Tracker SSD Ladder Preproduction Review

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Flight Ladder Design Status

• The design is complete and nearly identical to what was successfully used in the BTEM.
  – Greatly improved tooling and equipment for fast production, better reliability, better yield, and better alignment.
  – Improved encapsulation material, equipment, and procedure.
  – Assembly by a commercial vendor.
• No formal CDR has been held for the ladders, but there is not much to the “design” to be reviewed. The single drawing has been reviewed and signed off. A CDR was held for the SSDs.
• Assembly tooling: design, drawings, manufacturing, and testing is complete, but the drawings are not in Cyberdocs and are not under configuration control.
Requirements

• Level-III, LAT-SS-17, released.
  – 5.3.1: Converter-sensor spacing. This flows down to the 2mm gap between trays and to the wire-bond and encapsulation height limits (250 microns and 500 microns respectively) together with allowances for vibration amplitude (tray stiffness).
  – 5.7: Charge particle detection, >98% in detection volume. This implies much less than 2% bad strips in completed ladders, which is easily satisfied by the SSD production and ladder assembly.

• Level-IV Mechanical, LAT-SS-134, *not released*.
  – 5.3.9.1: SSD configuration
  – 5.3.9.5: SSD ladder stay-clear
  – 5.3.9.6: SSD ladder alignment
Requirements

– Tolerance stack-up required in production:
  • SSD dicing tolerance <20 microns (LAT-DS-11, SSD spec)
  • SSD alignment in ladders: maximum deviation <40 microns
– 5.3.10: Wire-bond encapsulation
  • Level-IV Electrical: LAT-SS-152, *not released*, and the SSD spec, LAT-SS-11.
    – Satisfaction of electrical requirements such as leakage current and depletion voltage is ensured by requiring the ladder to satisfy the same requirements as a set of four unassembled SSDs.
Production Plan

• Two assembly vendors: G&A Engineering and Mipot.
  – Only G&A is being certified now to begin production. The EM prototypes were assembled there.
  – Production at Mipot will begin several months later, after separate review.
• SSDs are received and tested at INFN institutes (already in progress), according to LAT-PS-527. They are then shipped to the assembly vendor.
• INFN personnel handle all of the electrical testing activities on the vendor’s premises and therefore have continual close supervision of the assembly process.
• P3 schedule: September ’02 through May ’03, to assemble about 2800 ladders. The completion date will move to September ‘03 due to the SSD production schedule.
Production Flow

WS1: Receiving and Inspection
  → Storage

WS2: SSD Edge Bonding
  → WS3: Metrology
  → Storage

WS4: Wire Bonding
  → Storage

WS5: Electrical Tests
  → Storage
  → WS6: Wire-Bond Encapsulation
  → Storage
  → WS7: Encapsulation Inspection
  → Storage
  → WS8: Electrical Tests
  → WS9: Storage of Completed Ladders

WS5 will not be Needed in the flight production
Tooling: Edge Bonding
Adhesive Application to SSD Edge

Phase 1:
- The tape slides a and b are attached to the base following the reference line
- The Scotchweld 2216 A/B glue is uniformly distributed in the rectangle defined by the tape using a flat blade
- The tape slides b are removed

Phase 2:
- The mechanical reference is put in place with two pins
- The SSD is manually aligned against the teflon bar and pushed down in the glue. The corners (0.9mm) of the wet side are left free from the glue.
Wire-Bonding, Testing, Encapsulation
Encapsulation Inspection
Storage Box and Vacuum Tool

Antistatic foam lining
Electrical Tests: IV and CV

- Verifies leakage current and depletion voltage after ladder assembly.
- Leakage current is very sensitive to nearly any possible kind of damage to the SSDs.
Electrical Tests: AC Strips

- Measure current vs time as the strip charges
  - Short time constant indicates missing wire-bond connection
  - Long time constant indicates shorts to neighboring strips
  - High DC current indicates a broken coupling capacitor

- Frequent broken capacitors or missing bonds could indicate a problem with wire-bonder settings

![Diagram of KEITHLEY 2410 Source Meter with R4=25MΩ and R1=100MΩ.]

4 strips test:
R4 selected, s1,s2,s3,s4 closed, τ=0.23s

Single strip test:
R1 selected, one switch s1-s4 closed, τ=0.23s
AC Test Examples

Pink = good
Blue = short

Pink = good
Blue = open

Pink = good
Blue = broken cap
Preproduction Results

- EM mechanical dummy ladders: see LAT-TD-879
- Only one ladder falls slightly outside of the specification.

![Histogram of mechanical ladders and wafer alignment errors]

- $\sigma = 5.5 \mu m$
- $\text{min} = -32 \mu m$
- $\text{max} = 47 \mu m$
Preproduction Results

• EM functional ladders: see LAT-TD-880
• Accurate dicing of HPK SSDs gives ladders with even better alignment.
Preproduction Results

- Bond thickness between wafers.
- Note that this bond serves no mechanical purpose after the ladders are bonded to the trays.

![Graph showing ladder #0003-#0046 joints with mean 31μm]
Preproduction Results

- On average a factor of 1.8 increase in leakage current results from the ladder assembly. Still well within our electronics requirements, since the new SSD leakage current is so low.
- Wafer 23 had anomalously high leakage from contamination. Wafers are now cleaned prior to assembly, when necessary, and the SSD packaging has been improved.

![Graph showing ladder leakage current at 150V (red) compared with the sum of the leakage currents of the relative SSDs (green).](image)
Depletion voltage of the ladders (red squares) and average values of the depletion voltages of the SSDs from which each ladder was made (green line).
Preproduction Results

- AC strip tests after wire bonding and after encapsulation:
  - <0.02% of strips were damaged during assembly.
  - Encapsulation causes no damage or current leakage.
Preproduction Results

Effect of encapsulation on the leakage current of three ladders.
Preproduction Results

- Monitoring for 3 weeks of the effect of the encapsulation material on leakage current of an HPK detector.
### Parts and Materials

<table>
<thead>
<tr>
<th>Item</th>
<th>Material</th>
<th>Part Number or LAT Drawing</th>
<th>Manufacturer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silicon Strip Detector</td>
<td>High resistivity Si</td>
<td>LAT-DS-00026</td>
<td>Hamamatsu Photonics</td>
</tr>
<tr>
<td>Wire for wire bonding, 25 µm diameter</td>
<td>99% Al, 1.0% Si</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adhesive for edge bonding SSDs</td>
<td>epoxy</td>
<td>Scotch-Weld 2216 B/A Gray</td>
<td>3M</td>
</tr>
<tr>
<td>Adhesive for encapsulation dam</td>
<td>silicone</td>
<td>3145 RTV</td>
<td>Dow Corning</td>
</tr>
<tr>
<td>Adhesive for encapsulation fill</td>
<td>silicone</td>
<td>615 RTV</td>
<td>General Electric</td>
</tr>
</tbody>
</table>

Problem with the dam and fill RTV: outgassing specifications can only be met after a bakeout, which is not feasible. We plan to investigate and test two Nusil products (CV 2500 and CV 1142), which pass specifications at room temperature.
Supporting Documentation

- See the Tracker web page for all documents.
- LAT-PS-527: SSD receiving & inspection procedures.
- LAT-PS-635: Ladder assembly procedure, parts, equipment, certification, requirements, etc.
- LAT-PS-891: Ladder nonconforming product procedure.
- LAT-TD-914: Ladder database and electronic traveler.
- LAT-TD-879: Results from EM dummy ladder production.
- LAT-TD-880: Results from EM functional ladder production.
- LAT-SS-172: Tracker mechanical parts and materials list.
Certifications

• G&A:
  – ISO 9001, Quality Control
  – ISO 14001, Environmental Management
  – OHSMS, Occupational Health and Safety

• Personnel?
# Equipment at G&A

<table>
<thead>
<tr>
<th>Device</th>
<th>Manufacturer &amp; Model</th>
<th>Calibration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coordinate Measuring Machine</td>
<td>Mytotoio ATEX 121210</td>
<td>Periodical calibration by Mytotoio Italy, daily check on reference sphere</td>
</tr>
<tr>
<td>Automated wedge wire bonder</td>
<td>Delvotec 6400</td>
<td>Destructive pull tests on 10 bonds on cutoff</td>
</tr>
<tr>
<td>Wire-bond puller</td>
<td>Westbond</td>
<td>Periodic calibration by supplier</td>
</tr>
<tr>
<td>Adhesive dispensing</td>
<td>Camalot</td>
<td>N/A</td>
</tr>
<tr>
<td>Probe Station</td>
<td>PA200</td>
<td>N/A</td>
</tr>
<tr>
<td>CV tests</td>
<td>Agilent 4284A LCR</td>
<td>See LAT-PS-635</td>
</tr>
<tr>
<td>IV tests</td>
<td>Keithley 2410 Source Meter</td>
<td>See LAT-PS-635</td>
</tr>
</tbody>
</table>
QC Provisions

• Hardware Traveler
  – Integrated with the database entry. See LAT-TD-914.
  – Database is supplied to G&A with SSD info already entered, including which SSD goes where, etc.
  – Each work station has a PS with database access.
  – Each working stage has a database form on which steps are checked off and data entered.
  – All relevant data and “as-built” info are captured in the database.
  – MS Access software.
  – Remote monitoring.

• Oversight
  – Trained INFN personnel do all electrical testing and final acceptance.
  – The testing does not lag the production by more than one day.
  – INFN Performance and Safety Assurance Manager makes all decisions regarding disposition of ladders set aside during production.
  – Trained INFN personnel are on site during all production, for continuous oversight.
QC Provisions

- Non-Conformance Reporting
  - See LAT-PS-891
  - All instances of non-conformance are logged in the database.
  - Actions include
    - Retesting.
    - Production halt for recalibration and tuning of wire-bonding, etc.
    - Ladder rejection (by INFN PSAM)
  - Marginal ladders can be kept, with their usage determined at the tray assembly stage.

- ESD Protection
  - SSDs are ESD sensitive (although not anywhere close to the sensitivity of CMOS gates)
  - 40% to 50% humidity
  - Conductive gloves
  - Grounded wrist bands
  - Grounded tools and machines
  - NASA-STD-8738.7
QC Provisions

- **Environmental Control**
  - Class 100,000 or better clean room
  - ISO 14001 certification
  - 20°C to 25°C
  - 40% to 50% humidity
  - Latex gloves, overshoes, hat, and disposable lab coat at all times
  - Face mask during specified procedures

- **SSD Handling**
  - *Clean* antistatic gloves for unpacking and for adhesive application.
  - 4-point vacuum tool for ladder handling. *Clean suction tips.*
  - Face mask when working with an exposed SSD.
  - TX4025 ESD Wipes are used to protect both sides of the SSDs during storage.
## Requested Items

<table>
<thead>
<tr>
<th>Production plan and flow diagram</th>
<th>LAT-PS-635</th>
</tr>
</thead>
<tbody>
<tr>
<td>Qualification/Environmental Test Plans and Test Flow</td>
<td>See LAT-TD-879 and LAT-TD-880 for completed testing of ladders.</td>
</tr>
<tr>
<td>Production Quality Control Plan</td>
<td>LAT-PS-635</td>
</tr>
<tr>
<td>Inspection and measurement documentation plan</td>
<td>LAT-DS-635 and LAT-DS-914.</td>
</tr>
<tr>
<td>Plans for handling, shipping containers, environmental control and mode of transportation, identification, and storage</td>
<td>LAT-PS-527 and LAT-PS-635. Mode of transportation for SSDs? Most ladders can remain at assembly vendor.</td>
</tr>
</tbody>
</table>
## Requested Items

<table>
<thead>
<tr>
<th>Traceability Plan for all flight hardware</th>
<th>Tracker database: LAT-TD-384 and LAT-TD-914.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production Schedule</td>
<td>LAT P3 schedule.</td>
</tr>
<tr>
<td>Closure of Actions from the Previous Reviews</td>
<td>None</td>
</tr>
<tr>
<td>Complete drawing package approved for production</td>
<td>LAT-DS-26 and LAT-DS-594 are the flight articles. The assembly fixture drawings are only in Italy.</td>
</tr>
<tr>
<td>Subsystem Specification Complete &amp; Under CM</td>
<td>No, only the level-3 document is under CM. Level-4, LAT-SS-134 is not released.</td>
</tr>
</tbody>
</table>
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<table>
<thead>
<tr>
<th>Complete fabrication, test, and assembly procedures</th>
<th>LAT-PS-635</th>
</tr>
</thead>
<tbody>
<tr>
<td>Complete analyses of production tooling and test equipment</td>
<td>The tooling and equipment are all at G&amp;A and have been tested. Analyses??</td>
</tr>
<tr>
<td>Certification of all flight hardware, production tooling and test equipment</td>
<td>Vendor certifications are listed in LAT-PS-635. Certification of test equipment? LAT certification?? Marsh and Virmani have visited G&amp;A and Mipot.</td>
</tr>
<tr>
<td>Control methods for all safety hazards</td>
<td>No unusual hazards known. Vendor is responsible for its workforce and has EH&amp;S certification.</td>
</tr>
</tbody>
</table>
# Requested Items

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<tr>
<th>Requested Item</th>
<th>Status</th>
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<tbody>
<tr>
<td>Interface Control requirements</td>
<td>Not relevant to ladder assembly</td>
</tr>
<tr>
<td>Materials</td>
<td>See LAT-PS-635 and LAT-SS-172</td>
</tr>
<tr>
<td>Equipment identification and certification</td>
<td>Equipment is identified in LAT-PS-635. Certification?</td>
</tr>
<tr>
<td>Personnel identification and certification</td>
<td>??</td>
</tr>
<tr>
<td>Leadership</td>
<td>Alessandro Brez</td>
</tr>
<tr>
<td>Contingency Plans</td>
<td>??</td>
</tr>
<tr>
<td>Risk Assessment, mitigation, and recovery plans</td>
<td>??</td>
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</table>