GLAST Large Area Telescope:

Tracker Subsystem

WBS 4.1.4

Robert P. Johnson
U.C. Santa Cruz
Santa Cruz Institute for Particle Physics
LAT Tracker Subsystem Manager

rjohnson@scipp.ucsc.edu
831-459-2125
Contents

• Overview
• Technical Status
• Risks
• Schedule and Tracker Staffing
• Cost and Budget
• Next 6 months
• Summary
Tracker Subsystem Overview

**Module Structure Components**
- SLAC: Ti parts, btm-tray closeouts, thermal straps, fasteners.
- Italy (Plyform): Sidewalls

**SSD Procurement, Testing**
- Japan, Italy (HPK)

**SSD Ladder Assembly**
- Italy (G&A, Mipot)

**Tracker Module Assembly and Test**
- Italy (Alenia Spazio)

**Tray Assembly and Test**
- Italy (G&A)

**Electronics Fabrication, burn-in, & Test**
- UCSC, SLAC (Teledyne)

**Readout Cables**
- UCSC, SLAC (Parlex)

**Composite Panel, Converters, and Bias Circuits**
- Italy (Plyform): fabrication
- SLAC: CC, bias circuits, thick W, Al cores
**Roadmap to Flight Hardware**

**EGSE:**
- MCM test and burn-in systems
- Stacked-tray and tower test systems*

**MGSE:**
- Static test fixture*
- Vibration fixtures*
- Thermal/Vacuum test fixtures*
- Shipping containers*
- Lifting fixture*
- Tray storage boxes

**Principal Assembly Fixtures:**
- Pitch-adapter gluing on MCM
- Mid panel assembly
- Bottom/Top panel assembly*
- Ladder assembly onto trays
- MCM assembly onto trays*
- Tray wire bonding*
- Stacked tray test*
- Tower Assembly

*In work, following EM experience
Technical Status

- EM Testing
  - Vibe test in November:
    - Tower OK — no damage, and frequencies matched predictions
    - Grid Interface Not OK — fasteners backed out
  - Thermal Balance test: all objectives achieved
  - Mini-tower: electronic readout meets requirements
Technical Status

- EM Thermal-Vacuum Test Completion
  - Thermal balances tests completed March 12
  - Test De-Briefing meeting in Bari March 23, 24

Team photo at Alenia Spatzio
Technical Status

• Thermal Balance Results
  – 7 cases were run:
    • 20°C: 8W and 12W power
    • 0°C: 8W, 10W, and 12W power
    • –15°C: 10W and 12W power
  – Correlated Tracker thermistor readings with tower temperature
  – Temperature gradients as good or better than expected
  – No design or workmanship problems found
Technical Status

• SSD Procurement
  – 10,500 received; 9500 tested (46 rejected).
  – Receipt of the final lot of 1000 is imminent.

• SSD Ladder Assembly (G&A & Mipot)
  – 967 assembled and tested; enough for >6 towers.
  – Only 16 were rejected (1.7%).
Technical Status

- **Tray Panel Production (Plyform, Milan Italy)**
  - Production readiness review completed in February.
  - Final assembly of ~20 bare mid-tray panels is taking place this week.
  - ESPI (interferometric testing to look for gluing defects) will be done next week, followed by bonding of tungsten and bias circuits.

Everything is in place for tray vibration tests and vacuum bakeout, starting April 19.
Technical Status

• MCM Production (Teledyne, L.A.)
  – Preproduction (50 units) completed; all manufacturing and test issues resolved.
  – Production Readiness Review completed Feb 10.
  – LAT QE is now working at Teledyne on-site full time.
  – Flight unit production began March 23.
  – The first flight MCMs are expected to be delivered April 16.
Technical Status

- Tray Assembly (G&A Engineering, Italy)
  - Ladder mounting fixtures (photo below) are in hand to support up to twice the needed production rate.
  - Fixture modifications are in process to accommodate the bottom tray with flexures already attached.
  - New fixtures to facilitate bonding of MCMs to trays have been designed and are being machined. 10 preproduction MCMs are at G&A for testing this process on dummy trays.
Technical Status

• Sidewall Fabrication
  – Prepreg procurement begun.
  – Sidewall drawings completed and under review (minor changes since EM).
  – Fabrication spec drafted; in review.

• Flex-Circuit Cables
  – EGSE cables for tray testing are on order.
  – 2 of 8 flight cable designs are completed and nearly ready for a PRR.
  – Remaining designs will be completed by mid April.
  – SLAC is working with Parlex on how they will test the cable assemblies.
Technical Status

• **Tower Assembly**
  – Assembly fixture is complete and tested on the EM tower.
  – Good progress on the test scripts and procedures.
  – New engineer on board to help solidify the plan for alignment.
Technical Status

- **Tracker-Grid Interface**
  - Design effort dramatically beefed up since the EM problems in November.
  - Bottom Tray to Grid detailed design nearly complete.
  - Interface and bottom tray parts are in procurement.
  - Qualification plan in place.

New design has conical holes at the flexure attachment points.
## Closed Issues

<table>
<thead>
<tr>
<th>Issue</th>
<th>Impact</th>
<th>Resolution</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Honeycomb core fabrication anomalies and handling damage</td>
<td>~$10,000</td>
<td>Reordered with improved spec &amp; inspection by LAT QA</td>
<td>Closed, although bottom tray core is on order</td>
</tr>
<tr>
<td>Bias circuit design errors</td>
<td>~$66,000</td>
<td>Scrap first order. Redesign and reorder</td>
<td>Closed; first 42 circuits are in Italy and the rest are on order</td>
</tr>
<tr>
<td>EM sidewall drawing errors and fabrication/test issues</td>
<td>~$230,000</td>
<td>Engineering help from Swales. Refab walls in parallel at 2 vendors</td>
<td>Closed; the final EM sidewalls conform to our requirements</td>
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<tr>
<td>GTRC TOT and timing margin problems</td>
<td>$160,000 Schedule threat</td>
<td>Debug, redesign, refab, screen, dice, and retest</td>
<td>Closed; little impact on schedule in the end</td>
</tr>
<tr>
<td>Pitch-adapter shrinkage during fabrication</td>
<td>Potential impact on wirebonding throughput at G&amp;A</td>
<td>100% screening with optical comparator</td>
<td>Closed; about 12% rejection of circuits</td>
</tr>
<tr>
<td>Purchasing contractual issues delay MCM production start</td>
<td>3 weeks delay on this critical path item</td>
<td>Funding arrangement to bridge fiscal years</td>
<td>Closed as of March 23</td>
</tr>
<tr>
<td>Numerous small manufacturing and QE issues with MCM production</td>
<td>Delayed completion of the MCM preproduction by about 6 weeks</td>
<td>Worked together with Teledyne to resolve all issues</td>
<td>Closed; flight production is in progress</td>
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</table>
## Open Issues

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<tr>
<td><strong>Tracker-Grid Interface Design</strong></td>
<td>$320,000+ Danger of the bottom tray fabrication becoming the critical path.</td>
<td>Brought in a new, augmented TKR mechanical design team. Implementing an adaptive, more complex interface (dual eccentric cones).</td>
<td>Drawings nearing completion. Ti corner brackets, flexures, &amp; closeouts are in fab; other parts being finalized. Verification plan established: complete by 31 May. New TKR alignment plan conceptualized.</td>
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</tbody>
</table>

*This is a LAT issue involving mechanical systems and I&T, as well as the Tracker*
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<td>Solid Models: lack of rigor in constraints</td>
<td>Most of the Tracker mechanical drawings are suspect. Production of parts has been delayed pending completion of the models and drawings.</td>
<td>Added engineers and designers to fix or redo the models and check and correct the fabrication drawings.</td>
<td>The most urgent design areas have been addressed; tower model to be complete by 30 Apr.</td>
</tr>
<tr>
<td>EMI/EMC: No Tracker test plan is in place.</td>
<td>Potential impact to the LAT I&amp;T schedule.</td>
<td>Plan for testing at SLAC upon tower delivery.</td>
<td>Requirements established; test plan in work.</td>
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</table>

**Tracker Subsystem**
## Technical & Schedule Risks

<table>
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<th>Mitigation</th>
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<tr>
<td>New interface design has not yet been tested.</td>
<td>Tower fabrication must proceed in parallel with validation of the new interface.</td>
<td>Early fabrication of engineering evaluation parts for pull testing. Repeat EM vibe test with new interface.</td>
<td>Drawings of the interface hardware are ready for machining. Two sets are on order already for initial tests.</td>
</tr>
<tr>
<td>Flight design interface between MCMs and SSDs has not undergone environmental testing.</td>
<td>Schedule risk if a problem is found with thermal cycling of the first flight trays.</td>
<td>Thermal cycle and vacuum test the first non-flight trays (preproduction MCMs) as early as possible.</td>
<td>This could be done no earlier than beginning of May.</td>
</tr>
</tbody>
</table>
## Technical & Schedule Risks

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<tr>
<td>MCM and ASIC qualification is not complete.</td>
<td>Flight production of MCMs is proceeding at risk.</td>
<td>Qualification is proceeding as rapidly as possible using preproduction MCMs.</td>
<td>5 MCMs underwent 220 thermal cycles (−30°C to 85°C) and 2 MCMs were put in high vacuum, all with no issues or changes.</td>
</tr>
<tr>
<td>Planarity of MCM pitch-adapter wire bonding surface</td>
<td>Possible slowdown and increased cost of tray assembly at G&amp;A</td>
<td>INFN/G&amp;A designed new fixtures for fine adjustment of MCMs during gluing to tray. SLAC will continue development of an improved pitch-adapter gluing fixture just in case.</td>
<td>MCM gluing fixtures are being machined and tests will begin soon with preproduction MCMs. G&amp;A prototype pitch-adapter gluing fixture is being purchased by SLAC.</td>
</tr>
</tbody>
</table>
Schedule Slips Since Rebaseline

• **MCM Flight Production Startup** (*critical path*)
  - Resolution of manufacturing and QA issues during the preproduction run and preparation for the PRR.
  - Delay in procurement formalities.

• **Bottom-Tray Design and Fabrication**
  - Independent review of redesigned interface uncovered small but important design errors throughout the detailed mechanical design.
  - Bottom tray (with flexures) is a critical path to Tower A.

• **Mid-Tray Fabrication**
  - Start-up delays:
    - Shipping and handling damage to honeycomb cores.
    - Bias circuit delays.
    - Review and release of documentation and drawings.
  - Still, not the critical path.
Schedule Slips Since Rebaseline (cont’d)

• Flex-Circuit Cable Design and Fabrication
  – Impacted by tower solid modeling problems.
  – Resolution of installation issues and interface issues at the Grid flange and at the top of the tower.
  – Resistors added to protect the GTRC address lines in case of a short on the MCM.
  – Mitigation: added full-time designer in order to complete electrical layouts.

• Overall manpower recently added to the SLAC Tracker team as well as borrowed from the LAT:
  – JAN 1: 3 engineers + 1 analyst + 1 designer
  – MAR 15: 7 engineers + 2 analysts + 4 designers
  – MAY 30: 6 engineers + \(\frac{1}{2}\) analyst + 2 designers
  – SEP 30: ????? + \(\frac{1}{4}\) analyst
Staffing

- **Tracker Engineering Team at SLAC:**
  - Albert Nguyen, EE: Teledyne MCMs and other electronics.
  - Mike Menning: Chief ME.
  - A Scholz, ME: TKR-Grid Interface (cones, studs, etc.).
  - Robert Ruland: Alignment Engineer, ME: work with INFN, Design Integration, and I&T.
  - New Hire, ME design supervisor, tower solid model.
  - Wing Ng, designer: top tray, mid-trays, thermal straps.
  - New Hire, designer: test fixtures, MGSE, shipping containers.

- **Engineering support recently added in Italy:**
  - Aldo Troianiello, senior quality engineer.
  - Emilio Rapposelli, senior mechanical engineer, tower assembly.
  - Nicola Saggini, junior ME, environmental tests of towers and trays.
  - Giovanni Foglia and Mirco Bagni, junior ME's: Production and QA.
Critical Path for Tower A

MCM Assembly & Test
Mar 22 to Apr 16

MCM Burn-In & Test
Apr 17 to Apr 29

Assemble MCMs on Trays
May 4 to May 12

Assemble Ladders on Trays
May 13 to May 31

Tray Thermal Cycles
Jun 1 to Jun 7

Stacked Tray Test
Jun 8 to Jun 16

Tower Assembly & Test
Jun 17 to Jul 7

Environmental and Final Tests
Jul 8 to Aug 9

Tower Shipping
Aug 10 to Aug 16

Shifted about 3 weeks later than the February PMCS report, primarily due to delays in starting MCM flight production.
Other Nearly Critical Paths

Mid Tray Fabrication
In Progress to Apr 15

Mid Tray Vibe and Bakeout
Apr 19 to Apr 27

Assemble MCMs on Trays
May 4 to May 12

Bottom Tray Parts Fab
In Progress to Apr 16

Bottom Tray Assembly
Apr 21 to May 4

Bottom Tray Test and Bakeout
May 5 to May 12

Interface Hardware
Mar 12 to Apr 14

Static Test Fixture
Mar 23 to Apr 23

Assemble MCMs &
Ladders on Bottom Tray
May 13 to May 21

Tray Thermal Cycles
Jun 1 to Jun 7
Feb 25 PMCS Schedule to Tower A

Bottom Tray Parts
04/09/04 (0)

Assemble Ladders – Lot A
4/19/04 (-4)

Assemble TMCMs to Tray Lot A
5/4/04 (-3)

Test Trays – Lot A
5/24/04/04 (-2)

Assemble Tower A
6/9/04 (0)

Electrical Tower Test
6/23/04/04 (0)

Environmental Test
7/21/04 (0)

Ready for Integration
7/28/04 (0)

Completion Dates (baseline variance)
Schedule Path to Tower 14

Tower A Delivery
Aug 16, 04

Tower B Delivery
Sep 23, 04

Tower 1,2 Delivery
Oct 14, 04

Tower 3,4 Delivery
Nov 4, 04

Tower 5,6 Delivery
Nov 26, 04

Tower 7,8 Delivery
Dec 15, 04

Tower 9,10 Delivery
Jan 11, 05

Tower 11,12 Delivery
Jan 25, 04

Tower 13,14 Delivery
Feb 15, 04

Shifted about 3 weeks later than the February PMCS report, primarily due to delays in starting MCM flight production.
Schedule Variance

- February: schedule variance of –$112k
  - –$34k, bottom tray closeouts not received
  - –$68k, bias circuits not received
  - +$58k, preproduction MCMs delivered (late)
  - –$50k, first lot of flight MCMs not received
  - –$18k, flex circuit cable production delayed

- Cumulative: schedule variance of –$434k from $11,386k budgeted cost of work scheduled.
  - This primarily reflects actual delays in starting the fabrication of flight electronics.
Budget

Approved Cost Changes Since Rebaseline:

4.1.4 Baseline, November 03 $13,595 k

Changes:

• QA Manpower at INFN $ 738 k*
• Tracker/Grid Interface Redesign $ 316 k
• Stanford Benefits Rate Increase $ 49 k

Total Change $ 1,103 k

4.1.4 Baseline, February 04 $14,698 k

*Corresponding NASA funding increase

PMCS February Cost Variance:

– February only: –$127 k
– Cumulative: –$190 k

– This cumulative variance is due to some of the items on the liens list (next page) that were already invoiced by February (e.g. GTRC V7 ASICs)
## Budget Liens

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MCM Production</strong></td>
<td>GTRC Redesign and Fabrication</td>
<td>$160 k</td>
</tr>
<tr>
<td></td>
<td>Preproduction Overrun (development)</td>
<td>$ 57 k</td>
</tr>
<tr>
<td></td>
<td>Nano connector issues</td>
<td>$ 95 k</td>
</tr>
<tr>
<td></td>
<td>MCM machining</td>
<td>$ 14 k</td>
</tr>
<tr>
<td></td>
<td>Full time source inspector charges</td>
<td>$ 84 k</td>
</tr>
<tr>
<td></td>
<td>Increase in flight production bid</td>
<td>$192 k</td>
</tr>
<tr>
<td><strong>Bias Circuits</strong></td>
<td>Repeat fabrication to correct design errors</td>
<td>$ 66 k</td>
</tr>
<tr>
<td><strong>Honeycomb Core</strong></td>
<td>Repeat procurement with better specs</td>
<td>$ 10 k</td>
</tr>
<tr>
<td><strong>Flex-Circuit Cables</strong></td>
<td>Extended design effort and increased fabrication costs</td>
<td>$170 k</td>
</tr>
<tr>
<td><strong>Additional Staffing</strong></td>
<td>About seven engineers/designers/analysts through Sep 2004</td>
<td>$230 k</td>
</tr>
<tr>
<td><strong>Tracker-Grid Interface HW</strong></td>
<td>Cones, studs, nuts, washers, inserts, shims for the new interface design</td>
<td>TBD</td>
</tr>
</tbody>
</table>
Next 6 Months

• Completion of all design activities (interface and flex-circuits).
• All drawings and documentation released.
• Completion of interface qualification tests, including another EM vibration test.
• Completion of all production readiness reviews.
• All flight-component manufacturers working full speed:
  – Teledyne, Plyform, G&A, Mipot
• Environmental testing running continuously at Alenia Spazio by the end of this period.
• Deliver of the first two flight towers!
Summary

• Testing of the EM has shown the Tracker design to be sound, with the exception of the bolted joint to the Grid.

• The upheaval of redesigning the Grid interface and correcting modeling problems throughout much of the Tracker mechanical design has impacted the startup of most flight-hardware production activities.

• Rapidly ramping up engineering and QA manpower at SLAC and in Italy to get on top of the workload.

• MCM production startup has been slow and still the critical path, but the many process improvements put in place during preproduction will pay dividends in product quality.

• Flight electronics and tray assembly have started.

• Working to complete Tower A before the August holidays.