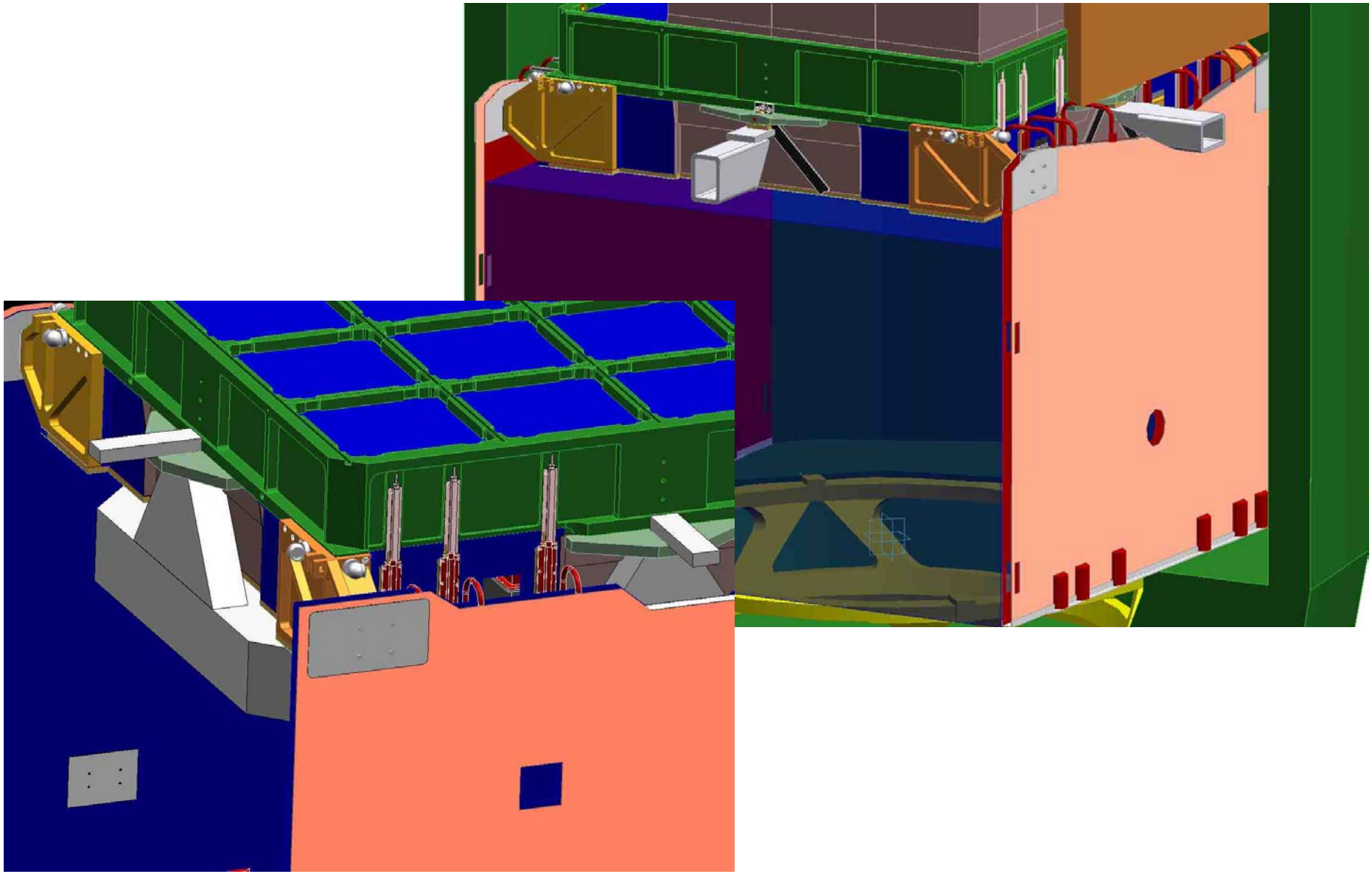
Dynamics Test Planning

Martin Nordby
Youssef Ismail
John Ku

LAT in the Launch Vehicle Fairing

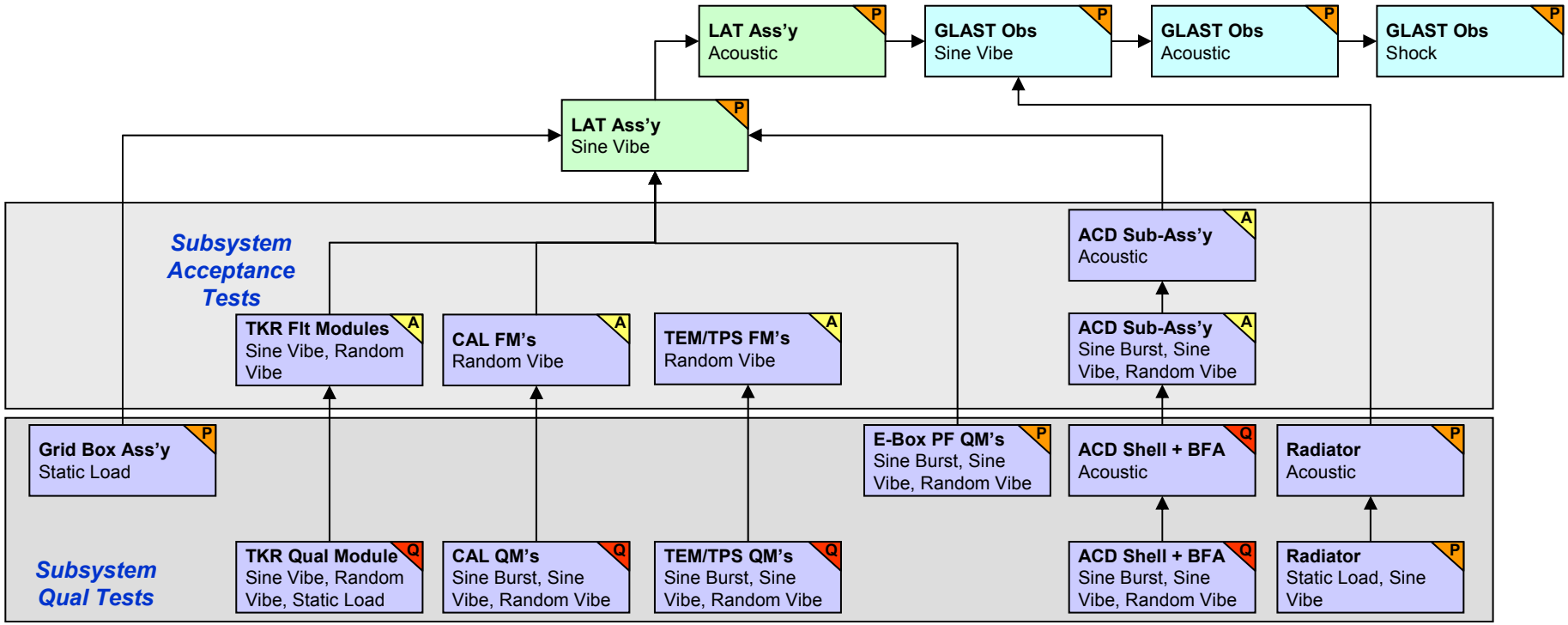


Baseline LAT Dynamics Test Plan

- Current baseline plan from LAT Performance Verification Test Plan
  - Modal survey—without Radiators, while at SLAC after integration
  - Sine vibration—without Radiators; includes sine sweep signature
  - Random vibration—without Radiators; test levels undefined
  - Acoustic—with Radiators
- Issues needing addressing
  - Random vibration
    - Is this test needed at LAT level?
    - If so, what are test levels and needed test configuration?
    - If not, what is risk of not doing this test?
  - Acoustic testing
    - Should Radiators be part of the LAT acoustic test?
    - If so, what is required fidelity of spacecraft dynamic simulator?
    - If not, what is risk of leaving Radiators out of test? How are Radiators verified fully?

Proposed Dynamic Verification Flow

- **Proposed plan**
  - LAT modal survey—without Radiators, while at SLAC
  - LAT sine vibration—without Radiators; includes sine sweep signature
  - LAT acoustic—without Radiators
  - GLAST Obs sine vibration—with Radiators but without solar arrays (TBR); includes sine sweep signature
  - GLAST Obs acoustic—with Radiators but without solar arrays (TBR)
  - GLAST Obs shock—shock event applied at PAF separation plane



Proposed Change: Remove LAT Random Vibration

- **Random vibration test plan history**
  - **Original LAT verification test plan included an Engineering Qualification Model (EQM) of the Grid**
    - EQM Grid qualification plans included a random vibration test
    - Test used mass/stiffness simulators of TKR, CAL modules
  - **EQM Grid test program was de-scoped to reduce costs**
    - Random vibration test was moved to the PF instrument level
    - Test could not be done on PF Grid, prior to delivery, since schedule could not support it, and cost of mass simulators had been de-scoped
- **Simplified Structural Background**
  - **Delta II history indicates that structures vibrate randomly in response to acoustics**
    - Most of the random vibration in GLAST is due to launch acoustics, not structure-borne vibrations
    - Delta II PPG 4.2.3.3: "No significant high-frequency random vibration inputs at the PAF/SC interface are generated by the Delta II LV"
  - **Coupling of acoustic energy into LAT structure produces a random vibration response in subsystem structures**
    - Thus, component random vibration testing verifies that subsystem structures can handle these dynamic acoustic loads
    - For the ACD and Radiators, acoustic testing induces the most flight-like random vibration environment to components. Thus, base-drive random vibration testing is of less value
  - **A random vibration (base-shake) test of the LAT has risks drawbacks**
    - Test may actually over-test some subsystems
    - For ACD and Radiators, this test has little value and may over-stress interfaces
    - LAT acoustic test will more accurately simulate the flight environment for the LAT subsystems and their interfaces

Summary and Recommendation

- LAT instrument high-frequency random vibration environment is fully attained in the instrument acoustic test
  - Therefore, the instrument random vibration test may be omitted with no technical impact
  - Risk to LAT likely decreases, since deletion of this test reduces the chance of over-test of subsystem components
- Subsystem components that experience random vibration as a result of transmission through structure should still go through a random vibration test
  - This includes the TKR, CAL, Electronics boxes
  - Test levels are set by either acoustic analysis or using GEVS levels to bound all possible flight environments (TBR)
- In light of this maturation in understanding of the environments and design of the LAT, the LAT-level random vibration test is inappropriate and should be deleted
  - Recommendation: remove the LAT-level random vibration test from the Performance Verification Plan

Proposed Change: LAT Acoustic Test with No Radiators

- Instrument-level Acoustic Test Objectives
  - Primary: demonstrate the structural integrity of the LAT components under the specified protoflight acoustic environment
  - Secondary: validate the acoustic analysis, i.e. that the LAT components were qualified to high enough levels of random vibration
- Other related assumptions
  - Sine vibe test will not have radiators integrated
  - Stand-alone Radiator will have a PF acoustic test with flight-like interfaces at the four attachment points and heat pipe joints
  - PF acoustic test duration is 60 seconds; qual duration is 120 seconds
- Trade Study
  - Evaluate impact of acoustic testing the LAT with no Radiators on the verification program and verification risk
  - Gauge relative cost and complexity of test set-up and STE

Trade Study: Acoustic Test LAT with Radiators

PROS

- Will verify thermal performance of the VCHP-DSHP joints after acoustics
- Radiator to Grid interfaces are flight-like
  - Interface is actual flight interface
  - Grid loads transferred from radiator are flight-like
  - Radiator loads transferred from grid are flight-like

CONS

- Spacecraft simulator needed to support Radiators and LAT
- Spacecraft simulator design requirements
  - Simulator must simulate acoustic coupling of the SC to/from the Radiators—this is deemed to be very difficult and expense to analyze and verify prior to testing flight hardware
  - Considerations must include TVAC test req's, or separate TVAC SC simulator is needed
- Reconfiguration needed after vibe for TVAC
  - Verification is lost on Radiator flight connections since Radiators must be de-integrated in preparation for TVAC test
- Radiator will see increased exposure to acoustic environment
  - 180 seconds prior to flight
  - Not typical for protoflight payloads

Trade Study: Acoustic Test LAT without Radiators

PROS

- Spacecraft simulator not needed
  - Test uses same STE as sine vibe
- LAT can go from sine vibe to acoustic test without reconfiguration
- Radiator will not see excessive acoustic loads
  - 120 seconds prior to flight
  - This is more typical for protoflight

CONS

- Thermal joint will not go through acoustics prior to TVAC
- Grid loads transferred from radiator will be absent
- Radiator mass replaced by mass simulator, which will not be able to reproduce acoustic behavior of Radiator at all

The Greatest Pros and Cons

- The cost of designing and manufacturing a spacecraft simulator is thought to greatly outweigh potential benefits → favors testing without Radiators
- We do not want to over-test the radiators → favors testing without Radiators
  - Flight acoustic environment is <10 seconds
  - High-frequency vibration may introduce fatigue
  - Typically do not fly hardware that has seen more than 120 seconds exposure
- Other factors mitigating negative impact of acoustic testing without Radiators
  - Radiator acoustic test
    - Radiator-to-Grid interface flight load configuration will be simulated well, using STE that is faithful to the design of the Radiator Mount Brackets
    - Acoustic loading on Radiator is largely independent of structure-borne random vibration of LAT/Grid, so this test (and the verification activity it represents) are separable from the LAT acoustic test
  - Radiator-to-Grid connection
    - Radiators would likely need to be de-integrated from the Grid after a combined acoustic test
    - This means that the final structural and thermal connections must be verified after acoustic test, whether the Radiators are integrated or not for the acoustic test
    - Final verification at the GLAST Observatory level will likely be needed either way, due to the packaging and size of the LAT with Radiators
    - This indicates that there is no net increase in risk

Summary and Recommendation

- Having no radiators at the instrument-level acoustic test:
  - does not compromise primary objectives, i.e. all interfaces will see random vibration at levels bounding the flight environment prior to observatory-level testing
  - greatly simplifies I&T, including STE design and validation
  - prevents radiators from being over-tested and minimizes associated chance of structural fatigue
  - is optimal—the best choice we have—given cost and schedule constraints
- Recommendations
  - Remove Radiators from LAT acoustic test
  - Identify needed verification activities at the GLAST Observatory testing
  - Direct Mechanical Systems to plan for a Radiator acoustic test with a high-fidelity, flight-like interface to its STE