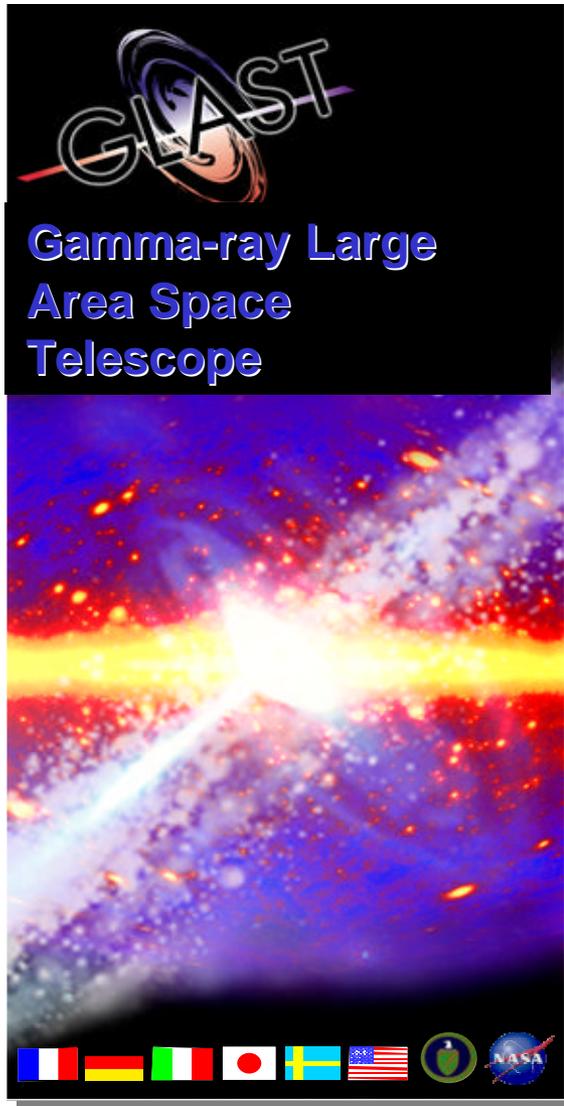


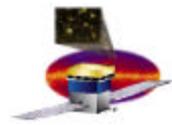
GLAST Large Area Telescope Calorimeter Subsystem

6.3 Mechanical Structure Fabrication

Paul V. Dizon
Naval Research Lab, Washington DC
Calorimeter Lead Mechanical Systems Engineer

paul.dizon@nrl.navy.mil
(202)–404–7193





Design Status - Parts

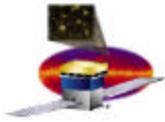
❑ **Metallic Parts**

- **No Significant Design Evolution is Expected: EM Design is Very Close to Flight Module Design**
 - **Fabrication Drawings Have Been Completed and Should Only See Cosmetic Modifications**
 - **Specifications and Verification Procedures for Flight Parts Have Been Released. Procurement Procedure Has Started**

❑ **Polymer Parts**

- **Materials and Vendor for Silicone Cords and Bumper Frames Have Been Chosen**
 - **Additional Testing is Being Performed to Provide the Additional Information Necessary to Finalize the Specifications for Both Polymer Parts**
- **Evaluating the Present CDE End Cap and Bumper Implementation to Determine If They Could Be Merged Into a Single Assembly**



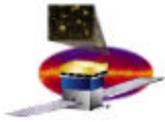


Design Status – Composite Structure

□ Composite Structure

- **Fabrication Procedure Has Been Improved and Changed Since EM: Autoclave Curing Process has Replaced Oven Curing in Order to Improve the Physical Properties of the Composite Material (Increase Fiber Content, Reduce Void Ratio)**
- **Improved Process Implies a New Fabrication Procedure, a Different Design for the Tooling and the Development of Prototype Structures**
 - **New Fabrication Procedure is Being Finalized**
 - **New Tooling Design is Complete and the Fabrication Drawings Are Being Generated**
 - **Two Prototype Composite Structures Have Already Been Produced from Test Tooling to Verify the Concept. A Third Structure Will Be Ready by CDR**





Design Status – Composite Structure

□ Composite Structure - Continued

– Improved Process will be Qualified

- Requires the Fabrication of Verification Models

- SM – Structural Model
- SFM – Structural Flight Model

- **SM**

- Will be Used for Qualification of the Improved Curing Process
 - » Industry Autoclave used for Development of Improved Process
 - » Structural Environment Testing
 - » Material Properties/Void Ratio Measurement
 - » Non-Destructive Testing

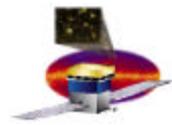
- **SFM**

- Will be Used to Verify the Improved Curing Process Prior to Flight Build
 - » IN2P3 Autoclave
 - » Material Properties/Void Ratio Measurement
 - » Non-Destructive Testing

– Verification Procedure for Flight Structures

- Non-Destructive Testing Still Needs to be Addressed in the Verification Procedure. Ultrasonic C-scan is Being Evaluated by a Vendor on Structure Test Samples





Manufacturing

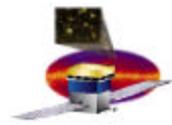
- Mechanical Components and Processes**
- Manufacturing Organization**
- Manufacturing Flow**
 - **Aluminum Piece Parts**
 - **Elastomeric Piece Parts**
 - **Composite Structure**
- Manufacturing and Tooling Methods for Composite Structure**
- Manufacturing Facilities**
- Quality Assurance Inspection**
- Verification Testing**



Manufacturing – Components & Processes

Component	Reference	Material	Process/coating	Vendor
EMI Shield	LAT-DS-01234	Al 99,0 aluminum	Cutting, Alodine	
Composite structure	LAT-DS-00918	T300 1K HS carbon M76 epoxy resin	Prepreg lay-up Cured 4h at 135°C	HEXCEL
Base plate	LAT-DS-00919	2618A T851 Aluminum	Machining, Alodine	
Top frame	LAT-DS-00917	2618A T851 Aluminum	Machining, Alodine	
Closeout plate X and Y	LAT-DS-00920/21	2618A T851 Aluminum	Machining, Alodine	
Side panel X and Y	LAT-DS-00923/24	5751 H111 Aluminum	Machining, Alodine	
Inserts	LAT-DS-00927/28/29	Ti-6Al-4V Titanium	Machining	
Nuts	LAT-DS-00922	Ti-6Al-4V Titanium	Machining	
Silicone cords	LAT-DS-00984	7611B Red silicone	Extrusion at 200°C Post-cured 16h at 200°C	ADDIX
Bumper Frame	LAT-DS-00925	VALOX DR48 PBT 7601B Red silicone	Injection molding Post-cured 16h at 175°C	ADDIX
Fasteners		CRES A286 AISI 316 Stainless		
Helical coils		INCONEL 750 Stainless Steel	Silver plating	



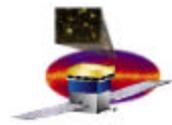


Manufacturing - Organization

- ❑ **Metallic Parts: Aluminum Plates, Titanium Inserts and Nuts**
 - **Contract with the Industry, Includes:**
 - **Fabrication of Parts**
 - **Alodine Surface Treatment of Parts**
 - **100% Verification of Parts**
 - **Proposal Released, Opened to EU Countries, 2 Month for Bids**
 - **Receiving Inspection at LLR, Pre-Assembly (PEM Mechanical and Shipping Configuration), Packaging and Shipping to NRL**

- ❑ **Polymer Parts: End Caps, Bumper Frames and Silicone Cords**
 - **Contract with Vendor, ADDIX, Includes:**
 - **Fabrication of Parts**
 - **Verification of Material Properties**
 - **Receiving Inspection at LLR Before Delivery to NRL/CEA**





Manufacturing - Organization

□ Composite Structure

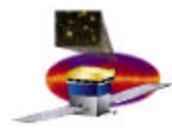
– Procurement of Pre-Preg Material by LLR

- A Procurement of 500 m² is Planned for Flight Structures (20 m² per Structure Required). The Specifications Have Been Released and Accepted by the Vendor, HEXCEL

– Contract for Cutting of Pre-Preg Plies and Preparation of Lay-ups

- Proposals from Several Vendors Have Already Been Received but Vendor Has Not Been Chosen
- The Specifications are Being Updated and Completed, Which Will Require New Proposals

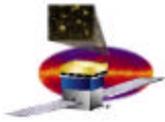




Manufacturing - Organization

- ❑ **Composite Structure - Continued**
 - **Structure Fabrication and Verification at LLR**
 - **Two Molds Will Be Used for Flexibility, Which Will Allow a Production Rate of up to One Structure Per Week (If Required)**
 - **Fabrication Will Include the Lay-up of the Pre-Preg Plies in the Molds, the Vacuum Bagging and the Autoclave Curing**
 - **The Verification Will Include:**
 - **Dimensional Inspection**
 - **Measurement of Physical Properties on Co-cured Samples**
 - **Structure Verification Test – Static Pull Test**
 - **Non Destructive Testing**
 - **A Contract for the Ultrasonic C-scan of the Composite Structure (Outer Walls) Is Required. The Company is Currently Evaluating the Procedure**





Structural Piece-Part Manufacturing Flow

Metallic Parts

Documents

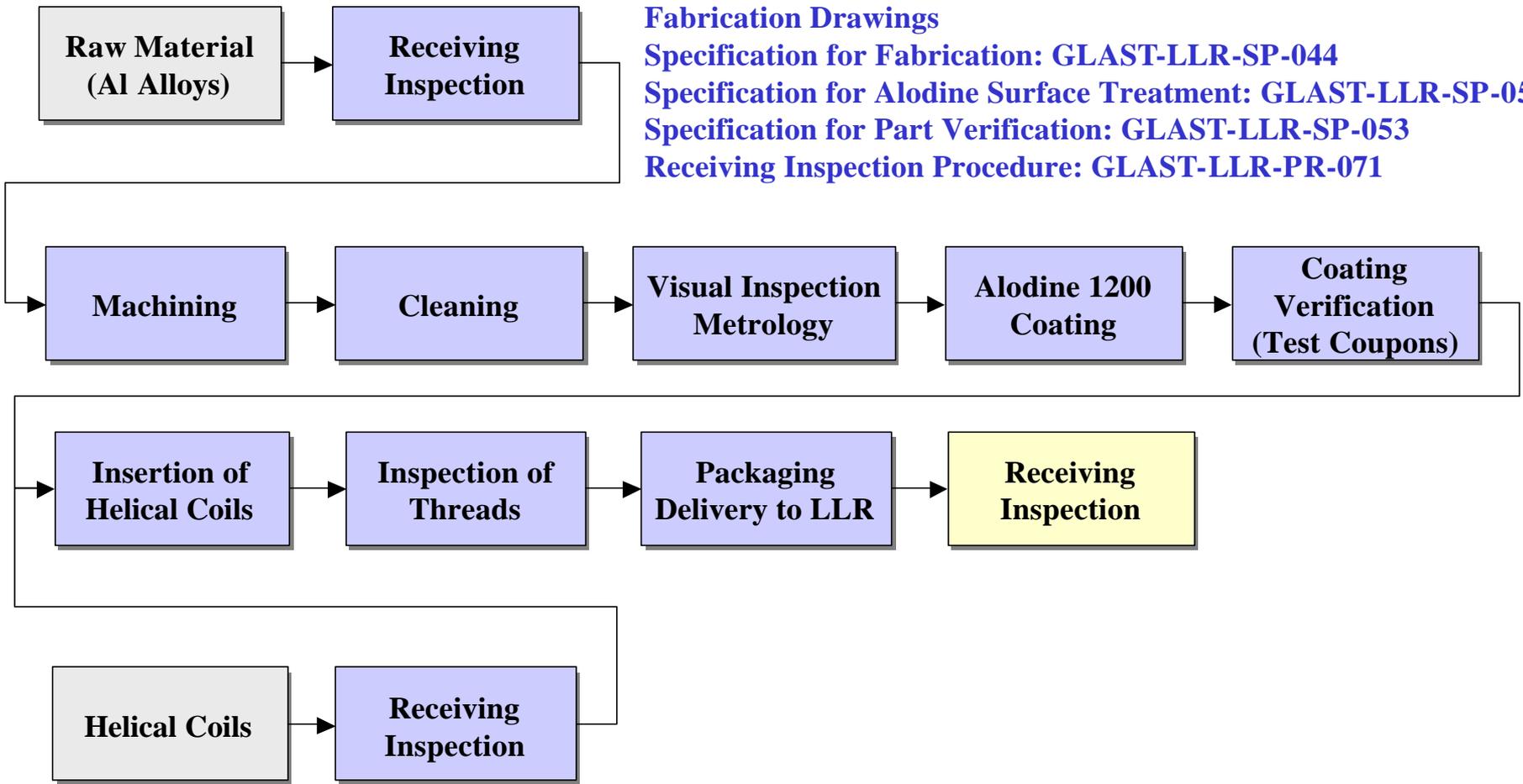
Fabrication Drawings

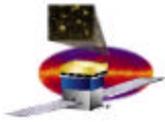
Specification for Fabrication: GLAST-LLR-SP-044

Specification for Alodine Surface Treatment: GLAST-LLR-SP-052

Specification for Part Verification: GLAST-LLR-SP-053

Receiving Inspection Procedure: GLAST-LLR-PR-071





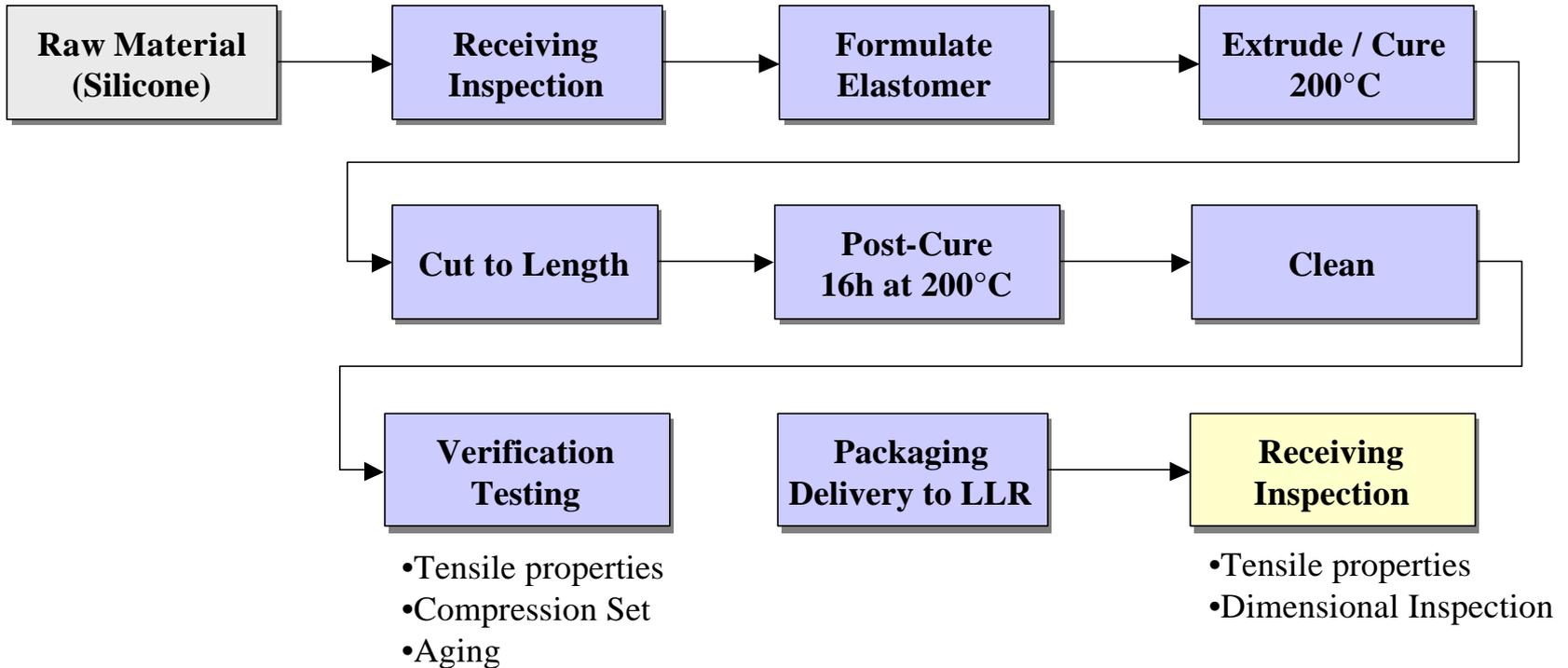
Polymer Piece-Part Manufacturing Flow

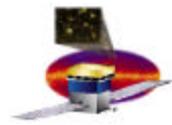
Elastomeric Cords

Documents

Specification: LAT-DS-00984

Receiving inspection: GLAST-LLR-PR-071





Polymer Piece-Part Manufacturing Flow

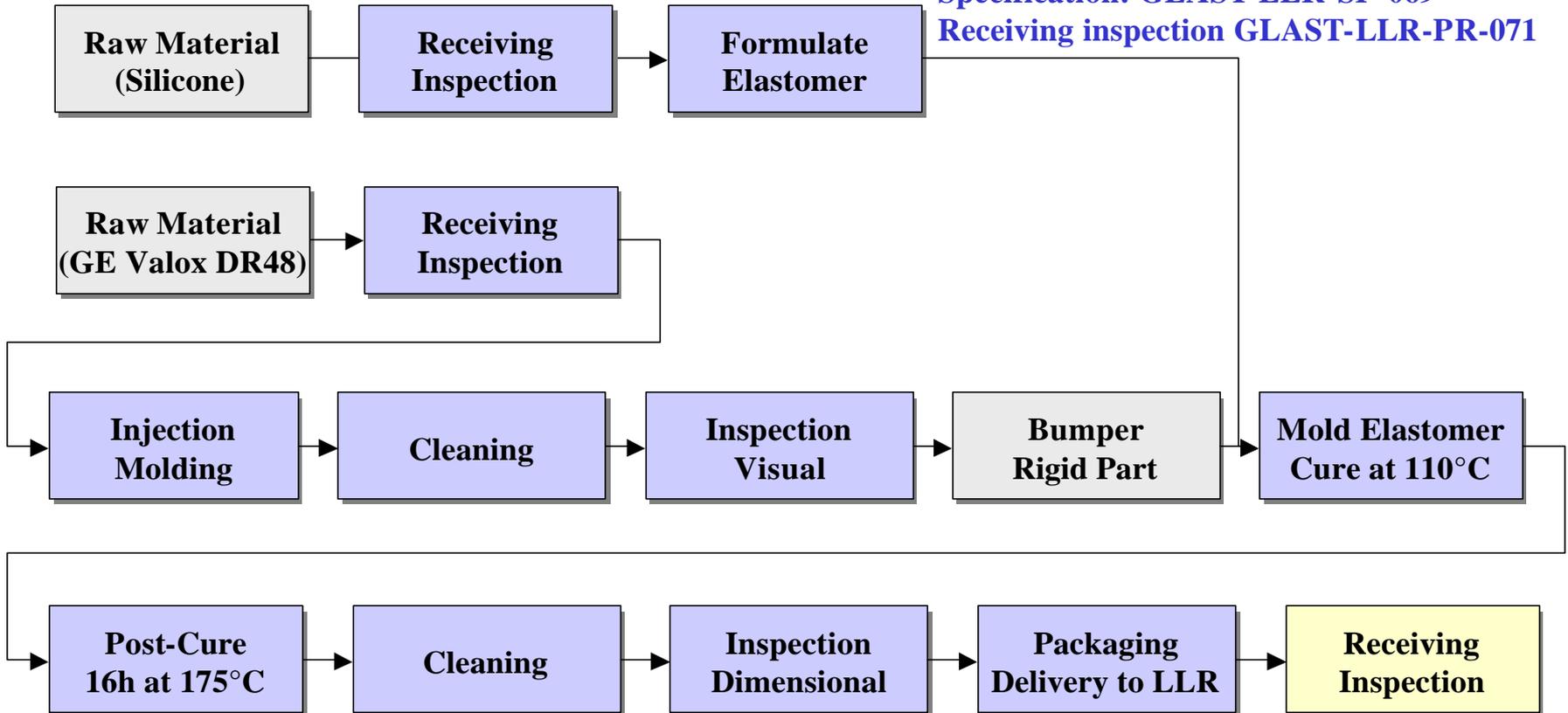
Bumper Frame

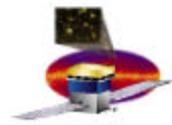
Documents

Drawing: LAT-DS-00925

Specification: GLAST-LLR-SP-069

Receiving inspection GLAST-LLR-PR-071





Composite Structure Manufacturing Flow

Documents

Drawing: LAT-DS-00925

Prepreg Handling and Storage: GLAST-LLR-PR-068

Prepreg Cutting : GLAST-LLR-SP-035

Receiving Inspection GLAST-LLR-

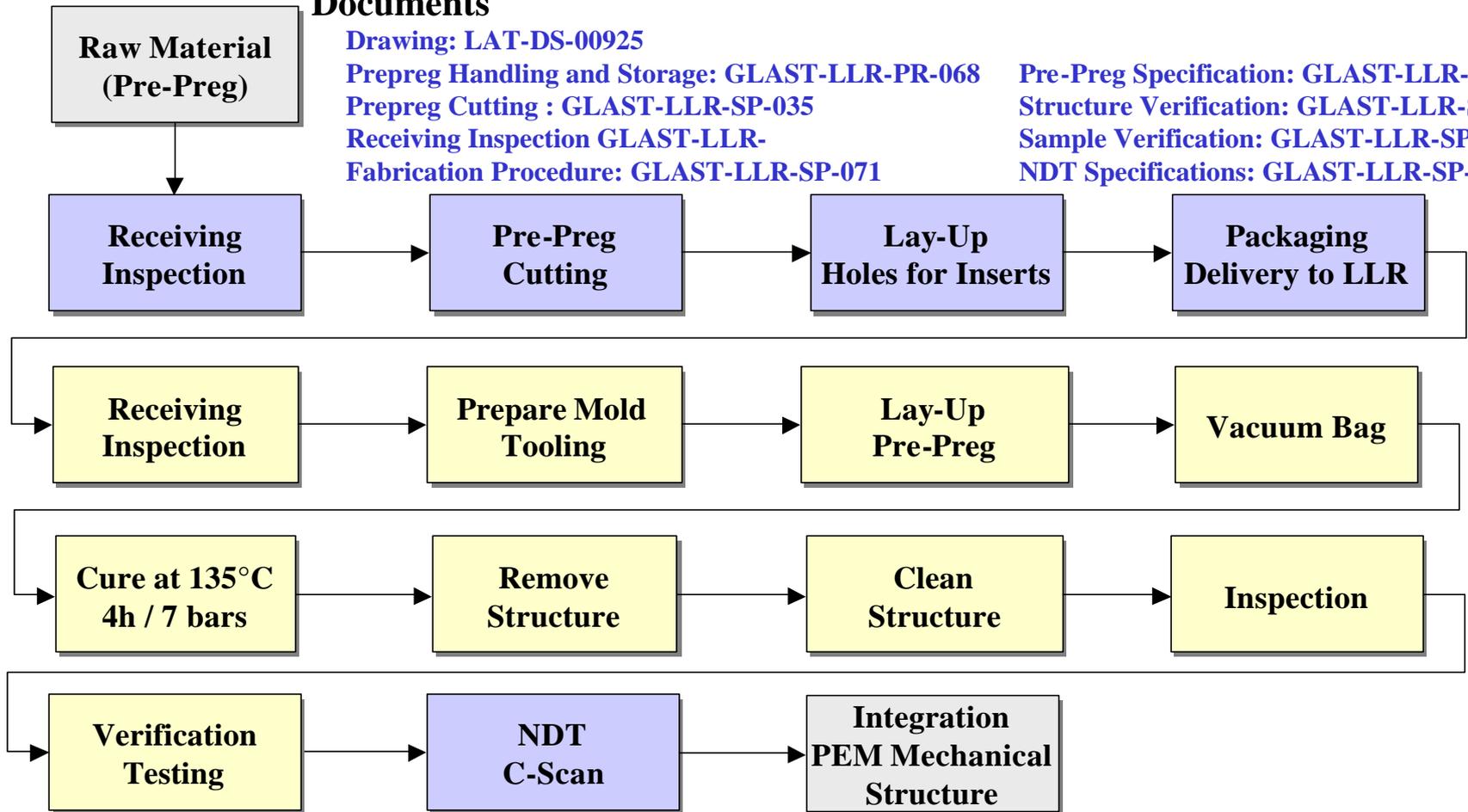
Fabrication Procedure: GLAST-LLR-SP-071

Pre-Preg Specification: GLAST-LLR-SP-048

Structure Verification: GLAST-LLR-SP-072

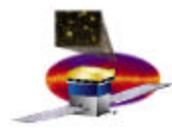
Sample Verification: GLAST-LLR-SP-073

NDT Specifications: GLAST-LLR-SP-074

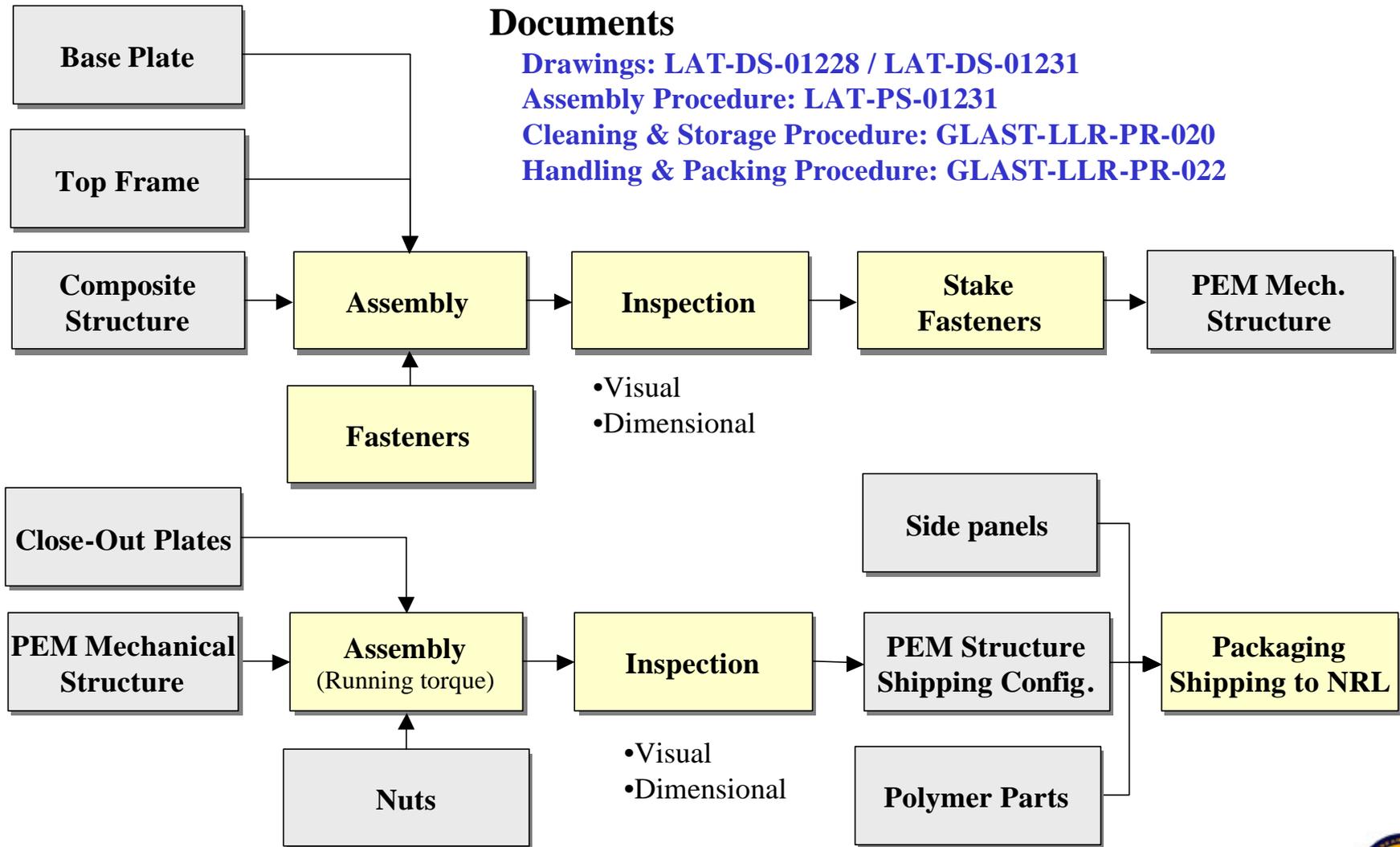


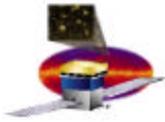
- Dimensional Inspection
- Physical Properties on Co-cured Samples
- Structure Verification Test: Static Pull Test





PEM Mechanical Structure Flow





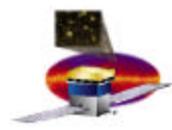
Composite Structure – Manufacturing Method

- **Pre-preg Material (GLAST-LLR-SP-048)**
 - T300 1K HS Carbon Fibers, Taffeta Weave
 - M76 Epoxy Resin: Cure Temperature 135°C to 177°C, Low Outgassing
 - Thickness per Ply Is 0.12 mm for 64% Fiber Content

- **Tooling**
 - Dimensions Account for Thermal Expansion of Aluminum vs. Composite
 - 96 Precise, Non Tapered Aluminum Mandrels Define the Shape of the Cells. The CTE Mismatch Allows an Easy Removal From the Cells
 - Mechanical Stops Allow to Control Outer Dimensions. Position of the Stops Account for a Ply Thickness of 0.12 Mm
 - All Inserts are Positioned by Composite Plates to Avoid Loads Resulting From CTE Mismatch Between the Aluminum Tooling and the Composite Structure

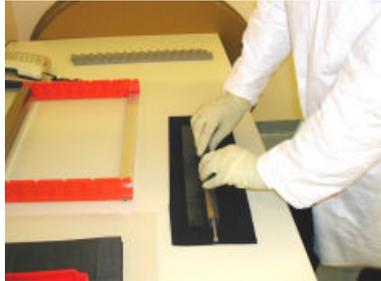
- **Process**
 - Complete Structure is Fabricated in a Single Curing Process
 - Titanium Inserts are Embedded in the Composite and Co-Cured
 - No Additional Bonding or Machining is Required





Composite Structure – Manufacturing Method

Wrapping of Mandrels



- Each Mandrel Wrapped with One Pre-Preg Ply

Preparation of Layer



- Stacking of Mandrels and Lateral Lay-Ups with Inserts
- Mechanical Pressure to Add Global Plies

Stacking of Layers



- Stacking of Layers, Base and Top Lay-Ups with Inserts

Closing of Mold



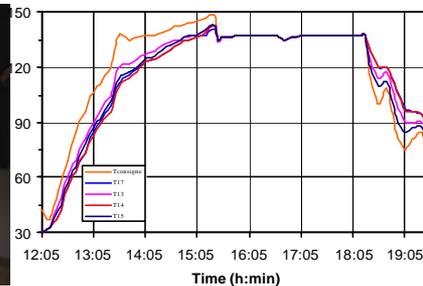
- 4 Side Plates and Cover
- Mechanical Stops to Control Outer Dimensions

Vacuum Bagging



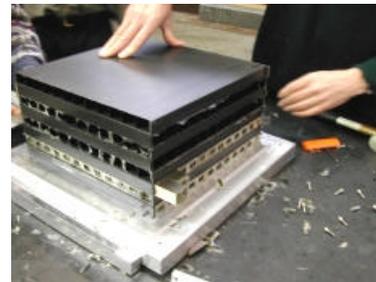
- Release Film
- Breather Felt
- Vacuum Bag

Autoclave Curing



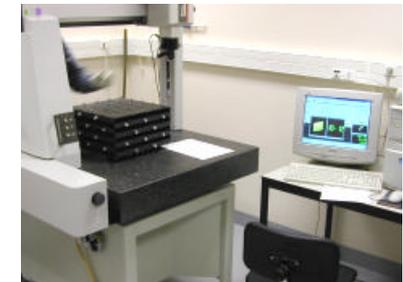
- Temperature 135°C
- Pressure 7 bars
- Cure Time 4h

Structure Removal



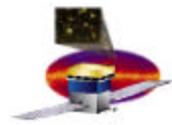
- Removal of Layer Frame
- Removal of 96 Mandrels
- Cleaning

Metrology



- Outer Dimensions
- Position of Inserts
- Dimension of Cells





LLR Manufacturing Facilities & Equipment

□ Clean Room

- **Class 100,000**
- **Temperature 21°C +/-2°C, RH 60% Max**
- **32 m² Dedicated to Pre-Preg Lay-Up**
- **14 m² for Cleaning and Packaging**

□ Metrology Room

- **3D Measuring Machine MITUTOYO EURO-M 574, Camera System Included for Optical Measurement**
- **Microscope for Verification of Small Parts**

□ Autoclave

- **F1000 x 1700 mm**
- **10 bars at 250°C**

Procurement in January, Delivery to LLR Early June

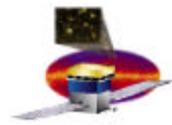


Manufacturing

QA Inspection/Verification Testing

COMPONENT	INSPECTION		VERIFICATION TESTING	
	Vendor	IN2P3/LLR	Vendor	IN2P3/LLR
Structural Piece Parts (Aluminum Alloy)	Visual Dimensional (100%)	Visual (100%) Documentation Check	None	None
Titanium Inserts / Nuts	Visual Dimensional (100%)	Visual (100%) Documentation Check	None	Pull Test (sample)
Elastomeric Cords	Visual Dimensional (sample)	Visual (sample) Dimensional (sample) Documentation Check	Tensile Properties Aging (Fabrication Lot)	Tensile Strength Outgassing (Sample/Lot)
End Caps, Bumper Frames	Visual Dimensional (sample)	Visual (100%) Dimensional (sample) Documentation Check	None	None
Composite Structure - Structure	N/A N/A	Visual Dimensional (100%)	Ultrasonic C-Scan	Static Pull Test
- Co-Cured Sample	N/A	Visual	Material Properties Void Ratio	

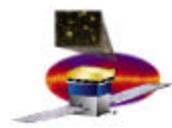




Procurement Status

- ❑ **SM/SFM Procurements**
 - **Prepreg received for SM/SFM/FMA/FMB** **28 Feb 2003**
(HEXCEL Specs for satellite pre-preg with additional testing)
 - **Procurement of SM parts** **25 Feb 2003**
 - **Delivery of SM parts** **15 Apr 2003**
- ❑ **FM Aluminum Piece Parts**
 - **Release of Proposal for FM parts** **24 Jan 2003**
 - **Selection of FM Structure Vendor** **15 Apr 2003**
 - **Delivery of first FM parts** **31 Jul 2003**
- ❑ **Pre-Preg Material**
 - **Release of Flight Specification** **15 Feb 2003**
 - **Purchase for flight** **1 Apr 2003**
 - **Delivery of First Roll** **15 Jun 2003**
- ❑ **Autoclave**
 - **Release of Specification** **Dec 2003**
 - **Purchase of Autoclave** **15 Jan 2003**
 - **Delivery and Installation** **31 May 2003**





Procurement Status- Continued

❑ Elastomeric Cords

- Release of Specification 15 Mar 2003
- Purchase 15 Apr 2003
- Delivery of first batch 15 Jun 2003

❑ Elastomeric Bumpers

- Release of Specification 1 Apr 2003
- Purchase 15 Apr 2003
- Delivery of first batch 15 Jun 2003

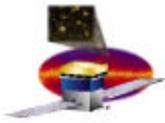
❑ End Caps

- Release of Specification 1 Apr 2003
- Purchase 15 Apr 2003
- Delivery of first batch 15 Jun 2003

❑ Flight Fasteners

- Release of Specification 15 Apr 2003
- Purchase 15 May 2003
- Delivery 31 July 2003





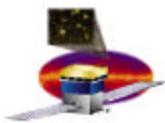
Issues and Concerns

- **Change in the Fabrication Process of the Composite Structure**
 - Added a Large Amount of Development Work
 - Delayed the Fabrication of the Tooling for the Flight Parts
 - Delivery Schedule Not Affected, but There is No Margin Left*

- **Internal Verification Prototypes Have Been Changed Into Verification Models (SM/SFM)**
 - As a Result, the Following is Required:
 - More Stringent Quality Control
 - Additional Testing
 - Extra Cost

Internal Resources at IN2P3 Can Still Cover These Additional Requirements, but Schedule Pressure Will Be High Until Delivery of FMB





Summary and Conclusion

No Major Problems

Component	Progress	Status
Composite Structure	Designed & Analyzed Partially Tested	Improved Curing Process Being Qualified
Aluminum Piece Parts	Designed & Analyzed Tested	Ready for Flight Build, Procurement Released
Titanium Inserts	Designed & Analyzed Tested	Ready for Flight Build, Procurement Released
Elastomeric Cords	Designed & Analyzed Tested	Ready for Flight Build
Elastomeric Bumper Frames, End Caps	Designed & Analyzed Tested	Evaluation of Redesign

