GLAST

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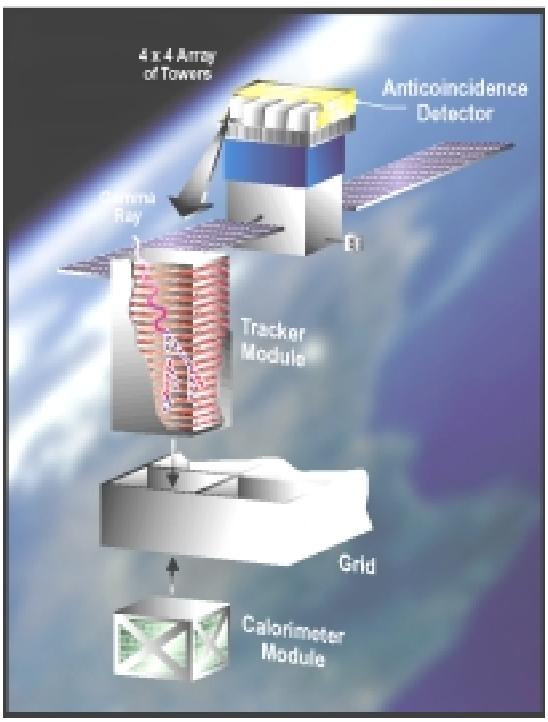
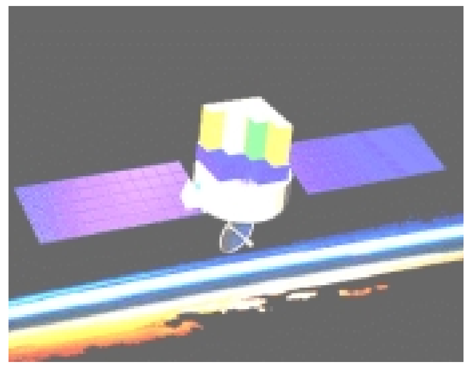
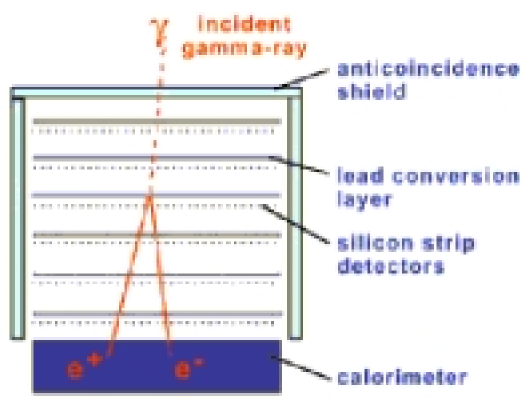
Gamma **R**ay **L**arge **A**rea **S**pace **T**elescope is a satellite provided by pair-converters metal and x, y silicon detectors for the study of gamma rays on the space. It will be launched on the 2005. The main aim of this instrument is to go thought all the discoveries started with earth telescope and other satellite (like AMS, EGRET, etc.).
The primer for Glast project is SLAC, but the integration and testing of subsystem modules will be completed in parallel assembly lines in the U.S., in Italy and in France.





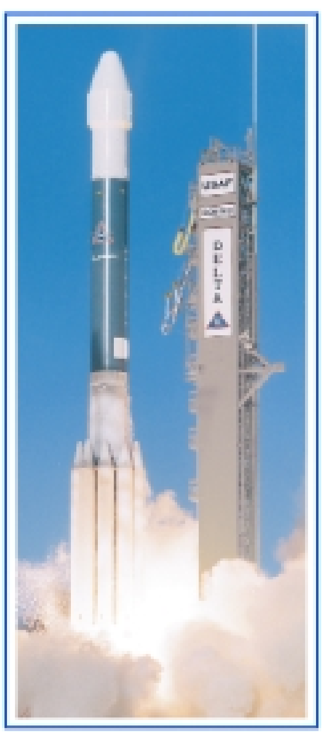


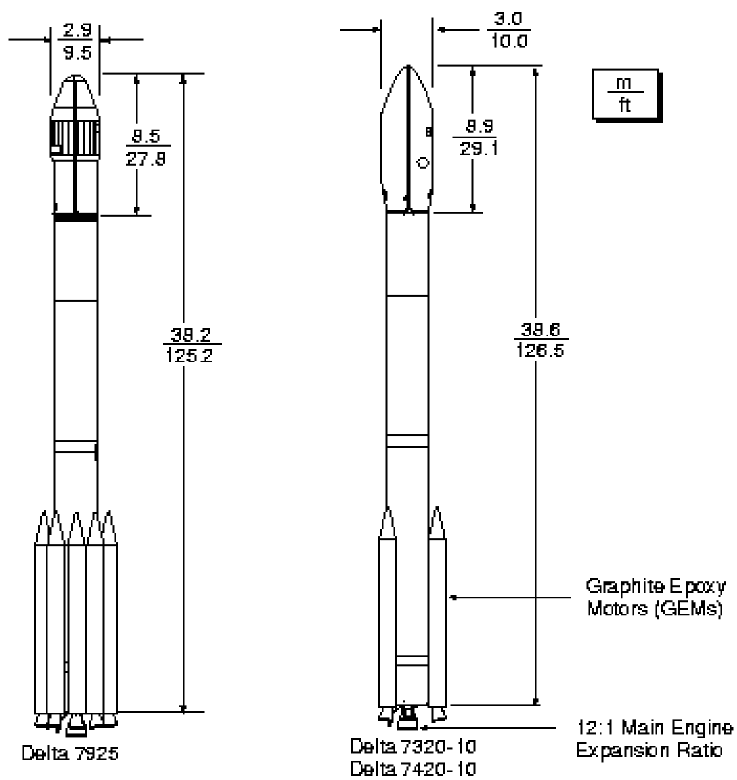
GLAST will investigate on mechanisms of particles accelerations on AGN`s (Active Galactic Nuclei), pulsar and super nova remnants, unidentified sources and diffuse emission, high-energy behavior of gamma-rays bursts and transients. For this purpose it is provided of an effective detecting area of 12,900 cm^2, an energy resolution of 100MeV-100GeV, an angular resolution of 0.39° and an on-board transient analysis for rapid alert, characteristics that distinguish Glast from the other gamma-rays satellite.
The Large Area Telescope is the detecting area of that satellite. It’s a pair-conversion telescope parted in:

- *Precision tracker* (TKR) composed of 16 identical towers. Every tower is made of 19 composite panels (Trays), disposed like drawers in a grid. Only 18 of them are provided by silicon-strip particle detectors and converters arranged in x, y tracker planes for the determination of photons` directions.

- *Calorimeter* (CAL) for energy measurement and precise shower localization provided by segmented array of CsI crystals and read output of PIN diodes.
- *Anticoincidence Detector* (ACD), that covers the TKR, is composed of segmented scintillator panels, which are read out by waveshifting fibers and photomultiplier tube.

All the three detecting components are mechanically and thermally integrated by a Grid and electronically connected to a Data Acquisition board (DAQ) Also the DAQ system is supported and thermally regulated by the main Grid.
The Grid avoids any kind of thermal and dynamic interface between the various tracker modules maintaining a rigid and planar structure and a thermal interface between the modules and the Spacecraft. The Spacecraft anyway supports the LAT thermal radiators, which receive the heat via heat pipes from the Grid.
NASA will launch the satellite in the space on 2005. The spacecraft used for launching Glast is type DELTA II series 7925. The position that the satellite will occupy and maintain is 28.5° equatorial.
The main aim of the work is to perform a thermal and mechanical analysis of the trays of the TKR, including a study of the adhesive behavior when they're subjected to thermal

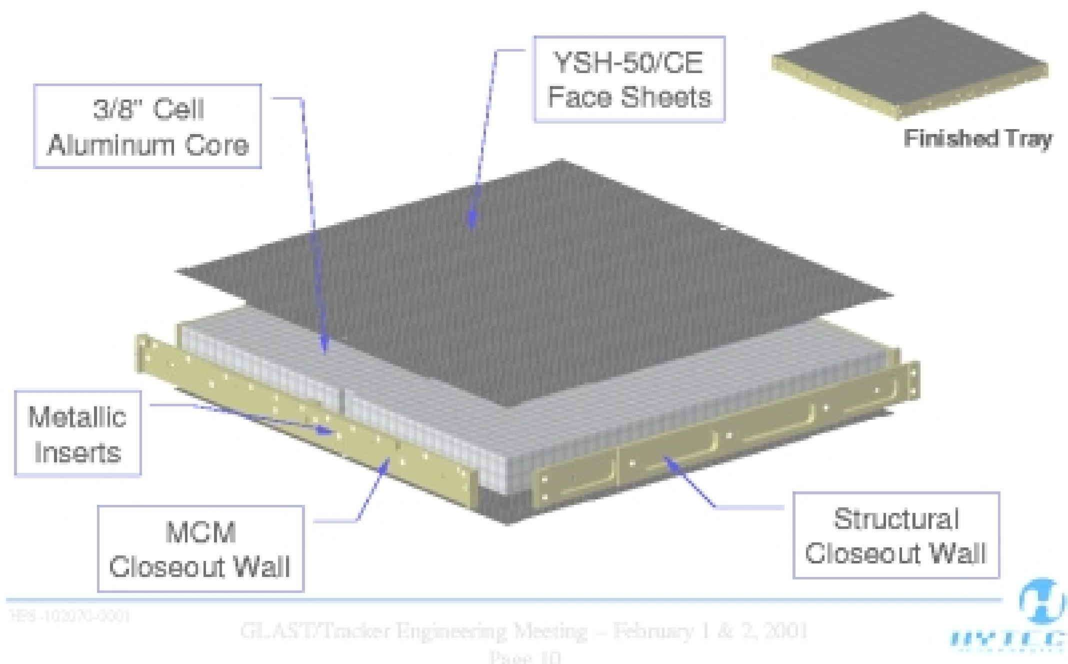




cycle. Mechanical analysis presented includes static, modal, transient and random vibration study for the TKR trays.
The structures of the LAT will be divided for their weight and the function, in primary and secondary structures. Primary and secondary structures will be subjected to different acceptance and qualification tests.
The Grid, the ACD, radiators and thermal micrometeorite shields are primary structures, while the single components of the towers (trays) are secondary structures.

What’s done?

The selection and the study of compatibility of most of the materials that constitute the trays are just done. The reasons for these choices are outgassig, mechanical and thermal compatibility and in part even price. The actual problem of the modules is the choice of the adhesives that glue the different layers.
The trays of TKR are composite squared panels (dimension 369x369 cm) aligned to the four corners and connected to a main grid. Sidewalls provide an additional strength and create a heat flux to the TKR base.



Their asymmetric structures is composed of various layers:

- Central sandwich of aluminum honeycomb (25.4 mm thick), carbon-carbon closeout, composite face sheet (cyanate matrix and carbon fibers composite of total thickness 0.4 mm),
- Tungsten converter (thickness 0.6 mm) is a layer divided in sixteen squares (each of 182.25 mm of edge) glued to one of the two carbon face sheet,

- Two kapton metalized foils, glued on one side to the converter and on the other side of the sandwich in honeycomb to the face sheet (kapton thickness is 0.2 mm) ,
- The detecting plane constituted of four adjacent silicon ladders (each ladder is made of 4 thin squared silicon layers with micro strips), disposed over the foils of kapton and glued with conductive adhesive to maintain the electric contact. The thickness of the silicon ladder is 0.4 mm

All the different layers are glued to the other with adhesives. It's evident the importance of the adhesives on the mechanical and thermal behavior of the structures.
The sandwich structures have to guarantee enough rigidity and to avoid superposition between the trays during qualification testing and launch.
The adhesives have to avoid de-bonding between the layers, big displacements and non-planarity caused by thermal and fatigue stress.

Moke-up production

Two different kinds of sandwich modules (without silicon ladder) will be produced in two Italian companies: Alenia Spazio and Plyform. The best producer will continue the production of all the other trays.
Alenia will realize a sandwich with cyanate and K139 2U carbon fibers composite face sheet and closeout and aluminum honeycomb (1/4-5052-2.54µm, total thickness 27 mm).
Each layer of the composite is 51µm and the composite series is $[0/\pm 60]_{2S}$
Plyform will produce moke-ups with 985-epoxy matrix and T300 carbon fibers closeout and face sheets (1/8-5052-17.78µm, total thickness 27 mm).
The composite series is $[0/90]_S$ because each ply is 0.234 mm thick.
The request for the two companies was to maintain a planar tolerance of 5 µm on the face sheets and other good working precision.
The decision was to give the production to the Plyform.
The moke up produced by Alenia has been measured and the general characteristic didn't correspond with the request.
(LINK FOR measurement)

Changing on the realization projects request the use of carbon-carbon closeout. The European producer of carbon-carbon that has been contacted is SGL Carbon. Four closeouts in carbon-carbon will be produced by SGL and then sent to Plyform that to produce in total 8 trays complete with tungsten converters. The 8 moke-ups will be different for the type of adhesives used and the lateral closeout. In 4 trays with composites closeout and 4 with carbon-carbon material particular will be produced.

What has to be done?

Experimental and computational analysis could be used to have a complete characterization of the structures and the adhesive used to glue the different materials layers in each tray. The program of work included test on the adhesive and on the moke-up.

a) Experimental thermal and mechanical test on adhesives

The adhesives selected for the production of the trays considering the mechanical, thermal and outgassing data furnished by the producing company are:

1) REDUX 312 UL epoxy adhesive (used to glue the honeycomb and the face sheets. Cured at 120°C)
2) REDUX 420 A/B paste adhesive (Adhesive used to glue the tungsten to the face sheet. Cured at room temperature)
3) 3M Scotch-Weld 2216 B/A gray epoxy (Used to glue silicon to form a ladder. Cured at room temperature)
4) The adhesives to glue the two kapton foils on the face sheet and on the tungsten are:
   - NUSIL CV-1142-1 silicon adhesive
   - REDUX 420 A/B paste adhesive
5) The adhesives to glue the silicon ladder are either silicon or epoxy and in particular:
   - NUSIL CV-2646 silicon conductive adhesive
   - EPO-TEK EP-410_LV epoxy conductive adhesive

The last four adhesives in the list cure at room temperature.
The main properties are listed in Annex A.
The experimental thermal analysis consists in tests performed on the DSC to measure the glass and cure temperature, gel time and the general changing in the property of the thermoset adhesives. Test on themo-mechanic analyzer to have information about thermal expansion's coefficient vs. the temperature.
Mechanical tests are used to give a measure of the Young's and shear modulus, about the adhesion and modality of rupture on the glue.

b) Experimental thermal study of trays

The thermal tests program on sandwiches (without electronic) and on trays provided of silicon strip ladder include tests on climatic room. The tests will be planned to be conform to the Mission Assurance Requirements for the LAT[1]. The trays will be

[1] *Mission Assurance Requirements for LAT*, Goddard Space Flight Center, Maryland (OCT 26, 2000)

subjected to 8 thermal-vacuum temperature cycles, at least 4 of which will be at the instrument level. The remaining cycles may be at lower level of assembly.
Thermal test temperatures on tray could be described in operating range (the extreme temperature for tray without silicon micro strips is 40°C and -10 °C), survival range and rapid transients (Range of temperature is 60 °C and -55 °C)[2]. The ramp rates of operational and survival tests are 20°C/hour, for the transient is 15°C/min. Tests on ladder strip trays have different range of survival temperature extremes of +60°C and -23°C. In particular the thermal test cycle is:

- Ramp 25°C to 50°C with a increase of temperature of 0.5°C/min,
- Isothermal condition for 30 min
- Ramp 50°C to -20°C with a decrease of temperature of 0.5 °C/min.
- Isothermal at –20 for 30min.
- Ramp with a temperature variation of 0.5 °C/min till 25°C.

c) *FEM thermal analysis of the tray*

Ansys simulation of the thermal behavior of the sandwich (including adhesive and materials thermal behavior) will be made creating implementation of the similar model used for Agile. Two student of Aerospace Engineering in Pisa has produced an Ansys simulation of the thermal behavior of trays of Glast.

d) *FEM static and dynamic analysis[3)]*

Static analysis will be performed to measure the equivalent flexural and Young's modulus of the 3D structure of the trays.
Dynamic analysis include:

- **Static-Equivalent acceleration** to measure the pre-stress on the structures caused from the fast acceleration during the lift-off of the Delta II
- **Modal analysis** to have a real representation of the natural modes of vibrations
- **Transient analysis** to give information about the shock forces that could be produced during the launch and permanence on the space
- **Random vibration analysis** that is analyzed with PSD method. The input for the PSD study is the response spectrum characteristic for Delta II.

Modal, transient and PSD analysis can be done on the pre-stressed structure
In the page below there will be the description of the input.

- **Static-Equivalent Acceleration**

The **primary structures** are subjected to different lift-off and MECO static-equivalent accelerations (Main Engine Cut-Off) on z-axes (thrust) and on the transversal axes. Values are listed in the table.

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[2] *GLAST tracker tray assembly thermal test plan*, Hytech Inc. (FEB. 17, 2000)
[3] *LAT Mechanical Performance Specification*, Martin Nordby, (NOV.1. 00)

AXIS	EVENT	
	Lift-off/transonic	MECO
THRUST	(+3.25/-0.8)g	(+6.0/-0.6)g
LATERAL	(+4.0/-4.0)g	(+0.1/-0.1)g

The **secondary structure** and components shall use a limit load factor of +/-12.0g applied to the three axes independently.

- **Transient analysis: mechanical shock**

Shock level could be simulated in Ansys with transient analysis.
Shocks analyzed in this work are produced from impacts with micro-meteor and other object in the earth's shadows. The thermal shocks, produced from sudden heat stress are not considered since produce lower effect than mechanical shocks.
The maximum flight shock level is listed in the table below.

	Shock Response Spectrum (G)	
Frequency (Hz)	QUALIFICATION	ACCEPTANCE
350	140	
350-1700	+12.3 dB/oct	+12.3 dB/oct
1700	3500	2500
1700-4000	+5.5 dB/oct	+5.5 dB/oct
4000-5000	7700	5500
5000-10000	-9 dB/oct	-9 dB/oct
10000	2730	1950

- **Random Vibration Magnitude and Frequencies**

The acceleration levels are the ones required for the launcher DELTA II and the random vibrations model could even not be applied in conjunction with the static-equivalent loads. The primary structures are subjected to lower levels of accelerations than the second type structures.
The Ansys simulation used to analyze the random vibration is a modal analysis (to get the primary vibration modes) and a PSD analysis.
In the table below is listed random vibration magnitude for second level structures that are used as input for the PSD analysis.

	ASD (Acceleration Spectral Density) Level (g^2/Hz)	
Frequency (Hz)	QUALIFICATION	ACCEPTANCE
20	0.026	0.013
20-50	+6 dB/ oct.	+6 dB/ oct.
50-800	0.16	0.08
800-2000	-6 dB/ oct	-6 dB/ oct
2000	0.026	0.013
overall	14.1 Grms	10.0 Grms

And the components have to be corrected for unit mass as follows:

	ASD (g^2/Hz)	Comments
dB reduction	=10 log(W/22.7)	For protoflight
ASD (50-800 Hz)	=0.16 (22.7/W)	For acceptance
ASD (50-800 Hz)	=0.08 (22.7/W)	
The slopes shall be maintained for +/-6 dB for component weighting up to 59 kg. Above that weight the slope shall be adjusted to be an ASD level of 0.01 g^2/Hz at 20 and 2000Hz.		