



GLAST Large Area Telescope: Tracker Subsystem WBS 4.1.4

Persis S. Drell
Stanford Linear Accelerator Center
LAT Deputy Project Manager

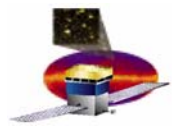
persis@slac.stanford.edu

650-926-8791

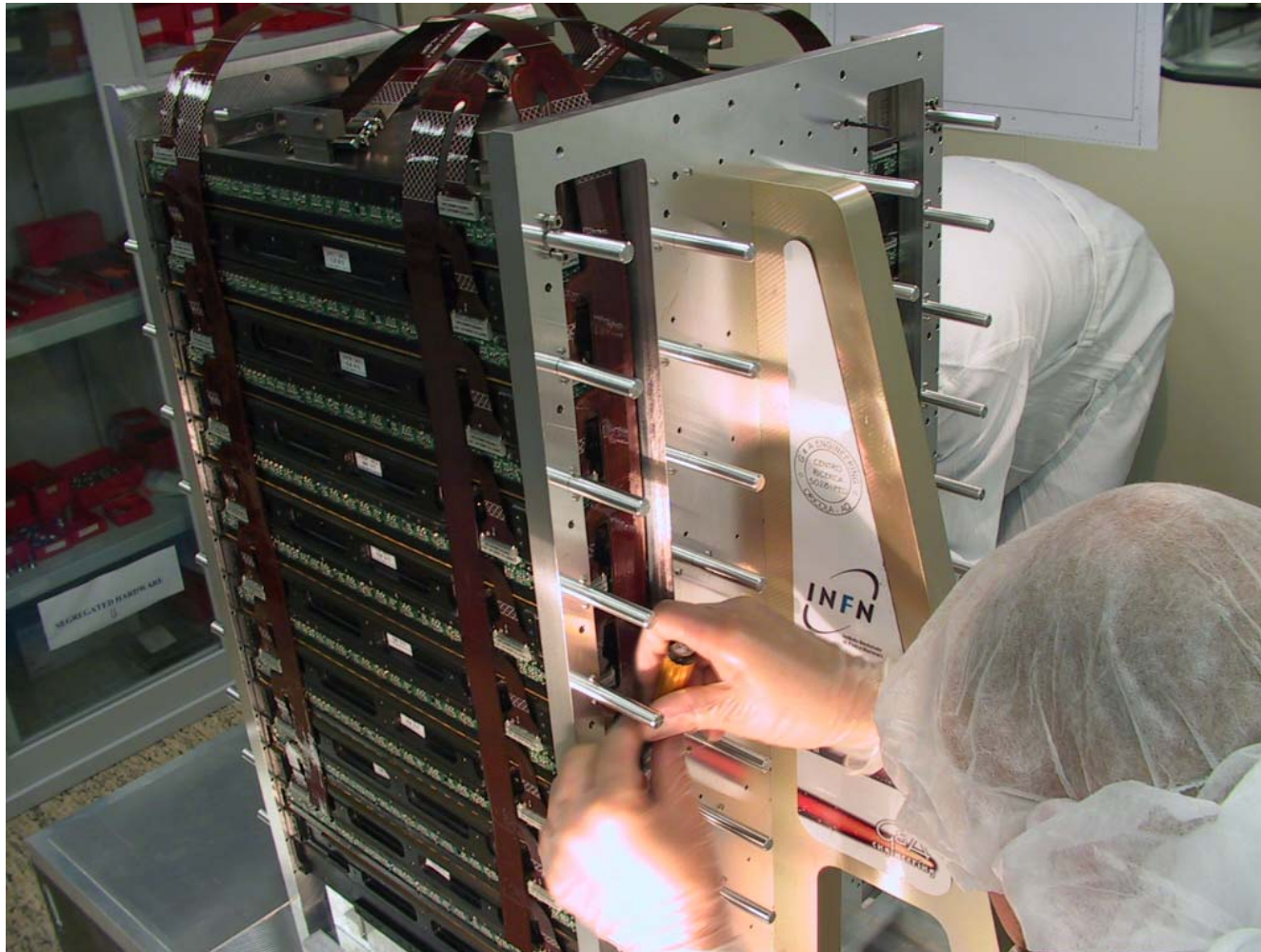


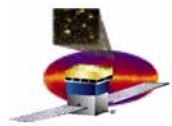
Outline

- **Summary Status**
- **Tower Fabrication Status**
 - **Tower A**
 - **Tower B**
 - **Tower 1**
- **Tracker Technical Issues**
 - **MCM encapsulant delamination**
 - **Pitch Adaptors and MCM production (details from CCY)**
 - **Ladder Breakage on Heavy Trays**
 - **Flight Cables**
- **Cost and Schedule Status**



Tower A Assembly in Pisa



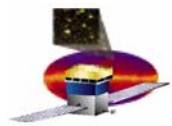


Tower A Arrives in SFO 1/14/05 ~4PM



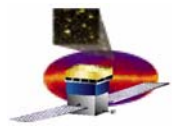
Tower A Arrives at SLAC 1/14/05 ~6PM





...and is unpacked 1/15/05

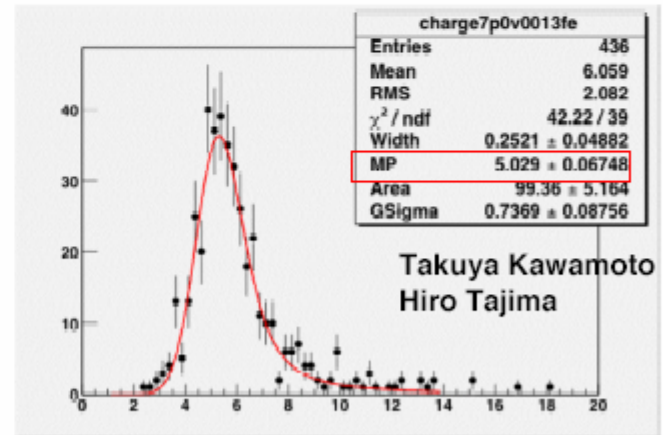
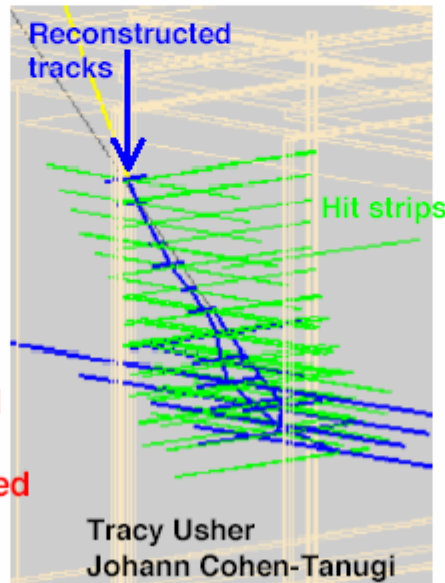
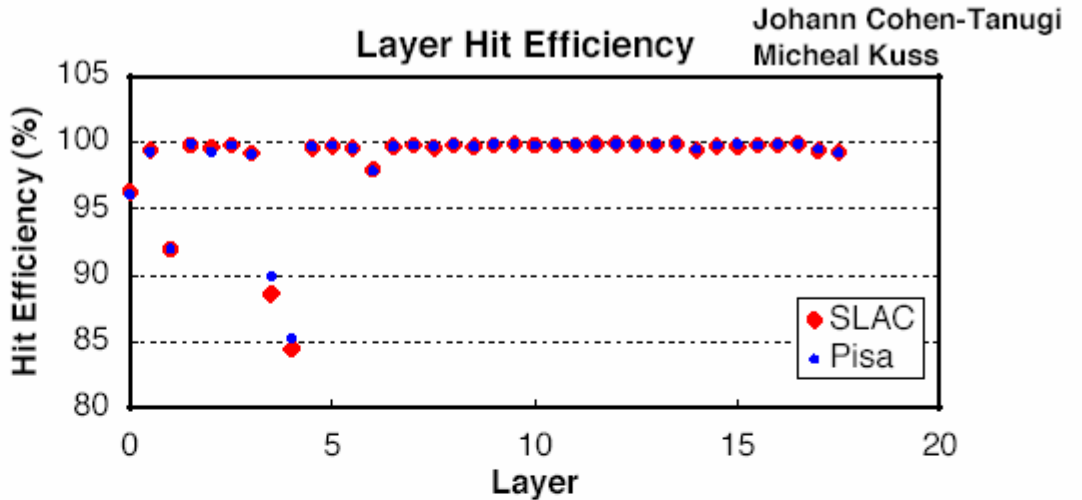




...and works beautifully!



First cosmic ray event recorded by TKR tower A in California. It was successfully reconstructed by GLAST TKR reconstruction software without any tuning.



TOT distribution (converted to charge). It peaks at 5 fC as expected without fine tuning.



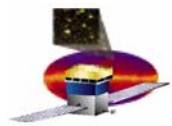
Summary

- **Tower A completed environmental testing at Alenia**
 - Arrived on time at SFO 1/14/05 without incident
 - 1/16/05 read out
 - 1/17/05 Tower A verified to be in excellent shape
 - 1/24/05 EMI acceptance test completed and passed
 - Currently undergoing EMI taping
 - Handoff to I&T scheduled 2/1/05
- **Tower B in assembly**
 - Tower B vibe test successful
 - Tower B T/V delayed by chamber problems at Alenia
 - Tower B ship date ~Feb 8 pending resolution of Alenia problems
- **Tower 1 Trays in assembly at G&A**
 - 10 trays delivered and in tray level T/V
 - Remainder next week
 - Tower 1 T/V scheduled to start ~Feb 17
- **Tower 2 Trays in assembly at Plyform**



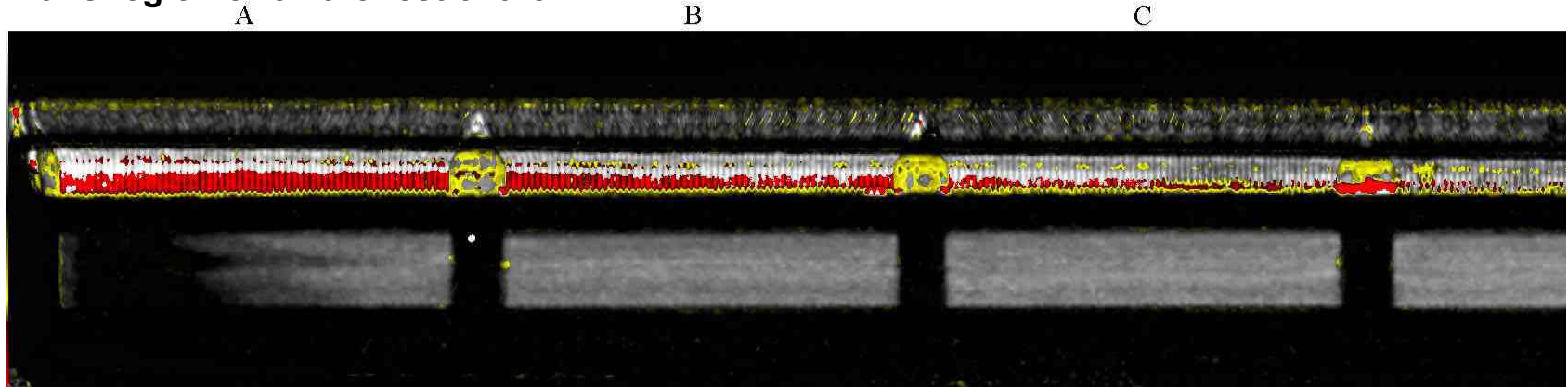
Tracker Technical Issues: MCM Encapsulant Delamination

- **MCM Anomaly Found During Tower A Tray Assembly at G&A**
 - First identified in tray production at G&A where MCM on tray found to have 300 disconnected channels
 - Subsequently found in MCM's at SLAC
 - Large numbers of missing channels seen in ~15% of MCM's screened at SLAC
 - Delamination occurs mostly during 21 thermal cycles done on MCM's at SLAC (-30C to +85C)
- **Missing channels due to wire bonds breaking at Pitch Adaptor to ASIC joint under black encapsulation due to delamination of the encapsulation**
 - Root cause hypothesized to be silicone contamination from masking tape applied to entire surface of pitch adapter prior to reflow soldering
- **C-SAM sonar images of MCM's confirm delamination**
 - some delamination likely in all MCM's but in most cases not enough to break wire bonds

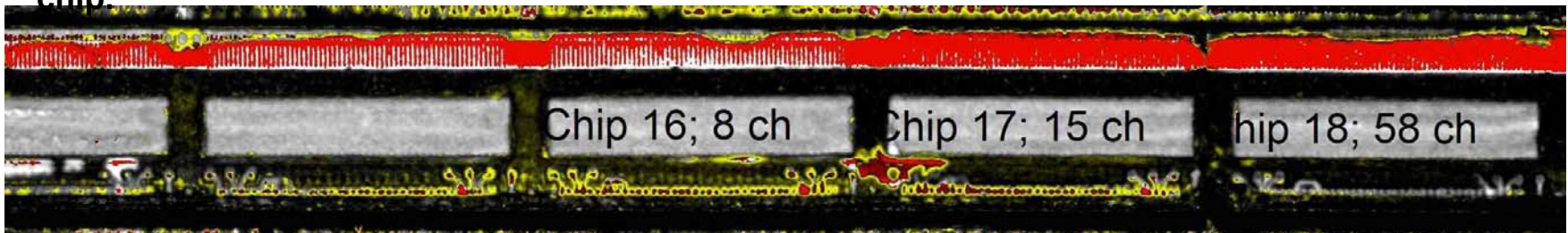


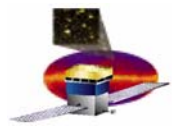
C-SAM Analysis of MCM Encapsulation Delamination Anomaly

C-SAM sonar image of the left-hand end of MCM S/N 600. The red areas are where the encapsulation has delaminated from the pitch adapter. There are no broken wire bonds in this region or on the rest of the MCM.



C-SAM sonar image of the region of MCM S/N 11046 where we find a transition from the left-hand 2/3 of the board, where no wire bonds are broken, to the right-hand 1/3, where nearly all the wire bonds are broken. The text indicates the number of broken wires for each chip.





Tracker Technical Issues: MCM Encapsulant Delamination

- **Electrical Test Procedure at SLAC effectively eliminates all MCMs with more than 15 broken signal wire bonds following thermal cycles.**
 - **Concern is additional delamination and breaking of bonds during tray and tower assembly and test**
- **In Tower A tray assembly, problems were seen**
 - **2 MCMs screened at SLAC developed significant delaminations in tray assembly (>125 consecutive wire bonds broken)**
- **In Tower B problems largely eliminated**
 - **Used modified procedures to put MCM's on trays to avoid encapsulation delamination**



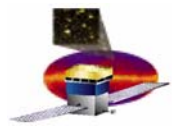
Impact on Tower Production

- **Tower A**
 - Two trays in Tower A have large numbers of missing channels (~150 each)
 - Accepted trays to keep Tower production on schedule
- **Tower B**
 - Put MCM's on trays with modified procedures to avoid encapsulation delamination
 - Evidence of small delaminations
 - Order of magnitude improvement over Tower A
- **Tower 1**
 - Continuing to use existing MCMs on Tower 1, 2, 3 trays
 - Including full electrical screening at SLAC
 - Modified procedures and visual screening at G&A



Summary of Tower A and Tower B experience

| Tower | Layer | SLAC | G&A | T-Cycle | Vibe | T/V |
|-------|-------|------|-----|---------|-----------|-----|
| A | X1 | 0 | 156 | 174 | 177 | 178 |
| A | X3 | 4 | 21 | 22 | 22 | 22 |
| A | Y3 | 2 | 128 | 138 | 140 | 128 |
| A | Y6 | 0 | 34 | 36 | 36 | 51 |
| A | X0 | 1 | 4 | 6 | 6 | 9 |
| B | X5 | 7 | 13 | 17 | No Change | -- |
| B | X0 | 15 | 17 | 28 | No Change | -- |
| B | Y3 | 7 | 8 | 9 | No Change | -- |

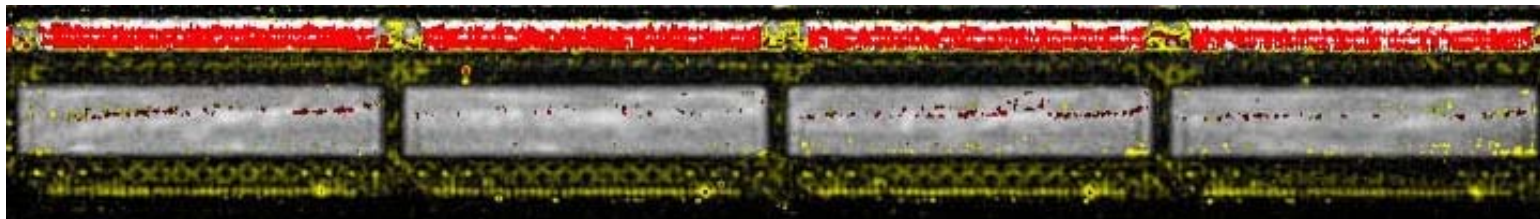
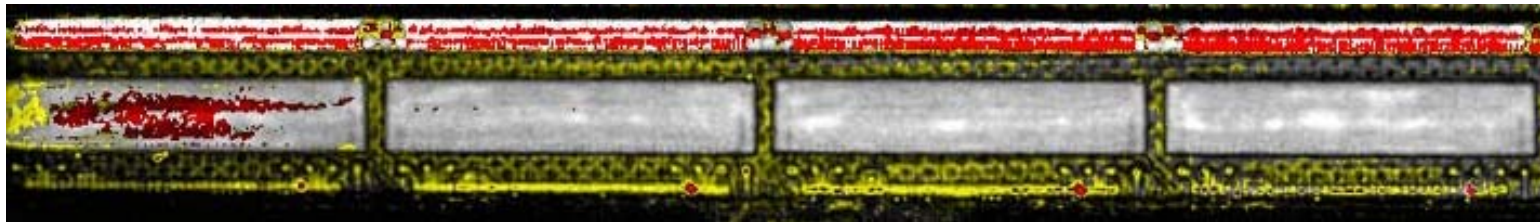


Tracker Technical Issues: MCM Encapsulant Delamination

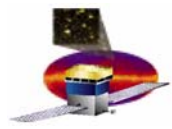
- For Teledyne restart, use reject MCM's at Teledyne to evaluate new process for delamination
 - 3 non functional, nonflight MCMs assembled by Teledyne with all silicone tape removed from the process (and the fixtures cleaned).
 - purpose was just to look at the encapsulation bonding using acoustic microscopy.
 - MCMs have not yet thermal cycled
 - only cooled down from the cure temperature of 125C to room temperature
 - next we will thermal cycle them.
- 3 images already show large-scale delamination along most of the pitch adapter wire-bonding area.
 - it is puzzling that they also show massive delamination in other areas
 - the surface of the GTRC chip
 - wire bond pads surrounding those chips
 - we have never had an issue with breakage of those wire bonds.
- Not sure how to interpret these results.



Tracker Technical Issues: MCM Encapsulant Delamination

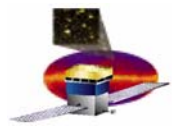


- Discussions today at Teledyne
 - Results disseminated to consultants
 - Plan to be developed



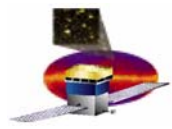
Plan Forward: MCM Encapsulant Delamination

| MCM Encapsulant Delamination | Status | Who | Date |
|---|---------------------------------|------------|-------------|
| 1. 100% electrical screening of MCM's at SLAC | 1. Done | | |
| 2. Process changes during MCM assembly on trays | 2. Done | | |
| 3. 1/3/05 MRB | 3. Done | RPJ | 1/3/2005 |
| 4. Proceed to put existing MCM's on Tower 1,2,3 | 4. Recommendation of 1/3/05 MRB | Pisa | 1/5/2005 |
| 5. Monitor bad channel rate during assembly and call an MRB if the number is greater than 15 | 5. Procedure exists | CCY | 1/10/2005 |
| 6. Sonagram a sample of test run MCM's to evaluate delamination and validate process changes | 6. In process; first results | CCY | 1/26/2005 |
| 7. Develop and execute a plan to retire risk on existing MCM sample by thermal cycling and C-SAM to demonstrate that delamination does not propagate. | 7. Needs plan | Kahn | 1/31/2005 |



Tracker Technical Issues: PA Trace Cracking

- **MCM Production at Teledyne was halted 10/1/04**
 - **Implement PWB bake out**
 - **ESD Controls**
 - **Variety of workmanship issues**
- **Teledyne restarted production 12/20/04**
 - **Immediately started having trouble with cracking of pitch adaptors**
- **Pitch Adaptor Cracking**
 - **18 boards failed inspection after bonding the PA**
 - **every board had a large number of cracked and open traces, spanning more than half the length of the board in some cases.**
 - **qualitatively different from earlier runs.**
- **Intensive Effort to Understand the Issues**



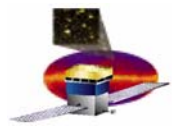
Tracker Technical Issues: PA Trace Cracking

- **THIS IS THE MOST CRITICAL ISSUE FACING THE TRACKER AT THIS TIME**
- **Last month: “To stay on current tracker fabrication schedule, MCM production must ramp up to deliver 25 MCMs/week by 2/2/05”**
 - **We have failed**
 - **Tracker schedule is impacted**
- **Dedicated presentation on technical issues by Charlie Young after my talk**



Plan Forward: PA Trace Cracking

| PA Trace Cracking | Status | Who | Date |
|---|----------------|----------|-----------|
| 1. Assess impact of PWB edge debur | 1. Done | CCY | 1/5/2005 |
| 2. Evaluate PA from 2nd vendor | 2. Done | CCY | 1/5/2005 |
| 3. Evaluate process changes at Parlex | 3. Done | RGobin | 1/5/2005 |
| 4. Evaluate process changes at Teledyne | 4. Done | CCY/RG | 1/7/2005 |
| 5. Section Boards at GFSC and SLAC | 5. In process | CCY/RG | 1/31/2005 |
| 6. Measure board radius with CMM at SLAC | 6. Done | CCY/RG | 1/7/2005 |
| 7. Review design to see if radius can be increased | 7. Done | RPJ | 1/6/2005 |
| 8. Find tool and operator history from Diamond | 8. Done | Rich | 1/19/2005 |
| 9. Order Diconnex Pitch Adaptors | 9. Done | RPJ/CCY | 1/7/2005 |
| 10. Design new assembly fixture | 10. In process | CCY | 2/1/2005 |
| 11. Evaluate clamping force vs breakage with Teledyne fixture | 11. Done | RGobin | 1/13/2005 |
| 12. Evaluate tension vs radius vs breakage with SLAC test fixture | 12. Done | Rich/CCY | 1/13/2005 |
| 13. Further analysis of flex circuit manufacturing at Parlex | 13. In process | CCY/RG | 1/31/2005 |
| 14. Plan for QC and monitoring of PWB radius | 14. In process | Craig | 1/31/2005 |
| 15. Plan to get pitch adaptors for MCM manufacturing | 15. In process | CCY/RG | 1/31/2005 |



Plan Forward in more detail (see CCY talk): PA Trace Cracking

| PA Trace Cracking | Status | Who | Date |
|--|----------------|------------|-------------|
| 1. Bond new Parlex PA to PWB | 1. In progress | RPJ/CCY | 1/28/2005 |
| 2. Document current process | 2. In progress | RG | 2/4/2005 |
| 3. Restart PA production | 3. Plan needed | RPJ/CCY | |
| 4. Oversight of PA production | 4. In progress | RG | On-going |
| 5. Demonstrate entire MCM production chain | 5. Plan needed | RPJ/CCY | 2/11/2005 |
| 6. Design new gluing fixture | 6. In progress | RPJ/CCY | 2/4/2005 |
| 7. Fab and test new fixture | 7. Need design | RPJ/CCY | 2/18/2005 |
| 8. PA from another source | 8. In progress | RPJ/CCY | 2/15/2005 |
| 9. Parallel copper grain direction | 9. In progress | RPJ/CCY | 2/11/2005 |



Tracker Technical Issues: MCM Production

- **To complete MCM's for 18 Towers, need to order more ASIC's**
 - **To date 15% loss of chips at Teledyne (under investigation)**
 - **Loss of 3 towers worth of MCM's from Tower 0, encapsulant delamination and other MCM problems (cracked traces, short circuits in PWB, PA delamination, etc.)**
 - **1 order of 20 wafers—will barely make 16 towers**
 - **2 orders of 20 wafers— will make 18 towers with spares**
 - **1 order of 20 wafers is being placed**
- **Critical path for tracker schedule is through MCM production now**
 - **Aggressively pursuing options to speed up production**
 - **need to get started first!**
 - **Burn-in is currently a bottle neck**



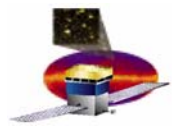
Plan Forward: MCM Production

| MCM Production | Status | Who | Date |
|--|----------------------------------|------------|-------------|
| 1. Make plan for pitch adaptor cracking | 1. Evolving | CCY/RPJ | 1/5/2005 |
| 2. Order parts to ensure full flight MCM production, esp ASICs | 2. In procoess | CCY/RPJ | 1/10/2005 |
| 3. Restart full production 25/week with goal of getting to 30/week | 3. Needs PA MRB, MRR | CCY/RPJ | 2/14/2005 |
| 4. Sonagram a sample of new production MCM's to evaluate delamination and validate process changes | 4. Procedure and criteria needed | CCY/RPJ | |
| 5. Extended qual program for at least 2 MCMs | 5. Procedure needed | CCY/RPJ | |
| 6. Increase production to >30/week | 6. Plan needed | CCY/RPJ | |



Tracker Technical Issues: Inter-ladder Strip Breakage on Heavy Trays

- **Description**
 - 3 different heavy trays belonging to 2 tower A trays showed signal strips interrupted at half their length
 - inferred from noise measurements (compatible with half strip capacitance)
 - seen in hitmap occupancy
 - trays could not be visually inspected as they were already assembled into tower A

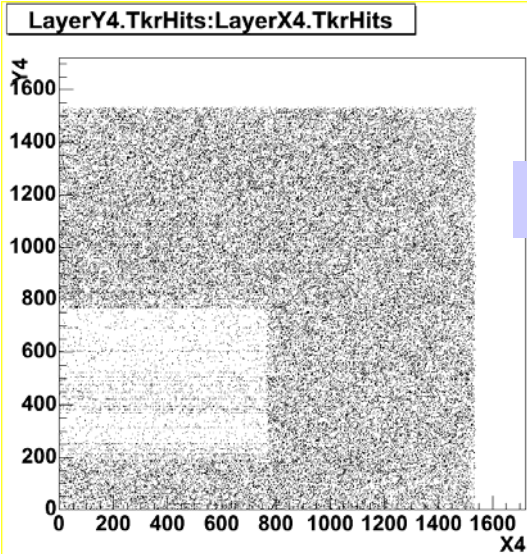


Inter-ladder Strip Breakage on Heavy Trays : Offline Analysis

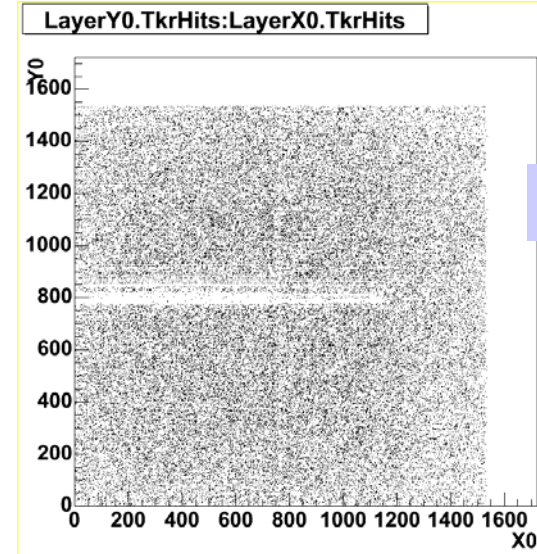
Y4 Heavy 20

12/27 Preship run

Y0 Bot 003



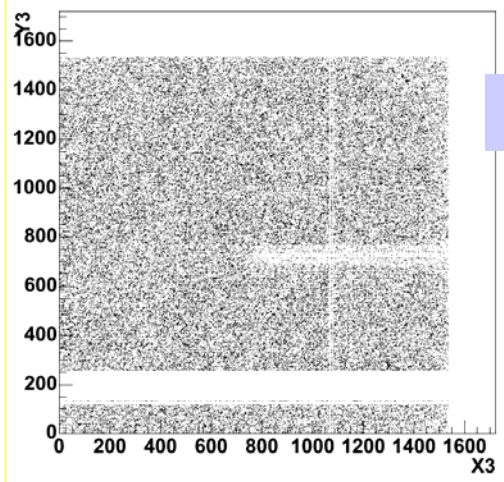
=85.3%



=96.1%

Y3 Heavy 20

LayerY3.TkrHits:LayerX3.TkrHits

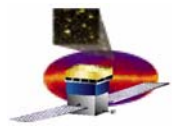


=89.9%



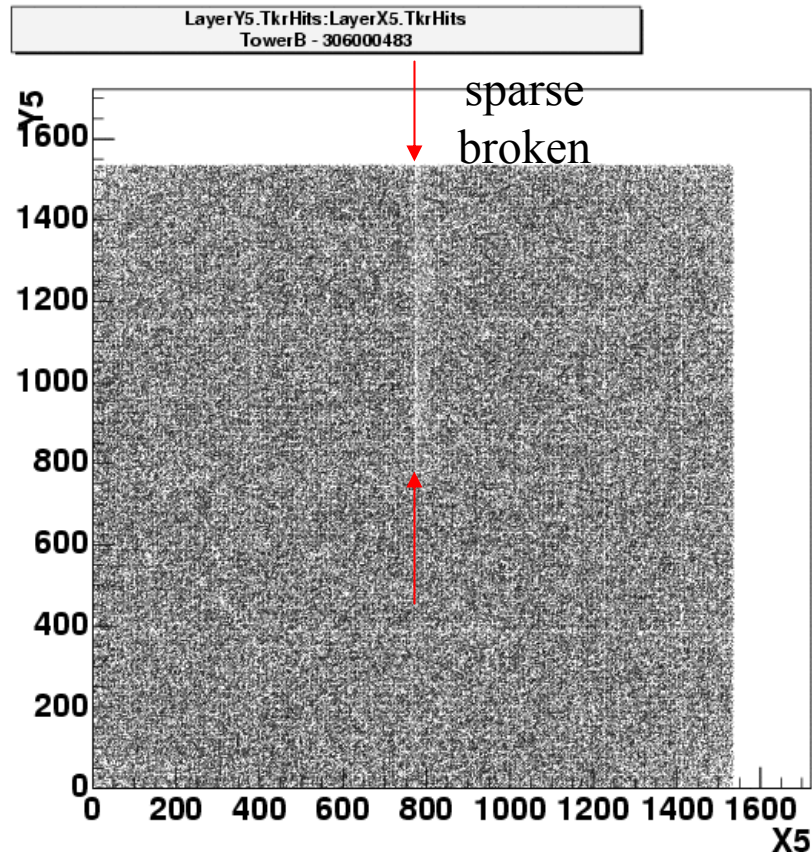
Tracker Technical Issues: Inter-ladder Strip Breakage on Heavy Trays

- **Root cause is very likely the same effect that broke wirebonds between strips and PA and led us to remove encapsulation of those wirebonds**
 - **We cannot remove encapsulation on ladders already built**
 - **Problem on heavy trays only**
 - **We can make ladders for heavy trays without encapsulation**
- **Plans forward: MRB 1/12/05**
 - **use trays as they are for tower A**
 - **reduce temperature ranges for thermal cycles and thermal-vacuum tests:**
 - **Cycle Tower B trays at tower acceptance level of -15C to +45C**
 - **Cycle Tower 1 and beyond at acceptance level of -15C to +45C (MRB 1/24/05)**
 - **for Tower 1 heavy and bottom trays, fabricate ladders without encapsulation**



Tracker Technical Issues: Inter-ladder Strip Breakage on Heavy Trays

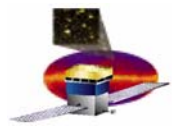
- For Tower B only one tray shows evidence of this problem
 - Heavy 37 (X5) shows 61 broken channels





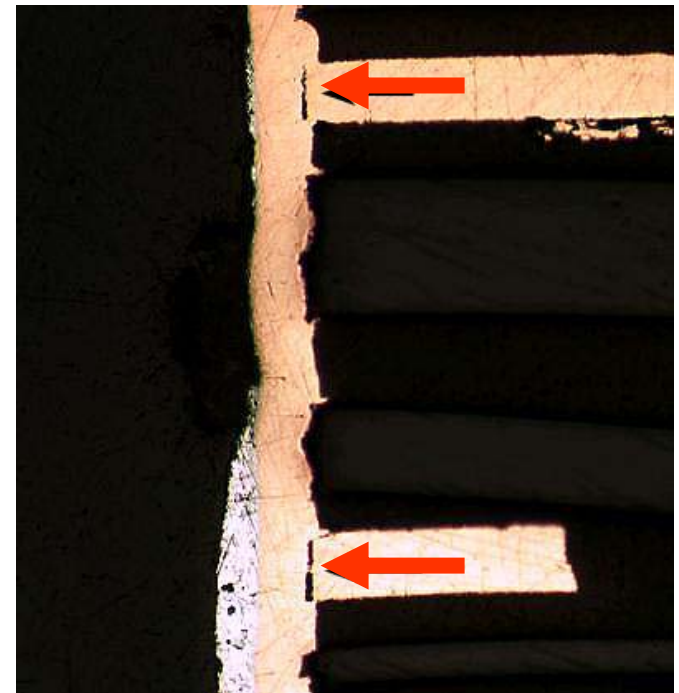
Plan Forward: Inter-ladder Strip Breakage on Heavy Trays

| Inter-ladder Strip Breakage on Heavy Trays | Status | Who | Date |
|---|---------------|------------|-------------|
| 1. Mine Perugia and Twr B data, including visual inspection of broken ladders from Perugia trays | 1. Done | Pisa | 1/12/2005 |
| 2. Assemble existing analysis to understand root cause for heavy tray problems and margin for mid-trays | 2. Done | Ku | 1/12/2005 |
| 3. 1/12/05 MRB INFN/PI_318/319 | 3. Done | Pisa | 1/12/2005 |
| 4. Proceed to make heavy trays for Tower 1 using ladders without encapsulation | 4. In process | Pisa | 1/17/2005 |
| 5. Use analysis and prototype ladders without encapsulation to retire risk | 5. In process | Kahn | 1/31/2005 |



Tracker Technical Issues: Flight Cables

- Technical, workmanship and schedule performance issues identified at Parlex
 - Technical Issue:
 - Bad coupon tests indicating separations between barrel plating and internal layers





Tracker Technical Issues: Flight Cables

- **Parlex**
 - CAP developed for assembly process
 - Production of new flex circuits restarted
 - Water blast step after drilling seems to improve plating
 - High level of interaction with Parlex
 - Daily telecons
 - Weekly visits from QA and tracker personnel
 - Weekly QA presence for onsite source inspection
 - GSFC visit
- **Currently installing cables in hand**
 - Tower A has 1 cable with bad coupon (NCR closed)
 - Tower B delayed so that can install cable set with all good coupons
 - Tower 1 all good coupons
 - Tower 2 and beyond we may face decisions on installing cables with bad coupons or delaying Tower assembly
 - There is the potential Parlex will deliver new process cables in time
- **All cables are fully functionally tested before installation in the Tower**



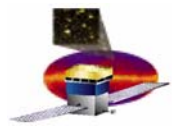
Path Forward: Flight Cables

| Flight Cables | Status | Who | Date |
|--|--------------------------------------|------------|-------------|
| 1. MRB to disposition cables for Tower A and B | 1. Done | DN/PSD | 1/4/2005 |
| 2. Complete test program for cables with bad coupons (100 cycles -25C to +55C) | 2. Done | HT | 1/7/2005 |
| 3. Fully restart Parlex | 3. Done | DN/DK | 1/7/2005 |
| 4. For Twr 1 and beyond use new cables/good coupons as much as possible | 4. Twr 1 done | DN/DR | 1/18/2005 |
| 5. Evaluate options for second sources that have been developed and develop a plan to mitigate downstream risk with Parlex | 5. In process. Need LAT IPO approval | HS/DN | |
| 6. Order parts to ensure full flight cable production | 6. In process | DN/DR | 1/15/2005 |



Tracker Costs

- **Since October rebaseline request:**
 - **Assessment of additional parts needed for flight build:**
 - **Complete inventory of additional parts needed to complete tray production in Italy**
 - Compensate for Tower 0
 - Compensate for drop out due to process development problems
 - **Assessment of additional parts and fabrication costs needed for MCM production**
 - Compensate for high drop out rate due to
 - » PA cracking
 - » Encapsulant delamination
 - Missing ASIC's at Teledyne
 - **Inventory of parts needed to complete flight cable production**
 - Large numbers of cables scrapped for workmanship issues
 - Failed coupon tests
 - **Assessment of costs to resolve technical issues**
 - **PA development prime example**



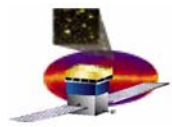
Tracker Costs

- **Identified:**
 - **\$280K of additional expenses for flight build**
 - **not included in re-baseline request**
 - **assumes that tower 15 and 16 are non flight**
 - **Note we anticipate we will have enough non flight parts to complete tower 15 and 16 for beam test using**
 - » **Tower 0 trays**
 - » **MCM's with >15 missing channels**
 - » **Cables with bad coupons**
 - » **Reworked trays**
 - **This estimate increases to \$500K if we make tower 15 and 16 flight**
- **Cost growth a problem and anticipate further costs will need to be incurred to get MCM production ramped up to avoid further schedule delays**
 - **Speed up burn in**
 - **Ramp up production rate at Teledyne**



Tracker Fabrication Schedule

- **January 5 schedule showed Tracker 14 RFI 7/25/05**
- **Identified 2 near term threats to this schedule in January:**
 - **Delay in assembly of Tower 1 trays due to funding issues in Italy**
 - **Delay schedule due to MCM supply drying up after Tower 3 if we cannot solve PA problem and get Teledyne restarted**
- **MCM production is still suspended**
 - **Root cause of problem tentatively identified**
 - **Back to production plan being put in place**
 - **Feb 14 earliest Teledyne restart**
- **MCM delays will result in 5 week work stoppage in Italy after Tower 3**
- **With no August shutdown in Italy, Tower 14 RFI 9/13/05**
 - **Note since Tower 14 assembled and tested 8/5, would be tempted to skip environmental testing to avoid August shutdown.**



Additional Schedule Threats

- **MCM Production is on the critical path**
 - **Affects production at Tower 4**
- **Face Sheet prepreg order to make Trays at Plyform next threat**
 - **Order should have been made in fall once ASI contract in place**
 - **In December this was identified as risk to production and SLAC assumed responsibility for the order**
 - **Potential to affect production starting at Tower 7**
- **New ASIC order needed for MCM's to complete Tower 14**
 - **Order is placed**
 - **Delivery schedule not yet confirmed**



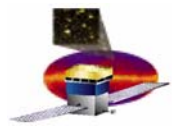
Conclusions

- **Arrival of Tower A a critical milestone for the tracker**
- **Continue to battle technical issues**
 - **PA problem the critical issue facing us**
- **Working intensively to deal with multiple schedule threats**
- **Concerned about growing costs**
 - **Currently considering making final 2 towers from non flight parts to help control costs**



Tracker Thermal Cycle Ranges

| | | Cycle | | Number |
|------------|-----|-------|------|--------|
| | | Low | High | |
| MCM | | -30 | 85 | 21 |
| Bare Panel | | | 60 | 4 |
| Tray | | -30 | 55 | 4 |
| Tower Qual | | -30 | 50 | 4 |
| Tower Acc | Old | -20 | 50 | 4 |
| Tray | | -15 | 45 | 4 |
| Tower Qual | | -20 | 50 | 4 |
| Tower ACC | New | -15 | 45 | 4 |



Tracker Costs

- **Parts costs covered in rebaseline request:**

| | |
|-------------------------|-------------|
| Cable Connectors | 60K |
| Misc Parts | 120K |
| C-C Material | 30K |
| TOTAL | 210K |

- **Additional Parts for Tray fabrication in Italy (18 flight towers)**

| | |
|-----------------------|------------|
| Tray Fab Parts | 76K |
|-----------------------|------------|

- **Additional costs for MCM parts and production (18 flight towers)**

| | |
|------------------|-------------|
| MCM Parts | 232K |
| MCM Fab | 86K |
| MCM TOTAL | 318K |

- **We are substantially over rebaseline request in parts replacement**



Tracker Costs

- We have identified additional liens not included in rebaseline:

| | |
|--------------------------------|-------------|
| Tower alignment support | 10K |
| Prepreg face sheets | 34K |
| TMCM Bonding tool | 16K |
| TMCM tests | 10K |
| TMCM bake out | 12K |
| Omnetic (suppl.) | 39K |
| Cable Parts | 22K |
| PA Development | 40K |
| TOTAL | 183K |

- We estimate we can save 220K in parts by making last 2 towers from non-flight parts (drop outs from flight production).