433-PLAN-0013

GAMMA-RAY LARGE AREA SPACE TELESCOPE (GLAST)

MISSION DESCOPE PLAN

AUGUST 12, 2003

GODDARD SPACE FLIGHT CENTER
GREENBELT, MARYLAND

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ACRONYMS

ASI	Italian Space Agency
BATSE	Burst and Transient Source Experiment
CGRO	Compton Gamma-Ray Observatory
CRM	Continuous Risk Management
CsI	Cesium Iodide
DOE	Department of Energy
DPAF	Dual Payload Attach Fitting
EGRET	Energetic Gamma-Ray Experiment Telescope
E/PO	Education and Public Outreach
GLAST	Gamma-ray Large Area Space Telescope
GBM	GLAST Burst Monitor
GRB	Gamma Ray Burst
HQ	Headquarters
I&T	Integration and Test
IA	Implementing Arrangement
JOG	Joint Oversight Group
km	kilometer
kg	kilogram
LAT	Large Area Telescope
MPE	Mark Planck Institute for Extraterrestrial Physics
MSFC	Marshall Space Flight Center
NaI	Sodium Iodide
NASA	National Aeronautics and Space Administration
NRL	Naval Research Laboratories
NSS	NASA Safety Standard
OSS	Office of Space Science

ACRONYMS (cont.)

RSDO	Rapid Spacecraft Development Office
SRD	Science Requirements Document
SRR	Systems Requirement Review
SSC	Science Support Center
TBR	To Be Resolved
UCSC	University of California at Santa Cruz

1. INTRODUCTION

The Gamma-ray Large Area Space Telescope (GLAST) mission begins a new epoch in space-based physics investigation. The GLAST Project is part of the Structure and Evolution of the Universe Theme and NASA's Office of Space Science (OSS) Strategic Plan. Scheduled for launch in the year 2006 on a Delta rocket, GLAST is a next-generation, high-energy gamma-ray observatory designed for making observations of celestial gamma-ray sources in the energy range extending from 10 keV to 300 GeV. It follows in the footsteps of the Energetic Gamma-Ray Experiment Telescope (EGRET) flown on board the Compton Gamma-Ray Observatory (CGRO) that was operational between the years 1991 to 2000.

1.1 PURPOSE

The purpose of this Descope Plan is to describe the project management approach used by the GLAST project office to evaluate a potential descope decision, should it become necessary to consider one. The objective of this approach is to integrate the Continuous Risk Management activities and the Contingency Planning activities, in order to maximize the science capabilities within the resource constraints of the program.

1.2 SCOPE

This Descope Plan is a project-level document. It references the science and mission requirements that the project must satisfy, and the process by which the project will continuously monitor, assess and manage the risks that may lead to a potential descope of these requirements. These potential descopes, and their potential for cost savings, will change at different times in the life cycle of the project. The project maintains a list of descope options as a living document that is periodically updated with changing conditions. The current descope options are shown in an Appendix to this document without any implication that a decision has been made to implement these items.

2. REFERENCE DOCUMENTS

The following reference documents were used to develop this plan.

1. LAT Flight Investigation Proposal: An Astro-Particle Partnership Exploring the High-Energy Universe, November 1999. AO-99-03-OSS-008

2. GLAST Burst Monitor – A Proposal to NASA for a Burst Monitor (GBM) for the GLAST Mission, November 1999. AO-99-03-OSS-014

3. NASA Safety Standard, "Guidelines and Assessment Procedures for Limiting Orbital Debris," NSS 1740.14

4. GLAST Project Continuous Risk Management Plan, 433-PLAN-0002

3. APPLICABLE DOCUMENTS

The following applicable documents have precedence over this document

1. GLAST Program Plan, 433-PLAN-0008, October -2002, which includes the Level 1 Requirements.

2. GLAST Science Requirements Document (SRD), 433-SRD-0001, September 2000

3. GLAST Project Plan , November 26, 2002, 433-PLAN-0001

4. THE GLAST OBSERVATORY

The GLAST spacecraft carries two scientific instruments that together provide coverage of the necessary energy range (~10 keV to ~300 GeV) to achieve the scientific objectives of the mission.

- Large Area Telescope (LAT)
- GLAST Burst Monitor (GBM)

Since both instruments have international contributors, ramifications to the partners must be considered before implementing any descope options.

4.1 LAT INSTRUMENT

The LAT is a collaborative effort managed by NASA and DOE, with domestic partners that include Stanford University/Stanford Linear Accelerator Center, GSFC, the Naval Research Laboratory (NRL), the University of California at Santa Cruz (UCSC), and international partners from France, Italy, Japan, and Sweden. It is a next generation, high-energy gamma-ray instrument designed to image celestial gamma-ray sources in the energy range extending from 20 MeV to more than 300 GeV. The LAT follows in the footsteps of the CGRO–EGRET experiment, but has greater than four times the field of view and a sensitivity about 30 to 50 times that of EGRET.

4.2 GBM INSTRUMENT

The GBM, a collaborative international effort involving a major contribution from the Max Planck Institute for Extraterrestrial Physics (MPE) in Germany, NASA’s Marshall Space Flight Center (MSFC), and the University of Alabama in Huntsville, traces its origins to the CGRO Burst and Transient Source Experiment (BATSE). The GBM will provide gamma-ray burst detection and notification to the ground within seconds, as well as spectra of the burst.

4.3 SPACECRAFT

The spacecraft has been procured on a fixed price contract from the RSDO catalog suitably modified for GLAST unique requirements. The manufacturer is Spectrum Astro in Gilbert, Arizona, who is also providing the SWIFT spacecraft.

4.4. LAUNCH VEHICLE

The baseline mission will use a Delta 2920H launch vehicle to place the GLAST observatory into a circular low-Earth orbit with an altitude of 565 kilometers (km) and an inclination of 28.5° to the Equator. The launch site will be the eastern launch range at Cape Canaveral, Florida. Mission reliability design will support a 5-year mission requirement with a 10-year goal.

5. GLAST SCIENCE AND MISSION REQUIREMENTS

GLAST science and mission requirements are summarized in tabular form in the Science Requirements Document (SRD), 433--SRD-0001, one table for LAT, one for GBM, and one for the mission. For each requirement, three levels are specified: a nominal requirement, a goal that is higher than the nominal, and a minimum requirement that is lower than nominal. The system is being designed and built to meet the nominal requirements. The goals may be achieved if the normal design margins stack up in the favor of the project, but no significant additional funds are being spent to meet these goals. The minimum requirement levels must be met, unless a waiver is granted.

5.1 LEVEL I REQUIREMENTS

The level I requirements are the controlling requirements on the GLAST program, and are collected in Appendix A of the GLAST Program Plan. The definitions of the required and minimum levels are consistent with those in the SRD. The SRD includes all Level I requirements, as well as other key science requirements.

Before implementation of any option that violates a Level 1 requirement, a review process, coordinated with the other partners, would be required. Approval of NASA Headquarters is required for any descopes. NASA HQ will coordinate this decision with DOE and international partners. The GLAST Project will also consult with the GLAST science community through the Project Scientist and the Science Working Group (SWG).

6. INTEGRATED PROJECT MANAGEMENT PROCESS

The GLAST project is implementing a disciplined process of project management to integrate various aspects leading to a potential descope decision. The project intent is to meet the SRD requirements as far as practicable. The ongoing design and development effort will be monitored on a continuing basis to evaluate the status and to predict any possibility that the performance may fall short of the requirement. This will be formalized in a Continuous Risk Management process as described in the CRM Plan, 433-PLAN-0002.

In case the total expected cost for the mission approaches or exceeds the available contingency funds, an unacceptable condition will exist that must be resolved. A stepwise approach will be used to protect the Level I requirements and assure the scientific integrity of the mission.

> (1) The first step would be to consider the science impact of, and the cost savings that could be realized by, relaxing SRD requirements but not Level I requirements and exercising one or more of the descope options. Depending on the point in the project life cycle, only some of these relaxations may be practical and lead to meaningful cost savings. A project decision will be made in consultation with the Project Scientist on ranking the available alternatives.
>
> (2) If the first step is not adequate to resolve the issue, two alternatives will be explored in the second step. The first alternative will be to evaluate reducing a requirement, that is not a Level I requirement, down to its minimum value to free up enough funds to protect the Level I requirements. The second alternative will be to consider proposing a reduction of a Level I requirement below its required value but above its minimum value. An obvious third alternative would be a judicious combination of the two.
>
> (3) A proposal to reduce a Level I requirement below its minimum value will be considered only if the above two steps do not resolve the problem. This is a very significant step and will be evaluated in detailed and extensive reviews involving all interested parties.

A project team will review the status of the requirements, assess the risks according to the prescribed CRM process, and conduct contingency planning on a monthly basis. The potential future need for evaluation of descope options will be an outcome of this regular exercise. Since these will depend on the project life cycle and many other factors, it is impossible to identify specifically what these are going to be. However, following this disciplined process provides the best chance of protecting the requirements, especially the Level I requirements, and ensures that the project will be able to foresee a problem and not be taken by surprise.

Some of the descope option considerations are described in the next section. These are only representative and should be read only as a discussion of the considerations involved. The details and prioritization will depend on the specific problem at a specific time. The potential descope list will be maintained by the project and updated on a regular basis. The current list of potential descopes are presented in an Appendix to this document, in unprioritized order. There is no implication that these descopes are necessary at this time.

7. DESCOPE OPTIONS

As with all programs, the key to the successful management of these options is to consider exercising them early enough so that mission requirements and resource savings can be realized. Each descope option must be examined on a case-by-case basis. It should be noted that the GLAST instruments and the overall mission are already highly optimized; as such, any descope has a significant scientific impact. The full list of descope options, together with their impacts on science, is given in the Appendix.

7.1 OPTIONS FOR WEIGHT REDUCTION

Certain options have the advantage of reducing weight and, in some cases, cost. These include:

- The option of eliminating the entire secondary GBM instrument would provide a weight reduction of 97 kg and significant cost savings (depending on when the GBM funding was stopped). However, it would also result in a major impact to the science. The potential for cost saving is rapidly decreasing with time as GBM is being built, and the spacecraft contractor is preparing to accommodate it.

- There may be some options of reducing mass and cost in the spacecraft. Options include such things as a selective decrease in redundancy without reducing overall reliability, smaller solar arrays and power systems if the mission duration is reduced and/or if the LAT instrument is descoped (i.e., reduction of towers), removal of the propulsion system and associated fuel, and a reduction in the number of star trackers from three to two.

- Potential descope of the LAT instrument mass consists of the removal of two or four towers, and/or replacing one or two back layers of CsI logs with lower-mass structures. Both of these options have very significant impacts on the science capabilities of LAT.

7.2 OPTIONS FOR BUDGET

Possible options for managing the cost of the mission include:

- If the funding profile rather than the total funding is a problem, reprogramming could be done to fit the work to the funding profile with a delay in launch. The total cost for the mission would increase in this scenario.

- Delete the GLAST Science Support Center (GSSC). The only high-level analysis performed would be whatever the instrument teams could afford. The instrument teams would also distribute the data to the community. The SSC cost savings could be significant during the total development phase. Actual project savings would be somewhat less depending on the increased scope of the Instrument Operations Centers. Deleting the SSC would also drastically reduce the effectiveness of the Guest Investigator program.

- Eliminate Inter-Disciplinary Scientists.

- Reduce Education and Public Outreach (E/PO) funding. This funding can be reduced and still remain at 1 percent of total NASA costs for the mission development (HQ Code S guidelines are 1 to 2 percent.)

- Perform instruments to spacecraft integration and test (I&T) in-house at GSFC. The cost benefits, if any, are still in the process of being quantified.

Cost reduction options for out-years:

- Reduce mission lifetime. However, this has a science impact.

- Reduce the Guest Observer funding after launch. This will realize annual savings.

- Continue refining manpower estimates and look for civil servants (vs. contractors) wherever possible.

8. SCIENCE IMPACTS

Implementing the options for cost reduction described in Section 7, in most cases, would result in an impact on the quality and quantity of scientific data received from the GLAST observatory. Some of the science impacts are discussed in this section.

8.1 MISSION DURATION REDUCTION CONSIDERATIONS

Any trade that requires mass reduction will usually lead to a preference to reduce area rather than mission duration. This is true for missions that last between 2 to 10 years. This is not necessarily true on shorter time scales. The effective area of the LAT should be significantly larger than that of EGRET so that objects which vary on time scales of hours to days can be studied with sensitivity that is significantly better that that of EGRET.

The tradeoff of LAT area and field of view (FOV) versus mission duration can be summarized as follows:

- On any given steady source, the dependence of the sensitivity on mission duration and area is the same.
- The statistical significance grows in proportion to the square root of both mission duration and area, so the relation between the two is linear.
- For observations of transients on time scales less than the mission duration, the impact of reducing effective area cannot be traded against duration. The objects being observed set the time scale.

- When in survey mode, which will likely be the majority of the operation time, the product of effective area times FOV determines the exposure. The sensitivity therefore depends approximately equally on these two quantities, except for effects of any off-axis degradation in the PSF.

8.2 LAT SUBSYSTEM COMPONENT STRATEGIES

There are two related strategies

- accept a limited number of out-of-spec TRACKER or CAL modules (e.g., with a large number of nonfunctional channels), or non-functional redundant ACD channels, provided they do not interfere with the functionality of the rest of the system;
- remove TRACKER or CAL modules.

These options mitigate against a wide variety of manufacturing schedule slips. The first option is obviously less draconian, and would be the first pursued.

If modules must be removed, to maintain dynamic balance, they will probably need to be removed in pairs. Towers should be removed so as to minimize the surface-to-volume ratio, otherwise effects will be larger than those estimated below and will need to be carefully calculated for any proposed configuration. For example, if four towers are removed, the minimum impact to the collecting power is different if all four corner towers or four towers in one row are removed.

Nominally, on-axis, removal of any corner tower would reduce the effective area by approximately 1/16. Off-axis, the cost in effective area would be larger. The instrument is no longer rectangular but has pieces removed that impact events that cross more than one tower. However, removal of towers also compromises the background rejection, and additional fiducial cuts will be made that will further reduce the effective area.

8.3 GBM REDUCTION OR REMOVAL

There are two options to explore regarding the GBM instrument. The first is to reduce the GBM capabilities to the minimum, providing only gamma-ray spectroscopy without providing locations. The second is to completely eliminate the GBM instrument.

The primary purpose of the GBM is to provide broad-band, low-energy gamma-ray spectroscopy to complement the Gamma Ray Burst (GRB) science from the LAT. This objective would still be satisfied with a reduced GBM that does not provide locations. However, the GRB locations from GBM do enable important additional science, as identified by the GLAST Facility Science Team. The GBM monitors approximately three times as much sky for GRBs as the LAT. With location capability, it can alert the observatory when an interesting GRB occurs outside the LAT field-of-view and the observatory can slew to point the LAT at the GRB position. The CGRO mission experience suggests that the best GRB science will be obtained for the few brightest GRBs per year. With GBM location capability, GLAST will be able to study approximately three times the number of bright bursts and approximately triple the key GRB science obtained with the mission.

The GLAST Facility Science Team identified the need for a GRB monitor for low-energy gamma rays to realize the GRB scientific discovery potential of the LAT. The LAT will make the first comprehensive study of high-energy afterglows from GRBs. However, without the GBM it will not be possible to relate the afterglow observations to the great body of knowledge of GRBs at lower energy. Afterglows will be detected, but without context of what kind of GRBs are producing them. Spectroscopy of the full range from hard X-rays to high-energy gamma-rays is needed to make the next big step in our understanding of GRBs. In addition to spectroscopy, the GBM will also provide locations of rare and interesting GRBs outside the LAT field-of-view enabling LAT studies of these events. As described above, this will approximately triple the rate of burst science obtained with GLAST. Even within the LAT field-of-view the GBM will detect bursts that are not seen by the LAT. These will be bursts with weak high energy emission during the event itself, but not necessarily ones with weak high afterglow. The GBM trigger will enable detailed LAT searches for afterglow of these interesting "soft" GRBs.

In addition to GRB science, the GBM will provide the only all-sky monitor of the hard X-ray/ low-energy gamma-ray sky in the timeframe of GLAST. Transients such as galactic jet sources will be discovered. LAT observations of such sources discovered by GBM could lead to the important discovery of galactic micro-blazars that theorists predict to exist. Even without the GBM, the LAT will scan the sky and may detect such transients, but the GBM will allow the LAT to give enhanced exposure to the location of the transients and thus observe them with greater sensitivity. Also, the GBM will provide the critical context observations to identify the nature of the source.

9. SUMMARY

Integrating the Continuous Risk Management process and the Contingency Management process with the Descope Planning process, and conducting these assessments periodically, leads to a disciplined project management approach that is likely to offer the best chance to protect the GLAST science requirements, especially the Level I requirements.

Appendix
Summary of Descope Options

ITEM	USE	TIMEFRAME	RISK IMPACT	IMPACTS ON SCIENCE
Accept a limited number of out-of-spec LAT components	Mitigates against a wide variety of schedule slips in manufacturing	Start of LAT production to LAT integration completion	Reduction of margin on science performance relative to requirements.	Degradation in Aeff, FOV, PSF and background rejection.
Delete 2 or 4 LAT Towers	Mitigates against severe schedule slips in manufacturing. Reduces mass.	Start of LAT production to LAT integration completion	2 towers: eliminates all margin on science performance and likely violates SRD lifetime/reliability and degradation requirement.	Both options result in substantial degradation in Aeff, FOV, PSF. Removing 4 towers violates Level 1 Aeff minimum requirement.
Remove 1 or 2 layers of LAT CsI logs	Reduces mass	Prior to start of LAT CAL production.	Reduces margin on science requirements (energy reach, resolution, removal of 2 layers might violate requirement at high energy); risk to background rejection.	Degradation of energy resolution/energy reach. Compromises background rejection.
Launch with no LAT onboard science algorithms	Prioritization of flight software, mitigates against schedule slips	Prior to observatory level testing	Loss of possible burst alerts during early operations until algorithms are uploaded and enabled.	Initially violates SRD GRB alert requirement (not a Level 1 requirement), but algorithms are uploadable on orbit.
Delete GBM	Mitigates against schedule slips if GBM is late; provides mass and cost reduction.	Prior to observatory level testing	Science.	Loss of spectral context measurements; loss of GBM burst alerts; loss of GBM FOV input for autonomous repoints.

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ITEM	USE	TIMEFRAME	RISK IMPACT	IMPACTS ON SCIENCE
Relax pointing knowledge requirement to 20 or 40 arcsec.	Reduces LAT and spacecraft verification and analysis time	Available anytime until completion of LAT and observatory testing.	Science. Might also involve elimination of one star tracker, reducing spacecraft redundancy.	Additional bright sources will be more poorly localized. Violates SRD requirement, but no Level 1 Requirement. 40 arcsec violates 20 arcsec SRD minimum.
Delete Interdisciplinary Scientist Funding	Reduces costs	Available anytime	Science	Reduces science community involvement. Loss of expertise in mission.
Reduce E/PO funding	Reduces costs	Available anytime	Might make the E/PO effort sub-critical and ineffective.	Reduces public benefit and understanding of the mission.
Reduce Guest Observer Program; Reduce or delete Science Support Center	Reduces costs	Available anytime	Science	Reduces science community involvement. Limits ultimate GLAST scientific accomplishments.
Delete propulsion system	Reduces mass	Prior to spacecraft CDR. Requires proof of disposal safety.	Reduces risk of premature mission termination. Reduces mission risk by creating additional mass margin.	May require redesign of LAT thick tungsten converters.
Delete autonomous burst repointing	Reduces observatory test time.		Science	Violates SRD requirement (not Level 1 requirement); loss of burst high-energy afterglow science.
Reduce mission life to two years	Reduces mission life cost.	Available anytime	Science	Loss of faint sources; loss of multiwavelength studies; loss of detection of transients; loss of detailed sky region studies; loss of discovery potential.