GLAST Task Statement-FY2001

I. Introduction

This statement of work describes tasks to deliver a final design for the GLAST Tracker. Included herein are general descriptions of the technical issues to be addressed and detailed descriptions of the tasks to be performed. The following outline provides a listing of the topics detailed in this statement of work.

- Tray Sandwich Development
  - Carbon-Carbon Coatings
  - Tray Closeout Structural Design and Testing
  - Tray Sandwich Structural Design and Testing
  - Tray Sidewall Design and Testing
  - Tracker Tower Mechanical/Structural Design and Testing
- Engineering Support of the E/M Prototype Testing
  - E/M Support
- Finalize Flight Hardware Tracker Design
  - Final Design
- Travel Expenses
- Summary of Costs

II. Tray Sandwich Development

A. Carbon-Carbon Coatings **Total: $49.6K**

Labor: $47.0K M&S: $2.6K

The tray closeout and potentially the tracker sidewalls will be constructed from carbon-carbon (C-C) material. Unsealed C-C material is prone to releasing small quantities of carbon dust during handling. It is presumed that the carbon dust may be emitted during launch conditions from either, surfaces releasing airborne particles, or from minute relative motion between contacting surfaces, dislodging particles, which may be induced by launch vibrations. It is speculated that the carbon dusting may lead to "*carbon tracking*" on the silicon strip detector, since the detector has a bias charge. To preclude this situation the C-C will be sealed.

Prior work has been done to seal C-C material using resin (cyanate ester) impregnation and parylene. The impregnation process is performed in either of two ways: via a pressure impregnation method or through vacuum bagging. At times, the vacuum bagging process leads to an uneven coating, which in some cases exposes parent C-C material during an abrasion test. Pressure impregnation in thin sections achieves, in most instances, a thorough impregnation. However, experience has shown that machining a pressure impregnated C-C specimen can expose material that will shed particles (simple transfer to hands or fingers). Additional work is needed to select the appropriate method and process for sealing the C-C material for the GLAST Tracker.

This task will evaluate the option of sealing the surface with either, (1) a very thin metallic coating, (2) parylene (vacuum deposited polymer), or (3) through resin impregnation. There are distinct advantages with each option. The first two options can be applied after constructing the tray closeout, whereas the resin-sealed option should be applied to the tray closeout components before bonding. Pressure impregnating or vacuum bagging an irregular shape like the tray closeout would require undesirable complications. Parylene coating of a complete tray should not be a problem, although this needs to be confirmed. This option is quite attractive, however, the resistance of parylene to abrasion needs to be confirmed. The resin-sealed option should not interfere with bonding of the tray components into a tray closeout, whereas the first two options[1] may result in lower bond strengths, if applied before bonding. A general statement of tasks to be performed is as follows:

- *Investigate allowable carbon dusting requirements for the GLAST tracker. Working with SLAC, design requirements will be investigated to define allowable carbon particulate levels to minimize the probability of "carbon tracking."*
- *Demonstrate resolution of carbon dusting by application of sealant and testing for compatibility of sealant with chosen adhesives and for resistance to abrasion. Test bond strength of chosen adhesives via adhesion testing on C-C specimens. Document bonding procedures; compare bonding strengths with published data for selected adhesive. Deliverable in form of test report.*

B. Tray Closeout Structural Design — Total: $241.4K

Labor: $220.8K M&S: $20.6K

The simplified tray closeout design is composed of 4 C-C elements bonded into a square frame. The C-C material tentatively chosen for the prototype tray is a commercially available C-C composite with a three-dimensional (3D) fiber orientation. The initial step is to review the simplified tray closeout design concept identifying possible production simplifications to lower cost, as well as re-examining all bonded joint designs for structural adequacy and inherent reliability. This task entails completing design calculations of the critical stressed areas in the tray, refining the corner joint design, and confirming the material choice over an alternative 2D C-C product.

There are two tray closeout configurations: a standard tray used throughout the tower and a bottom tray that interfaces with the grid. The bottom tray structural design issues are distinctly different from the standard tray, and CTE mismatch issues between the C-C tray and Al grid need to be addressed.

The tray closeout is the primary stacking element in the Tracker that insures the precision of the overall tower. Deliverables of this task are to demonstrate:

- *that four, pre-machined, tray closeout elements can be bonded together into a precise frame, without requiring further machining. This entails designing a bonding fixture constructed from low CTE materials with precision locating features for the tray corner elements.*

[1] Parylene coating has a very slick surface, Teflon like, that must be prepped before bonding.

- *<u>that the small threaded inserts used for attachment of the sidewalls throughout the tower and bottom will survive launch loads</u>. Fastener pullout strengths will be determined through testing. The component tests will validate choice of adhesive and any surface preparation (bonding primer) applied to the C-C.*
- *<u>that integrity of bonded interface in corner joints is high and repeatable</u>. Fabricate specimens from material selected for tray closeout. Consider adhesive options (room temperature cure versus elevated temperature cure) and method of application (film or liquid transfer). Select several adhesive/bonding options for prototype testing. Bond many specimens, conduct physical strength tests, and verify repeatability of process. Select bonding procedure for GLAST tray corner joint design. Prepare process specification for tray closeout prototype tests.*
- *<u>that structural integrity of bonded corner joints is consistent with expectations</u>. Static load tests will be performed on a tray, with the measured strains correlated with FEA predictions. Bond strength will be established by testing a tray to destruction.*
- *<u>all structural aspects (CTE mismatch) of the bottom tray design are resolved</u>. Task entails combination of structural analysis using FEA methods combined with testing. Bottom tray configuration will be established through FEA of structural loads from launch and thermal strains induced from CTE mismatch with Al grid. A bottom tray prototype, mounted onto a simulated grid interface, will be subjected to a sequence of temperature variations to confirm the robustness of the design. Insert pullout and shearout tests will be performed to confirm design requirements.*

The final delivery of this task will be technical notes which describe the two tray designs (standard and bottom), analysis thereof, and results of testing.

C. Tray Sandwich Structural Design **Total: $218.0K**

Labor: $164.8K M&S: $53.2K

The tray sandwich is comprised of an adhesively bonded structure formed from the tray closeout, honeycomb core, composite facings (graphite fiber (GF) and cyanate ester (CE) matrix), and the detector payload (silicon detectors, bias-circuit and converter layer). Testing is in process at SLAC to demonstrate that CTE mismatch issues between the SuperGLAST payload and the GF/CE composite facings are resolved through use of a compliant adhesive. It is not clear if structural decoupling will be achieved through the use of a compliant adhesive, nor what impact may result should this be achieved on the ability of the detector payload to resist vibratory loads. However, the payload design aspect is not part of the sandwich design proposed tasks; nonetheless, the tray sandwich design must be validated with this approach in mind. Tasks planned for tray sandwich design focus on confirming the selection of the facing and core materials, choice of adhesives, and bonding procedures, which provide adequate stiffness and minimize traction stresses in the silicon, for both the standard and SuperGLAST trays. Validation of the design will be based on prototype tests, complemented with confirming FEA type calculations.

The present status of the tray design is conceptual, formulated in the interest of obtaining budgetary production costs. The effort of completing the tray sandwich design is to be coordinated with the Task "*Tray Closeout Structural Design.*" The design objective is to provide a cost effective, composite tray sandwich design that minimizes programmatic risk. Where practical, without increasing risk, structural mass is to be minimized.

Material selections are to be chosen from conventional composite options. For example, in addition to the commercial 3D C-C brake material, the first choice for the sandwich facings and core are GF/CE composites. Material options will be driven primarily by cost, with stiffness and mass being considered as a secondary driver to meet performance requirements. A tentative choice for the tray facing fiber is the low cost Toray M55J. Prepreg material, M55J/CE, is available in a standard 63.5μm thickness per layer, resulting in a 6 layer quasi-isotropic laminate thickness of 380μm [2]. Prepreg material can be formulated with this fiber (6K tow) as thin as 25μm per layer at the expense of increased cost. This would yield a nominal tray face thickness of 150μm. Other fiber options would be Nippon Industries fibers XN50 and YSH50, and Mitsubishi K135. These fiber options are available for consideration also in the construction of the GF/CE honeycomb core. Our approach for elements, tray facings and core, is to make a choice largely driven by cost with secondary emphasis on material mass.

Purely from a cost standpoint, Al honeycomb is an obvious choice for the core. However, galvanic corrosion between Al and carbon composite materials has been observed. In the event that this option is selected, steps to protect the Al must be taken.

Deliverables of this task are to demonstrate:

- *<u>that tray sandwich material selections and material thickness are correct for both the standard trays and SuperGLAST trays</u>. Revise tray structural FE models to incorporate geometric modifications and material selections. Perform structural analysis, static and dynamic for the tray sandwich using specific face sheet materials and face sheet thickness chosen on the basis of cost/performance tradeoff (minimize face sheet mass). Perform thermal analysis to estimate the CTE induced traction stresses in the silicon. Order prototype facing material(s) for physical tests. Verify stiffness properties for composite facings (at 0° and 90° laminate directions). Verify material CTE for composite facings (at 0°, 45°, and 90°, using a strain rosette).*
- *<u>that design drawings are complete and the tray sandwich fabrication is a cost effective solution</u>. Finalize prototype tray and tray sandwich drawings. Obtain prototype and production tray component(s) cost estimate. Estimate labor to assemble production trays. Review cost estimates with project personnel and solicit decision on technical approach. Initiate fabrication of prototype tray and tray sandwich construction (units support prototype testing).*

[2] Advanced lightweight versions of the tracker design proposed 200μm. More expensive, thinner prepreg material is available that would lower the radiation length penalty. Depending on the final cost estimate for the tracker production a programmatic decision may elect to use the thinner material, or possibly switch to a 4 layer balanced 2D fiber orientation. This decision must be made before progressing into the sandwich development tests.

- *<u>that integrity of bonded interface between sandwich core to tray facing is high and repeatable</u>. Fabricate specimens for tray core and facing. Consider adhesive options (room temperature cure versus elevated temperature cure) and method of application (film or liquid transfer). Select several adhesive/bonding options for prototype testing. Bond many specimens, conduct physical strength tests, verify repeatability of process. Select bonding procedure for GLAST tray sandwich. Prepare process specification for full tray prototype tests.*
- *<u>that integrity of bonded interface between tray facing to tray closeout is high and repeatable</u>. Fabricate specimens for tray closeout and facing. Consider adhesive options (room temperature cure versus elevated temperature cure) and method of application (film or liquid transfer). Select several adhesive/bonding options for prototype testing. Bond many specimens, conduct physical strength tests, and verify repeatability of process. Select bonding procedure for GLAST tray sandwich. Prepare process specification for full tray prototype tests.*
- *<u>that tray sandwich can sustain structural and thermal loads</u>. Design and fabricate simple holding fixtures for single tray vibration test. Conduct vibration test on tray free of a simulated payload, correlate results with FEA prediction. Conduct static load test (shear load) and compare tray load-strain behavior with predictions. Temperature cycle sandwich tray and demonstrate no debonding occurs. Test validates tray structural design aspects and all bonded interfaces are acceptable (tray facing to closeout, tray facing to core). Thermal tests to confirm the thermal mismatch between commercial 3D C-C material (CTE +0.4ppm/C) and tray facing (–0.4ppm/C) and core (2ppm/C to 22ppm/C, depending on selection) does not present a problem. Tests also later permit the isolation of the CTE effect of the payload being superimposed on the behavior of the tray.*
- *<u>that tray sandwich with simulated payload will survive structural, thermal and mechanical, loads</u>. Conduct vibration tests, measure response of payload and correlate results with FEA. Conduct thermal cycle tests, observe and record strains induced through the presence of the simulated payload. Conduct outgassing/contamination tests to verify requirements are satisfied.*
- *<u>that addition of simulated GLAST payload, tray facing, tray core to the tray closeout does not upset the precision assembled state of the tray</u>. Re-inspect the tray features with a coordinate measuring machine. Correlate results with earlier inspections.*

The final delivery of this task will be technical notes presenting test results, and procedures recommended for constructing the GLAST Tracker Engineering Model (E/M) tray sandwich.

D. Tray Sidewall Design **Total: $77.1K**

Labor: $68.0K M&S: $9.1K

The tracker trays are stacked and compression loaded with tensioning cables. In this state, the stack can be handled and checkout tests can be performed on the individual tray detector electronic readouts. However, to provide structural integrity during launch four composite sidewalls are attached around the perimeter of the stack. These sidewalls, which effectively react >80% of the launch loads, serve another important role as a high performance thermal conductor. Heat flows from the tracker electronics down the sidewall into the grid, where it is collected with heat pipes, and thereafter transported to the radiators. Consequently, the tower sidewall design parameters include both structural and thermal properties. The material must also possess a low CTE, to be compatible with the CTE of the composite material chosen for the tray.

To date several composite materials have been identified which possess the right attributes to satisfy the sidewall fundamental parameters for stiffness and thermal conductivity. Both candidates also have low CTEs. However, a question remains, how best to mechanically fasten the sidewalls to the trays. The fasteners carry structural loads, as well as providing pressure to enhance the thermal contact between the sidewall and the tray. Localized loads around fasteners may damage the sidewall material, thereby reducing the structural integrity and thermal performance of the panels. For this reason, inserts are being considered to eliminate localized failures around fasteners. To this end, two panels from the candidate materials (P30 and YS90) were procured for testing (both mechanical fastening and thermal contact tests).

Deliverables of this task are to demonstrate:

- *that the candidate sidewall material properties meet published values with respect to stiffness and thermal conductivity. Specimens will be cut from the panels and sent to an independent material test laboratory for evaluation. Stiffness, strength, conductivity and CTE properties will be verified and compared to published data (in 0° and 90° directions).*
- *that sidewalls constructed from C-C (carbonized P30 unitape) material can be sealed by procedures developed for the C-C tray material. For the C-C candidate, if chosen, specimens will be sealed to achieve a dust free state by procedures developed for the tray.*
- *that the chosen mechanical fastening concept has high structural integrity. Structural test will be performed on the sidewall attachment concept to establish shearout and pullout strengths. Comparison with design loads will be made to establish design margin.*
- *that the thermal interface between sidewall and tray will passively conduct heat reliably and in a predictable manner. An option would be to use Kapton-foil surface heaters to simulate electronics mounted on a tray. Mount a short segment of the sidewall panel on the side with the surface heaters. Thermally isolate the assembly so that heat extraction occurs along bottom edge of sidewall. Immerse exposed edge of sidewall into constant temperature liquid bath. Apply heat and*

record DT. Repeat test several times, attaching and un-attaching the interface. Compare results with predictions from Rohsenow "Handbook of Heat Transfer Fundamentals". Use Rohsenow's method for adjusting for contact coefficient in a vacuum.

The final delivery of this task will be technical notes presenting test results, and finalization of the design drawings for the sidewalls and fastening concept.

E. Tracker Tower Mechanical/Structural Design and Testing Total: $301.3K

Labor: $269.3K M&S: $32.0K

The GLAST silicon-based Tracker, comprised of a 4 by 4 array of based mounted towers, which may be physically connected between towers at the their top[3] to assist in resisting launch loads. A number of analytical studies have been performed to evaluate the structural dynamic behavior of the tower and individual trays to analytically simulated launch conditions. The studies were based on a composite tower design that embodied a *lightweight* C-C tray closeout and a *structurally coupled* tray payload. The results of this work indicated that the dynamic response of the tray to vertical acceleration could result in a rather significant deflection, reducing space between trays to potentially unacceptable limits. Simulations of the lateral acceleration indicated that space between towers, likewise, could diminish to a point where contact between towers became problematic. Recently, the tray design has been re-configured affecting these results, first the tray closeout is thicker, adding more mass, and secondly, the tray payload is structurally decoupled for SuperGLAST. To what extent these changes affect the structural dynamics of the tower design can only be assessed through further design studies. As a step in this process, it is recommended that the HYTEC technical note " Tracker Design Requirements for GLAST" HTN-102050-0021-Draft be reviewed and accepted by the GLAST Tracker project management. It is important to establish consensus on the design requirements before the final design and validation process commences.

Deliverables of this task are to demonstrate:

- *<u>that revised tracker tower design structural performance is still acceptable</u>. Prepare and/or revise FE models for the tracker tower and tray assembly. Evaluate structural dynamics per released Tracker Design Requirements document. Assess need to couple tower to tower. Evaluate tray response to vertical acceleration with decoupled SuperGLAST payload concept.*
- *<u>that tensioning cable design concept and stack assembly tooling function properly.</u> Re-visit stack compression loading concept provided by 4 corner cables. Re-size, if appropriate cable design loads and cable size. Design production assembly tooling for GLAST Tracker Engineering Model. Fabricate tooling and test functionality with mini-tracker stack.*
- *<u>that all composite tracker tray stack with sidewalls will survive simulated GLAST launch conditions</u>. Evaluate all thermal and mechanical issues with a*

[3] Another design item that needs clarification pertains to possible support for the ACD by the tracker tower structure.

composite mini-tower. Conduct vibration tests of tower stack, establishing modal response. Compare with FEA. Conduct thermal test of passive cooling down 5 layer stack. Mini-tower will reflect proposed design for GLAST Tracker Engineering Model with exception of simulated surface heaters for electronics and dummy payload for the silicon modules and lead converters. Simulation of the payload will be fashioned in such a manner as to simulate the structural coupling of payload in the GLAST design. Fabricate and assemble 5-sandwich C-C tray assemblies with simulated payload, 1-bottom tray, 1-SuperGLAST tray, and 3-standard trays. Fabricate partial sidewall and assemble into stack; include features to mount partial stack to aluminum base.

III. Engineering Support of the E/M Prototype Testing

A. E/M Support **Total: $126.9K**

Labor: $120.9K M&S: $6.0K

The engineering model (E/M) prototype testing will be performed to validate design concepts selected for the GLAST instrument. A full qualification level test plan is presumed and will be managed (possibly performed) by the SLAC GLAST program office. Fabrication of the E/M is expected to begin shortly after PDR, August 2001, which would begin with the procurement of E/M hardware, followed by integration and testing of the full E/M prototype unit, FY'02. In an effort to ensure a successful test, engineers at HYTEC will support all stages of the E/M prototype testing. This includes supporting the procurement, fabrication, integration and testing phases. It is assumed that SLAC will provide the resources to procure the E/M hardware, and HYTEC will support the contracting efforts, as required.

As described, the tasks outlined below include tasks that begin in FY'01 and extend into FY'02. Of the total, $108.4K will be spent in FY'02. Leaving $18.5K for FY'01 expenditures.

Deliverables of this task are:

- *<u>to finalize design drawings for the E/M prototype hardware.</u> Design modifications will be made to the CAD models, which incorporates necessary changes identified during Tracker level testing (previous tasks described above). A final drawing package will be checked and released for E/M fabrication.*
- *<u>to support E/M hardware fabrication and assembly of the Tracker Tower.</u> Tasks would include selecting vendors, assisting with contract negotiations, coordinating hardware fabrication and delivery, inspecting finished hardware components, and supporting Tower assembly/integration.*
- *<u>to support E/M prototype qualification level testing</u>. Engineering support will be provided to assist with 1) test plan preparation, 2) test fixture design, and 3) manage qualification level testing, as it relates to the Tracker E/M. It is assumed that SLAC will provide a significant portion of the resources to complete the qualification testing, including hardware procurement costs that are not included in this statement of work. Support will also be provided to reduce data and report findings.*

IV. Finalize Flight Hardware Tracker Design

A. Final Design **Total: $55.5K**

Labor: $55.5K M&S: $0.0K

Final design of the Tracker sub-system will be required after the E/M prototype testing, which incorporates design modifications that may be necessary to improve design features that were not previously addressed or make changes to reflect testing results. The final design phase will provide the resources to incorporate these changes into the Tracker design and deliver a space qualified design. All tasks performed under this category will occur during FY'02.

Deliverables for this task are:

- *<u>to deliver a complete drawing package for the flight hardware</u>. Modifications to the Tracker design will be incorporated into CAD models and FEA will be performed (as required) to validate design changes. The drawing package will be updated, checked, and finalized, before procurement of flight hardware begins.*

V. Travel Expenses **Total: $6.0K**

Travel will be required to attend collaboration meetings and coordinate engineering development with the other subsystems through FY'01. Travel costs required for FY'02 are not included in this statement of work and will be negotiated at the time of service. The travel expense budgets proposed to support this travel are as follows (trips include East and West coast destinations, and sometimes international travel; typical duration is 2 to 5 days; an average expense of $1,500/person/trip has been assumed):

- *<u>Collaboration Meeting:</u>*
  Periodic conference of the GLAST collaboration.
  One (1) engineer x 1 trip = $1.5K
- *<u>Program Management (Instrument level meeting):</u>*
  Coordinate at system level with program and sub-system managers.
  One (1) engineer x 1 trip = $1.5K
- *<u>Tracker Development (Tracker level meetings):</u>*
  Coordinate at Tracker level with Tracker sub-system manager.
  Two (2) engineers x 1 trip = $3.0K

VI. Summary of Costs

	Labor	M&S	Total
FY'01 Expenditures:	$788.4K	$123.5K	$911.9K
FY'02 Expenditures:	$157.9K	$6.0K	$163.9K
Total Expenditures:	**$946.3K**	**$129.5K**	**$1,075.8K**

Presented above is a cost breakdown of labor and M&S for the tasks outlined above. Totals for the tasks outlined in this statement of work are presented along with a breakdown for FY'01 and FY'02. Labor rates were held constant from the previous contract (#15983), dated November 22, 1999.