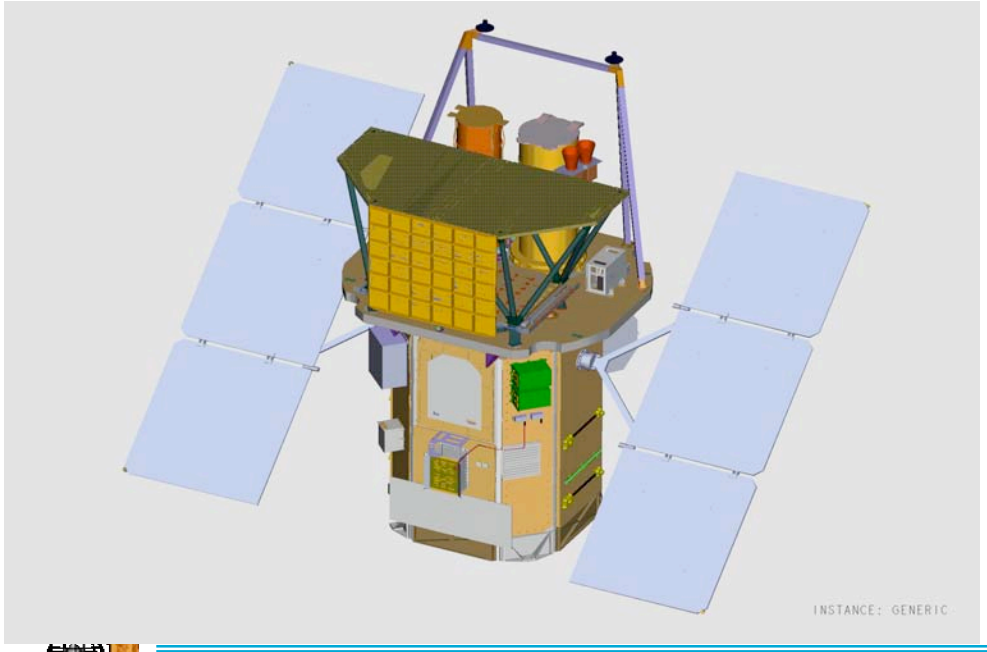
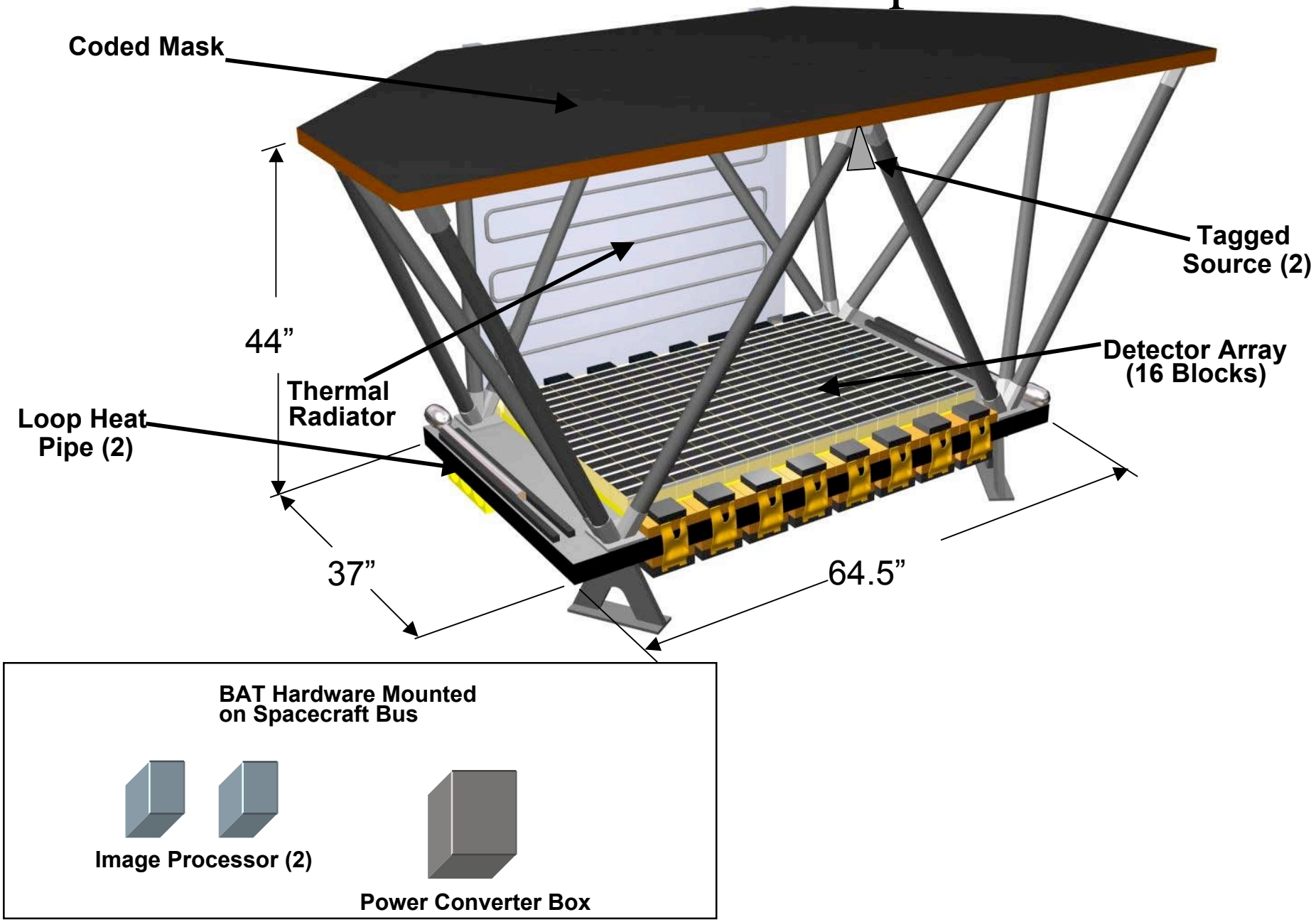
Burst Alert Telescope (BAT) Flight Operations

Scott Barthelmy

NASA-GSFC



Burst Alert Telescope



BAT Instrument Parameters

• Energy Range	15 - 150 keV
• Field of View	2 Steradian, partially coded
• Spatial Resolution	17' sky pixel, centroided to 4' position information
• Spectral Resolution	7 keV FWHM, average
• Sensitivity	0.2 photons/cm^2/sec
• Timing Accuracy	250 usec (knowledge; end-2-end)
• Timing Resolution	100 usec
• Max Flux (BBOY)	200,000 Counts/sec (entire array)
• Position Notice	5', on the ground by T+20 sec

Observing Plan

- BAT staring at sky waiting for a burst or transient
  - XRT & UVOT observing previous bursts
- Rate & Image Triggers initiate the burst response
  - SC slews to new burst position (if safe)
  - XRT & UVOT begin a series of standard observations

- BAT Hard X-ray survey while waiting for a burst
  - Longer timescale transients (≥few hrs) found in ground analysis

- Daily Galactic Plane scans
- Weekly "all sky" coverage (100%)

} After T+1yr

- For now, BAT will random walk across the sky

BAT Observing Sequence

- Stare mode waiting for a rate-increase trigger
  - Calculate the sky image, Scan for a peak, Find the position, Compare to on-board catalog
- Sends position to the FOM, Calculate the Merit, Request a slew, S/C checks observing constraints (safety), Slew to the new burst position.
- Position (& other messages) also sent to TDRSS/GCN
- All events are recorded: Prior to slew (~3 min), during slew (20-70 sec), and after slew (~6 min).
- Lightcurve is recorded (even during the slew)
  - So bursts longer than 20 sec will have full lightcurves
- After the slew, 1-min & 5-min sky images are made
  - Hard x-ray afterglow is expected for 0 to ~10 min

Other On-Orbit Operations

- Periodic e-pulser calibration cycles (gain and offset)
  - Done during non-burst slews (ie Pre-Planned Target slews)
- Monitoring/disabling for Noisy and Dead detectors
- All burst data & survey data into SSR
- TLM downlinks 5-8 passes per day (Malindi)
- Command uplinks (Malindi and occasionally TDRSS)
  - Instrument maintenance commands, and TOO target commands
- MOC is 8/5 with auto-paging for emergencies

Ground Ops Supporting Effort

- Checking the Trigger criteria performance
  - Adjusting the criteria parameters
- Checking the offset, gain, linearity, and threshold variations
  - Can do a better job than the flight s/w can
  - Trending
  - Command uploads generated
- Checking the housekeeping
  - Rates, Temperatures, CZT Bias currents, Voltages, Currents, etc
- Checking the Mask-to-Detector alignment
  - Uploading adjustment parameters
- Quick-look analysis of the Survey data for Transients and TOO generation

Burst Triggering

- Fast Rate triggers: 4, 8, 16, 32, 64 msec
- Slow Rate triggers: 64, 128, 256, 512, 1024 msec, and 2, 4, 8, 16, 32, 64 sec
- In many E-bands, and in 9 geographic regions
- Pre- & Post-trigger background subtraction intervals selectable
- Background det rate map is subtracted to eliminate steady-state sources (so only the burst should be present in the image).
- If image does not produce a significant point source, then scanning for higher-significance triggers continues and a new image is calculated & scanned for a point source (every 7 sec).
- Image Triggers: 1 min, 5 min, & "Pointing_Obs" min
  - These are not background-subtracted
  - Scanned for point source and compared to on-board catalog

BAT Data Products

- Data Products: TDRSS (T+<seconds>)
  - Burst Alert, Timestamp (1 sec)
  - Burst positions, 5 arcmin (Ack or Nack) (7-8 sec, 15, 22, …)
  - FOM decision (Ack or Nack) (8 sec)
  - Slew decision (Ack or Nack) (8 sec)

  } Nack ~15% of the time

  - Light curve of burst (and during slew as well) (150 sec)
  - Scaled map (counts in all dets, 1 E-bin, of the trigger interval, good & bad triggers)
- Data Products: Malindi Downlink (0-7 hrs plus ~2 hrs)
  - Pre- & post-history of burst (10 min of event-by-event)
    - Masked weighted for the burst position; energy corrected.
  - 1-min & 5-min, 80-channel images until occultation
  - Burst spectra (including slew) on various timescales
  - Response matrices (same timescales as burst spectra)
  - Lightcurves, slew-corrected
  - Sky images (will include steady-state sources in the BAT FOV)
  - Pulsar light curves (on-board folding)

BAT Data Dissemination

- Rapid dissemination of burst data to the world via GCN & WWW
  - Positions, Lightcurves, Spectra, Images
- All data to everyone, immediately (seconds. minutes, hours)

- There are pre-arranged follow-up teams
  - coordinated by Kevin Hurley (UCB).
- "Burst Advocates" will answer all immediate, burst-specific questions about the importance of "this burst".

- Swift can respond, via uploaded ToO, to GRBs and other transients detected by other instruments.

GCN/Swift Data Products

Notice	Socket	Email	Email	Email	Email	Email	Pager /Cell	Pager /Cell	Pager /Cell
		Text	PS	GIF	JPEG	FITS	Reg	Short	Subj
BAT Alert	X	X					X	X	X
BAT Pos	X	X					X	X	X
BAT Nack	X	X					X	X	X
FOM	X	X					X	X	X
FOM Nack	X	X					X	X	X
S/C Slew	X	X					X	X	X
S/C Slew Nack	X	X					X	X	X
BAT L.C.	X	X	X	X	X	X	H & U	H & U	H & U
XRT Pos	X	X					X	X	X
XRT Spectra	X	X	X	X	X	X	H & U	H & U	H & U
XRT Image	X	H & U	X	X	X	X	H & U	H & U	H & U
UVOT Image	X	H & U	X	X	X	X	H & U	H & U	H & U

H&U = Header and URL

Ground Compliments Swift

- Swift follow-up will not be a complete nor comprehensive set of observations:
  - Won't slew to all burst; ~15% missed
    - And ~10% will have a delayed slew (due to observing constraints)
  - Won't have 100% coverage due to orbital occultations
    - This is significant for the early-time portion of the Afterglow
  - Won't have 100% time-coverage due to overlapping targets
  - Follow-up observation terminated by sensitivity limits
  - Won't cover all energy bands (eg R, IR, radio)
  - No polarization
  - No high-resolution spectroscopy
  - No TeV, gravity waves, or neutrino

Activation Plan

- Day 4
  - Turn on IP-Prime
  - Turn on PCB
- Day 5
  - Turn on 1st DM of 1st Block
  - Turn on HV
  - Start mapping bkg and SAA
- Day 6
  - Turn on 2-7 more DMs & HV
  - Enable triggers (no FOM)
- Days 7
  - Turn on 2nd Block
- Day 8
  - Turn on a few more Blocks
- Day 9
  - Turn on a few more Blocks
- Day 10
  - Turn on remaining Blocks
- Day 11+
  - Start on-orbit calibrations
    - Crab Mask/FOV mapping
    - Cygnus trigger tests
- Day TBD
  - Enable FOM
- Day ~45
  - Begin ~normal ops

Burst Distribution Schedule:

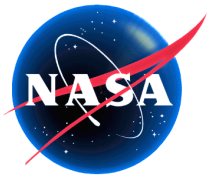
<45 day Any special gold-plated bursts will be manually sent to the GCN.

46-135 Moving towards the automatic distribution by the GCN.

>135 All bursts distributed through GCN automatically.

GCN Circulars

Item	Value / Comment
Website	gcn.gsfc.nasa.gov/gcn There will be a “Swift” page/table (like all the other missions).
Number of readers	710. There will be a step-increase when Swift is launched.
Cost	Free
Sign-up/Register	Yes, but most of you are already signed up.
Topics	GRBs, SGRs, x/g-Transients Always looking for new topics/subjects: AGN, pulsars, QPOs.
Time delay	Practically instantaneous.
Filtering? Editing?	Eventually. No -- what you type is what you distribute.
Citable	Yes. All submissions are assumed citable.
Number issued per year	750/year; 2694 total to date; 177 for 030329

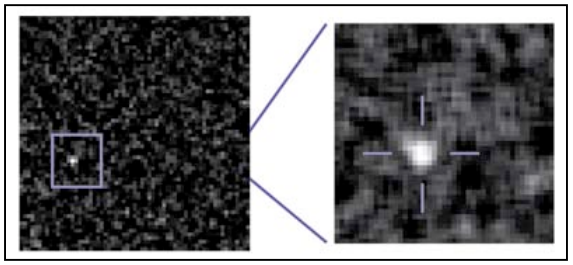


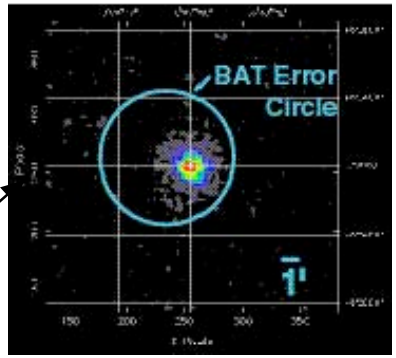
Extra Slides for Background Information

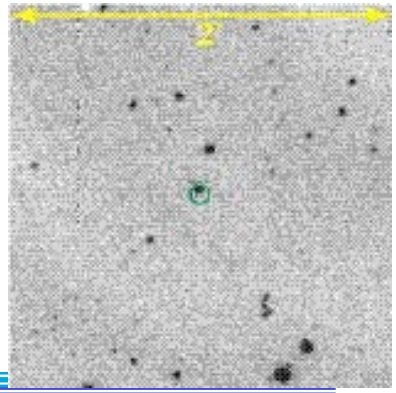
Swift Data

Notification	Time (sec)	Event
T_zero	0	GRB
Rapid position	11	BAT position
		Spacecraft slew
Light Curve	60-150	Burst,slew,& early AG
Arcsec position	85	XRT image
UVOT finding chart	250	UVOT image

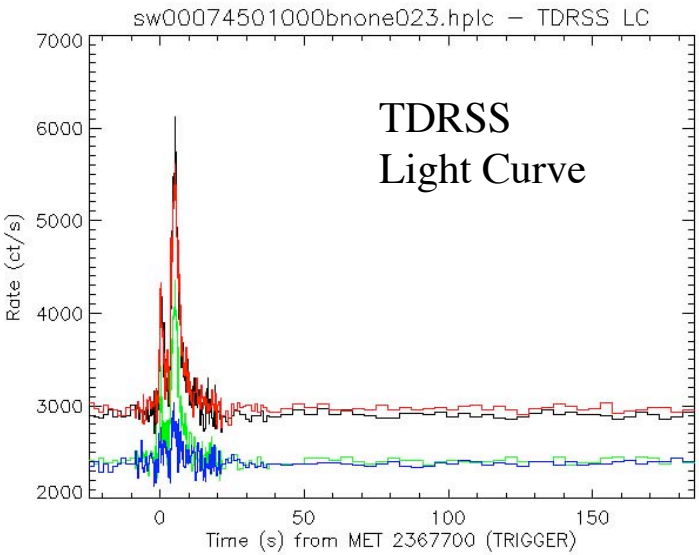
Cascade of Images

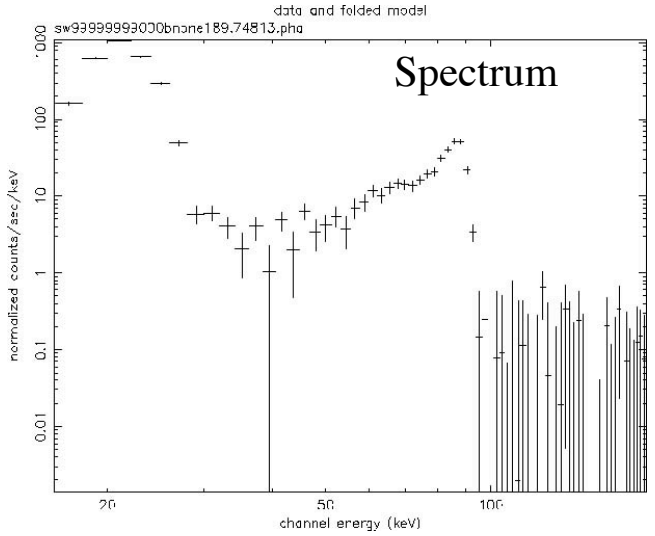


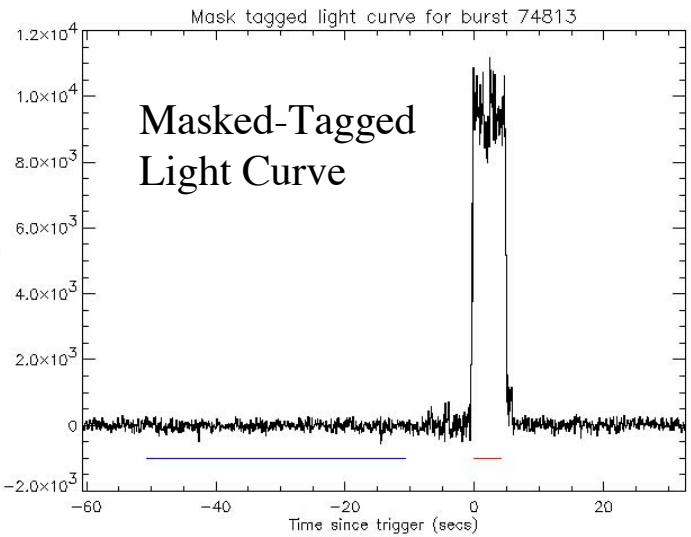




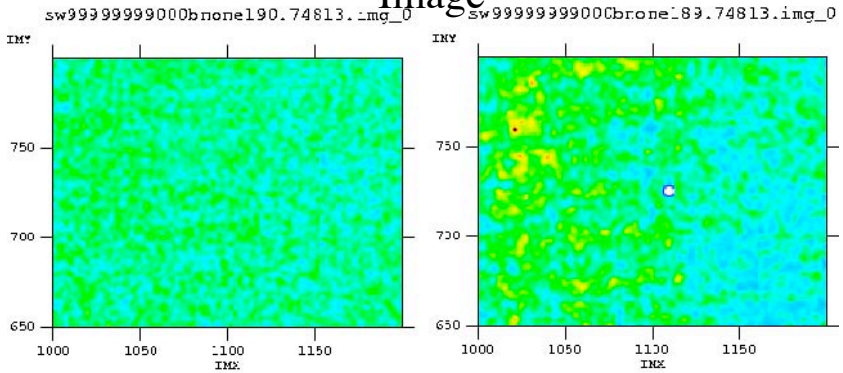
Burst Data Products Example



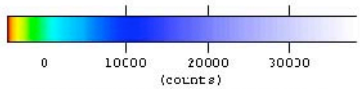




Image



Background



Foreground

sw99999999000bnone189.74813.img_0 Colorbar

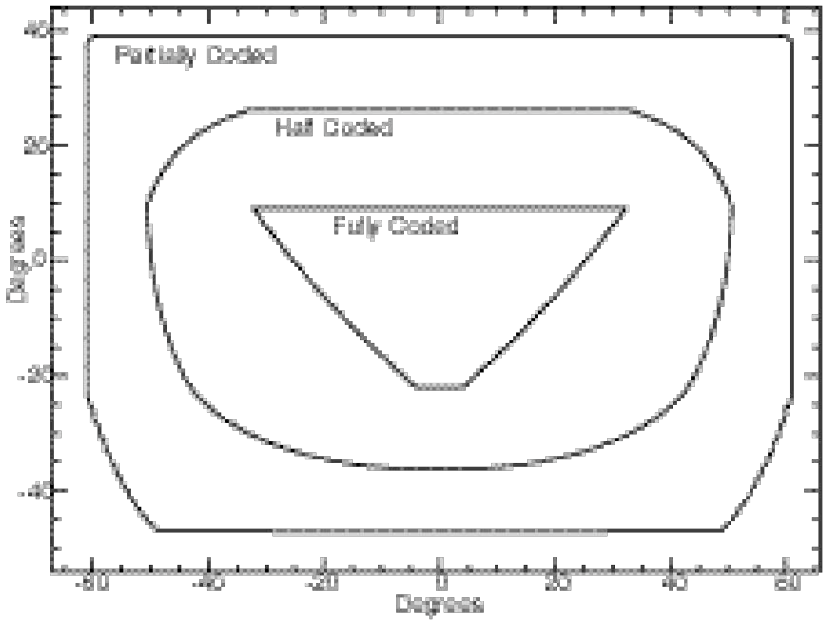
BAT Burst Tools

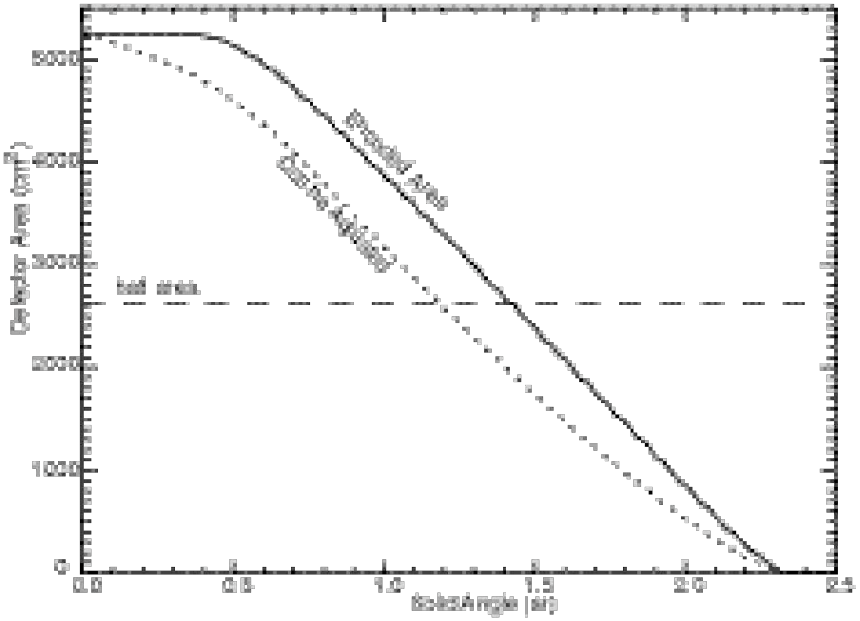
- tdrss2fits - convert TDRSS packets to FITS files
- batbinevt - bin up evt-by-evt data in time and energy
- batmaskwtevt - calc mask weighting factor for each event
- bateconvert - convert raw pulse height into true energy
- batbayesblock - break up a lightcurve into baysian blocks
- batdrmgen - generate the DRM for a burst position
- xspec - enhanced with BAT-specific features
- batfftimage - calc an FFT image for the burst
- batevt2dpi - make a Det Plane Image from evt-by-evt data
- batdph2dpi - make a Det Plane Image from Det Plane Histogram

BAT Flight Software

- Software resides in both the RAD6000 & DSP
- Divided into two parts: 1) Engineering, 2) Science
- Software does:
  - Command, control, HK, telemetry
  - Ingest/sort/unpack data from Detector Array
  - Monitor event rates to detect GRB's (rate triggers)
  - Produce images to locate GRB's when triggered
  - Notify FOM and GCN (via TDRSS) when GRB is detected
  - Collect Survey data; Monitor for transients (image triggers)
- Includes the FOM s/w
  - It decides: "Is this latest burst important?"

BAT FOV and Solid Angle

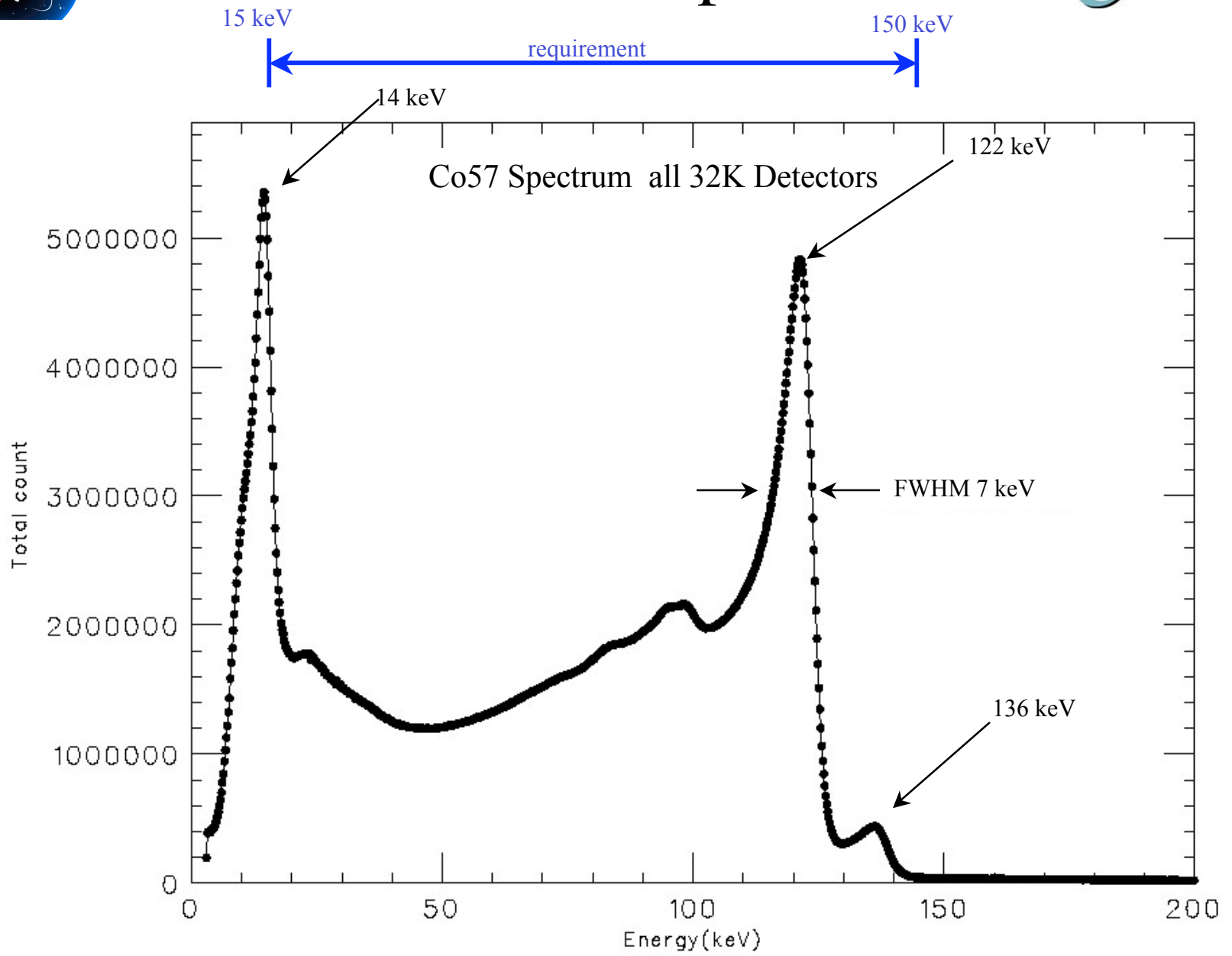




Detector Array

- The array consists of
  - 16 Blocks, each with 8 DMs, each with 2 Sandwiches, each with 128 dets (16*8*2*128 = 32,768) (5200 cm^2)
  - Each Block has a BCDH card, a BVR card, an XA1VR card, a Filter Box, a Heater Controller, and DM Heaters
  - Individual detectors can be disabled (expect 2-3% disabled due to noisy behavior)
  - Individual Sandwiches, DMs, even Blocks can be disabled; BAT will still produce a burst position! (Coded aperture technique is very forgiving of "holes" in the detector array.)
  - Threshold commandable at the Sandwich-level: 0 to ~200 keV
    - Expect to run the array with a 12-13 keV threshold
  - Energy quantization is ~1/4 keV
  - Bias voltage commandable: 0 to -300v (expect to use -200v)
    - Leakage currents in the 200-800 nA/Sandwich @-200v @20°C
  - E-pulser to calibrate the gain, offset, & INL of each of the 32K channels
  - TaggedSource (Am241) provides absolute E-scale & Effective Area calibration

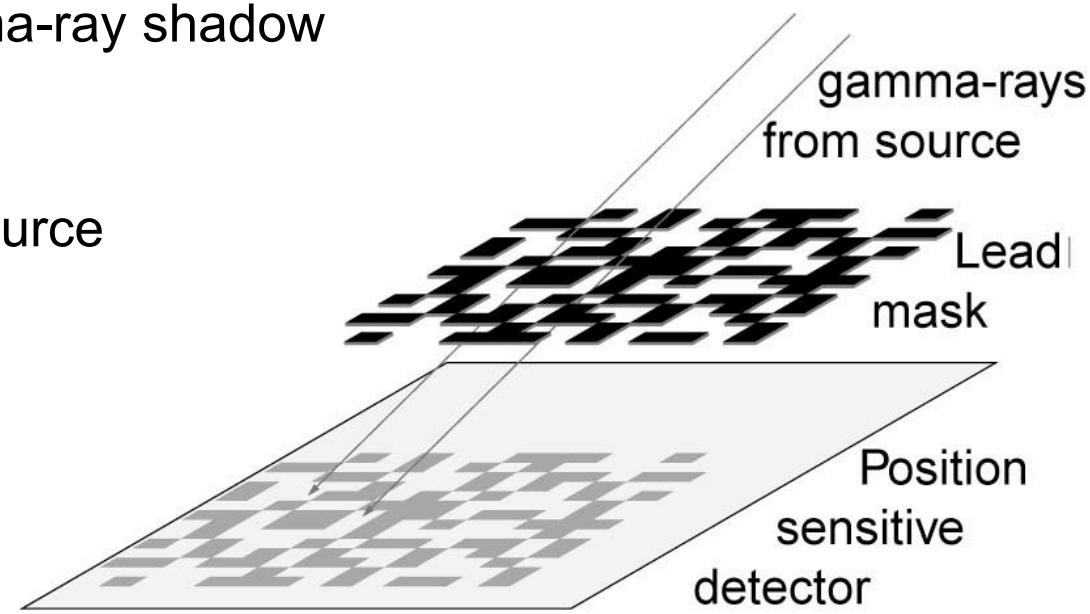
Combined Spectrum



BAT Flight Mask (52,000 Lead Tiles)

Coded Aperture Imaging

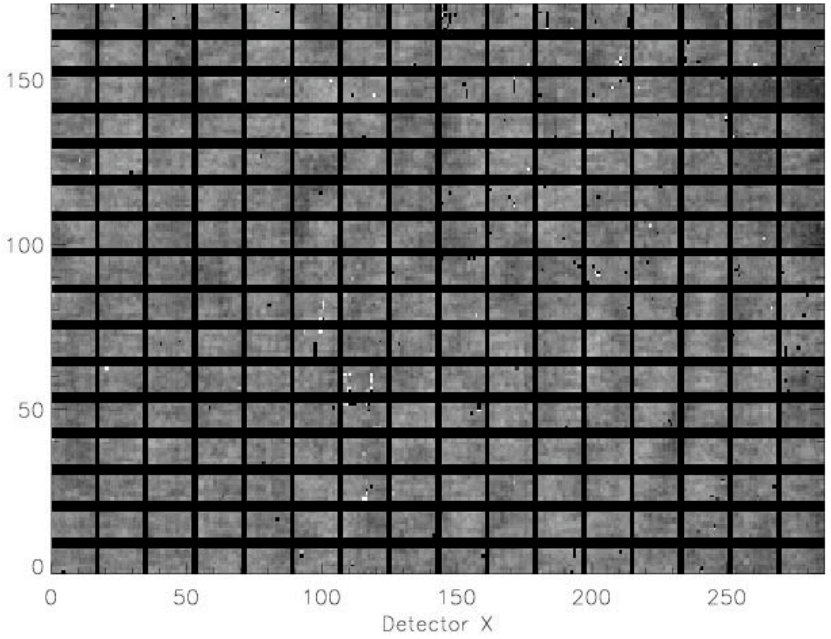
- Source casts gamma-ray shadow on detector
- Location of shadow yields location of source



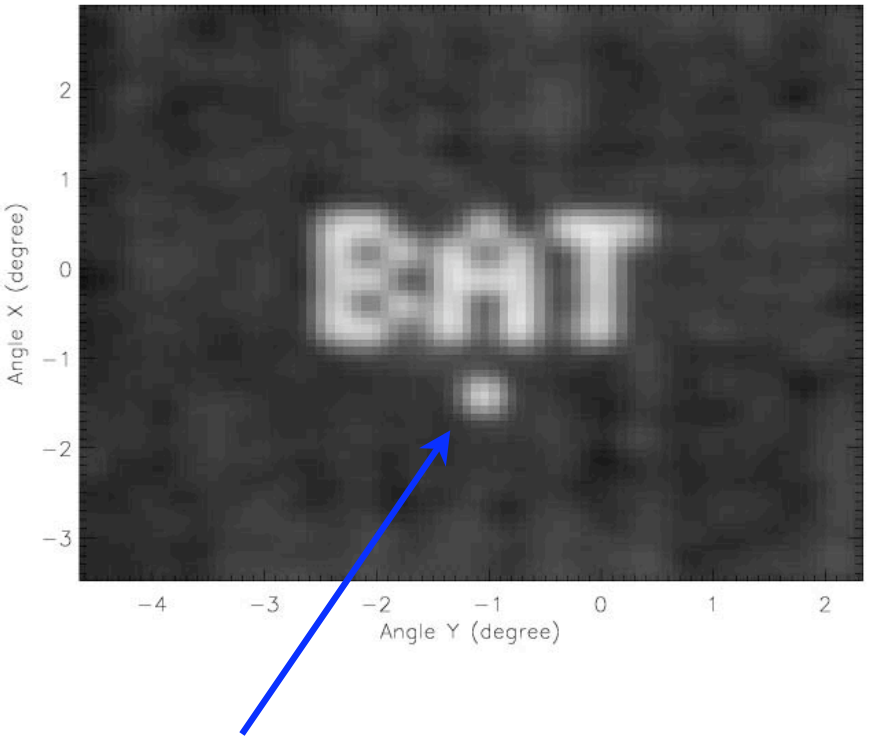
- Calculation of shadow location is computer-intensive:
  - FFT, Convolve with mask Pattern, FFT^{-1}
  - Scan for peak, Compare to on-board catalog
  - Send position of "new" source to RAD6000 and FOM
  - 7 seconds

Coded Aperture Before and After

Raw Detector Rate Map

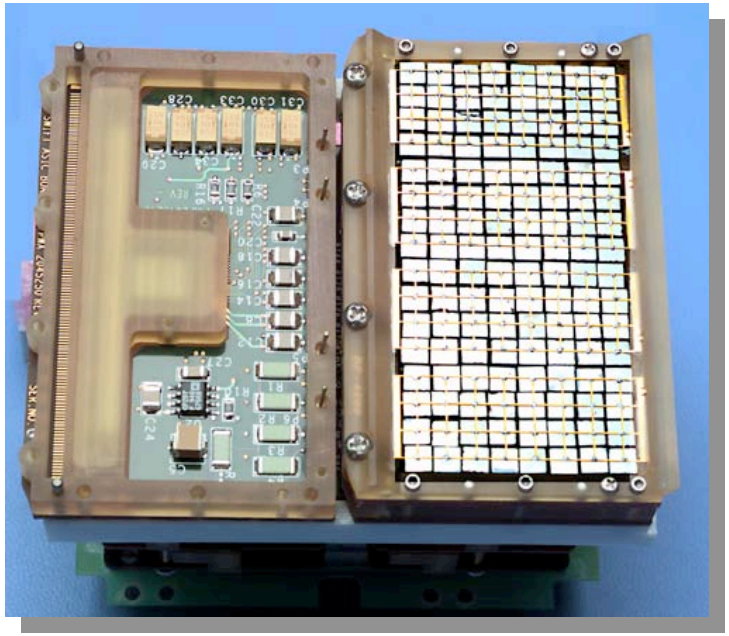


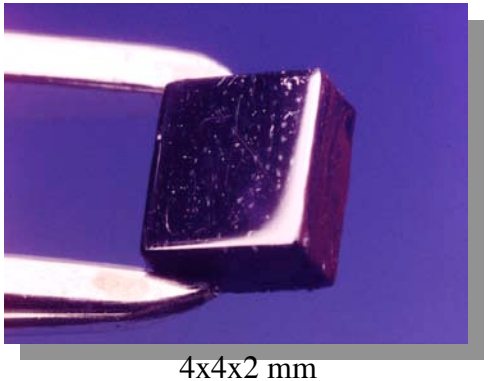
Sky Image, after FFT, Mask Convolution, InvFFT



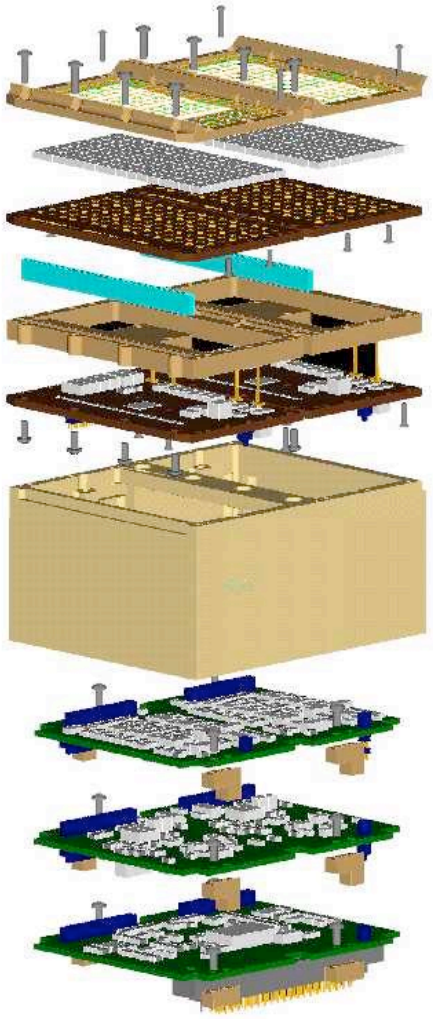
PSF is 17 arcmin; Centroided to 1arcmin

Detector Module





4x4x2 mm



Dual EMI frame & HV grids

Dual 16x8 CZT detector arrays

Dual R&C detector boards

Dual Elastomeric connectors

Dual ASIC frames

Dual ASIC boards

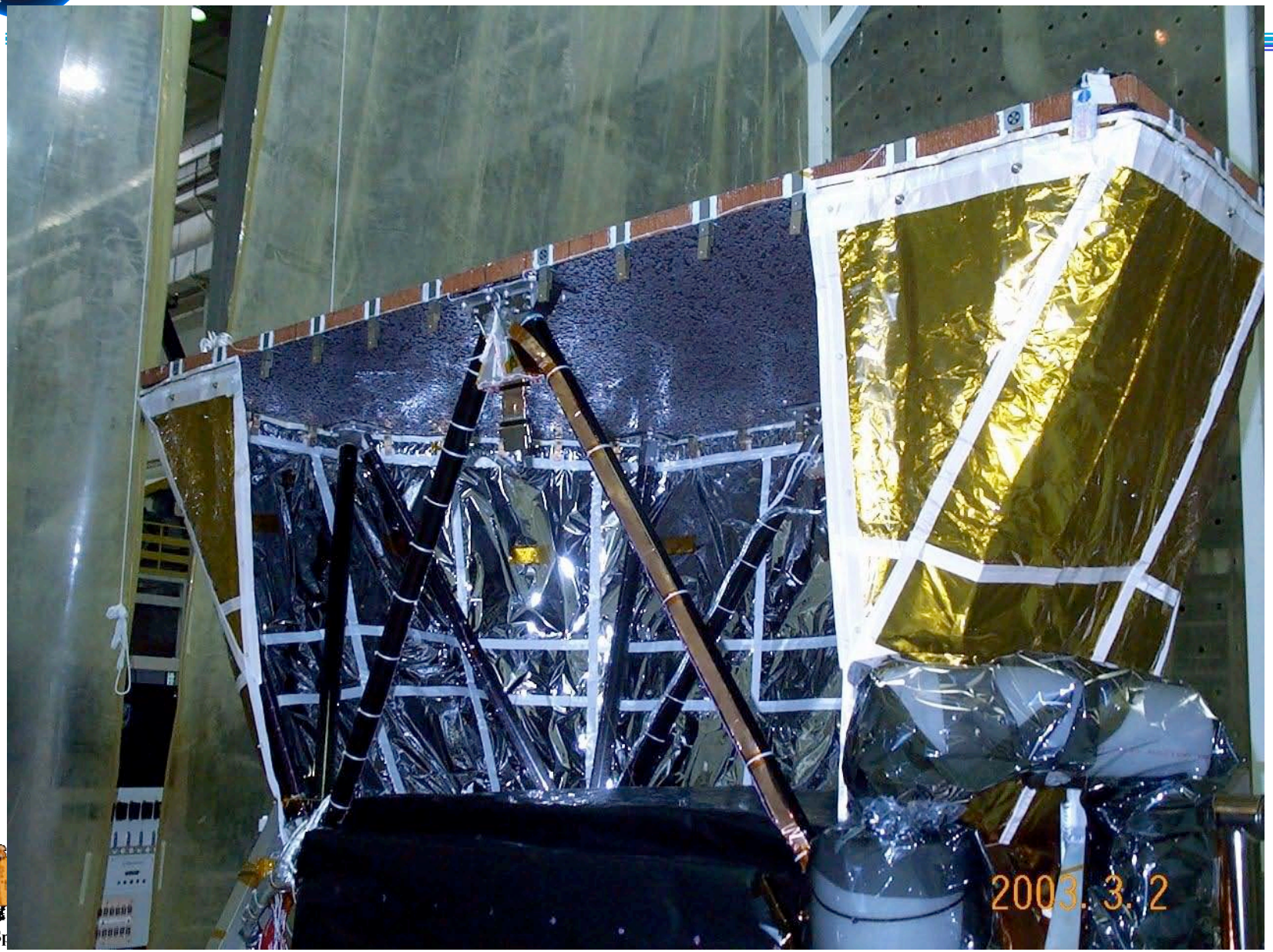
DM housing

Analog board

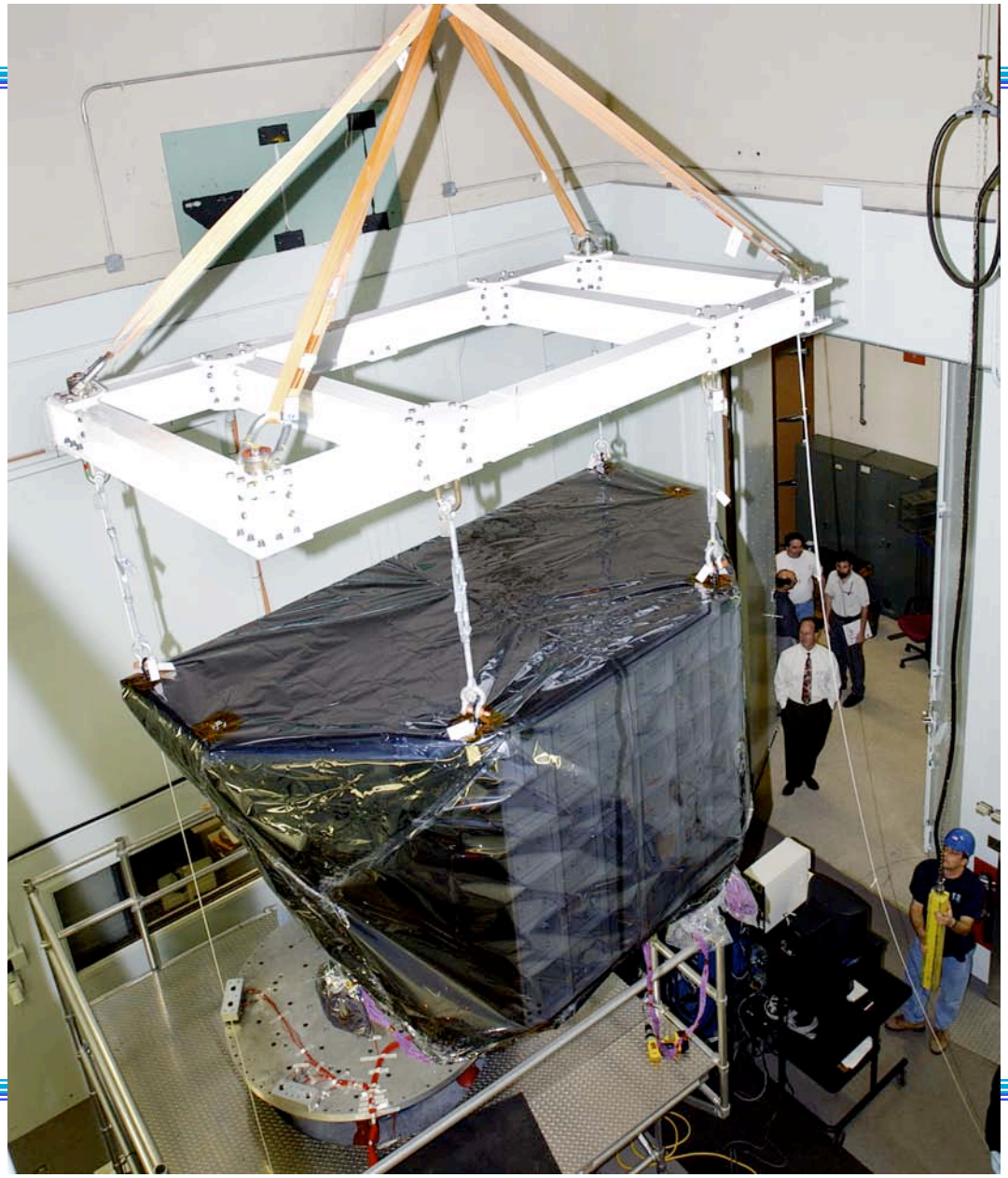
Mixed-signal board

Digital board

With the Backside of Fringe Shield Removed

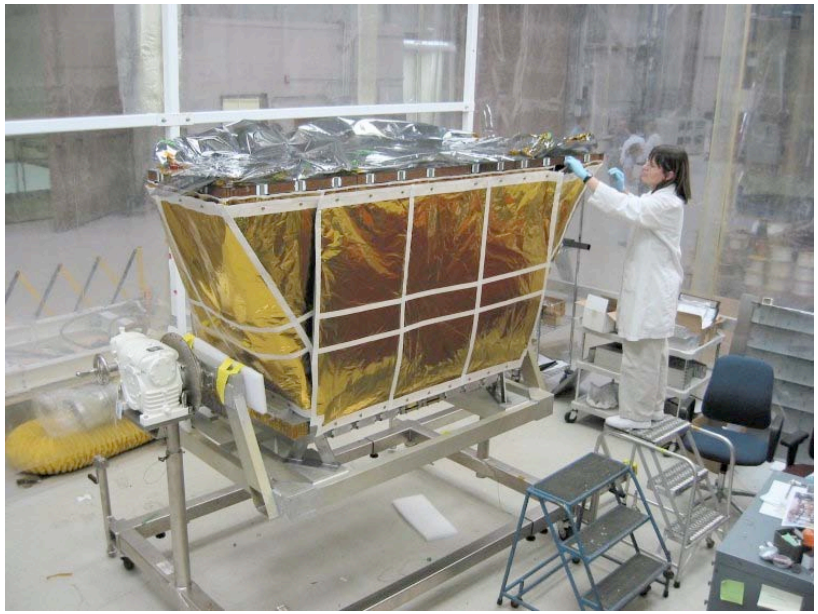


BAT into Vib Cell

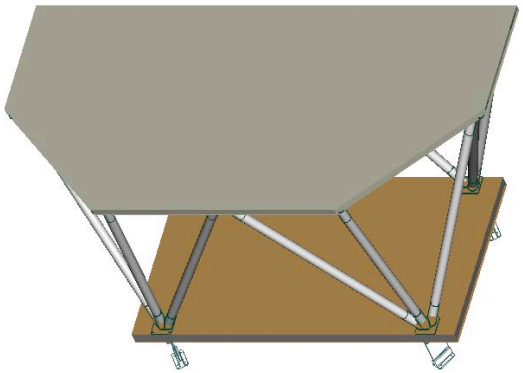


BAT Structural System

- The BAT Structural System
  - Consists of:
    - Mask Substrate
    - Mask Support Structure (struts)
    - Detector Array Plate (DAP)
    - Graded-Z Shield
    - Flexures

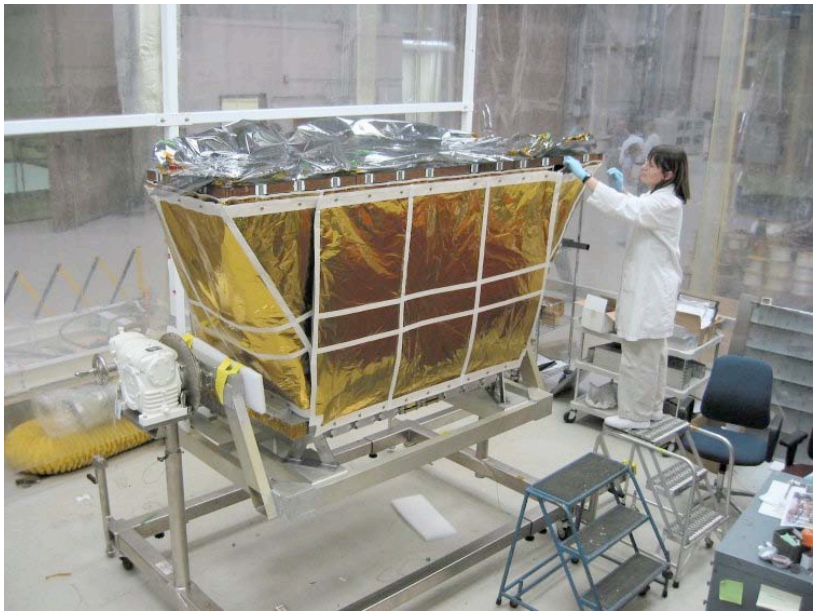


Puli installing flight Fringe Shield for fit-check.



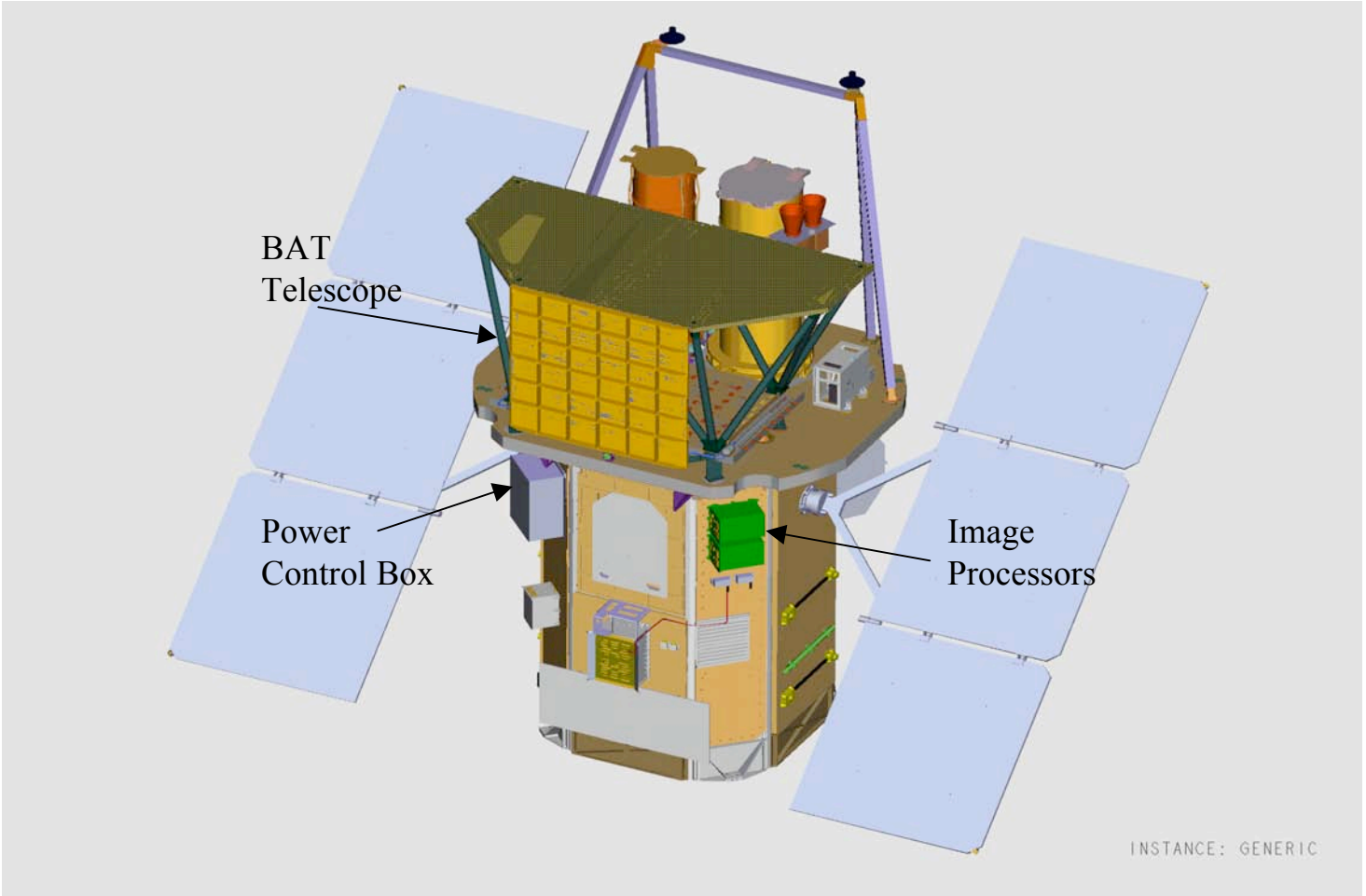
BAT Structural System

- The BAT Structural System
  - Consists of:
    - Mask Substrate
    - Mask Support Structure (struts)
    - Detector Array Plate (DAP)
    - Graded-Z Shield
    - Flexures

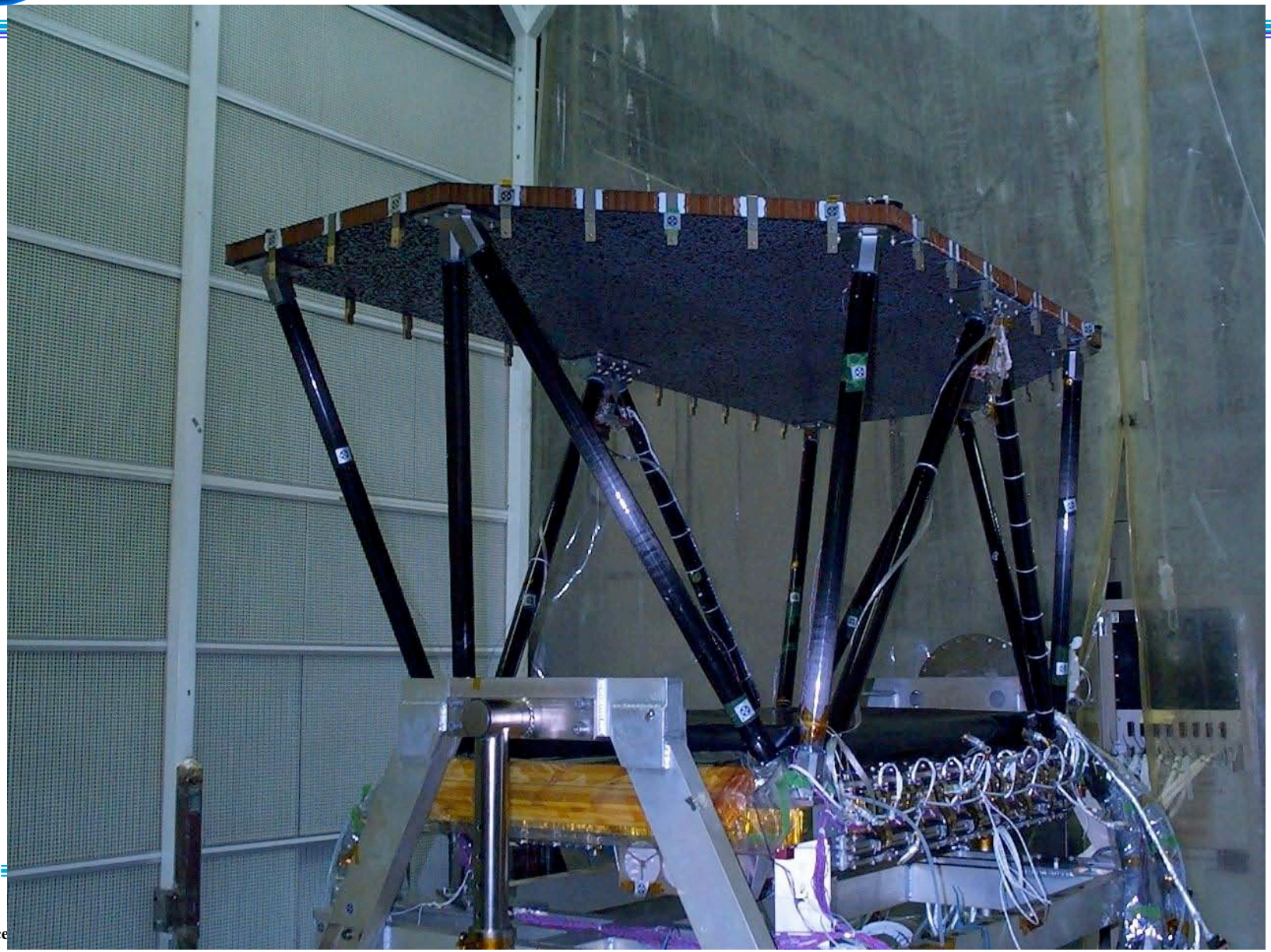


Puli installing flight Fringe Shield for fit-check.

BAT General Description



BAT without the Fringe Shield



Goddard Space

Graded-Z Shield

Flight unit Done -- ETU shown here.