GLAST Large Area Telescope:

Tracker Subsystem
WBS 4.1.4

October 8 Management Meeting

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## Key Milestones to Tower A

Extracted from our new baseline schedule (still somewhat in progress):

<table>
<thead>
<tr>
<th>Event</th>
<th>Date</th>
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<tbody>
<tr>
<td>Start flight tray panel assembly</td>
<td>9/2/03</td>
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<tr>
<td>Start flight MCM assembly</td>
<td>10/14/03</td>
</tr>
<tr>
<td>Complete EM sidewalls</td>
<td>10/29/03</td>
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<tr>
<td>First-article flex-circuit cables</td>
<td>4 weeks after drawings done</td>
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<tr>
<td>Finish EM testing</td>
<td>12/19/03</td>
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<tr>
<td>First MCM delivery to Pisa (preproduction)</td>
<td>1/6/03</td>
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<tr>
<td>Begin testing of new mini-tower in Italy</td>
<td>1/31/03</td>
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<tr>
<td>Begin cosmic-ray test on tower A stack of trays</td>
<td>3/5/04</td>
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<tr>
<td>Sidewalls, trays, Ti parts, fasteners, cables, fixtures, etc. ready for tower assembly</td>
<td>4/20/04</td>
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<tr>
<td>Begin functional tests on completed tower A</td>
<td>5/6/04</td>
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<tr>
<td>Begin environmental tests on A</td>
<td>5/20/04</td>
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<tr>
<td>Tower A delivered to SLAC</td>
<td>6/24/04</td>
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Status Snapshots

EDM Tungsten Cutting in Italy
- No start hole
- 2 slots 2 mm out of center
- Symmetric

Test on 0.1 mm W sample
Offline analysis of Mini-Tower data from Italy.

Angular Distributions

- Black histograms: data.
- Blue crosses: Monte Carlo.
- Red line: expected distribution (CR flux + detector angular response).

Red dotted line is the geometric upper limit on theta (~82 degrees), given the minitower aspect ratio.
Status Snapshots

Mini-Tower Hitmaps

- Black histogram: data.
- Blue crosses: Monte Carlo simulation.
- Red line: expected distribution for a “perfect” detector (not including the shadow effect of not active regions on ladder edges, which are very well reproduced by the Monte Carlo simulation).
Mini-Tower TOT vs. Theta

- The average of the TOT distribution increases as theta increases (the bigger the angle, the longer the path in the silicon).
- The MC simulation is good but could be tuned slightly to agree with the time constants in the actual amplifiers.

Data Monte Carlo
TOT Analysis (Simulation)

100 MeV Gammas

TOT Asymmetry between 1st 3 and last 3 planes.

Albedo Protons

TOT Average

TOT here is truncated to 250 counts by GTRC
The asymmetry is not useful with the 50 microsecond truncation imposed in the GTRC design.

But the average TOT still gives good separation, only about 10% worse than with no truncation.
Background Analysis (Simulation)

3 Classes of Background Events Remain:

• Range-outs from below (.04 Hz)
• Horizontal Events (.004 Hz)
• ACD Leakage and inefficiency (.04 Hz)

Elimination Strategy

1) Range-outs
   - ToT Identification in Tracker - kills > 90%
   - MIP Identification in CAL - should kill > 50%

2) Horizontal Events - should kill > 50%
   - Edge CAL hits

3) ACD Leakage
   - Events found accurately;
   - Cover cracks with Tapes - should kill > 95%

Estimated Rate after this to be < .006 Hz
(about 3% residual background in EGD signal)

A_{eff} & Background Rate:
A_{eff} = 8400 \text{ cm}^2 \text{ on Axis (E > 3 GeV)}
A_{eff} \times \Delta \Omega = 2.0 \text{ m}^2\text{-str}

But... Background Rate 4-5 times too high

LAT Face-to-Face Management Meeting
Open Design Issues

• Flex-Circuit Cables
  – Issues in mini-tower fit check are better understood.
  – M. Nordby doing an excellent job of tracking issues, actions and decisions. Evolved into wide-ranging study of Tracker/Grid/TEM/CAL interface issues.
  – Requirements are now understood well enough to proceed with cable mechanical design followed by updating electrical layout.
  – Possibly new requirements for termination/bias resistors on cable (see below).

• Carbon-Carbon Passivation
  – Closed: stay with EM solution: resin.

• Core Grounding
  – Closed, except for finalizing some documentation.
Open Design Issues

• MCM Mounting and Wire-Bond Encapsulation
  – The process has been developed and tested.
  – Further testing is in progress to refine the procedures.
  – Encapsulation procedure at Teledyne, has been modified and tested.
  – Full verification in environmental test will be done using the first flight-like trays off the assembly line.

• Mechanical Design
  – Complete, with no known issues.
  – Static-test of flexures in progress. Still must complete the EM environmental tests.

• Split Heavy Tungsten Foils
  – Closed: decided, tested, and drawings are being updated.

• Light Tightness
  – Does the Tracker need to cover all cable access holes?
  – If so, how does the air get out?
Open Design Issues

• GTRC Time Over Threshold:
  – Logic in existing chip is flawed (causes frequent DAQ time-outs) and can only be repaired by repeating the production. Existing chip can only be used with the time-over-threshold disabled.
  – Repeating the GTRC production: cannot achieve the required Tracker schedule unless the new chip is used only in latter towers. Also would drain some Tracker manpower resources.
  – TOT in TEM: attractive but would drain electronics resources.

• GTRC data input bias:
  – Recently discovering that some MCMs don’t like to be at the top of the readout chain.
  – Realized that the GTRC wafer test did not verify the self biasing of the data inputs.
  – May be wise to add two or three resistors to the flex-circuit cables to bias those inputs (to logic zero) externally.
Open Design Issues

- GTRC to GTRC data transfer and timing margins:
  - Observed internal delays are not (yet) understood in simulation.
  - Big margins at 20 MHz could be had by redesigning to output data on the rising clock edge, but schedule... (Must be the same on all MCMs.)
  - Using the existing chips:
    - At 20 MHz and 2.5V they skip a clock on each transfer.
      - Not a problem in itself (same timing as would be achieved by output on the rising edge), BUT
        - Fails if the frequency is lowered to 19 MHz.
        - Fails at 20 MHz if the voltage is raised.
    - It works properly up to about 15 MHz at 2.44V, or to higher frequency if the voltage is raised (but insufficient power to fix the problem).
    - The frequency limit of correct operation at 20 MHz can be raised by lowering the termination resistance, with 200-ohm external resistors placed in parallel with the existing internal 700 ohms.
      - Requires 16 resistors on each flex-circuit cable (not difficult or expensive).
      - Good margins still require some increase in the nominal voltage.
      - Margins, including frequency, voltage and temperature, are being studied with a string of 9 MCMs.
GTRC Data Transmission

Measured 36 ns delay from A to B is not understood.
Open Design Issues

- How to reach a decision on the GTRC?
  - Redoing the design for all towers is at least a 2-month delay to Tower A and Tower 16, and time is slipping…
  - Redoing it for just some towers cannot address the timing issues.
  - I am not confident that 1152 copies of the existing chip can operate properly and reliably at 20 MHz and VDD=2.5V, even with 200 ohms termination resistors installed.
    - Lower frequency (trigger issues?, dead time?)
    - Lower clock duty cycle: 40% helps a lot, but kind of ugly…
    - Higher voltage: power issues; how much can we afford?
      - Some of the power increase, in GTFE for example, can be compensated by changing the bias resistors, but the QML resistors are already purchased and have a long lead time.
    - Run as in the present Mini-Tower (20 MHz with 700 ohm term.)
      - Unstable if the clock frequency is lowered or VDD raised. Not safe!
  - Working at UCSC on measurements of margins and power.
  - Working on understanding design versus simulation at SLAC.
Mini-Tower Hit Efficiency

From Hiro Tajima, measured using cosmic rays under 3 different trigger conditions. 5 layers are used for tracking (exactly 5 clusters required, with straight track in the view with 3 hits); the 6th layer is used to find the hit efficiency, including cutting away from dead areas between wafers.

The peak amplifier pulse height occurs at about 1.0 to 1.5 μs TACK delay.

For the EXT trigger (scintillator), zero on this scale is about 0.9μs after passage of the particle.
• Measurements made this week at 20 MHz with the latest MCMs.
• Assuming 4 $\mu$A/SSD at 120 V bias (total of 4.4 W of bias power).
• CDR allocation: 155 W.
Flight Hardware Procurements

- MCM assembly (Teledyne)
  - SMT parts are in hand.
  - Connectors are coming this week (but not yet approved by PCB).
  - Lapping & dicing of wafers is done; chips are going to Teledyne.
  - PWB preproduction was repeated and boards were machined.
  - Pitch-adapter flex circuits are going to Teledyne this week.
  - The purchase order for the preproduction is being place this week.
  - Pre-production Readiness Review at the end of this week.
  - QA visit to Teledyne next Monday.
  - Process changes have been tested, except that the vibration test has not yet been done (to test capacitor staking).
  - Pitch-adapter flex-circuit bonding is greatly improved, but we still have concerns about yield, due to trimming difficulties, and the Teledyne fixture cannot achieve the flatness wanted by G&A.

- Develop an improved bonding fixture at G&A in parallel with the preproduction.
Flight Hardware Procurements

- Tray panel production (Plyform)
  - All of the carbon-carbon is in hand and is being machined into closeout pieces.
  - Assembly fixtures are ready and work well.
  - Assembly drawings are being reviewed and released and other documentation updated.
  - Bias circuits are on order from Parlex.
  - Tungsten is in hand, with thick foils ready to be slit.
- Bottom-tray panel production (COI, Plyform)
  - Closeouts.
  - Titanium parts.
Flight Hartware Procurements

• SSDs & Ladders (G&A, Mipot), in production, with no issues
• Tray assembly (G&A)
  – Still testing the MCM mounting, wire bonding, encapsulation.
  – Documentation of procedures still needs to be done.
  – Production Readiness Review.
• Flex-Circuit Cables
  – Detailed layout is starting again
    • Update the mechanical design.
    • Add termination and bias resistors.
    • Finish the electrical layout (8 different cables).
  – PPR.
  – Test with a new set of mini-tower cables.
Flight Hardware Procurements

• Sidewalls
  – New prepreg and aluminum are in hand.
  – Drawings have been extensively reviewed and released.
  – Fabrication is starting at Plyform (and at COI as a backup).
  – A PRR will be held after fabrication of new EM sidewalls.

• Tower assembly
  – The EM tower assembled well, within the desired straightness.
  – Fixtures need to be completed with protections for live trays. A lot of work in this area is in progress in Italy.
  – Test scripts are getting into good shape for the Mini-Tower but need more effort for flight tower production.
  – Shipping container: first prototype was received and needs testing.
  – Procedure documentation.
  – Production Readiness Review.
Interdependencies

- Grid Interface:
  - Cable passage and length issues.
  - Interface drawings.
- Support of electronics and flight-software efforts:
  - Teledyne production is running too late, so we are supporting the electronics group with parts to build 36 MCMs without right-angle-interconnects. 9 have been completed, tested, debugged.
  - Burn-in cables can be used in the near term to connect the MCMs to a TEM. The 9 MCMs are presently working on 2 such cables (modified with 200-ohm termination resistors).
- EGSE systems: need 9 for Tracker production (NOT including one on Dave Nelson’s desk).
- Working together with I&T on test scripts and completion of Mini-Tower testing.
Documentation Plan

- All Tracker flight hardware drawings are organized in the Tracker Drawing Tree, which also gives the release status.
- All other documents related to the Tracker design and fabrication are organized on a web page
- Working to get a complete set of production fixtures and GSE drawings onto another web page.
- All as-built data for fabricated hardware are archived in an MS Access database. This is in progress already for SSDs, ladders, and ASICs.
- We need to get our document source files and CAD design files into the new archive.
- Could use some manpower for maintenance of the documents, drawings, and web pages.
Top Threats to Cost/Schedule

1. GTRC issues
   - High priority to demonstrate a working point with good timing margins.
   - Or make a new chip now with an immediate schedule hit.
   - TOT issues go beyond the Tracker group but could have major impacts on Tracker cost and schedule.

2. Readout electronics production line start-up. Critical path.
   - Flex-circuit bonding and trimming are still not completely satisfactory
     - May have to throw a lot of PWB+flex into trash can.
     - May slow down the wire bonding during tray assembly at G&A.
   - I think we have to start into the preproduction flex-bonding at this time, so that we can find out the extent of the problem.
   - Cover risk by starting a parallel fixture development.

3. Completion of the engineering models and their testing.
   - This was delayed by two months with the failure to produce good sidewalls.
   - There is a danger of this EM effort continuing to sap manpower from starting the flight hardware fabrication.