LAT Structural Overview

M. Nordby nordby@slac.stanford.edu
Y. Ismail ymi@slac.stanford.edu

LAT Structural Design at Delta PDR

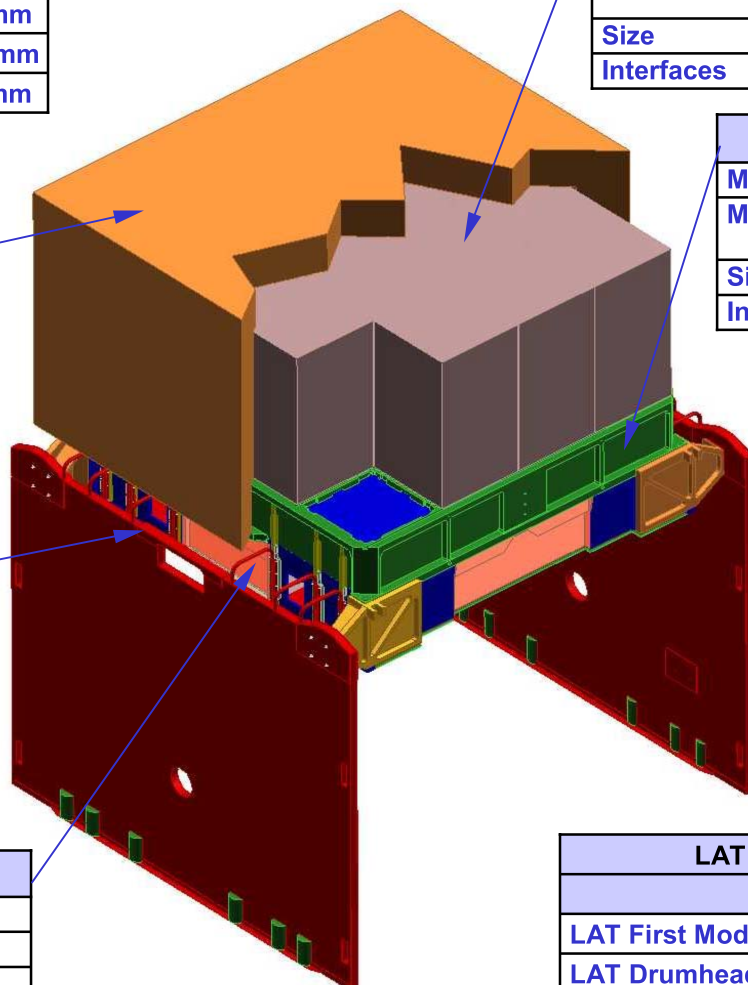
LAT Structural Design Parameters		
	Design	Spec
Mass	2699 kg	<3000 kg
Center of Gravity	154.5 mm	<185 mm
Width	1796 mm	<1800 mm
Height	1047 mm	1100 mm

Tracker (TKR)	
Mass	504.9 kg (May 2002 est)
Materials	GrEp, CC structures, Silicon, Tungsten
Size	372 mm sq x 640 h
Interfaces	Grid Ti flexure mount

Calorimeter (CAL)	
Mass	1466.3 kg (May 2002 est)
Materials	CFC support shell, alum structure, CsI
Size	364 mm sq x 224 mm h
Interfaces	Grid bolted friction joint

Anticoincidence Detector (ACD)	
Mass	228.1 kg (May 2002 est)
Materials	CFC honeycomb, alum base frame, MLI/ Micrometeorite Shield
Size	1796 mm w x 1015 mm h
Interfaces	Grid bolted joint, shear pins

Grid/X-LAT Plate/Radiators	
Mass	295.3 kg (May 2002 est)
Materials	Aluminum, heat pipes, alum honeycomb plates
Size	1566 mm sq x 236 mm h
Interfaces	Four-point mount to SC flexures



LAT Structural Overview

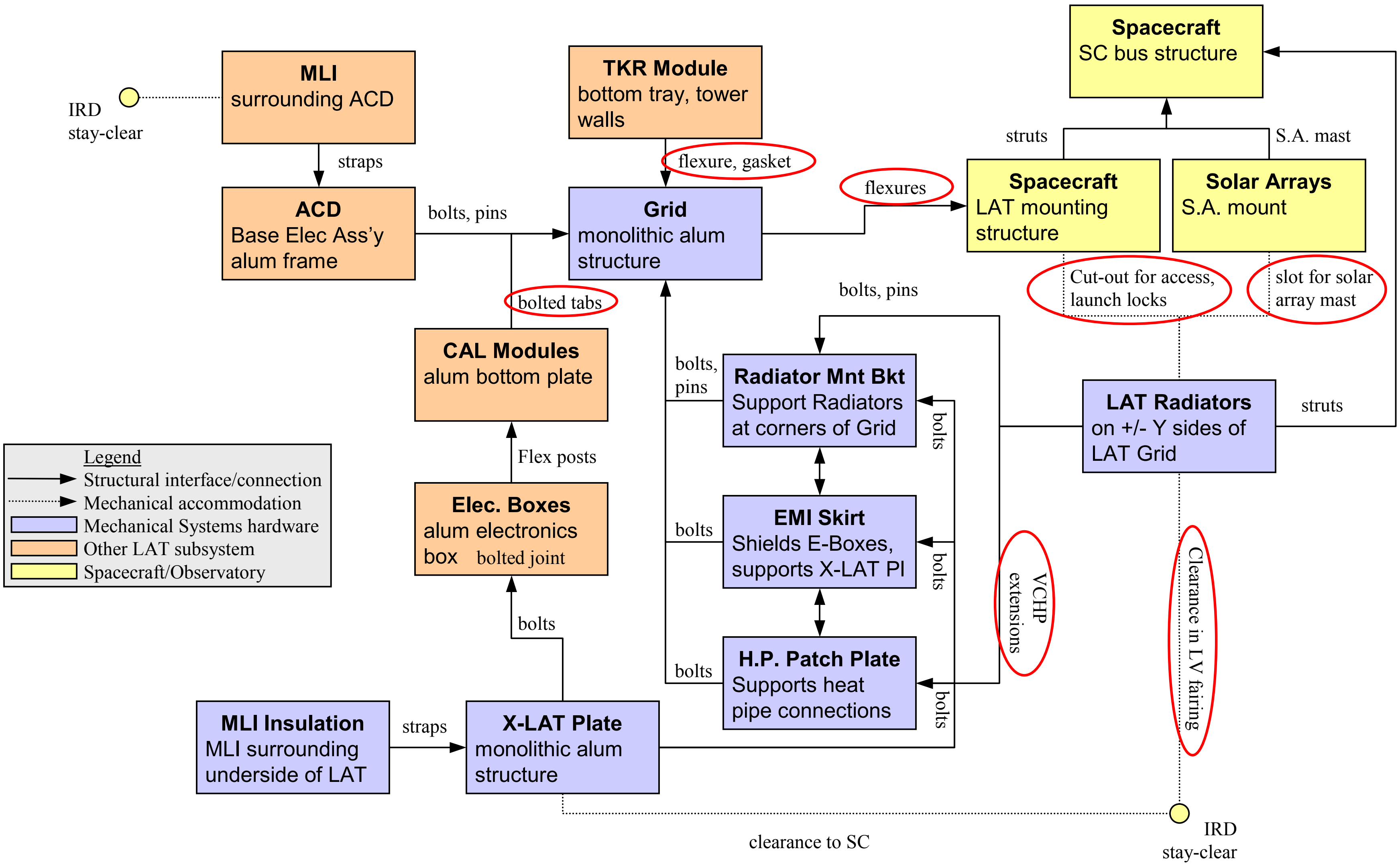
LAT Mass Budget and Current Estimates (kg)		
	Estimate	Budget
TKR	504.9	510.0
CAL	1466.3	1480.0
ACD	228.1	235.0
Mech	295.3	323.0
Elec	204.4	220.0
LAT Total	2699.0	3000

Source: LAT-TD-00564-3 “LAT Mass Status Report Mass Estimates for May 2002”

Electronics	
Mass	204.4 kg (May 2002 est)
Materials	Aluminum
Size	1417 mm sq x 222 mm h
Interfaces	Flexure mount to CAL; bolted friction joint to X-LAT Plate

LAT Structural Performance		
	Design	Spec
LAT First Mode Freq.	55.5 Hz	>50 Hz
LAT Drumhead Freq.	60.2 Hz	>50 Hz
Radiator First Mode Freq.	65.1 Hz	>50 Hz
Deflection at Grid Center	0.49 mm	---

LAT Structural Block Diagram

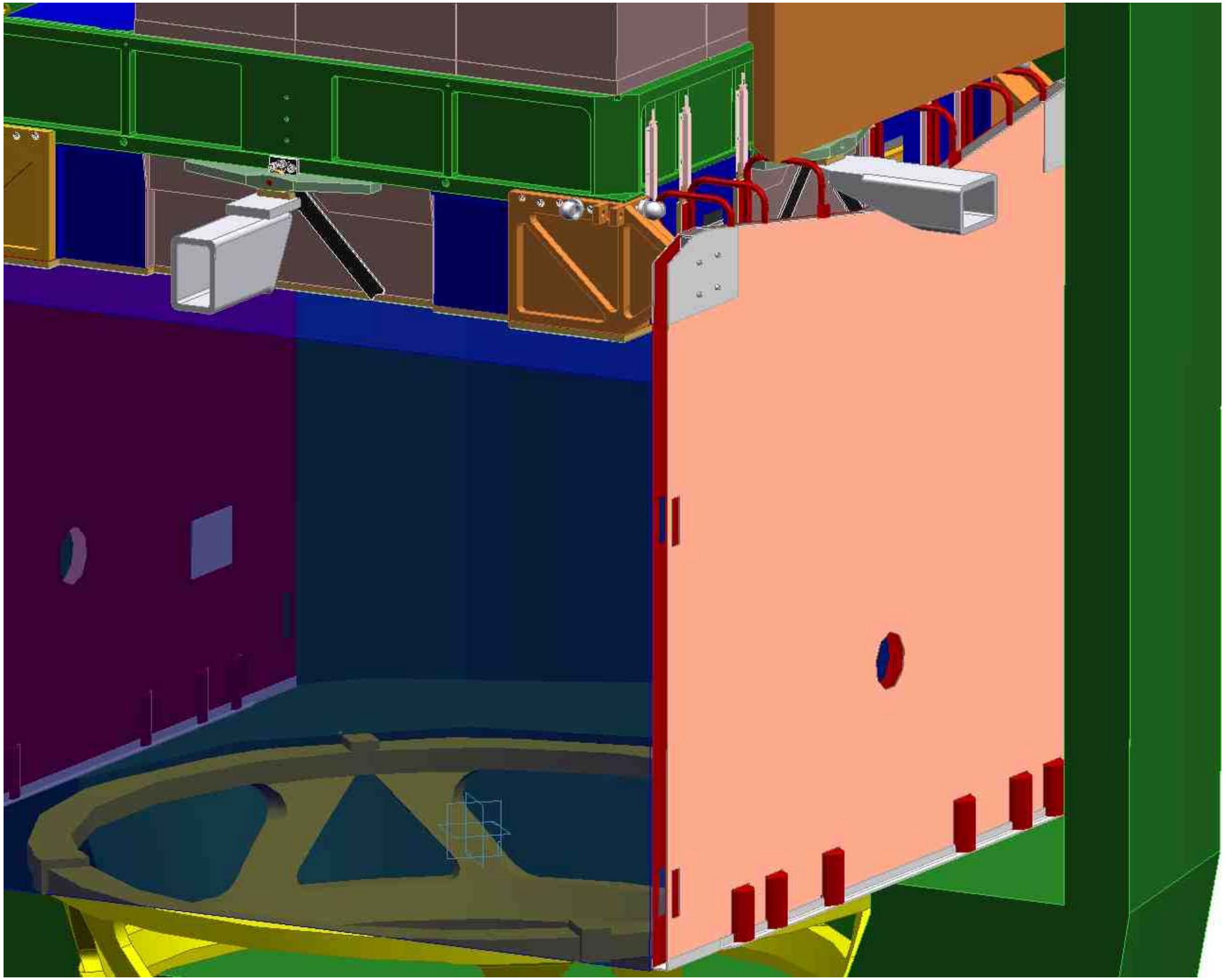


LAT Structural Block Diagram

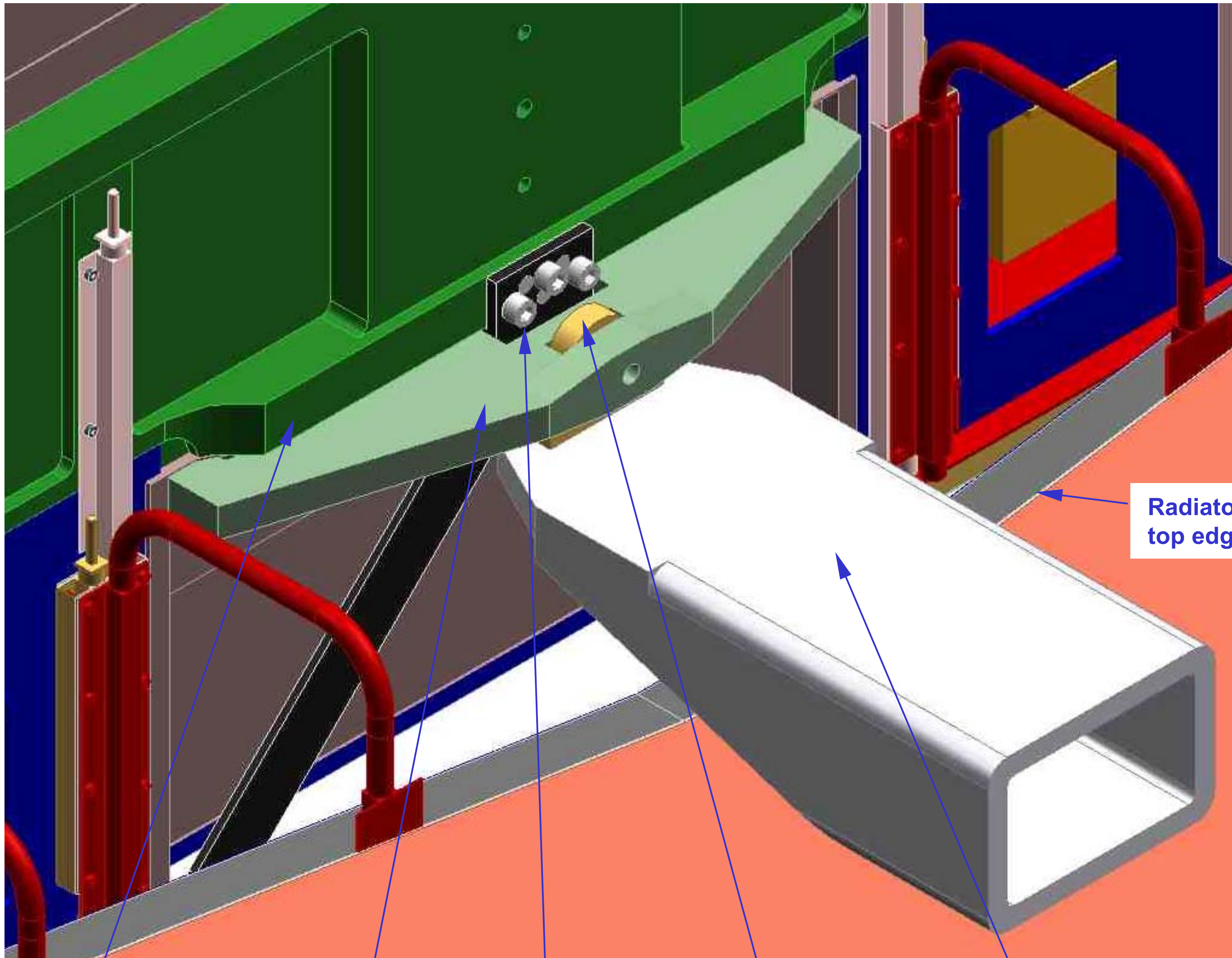
Design changes Since dPDR

- Radiators moved and slightly enlarged
  - Moved inward and down to provide added volume for solar arrays
  - Lengthened down to PAF separation plane
  - Resultant available area grew modestly (~5%)
  - Top profile changed to improve integration access for Radiators and ACD cabling
- Radiator cut-outs finalized
  - Launch lock and solar array cut-out sizes and locations agreed to by Spectrum and LAT
  - Awaits formal CR to IRD
- CAL Plate tabs thinned to reduce localized stresses
  - Changes included in CAL EM base plate
  - Interface EM testing underway by Mech Systems with updated tabs
- Wing design modified to improve coupling to CAL Plates
  - Design accommodates requested changes to SC flexure mount
  - Expected to further reduce tab loads in CAL Plates
- LAT stay-clear around Grid increased by 10 mm
  - Accommodates needed growth in ACD cable connector space
  - OK'd by Spectrum and Project, but still need formal CR to IRD

Updated Radiator Design



Detail of SC-LAT Mount Region and Grid Wing



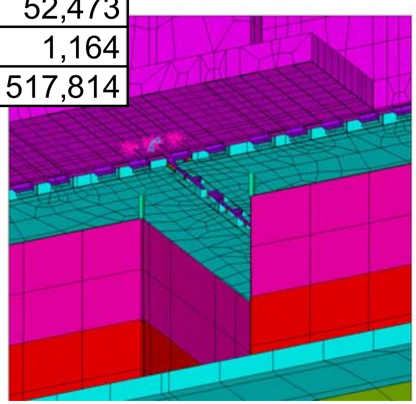
Design/Trade Studies Underway

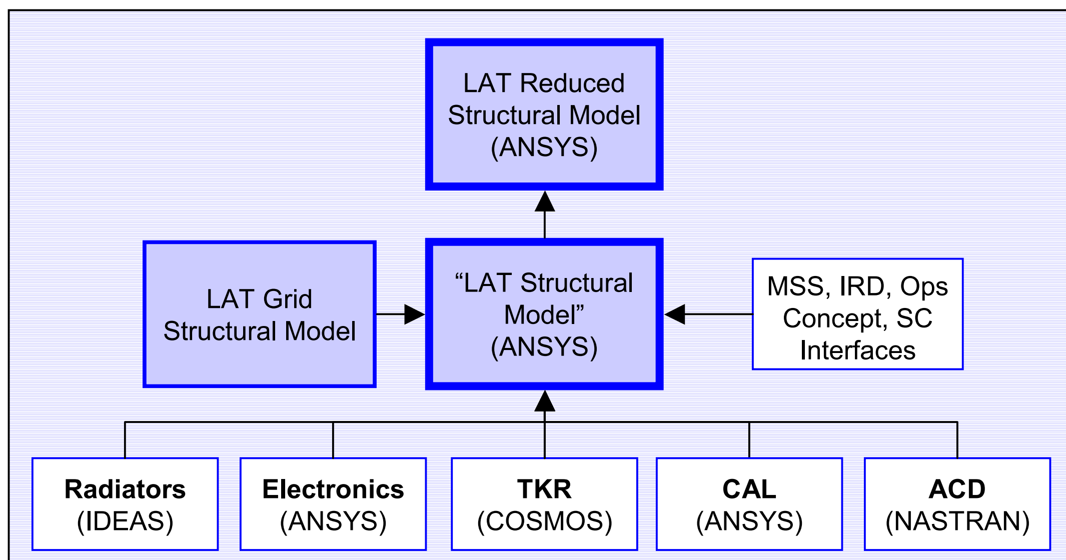
- E-Box support off CAL/X-LAT Plates
  - Mech Systems investigating a simplified rigid mount to the CAL
  - Change in structural design awaits testing of thermal spring finger joint to X-LAT Plate
- Radiator Mount Bracket accommodation of Radiator differential contraction
  - Investigating 2 flexible brackets or 1 rigid bracket and 1 flexure
- LAT connection to SC flexures may be moved to the side faces of Grid, instead of underside
  - Improves access for integration
  - Reduces localized stresses in Grid
- TKR flexure connection to Grid
  - Design updated to remove “diving board”
  - TKR/Mech Systems plan to baseline drilling matching holes using interface jig
  - Final design awaits completion of bottom tray re-work
- Integration GSE design
  - Grid Perimeter Ring size and mount points firmed up
  - Design of mount is underway
  - Handling load cases (especially for Observatory handling) being finalized

LAT Structural Analysis

- **June 2001 Mechanical PDR Structural model (a.k.a.: lat1)**
  - **CLA results started arriving in January 2002**
  - **Accelerations and some interface loads from this CLA are in the Env. Spec**
- **August 2002 dPDR Structural model complete (a.k.a.: lat9)**
  - **Used for generating interface loads predictions for Environmental Spec**
  - **Reduced model delivered in October 2002**
  - **Model being converted for use in Observatory coupled loads analysis (CLA)**
  - **ETA is February 2003 for CLA results**
- **April 2003 CDR Structural model**
  - **Moving to NASTRAN for improved compatibility with GSFC**
  - **We will start model update with CDR subsystem models soon**

Model Feature	Number
Nodes	118,749
Total elements	98,705
Brick elements	45,068
Shell elements	52,473
Beam elements	1,164
Degrees of freedom	517,814





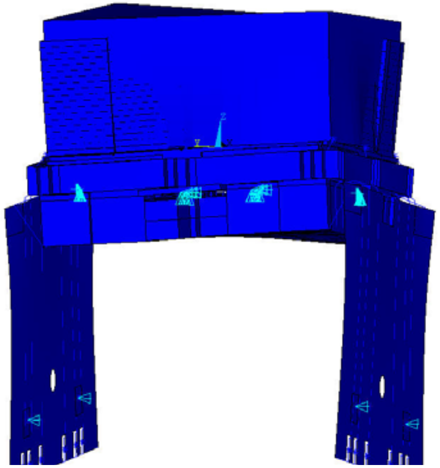
Relationship Between LAT Structural Analysis Models

Status of Subsystems in the August 2002 LAT dPDR Structural Model

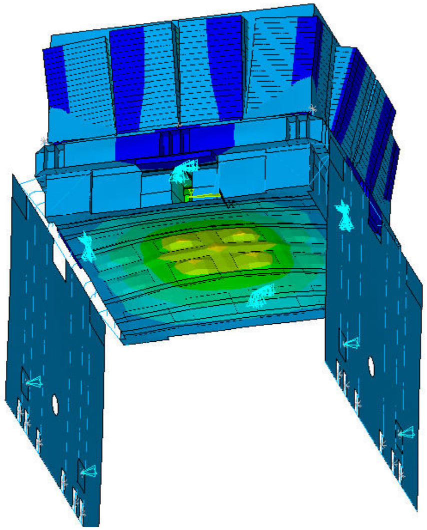
- Grid Box
  - Modeled with linear brick elements
  - X-LAT/Mid-Plates modeled with shells with honeycomb properties
- Electronics Boxes
  - Simple boxes modeled, since details did not exist yet
  - Box and board mass lumped into sidewalls
  - Compliant Posts to CAL modeled with beam elements
- Tracker
  - Bottom tray modeled with brick elements, based on "old" design
  - Remaining trays and side walls modeled with linear shell elements
  - Flexures crudely modeled with linear shell elements
- Calorimeter
  - No details of CAL internals included
  - Bottom plate modeled with linear shells, including tab details
- ACD
  - Imported from ACD subsystem and constrained to Grid
  - Modeled with shells to simulate BEA, flexures, and honeycomb TSA
- Radiator
  - Imported from Lockheed-Martin and constrained to Mount Bracket
  - Heat Pipes modeled as offset beams and constrained to EMI Skirt
  - Panel modeled with linear shells, with honeycomb properties
  - Shear deflection accounted for by adjusting moment of inertia ratio

Results

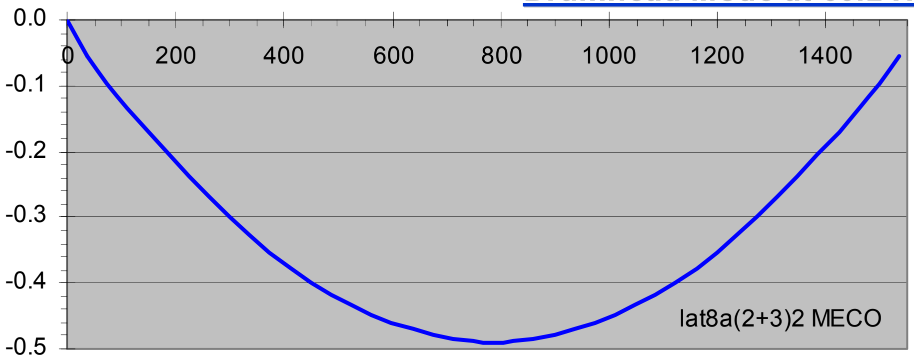
- Modes and frequencies
  - 60.2 Hz drumhead mode is well over 50 Hz requirement
- Deflections
  - Most peak deflections occur at MECO under 6.8g axial load
- Interface loads
  - Interface loads derived from static-equivalent LAT analysis, and coupled-loads analysis of Observatory
  - Environmental Spec collects those loads in one place



Twisting Mode at 55.5 Hz



Drumhead Mode at 60.2 Hz



Deflection of Grid Along Y-Axis (mm)

Load Case Name:	lat8a(2+3)1	lat8a(2+3+4)	lat8a(2+3)2
Grid center Uz (mm)	-0.30	-0.30	-0.49
Grid corner Uz (mm)	-0.13	-0.16	-0.16
Grid center Ux (mm)	-0.12	-0.08	0.00
TKR gap closing (mm)	0.27	0.28	0.39
ACD-TKR gap closing (mm)	0.31	0.19	0.18
Radiator Ux (mm)	-0.25	-0.18	-0.02
Radiator out-of-plane (mm)	0.05	-0.24	-0.33*

Key LAT Deflections (mm)

Modeling Plans for CDR

- Updated FEA models from all subsystems must delivered by late January
  - Must include all CDR design updates
  - Prefer that this is a model that has been validated/correlated with EM test results
- Modeling fidelity
  - Reduced model should include details of all key structural interfaces, both within and outside the subsystem
    - These details assure that LAT and CLA analyses using these models accurately predict interface loads
  - Model must correlate with the detailed subsystem model for all primary modes, and those with large mass participation
    - This is critical to assure that the LAT model can accurately predict key subsystem modes and transfer functions
  - Minimize the use of specialized element types, to streamline any conversion to other FEA software
- LAT CDR analysis cycle
  - Modeling and analysis will be complete by LAT CDR in early April
  - Subsystems will use current Environmental Spec for all CDR design and test work
  - Any surprises from the LAT CDR analysis or CLA results will be handled individually → we expect that the current loads bound the design load cases, but….

Subsystem Modeling for CDR

- TKR
  - Incorporate new TKR reduced model
    - Modified bottom tray design
    - Updated sidewall properties
    - As-measured stiffness and frequencies
  - Model flexures with improved fidelity
- CAL
  - CAL reduced model in-hand—delivered too late for dPDR work
  - Model needs update to EM design
- ACD
  - Incorporate updated model
    - Significant mass growth in ACD could impact LAT fundamental modes
    - Details of flexures and mount to Grid need to be included
- Electronics
  - Incorporate final box design
  - Model final mounting configuration
- Radiators
  - Update model with new position and size
  - Include stiffness of SC support struts
- Grid Box
  - Incorporate changes to Wing and SC flexure mount
  - Modify CAL joint modeling to reflect EM test validation

Dynamics Test Plan

- Dynamics Test Plan is being written now
- Issues being worked
  - Acoustic testing
    - Should Radiators be integrated when LAT goes through acoustic test
    - If not, what are risks that are added by the lack of complete verification
    - What is impact on component acoustic test configuration for the Radiators
  - LAT Random vibration testing
    - LAT Verification Test Plan has a random vibe test for the LAT baselined
    - This test is not recommended by GLAST project structural team
      - Primary source of random vibe in the Delta II is acoustic coupling to the structure
      - Components are not particularly excited except by acoustic loading
    - We are investigating the added risks, if any, of NOT doing a random vibe
  - Subsystem random vibration testing
    - Random vibe/acoustic environment of Delta II-H is not fully known
    - Therefore, design environment is GEVS standardized spectrum, to assure that we will have margin to handle any increases in drivers in the future
    - Acoustic analysis being done now *may* be used to set test levels
- Test instrumentation still to be defined
  - Once Dynamics Test Plan is in rough draft, we will look at instrumentation trades
  - Issues
    - Removing the ACD after vibe to remove accelerometers
    - Impact of fly-away test accel's on TKR top tray and CAL top frame design
    - Do we need gap monitors/proximity sensors for full verification of TKR gap closing

Design and Test Environments

- Acoustic
  - Delta IIH acoustic spectrum just recently released by Boeing. This will be added to Env. Spec, and used for acoustic analysis driver
  - The spectrum is lower, in general, but 2-3 dB higher up to 100 Hz
- Random Vibe
  - Subsystem random vibe design environment is GEVS standardized spectrum, adjusted for mass → this is in Env. Spec. for CDR work
  - Acoustic analysis will generate predicted random vibe spectra for subsystems, which we may decide to use for AT and QT on flight hardware
- Static-Equivalent Accelerations
  - Net C.G. accelerations for all subsystems were generated from Dec 2001 C.L.A. This is current design environment for subsystems
  - Updated CLA will generate new (probably lower) predictions, but results won't be available until April 2003 → don't wait for this
  - MECO peak thrust acceleration is from PPG, not CLA, and will not change → this 6.8 g thrust load is driver for many subsystems
- Interface Limit Loads
  - Limit loads set as the maxima of predictions from LAT static-equivalent analysis and GSFC preliminary CLA
  - All subsystem interface limit loads are defined in the Env Spec
- Interface Distortion
  - AT MECO, the Grid sees its maximum out-of-plane distortion
  - The shape of this distortion is specified in the Env Spec, and a static strength qualification test should be planned to verify this

Structural Load Environments

Sec	Topic	Status
7	**Ground Environments**	
7.1.	*Structural Load Environments*	
	Seismic Environment	complete--from SLAC Seismic Spec
	Ground Transportation Static-Equiv Accel's	waiting carrier data (E. Gawehn)
	Airplane Static-Equiv Accel's	waiting carrier data (E. Gawehn)
7.2.	*Dynamic Environments*	
	Ground Transport Dynamic Environment	waiting carrier data (E. Gawehn)
	Airplane Transport Dynamic Environment	waiting carrier data (E. Gawehn)
8	**Structural Load Environment**	
8.1.	*Static-Equivalent Accelerations*	complete for all subsystems, LAT
8.2.	*Interface Limit Loads*	
	Tracker—Grid Interface Loads on Flexures	complete--from LAT dPDR analysis
	CAL—Grid Interface Loads on CAL Tabs	complete--from LAT dPDR analysis
	ACD—Grid Mount	complete--from prelim CLA
	Electronic Box—CAL Interface Loads	complete--from LAT dPDR analysis
	LAT—SC at LAT Mount Boss	complete--from CLA, dPDR analyses
	Radiator Interface Loads	complete--from LAT dPDR analysis
8.3.	*Pressure and Pressure Changes*	complete--from PPG
9	**Vibration and Acoustic Environments**	
9.1.	Sinusoidal Vibration	complete--from PPG
9.2.	Random Vibration	complete--from GEVS, scaled by mass
9.3.	Acoustic	waiting updated spectrum (S. Seipel)
10	**Shock Environment**	clarifying S.A./IRD spectra (M. Nordby)

MECO Transient Event and Impact on LAT

- Description
  - 2 g amplitude transient acceleration at 115-125 Hz at MECO
  - Short duration event: 0.2 sec
  - This is an axial acceleration only, with no transverse component
  - Seen on all Delta II launches
- Plans for LAT design and analysis
  - Do NOT modify any designs in response to this new information
    - Loads and any ensuing requirements are still being investigated by KSC and Boeing → re-design has not been required for other missions
    - This is an axial acceleration, and all LAT subsystems are either very stiff or relatively flimsy in the axial direction → this reduces the likelihood of coupling to this mode
  - Subsystem and LAT FEA models must be modified to include adequate fidelity to predict all “primary” modes up to 150 Hz for all subsystems → definition of important modes is up to us
- Impact on LAT testing
  - Need instrumentation to capture all primary modes, and any modes with significant mass participation
  - This must be done at subsystem level as much as possible, since access at LAT level is poor
  - Implications for subsystem Test Plans needs to be assessed
- Plan of attack
  - Complete Dynamics Test Plan
  - Assess subsystem dynamics test plans with this and other instrumentation needs