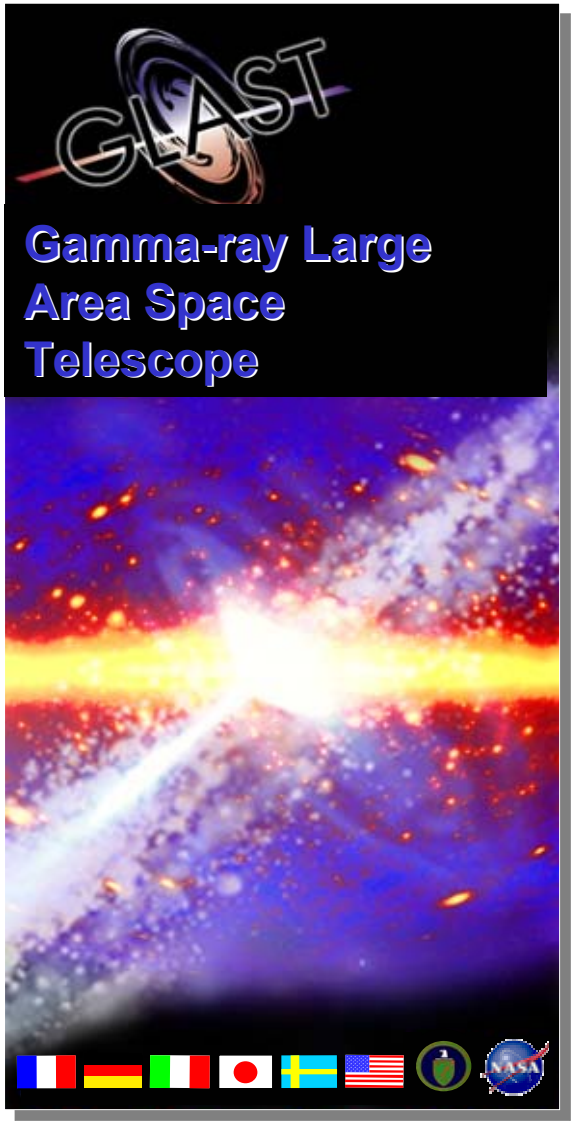

GLAST Large Area Telescope:

Calorimeter Overview
WBS 4.1.5

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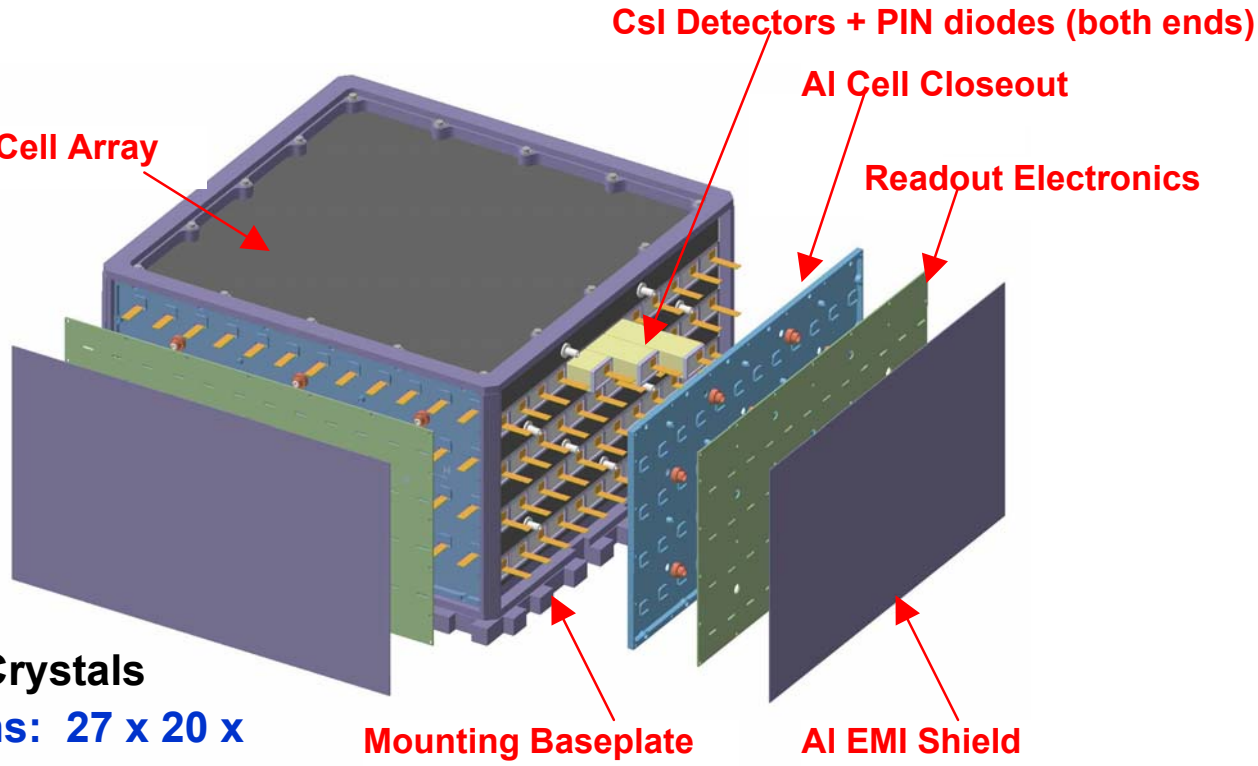
Outline

- Overview
- Level III Requirements Summary
- Heritage
- Status
- WBS Interfaces
- Schedule Milestones
- Cost Plan

Calorimeter Module Overview

Modular Design

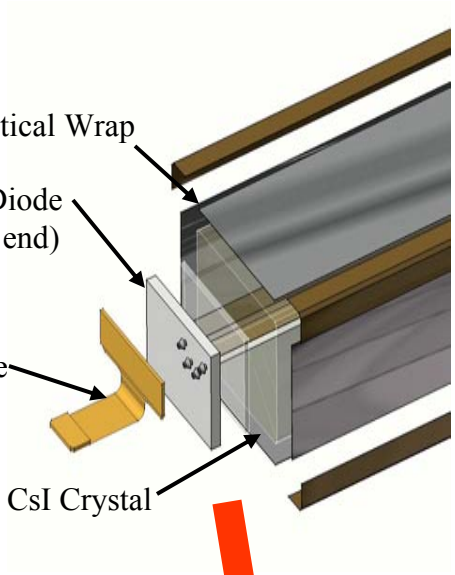
4 x 4 array of calorimeter modules



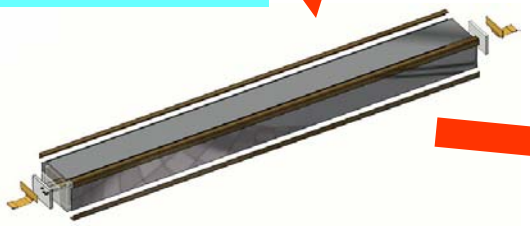
Each Module

- 8 layers of 12 CsI(Tl) Crystals
  - Crystal dimensions: 27 x 20 x 333 mm
  - Hodoscopic stacking - alternating orthogonal layers
- Dual PIN photodiode on each end of crystals.
- Mechanical packaging – Carbon Composite cell structure
- Electronics boards attached to each side.
- Electronic readout to connectors at base of calorimeter.
- Outer wall is EMI shield and provides structural stiffness as well.

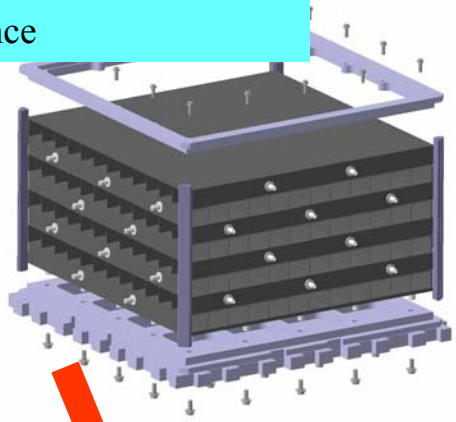
Calorimeter Production Overview



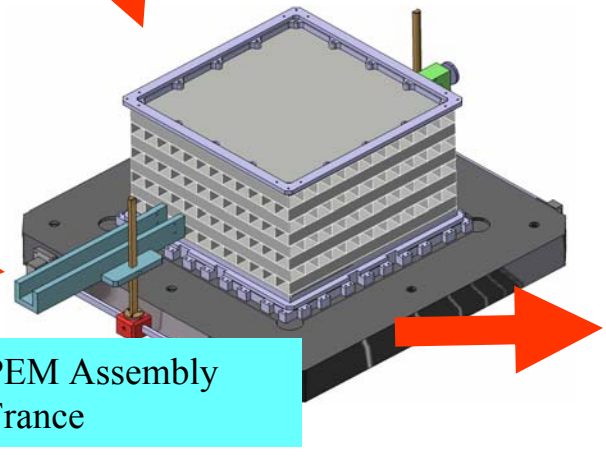
CDE Assembly
France



Mechanical Structure
France

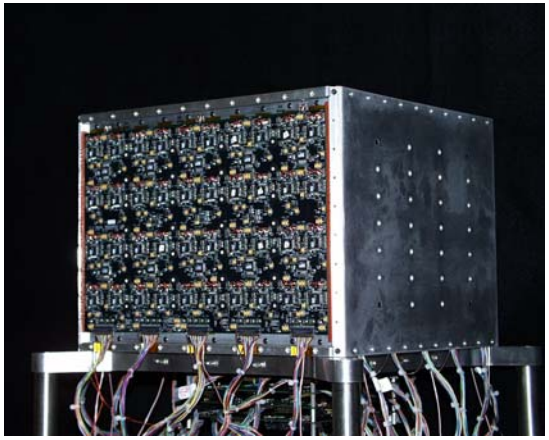


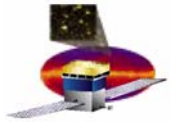
PEM Assembly
France



Front End Electronics
NRL, SLAC

Module Assembly
and Test, NRL





CAL Level III Requirements

Reference: LAT-SS-00018

Parameter	Requirement	Verification	Expected Performance
Energy Range	20 MeV – 300 GeV 20 MeV – 1 TeV (goal) 5 MeV – 100 GeV, single crystal	Simulation, Beam Tests	Required performance ~2 MeV threshold (BOM)
Energy Resolution (1 sigma)	< 20% (20 MeV < E < 100 MeV) < 10% (100 MeV < E < 10 GeV) < 6% (10 GeV < E < 300 GeV, incidence angle > 60 deg)	Simulations and EM and LAT calib unit Beam Tests	Simulations demonstrate required performance
Energy Resolution (1 sig) Single Crystal	< 2% for Carbon Ions of energy >100 MeV/nuc at a point.	EM (and Calib Unit) beam test	< 0.5% (correlation of ends removes Landau)
Design	Modular, hodoscopic, CsI > 8.4 RL of CsI on axis	Inspection	> 8.5 RL
Active Area	>1050 cm^2 per module < 16% of total mass is passive mtrl.	Inspection	>1100 cm^2 per module
Position Resolution	< 3 cm in 3 dims, min ionizing particles, incident angle < 45 deg.	Test with cosmic muons, all modules	< 1.75 cm in longitudinal measurement
Angular Resolution	15 × cos(θ) deg, for cosmic muons in 8 layers	Test with cosmic muons, all modules	8.5 × cos(θ) deg
Dead Time	< 100 μs per event < 20 μs per event (goal)	Test	< 19 μs per event

CAL Level III Requirements (cont)

Parameter	Requirement	Verification	Expected Performance
Low Energy Trigger	>90% efficiency for 1 GeV photons traversing 6 RL of CsI < 2 μs trigger latency	Simulations	> 93% < 1 μs
High Energy Trigger	>90% efficiency for 20 GeV photons depositing at least 10 GeV < 2 μs trigger latency	Simulations, Calib unit test in beams	> 91% < 1 μs
Size (module)	< 364 mm in width (stay clear) < 224.3 mm in height (stay clear)	Inspection	363 mm 224 mm
Mass	< 1492 kg (93.25 kg/module)	Test	< 1476 kg
Power	< 91 Watts (conditioned) (5.69 W/module)	Test	< 67 Watts (conditioned)
Temperature Range	– 10 to +25 C, operational – 20 to +40 C, storage – 30 to +50 C, qualification	Subsystem TV Test, 4 cycles	Required performance
Reliability	> 96% in five years	Analysis	> 99% in five years (15/16 modules) LAT-TD-00464-01

Calorimeter Heritage

- CsI Detector Systems in Space
  - 1970's – HEAO 1 & 3 (CsI (Na))
  - 1990's – CGRO OSSE (CsI (Na))
  - 2002 – Integral IBIS (CsI(Tl)+PIN diodes)
- CsI Calorimeters in High Energy Physics
  - B-Factory experiments at Cornell, SLAC and KEK
- GLAST LAT Experience (NASA ATD Program)
  - 1996 16 crystal prototype in SLAC beam test
  - 1997 24 crystal hodoscopic prototype in SLAC beam test
  - 1998 2 beam tests – MSU (heavy ions) and CERN (muons)
  - 1999 CERN beam test
  - 1999 – 2000 full sized (80 crystal) hodoscopic prototype w/ flight-like electronics (BTEM CAL) in LAT tower beam test at SLAC
  - 2000 GSI beam (heavy ions – C, Ni) BTEM CAL
  - 2001 Balloon Flight of the BTEM CAL

Feb 2001 Review Recommendation Status

- **Sign and implement international agreements**
  - Drafts exist of MoA among participating laboratories and of NASA-CNES International LoA.
  - MoA has been updated by US and French participants. Successful PRR should permit French signatures.
- **Organize French efforts and commitment to roles and responsibilities**
  - Done. Documented in MoA and WBS.
- **Develop bottoms up resource-loaded schedule**
  - Done. Delivered to PMCS on 7/20/01. Revisions completed 11/21/01
- **Update the cost estimate and assign adequate contingency**
  - Bottoms up costing completed. Contingency analysis is complete. Carrying 23% contingency on remaining US CAL work.
- **Resolve PIN diode glue problems**
  - Resources have been applied. Test and selection program identified. Backup solution identified. Testing of prime candidate is complete.
- **Define responsibilities for procurement, qualification and testing of ASICs**
  - Done. SLAC designs and tests prototypes. NRL does the rest.

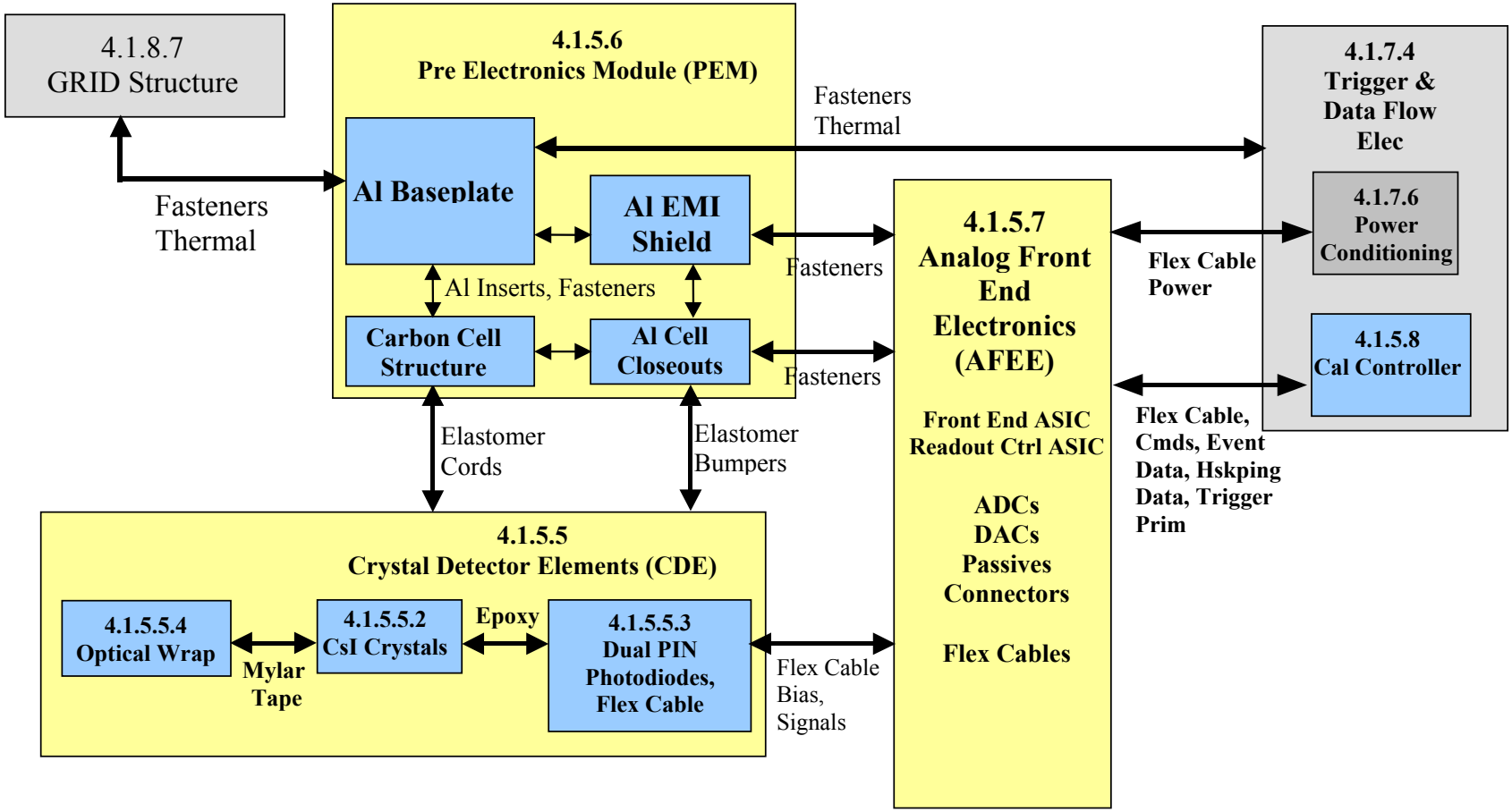
Calorimeter Hardware Status

- Specification and procurement of CsI crystals is in place.
  - 130 crystals have been received and tested.
  - Flight crystals are included in the existing contract
- Specification and procurement of dual PIN photodiode prototypes is complete
  - 400 photodiodes have been received.
  - Spec for flight units is in development.
- A bonding analysis program has been completed on requirements for materials to be used to bond the PIN photodiodes to the CsI crystals.
  - Simulations studied stresses caused by CTE differences
  - Various epoxies and elastomers were tested in up to 100 thermal cycles
  - Prime candidate bonding material, DC93-500 - a silicone elastomer, will be submitted to materials review process
- CsI crystal wrapping materials have been investigated.
  - Prime candidate material, VM2000 specular reflector film from 3M, will be submitted to materials review process
- Prototype (VM2) mechanical structure design and tooling has been completed
  - VM2 has been assembled and is undergoing testing
  - The same tooling will be used to fabricate the Engineering Model
  - Slight modifications are expected for flight units

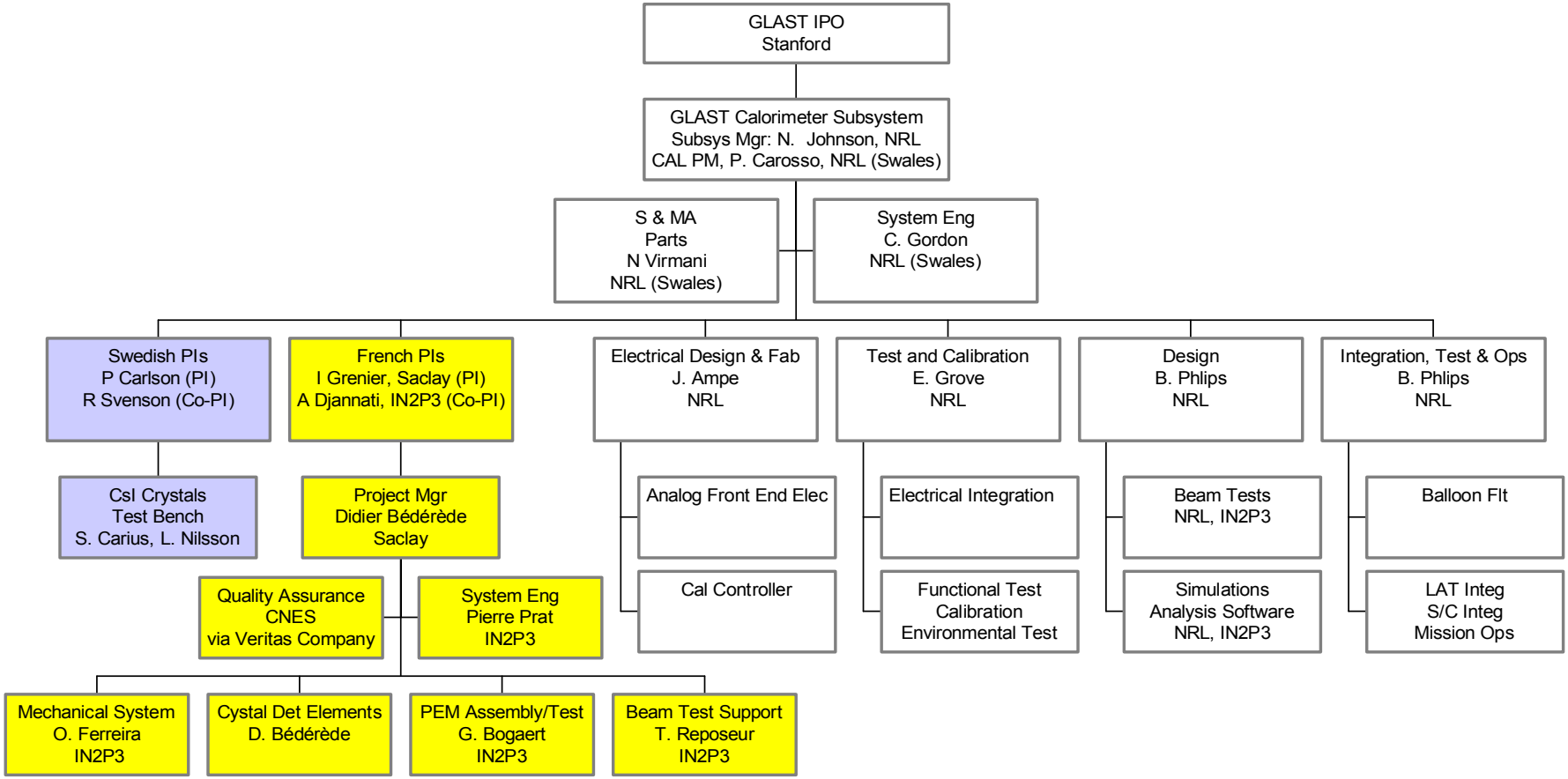
Calorimeter Hardware Status (cont)

- CAL Analog ASIC (GCFE) prototype with complete flight-model functionality and interfaces is being tested
  - Performance testing at SLAC and NRL
  - Latchup testing completed at NRL
- CAL digital ASIC (GCRC) first submission occurred Dec 2001
  - Simulations and FPGA implementation used in verifying functionality.
- Commercial off-the-shelf (COTS) ADCs, DACs, voltage references and opamps have been tested for radiation susceptibility – latchup and single event upsets – using laser probing at NRL and heavy ion beams at Brookhaven.
- CAL analog front end electronics boards (AFEE) have been prototyped
  - GCFE test board controls single GCFE. Used for performance testing, ADC interface and radiation susceptibility testing
  - Verification model (VM) AFEE contains complete row of GCFE and a GCRC readout controller. Xilinx FPGA version of GCRC is being used in current testing. It will be replaced when GCRC ASIC is delivered.
- Preliminary CAL FMEA Analysis
  - reliability of 0.998 for 15/16 fully functional models
  - reliability of 0.94 for 16/16 partially functional models

CAL Subsystem & External Interfaces



Calorimeter – Institutional Organization



Calorimeter Level III Milestones

Calorimeter Subsystem Requirements Review	03/28/01
Calorimeter PDR	07/27/01
VME Com Card (TEM Sim)-from Elec to CAL	11/05/01
VM Versions of CAL AFFE-CAL to Elec	04/12/02
Calorimeter CDR	06/05/02
Pre-EM TEM-from Elec to CAL	06/14/02
CAL AFFE Engr Model-CAL to Elec	08/01/02
Sub System Production Readiness Review-CAL	02/21/03
Sub System Qual Readiness Review-CAL	03/03/03
(6) EM2 TEM-from Elec to CAL	03/17/03
Calorimeter Modules A & B RFI (for Calibration)	08/15/03
Sub System-CAL RFI's --1st Article	08/15/03

Calorimeter Level III Milestones (cont)

EM from CAL to I&T	08/29/03
Sub System Qual Review-CAL	09/18/03
Calorimeter Modules 1 & 2 RFI (for Calibration)	11/03/03
Flight Calorimeter Tower 3, 4 RFI	01/02/04
Flight Calorimeter Tower 5, 6 RFI	01/15/04
Flight Calorimeter Tower 7, 8 RFI	01/29/04
Flight Calorimeter Tower 9, 10 RFI	02/12/04
Flight Calorimeter Tower 11, 12 RFI	02/26/04
Flight Calorimeter Tower 13, 14 RFI	03/10/04
Flight Calorimeter Tower 15, 16 RFI	03/24/04
Flight Calorimeter Tower 1,2 RFI from I&T to I&T	04/26/04

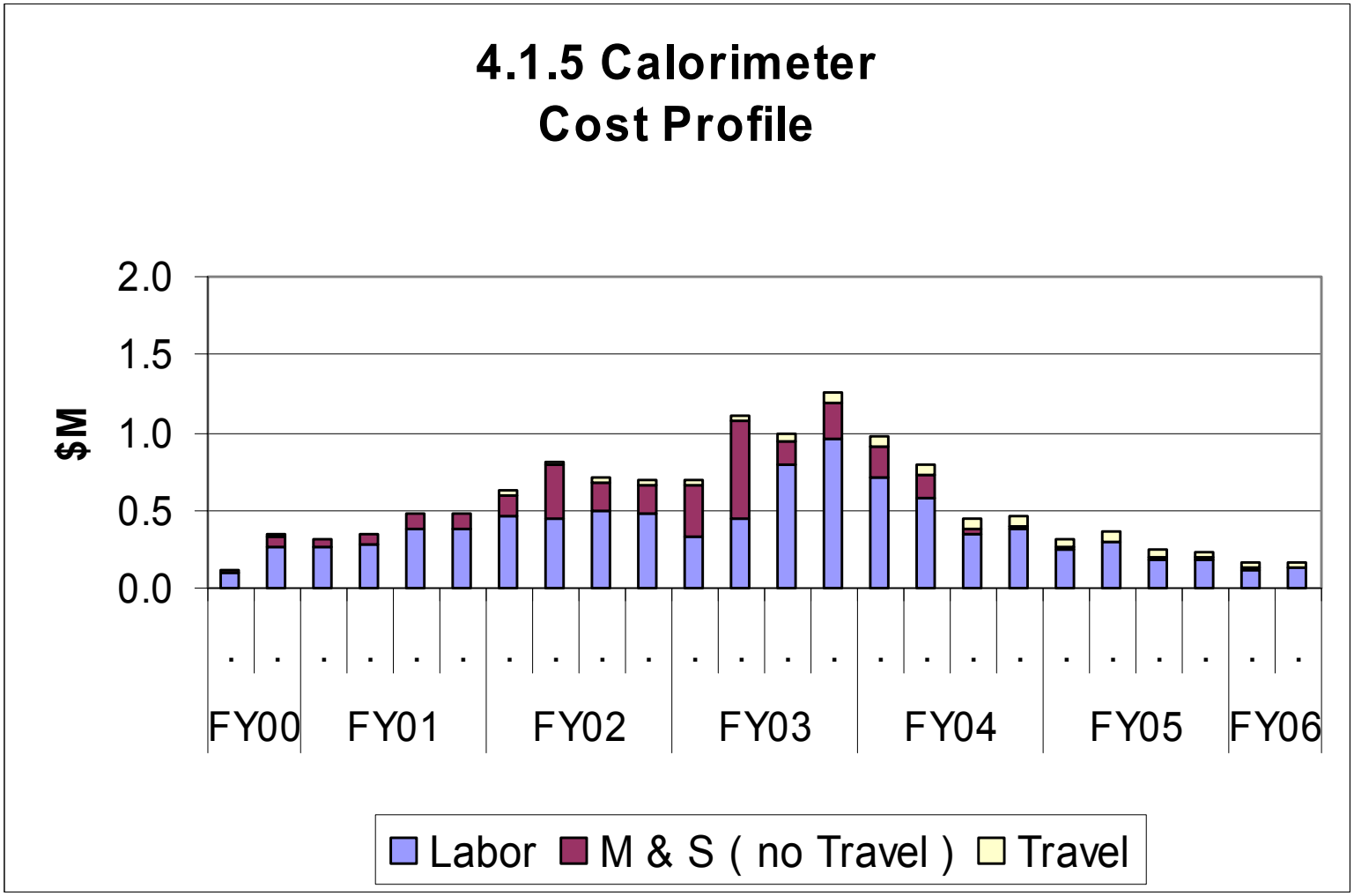
Calorimeter Level IV Milestones

Delivery VM CsI (24) to France	06/12/01
Ratification of PIN-CsI bonding concept	08/14/01
EM CRYSTALS - CsI Delivery to S (106 logs)	09/10/01
VM2 structure ready	09/14/01
VM2 - Last 3 CDE ready for integration	11/19/01
CDE ready for EM assembly	12/21/01
EM start assy	01/10/02
VM2 Testing Complete	01/29/02
GCRC for EM Ready	03/20/02
Shipment of EM PEM to NRL	04/16/02
Flight Diodes order realization	06/19/02
Manufacturing Readiness Review w/ Foreign partners	09/16/02
FM A CDE ready	11/18/02
Digital ASIC Parts Available - Flight	11/27/02
EM Test Program Complete	01/12/03

Calorimeter Level IV Milestones

GCFE ASIC Parts Available - Flight	02/19/03
1st Flight AFEE Boards Ready	04/10/03
FM A Module Comprehensive Functional Test	04/28/03
FM A Preship Review (delivery to SLAC)	06/05/03
Last Flight AFEE Boards Ready	10/16/03

Calorimeter Cost Profile (US)



Calorimeter Cost & Commitments (US)