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	Author(s): E. Gawehn M. Huffer M. Nordby L. Wai	Approval(s): E. Bloom J. Clinton G. Haller D. Marsh
GLAST LAT	Subsystem/Office **Integration and Test Subsystem**	
Document Title **LAT Assembly Sequence**		

DRAFT

Gamma-ray Large Area Space Telescope (GLAST)

Large Area Telescope (LAT)

Integration and Test Subsystem

LAT Assembly Sequence

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Change History Log

Revision	Effective Date	Description of Changes
1	March 11, 2003	Initial Release

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1. PURPOSE

This document contains the sequence for mechanical and electrical assembly of the LAT in SLAC Building 33.

2. SCOPE

This document covers the activities that occur at SLAC and NRL using components provided by other subsystems as well as components provided by the Integration and Test Subsystem. This document clarifies the configuration and the test methodologies for mechanical and electrical assembly of the LAT.

An overview of assembly is given in section 5 below. The required ground support equipment are summarized in section 6 below along with which organization will provide the components. The assembly sequence is given in sections 7 through 9. The sequence for spare tower swap is given in section 10. Supplemental figures are given in section 11.

3. ACRONYMS / DEFINITIONS

3.1. ACRONYMS

ACD	Anticoincidence Detector
CAL	Calorimeter
EGSE	Electrical Ground Support Equipment
EPU	Event Processor Unit
GLAST	Gamma-ray Large Area Space Telescope
GLT	Global Trigger
GUI	Graphical User Interface
I&T	Integration and Test
LAT	Large Area Telescope
MGSE	Mechanical Ground Support Equipment
TEM-PSU	Tower Electronics Module Power Supply Unit
SIS	Spacecraft Interface Simulator
SVAC	Science Verification Analysis and Calibration
TEM	Tower Electronics Module
TBD	To Be Determined
TKR	Tracker

3.2. DEFINITIONS

4x4 Grid	Flight Grid that contains 16 bays in a 4x4 square.

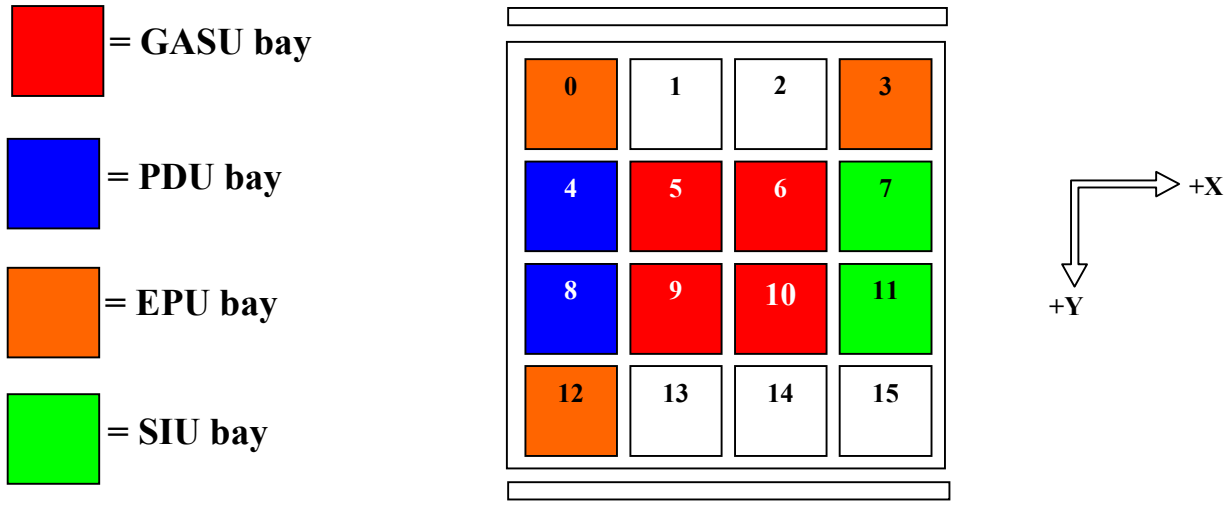
4. APPLICABLE DOCUMENTS

Documents relevant to the LAT Assembly Sequence:

- LAT-MD-01462 MGSE Development Plan
- LAT-MD-01055 LAT Electrical Performance Tests
- LAT-MD-01386 LAT I&T Facilities
- LAT-MD-00895 LAT Surveying Plan
- LAT-MD-01586 LAT I&T Survey and Alignment Plan

5. OVERVIEW

For the purposes of defining installation sequence, we refer to the following diagram showing the bay numbering scheme and system-level electronics box spaces:



For reference, the horizontal bars represent the location of the as-installed radiators. The +Z direction is perpendicular to the plane of the grid and points from the grid to the top/front of the TKR (i.e., in a direction opposite to the gravity vector). We may refer to the ground orientation of the LAT assembly as follows: "upright" means tracker towers pointing upwards (i.e., in a direction opposite to the gravity vector), "upside-down" means tracker towers pointing downwards (i.e., in the same direction as the gravity vector), "sideways" means tracker towers pointing in a direction parallel to the ground (i.e., in a direction perpendicular to the gravity vector).

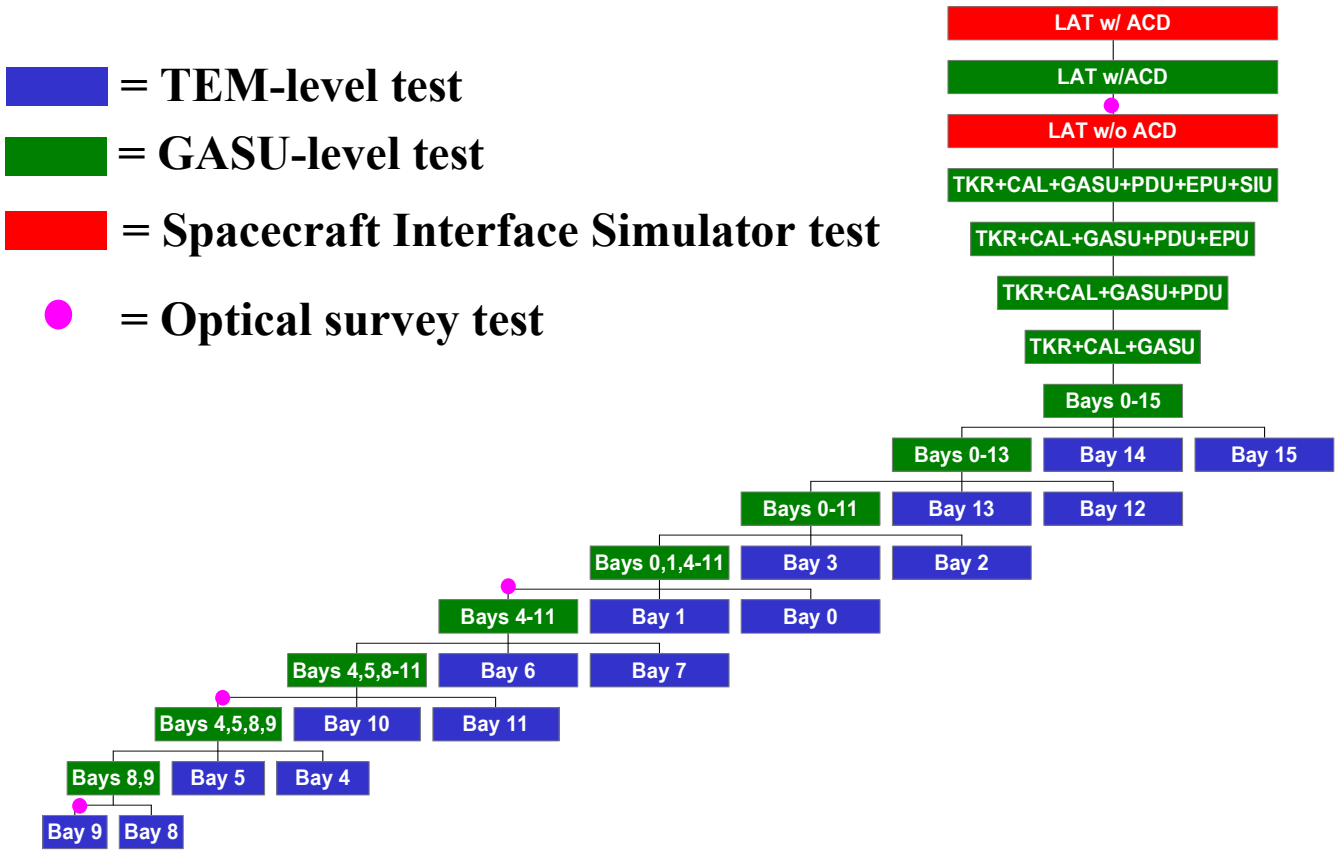
The overall sequence for assembly of the LAT can be briefly summarized as follows:

a) Bay-level integration (section 7)

b) System-level electronics integration (section 8)

c) ACD-level integration (section 9)

The hierarchy of tests for LAT assembly sequence is summarized in the following chart. Electrical performance test definitions and methodology are given in LAT-MD-01055. Survey test methodology and analysis is given in LAT-MD-01586.


= TEM-level test
= GASU-level test
= Spacecraft Interface Simulator test
= Optical survey test
LAT w/ ACD
LAT w/ACD
LAT w/o ACD
TKR+CAL+GASU+PDU+EPU+SIU
TKR+CAL+GASU+PDU+EPU
TKR+CAL+GASU+PDU
TKR+CAL+GASU
Bays 0-15
Bays 0-13
Bay 14
Bay 15
Bays 0-11
Bay 13
Bay 12
Bays 0,1,4-11
Bay 3
Bay 2
Bays 4-11
Bay 1
Bay 0
Bays 4,5,8-11
Bay 6
Bay 7
Bays 4,5,8,9
Bay 10
Bay 11
Bays 8,9
Bay 5
Bay 4
Bay 9
Bay 8

6. REQUIRED GROUND SUPPORT EQUIPMENT

This section summarizes the required ground support equipment components and is organized by the subsystem who will contribute the items.

6.1. ELECTRONICS SUBSYSTEM CONTRIBUTION

The Electronics Subsystem will provide the following electrical test equipment:

6.1.1. TEM-Level Test Equipment

The TEM-Level Test Equipment is defined by LAT-MD-01055. One dedicated set is required for LAT assembly.

6.1.2. GASU-Level Test Equipment

The GASU-Level Test Equipment is defined by LAT-MD-01055. One dedicated set is required for LAT assembly.

6.2. INTEGRATION AND TEST SUBSYSTEM CONTRIBUTION

The Integration and Test Subsystem will provide the following electrical test and mechanical ground support equipment:

6.2.1. Online Test Station and Software

The Online Test Station and Software is defined by LAT-MD-01533. Two dedicated sets are required to support the total Electronics Subsystem contributions to electrical test equipment, summarized above.

6.2.2. MGSE

The MGSE is defined by LAT-MD-01462.

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7. BAY-LEVEL ASSEMBLY SEQUENCE

7.1. FLIGHT GRID PREPARATION

7.1.1. Mount MGSE Calorimeter Shear Plates into Grid Box Base Assembly.

7.1.2. Mount Grid Box Base Assembly into the LAT Grid Perimeter Ring (GPR)

7.1.3. Attach LAT Lifting Fixture to GPR, lift GPR w/ Grid and mount into the LAT Tilt-Over Stand, with the + Z axis pointing downward.

7.1.4. Mount purge lines to Grid and start purge.

Purge should be going whenever integration is underway on LAT (TBR).

7.2. BAY 9 INSTALLATION

7.2.1. Remove Non-Flight CAL Shear Plate.

7.2.2. Invert GPR by crane operation to + Z up (upright orientation)

7.2.2.1. Check anchor pivot points. Connect lifting fixture from crane to pick-points on +X side of GPR (TBR). Invert LAT by crane operation

7.2.2.2. Bolt GPR to Tilt-Over Stand using four GPR corner bolts. Torque per TBD.

7.2.3. Tracker installation

Note: The Trackers will be installed using a crane from above the Grid's + Z axis and fasteners installed / torqued from underneath (i.e., from the Grid - Z axis).

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7.2.3.1. Lift TKR module with Tracker Lifting Fixture, its cabling grouped together near the tracker's local -z axis and lightly bound together using kapton tape

7.2.3.2. Align TKR module over Bay and lower into position onto Grid flange.

7.2.3.3. Attach TKR Module flexures to Grid top flange with 12 fasteners

7.2.3.4. Untape TKR kapton flex cables and check fit in all Grid grooves and slots

7.2.3.5. Fasten TKR thermal straps to Grid top flange with 24 fasteners (TBR).

7.2.3.6. Torque TKR flexure mount bolts

7.2.4. Tape TKR flex cables into their respective cable chase ways using flight kapton tape (TBR).

[EG Note: From recent TKR cable chase way discussions, it appears a spring type tool will need to be developed to allow correct placement of the TKR's ribbon cables where they jog around the + Z end of the grid into their respective chase ways. There is a strong chance that the cables will need to have a slight twist to ensure they lay down correctly. To do this for all 8 cables at the same time without a tool may be too difficult. After the tool is used to position all cables, each one is taped down using flight kapton tape or TBD.]

7.2.5. The TEM connector ends are temporarily taped out of the way using Kapton tape to allow safe insertion of the CAL module. Temporarily held in place by TBD

[EG Note: Need clearance assessment views to validate functionality of this.]

7.2.6. Invert GPR by crane operation to + Z down (upside down) orientation

7.2.7. CAL Integration

7.2.7.1. CAL modules are shipped with their Handling Fixture facing downward (i.e., the CAL module's + Z axis pointing opposite the gravity vector).

7.2.7.2. Each CAL module is delivered within its NRL-provided Handling Fixture and includes the Tower Electronics Module (TEM) and Power Supply (TPS) attached for flight.

7.2.7.3. Upon receipt, lift the CAL module and attached TEM and TPS modules using the CAL-supplied lift sling and place into a SLAC provided CAL Module Rotation Stand.

7.2.7.4. Rotate CAL module 180°

7.2.7.5. Position / roll Personnel Access Platform over Grid, next to Grid bay, then lock in place.

7.2.7.6. Attach Calorimeter Alignment Rods to the same receptacles as the Calorimeter Handling Fixture Posts in any (TBR) bay neighboring Grid Bay for bays 3 and 15

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(reference drawing GLT-LLR-00-06, zone F6), or similar receptacles at each of the four corners of the MGSE Calorimeter Shear Plates for all other bays. Torque Alignment Rods to 10 ft lbs (TBR).

7.2.7.7. Attach the Calorimeter Alignment Tool to two of the CAL module's Handling Fixture support posts per Calorimeter Alignment / Installation Procedure TBD.

7.2.7.8. Attach the SLAC provided Calorimeter Lift Fixture to the CAL's Handling Fixture Plate per Calorimeter Alignment / Installation Procedure TBD. .

7.2.7.9. Lift the CAL module/TEM/TPS assembly using the crane and SLAC-provided Lift Fixture. While suspended, adjust lift fixture turnbuckles until the CAL / Alignment Tool assembly is level to TBD degrees.

[MN note: are turn-buckles designed to be adjustable while under load? EG: Yes.]

7.2.7.10. Lower the CAL module until the Calorimeter / Alignment Tool Assembly engages the Alignment Rods.

7.2.7.11. Ensure TKR kapton flex cables are temporarily tapped away from the Calorimeter to Grid bay entry point.

7.2.7.12. Lower the CAL module into place on the Grid, using the Alignment Rods as guides. The CAL back plate is keyed onto 2 pins which are pressed into the Grid walls. Check that TKR flex cables stay in their grooves to avoid pinching.

[EG Note: TKR cables will be tapped into chase ways so we shouldn't need to worry about pinching.]

7.2.7.13. After CAL installation, Install all CAL attach fasteners per Figure TBD to finger tight condition (i.e. < 5 in lbs).

7.2.7.14. Torque TBD number of CAL fasteners to TBD per Figure TBD (to ensure that the Grid to Cal alignment pins are not damaged during the next step).

7.2.7.15. Disconnect the Calorimeter Handling Fixture Plate (about 10 to 15 ft lbs of torque to do this) from the CAL back plate, and remove with the crane. Disengage CAL Alignment Tool and remove by hand.

7.2.7.16. Remove the Calorimeter Alignment Rods

7.2.7.17. Remove the Calorimeter Handling Fixture Support Rods.

7.2.7.18. Untie TKR flex cables and check approximate fit to TEM box connectors.

7.2.7.19. Remove TKR flex cable connector-saver and connect to respective TEM box connector.

7.2.7.20. Torque all CAL mounting fasteners. Reference Figure TBD for fastener torque pattern and description.

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7.2.8. Unlock and roll personnel support gantry away from Grid Tilt Over Stand.

7.2.9. TEM-Level electrical test

7.2.9.1. Install E-GSE Test Stand near the + X, + Y corner (TBR, near LAT Bulkhead Panel 1, see Figure or Dwg TBD) of the LAT / GPR

7.2.9.2. *Connect TEM and TPS to TEM-Level Electrical Test Equipment using test cable harness. Temporarily tape test cables the top of each TPS box (TBD) to ensure TEM connectors aren't over stressed during test activity. Note, test cable harness is integrated to TEM and TPS with connector savers on the boxes*

7.2.9.3. Single Bay functional test

Defined in LAT-MD-01055, per procedure TBD.

7.2.9.4. Removal of TEM-Level electrical test equipment

7.2.9.5. Disconnect test harness from TEM and TPS. Remove temporary strain-relief tape from back of TPS box.

7.2.9.6. Remove TEM-Level GSE Electrical Test Equipment

7.3. BAY 9 OPTICAL SURVEY

7.3.1. Optical survey preparation

7.3.1.1. Rotate LAT to +Z axis up orientation

7.3.1.2. Set up 2 (TBR) laser trackers at +X, + Y and -X, - Y (TBR) corners of LAT.

7.3.1.3. Allow to thermally stabilize with room

[MN: TBD hours, usually 24 hrs]

[EG: Does this mean to let LAT thermally stabilize for 24 hrs after last electrical power input turn off. Can LAT be considered to be in a thermally stable environment when in the B-33 Integration Hall ?]

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7.3.2. Place TKR survey "hat" on top TKR tray in bay 9

7.3.3. Place 4x reflectors balls in bushings in TKR survey "hat"

7.3.4. Place 12x reflector balls in reamed holes in grid corners and mid-sides

7.3.5. Survey position of Laser trackers. Survey locations of Grid and Bay 9 TKR (SLAC Metrology team)

7.3.6. Post-process survey data to verify accuracy of TKR module placement

7.3.7. Remove reflector balls, TKR Survey Hat, and laser trackers.

[EG: Seems that it would be best to leave tracker balls in place (lightly bonded ?) and that we need a set of 16 TKR Hats to reduce measurement uncertainty.]

7.4. BAY 8 INSTALLATION

(Same as for 7.2 above.)

7.5. BAYS 8,9 FLIGHT CABLE INSTALLATION

7.5.1. Install intervening cable support tray

Note: For Bays 0-3 and Bays 12-15, also install adjacent +/-X Cable Trays

7.5.2. Integrate and fasten TEM-PDU and TEM-GASU flight cables

7.5.3. Multi-Tower Functional Test

[LW Note: the number of bays with standoffs will reduce until bays 4,8 are populated with flight hardware; at that time the EM PDU will not be removed until installation of flight PDU. Similarly, the number of bays with standoffs will reduce until all the inner 4 bays are populated with flight hardware; at that time the EM GASU will not be removed until installation of flight GASU]

[EG: It seems like we can use the Calorimeter Handling Fixture support post receptacles to attach temporary GSE posts to. The GSE posts could include nice tie points to ensure the EM GASU doesn't get bumped out of position. And we electrically disconnect the EM GASU and move it away prior to each tilt over (since it has connector savors]

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7.5.3.1. Prior to complete flight hardware population of inner 4 bays, temporarily fasten standoffs to unpopulated inner bays and EM GASU into GASU space

7.5.3.2. Prior to complete flight hardware population of bays 4,8, temporarily fasten standoffs to unpopulated bay 4 and EM PDU into PDU space

7.5.3.3. Install GASU-Level electrical test equipment

7.5.3.4. Multi-Tower Functional Test for all installed bays

7.5.3.5. Remove GASU-Level electrical test equipment

7.5.3.6. Prior to complete flight hardware population of inner 4 bays, remove EM GASU from GASU space

7.5.3.7. Prior to complete flight hardware population of bays 4,8, remove EM PDU from PDU space

7.6. BAY 5 INSTALLATION

(Same as for 7.2 above.)

7.7. BAY 4 INSTALLATION

(Same as for 7.2 above.)

7.8. BAYS 4,5 FLIGHT CABLE INSTALLATION

(Same as for 7.5 above.)

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7.9. OPTICAL SURVEY FOR BAYS 4, 5, 8, 9

7.9.1. Optical survey preparation

7.9.1.1. Rotate LAT to +Z axis up orientation

7.9.1.2. Set up 2 (TBR) laser trackers at +X, + Y and -X, - Y (TBR) corners of LAT.

7.9.1.3. Allow to thermally stabilize with room (see subsection 7.3.1.3 above)

7.9.2. Place TKR survey "hats" on tops of all 4 TKR trays

7.9.3. Place 16x reflectors balls in bushings in TKR survey "hats"

7.9.4. Place 12x reflector balls in reamed holes in grid corners and mid-sides

7.9.5. Survey position of Laser trackers. Survey locations of Grid and TKRs (SLAC Metrology team)

7.9.6. Post-process survey data to verify accuracy of TKR module placement

7.9.7. Remove reflector balls, TKR Survey Hats, and laser trackers.

7.10. BAY 10 INSTALLATION

(Same as for 7.2 above.)

7.11. BAY 11 INSTALLATION

(Same as for 7.2 above.)

7.12. BAYS 10,11 FLIGHT CABLE INSTALLATION

(Same as for 7.5 above.)

7.13. BAY 6 INSTALLATION

(Same as for 7.2 above.)

7.14. BAY 7 INSTALLATION

(Same as for 7.2 above.)

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7.15. BAYS 6,7 FLIGHT CABLE INSTALLATION

(Same as for 7.5 above.)

7.16. OPTICAL SURVEY FOR BAYS 4-11

7.16.1. Optical survey preparation

7.16.1.1. Rotate LAT to +Z axis up orientation

7.16.1.2. Set up 2 (TBR) laser trackers at +X, + Y and -X, - Y (TBR) corners of LAT.

7.16.1.3. Allow to thermally stabilize with room (see subsection 7.3.1.3 above)

7.16.2. Place TKR survey "hats" on tops of all 8 TKR trays

7.16.3. Place 32x reflectors balls in bushings in TKR survey "hats"

7.16.4. Place 12x reflector balls in reamed holes in grid corners and mid-sides

7.16.5. Survey position of Laser trackers. Survey locations of Grid and TKRs (SLAC Metrology team

7.16.6. Post-process survey data to verify accuracy of TKR module placement

7.16.7. Remove reflector balls, TKR Survey Hats, and laser trackers.

7.17. BAY 1 INSTALLATION

(Same as for 7.2 above.)

7.18. BAY 0 INSTALLATION

(Same as for 7.2 above.)

7.19. BAYS 0,1 FLIGHT CABLE INSTALLATION

(Same as for 7.5 above.)

7.20. BAY 2 INSTALLATION

(Same as for 7.2 above.)

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7.21. BAY 3 INSTALLATION

(Same as for 7.2 above.)

7.22. BAYS 2,3 FLIGHT CABLE INSTALLATION

(Same as for 7.5 above.)

7.23. BAY 13 INSTALLATION

(Same as for 7.2 above.)

7.24. BAY 12 INSTALLATION

(Same as for 7.2 above.)

7.25. BAYS 12,13 FLIGHT CABLE INSTALLATION

(Same as for 7.5 above.)

7.26. BAY 14 INSTALLATION

(Same as for 7.2 above.)

7.27. BAY 15 INSTALLATION

(Same as for 7.2 above.)

7.28. BAYS 14,15 FLIGHT CABLE INSTALLATION

(Same as for 7.5 above.)

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8. SYSTEM-LEVEL ELECTRONICS ASSEMBLY SEQUENCE

8.1. TEST AND HOUSEKEEPING INSTRUMENTATION INSTALLATION

Note: Test instrumentation will be placed on LAT structure under GASU and PDU boxes

8.1.1. Disconnect GASU end of all cables running to EM-GASU. Pull flight cable back and tie out of way.

8.1.2. Remove EM GASU

8.1.3. Attach thermistors on back side of CAL plates and electronics boxes per drawing TBD

8.1.4. Route thermistor cables to PDU location and terminate at connector per drawing TBD. Connect temp connector to EM-PDU and check.

8.1.5. Attach accelerometers and thermocouples Grid, CAL bottom plates, and electronics boxes per drawing TBD

8.1.6. Route accelerometers and TC cables to EMI Skirt test plug and terminate

8.1.7. Check interfaces to test plug to verify connectivity

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8.2. FLIGHT GASU INSTALLATION

8.2.1. Flight GASU integration prep

8.2.1.1. Remove EM GASU and associated connector savers (TBR)

8.2.2. GASU Integration

8.2.2.1. Pick up GASU with crane and lower into position on 4 inner bays.

8.2.2.2. Integrate GASU to mating TEM-PSU boxes and fasten in place

8.2.2.3. Rough-check alignment with respect to GPR

***8.2.2.4.** Torque GASU mounting bolts*

8.2.3. Install GASU-PDU flight cable

8.2.3.1. Remove GASU-PDU cable connector-saver on GASU

8.2.3.2. Tie down GASU-PDU flight cable

8.2.3.3. Flight Mate GASU-PDU cable to GASU

8.2.3.4. Check connectivity to EM-PDU

8.2.3.5. Multi-tower Functional test

8.2.4. Integrate 16x TEM-GASU cables

8.2.4.1. Remove Bay 0 TEM-GASU cable connector-saver

8.2.4.2. Flight Mate Bay 0 TEM-GASU cable

8.2.4.3. Multi-Tower Functional Test for all bays

8.2.4.4. Repeat above steps for Bays 1-15

[MN note: or should towers be integrated in same order as during initial electrical integration of towers?]

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8.2.5. Integrate 2x SIU-GASU cables

8.2.5.1. Remove Bay 7 SIU-GASU cable connector-saver

8.2.5.2. Flight Mate Bay 7 SIU-GASU cable

8.2.5.3. System level functional test of TKR+CAL+GASU+SIU

8.2.5.4. Repeat above steps for Bay 11

8.2.6. Integrate 3x EPU-GASU cables

8.2.6.1. Remove Bay 0 EPU-GASU cable connector-saver

8.2.6.2. Flight Mate Bay 0 EPU-GASU cable

8.2.6.3. System level functional test of TKR+CAL+ GASU+SIU+EPU

8.2.6.4. Repeat above steps for Bays 12,3

8.3. PDU INSTALLATION

8.3.1. PDU integration prep

8.3.1.1. Disconnect PDU side of all cables running to EM-PDU

8.3.1.2. *Remove EM-PDU from PDU space*

8.3.2. PDU Integration

8.3.2.1. Pick up PDU with crane and lower into position over bays 4 and 8

8.3.2.2. Integrate PDU to mating TEM-PSU boxes and fasten in place

8.3.2.3. Rough-check alignment with respect to GPR

8.3.2.4. Torque PDU mounting bolts

8.3.3. Flight Mates for PDU connectors

8.3.3.1. Remove GASU-PDU cable connector saver on PDU

8.3.3.2. Flight Mate GASU-PDU cable connector on PDU

8.3.3.3. System level functional test

8.3.3.4. Remove Bay 0 TEM-PDU cable connector saver on PDU

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8.3.3.5. Flight mate Bay 0 TEM-PDU cable connector on PDU

8.3.3.6. System level functional test

8.3.3.7. Repeat steps for Bays 1-15 TEM-PDU cable connectors on PDU

8.3.3.8. Remove Bay 7 SIU-PDU cable connector saver on PDU

8.3.3.9. Flight Mate Bay 7 SIU-PDU cable connector on PDU

8.3.3.10. System level functional test

8.3.3.11. Repeat steps for Bay 11 SIU-PDU cable connectors on PDU

8.3.3.12. Remove Bay 0 EPU-PDU cable connector saver on PDU

8.3.3.13. Flight Mate Bay 0 EPU-PDU cable connector on PDU

8.3.3.14. System level functional test

***8.3.3.15.** Repeat steps for Bays 12,3 EPU-PDU cable connectors on PDU*

8.4. EPU INSTALLATION

8.4.1. EPU integration prep

8.4.2. EPU integration in bay 0

8.4.2.1. Pick up EPU with crane and lower into position over bay

8.4.2.2. Integrate EPU to mating TEM-PSU box and fasten in place

8.4.2.3. Rough-check alignment with respect to GPR

8.4.2.4. Torque EPU mounting bolts

8.4.2.5. Install EPU-GASU cable

8.4.2.6. Install EPU-PDU cable

8.4.2.7. System level functional test of TKR+CAL+SIU+EPU

8.4.3. EPU integration in bay 12

Same as in section 8.4.2 above.

8.4.4. EPU integration in bay 3

Same as in section 8.4.2 above.

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8.5. SIU INSTALLATION

8.5.1. SIU integration prep

8.5.2. SIU integration in bay 7

8.5.2.1. Pick up SIU with crane and lower into position over bay

8.5.2.2. Integrate SIU to mating TEM-PSU box and fasten in place

8.5.2.3. Rough-check alignment with respect to GPR

8.5.2.4. Torque SIU mounting bolts

8.5.2.5. Install SIU-GASU cable

8.5.2.6. Install SIU-PDU cable

8.5.2.7. System level functional test of TKR+CAL+SIU

8.5.3. SIU integration in bay 11

Same as in section 8.5.2 above.

8.5.4. EPU integration in bay 3

Same as in section 8.5.2 above.

8.6. CABLING TO EMI SHIELD

8.6.1. EMI Skirt Integration

8.6.1.1. Mechanically integrate EMI Skirt pieces with their bulkhead plate on all 4 sides of Grid

[EG Note: A mechanical clearance analysis should be performed to ensure we have enough room to clear all potential items in the path. Drawing views should be developed for each operation to demonstrate appropriate clearance. Most of these views could be folded into the formal flight integration procedure well after the CDR. The views would also be annotated to help clarify what the technicians will be facing]

8.6.1.2. Verify flatness of bottom edges (-Z) of EMI Skirt pieces for future X-LAT Plate mate-up

[EG Note: Has a True Position Tolerance Analysis been performed between the Grid and the EMI Skirt elements? This should clarify where the problems are. Also, no comment about what is done if not flat to within TBD Remove pieces as required, root to machine shop, etc.

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To reduce schedule risk, this flatness verification should be done prior to hardware turn over from Mech Sys to I&T.]

8.6.2. GASU internal cable integration

8.6.2.1. Mate GASU-Bulkhead flight cables at both ends.

8.6.2.2. Check connectivity through EMI Skirt bulkhead connector

8.6.2.3. Connect E-GSE "Crate 6" to outer bulkhead connector

8.6.3. PDU internal cable integration

8.6.3.1. Mate PDU-bulkhead flight cables, including power feeds, external temp sensors

8.6.4. SIU internal cable integration

8.6.4.1. Disconnect SIU-EGSE test cables. Remove connector-savers on SIU boxes

8.6.4.2. Electrically integrate SIU-bulkhead inner cables to SIU.

8.6.4.3. Mechanically connect to cable ways, and integrate to inside connector of bulkhead panels

8.6.4.4. Verify that bulkhead panels can be removed with service loop on internal cables

8.6.4.5. Verify electrical connectivity of SIU internal cables

8.6.4.6. Connect test cable harness to SIU outside bulkhead connectors. Strain relieve to TBD

8.6.5. ACD internal cable integration

8.6.5.1. Integrate flight ACD cable harness to GASU. Mechanically connect to cable ways, and integrate to inside bulkhead of patch panels [MN note: if bulkhead plate has all cables and connector physically mounted to it, some of ACD cable will need to be integrated along with other cables on that bulkhead]

8.6.5.2. *Verify that bulkhead panels can be removed with service loop on ACD internal cables*

[EG: Shouldn't have a cable service loop unless we plan to demonstrate cable can survive independent vibe test.]

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8.6.5.3. Verify electrical connectivity of ACD internal cables

8.6.6. Switch box integration

8.6.6.1. Mechanically integrate VCHP heater switch boxes to Radiator Mount Bracket on corners of Grid Box

8.6.6.2. Electrically integrate VCHP heater switch boxes to outside bulkhead connectors on EMI Skirt

8.6.6.3. Electrically integrate test cable harness to VCHP heater switch boxes and to E-GSE

8.6.6.4. Electrically integrate VCHP heater STE to heater switch box

8.6.6.5. Run limited functional test of VCHP heater switch box through SIU

8.6.7. ACD FREE Simulator Test

8.6.8. System level test through spacecraft interface

8.6.8.1. Setup of SIS test equipment

8.6.8.2. Comprehensive Performance Test without ACD

8.6.8.3. Remove SIS test equipment

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9. ACD-LEVEL ASSEMBLY SEQUENCE

9.1. LAT REFERENCE SURVEY

9.1.1. Optical and muon survey preparation

9.1.1.1. Rotate LAT to +Z axis up orientation

9.1.1.2. Level LAT Grid using TBD

9.1.1.3. Mount temporary cooling to back side of electronics boxes

9.1.1.4. Integrate test heat exchangers to side of Grid

9.1.1.5. Place TKR survey "hats" on tops of all 16 TKR trays

9.1.1.6. Place 64x reflectors balls in bushings in TKR survey "hats"

9.1.1.7. Place 12x reflector balls in reamed holes in grid corners and mid-sides

9.1.1.8. Set up 2 (TBR) laser trackers at +X, + Y and -X, - Y (TBR) corners of LAT.

9.1.2. Muon survey

9.1.2.1. Turn on LAT and perform abbreviated CPT (MN note: this is not the baseline, since ACD is not there, but we probably need something, since we will need some calibration data to interpret cosmic ray muon data. Is this true?]

9.1.2.2. Run LAT for at least TBD hours to stabilize all temperatures within the LAT to TBD degrees (See Survey Plan for details)

9.1.2.3. Cosmic ray muon surveying run to establish baseline relative position of Tracker modules. Perform muon survey with LAT + Z axis up (see Survey Plan)

9.1.3. Optical survey all 16 TKR modules and grid (SLAC Metrology team)

9.1.4. Post-process survey data to verify accuracy of TKR module placement

9.1.5. Turn off LAT

9.1.6. Remove reflector balls, TKR Survey Hats, and laser trackers.

9.1.7. Disconnect test heat exchangers from sides of Grid

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9.2. ACD INTEGRATION PREPARATION

9.2.1. Install thermocouples on tops of TKR modules per drawing TBD. Route TC cables and mount to tops of TKR modules.

9.2.2. Terminate TC's at LAT External Test Plug. Check conductivity and function of TC's through test plug using E-GSE

9.2.3. Install accelerometers on tops of TKR modules per drawing TBD. Route accel cables and mount to tops of TKR modules per drawing TBD

9.2.4. Terminate accel cabling at LAT External Test Plug. Check conductivity and function of accel's through test plug using E-GSE

9.2.5. Test accelerometer functionality through Modal Survey DAQ with a test model survey. Excite LAT Grid using stingers or calibrated hammer and check accel orientation and functionality

[EG Note: is accel place correctly? Is gain as expected? Do accel's correlate with phase and relative magnitude as expected?]

9.3. ACD INSTALLATION

9.3.1. Relocate LAT onto ACD Install Stand

Note: Starting configuration for the next step is +Z axis up

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9.3.1.1. Bundle all E-GSE and test cables onto moving cable way to allow for relocation of the LAT

9.3.1.2. Connect LAT Lift Fixture to LAT GPR

9.3.1.3. Disconnect GPR from Tilt Over Stand and lift LAT.

9.3.1.4. Crane op LAT from the Tilt Over Stand to the ACD Installation Stand.

9.3.1.5. Lower LAT onto the ACD Installation Stand

9.3.1.6. Mount GPR to ACD Integration Stand.

9.3.1.7. Level Grid to TBD and remove the LAT Lift Fixture

9.3.2. ACD Installation

9.3.2.1. Install auxiliary ACD installation tooling/guides onto LAT Mounting Stand.

9.3.2.2. Align installation tool/guides to LAT (TBD)

9.3.2.3. Attach ACD Lift Fixture to crane

9.3.2.4. Pick up ACD Lift Fixture, locate ACD Lift Fixture over ACD

9.3.2.5. Integrate onto ACD corners.

9.3.2.6. Level using ACD Lift Fixture's X, Y Cg adjustment screws

9.3.2.7. Lift ACD with ACD Lifting Fixture above Trackers

9.3.2.8. Re-level ACD and align onto installation tool/guides

9.3.2.9. Lower ACD over TKR modules toward LAT interface

9.3.2.10. Set ACD onto registration pins in corners of Grid

9.3.2.11. Start fasteners through LAT corner to ACD interfaces.

9.3.2.12. After ensuring no binding, lower ACD fully onto mounting pads at corners of Grid

9.3.2.13. Mate ACD cables and perform functional verification.

9.3.2.14. Install dowel pins through ACD Base Frame Assembly mid-sides and into Grid, finger tight only (i.e., < 5 in lbs).

9.3.2.15. Finger tighten (i.e., < 5 in lbs) ACD-Grid corner fasteners

9.3.2.16. Torque ACD to LAT mid-side fasteners to 20% of final torque in a cris-cross fashion per Figure TBD

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9.3.2.17. Torque ACD to LAT corner fasteners to 20% of final torque in a cris-cross fashion per Figure TBD

9.3.2.18. Torque ACD to LAT mid-side fasteners to 50% of final torque in a cris-cross fashion per Figure TBD

9.3.2.19. Torque ACD to LAT corner fasteners to 50% of final torque in a cris-cross fashion per Figure TBD

9.3.2.20. Torque ACD to LAT mid-side fasteners to 100% of final torque in a cris-cross fashion per Figure TBD

9.3.2.21. Torque ACD to LAT corner fasteners to 100% of final torque in a cris-cross fashion per Figure TBD

9.3.2.22. disconnect ACD from lifting fixtures and remove lifting fixture.

9.3.2.23. Disconnect auxiliary ACD installation tooling/guides from LAT Mounting Stand.

9.3.2.24. System Level Functional Test

9.3.3. Flight Connector Mates between ACD and Cross-LAT Box Bulkhead Connectors

9.3.3.1. Safe-to-mate checks.

[EG: Is this the same as the set of flight verification tests?]

9.3.3.2. Mate ACD-bulkhead cables to ACD and to bulkheads.

9.3.3.3. Turn on LAT and verify ACD-bulkhead cable connectivity.

9.3.3.4. Perform ACD CPT (TBR) through GASU and E-GSE

9.3.3.5. Turn off LAT

9.3.4. Relocate LAT to Tilt-Over Stand

9.3.4.1. Bundle all E-GSE and test cables onto moving cable way to allow for relocation of the LAT

9.3.4.2. Attach LAT lift fixture to GPR to allow relocation of it back onto the LAT Tilt-Over Stand.

9.3.4.3. Disconnect GPR from ACD installation stand and lift LAT. Lower LAT onto the LAT Tilt-Over Stand

9.3.4.4. Mount GPR to LAT Tilt-Over Stand.

9.3.4.5. Level Grid to TBD and remove the LAT Lift Fixture

Note: LAT is now oriented with its + Z axis upright and leveled.

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9.4. X-LAT HEAT PLATES INSTALLATION

[LW note: MN favors LAT with +Z downwards for X-LAT Plate Integration, whereas EG favors LAT with +Z horizontal.]

[MN note: ACD is integrated. We must be able to invert the LAT with the ACD on. If current M-GSE concepts prevent this, then we need to talk about how to change the design

[EG Note: E. Bloom gave the current direction]

9.4.1. Integrate X-LAT Thermal Straps

[EG: I thought thermal conduction straps come attached to e-boxes and we attach to them. How do we remove the X-LAT HP after the epoxy step below?]

9.4.1.1. Position Thermal Strap locating plate onto EMI Skirt and check alignment

9.4.1.2. Epoxy thermal straps into place, registering on the locating plate as you go

9.4.1.3. Verify workmanship of mechanical integration of thermal straps with shear test (TBR)

9.4.1.4. Remove locating plate

9.4.2. Integrate +X X-LAT Plate (TBR) onto underside of LAT. Locate on EMI Skirt and bolt in place

9.4.3. Check XLHP/DSHP joint alignment on both sides of Grid with Mech Systems alignment fixture (TBR)

9.4.4. Bolt and torque thermal straps to X-LAT Plate

9.4.5. Integrate -X X-LAT Plate (TBR) onto underside of LAT. Locate on EMI Skirt and bolt in place

9.4.6. Check XLHP/DSHP joint alignment on both sides of Grid with Mech Systems alignment fixture (TBR)

9.4.7. Bolt and torque thermal straps to X-LAT Plate

9.4.8. Integrate Mid-Plate to underside of LAT. Locate on EMI Skirt and neighboring X-LAT Platesl. Bolt in place

9.4.9. Torque all X-LAT and Mid-Plate mounting bolts

9.4.10. Integrate thermistors on back side of X-LAT Plates. Run cabling to SC interface plug on outside of EMI Skirt

9.4.11. Integrate TC's on back side of X-LAT Plates. Run cabling to LAT Exterior Test Plug

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9.5. RADIATOR FIT CHECK

9.5.1. Tip LAT up on Edge

9.5.1.1. Tip LAT up using turn-over fixture and mount vertical restraining brackets. Level LAT in the +Z horizontal postion to within TBD degrees

9.5.1.2. Set up Laser Tracker stations and allow to thermally stabilize for 24 hours (TBR)

9.5.1.3. Mount reflector balls on Grid and verify position and orientation of LAT

9.5.2. Integrate M-GSE Radiator support structure to the GPR and align

9.5.3. Integrate –Y Radiator onto LAT.

9.5.4. Survey position of Radiator, align as needed to place Radiator correctly and pin Radiator to Radiator Mount Bracket. Mount Radiator to Rad Mnt Bkt and M-GSE struts

[EG: The true position uncertainty analysis indicates this is needed ? I wouldn't have expected very much allowable movement. I need to learn more about these aspects.]

9.5.5. Integrate VCHP's to DSHP/XLHP's. This is just a structural and electrical integration, so do not use silicone at the VCHP-DSHP/XLHP joints

9.5.6. Integrate +Y Radiator onto LAT.

9.5.7. Survey position of Radiator, align as needed to place Radiator correctly and pin Radiator to Radiator Mount Bracket. Mount Radiator to Rad Mnt Bkt and M-GSE struts

9.5.8. Integrate VCHP's to DSHP/XLHP's. This is just a structural and electrical integration, so do not use silicone at the VCHP-DSHP/XLHP joints

9.5.9. Electrically integrate Radiator cables to bulkhead connectors, VCHP Heater Switch boxes and patch panels outside EMI Skirt

9.5.10. Turn on SIU/PDU and perform Radiator LPT [MN note: may need heat sinks/fans on VCHP reservoirs to keep them cool during testing

9.5.11. Remove Radiators (TBD)

[MN note: we could conceivably keep the Radiators on for the CPT. Does schedule support this? Is this prudent? Is this a good idea?]

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9.6. LAT REFERENCE COMPREHENSIVE PERFORMANCE TEST AT SLAC.

9.6.1. Power up LAT DAQ and run LPT

9.6.2. Verify X-LAT thermal strap thermal connections by checking electronics box temperatures

9.6.3. LAT System Test Readiness Review at SLAC.

9.6.4. Setup of SIS test equipment

9.6.5. Re-check LAT alignment using optical surveying

9.6.6. Comprehensive Performance Test including ACD

9.6.7. Cosmic ray muon survey of the LAT

9.6.8. Remove SIS test equipment

9.6.9. De-integrate Radiators from LAT and pack away.

[EG: Need clarification about how to detach Radiators from DSHPs. This could be needed at Spectrum and we should know how to do it (i.e., does each DSHP include jack away receptacles to break silicone joint with out prying?)]

9.6.10. Remove vertical support brackets from LAT and tip LAT down to +Z axis up orientation

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10. SINGLE TOWER SWAP SEQUENCE

We consider the case for swapping a single Non-Conforming Tower with a Spare Tracker Module, Spare Calorimeter Module, and Spare Tower Electronics Module after full assembly of LAT.

TBD

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11. APPENDIX: SUPPLEMENTAL FIGURES

This section contain supplemental figures of items that do not currently have drawing numbers but have conceptual CAD models.

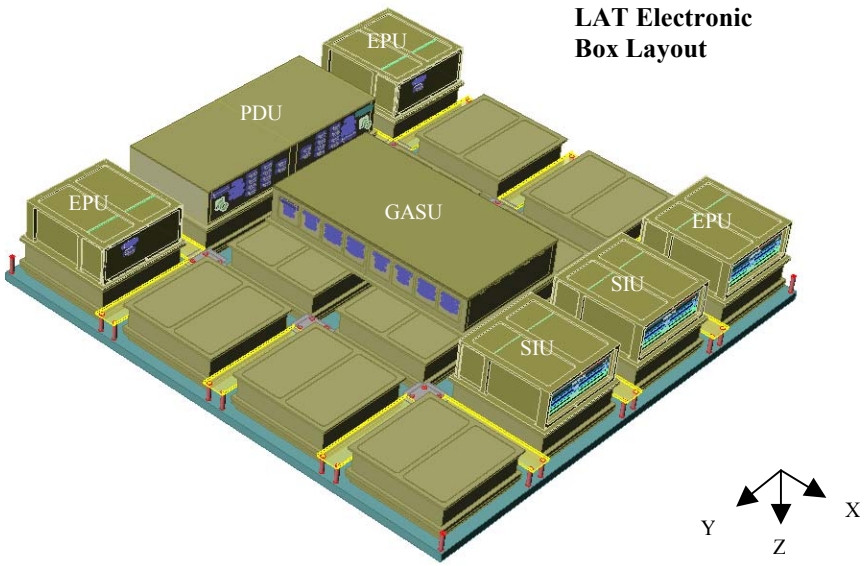

Figure 1: LAT Electronic Box Layout