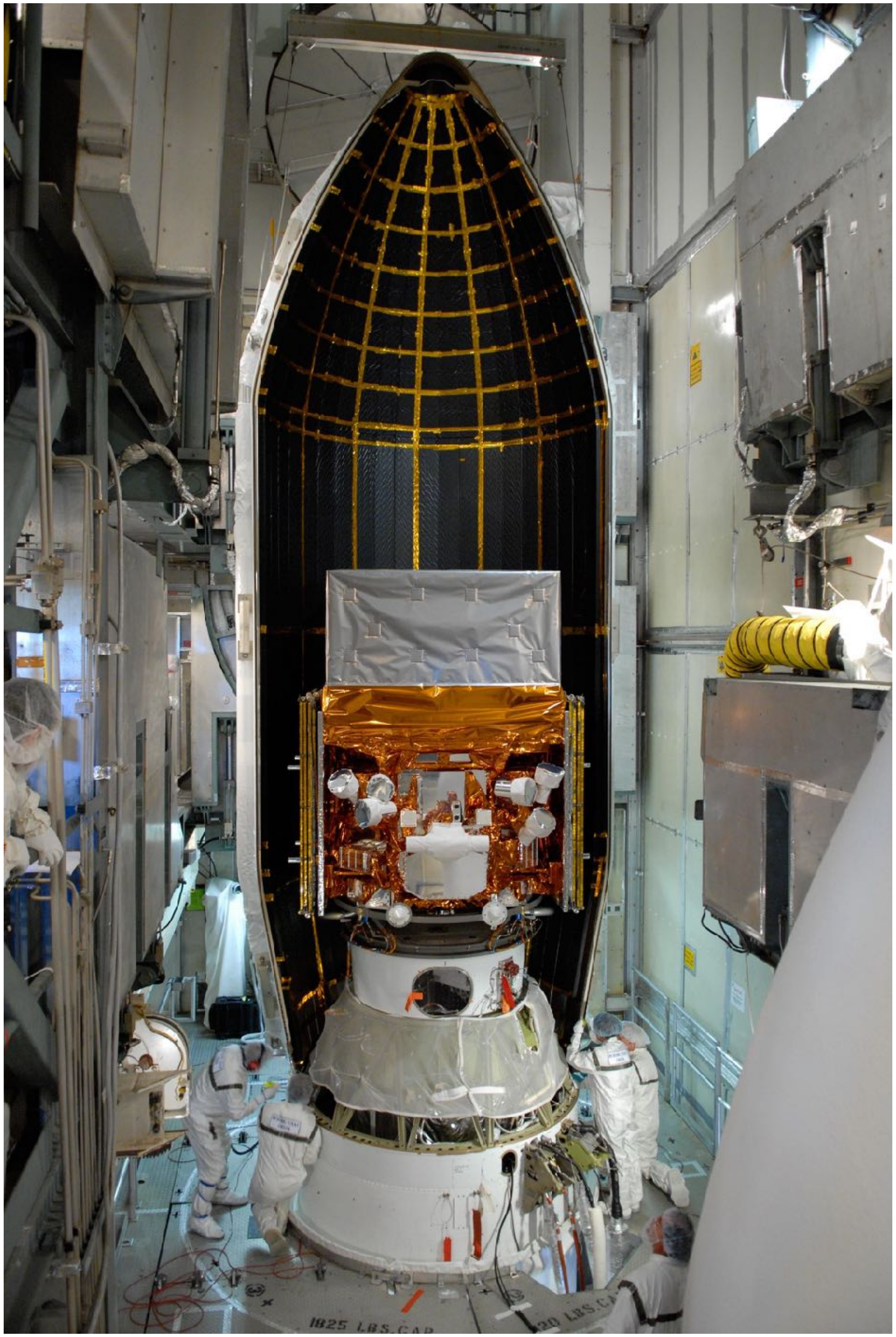


From GLAST to Fermi

J. Eric Grove
Naval Research Laboratory
Fermi LAT Commissioner

History

GLAST

Project History

1992

- SR&T to Stanford collaboration including SLAC and NRL, to study GLAST instrument concept and develop hardware.

1994

- Dr. Peter Michelson at Stanford University (with tam: SLAC, NRL, Internationals) responds to NASA NRA for new mission concepts.

1995

- NASA funds Dr. Michelson team for advanced mission concept study for GLAST; SR&T funds continue for technology research.

1997

- GLAST recognized as a future Space Science Mission per the SEU Science Roadmap and the Space Science Strategic Plan.
- Dr. Alan Bunner requests GSFC to lead an effort better defining GLAST in terms of technical requirements, scope, and cost, and as a partnership with the DoE. Results due in March 1998.
- GLAST conducts a Technology Readiness Review which results in recommendation to NASA to fund a technology development program.

1998

- NASA Research Announcement (NRA) issued 1/98 for GLAST instrument technology development; two (2) instrument teams selected and under contract.
- GLAST appears as a line item in Code S budget with a 2002 new start date.
- GLAST Feasibility Study Report May, 1998; used Silicon GLAST as baseline.
- Mission Concept Review in September.

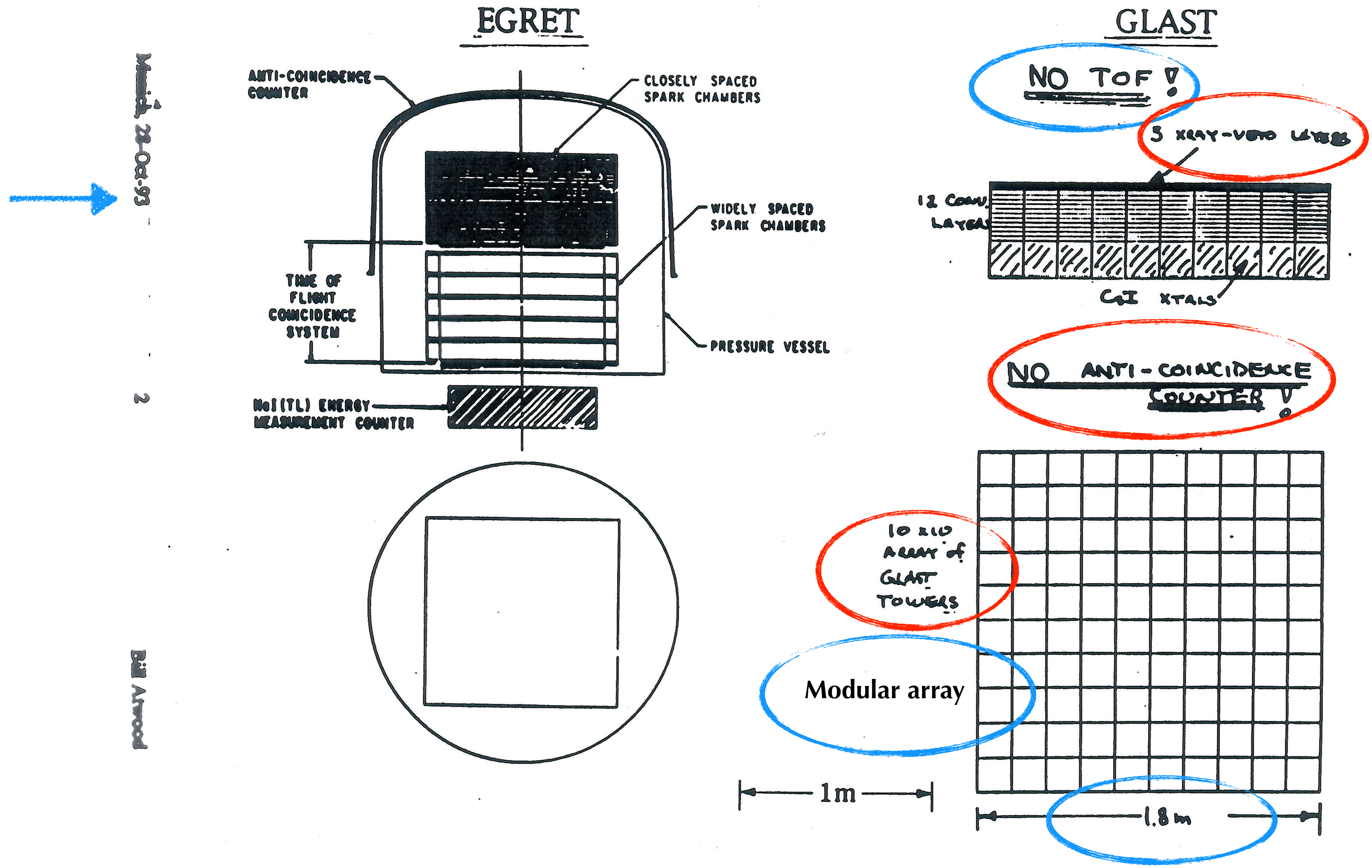
5

S. Lambros Jan 1999

Scott Lambros, GLAST Project Manager, 1999

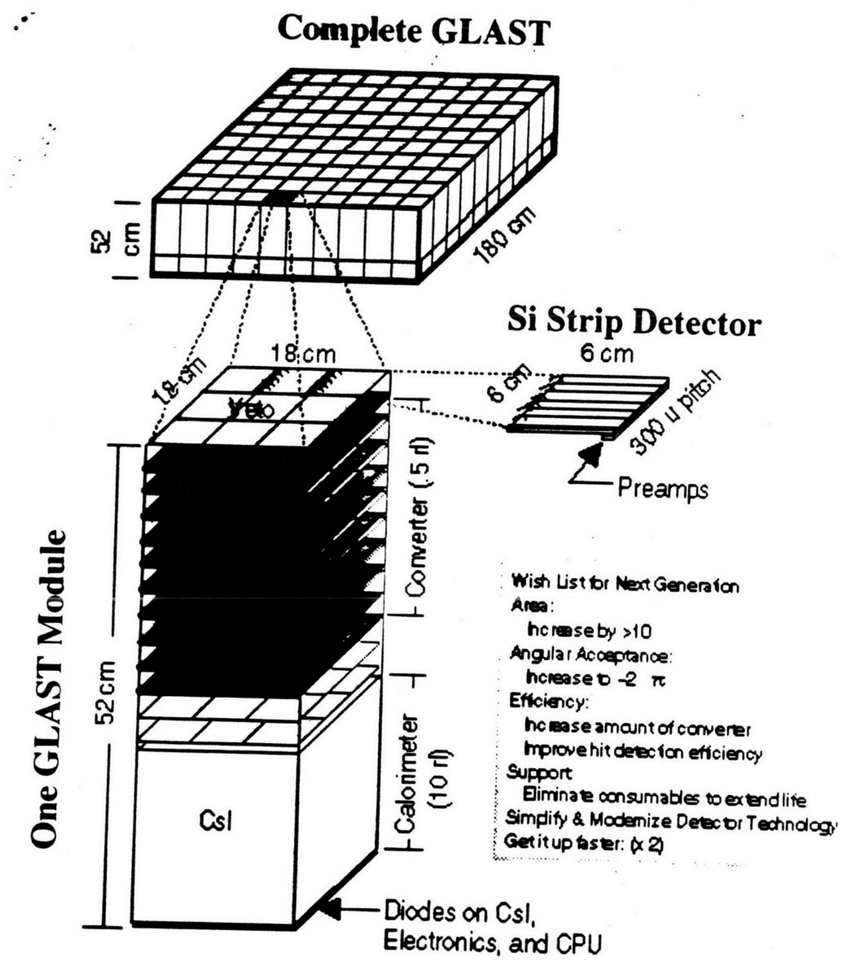
Early history

Didn't change much
Did change



Make it modular

- ✦ Modular design
  - Provides redundancy and soft failure modes
  - Construction and test are more manageable
    - ✦ Reduces cost and schedule risk
  - Early prototypes and tests are on full-scale detector modules
  - Module size is good match with high-energy electromagnetic shower



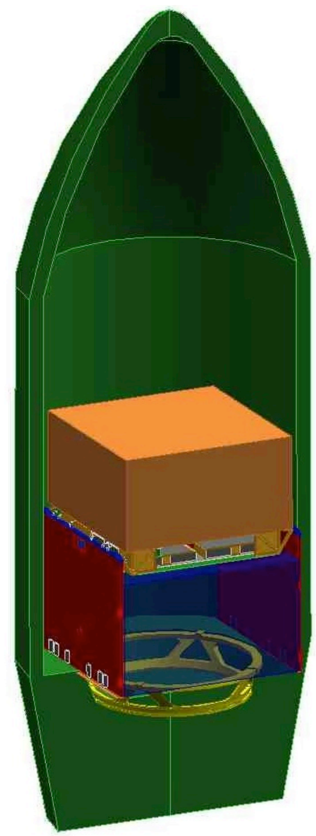
Gamma-ray Large Area Space Telescope (1992)

Size the instrument

- ✦ Pick the launch vehicle

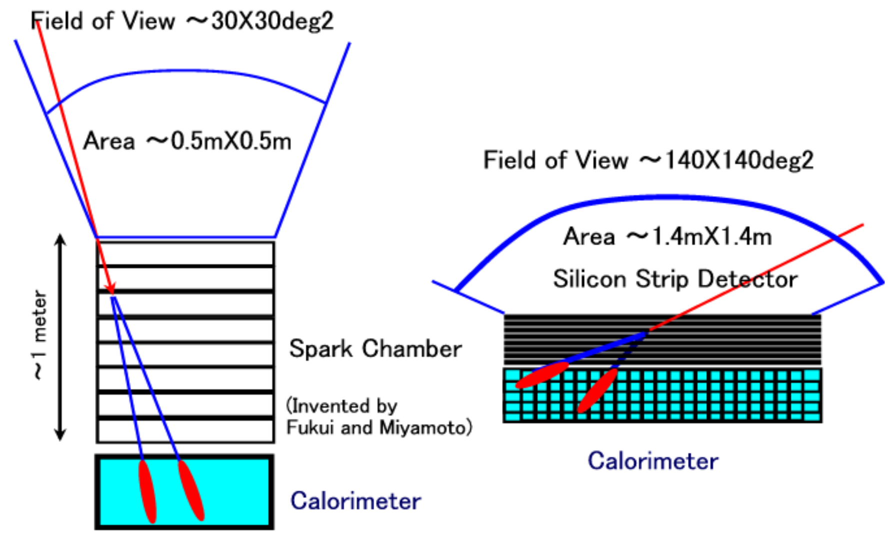
- Delta II (7920/25), reliable commercial launcher
- Relatively cheap (well… ok…)

- ✦ Fill it to capacity
  - Transverse dimensions of LAT constrained by the Delta II fairing diameter
  - Total mass of LAT (i.e. maximum depth of Calorimeter) constrained by 4700 kg payload capacity of Delta II



Design drivers

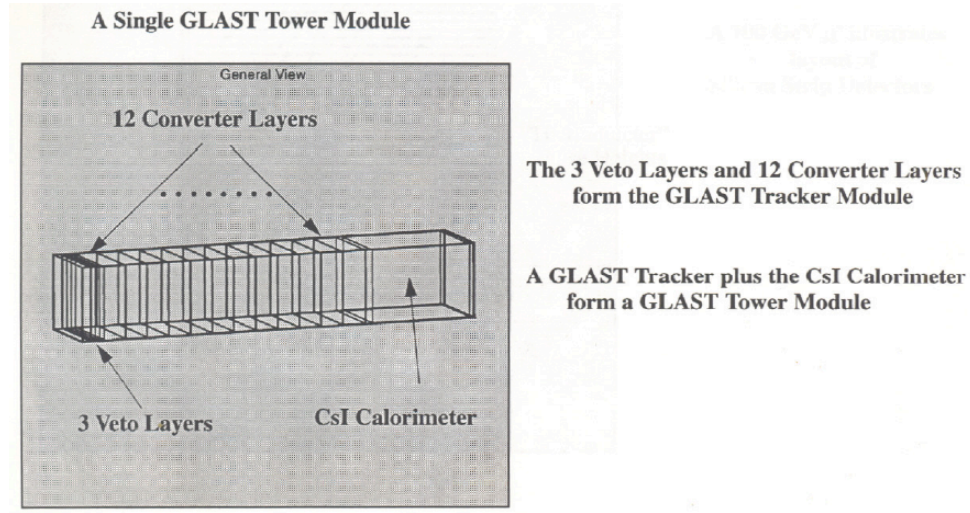
- Size to Delta II payload capacity
  - Instrument mass <3000 kg
  - Maximum transverse size ~1.8 m
- Module size
  - Maximum length of silicon strip detectors read out by single channel of electronics
    - Noise from strip capacitance
- Power < 1000 watts
  - Limit on silicon strip detector channel count, maximum number of tracking layers
- Mass < 3000 kg
  - Adjust depth of calorimeter
  - Minimum depth 10 radiation lengths



- Large field of view
  - Zenith-pointed, sky-survey instrument
  - Cover large fraction of sky each orbit
- Energy reach
  - 20 MeV to 300 GeV (and more)
- Event dead time
  - <100 us requirement

Keys to success: Simulation

Within one day of first GLAST concept,
Monte Carlo was set up



- ✦ Design by Monte Carlo
  - Gamma and particle background rates and orbital variations
  - Event topologies
  - Communication bandwidths and distributed buffering
  - Trigger modes and trigger rates

Instrument had been through multiple design cycles before flight build

- ✦ Analysis software design
  - Event reconstruction software
  - Event analysis and science software

Analysis software in place as soon as the data arrive

- ✦ Iterate MC based on prototype test data, beam tests, and flight instrument

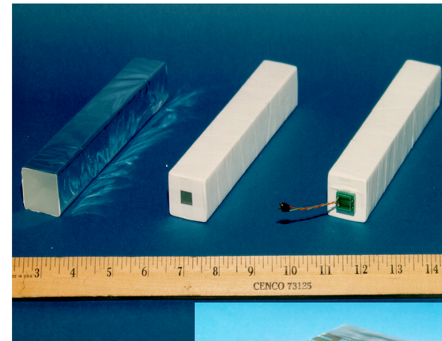
Monte Carlo becomes a second copy of the flight instrument

Calorimeter Concept

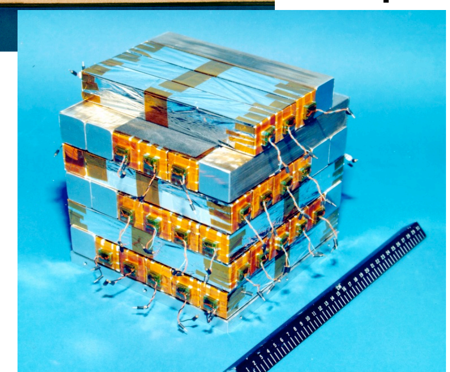
- Calorimeter Concept, or, How we got there from here….
- LAT is modular
  - So CAL is modular
- Active CAL or Sampling CAL?
  - Low E performance rules out sampling
  - Maintain high stopping power for EM showers within the mass budget
- Imaging CAL
  - Energy-profile fitting improves energy resolution
  - Background rejection
  - CAL-only events
- Segmentation
  - Moliere radius is 38 mm
  - Radiation length is 19 mm
  - Bkg rejection requires positioning on same order
    - Xtals have cross section with dimension on this order
    - Xtals give longitudinal positions better than this order

Design Evolution

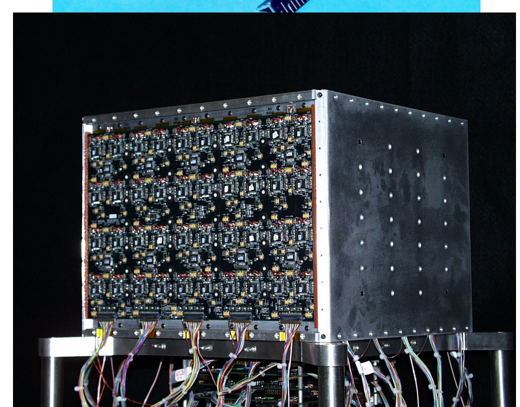
- Sampling calorimeter rejected
- Active CsI calorimeter
  - Initial concept
    - Vertical CsI bars, one PD per xtal
  - 1996 beam test prototype
    - Transverse CsI bars, two PDs per xtal
    - Demonstrated shower energy profiling
  - 1997 beam test prototype
    - Transverse CsI bars, hodoscopic layout
    - Demonstrated good longitudinal position resolution
  - Beam Test Engineering Model (BTEM)
    - Essentially full-size tower (10 xtals x 8 layers)
    - ASIC readout
    - SLAC beam test, GSI beam test, Balloon flight



’96 bars



’97 proto



BTEM

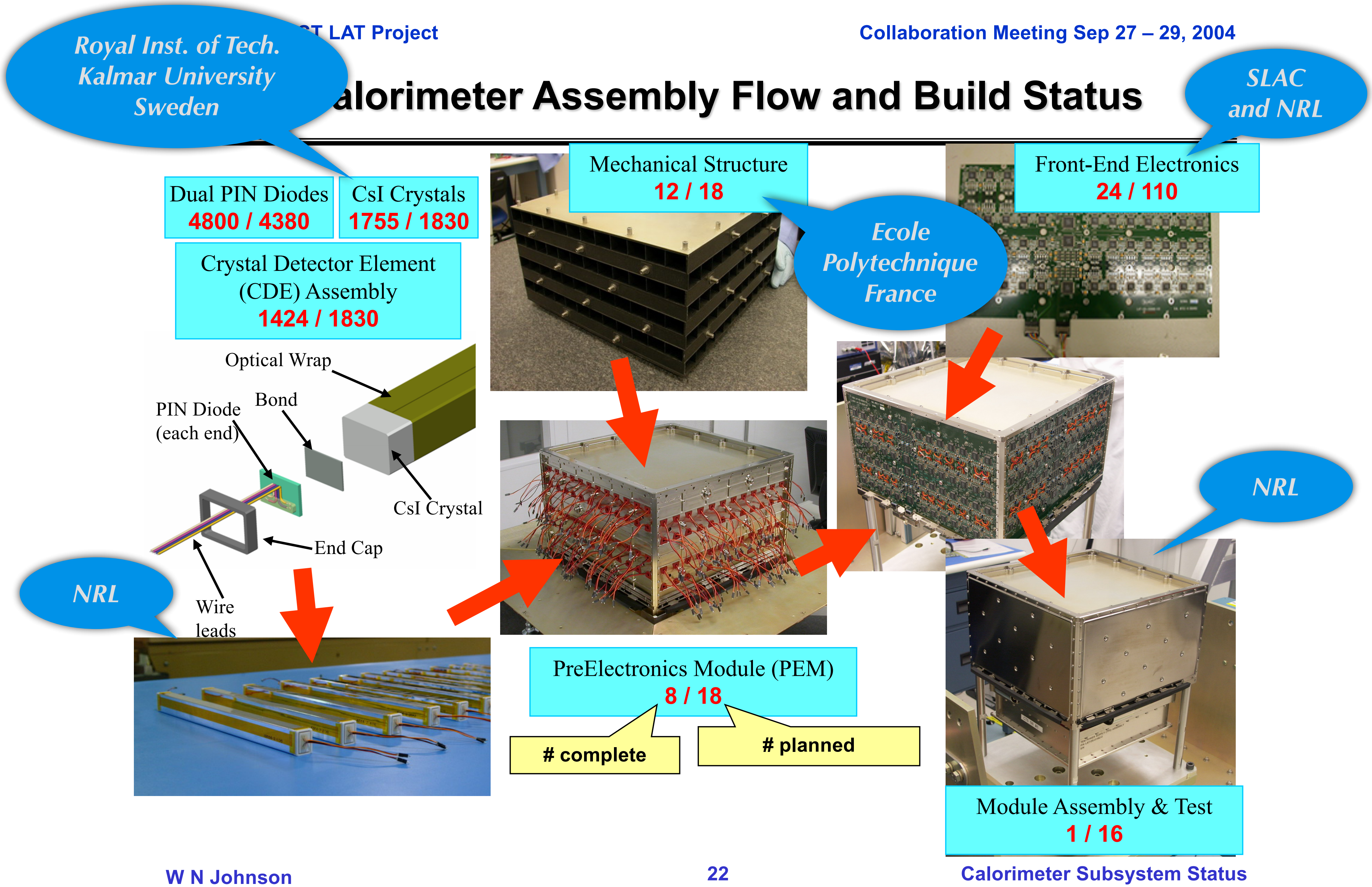
Build engineering models early enough to affect final design

Testing History

- Calorimeter Beam Tests

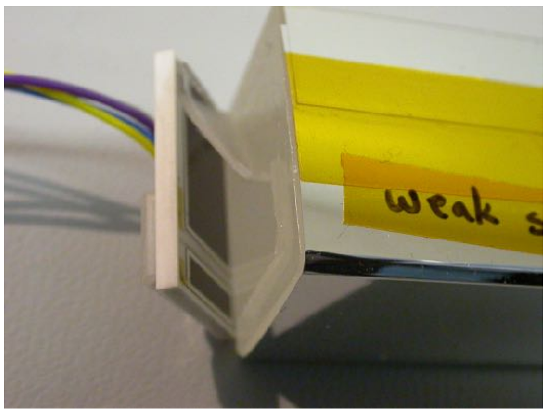
Test	Beams	Instrument	Proof of Concept
SLAC 1996	Photon and e	19-cm xtals on axis	CsI(Tl) with PD readout
SLAC 1997	Photon and e	Hodoscopic 19-cm xtals	Shower profiling Position reconstruction
MSU 1998	H, He, and C at 160 MeV/u	1997 CAL and 31-cm xtals	Crystal mapping with particles
CERN 1998	Photon and e	31-cm xtals	Crystal mapping
SLAC 1999	Photon, e, and p	BTEM calorimeter	Full-size Tower concept, DPD, ASICs
CERN 1999	Photon and e	31-cm xtals	High energy shower profiling
GSI 2000	C and Ni at 400-700 MeV/u	BTEM and 37-cm xtals	Charged-particle identification

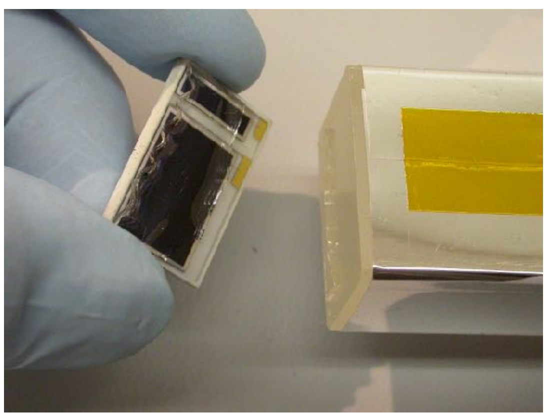
International Calorimeter team



Uh-oh, a problem

Issue at PDR: Diode Bonding



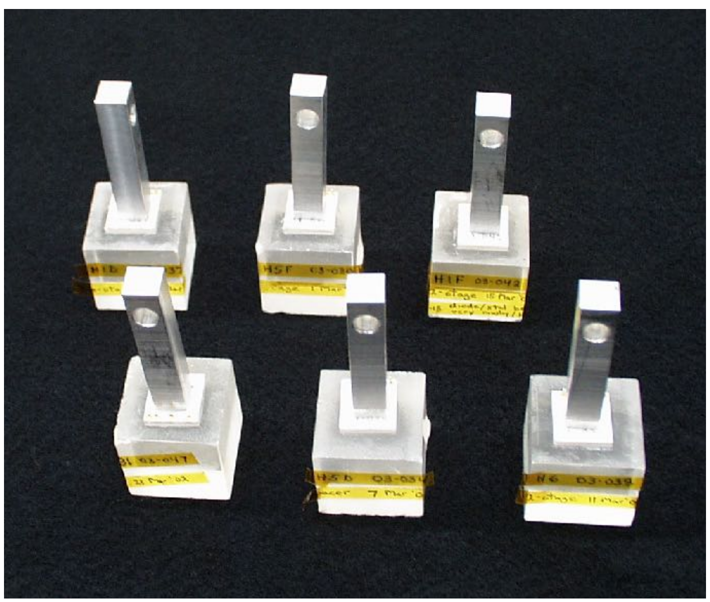


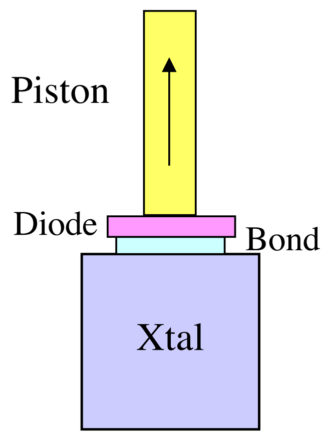
- Need an optical bond between photodiode and CsI
  1. Must be optically clear
  2. Must adhere to CsI
  3. Must be stable against thermal cycling
  - Items 2 & 3 were a problem
    - CsI behaves like "oiled lead"
      - Not all adhesives adhere to it
    - Mismatch between large coef of thermal expansion (CTE) of CsI and small CTE of PD
      - Hard epoxies used in BTEM failed optically
      - Optical waxes used in earlier prototypes would liquify
  - Extensive research program in US and France
    - Soft epoxies, silicones, bonding surface treatments, …
    - Solution: silicone encapsulant with compatible primer
      - Dow Corning DC93-500 with DC92-023
      - Developed bonding process, implemented on EM CAL

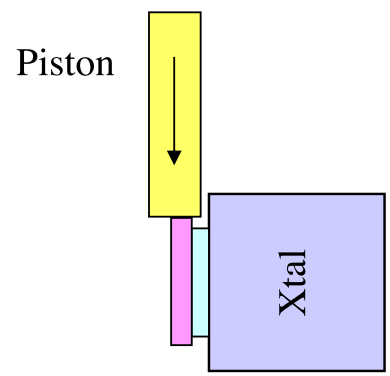
EM Bond: Mechanical Strength Tests

- Two types of destructive tests were performed at NRL
  - Tensile strength requirement
    - 10 N (2.2 lbf)
  - Shear strength requirement
    - 0.12 N/mm^2 (8 lbf = 35 N for EM diode)

- Samples are pulled or sheared to failure in Dynamic Load Test Stand





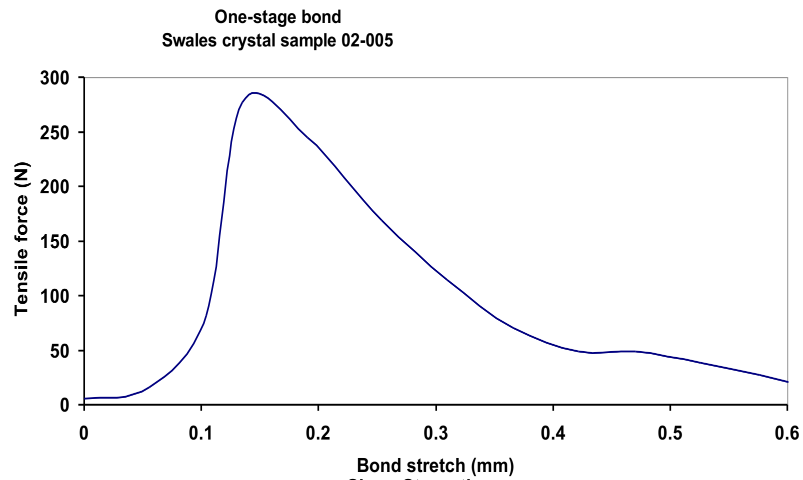


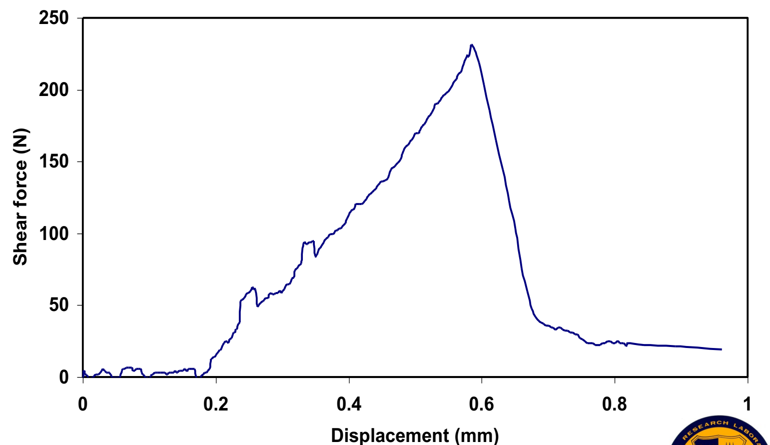
Problem solved

GLAST LAT Project | CAL Peer Design Review, Mar 17-18, 2003

EM Bond: Strength Tests

- More than 65 bonds tested
  - Tensile strength sample
    - Fails at ~280 N
      ➔ 28 x requirement
  - Shear strength sample
    - Fails at ~230 N
      ➔ 7 x requirement
- Typical failures are
  - ~10 x strength requirement
  - At interfaces, rather than in bond material
    - Slightly more likely at diode face
- Adhesion problem with CsI is solved





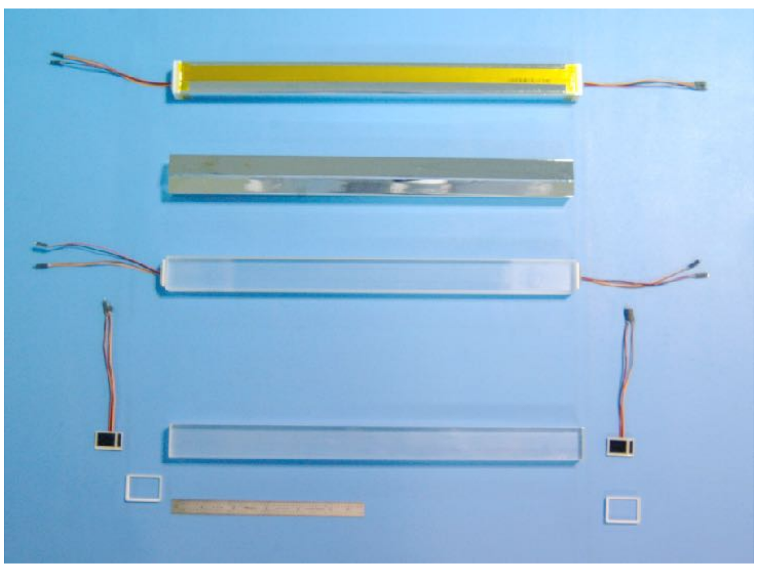
Naval Research Lab
Washington DC

E. Grove 4-28

Calorimeter production line: 1800 crystals to bond

Superb engineers and technicians

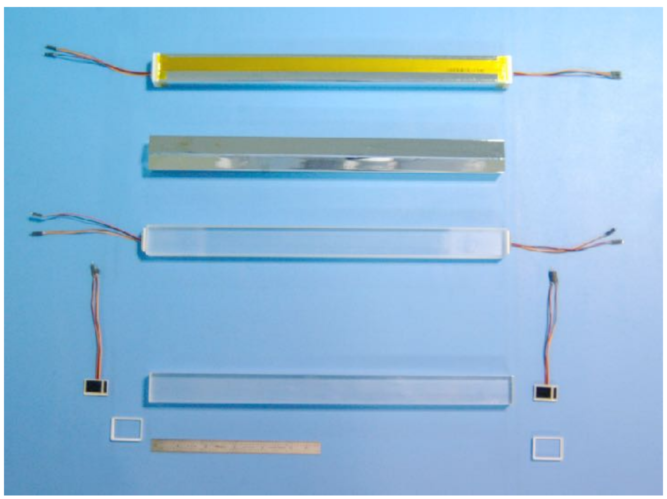
Crystal Detector Elements (CDEs) assembled and tested by Swales Aerospace



CsI(Tl) crystals tested by Kalmar University, Sweden

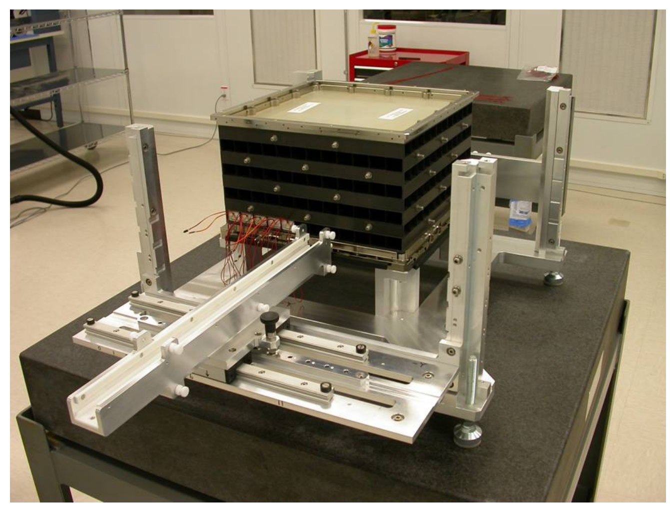
Keys to success

- Experienced hardware groups at core of team from the start
  - Prototyping, beam tests. Build engineering modules early enough to affect flight design
- Active involvement of scientists throughout design, manufacture, and assembly phases
  - Positive tension between engineers ("Simplify") and scientists
- Openness to new collaborators
  - Early concepts and later major collaborators and financial contributions



CsI(Tl) crystal purchase by KTH and testing by Kalmar University

Assembly-line manufacturing of Crystal Detector Elements by Swales Aerospace

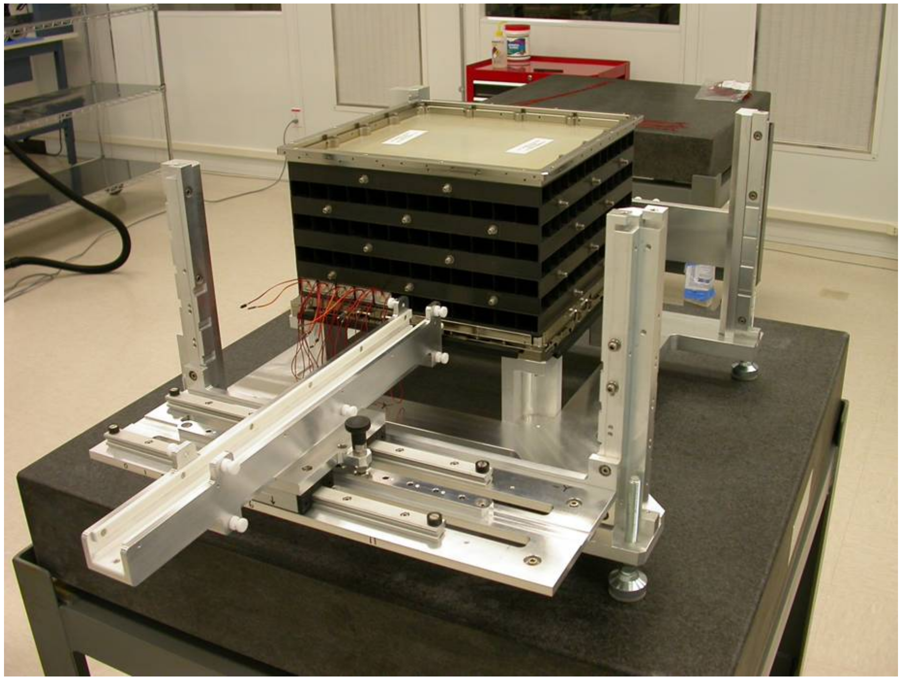


Carbon composite mechanical structure manufactured at LLR, Ecole Polytechnique, Palaiseau, France

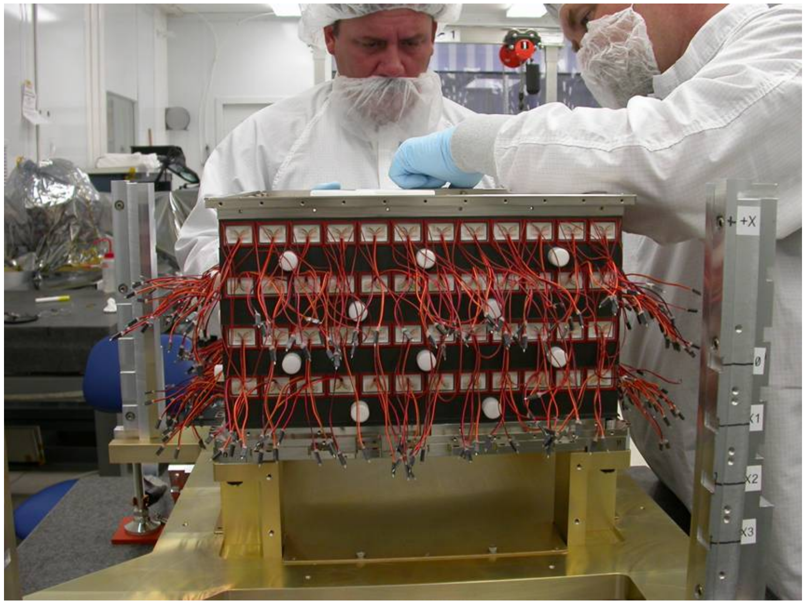
LAT Calorimeter assembly and test at NRL

Superb engineers and technicians

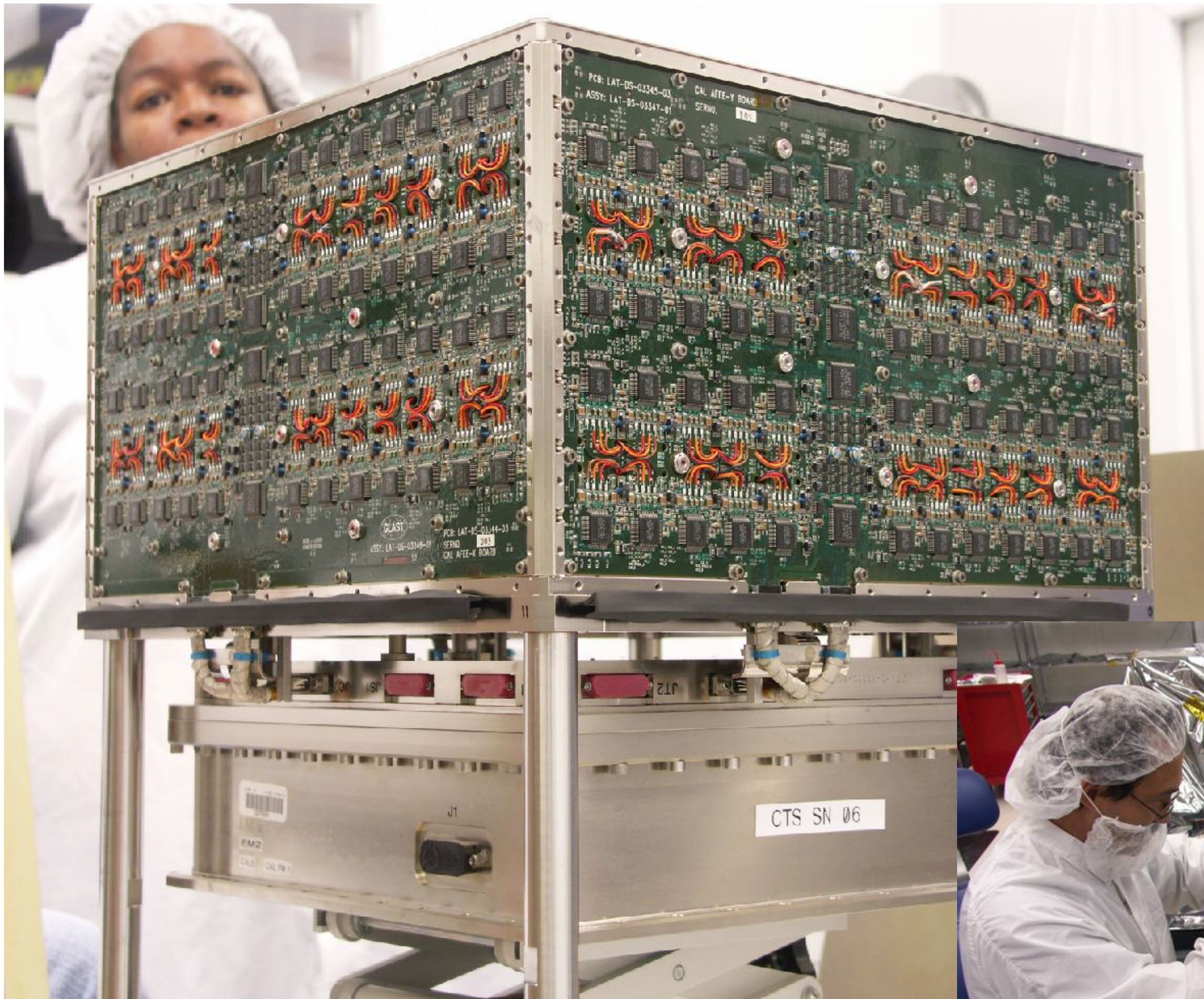
Carbon composite mechanical structure manufactured at
Ecole Polytechnique, Palaiseau, France



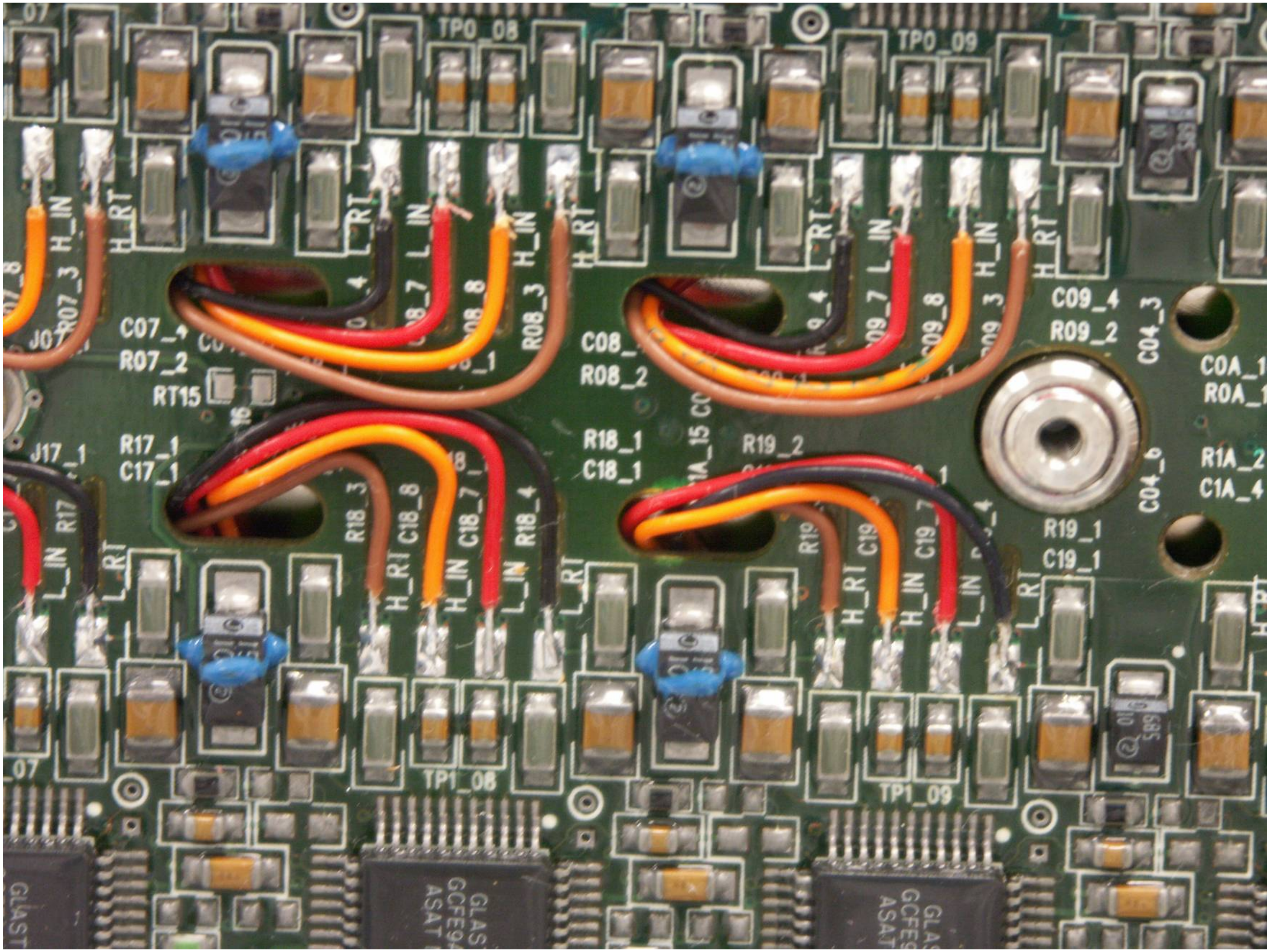
Populating the mechanical structure with CDEs



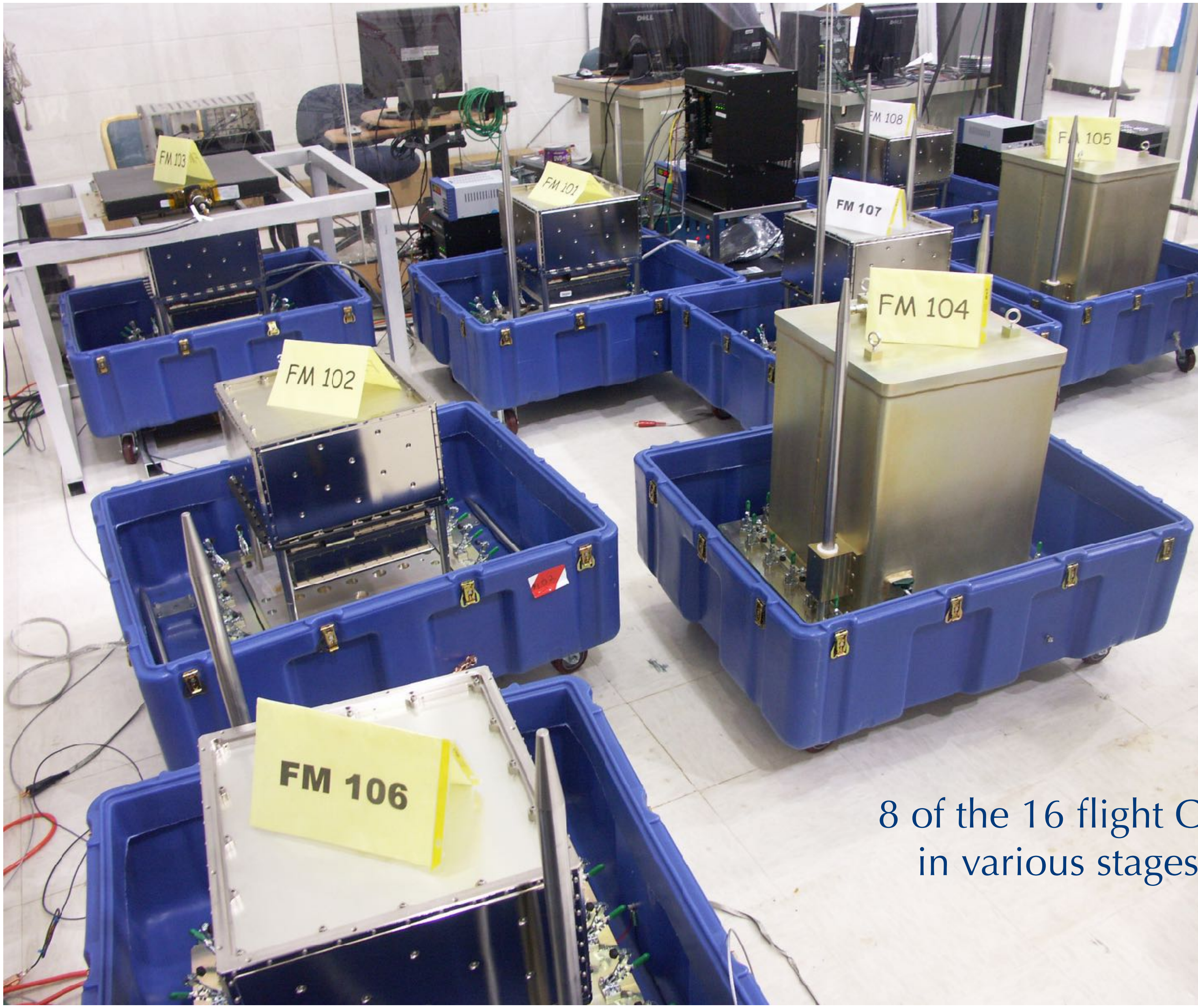
Keys to success: Superb technicians



14,592 of these hand-soldered joints



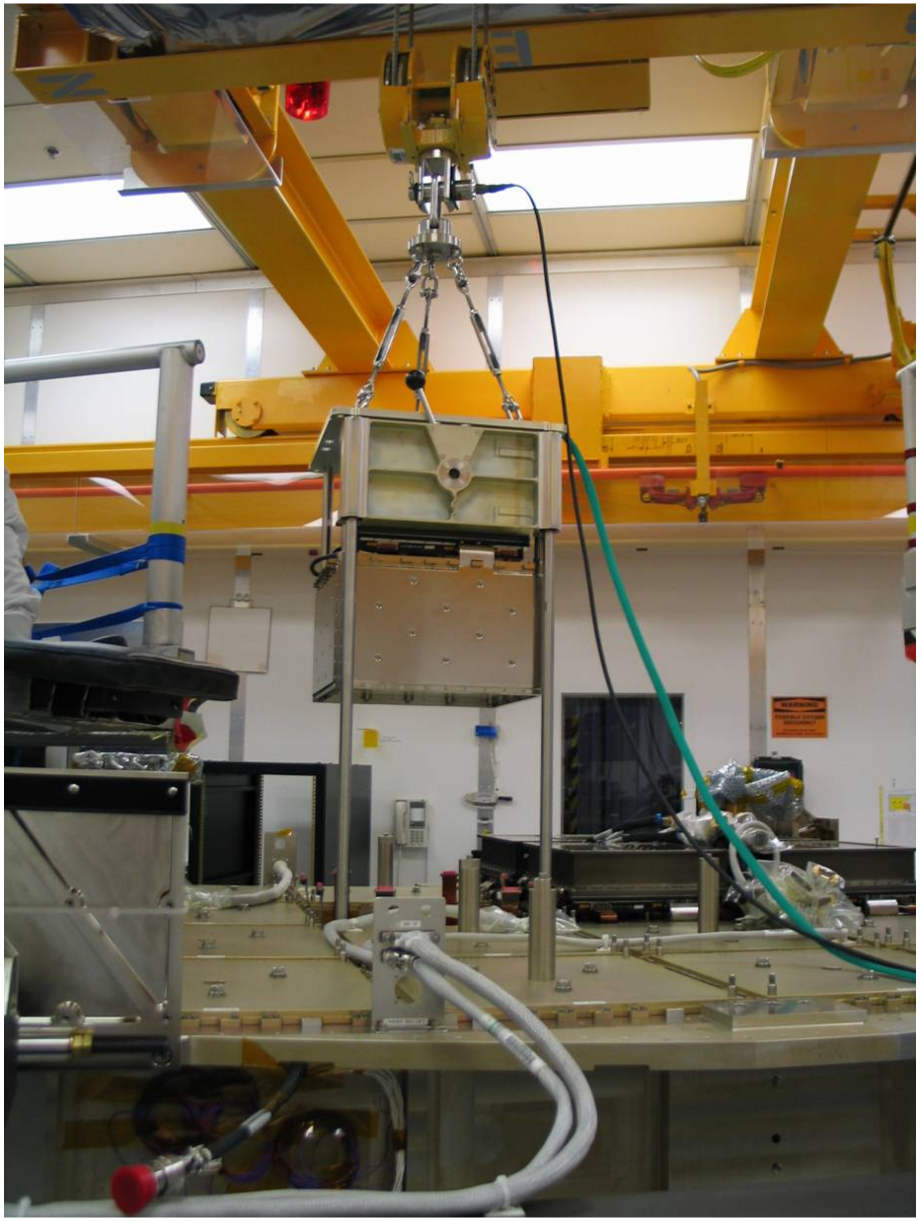
Calorimeter production line

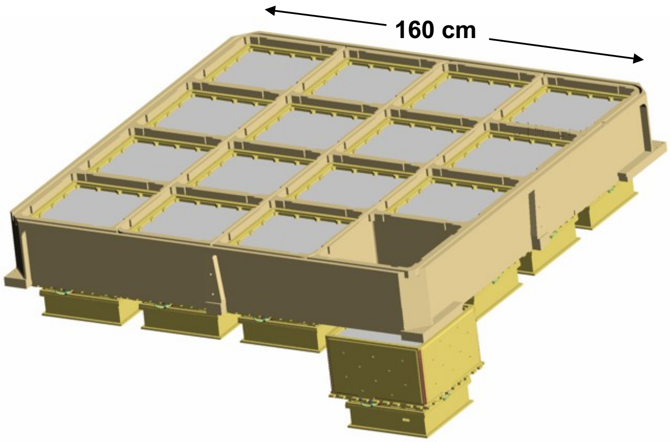


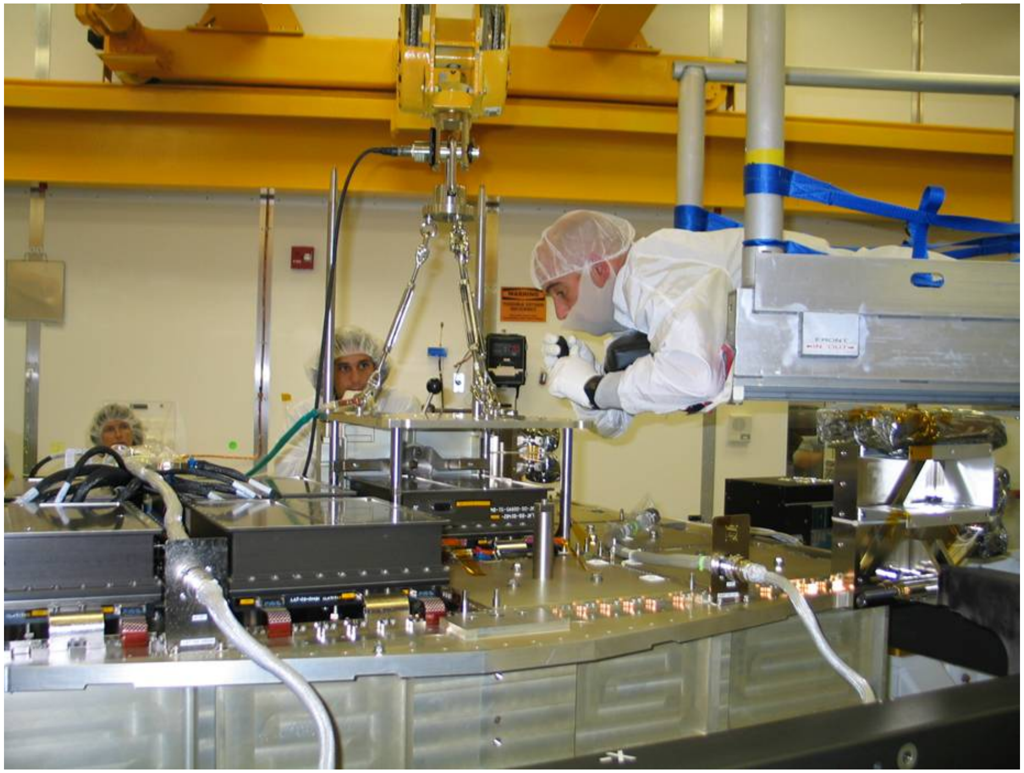
8 of the 16 flight CAL Modules
in various stages of testing

Inserting CAL Module into Grid

LAT Integration at SLAC (2005)







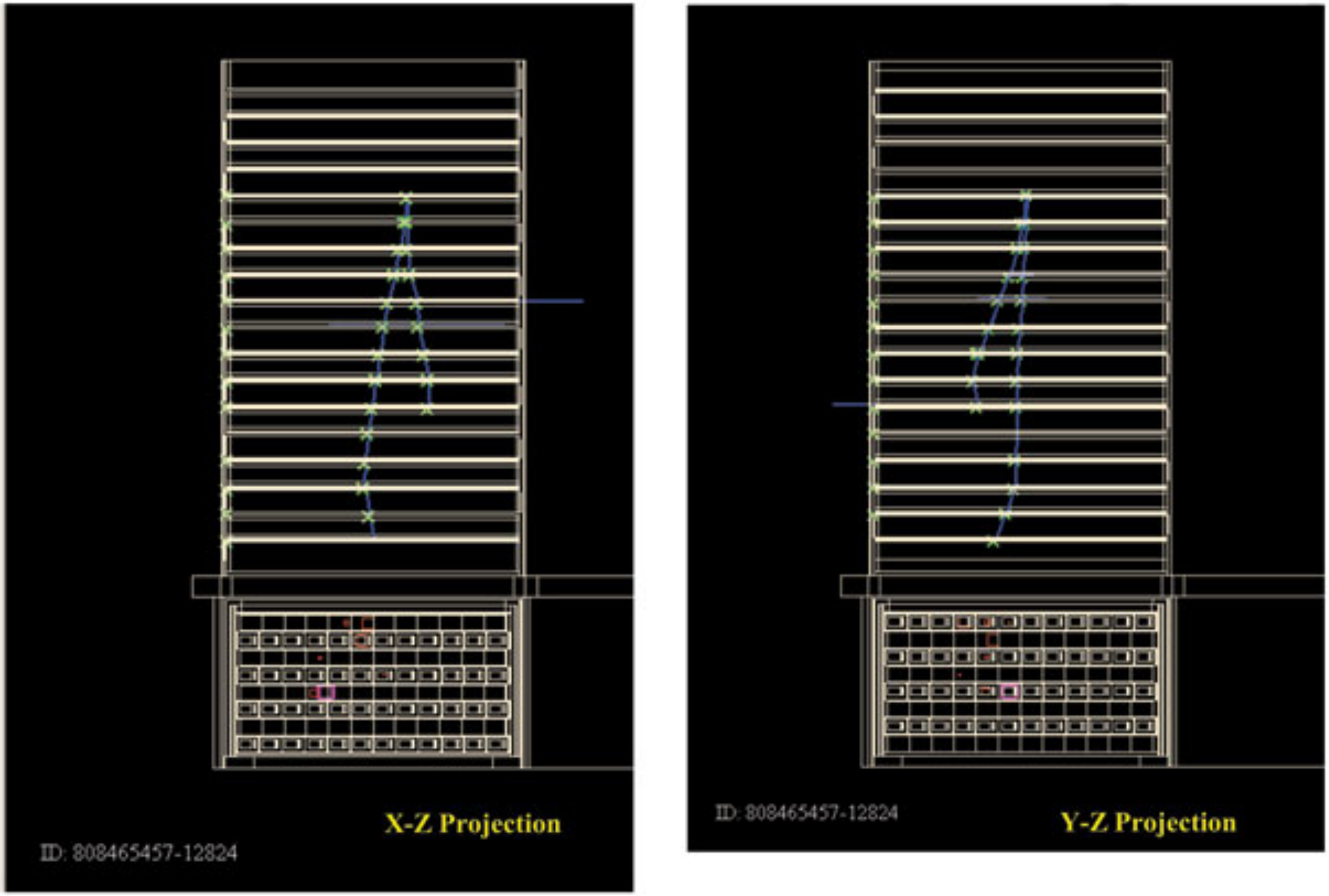
Fermi
Gamma-ray
Space Telescope

Six towers installed. Ten to go.

LAT Integration at SLAC (2005)

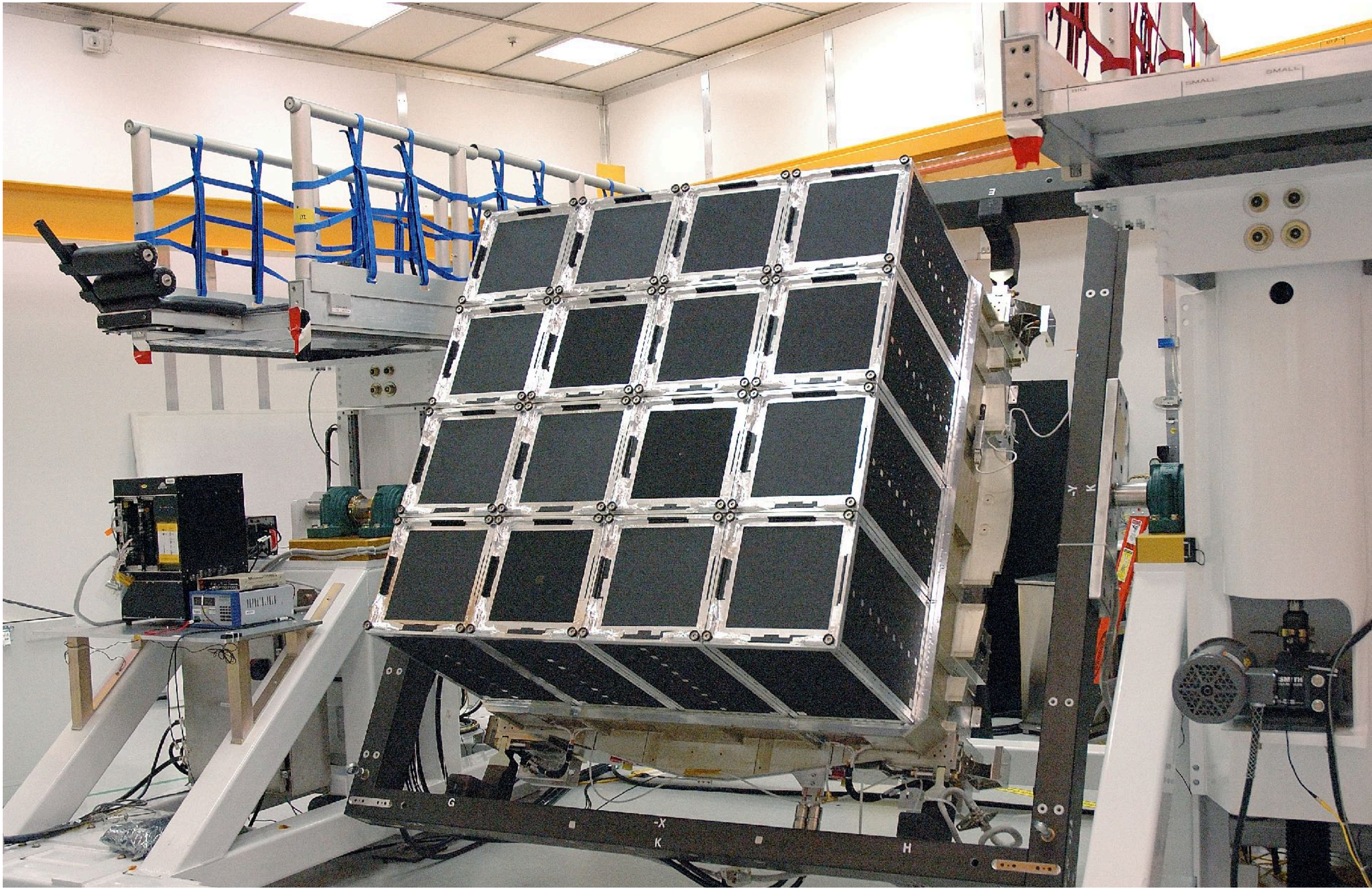
First photon in a LAT tower

Test it early and often. Analysis software is ready to go.



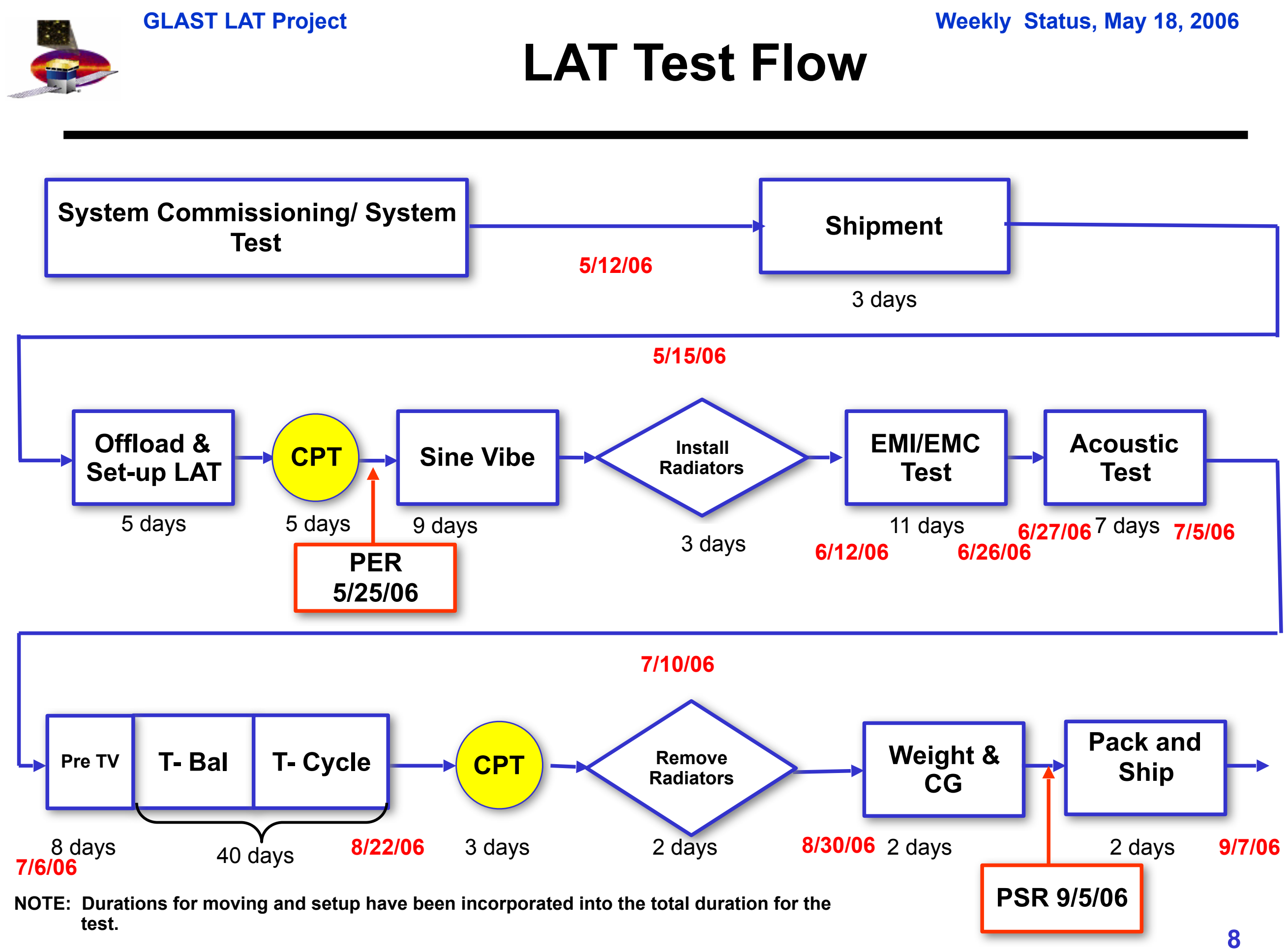
Candidate Gamma-ray Event in 1st LAT Flight Tower

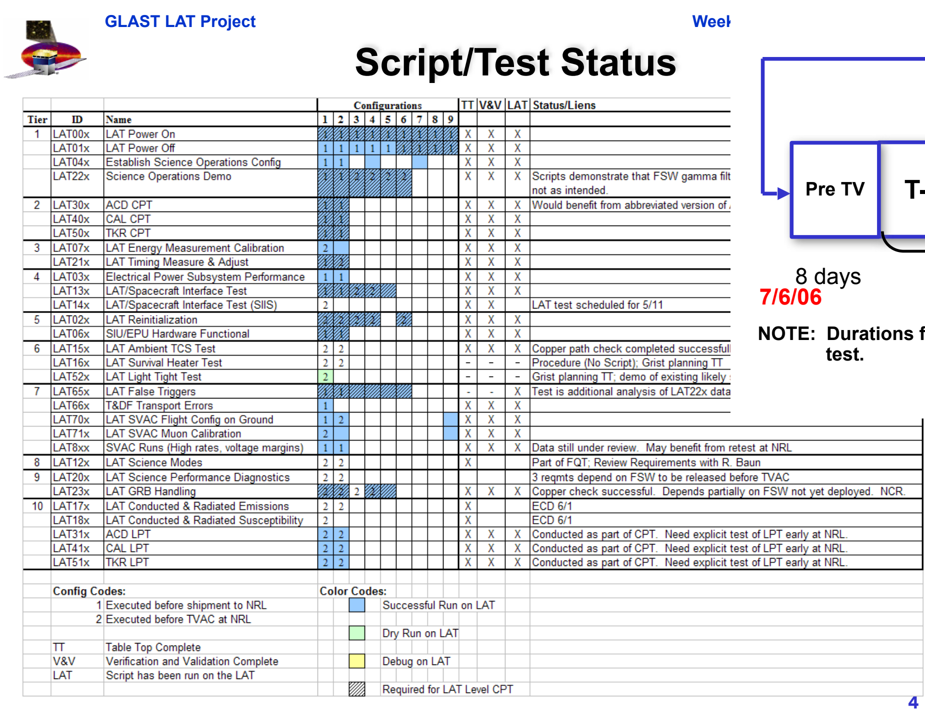
16 towers installed



Commissioning

- ✦ Test, calibrate, verify every requirement
- ✦ Shake it. Scream at it. Bake it. Freeze it.
- ✦ Send every command





			Configurations									TT	V&V	LAT	Status/Liens
Tier	ID	Name	1	2	3	4	5	6	7	8	9				
1	LAT00x	LAT Power On	1	1	1	1	1	1	1	1	1	X	X	X	
	LAT01x	LAT Power Off	1	1	1	1	1	1	1	1	1	X	X	X	
	LAT04x	Establish Science Operations Config	1	1								X	X	X	
	LAT22x	Science Operations Demo	1	1	2	2	2	2				X	X	X	Scripts demonstrate that FSW gamma filt not as intended.
2	LAT30x	ACD CPT	1	1								X	X	X	Would benefit from abbreviated version of
	LAT40x	CAL CPT	1	1								X	X	X	
	LAT50x	TKR CPT	1	1								X	X	X	
3	LAT07x	LAT Energy Measurement Calibration	2									X	X	X	
	LAT21x	LAT Timing Measure & Adjust	1	2								X	X	X	
4	LAT03x	Electrical Power Subsystem Performance	1	1								X	X	X	
	LAT13x	LAT/Spacecraft Interface Test	1	1	2	2						X	X	X	
	LAT14x	LAT/Spacecraft Interface Test (SIIS)	2									X	X		LAT test scheduled for 5/11
5	LAT02x	LAT Reinitialization	2	2	2	2		2				X	X	X	
	LAT06x	SIU/EPU Hardware Functional	1	1								X	X	X	
6	LAT15x	LAT Ambient TCS Test	2	2								X	X	X	Copper path check completed successfull
	LAT16x	LAT Survival Heater Test	2	2								-	-	-	Procedure (No Script); Grist planning TT
	LAT52x	LAT Light Tight Test	2									-	-	-	Grist planning TT; demo of existing likely
7	LAT65x	LAT False Triggers	1	1								-	-	X	Test is additional analysis of LAT22x data
	LAT66x	T&DF Transport Errors	1									X	X	X	
	LAT70x	LAT SVAC Flight Config on Ground	1	2								X	X	X	
	LAT71x	LAT SVAC Muon Calibration	2									X	X	X	
	LAT8xx	SVAC Runs (High rates, voltage margins)	1	1								X	X	X	Data still under review. May benefit from retest at NRL
8	LAT12x	LAT Science Modes	2	2								X			Part of FQT; Review Requirements with R. Baun
9	LAT20x	LAT Science Performance Diagnostics	2	2											3 reqmts depend on FSW to be released before TVAC
	LAT23x	LAT GRB Handling	2	2	2	2						X	X	X	Copper check successful. Depends partially on FSW not yet deployed. NCR.
10	LAT17x	LAT Conducted & Radiated Emissions	2	2								X			ECD 6/1
	LAT18x	LAT Conducted & Radiated Susceptibility	2									X			ECD 6/1
	LAT31x	ACD LPT	2	2								X	X	X	Conducted as part of CPT. Need explicit test of LPT early at NRL.
	LAT41x	CAL LPT	2	2								X	X	X	Conducted as part of CPT. Need explicit test of LPT early at NRL.
	LAT51x	TKR LPT	2	2								X	X	X	Conducted as part of CPT. Need explicit test of LPT early at NRL.

Config Codes:
1 Executed before shipment to NRL
2 Executed before TVAC at NRL

TT Table Top Complete
V&V Verification and Validation Complete
LAT Script has been run on the LAT

Color Codes:
Successful Run on LAT
Dry Run on LAT
Debug on LAT
Required for LAT Level CPT

4

Keys to success: Test, even if you're sure it works

- Absolute time stamps of LAT events
  - How hard can it be to get accurate event times?
  - It isn't as easy as you may think, and many major missions have goofed

Timing failures on 6 missions (1 of 2)

USA (X-rays): The GPS often froze on orbit and had to be reset a few times a day. The satellite would go through GPS beams intense enough to confuse the receivers. Also, the speed of the satellite relative to GPS's was far from the design-regime for ground-based GPS's.

XMM: Two years elapsed before absolute phases were reliable, after a series of 5 different kinds of electronics problems. Proc. SPIE 5165, 85-95 (2004).

INTEGRAL: Orbital inaccuracies due to ground software caused 300 us problems.

CHANDRA: For the HRC, the time stamp of a given event was that of the previous event. On-board filters remove events, so obtaining the right date for a given event was impossible. The solution is to trigger only on the central CCD chip, to reduce the event rate, to allow sending all events to the ground ("timing mode").
S. Murray et al, ApJ 568:226-231 (2002) and references therein.

Timing failures on 6 missions (2 of 2)

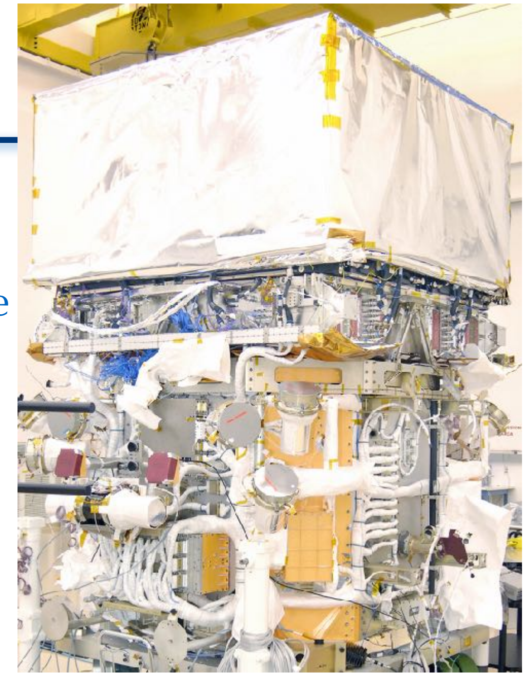
Compton GRO: In the days before GPS. Events were assembled into packets on board, and the packets were grouped into a "major packet", to which a time stamp was afixed. These packets were sent to the ground. But the time stamp was from the preceding packet! And the time was off by over a second.

ROSAT: Excerpt from http://www.mporzio.astro.it/~gianluca/phdthesis/node28.html :
"A problem was…found…timing individual events, due to…software (Briel *et al.* 1994). The origin…was the spacecraft clock reset which followed the spacecraft tumbling incident of 1991 Jan. 25. All PSPC data after that time are affected. The problem leads to relative shift of 1s between adjacent PSPC events."

Slides courtesy David Smith

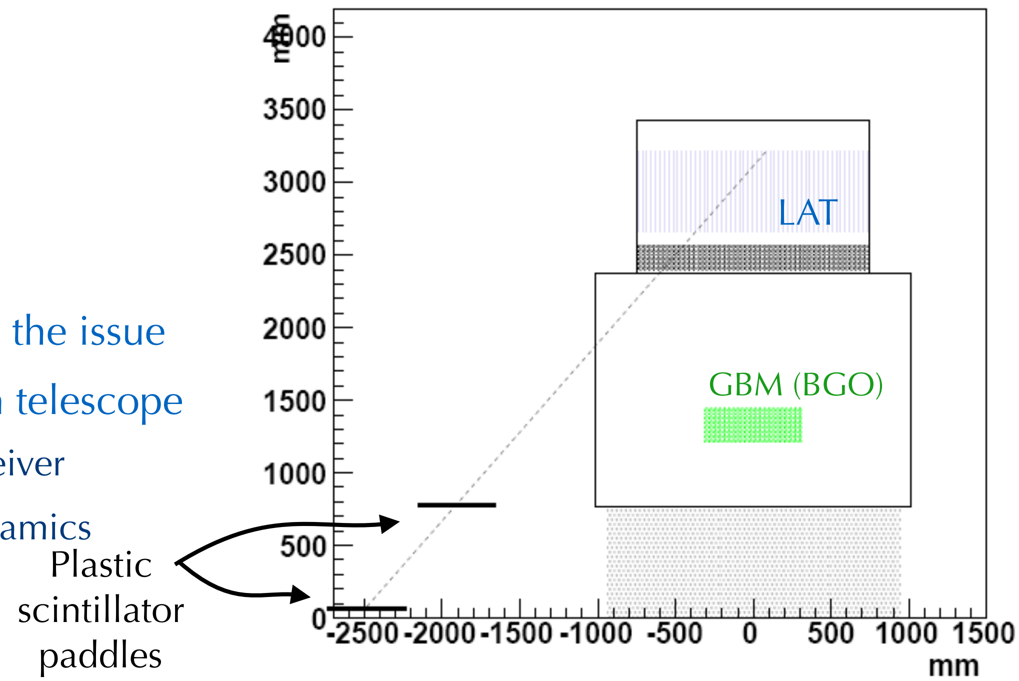
Never quite the same problem twice…
GPS issues seem easily avoidable today, not the others…
The above problems were either large (100's and 1000's of μs) or fatal.

LAT event time stamps



- Fermi spacecraft
  - GPS receiver generates time message and pulse-per-second (PPS) time tone
  - Spacecraft electronics
    - Accepts GPS time message and time tone
    - Generates its own time message and PPS to distribute to LAT and GBM
      - Instruments need accurate times even if GPS receiver has lost lock on time and nav solution
  - Requirements
    - Absolute event times: dt < 10 us, with goal < 2 us
    - Time drift, if no GPS lock: < 0.01 us / s
  - Actual performance?

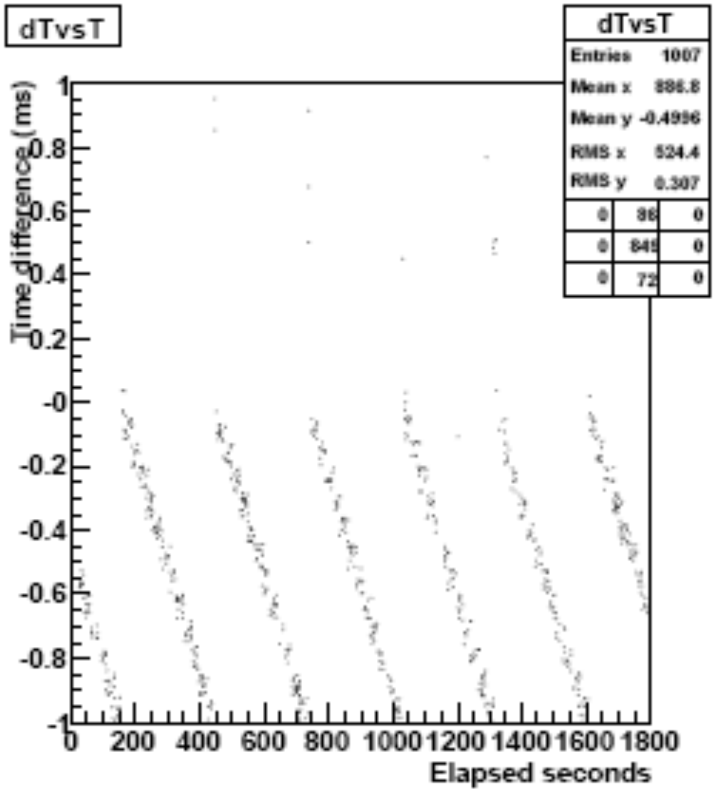
- Need to verify. Test it!
  - Kudos to David Smith (CENBG) for pressing the issue
  - Compare LAT muon times to external muon telescope
    - Muon telescope with independent GPS receiver
    - 8 runs, each half hour long, at General Dynamics



LAT event time stamps

- What we saw…
  - Something was wrong!
    - With GPS locked, LAT event times were 1 sec ahead of UTC and varied with 1.0 ms sawtooth at 290-sec period
    - With GPS not locked, times continuously drifted at constant rate of 1 ms per 290 sec
  - Diagnosis
    - GLAST Project Office very supportive. Telecons with GD engineers, GPO systems eng, LAT team members
    - Diagnosis took weeks, and spacecraft FSW fix took months

1. Sawtooth with GPS lock: "subseconds" output (a 32-bit integer) from S/C GPS shows the 1ms sawtooth. If set to zero in S/C FSW then "should work". Should *not* have been wired to input.
2. Ramp without wrap-around when no GPS lock: UDL FSW averages PPS's over preceding 100 seconds, to give good PPS when GPS fix lost. Lock problem thus propagated to un-lock mode.
3. 1 second offset from UTC: Spacecraft epoch ("MET") is set to ground PC NTP server time, not to GPS UTC. Estimate of time-to-set can be off by an integer step. Looking into a CCSDC compliant method change.

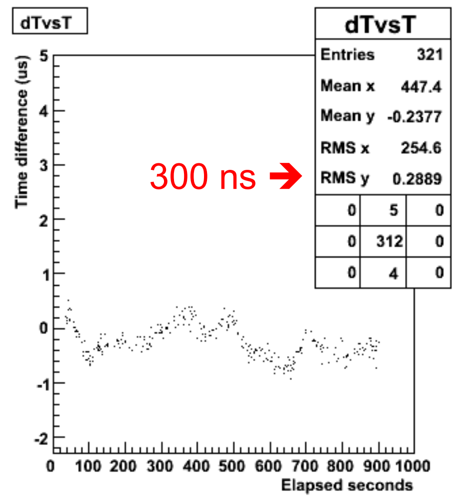


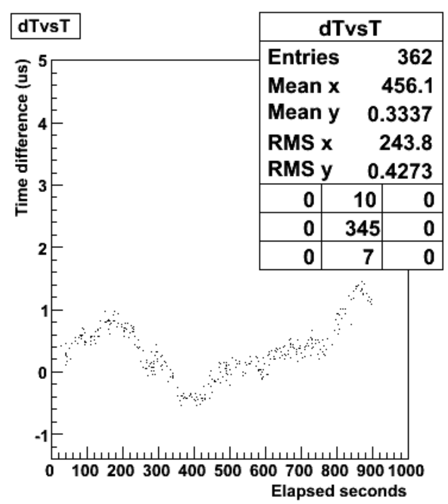
LAT event time stamps

- After spacecraft FSW update, we set up the telescope at GD and checked again
  - Success!

Verification of Absolute Time Accuracy

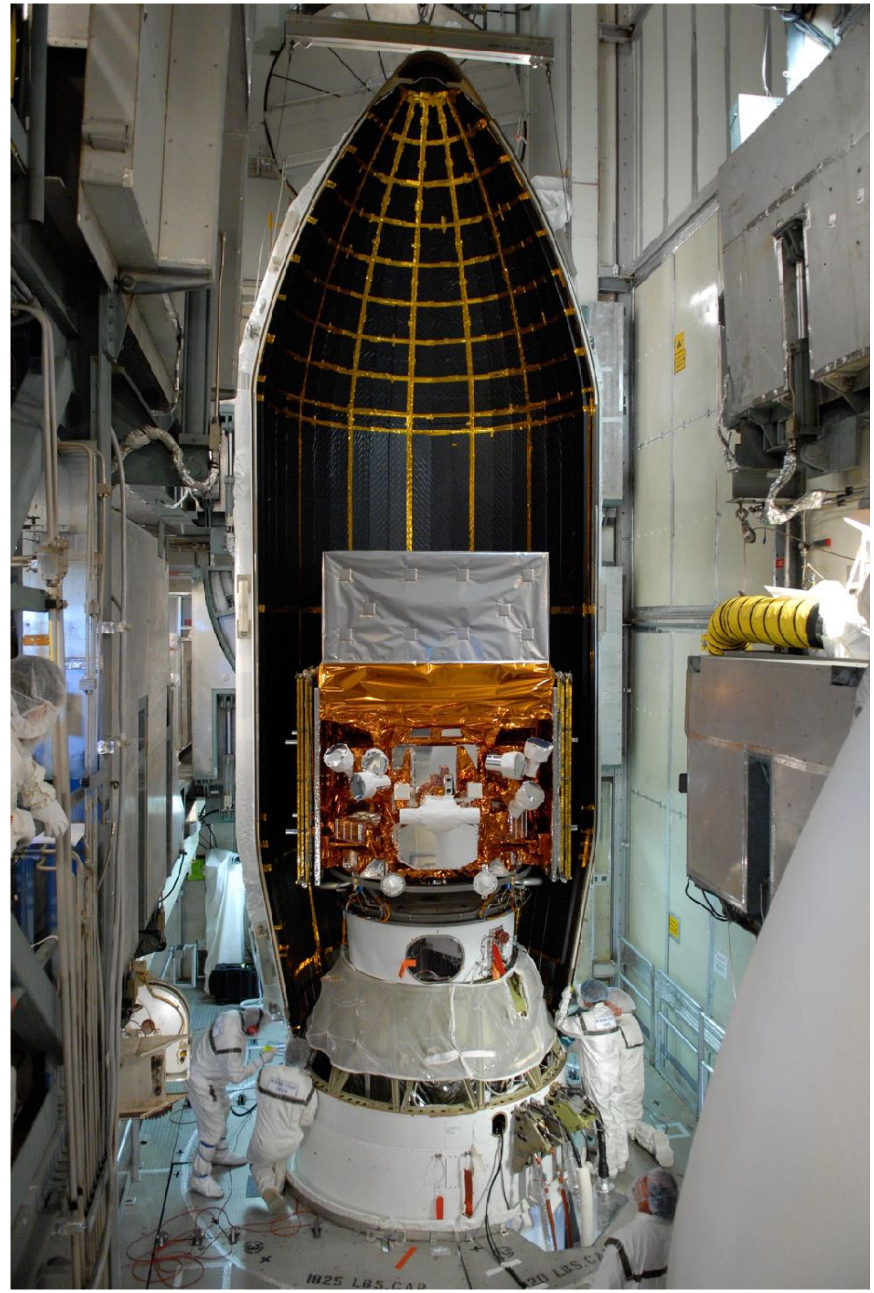
- **SC PPS meets spec with and without GPS sync**
  - **July/Aug and Oct 07 retest demonstrate that SC FSW bug is fixed**
    - **With GPS sync, SC PPS is in phase with GPS PPS**
      - **See upper panel**
    - **Without GPS sync, SC PPS drift rate ~10x better than spec**
      - **See lower panel**
- **Getting the integer seconds right…**
  - **Our tests amply demonstrate that SC PPS will have correct subseconds**
  - **Integer seconds are set by procedure at SC power-up**
    - **Recall that SC time is seconds since reference epoch**
    - **LAT, GD, and GPO are working together on power-up procedure**





Nov 2007

Ready for launch




USAF
ULA
DELTA
GLAST

Our view from the beach

Launch day at SLAC and here in Pisa

L&EO timeline

- Let's look at the timeline at the highest level
  - Many activities are not shown
  - Some activities are overlapping

Start day	Stop day	Activity
L+0	L+13	Spacecraft checkout
L+13	L+15	LAT power up
L+16		Initial checkout "physics" runs
L+17	L+41	Detector timing and calibration runs
L+19	L+23	"First Light" sky survey; LAT not calibrated
L+27	L+30	Target of Opportunity and Autonomous Repoint Request checkout
L+34	L+49	Pointed observation tuning
L+41		LAT FSW upgrade
L+52	L+60	Sky survey tuning

Mission Operations Center at GSFC

LAT turn-on

LAT instrument activation team at the MOC at GSFC ready to go

LAT activation timeline

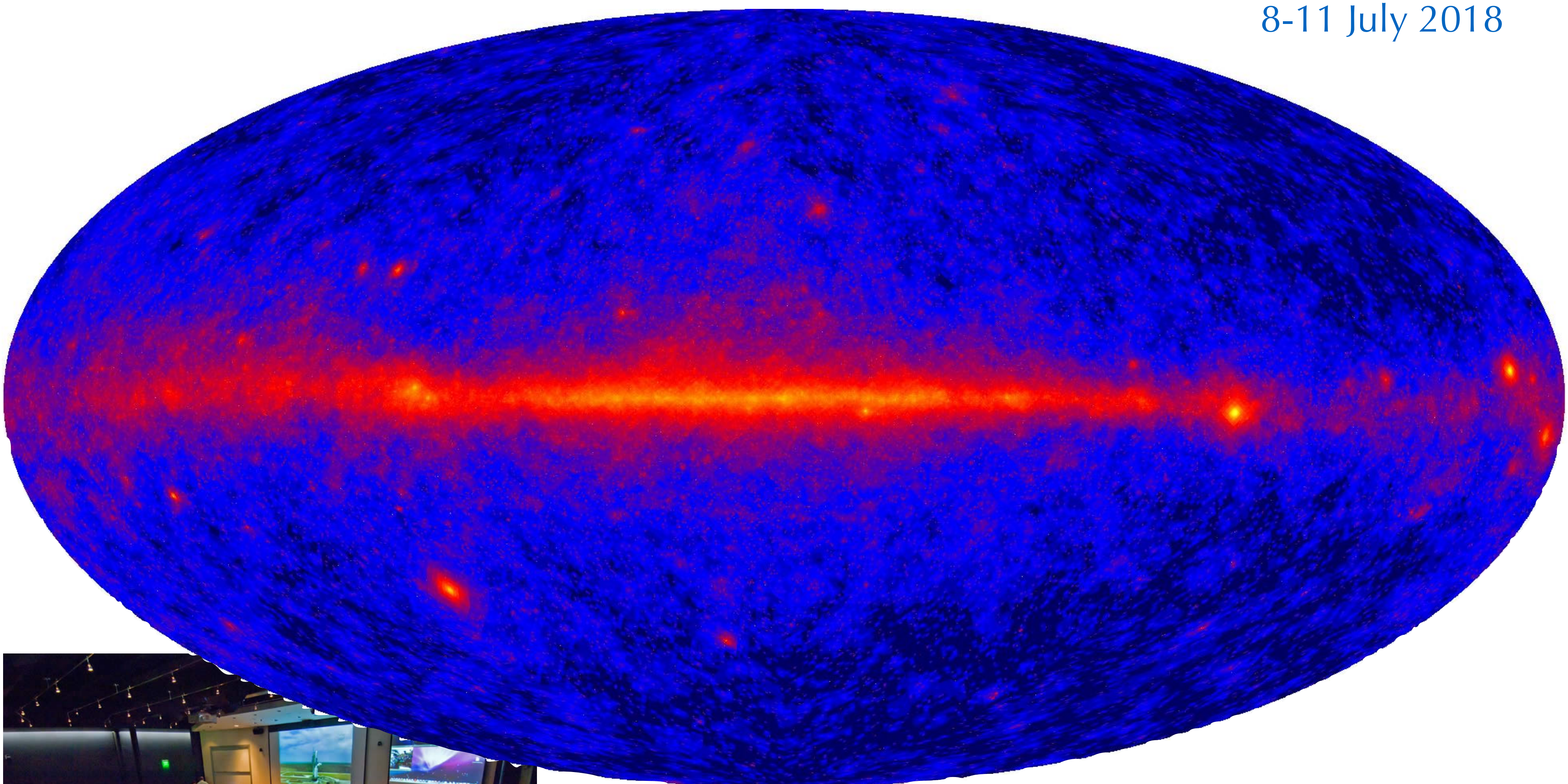
Version 20 | LAT On-Orbit Checkout Timeline | JEG version: 10 Mar 2008

L&EO Activity #	Approx Start Day (L+n)	Activity Name	Activity Details	Activity NPs	MOC Support	Expected Telemetry Type	GSSC Support	Observatory Mode	Duration (hours)	Command Contacts	# and duration of runs	PROCs, Cmds, and Params	LPA or LCI Config	Analysis Products or Essential Deliverables	Analysis due before: Activty	Analysis due before: Date
1	14	LAT Power On	Enable SIU and DAQ feeds, power on and boot SIU	SC-OBS-02	Continuous	HSK & Diag Tlm	No	Any attitude	1	2 - KU						
2		LAT Start Up	Start LAT termal control and adjust as necessary through L&EO. Power on and boot EPUs. Power on GASU, PDU, Towers and FREE boards	L-LEO-01	Continuous	HSK & Diag Tlm	No	Any attitude	5.5 + ~ 2 for tower warm up	7 - KU						
3		SIU/EPU Hardware Functional	Baseline memory, file sys dump, memory write test	L-LEO-02	Limited	Sci, HSK & Diag Tlm	No	Any attitude	4	TBD						
4	L+16	HVBS Power On	Turns on TKR (reduced voltage values), CAL, and ACD HVBSs, perform SAA high voltage test through the first SAA pass.	L-LEO-03	Continuous	HSK & Diag Tlm	No	SAA restrictions -see NP	3 + SAA wait time	6 - KU				Rates in core of SAA for TKR bias concern	10	L+18
5	L+16	SAA Boundary Study Start, First Day	Configure for one conservative LPA run to set thresholds for LRS monitoring. Set LPA default to conSciOps_NoCal. Start and stop one convervative LPA run between SAA passes. Start LRS counters at high rate (10 Hz) after first brief SAA pass, and continue at high rate through remainder of first SAA season. Define the first SAA season that occurs after bias is turned on to be "first SAA season".	L-LPA-04 L-LPA-01/02 L-LMC-02	Continuous	HSK & Diag Tlm	No	SAA restriction. Start and stop LPA run between first and second SAA passes of first SAA season. Start LRS counters after this conservative LPA run starts, after first SAA pass in first SAA season				LPASETDEFAULT LPAASSOCIATE, LPACONFIGURE LPASTART, LPASTOP LATACDTPLRSCNTR(100, 0, 0x3C, 0x60, SCIENCE) LATCALLRSCNTR(100, 0, 0x0FFFFF0F, 0xFFFF, SCIENCE) LATTKRLRSCNTR(100, 0, 0x7BDE, 0xFFFF, SCIENCE)	1 LPA Config conSciOps_NoCal	Rates in core of SAA for TKR bias concern	10	L+18
6	L+16	Conservative LAT Physics Runs, SAA Season	Optionally, start and stop LPA runs between SAA passes. Use conservative LPA configuration.	L-LPA-04 L-LPA-01/02	Continuous	HSK & Diag Tlm May exceed 100 Gbit-per-day rate	No		TBD		TBD	LPASTART, LPASTOP x TBD	1 LPA Config conSciOps_NoCal			
7	L+17	Restart SAA Boundary Study	Restart LRS counters to configure for on-going study of SAA boundary through remainder of L&EO. **NOTE**: LRS data rate ~ 1.6 kB/s	L-LMC-02	Limited	Sci (counter data to SDI if LAT FSW is updated), Diag, HSK	No	Any attitude	Counter continuous for L&EO	1	Send after the first SAA season	LATSTOPLRSCNTR all counters LATACDTPLRSCNTR(1000, 0, 0x3C, 0x60, SCIENCE) LATCALLRSCNTR(1000, 0, 0x0FFFFF0F, 0xFFFF, SCIENCE) LATTKRLRSCNTR(1000, 0, 0x7BDE, 0xFFFF, SCIENCE)		Revised SAA boundary At least one revision is expected before end of L&EO		
8	L+17	LAT Configuration Check	Configure the LAT and perform the initial physics runs to verify that configurations and downlink are acceptable. Conservative SAA boundary, perform outside SAA. Step through all unique LPA runs, acquiring for a few minutes each. Fill the time until some minutes before next SAA season. So Timing-In configs early in the sequence, since actual Timing-In will be done on the next day	L-LPA-04 L-LPA-01/02	Limited	Sci, HSK, & Diag Tlm Some or all may exceed 100 Gbit-per-day rate	No	No SAA transit during this period >6 hrs with no SAA Any attitude	~6-10 hrs	1 (use ATS)	This activity must fit in one window containing no SAAs. Even with our conservative SAA bdy on launch, that window is at least ~8 hrs. Next activity should start at least some minutes before next SAA season. Each of the ~60 runs should be at least 5 min long. The final list of LPA configs may contain more or less than 60 entries. List will be delivered ASAP.	LPASTART, LPASTOP x ~60 Need LPAASSOCIATE several times to switch among filter instances and LPACONFIGURE to select filter set	All ~60 different LPA configurations	Trigger and data rate report identifying any LPA runs with unexpectedly high rates	13	L+18
9	L+17	Conservative LAT Physics Runs, SAA Season	Add filler LPA runs that are guaranteed to have reasonable trigger rates. Fill remainder of first day of science. Use conservative Sci Ops config with CALLO and CALHI not allowed to open window. This is a useful period for an initial verification of LAT-SC alignment.	L-LPA-04 L-LPA-01/02	Limited	Sci, HSK, & Diag Tlm Some or all may exceed 100 Gbit-per-day rate	No	Any attitude Start this step before second SAA season	~14-18 hrs	1 (use ATS)	Run this one configuration throughout all orbits of the second SAA season.	LPASTART, LPASTOP x TBD	1 LPA Config conSciOps_NoCal	ACD and CAL threshold measurement	13	L+18
10	L+18	Set TKR HVBS Ops Voltages	Raise TKR HVBS voltages to ops voltage after end of second SAA season. Conduct physics run for one orbit or less.	L-LIM-06 L-LPA-04 L-LPA-01/02	Limited	HSK & Diag Tlm	No	SAA restrictions -see NP	~1.5	1	1 run, 90 minutes or less. No need to run full orbit.	Load RTS40 LATTKRHVBIAS(tkrfile) tkrfile - all 16 valid, all 16 voltages 0x54fe (105V) LPASTART, LPASTOP	1 LPA Config conSciOps_NoCal			
11	L+18	Electronic Calibration Step 1	TKR and CAL electronic calibration elements: a. TkrNoiseAndGain b. TkrNoiseOccupancy c. TkrThresholdCal d. calibGen_flt, CAL electronic calibration e. AcdPedestal	L-LCI-01	Limited	Sci, HSK, & Diag Tlm	No	No SAA transit during this period Any attitude	~5 hrs	1 (use ATS)	Durations are longest successful runs in Observatory TV Jan 08. Need to add margin to these times.	LATSTARTLCI x 5	5 LCI configs TkrNoiseAndGain TkrNoiseOccupancy TkrThresholdCal	GTFE thresholds CAL intlin ACD pedestals	19	L+24
12	L+18	TKR Buffer Study	TRC register optimization a. layer OR gate width (1 orbit) b. TFE split (1 orbit) c. TRC buffer size (1 orbit) TCC register optimization (optional) d. TCC FIFO full condition (3 orbits) TFE threshold optimization e. CAL backsplash (1 orbit)										e. TkrThrMod_CalSplash	tings	19	L+22 L+36
13	L+18	Finish an Instrument Configuration Load and Regression Test	Optionally, load LATC files if needed for 0 - 60+ LPA configs as determined by LAT Configuration Check activity. Optionally run brief regression test of some revised configs.	L-FIL-01 L-LPA-04 L-LPA-01/02	Limited	Sci, HSK, & Diag Tlm Some or all may exceed 100 Gbit-per-day rate	No	Any attitude	TBD	TBD	TBD	LPASTART, LPASTOP x TBD				
14	L+18 or 19	LAT Timing In	TREQ delay measurement, TACK delay optimization a. TREQ alignment measure at (pre-launch) flight thresholds TREQ TKR v. CALLO and CALHI with GAMMA events -- 2 orbits TREQ TKR v CAL with MIP events -- 1 orbit TREQ TKR v. ACD (ROI and CNO) -- 1 orbit b. TACK scan at (pre-launch) flight thresholds and TREQ delays Scan through 6 distinct TACK delays, 9 configs -- 7 orbits	L-LPA-04 L-LPA-01/02	Limited	Sci, HSK, & Diag Tlm Some or all may exceed 100 Gbit-per-day rate	No	Sky Survey preferred	~17 hrs	1 (use ATS)	Item a. is 1-orbit runs, respectively Treq_TkrCalGamma twice Treq_TkrCalMip Treq_TkrAcd Item b. is six one-orbit runs of Tack_scan[0-5] three one-third-orbit runs of Tack_scan[2,3,4]ver	LPASTART, LPASTOP x 13	12 LPA Configs Treq_TkrCalGamma Treq_TkrCalMip Treq_TkrAcd Tackscan* (all 9 configs)	TREQ and TACK delays	19	L+24
15	L+19	Add filler activity if needed to delay nadir pointing														
16	L+19	Background Study	Study backgrounds with Nadir pointing (sky survey with 180 deg slew), no gamma ray science data. Not to be started before Day 19 (end of Obs slew testing) a. Sky survey with 60-deg slew with Bkg Study Ops config b. Nadir pointing (sky survey with 180 deg slew). c. Sky survey with Background Study Ops config d. Sky survey with (conservative) Nominal Science Ops config e. Sky survey with (conservative) Nominal Science Ops config, Alternate DGN	L-LPA-04 SC-OBS-13 L-LPA-01/02	Limited	Sci, HSK, & Diag Tlm Some or all may exceed 100 Gbit-per-day rate	No	a. Sky survey, 60 deg slew b. Nadir pointing b-e. Sky survey	~7.5 hrs	1 (use ATS)	Do one orbit of each background study a. 90 min b. 90 min c. 90 min d. 90 min e. 90 min	LPASTART, LPASTOP x 5 Note, need LPAASSOCIATE to switch to alternate DGN then again back to nominal DGN	3 LPA Configs conBkgNadir three times conSciOps conSciOps_DgnTkr Alternatively, LPA configs might be 3 LPA Configs bkgNadir (or bkgPrescaled) three times nomSciOps nomSciOps_DgnTkr	Bkg model verification report		

Activation was flawless and completed ahead of schedule, thanks to a great team and years of testing

First light image

8-11 July 2018



Thanks to the Launch & Early Operations analysis team gathered at SLAC

Acknowledgements

- The Fermi LAT Collaboration acknowledges support from a number of agencies and institutes for both development and the operation of the LAT as well as scientific data analysis. These include NASA and DOE in the United States, CEA/Irfu and IN2P3/CNRS in France, ASI and INFN in Italy, MEXT, KEK, and JAXA in Japan, and the K. A. Wallenberg Foundation, the Swedish Research Council and the National Space Board in Sweden. Additional support from INAF in Italy and CNES in France for science analysis during the operations phase is also gratefully acknowledged.