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Gamma-ray Large Area Space Telescope (GLAST)
 Large Area Telescope (LAT)
 Integration and Test Subsystem
 Mechanical Ground Support Equipment Development Plan

Change History Log

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1. PURPOSE

The purpose of the LAT Mechanical Ground Support Equipment (MGSE) Development Plan is to identify mechanical tooling and ground support equipment required to assemble, test and transport the LAT during its five phases of hardware development. The five phases of LAT MGSE development are Engineering Model, Calibration Unit, Flight Unit build, Flight Unit Environmental Test and Flight Unit mate to SC Bus.

2. SCOPE

This document provides a description of the MGSE items required for each phase of integration, test and transport and is intended to bound design and analysis requirements in a responsive and general manner.

3. ACRONYMS / DEFINITIONS

3.1. ACRONYMS

ACD	Anticoincidence Detector
CAL	Calorimeter
CDE	Crystal Detector Element
DAQ	Data Acquisition System
EGSE	Electrical Ground Support Equipment
EM	Engineering Model
EM1	Engineering Model 1
EM2	Engineering Model 2
EMI	Electromagnetic Interference
GLAST	Gamma-ray Large Area Space Telescope
I&T	Integration and Test
LAT	Large Area Telescope
MGSE	Mechanical Ground Support Equipment
PDR	Preliminary Design Review
SVAC	Science Verification Analysis and Calibration
TEM	Tower Electronics Module
TBD	To Be Determined
TBR	To Be Resolved
TKR	Tracker
TBW	To Be Worked

3.2. DEFINITIONS

1x 1 Grid	Mockup of a single grid bay used for Calorimeter Alignment Demonstration Test.
1 x 1 EM Grid	Modified Calorimeter Alignment Test single bay to include PDR level interface for the Mini-Tracker Module and the CDR level interface for the Calorimeter.
1 x 4 Grid	Engineering Model Grid that provides 4 bays in a row. I&T will use the 1 x 4 Grid for assembly and test of the four bay Calibration Unit.
4 x 4 Grid	Flight Model Grid that provides 16 bays, arranged as a matrix of 4 bays x 4 bays, as the starting point for integration of the LAT.

4. APPLICABLE DOCUMENTS

Documents relevant to the LAT MGSE Development Plan.

- LAT-TD-00856 Engineering Model System Integration Work Instructions
- LAT-TD-01164 EM Functional Test Plan
- LAT-TD-01014 I&T Engineering Models Usage Plan
- LAT-MD-00466 LAT I&T SVAC Plan
- LAT-TD-00440 LAT Beam Test Plan
- LAT-MD-00573 LAT – SVAC Plan for the Engineering Model
- LAT-TD-00550 Airplane Test Plan
- LAT-SS-00138 LAT Tracker Interface Control Specification
- LAT-SS-00176 Tracker-LAT Electrical Interface Control Document
- LAT-SS-00238 Calorimeter-LAT Interface Control Document
- LAT-DS-00916 EM – Live Calorimeter Module
- LAT-DS-01038 1 x 4 Grid Drawing
- LAT-DS-00233 Interface Definition Drawing, CAL-LAT Mechanical Interface
- NASA-STD-8719.9 Lifting Devices and Equipment
- EWR-127.1 East-West Range Safety Requirements,
- SLAC-I-720-0A24E-001 Specification for Seismic Design at SLAC
- JSC-22267 NASA/FLAGRO, or equivalent

5. REFERENCE DOCUMENTS

- NASA-Std-5005A Ground Support Equipment
- ASME B30.1 Jacks

6. INTEGRATION OVERVIEW

The assembly sequence for the flight LAT is 1) support the 4 x 4 Grid (~ 150 Kgs with Radiator Brackets/ Heat Pipes, EMI Corner Shields and miscellaneous small items), 2) Install Tracker Tower (~ 32 Kg each), 3) Install Calorimeter Module (~ 105 Kg with TEM and PS attached), 4) Repeat 2 & 3 for all 16 bays, 5) Install Electronics boxes (< 20 Kg), 6) Install electrical cabling (by hand), 7) Install X-LAT Heat Plates (~32 Kg each), Install Radiators (~ 32 Kg each). After test check operations are completed, the Radiators are removed and the LAT is to be shipped to the Navy Research Laboratory (NRL) for environmental test.

- Grid is supported by an MGSE Grid Perimeter Ring and associated brackets.
- Tracker Modules attach to Grid with 16 fasteners for structural and 24 fasteners for thermal purposes (**TBR**). 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).
- Each of the Calorimeter Modules attach to the Grid with 74 (**TBR**) small fasteners for structural and thermal purposes. Due to man-ergonomic considerations and to reduce risk related to personnel fatigue, the project decision is to rotate the Grid 180° after each Tracker Module is installed and then install the Calorimeter Module from above into position using a crane, alignment rods and an alignment tool. After installation, the Calorimeter attach fasteners will be installed and torqued from above the Grid - Z axis (i.e., when the LAT + Z axis is pointing in the same direction as the gravity vector). After final torque, the Grid will be rotated 180° and prepared for the next Tracker installation. The process is repeated until all Calorimeters are torqued into position.
 - a. Calorimeter Alignment Rods attach to the same receptacles as the Calorimeter Handling Fixture Posts (reference drawing GLT-LLR-00-06, zone F6).
 - b. The Calorimeter is intended to ship with its Handling Fixture facing downward (i.e., the Calorimeter's + Z axis pointing opposite the gravity vector).
 - c. Each Calorimeter is delivered within its NRL provided Handling Fixture and includes the Tower Electronics Module (TEM) and Power Supply (PS) attached for flight.
 - d. Upon receipt, the Calorimeter and attached electronics modules will be lifted using the Calorimeter supplied lift sling and placed into a SLAC provided Calorimeter Rotation Stand. After 180° rotation, A SLAC provided Lift Fixture will be used to prepare the Calorimeter with TEM and PS for installation.
 - e. The alignment tool includes a mechanism to attach it firmly to the Calorimeter's Handling Fixture Support Posts. After connection of the alignment tool, lift fixture turnbuckles are adjusted until the assembly is level.
 - f. The Calorimeter Alignment Tool Assembly is then lowered into position using the Alignment Rods.
 - g. Once in position, several attach fasteners are installed, The Calorimeter Handling Fixture Plate is removed followed by the Alignment tool.
 - h. The Calorimeter Alignment Rods are then removed and the balance of Calorimeter fasteners are installed and torqued.
 - i. After the Calorimeter fasteners are torqued, the Calorimeter Handling Fixture Support Rods are removed.

Note: The Calorimeter Alignment Demonstration Test was concluded successfully in Nov. 02. The Alignment Rods, Alignment Tool and Lift Fixture are available for integration use.

- After the final Calorimeter, TEM and PS Assembly is installed, cable trays and associated electrical harnesses are installed. These operations are accomplished by hand using standard off the shelf tools..
- Additional electronics boxes and electrical cabling are installed as required from above, or from the side.
- The X-LAT Heat Plates are then installed from above the -Z axis of the Grid using a crane. After both X-LAT Heat Plates are installed, the X-LAT Close-Out Panel and EMI Skirting is installed
- This assembly is then rotated 180° such that the + Z axis points opposite the gravity vector.
- The LAT lift fixture is attached to this assembly to allow relocation of it onto the ACD Installation Stand.
- After the LAT is lowered onto the ACD Installation Stand, the LAT Lift Fixture is removed to prepare for ACD installation.
- A SLAC provided ACD Lift Fixture will be used to lift the ACD over the Tracker Towers and align it into position. Once the ACD has been installed, the assembly can not be rotated more than 90° without prior removal of the ACD.
- LAT Performance Tests in excess of 10 hours (**TBR**) will require connection of a fluid loop heat exchange system around the bottom 1" tall perimeter zone of the LAT.
- After ACD installation, the assembly is rotated 90° and the LAT 90° Support Brackets are installed.
- A Radiator Support Structure is attached to the LAT Support and the Radiators installed with their Z axis horizontal.
- After verification of the Radiator assembly process they are removed and the LAT rotated so that its + Z axis points upward (i.e., in the opposite direction of the gravity vector).
- The LAT with ACD and X-LAT Plates installed can then be lifted and placed into its transport container.

Note: Due to size limitations of transport containers on aircraft, the LAT may need to be attached to its Vibration Test Fixture prior to being placed in the transport container

- After shipment to NRL, The LAT is lifted away from the Transport Container using the LAT Lift Fixture and attached to the + Z Axis up Support Stand an prepared for EMI Test.
- After completion of EMI Test the LAT is lifted onto its Vibration Test Fixture
- After completion of the Sine-Vibe Test, the LAT will be prepared for Acoustic Test, most likely using the Vibration Test Fixture.

- After the Acoustic Test is completed the LAT will be transferred back to its tilt over stand and placed so that the +Z axis is horizontal
- The Radiators shall be installed with their +Z axis horizontal for preparation and performance of the LAT Thermal - Vacuum Balance / Cycling (TBR) Test .
- After the thermal balance test is concluded, the LAT will be removed from the vacuum chamber, its Radiators removed and rotated 90° so that it + Z axis points upward. (TBR) The Thermal Vacuum Cycling test may continue with + Z axis horizontal, but for a longer TBD amount of time.
- Thermal - Vacuum, Thermal Cycling Test will be performed with LAT + Z axis pointing upwards (TBR).
- At conclusion of the Thermal-Vacuum Tests, the LAT will be placed into its Transport Container and shipped either back to SLAC, or directly to Spectrum Astro.
- After arrival at Spectrum Astro, the LAT Lift Fixture will be used to assist installation onto the SC bus.

7. REQUIRED MGSE

This section describes the required MGSE for assembly and test for each phase and defines provision responsibility.

7.1. ENGINEERING MODEL PHASE

7.1.1. EM Single Grid Bay

I&T will provide the EM Single Grid Bay LAT-DS-1423, see Figure 1.

- The EM Single Grid Bay provides
 1. PDR maturity attach interface for the Tracker Mini-Tower.
 2. CDR maturity attach interface for the Calorimeter EM.
 3. CDR maturity of the Tracker ribbon harness chase ways.
- To assemble the EM, the following hardware will be required:
 1. EM-Cal Rotation Stand (SLAC Provided LAT-DS-01306 - existing).
 2. Calorimeter Rotation Interface Bracket (SLAC Provided LAT-DS-01434 - existing).
 3. Calorimeter Handling and + Z Up Lift Fixture (NRL Provided).
 4. Calorimeter + Z Down Lift Fixture (SLAC Provided LAT-DS-01087 - existing).
 5. Calorimeter Alignment Rods and attach interface (SLAC Provided LAT-DS-TBD - existing).
 6. Calorimeter Alignment Tool (SLAC Provided LAT-DS-01088 - existing).
 7. EM 1x1 Single Bay Assembly (SLAC Provided LAT-DS-01423 - existing)
 8. Class 100,000 Clean Room with 30 to 50% RH control (SLAC Provided - existing).

9. 5 Ton Precision Crane (SLAC Provided - existing).
- To test the EM with 17.6 MeV Gamma Ray Photons, the following hardware will be required:
 1. Van de Graaff Generator (SLAC Provided - existing)
 2. Van de Graaff Support Stand (SLAC Provided - **To Be Worked (TBW)**)
 3. Van de Graaff Target Tube Support Stand (SLAC Provided - **TBW**)
 4. EM Scintillator Support Bracket (Tracker Provided - **TBW**).
- To allow characterization testing of the integrated EM Single Bay, it will be sent to GSI, a heavy ion research center in Germany. The following hardware will be required:
 1. EM-Single Bay Transport Container, for international flight shipment (SLAC provided - **TBW**).
 2. Humidity control by using nitrogen purged, sealed ESD conductive bag with desiccant cartridges at each of two layers (SLAC provided - **TBW**).

Notes: How will the EM Single Bay be moved around at GSI? LAT is building one EM-Cal Support Stand and will need it for assembly of the 1 x 4 Calibration Unit. They may need a way to lift the EM Single Bay Assembly and a way to locate it during their tests.

7.2. CALIBRATION UNIT PHASE

7.2.1. 1 x 4 Calibration Unit

SLAC Mechanical Systems will provide a 1x 4 Grid. The 1x 4 Grid will include CDR maturity interfaces for the 19 Tray Tracker Tower, CDR maturity Tracker ribbon cable chase ways and CDR maturity Calorimeter and electronics interfaces.

- The following hardware will be required for integration and test of the Calibration Unit:
 1. EM-Cal Rotation Stand (SLAC Provided LAT-DS-1444 - existing).
 2. Tracker Tower Lift Fixture (Tracker Provided - existing **TBR**).
 3. Calorimeter Rotation Interface Bracket (SLAC Provided LAT-DS-**TBD** - existing).
 4. Calorimeter Handling and + Z Up Lift Fixture (NRL Provided).
 5. Calorimeter + Z Down Lift Fixture (SLAC Provided LAT-DS-01087 - existing).
 6. Grid Bay Shear Plate with Alignment Receptacles (SLAC Mech Systems provided).
 7. Calorimeter Alignment Rods and attach interface (SLAC Provided LAT-DS-**TBD**- existing).
 8. Calorimeter Alignment Tool (SLAC Provided LAT-DS-01088 - existing).
 9. Class 100,000 Clean Room with 30 to 50% RH control (SLAC Provided - existing).
 10. 5 Ton Precision Crane (SLAC Provided - existing).
- To test the CU with 17.6 MeV Gamma Ray Photons, the following hardware will be required:
 1. Van de Graaff Generator (SLAC Provided - existing).
 2. Van de Graaff Support Stand (SLAC Provided - (**TBW**)).
 3. Van de Graaff Target Tube Support Stand (SLAC Provided - **TBW**)

- To Calibration Test the CU at SLAC ESA, the following hardware will be required:
 1. Remote controllable X, Y, Theta Movement System (SLAC Provided - **TBW**).
 2. Integrated 1x 4 CU Transport Container (SLAC Provided - **TBW**).
 3. Class 100,000 Environmental Control Volume at ESA, Room Temperature, 30-50 RH, (SLAC Provided - **TBW**).
 4. Integrated 1X4 CU Lift Fixture (SLAC Provided - **TBW**).
 5. Side Attach Plate, Integrated 1x 4 (SLAC Provided - **TBW**).
 6. Means to lift Integrated 1x 4 CU onto and off of X, Y, Theta Movement System (SLAC Provided - **TBW**).
 7. Air based cooling to reject 1,000 watts (SLAC Provided - **TBW**).
 8. CU Scintillator Support Bracket (SLAC Provided - **TBW**).

7.3. FLIGHT UNIT INTEGRATION PHASE

SLAC Mechanical Systems will provide a flight 4 x 4 Grid with internally mounted heat pipes, Radiator Corner Brackets, Downspout Spout Heat Pipes and other miscellaneous items. The following MGSE will be required for integration and test of the Flight Unit at SLAC.

7.3.1. 4 x 4 Flight LAT

- To integrate the flight LAT in SLAC B-33:
 1. Grid Perimeter Ring (GPR) (SLAC Provided - **TBW**).
 2. GPR to Grid Interface Brackets (SLAC Provided - **TBW**).
 3. Tilt-Over Stands, two each (SLAC Provided - **TBW**).
 4. Tilt-Over Rotation Supports, two each (SLAC Provided - **TBW**).
 5. Tilt-Over Interface GPR to Crane (SLAC Provided - **TBW**).
 6. 90° Angle Support, GPR, four each (SLAC Provided - **TBW**).
 7. Calorimeter Rotation Stand (SLAC Provided LAT-DS-**TBW** - existing).
 8. Tracker Tower Lift Fixture (Tracker Provided - existing **TBR**).
 9. Calorimeter Rotation Interface Bracket (SLAC Provided LAT-DS-**TBD** - existing).
 10. Calorimeter Handling and + Z Up Lift Fixture (NRL Provided).
 11. Calorimeter + Z Down Lift Fixture (SLAC Provided LAT-DS-01087 - existing).
 12. Grid Bay Shear Plates, 16 each, with Alignment Receptacles (SLAC Mechanical Systems provided).
 13. Calorimeter Alignment Rods and attach interface (SLAC Provided LAT-DS-**TBD** - existing).
 14. Calorimeter Alignment Tool (SLAC Provided LAT-DS-01088 - existing).
 15. ACD Integration, De-integration Stand (SLAC Provided - **TBW**).
 16. ACD Lift Fixture (SLAC Provided - **TBW**).

17. LAT Lift Fixture (SLAC Provided - **TBW**).

- To test the FU with 17.6 MeV Gamma Ray Photons, the following hardware will be required:
 1. Van de Graaff Generator (SLAC Provided - existing).
 2. Van de Graaff Support Stand (SLAC Provided - (**TBW**)).
 3. Van de Graaff Target Tube Support Stand (SLAC Provided - **TBW**).
- To perform the LAT Modal Survey at SLAC, the following MGSE will be required:
 1. Vibration Test Fixture (with openings for Z axis excitation) (SLAC Provided - **TBW**).
 2. Air Bladder Support Stands (to allow Z axis excitation equipment to fit under the LAT during test) (NRL Provided - **TBW**).
 3. ACD Integration, De-integration Stand (SLAC Provided - **TBW**).
 4. ACD Lift Fixture (SLAC Provided - **TBW**).
 5. LAT Lift Fixture (SLAC Provided - **TBW**).
- To test the FU LAT Gamma Ray Trigger Rate on board a Jet Aircraft the following MGSE will be required:
 1. Vibration / shock isolated Transport Container (SLAC Provided - **TBW**).
 2. Rigging to get Transport Container onto and off of aircraft (SLAC Provided - **TBW**).
 3. Environmental Control Station (thermal and humidity control) (SLAC Provided - **TBW**).
- To perform Environmental Test at NRL, the following MGSE will be required:
 1. Transport Container (SLAC Provided - **TBW**).
 2. LAT Lift Fixture (SLAC Provided, Also lifts Vibe Test Fixture - **TBW**).
 3. Tilt-Over Stands, for EMI and Thermal Cycling Tests (SLAC Provided - **TBW**).
 4. Vibration Test Fixture, for Acoustic and Sine-Vibe Test (SLAC Provided - **TBW**).
 5. 90° Angle Support, GPR, four each, for Thermal Balance Test (SLAC Provided - **TBW**).
 6. Radiator Support Structure for Thermal Balance Test (SLAC Provided - **TBW**).
 7. Thermal Vacuum Heat Exchangers (SLAC and NRL Provided - **TBW**).

8. DESIGN CRITERIA

8.1. GENERAL DESIGN STANDARDS FOR ITEMS NOT EXPOSED TO CYCLIC LOADING

Design factor of safety will meet East-West Range Safety Requirements 127.1 for MGSE, tailored as follows by SLAC. Materials shall be chosen such that the yield point is $\leq 85\%$ of the material's ultimate strength. With this criteria met, the design factor of safety shall be ≥ 3.0 times the design limit load and proof test shall be ~ 2.0 times the design limit load. A Single Point Failure Analysis shall also be performed. With exception to the Vibration Test Fixture, all Single Point Failure Items shall be inspected for crack initiation sites to ensure there are no crack lengths in excess of 0.030".

In addition, the design limit load shall be based upon the Specification for Seismic Design at SLAC, document number SLAC - I - 720 - 0A24E - 001.

The above design criteria were based upon review of the following standards:

- Lifting Devices and Equipment, NASA-STD-8719.9
- Ground Support Equipment, NASA-Std-5005A
- ASME B30.1, Jacks
- East-West Range Safety Requirements, EWR-127.1
- Specification for Seismic Design at SLAC, SLAC - I - 720 - 0A24E - 001.

8.2. DESIGN STANDARDS FOR ITEMS EXPOSED TO CYCLIC LOADING

The LAT Vibration Test Fixture (VTF) will require that a safe-life analysis be performed using a fatigue crack growth computer program such as NASA/FLAGRO (JSC-22267) to define maximum allowable flaw size prior to test. Fatigue cycle loading for the VTF shall assume one set of X, Y, Z axis sine-vibe test plus four additional test cycles to determine the allowable initial flaw size. The single point failure areas of the VTF will be inspected using appropriate processes to ensure any / all flaws are below the analyzed size.

Fatigue cycle loading of the flight hardware side of the interface shall assume three sets of X, Y, Z axis sine-vibe tests (i.e., one at payload level, second at integrated SC level and the third for the actual flight) plus four additional test cycles to determine the allowable flaw size. A design coupled loads analysis shall be performed consisting of the shaker excitation interface to the LAT VTF, the LAT VTF, associated brackets to attach the LAT VTF to the LAT flight interface and the LAT flight interface.

8.3. DESIGN CRITERIA FOR ITEMS THAT INTERFACE DIRECTLY WITH FLIGHT HARDWARE

The Grid Perimeter Ring (GPR) is intended to support the Grid from handover from Mechanical Systems to I&T, through out integration processing and handover from I&T to the SC bus. The GPR with its interface brackets to the Grid will be used to rotate from + Z up to + Z down on the order of 20 times. The allowable maximum deflection of the Grid during the rotation when fully integrated with all Tracker Towers, all Calorimeters, all TEMs and all Power Supplies is **TBD** inches. The actual deflection of the Grid will be a function of the deflection of the GPR, the GPR to Grid interface brackets and the Grid assembly as a system. For this reason, finite element analysis is required understand deflection states of the system during rotation, particularly as the LAT becomes more fully assembled.

The GPR and associated brackets will be designed with a Factor of Safety against yield of 1.4 and will be proof tested at 1.25 times maximum expected load. The design shall assume that out of a total of four corner brackets (i.e., flight Radiator Corner Brackets that attach to the flight Grid), that only two brackets, diagonally opposed from one another will carry the entire load.

The not to exceed maximum wet mass of the observatory level spacecraft is 4,720 Kg. This is based upon 3,200 kg for the LAT, 93 Kg for the Payload Adapter Fitting and 1,427 kg for the fully fueled Spacecraft bus plus the Gamma Ray Burst Detector payload.

With the above criteria, each flight corner support bracket will be designed to carry $(1.4) (4,720 \text{ kg} / 2) = 3,304 \text{ Kg}$ and will be proof tested at $(1.25) (4,720 \text{ kg} / 2) = 2,950 \text{ Kg}$ for use locations in Arizona and Florida where the maximum ground acceleration is 1.0 g.

For SLAC, assuming 5% damping, the maximum acceleration is 1.5 g acting horizontally and 1.5 g acting vertically; the vector sum of this acceleration is 2.12 g acting at 45°. For use at SLAC, the radiator corner mount interfaces to MGSE shall be designed to $(1.4) (3,200 \text{ kg} / 2) (2.12) = 4,752 \text{ Kg}$ mass equivalent (i.e., 10,500 lbs) and proof tested to $(1.25) (3,200 \text{ kg} / 2) (2.12) = 4,240 \text{ Kg}$ mass equivalent (i.e., 9,370 lbs). The factor of Safety for MGSE will be increased to 3, with proof test at 2 times maximum expected load as soon as is practical when going from the flight interface to the GPR.

During integration, the position of the Tracker Towers will be surveyed using a Laser Tracker System that views Laser Tracker Balls attached to the Grid and the Tracker Towers to determine and quantify their relative position in a three dimensional coordinate system. The design of the GPR must provide a **TBD** ° field of view to accommodate measurements using not more than three (**TBR**) Laser Tracker Systems at any one time.

8.4. GENERAL DESIGN REQUIREMENTS FOR THE X, Y, Θ MOVEMENT SYSTEM

The X, Y, Θ Movement System will be used to move the 1 x 4 Calibration Unit with respect to the ESA beam from a remote location. The X, Y, Θ Movement System will support the 1 x 4 Calibration Unit in the one bay high, four bays wide configuration. The X, Y, Θ Movement System will move the 1 x 4 across the beam ± 40 inches from its center point, rotate $\pm 180^\circ$ from its center point and move the 1 x 4 up and down over the height of the single bay, about 17 inches. With exception to the fasteners that attach the 1 x 4 to its ground support equipment, the design criteria described in section 8.1 will be met.

8.5. GENERAL DESIGN REQUIREMENTS FOR THE LAT TRANSPORT CONTAINER

The LAT Transport Container shall be designed to fit within the exterior dimensions of an ATA (?) M1 Air Transport Unit Load Device (ULD). The exterior dimensions of the M1 Unit Load Device are 96" tall by 96" wide by 125" long with a 15,000 lb maximum weight.

The LAT Transport Container shall include a vibration / shock isolation system capable of **TBD**. It shall provide up to 6 inches of no contact travel in each of three orthogonal axes when exposed to **TBD** acceleration. The isolation system will not attenuate accelerations with a period of less than 3 Hz. Above 3 Hz, the isolation system shall attenuate the acceleration by **TBD** per frequency decade.

9. APPENDIX: SUPPLEMENTAL FIGURES

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

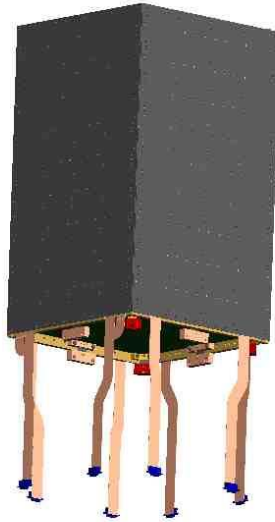


Figure 1: Tracker Mechanical EM Tower

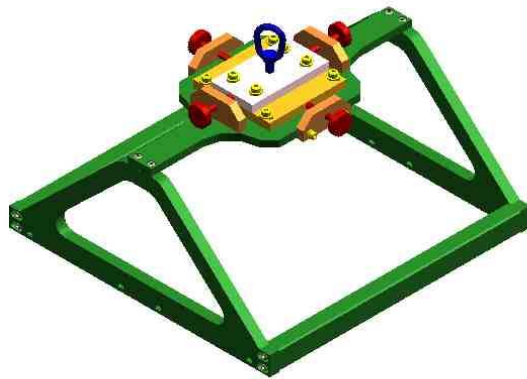


Figure 2: Tracker Lifting Fixture

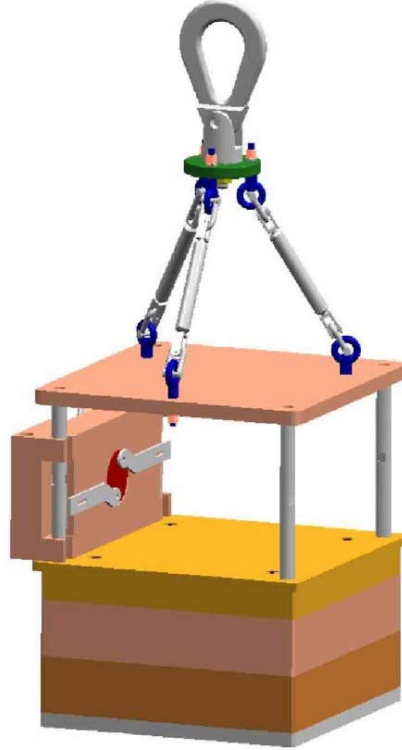


Figure 3: Calorimeter lift fixture, with Alignment tool and Mockup Cal