Delta II MECO Transient: A Payload Perspective

Presented at the
S/C & L/V Dynamic Environments Workshop
June 25-27, 2002

Scott Gordon
Code 542
Goddard Space Flight Center
Scott.Gordon@gsfc.nasa.gov

Agenda

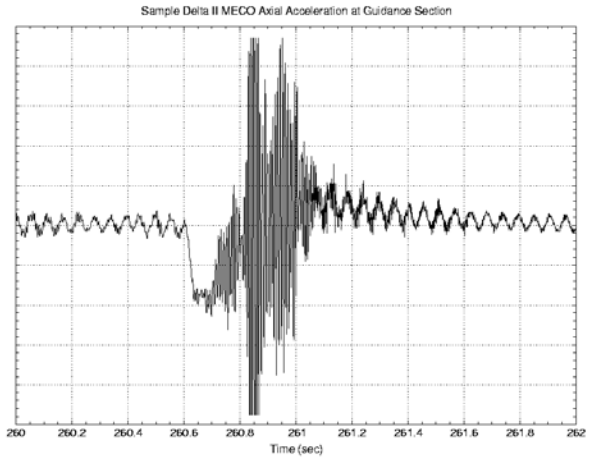
- **Background**
- **MECO Transient Description**
- **Approach for Clearing the EOS-Aqua Spacecraft**
- **Other Payloads**
- **Summary**

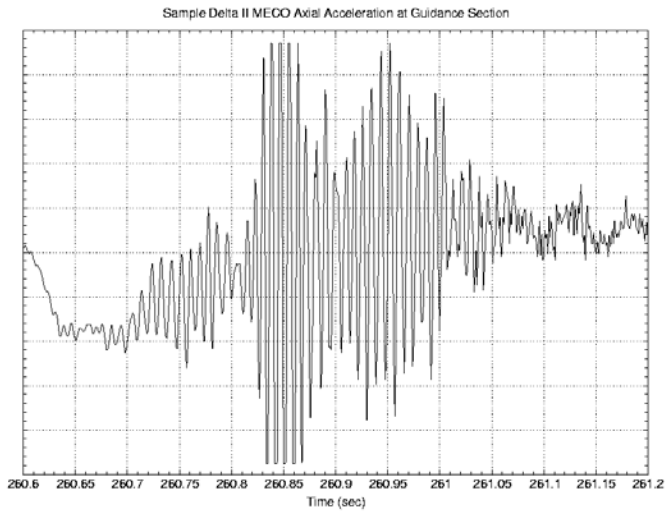
Background

- **KSC alerted NASA Delta payloads on Feb 11, 2002 that there was an event associated with MECO that could cause significant response for structure and components with frequencies around 115 Hz.**
- **EOS-Aqua (formerly EOS-PM) was in the process of shipping to Vandenberg for launch in Mid-April.**
- **GSFC worked closely with KSC/Boeing to assess risk of launch failure for Aqua due to MECO transient event**
  - Understand specifics of flight event
  - Develop methodology for predicting flight responses
  - Assess flight predictions against test levels and design capability
- **Aqua cleared and successfully launched on May 4, 2002**

MECO Transient Description

- **Approximately 4g's input at 115 Hz - 125 Hz**
- **Short duration transient event lasting about 0.2 secs**
- **Event seen on all previous Delta II flights**
- **Higher magnitude and longer duration with newer main engines - Approximately 8 flights**
- **No known launch anomalies associated with event**
- **Is this event a driver for payload design????**





EOS Aqua Spacecraft

- **Height: 21 Ft.**
- **Weight: 6500 lbs**
- **Cost: $952 Million**
- **LV: Delta 7920-10L**
- **Frequency (w/PAF):**
  - Lateral: 11.5 Hz
  - Axial: 56 Hz (20% MEW > 100 Hz)
- **SC Builder/Integrator: TRW**
- **On-board Instruments:**
  - AIRS (JPL/BAE)
  - CERES (LaRC/TRW)
  - MODIS (GSFC/Raytheon-SBRS)
  - AMSU-A (GSFC/Aerojet)
  - AMSR-E (NASDA/Mitsubishi)
  - HSB (INPE/Matra - Brazil)

Basic Assessment Approach for Aqua

- **Update VCLA Craig-Bampton Model & LTM to include frequency content out to 150 Hz**
- **KSC/Boeing perform MECO transient simulation using updated C-B model and provide response predictions**
  - Boeing - Coupled system transient analysis with "high-fidelity" LV model
  - KSC - Force limited frequency response base-drive, 100-150 Hz
  - Both sets of results provided for evaluation
- **Assessment performed in 2 basic catagories:**
  - Structural integrity (element stresses/forces)
  - Instrument/Subsystem dynamic response
- **Structural Integrity - Direct comparison between VCLA predictions and MECO transient base-drive results**
- **Instrument/subsystem Response - Compare input g's with equivalent g levels from random testing**

Aqua Strength Assessment

- **Preliminary base-drive results not-promising**
  - 3710 row force LTM - 1674 exceedances (177 > factor of 10)
  - Significant exceedances of forces at instrument interfaces (kinematic mounts)
- **KSC/Boeing redefined analysis to simulate coupled system**
  - Flight data playback using coupled system with “high fidelity” LV model
  - Force limited base-drive using limits derived from coupled system model
- **Using coupled system approach - Results were much more in-line with VCLA predictions.**
  - 77 force exceedances
  - 57 found to be enveloped by static test levels
  - Remaining exceedances found to be in areas with high design margins
- **Instrument/component equivalent static loads enveloped by design limit loads**

Component/Instrument Assessment

- **Compare equivalent SDOF G-level input from random testing with predicted levels from MECO transient**

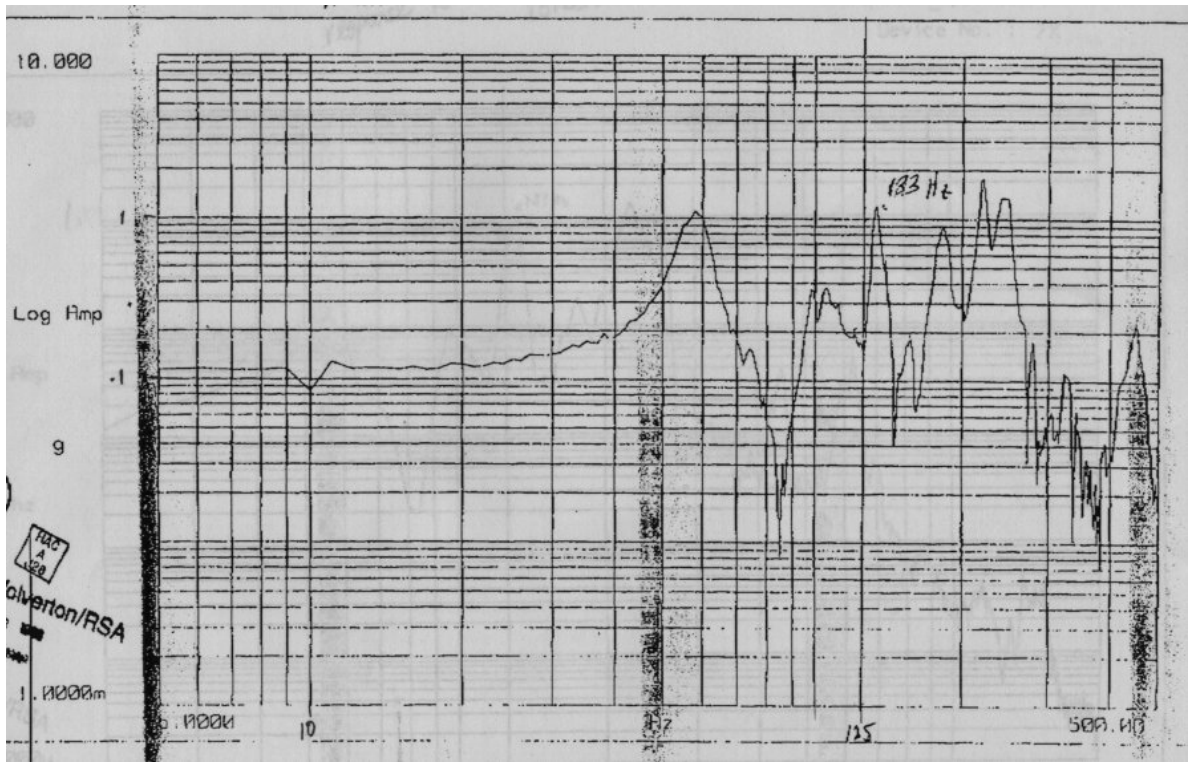
$$G_{eq} = 3 * \sqrt{\frac{\pi}{2} * F * PSD * Q} \Big/ Q$$

  - where
    - F = Frequency of MECO event = 115 Hz
    - PSD = Component random test level at 115 Hz
    - Q = Amplification = 20 (or from test data)

- **TRW reviewed spacecraft avionics and on-board components**
- **Instrumenters/Subsystem providers asked to assess their hardware**
- **Two instances where could not show random testing adequate to envelope MECO transient input (MODIS & AMSR-E).**
- **Both cases cleared after review of test data and input predictions**

MODIS FPA Example

- **SBRS concerned with resonance of FPA component**
- **Originally predicted around 125 Hz from random test data**
- **Review of sine signature data showed resonance at 130+ Hz**
- **Random test through resonance more severe than off-resonance response to MECO transient**



Other Payloads

- **Goddard Delta II Payloads**
  - ICESat - December 2002
  - Swift - June 2003
  - EOS Aura - Jan 2004
  - NOAA-N - June 2004
  - GLAST - August 2006
- **Current Approach**
  - Run preliminary base-drive analysis w/o force limiting and assess situation
  - Extend signature sweeps to 150 Hz to get data from subsystem level testing
  - Based on need, request that coupled SC & LV system be run and assessment be performed against refined numbers
- **Concerns**
  - Approach assumes success oriented outcome
  - Too late to effect testing if analysis cannot show good results
  - Burden on payload to show problem exists

Summary

- **EOS-Aqua design and test levels were shown to envelope the predicted flight loads for the MECO transient event**
- **Analysis has shown that treating event as equivalent steady-state sinusoidal input can be damaging if coupled system behavior is not considered**
- **We are in risk assessment mode for other Delta II payloads. No plans at this time to change test levels or verification philosophy based on MECO transient data**
- **Goddard is reluctant to perform sine testing in frequency ranges where we do not have reasonably accurate predictions of flight responses (GEVS & NASA Standard 7002)**
- **Acceleration levels are known but damage potential is not. Need an accurate and realistic way of predicting flight loads for this event.**