1,437** | **$9,797** |
| SU-HEPL | | | | | | | $895 | $779 | $686 | $580 | $491 | $3,432 |
| GSFC | | | | | | | $674 | $585 | $434 | $357 | $359 | $2,408 |
| NRL | | | | | | | $974 | $816 | $707 | $617 | $526 | $3,640 |
| SSU | | | | | | | $65 | $68 | $64 | $59 | $61 | $317 |
| **Cost to NASA** | $3,594 | $3,891 | $15,499 | $20,291 | $18,890 | $6,536 | $2,609 | $2,248 | $1,890 | $1,612 | $1,437 | $78,497 |
| | | | | | | | | | | | | |
| **Formulation** | **$8,490** | **$19,865** | | | | | | | | | | **$28,356** |
| SU-SLAC | $3,822 | $7,950 | | | | | | | | | | $11,772 |
| SU-Cost Share | $40 | $84 | | | | | | | | | | $124 |
| UCSC | $243 | $505 | | | | | | | | | | $748 |
| CNES/CEA/IN2P3 | $2,571 | $4,068 | | | | | | | | | | $6,640 |
| INFN/ASI | $593 | $3,558 | | | | | | | | | | $4,151 |
| JGC | $770 | $1,790 | | | | | | | | | | $2,561 |
| Sweden | $416 | $1,839 | | | | | | | | | | $2,256 |
| UW | $34 | $70 | | | | | | | | | | $104 |
| **Implementation** | | | **$23,015** | **$18,624** | **$13,376** | **$9,650** | | | | | | **$64,665** |
| **SU-SLAC** | | | $7,522 | $10,053 | $7,067 | $4,088 | | | | | | $28,730 |
| SU-Cost Share | | | $87 | $91 | $94 | $98 | | | | | | $370 |
| UCSC | | | $526 | $546 | $568 | $544 | | | | | | $2,184 |
| CNES/CEA/IN2P3 | | | $5,406 | $4,018 | $2,293 | $1,890 | | | | | | $13,607 |
| INFN/ASI | | | $3,988 | $2,330 | $1,904 | $1,436 | | | | | | $9,658 |
| JGC | | | $3,278 | $460 | $340 | $0 | | | | | | $4,077 |
| Sweden | | | $2,136 | $1,051 | $1,031 | $1,512 | | | | | | $5,730 |
| UW | | | $73 | $76 | $79 | $82 | | | | | | $309 |
| **Operations** | | | | | | | **$11,276** | **$9,132** | **$8,923** | **$9,271** | **$9,632** | **$48,234** |
| SU-SLAC | | | | | | | $10,525 | $8,352 | $8,112 | $8,428 | $8,757 | $44,175 |
| SU-Cost Share | | | | | | | $102 | $106 | $110 | $114 | $118 | $549 |
| UCSC | | | | | | | $564 | $586 | $609 | $633 | $658 | $3,050 |
| CNES/CEA/IN2P3 | | | | | | | $0 | $0 | $0 | $0 | $0 | $0 |
| INFN/ASI | | | | | | | $0 | $0 | $0 | $0 | $0 | $0 |
| JGC | | | | | | | $0 | $0 | $0 | $0 | $0 | $0 |
| Sweden | | | | | | | $0 | $0 | $0 | $0 | $0 | $0 |
| UW | | | | | | | $85 | $88 | $92 | $95 | $99 | $460 |
| **Contributed Costs** | **$8,490** | **$19,865** | **$23,015** | **$18,624** | **$13,376** | **$9,650** | **$11,276** | **$9,132** | **$8,923** | **$9,271** | **$9,632** | **$141,254** |
| **Grand Total Costs** | **$12,084** | **$23,756** | **$38,514** | **$38,915** | **$32,266** | **$16,186** | **$13,885** | **$11,380** | **$10,813** | **$10,883** | **$11,069** | **$219,752** |

**Table 2.6.3** Summary of Total Cost by Phase with Full-Cost Accounting for NASA Institutions (FY99 K$)

| Phase/Institution | FY00 | FY01 | FY02 | FY03 | FY04 | FY05 | FY06 | FY07 | FY08 | FY09 | FY10 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Formulation** | **$3,918** | **$4,471** | | | | | | | | | | **$8,389** |
| SU-HEPL | $783 | $933 | | | | | | | | | | $1,716 |
| GSFC | $1,309 | $1,878 | | | | | | | | | | $3,187 |
| NRL | $1,791 | $1,575 | | | | | | | | | | $3,365 |
| SSU | $36 | $84 | | | | | | | | | | $120 |
| **Implementation** | | | **$14,861** | **$18,559** | **$16,715** | **$5,849** | | | | | | **$55,983** |
| SU-HEPL | | | $4,761 | $7,624 | $7,659 | $2,692 | | | | | | $22,736 |
| GSFC | | | $4,738 | $5,175 | $4,108 | $1,507 | | | | | | $15,527 |
| NRL | | | $5,099 | $5,441 | $4,297 | $1,302 | | | | | | $16,139 |
| SSU | | | $263 | $319 | $651 | $347 | | | | | | $1,580 |
| **Operations** | | | | | | | $2,389 | $1,991 | $1,639 | $1,376 | $1,208 | $8,602 |
| SU-HEPL | | | | | | | $684 | $573 | $485 | $395 | $322 | $2,459 |
| GSFC | | | | | | | $911 | $768 | $608 | $521 | $501 | $3,309 |
| NRL | | | | | | | $744 | $600 | $500 | $420 | $345 | $2,609 |
| SSU | | | | | | | $50 | $50 | $45 | $40 | $40 | $225 |
| **Cost to NASA** | **$3,918** | **$4,471** | **$14,861** | **$18,559** | **$16,715** | **$5,849** | **$2,389** | **$1,991** | **$1,639** | **$1,376** | **$1,208** | **$72,975** |
| | | | | | | | | | | | | |
| **Formulation** | **$8,156** | **$18,360** | | | | | | | | | | **$26,516** |
| SU-SLAC | $3,671 | $7,348 | | | | | | | | | | $11,019 |
| SU-Cost Share | $39 | $78 | | | | | | | | | | $116 |
| UCSC | $233 | $467 | | | | | | | | | | $700 |
| CNES/CEA/IN2P3 | $2,470 | $3,760 | | | | | | | | | | $6,230 |
| INFN/ASI | $570 | $3,288 | | | | | | | | | | $3,858 |
| JGC | $740 | $1,655 | | | | | | | | | | $2,395 |
| Sweden | $400 | $1,700 | | | | | | | | | | $2,100 |
| UW | $32 | $65 | | | | | | | | | | $97 |
| **Implementation** | | | **$20,476** | **$15,945** | **$11,027** | **$7,659** | | | | | | **$55,107** |
| SU-SLAC | | | $6,692 | $8,607 | $5,826 | $3,244 | | | | | | $24,370 |
| SU-Cost Share | | | $78 | $78 | $78 | $78 | | | | | | $311 |
| UCSC | | | $468 | $468 | $468 | $432 | | | | | | $1,835 |
| CNES/CEA/IN2P3 | | | $4,810 | $3,440 | $1,890 | $1,500 | | | | | | $11,640 |
| INFN/ASI | | | $3,548 | $1,994 | $1,570 | $1,140 | | | | | | $8,252 |
| JGC | | | $2,916 | $394 | $280 | $0 | | | | | | $3,590 |
| Sweden | | | $1,900 | $900 | $850 | $1,200 | | | | | | $4,850 |
| UW | | | $65 | $65 | $65 | $65 | | | | | | $260 |
| **Operations** | | | | | | | **$8,614** | **$6,714** | **$6,314** | **$6,314** | **$6,314** | **$34,268** |
| SU-SLAC | | | | | | | $8,040 | $6,140 | $5,740 | $5,740 | $5,740 | $31,400 |
| SU-Cost Share | | | | | | | $78 | $78 | $78 | $78 | $78 | $388 |
| UCSC | | | | | | | $431 | $431 | $431 | $431 | $431 | $2,155 |
| CNES/CEA/IN2P3 | | | | | | | $0 | $0 | $0 | $0 | $0 | $0 |
| INFN/ASI | | | | | | | $0 | $0 | $0 | $0 | $0 | $0 |
| JGC | | | | | | | $0 | $0 | $0 | $0 | $0 | $0 |
| Sweden | | | | | | | $0 | $0 | $0 | $0 | $0 | $0 |
| UW | | | | | | | $65 | $65 | $65 | $65 | $65 | $325 |
| **Contributed Costs** | **$8,156** | **$18,360** | **$20,476** | **$15,945** | **$11,027** | **$7,659** | **$8,614** | **$6,714** | **$6,314** | **$6,314** | **$6,314** | **$115,891** |
| **Grand Total Costs** | **$12,074** | **$22,831** | **$35,337** | **$34,504** | **$27,742** | **$13,507** | **$11,003** | **$8,704** | **$7,952** | **$7,690** | **$7,522** | **$188,866** |

## **Table 2.6.4** Summary of Total Cost by Phase with Full-Cost Accounting for NASA Institutions (RY K$)

| **Phase/Institution** | **FY00** | **FY01** | **FY02** | **FY03** | **FY04** | **FY05** | **FY06** | **FY07** | **FY08** | **FY09** | **FY10** | **Total** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Formulation | **$4,079** | **$4,837** | | | | | | | | | | **$8,916** |
| SU-HEPL | $815 | $1,010 | | | | | | | | | | $1,825 |
| GSFC | $1,363 | $2,032 | | | | | | | | | | $3,395 |
| NRL | $1,864 | $1,704 | | | | | | | | | | $3,568 |
| SSU | $38 | $91 | | | | | | | | | | $129 |
| **Implementation** | | | **$16,704** | **$21,676** | **$20,275** | **$7,369** | | | | | | **$66,025** |
| SU-HEPL | | | $5,352 | $8,905 | $9,290 | $3,392 | | | | | | $26,939 |
| GSFC | | | $5,325 | $6,044 | $4,983 | $1,899 | | | | | | $18,251 |
| NRL | | | $5,731 | $6,355 | $5,213 | $1,641 | | | | | | $18,940 |
| SSU | | | $296 | $373 | $790 | $437 | | | | | | $1,895 |
| Operations | | | | | | | $3,128 | $2,708 | $2,316 | $2,021 | $1,843 | $12,015 |
| SU-HEPL | | | | | | | $895 | $779 | $686 | $580 | $491 | $3,432 |
| GSFC | | | | | | | $1,193 | $1,044 | $860 | $765 | $765 | $4,626 |
| NRL | | | | | | | $974 | $816 | $707 | $617 | $526 | $3,640 |
| SSU | | | | | | | $65 | $68 | $64 | $59 | $61 | $317 |
| **Cost to NASA** | **$4,079** | **$4,837** | **$16,704** | **$21,676** | **$20,275** | **$7,369** | **$3,128** | **$2,708** | **$2,316** | **$2,021** | **$1,843** | **$86,956** |
| | | | | | | | | | | | | |
| **Formulation** | **$8,490** | **$19,865** | | | | | | | | | | **$28,356** |
| SU-SLAC | $3,822 | $7,950 | | | | | | | | | | $11,772 |
| SU-Cost Share | $40 | $84 | | | | | | | | | | $124 |
| UCSC | $243 | $505 | | | | | | | | | | $748 |
| CNES/CEA/IN2P3 | $2,571 | $4,068 | | | | | | | | | | $6,640 |
| INFN/ASI | $593 | $3,558 | | | | | | | | | | $4,151 |
| JGC | $770 | $1,790 | | | | | | | | | | $2,561 |
| Sweden | $416 | $1,839 | | | | | | | | | | $2,256 |
| UW | $34 | $70 | | | | | | | | | | $104 |
| **Implementation** | | | **$23,015** | **$18,624** | **$13,376** | **$9,650** | | | | | | **$64,665** |
| SU-SLAC | | | $7,522 | $10,053 | $7,067 | $4,088 | | | | | | $28,730 |
| SU-Cost Share | | | $87 | $91 | $94 | $98 | | | | | | $370 |
| UCSC | | | $526 | $546 | $568 | $544 | | | | | | $2,184 |
| CNES/CEA/IN2P3 | | | $5,406 | $4,018 | $2,293 | $1,890 | | | | | | $13,607 |
| INFN/ASI | | | $3,988 | $2,330 | $1,904 | $1,436 | | | | | | $9,658 |
| JGC | | | $3,278 | $460 | $340 | $0 | | | | | | $4,077 |
| Sweden | | | $2,136 | $1,051 | $1,031 | $1,512 | | | | | | $5,730 |
| UW | | | $73 | $76 | $79 | $82 | | | | | | $309 |
| **Operations** | | | | | | | **$11,276** | **$9,132** | **$8,923** | **$9,271** | **$9,632** | **$48,234** |
| SU-SLAC | | | | | | | $10,525 | $8,352 | $8,112 | $8,428 | $8,757 | $44,175 |
| SU-Cost Share | | | | | | | $102 | $106 | $110 | $114 | $118 | $549 |
| UCSC | | | | | | | $564 | $586 | $609 | $633 | $658 | $3,050 |
| CNES/CEA/IN2P3 | | | | | | | $0 | $0 | $0 | $0 | $0 | $0 |
| INFN/ASI | | | | | | | $0 | $0 | $0 | $0 | $0 | $0 |
| JGC | | | | | | | $0 | $0 | $0 | $0 | $0 | $0 |
| Sweden | | | | | | | $0 | $0 | $0 | $0 | $0 | $0 |
| **UW** | | | | | | | $85 | $88 | $92 | $95 | $99 | $460 |
| **Contributed Costs** | **$8,490** | **$19,865** | **$23,015** | **$18,624** | **$13,376** | **$9,650** | **$11,276** | **$9,132** | **$8,923** | **$9,271** | **$9,632** | **$141,254** |
| **Grand Total Costs** | **$12,569** | **$24,703** | **$39,719** | **$40,301** | **$33,651** | **$17,019** | **$14,404** | **$11,839** | **$11,239** | **$11,291** | **$11,475** | **$228,210** |

**Table 2.6.5** Total Cost for Formulation and Implementation Phases, by WBS Element (FY99 K$)

| | | Formulation | | | | Implementation | | |
|---|---|---|---|---|---|---|---|---|
| **WBS** | **Instrument Subsystem** | **FY00** | **FY01** | **FY02** | **FY03** | **FY04** | **FY05** | **Total** |
| **4.1** | **Total Cost** | **$11,608** | **$21,956** | **$34,266** | **$33,318** | **$26,600** | **$12,846** | **$140,593** |
| **4.1.1** | **Instrument Management** | **$552** | **$1,270** | **$1,401** | **$1,469** | **$1,701** | **$1,191** | **$7,583** |
| | SU-HEPL | $64 | $114 | $241 | $261 | $315 | $195 | $1,190 |
| | SU-Cost Share | $39 | $78 | $78 | $78 | $78 | $78 | $427 |
| | SU-SLAC | $449 | $1,079 | $1,082 | $1,131 | $1,308 | $918 | $5,967 |
| **4.1.2** | **Systems Engineering** | **$524** | **$1,294** | **$1,499** | **$1,271** | **$1,444** | **$345** | **$6,376** |
| | SU-SLAC | $489 | $1,202 | $1,226 | $1,116 | $1,159 | $345 | $5,538 |
| | L-M | $34 | $92 | $273 | $155 | $285 | $0 | $839 |
| **4.1.3** | **Science** | **$611** | **$936** | **$1,656** | **$1,796** | **$1,888** | **$1,641** | **$8,527** |
| | SU-HEPL | $120 | $169 | $619 | $671 | $809 | $779 | $3,167 |
| | GSFC | $261 | $303 | $567 | $650 | $580 | $381 | $2,743 |
| | SU-SLAC | $65 | $135 | $141 | $147 | $171 | $153 | $813 |
| | UCSC | $132 | $263 | $263 | $263 | $263 | $263 | $1,448 |
| | **UW** | $32 | $65 | $65 | $65 | $65 | $65 | $357 |
| **4.1.4** | **Tracker** | **$3,234** | **$7,613** | **$8,755** | **$6,338** | **$3,240** | **$1,989** | **$31,168** |
| | SU-SLAC | $1,822 | $2,466 | $2,087 | $3,745 | $1,185 | $680 | $11,986 |
| | UCSC | $102 | $204 | $204 | $204 | $205 | $168 | $1,087 |
| | Hiroshima University | $740 | $1,655 | $2,916 | $394 | $280 | $0 | $5,984 |
| | INFN | $570 | $3,288 | $3,548 | $1,994 | $1,570 | $1,140 | $12,110 |
| **4.1.5** | **Calorimeter** | **$4,130** | **$6,560** | **$10,105** | **$7,998** | **$4,990** | **$3,481** | **$37,264** |
| | NRL | $1,260 | $1,100 | $3,395 | $3,658 | $2,250 | $781 | $12,444 |
| | CNES | $2,470 | $3,760 | $4,810 | $3,440 | $1,890 | $1,500 | $17,870 |
| | Sweden | $400 | $1,700 | $1,900 | $900 | $850 | $1,200 | $6,950 |
| **4.1.6** | **Anticoindence Detector** | **$529** | **$624** | **$3,077** | **$3,268** | **$2,272** | **$465** | **$10,234** |
| | GSFC | $529 | $624 | $3,077 | $3,268 | $2,272 | $465 | $10,234 |
| **4.1.7** | **Data Acquisition System** | **$1,357** | **$1,630** | **$4,711** | **$6,564** | **$5,547** | **$1,455** | **$21,263** |
| | SU-HEPL | $573 | $625 | $2,454 | $4,263 | $3,143 | $615 | $11,672 |
| | NRL | $531 | $475 | $1,704 | $1,783 | $2,047 | $521 | $7,061 |
| | **SU-SLAC** | $253 | $530 | $553 | $518 | $356 | $319 | $2,529 |
| **4.1.8** | **Grid** | **$251** | **$779** | **$1,240** | **$1,276** | **$617** | **$113** | **$4,274** |
| | SU-HEPL (L-M) | $0 | $0 | $1,218 | $1,205 | $503 | $113 | $3,038 |
| | SU-SLAC (L-M) | $251 | $771 | $0 | $0 | $0 | $0 | $1,022 |
| | GSFC | $0 | $8 | $21 | $71 | $113 | $0 | $214 |
| **4.1.9** | **Integration and Testing** | **$93** | **$446** | **$639** | **$1,712** | **$2,137** | **$511** | **$5,538** |
| | SU-SLAC | $41 | $377 | $639 | $858 | $300 | $269 | $2,484 |
| | SU-HEPL | $0 | $0 | $0 | $854 | $1,837 | $242 | $2,933 |
| | GSFC | $52 | $69 | $0 | $0 | $0 | $0 | $121 |
| **4.1.10** | **Performance Assurance** | **$135** | **$629** | **$622** | **$616** | **$642** | **$157** | **$2,802** |
| | SU-SLAC | $135 | $629 | $622 | $616 | $642 | $157 | $2,802 |
| **4.1.11** | **Instrument Operations Center** | **$156** | **$91** | **$299** | **$691** | **$1,471** | **$1,152** | **$3,862** |
| | SU-HEPL | $25 | $25 | $229 | $372 | $1,051 | $750 | $2,452 |
| | SU-SLAC | $131 | $66 | $70 | $320 | $420 | $403 | $1,410 |
| **4.1.12** | **Education & Public Outreach** | **$36** | **$84** | **$263** | **$319** | **$651** | **$347** | **$1,701** |
| | SSU | $36 | $84 | $263 | $319 | $651 | $347 | $1,701 |