Combined Environment Testing

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• Motivation
  – Current issues
  – Limitations of traditional testing

• Proposed solution
  – System setup
  – Preliminary test results

• Conclusion
  – Benefits to satellite community
Actual Launch Environment

- Grounded vibration test does not simulate sustained acceleration
  - How does response change when “pre-loaded”?
  - Can we get away with lower level vibration?
  - Does alignment and sensor calibration change?

(Example) NASA Terrior-Orion rocket data
Current Test Methods

- Vibration test
  - Shock
  - Sinusoidal
  - Random

- Example vibration profile: NASA-GEVS

http://www.rocketrange.no/?p=1323
Fluid Systems

- Rocket engine plumbing
- Propellant tanks
• Calibration of sensors
• Characterizing noise, bias, non-linear behavior
• Sensitive payload
  – Need to minimize unnecessary loading
  – Deformation/shifting important
Current Test Methods

- Vibration test
  - Shock
  - Sinusoidal
  - Random

- Example vibration profile: NASA-GEVS

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Combined-load Testing

Operate shaker table inside centrifuge

Payload
Sustained g-load
Shaker

Can test multiple axis at same time (Concept drawing)

Closely simulate actual conditions

Acceleration(g)
Time(s)

Acceleration(g)
Time(s)

Acceleration(g)
Time(s)
Preliminary Testing

- Combined axial acceleration and vibration loads
- Shaker table was integrated to centrifuge
- Tested at reduced NASA-GEVS levels
  - Reduced Grms
  - Same frequency profile

NASTAR Center centrifuge

DragonSat-1 installed inside gondola
Shaker Cannot Take Lateral Loads

Figure 1: Transverse mode test fixture during checkout at AAAI

Figure 14: Parallel Fixture (left), Transverse Fixture (right). Arrow shows direction of G load.
Payload and Fixture Setup
Control Room During Test
1. Increase in response frequency
   - Non-linear behavior
   - Actual response frequency is higher → lower vibration test requirements?

2. Shifting or settling of components
   - May only show under combined conditions
   - Allows for more accurate calibration
- Green: sine sweep at idle condition, before and after high-g loading
- Black: sine sweep during high-g loading
- Note shift in response frequency
Random Vibration Test Result

- Lines represent 1g, 5g, 9g conditions
Shifting of Components

Display Mode: Magnitude
Traces:
TS-After9: FFT1: AvSpc [5]-Panel_Out(Pk-pk)
TS-Before3: FFT1: AvSpc [5]-Panel_Out(Pk-pk)

Overall levels:
Cursor1
X: AvSpc [5](Pk-pk) Y: AvSpc [5](Pk-pk)
(15:28:35 10/26/12)
RMS : 1.615 m/s²

Cursor2
X: AvSpc [5](Pk-pk) Y: AvSpc [5](Pk-pk)
(14:05:52 10/26/12)
RMS : 1.637 m/s²

0 Hz
14.37 mm/s²
16.29 mm/s²
Fluid Systems

- Rocket engine plumbing
- Propellant tanks
Guidance, Navigation, and Controls

- Calibration of sensors
- Characterizing noise, bias, non-linear behavior
• Sensitive payload
  – Need to minimize unnecessary loading
  – Deformation/shifting important
Conclusion

- Combined-load tests can simulate the launch condition more closely by bringing out the modified satellite response to the launch environment
  - Changes to response verified in both natural frequencies and response to random vibration conditions
- The physical shifting of components under g-loads (single direction) was identified
  - Shifting of loose articles where high-g loads “settles” the articles, as to vibration load that will continue to excite the articles in multiple directions
  - Testing of fluid systems for launch load environment
- Capability to provide more realistic environment testing can lead to large cost reductions
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