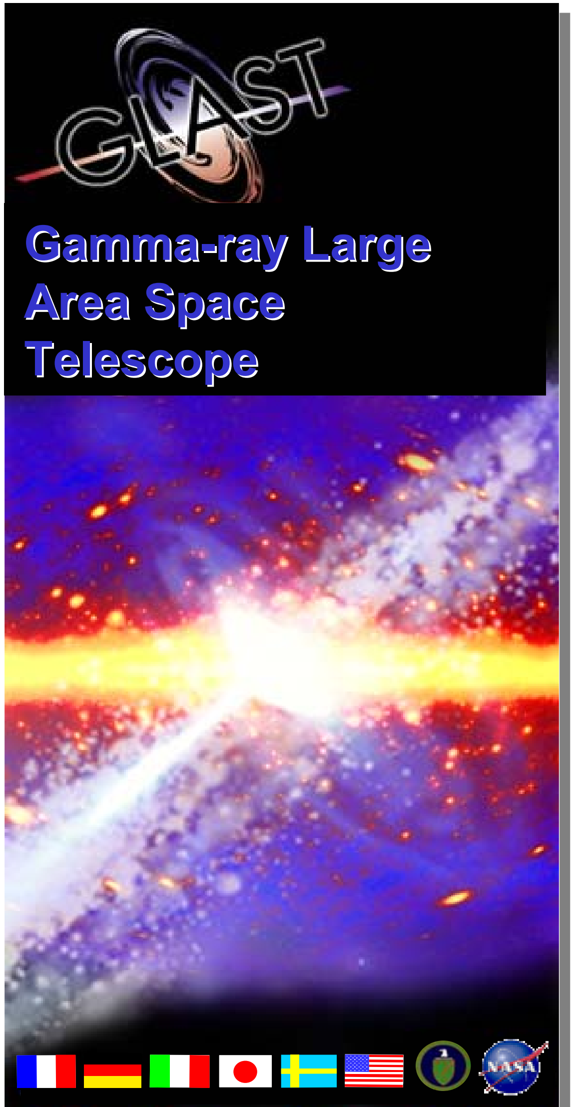
REV 2



GLAST Large Area Telescope:

Mechanical Systems Overview WBS: 4.1.8

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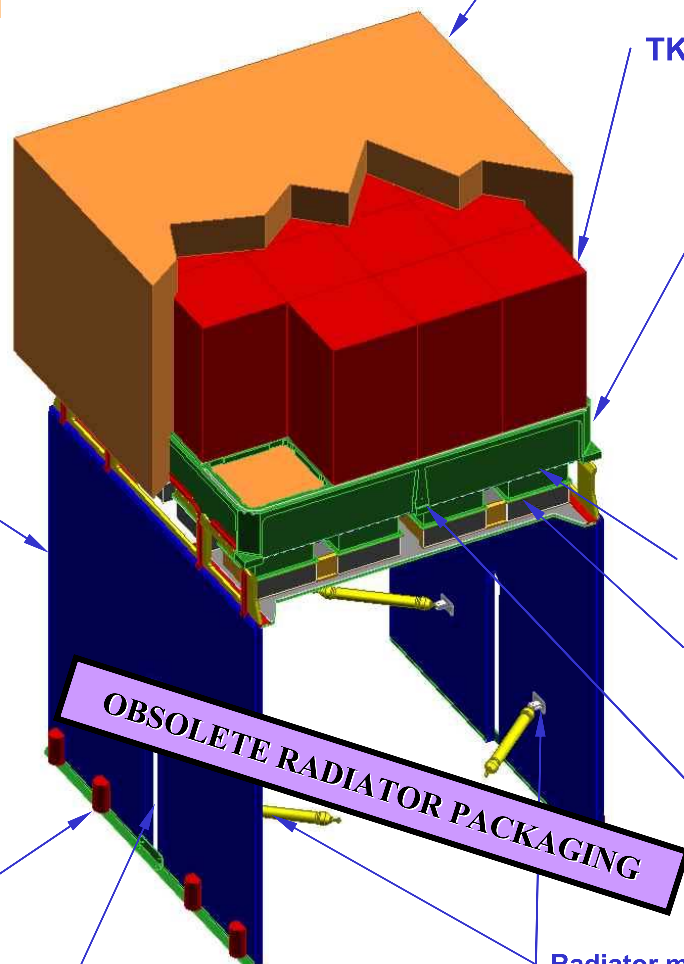
LAT Mechanical Systems Overview

LAT Design Parameters

LAT Parameter	Design	Spec
Mass	2614 kg	< 3000 kg
Center of gravity	169.5 mm	< 185 mm
Width	1796 mm	<1800 mm
Height	1047 mm	< 2388 mm



ACD surrounded by Micrometeorite shield and MLI

TKR Modules mount to Grid top flange

Grid Assembly

- Aluminum strongback
- Embedded heat pipes for thermal management
- Provides mech, thermal interfaces for SC, TKR, CAL, ACD

Radiators/Thermal Control System

- Provide thermal control in changing thermal environments
- Variable-Conductance Heat Pipes provide active control of Radiator area
- Radiators structurally supported by LAT and SC
- Thermal control electronics in LAT SIU and PDU

CAL Modules inside Grid egg crate

Electronics boxes mount to Grid, X-LAT Plate

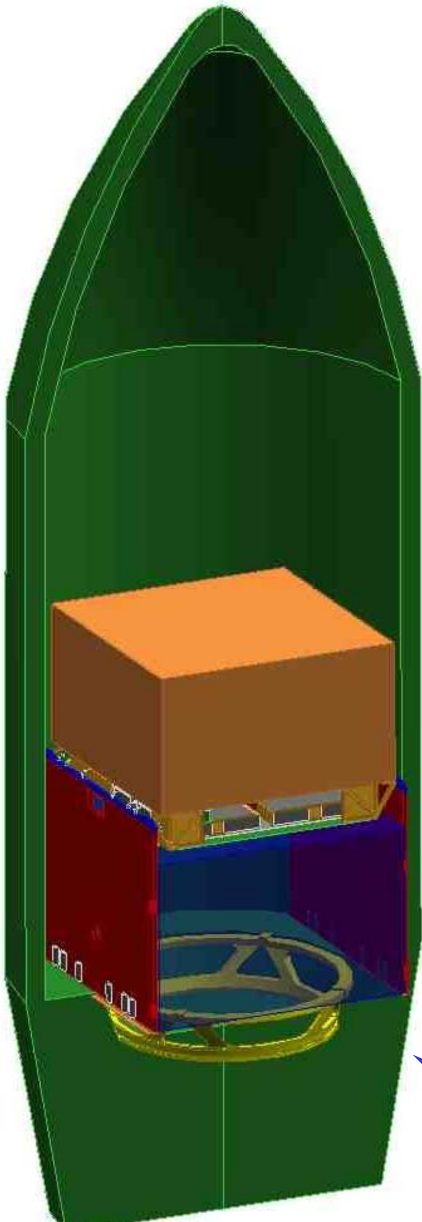
Spacecraft mounts at center of each side

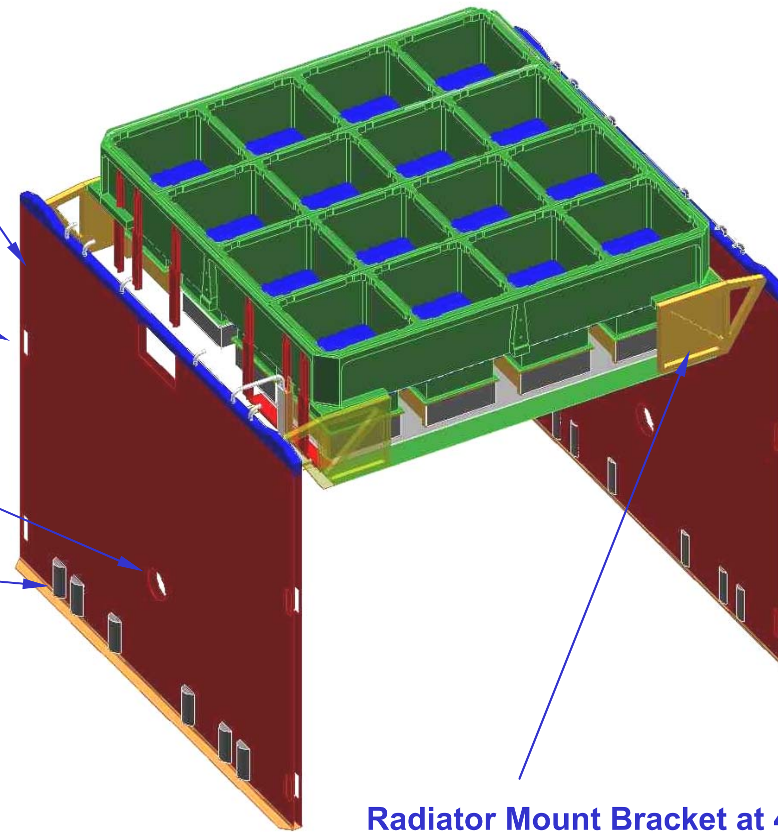
VCHP reservoirs

Slot accommodates solar array mast

Radiator mounts to SC body

LAT Mechanical Systems Details





LAT Radiator

Cut-outs for possible S.A. launch locks

Hole to accommodate Solar Array mast

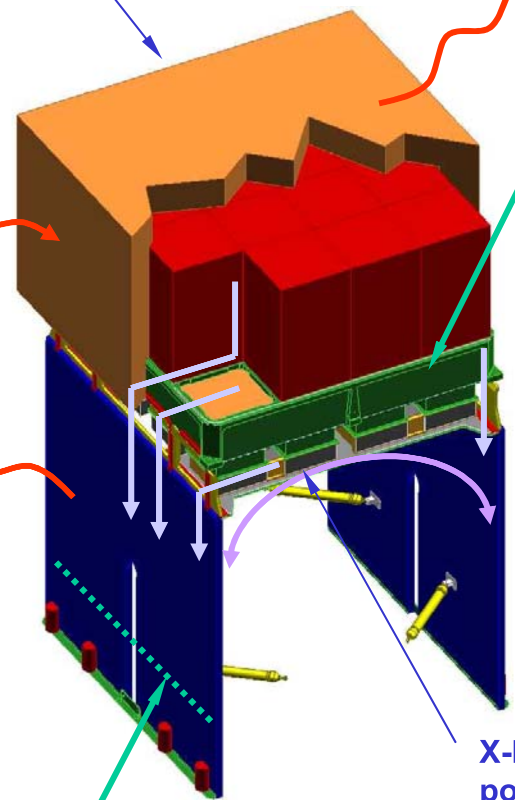
VCHP reservoirs

Radiator Mount Bracket at 4 corners of Grid

LAT with updated Radiator package, 6915 PAF, and SC stay-clear volume in the Delta-II fairing

LAT Thermal Systems Overview

On-Orbit Thermal Environment			
	Cold	Hot	Units
Earth IR	208	265	W/m^2
Earth Albedo	0.25	0.40	
Solar Flux	1286	1419	W/m^2



Active Make-up Heaters

- ❑Maintain LAT inside survival temp range when GLAST is in safemode
- ❑Mounted on Grid, X-LAT Plates

Predicted Interface Temp's (°C)		
	Cold	Hot
Radiator		
TKR		
CAL		
ACD		
Electronics		

Predict temp updates waiting thermal model re-run

Active VCHP Control

- ❑Allows for variable Radiator area to maintain constant interface temp to LAT

Level III Key Requirements Summary

Parameter	Requirement	Verif.	Expected Performance
Mech Systems mass budget	< 323 kg	M	310 kg
Mech Systems power budget	< 50 W	D	48 W
Radiator-Grid interface temp	-10 > Temp < +3.6 ^{o}C	T	-10 > Temp < +1.5 ^{o}C
TKR alignment stability	< 7 arc-sec (1σ radial)	T, A	6.9 arc-sec (3σ radial)
Prevent TKR modules from colliding	> 0 mm	T	Δgap = 0.39 mm Nom gap: 2.5 mm
Capable of dissipating LAT process power	650 W	T	50% of A_{rad} needed for 650 W
Earth IR thermal flux environment	265 W/m^2 hot 208 W/m^2 cold	T	OK
Earth Albedo factor	0.40 hot 0.25 cold	T	OK
Solar array backloading	28 W/m^2 max	T, A	OK
Vibration loads per LPS 5.3.12.5	f_1 > 50 Hz	T	f_1: 62 Hz ACD f_4: 64.8 Hz Grid

Summary of PDR Action Items

- **Re-evaluate thermal interface requirements**
  - ✓ Solar array heat loading → current IRD includes more realistic hot-case backloads
  - ✓ Survival heater power → IRD revised to match current design—with margin—of 300 W
  - ✓ Total hot-case process power → LAT process power for hot-case analysis is 602 W
- **Investigate alternate design implementations**
  - ✓ Radiator re-packaging → completed detailed CAD modeling of SC, LV fairing, and LAT
  - ✓ TKR peak temperature → re-evaluated impact of increasing max TKR temp (no change)
  - ✓ Higher emissivity thermal coatings on the Radiator → 6% increase with thicker FOSR
  - – LAT thermal control in survival mode → defined as LAT responsibility since I-PDR. Operations concept and implementation have been defined
  - – Investigate alternate sources of heat pipes → escalated to LMMS VP for action plan
- **Amplify test plans**
  - – Strength qualification testing → incorporate into updated LAT Test Plan
  - – Sine-vibration test philosophy → incorporate into updated LAT Test Plan
  - ✓ Thermal-vacuum testing of Grid assembly → current cost, schedule include this test
- **Mitigate programmatic risks**
  - – Cost and schedule impact of replacing a TKR module after LAT integration → under investigation by I&T group
  - – Evaluate LAT thermal-vacuum cycle time regarding SC test schedule → on the list of planned thermal analyses
  - – Complete internal mechanical ICD’s with subsystems → updates are underway
  - – Advance Radiator fabrication schedule by 1 year → constrained by funding profile
  - ✓ Evaluate effect of thermal design changes on cost baseline → re-packaging effort and expected future design modifications are included in current budget

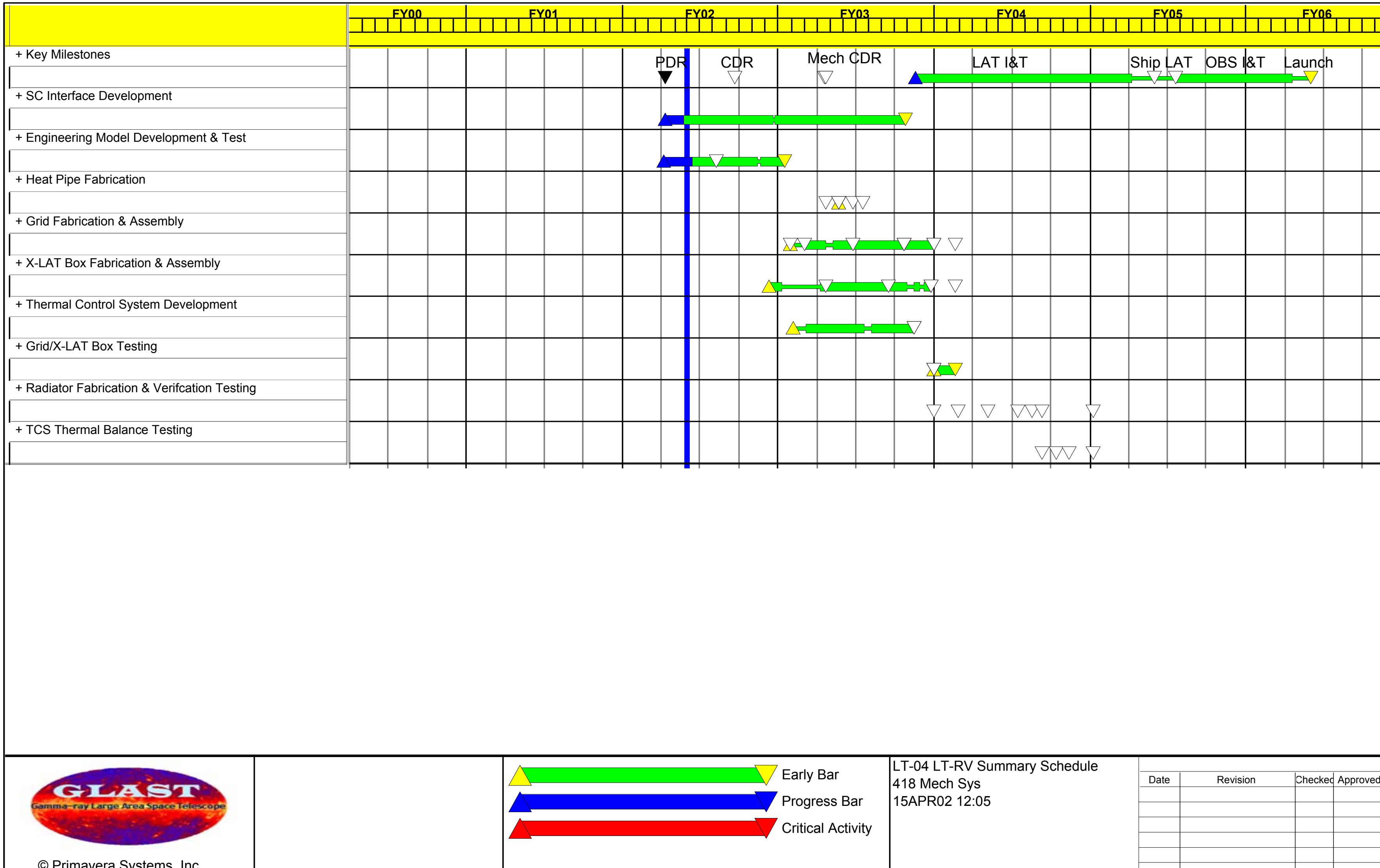
Near-Term Risk Mitigation: Planning for Delta PDR

- Risk: external interfaces to SC have been vague and incomplete
  - GLAST and LAT teams have re-worked IRD, MSS, and SPS to tighten up requirements definition and clarify interfaces
  - We have run thermal trade studies to develop/evaluate the new req’s
- Risk: Radiator design interfered badly with proposed SC designs
  - LAT has fully modeled SC envelopes, LV fairing and PAF, LAT, and Radiators to completely characterize all external design interfaces
    - Includes attempting to accommodate range of SC mass and center-of-gravity, since they influence Radiator sizing
  - Current LAT Radiator design accommodates all SC features that are needed, while providing adequate radiating area to meet requirements
  - Current design is “generic,” so it does not necessarily accommodate all possible SC designs → this is an on-going risk
- Risk: marginal Radiator thermal design at PDR
  - Updates to requirements and design result in Radiators with ~7 degC temperature margin
  - End-to-end thermal analysis model is being completely revised to reflect changes to design. This will produce definitive result

Mid-Term Risk Mitigation: Planning for CDR

- **Risk: key thermal and structural joints rely on unproven interface performance**
  - Prototype program has been underway since last summer to test joint designs
  - Engineering model program is in progress to retire most significant technical risks
    - Grid-CAL bolted joint structural behavior: 3 sets of structural EM's to test integrity and strength of this joint
    - Thermal-vac testing of key bolted thermal interfaces is underway now
    - Plan thermal-vac tests of TKR, CAL, DSHP, and X-LAT HP interfaces
- **Risk: inability to finalize external interfaces due to late arrival of SC contractor**
  - SC contractor being selected this summer (advanced 9 months from original schedule)
  - Radiator packaging is designed to handle most "generic" needs of any SC
  - LAT is expecting to accommodate most non-trivial interface changes
  - Current cost and schedule supports a moderate re-design effort of the Radiators and Grid to respond to changes needed by the SC

Summary Schedule



Mechanical Systems Level III Milestones

P3 ID	Milestone Description	Date
8M0016002	Av: Deliver I-PDR LAT TMM to GSFC	✓6/15/01
8M0001200	Av: I-PDR material ready	✓12/21/01
8M110005	AV: Mech dPDR Draft Mat'l Ready for Pre-View	✓4/4/02
8M110015	AV: Mech dPDR Material Ready	5/31/02
8M0016402	Av: Deliver I-CDR LAT TMM model to GSFC	10/8/02
8M0001300	Av: Mech-CDR material ready	11/5/02
8M0027690	AV: Delv of EM (2X2) Grid-Mech to I&T/MGSE	12/2/02
8M0001402	Av: I-CDR material ready	12/6/02
8M0029520	AV: Flight Grid ready for ACD Fit Test	1/7/03
8M0016508	Av: Deliver final LAT TMM to GSFC	8/15/03
8M0037302	AV: Flt Grid Assy RFI	12/12/03
8M0037312	AV: X-LAT Box parts RFI	12/12/03
8M0038506	ND: T-vac Chamber available	7/15/04
8M670015	Av: Deliver T-Bal test results analysis to I&T	9/14/04
8M0039500	Av: Radiators ready for Mission I&T	10/8/04
8M0002210	AV: GLAST delivered to L/V integrator	10/3/05

Long-Term Schedule Risks and Concerns

- Risk: post-CDR design changes due to SC-CDR planning in Jan-Jul 2003 could impact our interface design and force changes to flight hardware or in-process parts
  - We plan to isolate potential impacts to just the physical interface points
  - We will evaluate this risk with SC contractor at our CDR in December, 2002
- Risk: the new HPPC in MS is behind schedule, and could impact our Heat Pipe delivery
  - We have escalated this to VP level at LMMS for development of an action plan
  - HP's are not on the Grid critical path. We are evaluating total float of this work
- Risk: overlapping Mech Systems and LAT verification test schedules
  - We may need a duplicate set of X-LAT Plates to support TCS testing and LAT thermal-vacuum testing → still being evaluated (budget carries only one set of X-LAT Plates)
  - Advancing delivery date of flight Radiators greatly mitigates this risk, but is driven by funding profile
  - Plan to evaluate this for dPDR, once our schedule is complete

Technical Risks

Risk	Recovery	Po	Impact	Mitigation
Tracker gasket failure during vibe test	Replace	0.06	6-10 wk	Integration process control
VCHP to Down Spout heat pipe joint failure during T-Vac	Replace after T-vac. Re-test local joint only	0.1	2 wk	Installation process control; bench-top verification testing
LM Heat Pipe Product Center qual status	Early commitment by LM; early start on qual'ing new fab line	0.3	10 wk	VP-level follow-up with LM
Failure of TKR-Grid flexure during vibe	Replace	0.01	6–10 wk	Integration process control; verification testing at TKR module
Slipping of CAL-Grid friction joint during vibe	Re-vibe to verify no changing in mode shapes or frequencies	0.2	2 wk	Integration process control
Subsystem response to Grid flexing	Re-design interface	0.01	16 wk	Subsystem qual testing uses CLA results to bound load transfer extremes
Cable harness routing problems during integration	Re-design cable routes	0.5	3–6 wk	Mock up all cables, connectors and routing during EM program

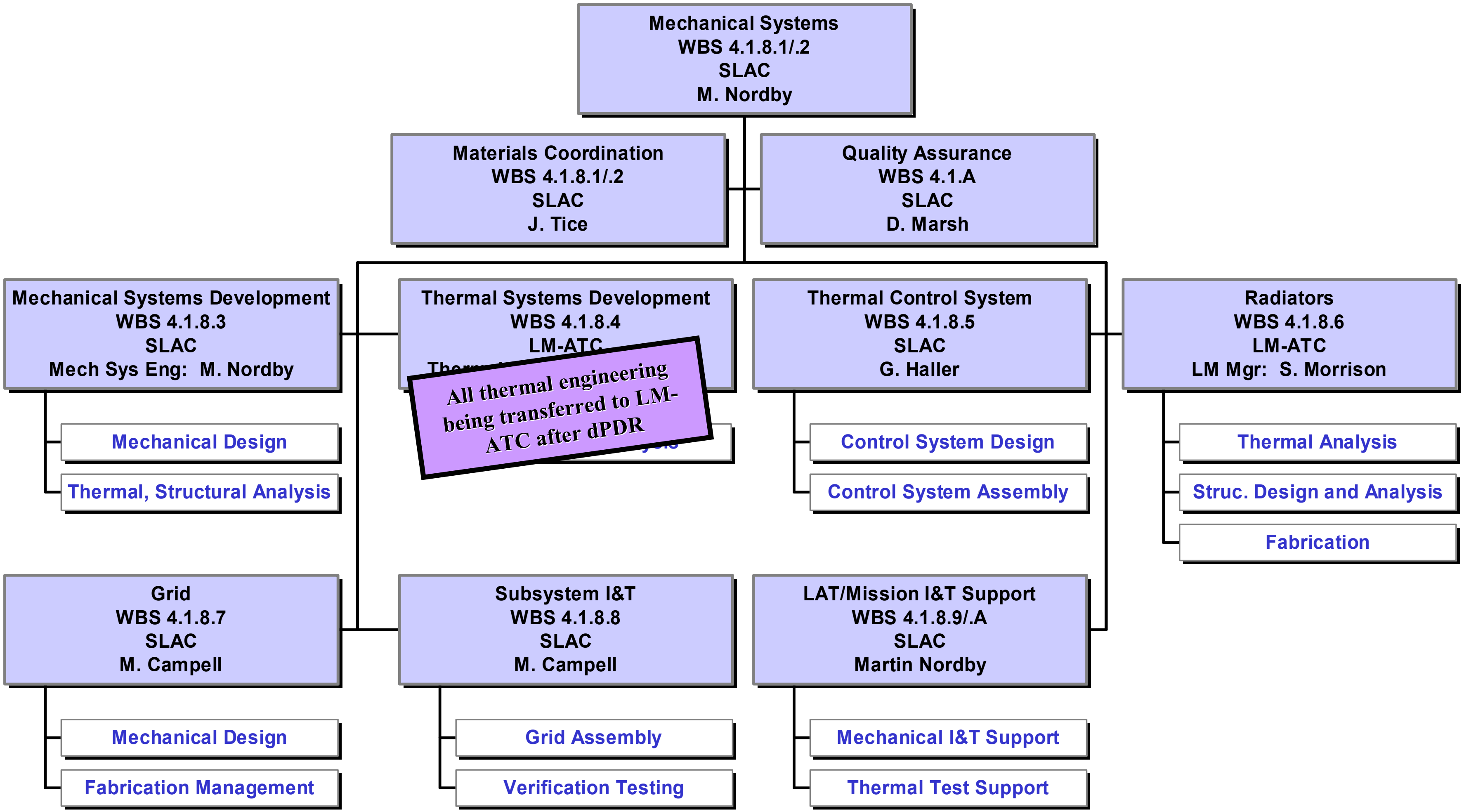
Dependences on SLAC and Suppliers

- SLAC Infrastructure
  - Bldg 33 high-bay and clean room: controlled by LAT I&T group
  - Design Group designer pool: including use of Klystron designers
- Suppliers
  - LM-ATC
    - Thermal engineering
    - Thermal-vacuum chamber test facilities for TCS testing
  - LM-MS, Sunnyvale
    - Thermal and structural engineering
    - Radiator fabrication facilities
    - Vibration test facilities for Radiator testing
  - LM-MS Heat Pipe Product Center (HPPC), Mississippi
    - Heat pipe fabrication and functional testing
  - Grid fabrication facility
    - Identified >4 vendors to competitively bid the Grid fabrication work as a turn-key operation—machining, cleaning, plating, assembly, testing
  - Orbital Network Engineering
    - Limited system engineering support

Work Breakdown Structure

- Management
  - 4.1.8.1 Management
  - 4.1.8.2 Reliability and Quality Assurance
- Systems Engineering/Design Integration
  - 4.1.8.3 Mechanical Systems Development (SLAC)
  - 4.1.8.4 Thermal Systems Development (LM)
- Flight Hardware and Development
  - 4.1.8.5 Thermal Control System
  - 4.1.8.6 Radiators, Heat Pipes, and Thermal Testing (LM)
  - 4.1.8.7 Engineering Modeling (SLAC)
  - 4.1.8.8 Fabrication, Assembly, and Test (SLAC)
- Integration and Test Support
  - 4.1.8.9 LAT I&T Support
  - 4.1.8.A Mission I&T Support

Mechanical Systems Organization Chart



Mechanical Systems Cost & Commitments

IN PROGRESS

Mechanical Systems Cost Profile

IN PROGRESS

Mechanical Systems Back-Up Slides

PDR Action Items--Verbatim

- 1. Generate a comprehensive strength qualification plan for the LAT instrument.
- 2. Provide the sine test philosophy for the LAT instrument and subsystems.
- 3. Provide an initial, top-level estimate of the cost and schedule impact of replacing a Tracker tower after complete instrument assembly.
- 4. Evaluate modifying the requirements being used for thermal design analyses in the following areas:
  - Temperature profile for solar arrays for hot, cold and survival cases.
  - The end-of-life temperature margin that could be achieved by raising the allowable operating temperature of the tracker detectors.
  - Evaluate increasing the survival heater power allocation.
  - Evaluate the maximum power that the thermal system should reject.
- 5. Investigate using thermal coatings with higher emissivity (while maintaining a low absorptivity) for the radiator.
- 6. Perform thermal vacuum cycling testing of the assembled grid with heat pipes (no other components) to evaluate workmanship.
- 7. Determine configuration of survival heaters, i.e., spacecraft control or thermostats.

PDR Action Items—Verbatim (cont.)

- 8. Ensure that the Rapid Spacecraft Development Office contractor is aware of the long time constant LAT instrument that will effect the duration of performing 4 thermal vacuum cycling. Also consider the thermal time constant effect on the LAT thermal vacuum test.
- 9. Conduct a delta mechanical/thermal PDR to evaluate technical, cost, and schedule impacts of the thermal changes necessary to meet requirements with margin.
- 10. Consider second sourcing thermal control components (such as Constant and Variable Conductance Heat Pipes) due to Lockheed Martin facility relocation to Mississippi.
- 11. Internal mechanical/thermal Interface Control Documents need to be completed.
- 12. Pursue with the GLAST project whether funding can be found to fabricate the radiators on the original schedule (rather than the year slip apparently mandated by the funding profile). This is a programmatic risk that should be avoided if possible.
- 13. The Mechanical Subsystem is not ready to be baselined at this time. Contingencies must be reassessed after impacts of thermal design changes and radiator repackaging are understood.

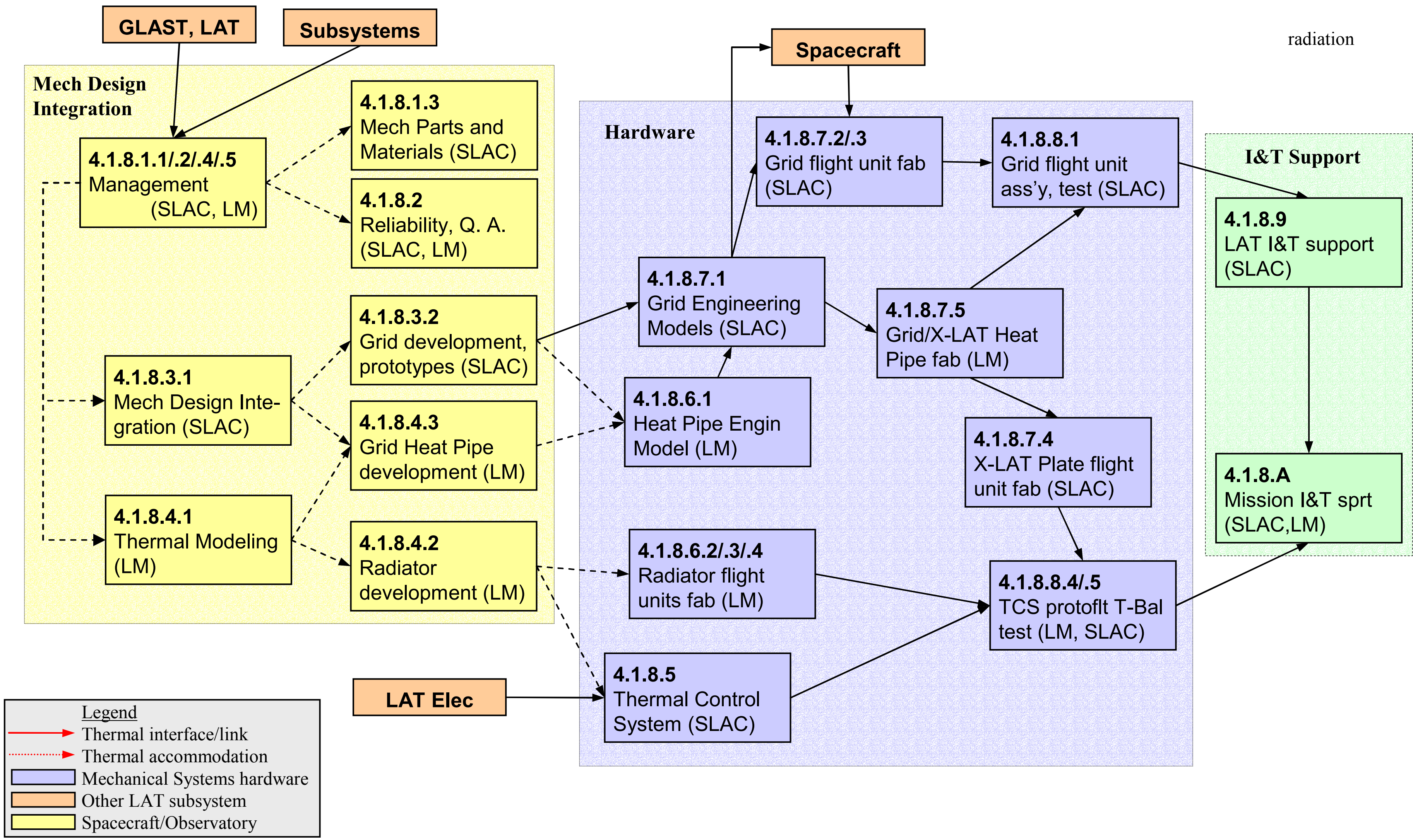
Mechanical Systems WBS Dictionary

- **4.1.8 Mechanical Systems**
  - Perform LAT system-level thermal and structural analysis, and manage system internal and external structural and thermal interfaces. Manage the LAT Mechanical Parts list, and mass and dimensional bookkeeping. Develop, fabricate, assemble, and test LAT Grid support structure, Radiators, and the LAT thermal control system. Support LAT integration and test by maintaining and updating system thermal and structural models through LAT, SC, and LV I&T, and on-orbit check-out.
- **4.1.8.1 Management**
  - Provide subsystem scheduling, cost-accounting, and performance tracking and reporting. Support development of subsystem specifications, plans, and interfaces. Control mass, power dissipation. Support team meetings and project reviews. Travel to team meetings, vendor visits, and integration facilities. This includes management of and by subcontractors. Also includes development of mechanical parts database, and tracking of all parts and materials for the LAT.
- **4.1.8.2 Reliability and Quality Assurance**
  - Provide input to LAT reliabilitiy and hazard analyses. Develop procedures for the fabrication of components and assemblies. Support PHA development. Collect quality records and report to LAT PSAM as needed. Includes subcontractor QA activities.
- **4.1.8.3 Mechanical Systems Development (SLAC)**
  - Perform thermal and mechanical design integration and analysis for the instrument. Design and develop subsystem interfaces, and interfaces with spacecraft. Develop Grid structure, including prototyping and analysis of Grid.
- **4.1.8.4 Thermal Systems Development (LM)**
  - Perform overall orbital dynamic and radiation thermal analysis for the instrument, and interface with LAT thermal-mechanical analysis. Develop conceptual thermal and structural design of LAT Radiators and Grid heat pipes.

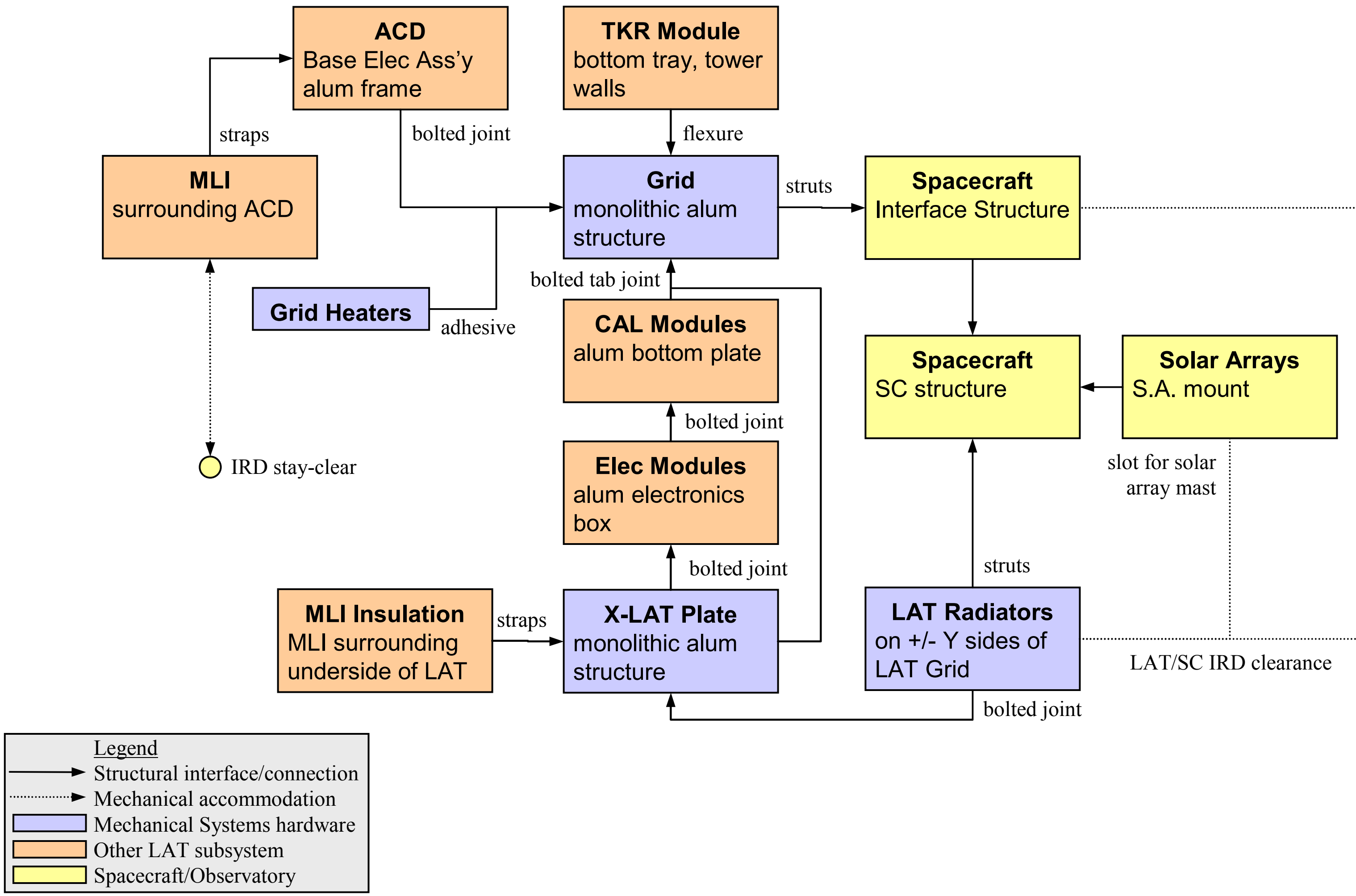
Mechanical Systems WBS Dictionary (cont.)

- **4.1.8.5 Thermal Control System**
  - Develop control system for thermal management of instrument, including heater and heater power design, feedback and control system for heaters, and monitoring systems. Procure, fab, assemble, and test on the LAT. Also includes thermal control GSE for bench-testing and during environmental testing (if separate from test GSE).
- **4.1.8.6 Radiators, Heat Pipes, and Thermal Testing (LM)**
  - Fabricate Heat Pipe engineering model (EM). Finalize Radiator designs after dPDR and fabricate, assemble, and test flight Radiators. Complete detailed design and fabricate heat pipes for flight Grid and X-LAT Thermal Plate. Thermal-balance test proto-flight Radiators and X-LAT Plate, including development of STE and test plan. Support LAT instrument thermal-balance test with in-chamber thermal analysis and predicts and operational support of TCS.
- **4.1.8.7 Engineering Modeling (SLAC)**
  - Develop, fab, and test Grid engineering models and prototypes after I-PDR. Finalize flight Grid interface designs.
- **4.1.8.8 Fabrication, Assembly, and Test (SLAC)**
  - Fabricate Grid, X-LAT Plate, and EMI Shield Box. Supervise fabrication. Develop assembly and inspection plans for Grid/Heat Pipe assembly and qualification testing. Carry out fabrication, assembly and test work for flight and spare Grids. This includes fabricating assembly fixtures and procedures for structural and thermal testing,
- **4.1.8.9 LAT I&T Support**
  - Support LAT instrument integration and structural and thermal testing. This includes engineering support to resolve interface issues, to update as-built drawings and to perform structural and thermal analysis and testing during LAT integration and test.
- **4.1.8.A Mission I&T Support**
  - Support integration to SC and LV, and test activities after delivery of full instrument to SC vendor. This includes engineering and technician support of testing at SC test site. Includes engineering support at SLAC of post-launch check-out.

Mechanical Systems WBS Interfaces

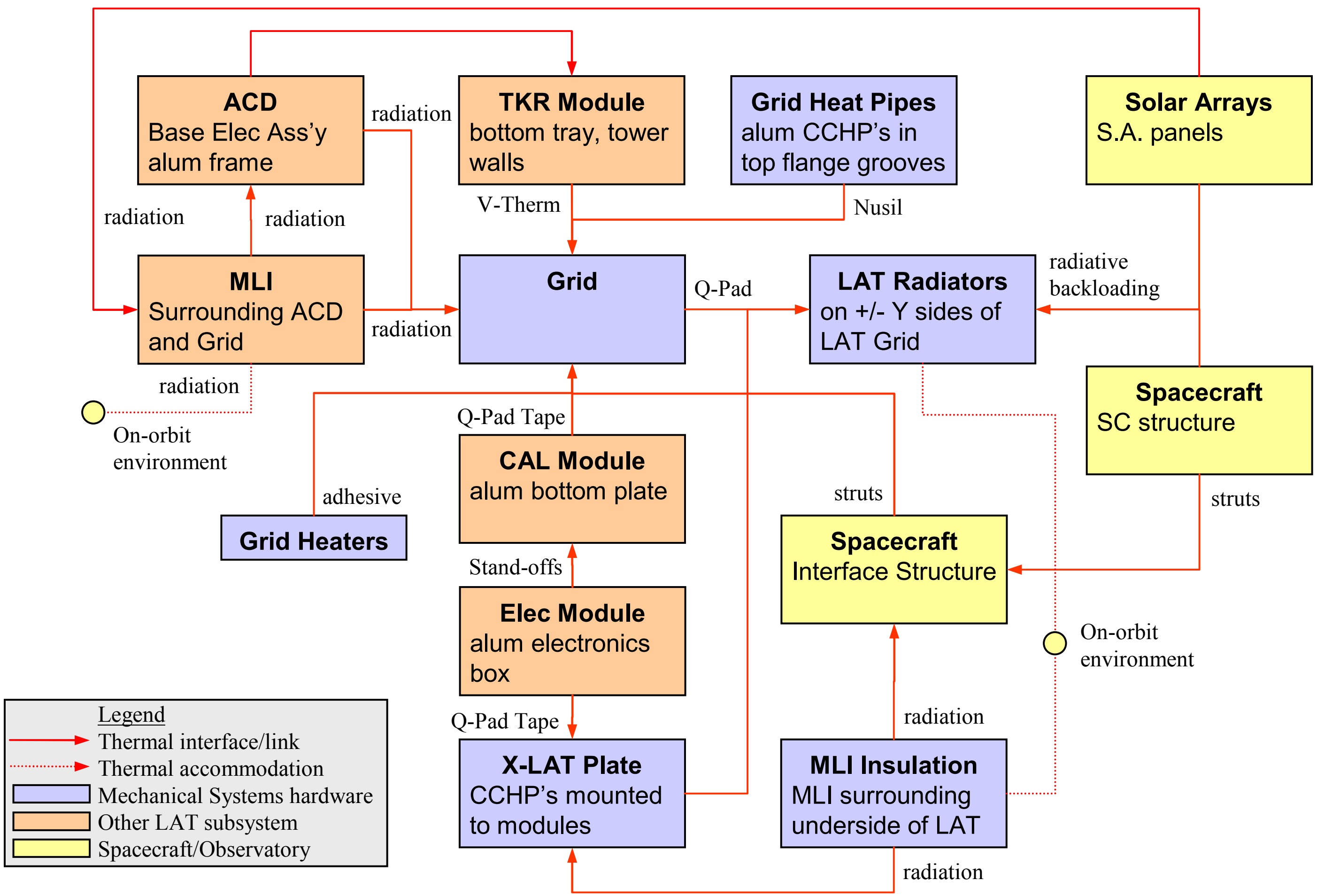


LAT Structural Block Diagram



LAT Structural Block Diagram

LAT Thermal Block Diagram



LAT Thermal Block Diagram