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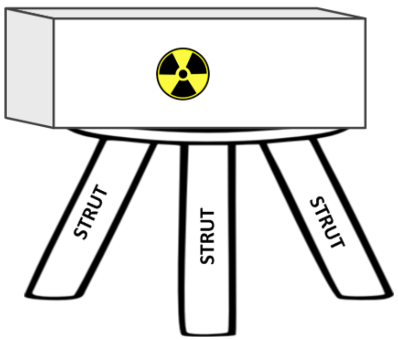

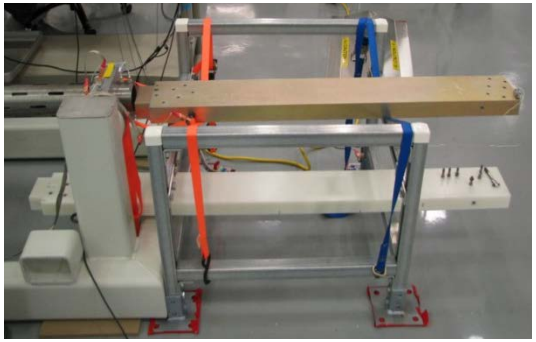

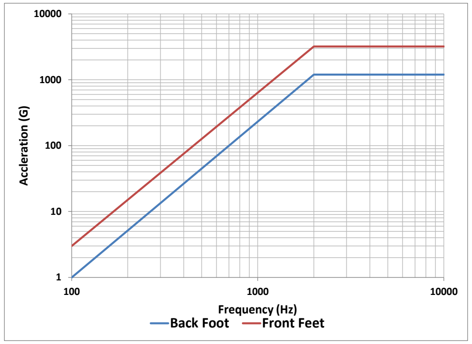

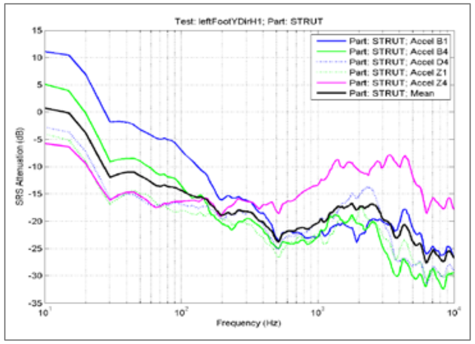

Spacecraft Shock Attenuation: Satellite Payload Case Study

Vit Babuska, Eric Pulling & Scott Klenke

U.S. DEPARTMENT OF ENERGY   NNSA National Nuclear Security Administration

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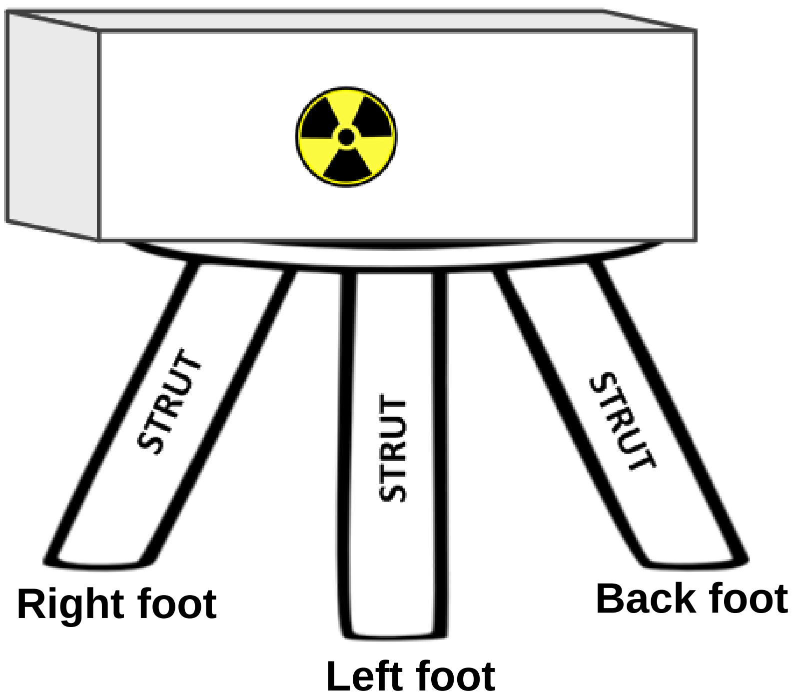
Introduction

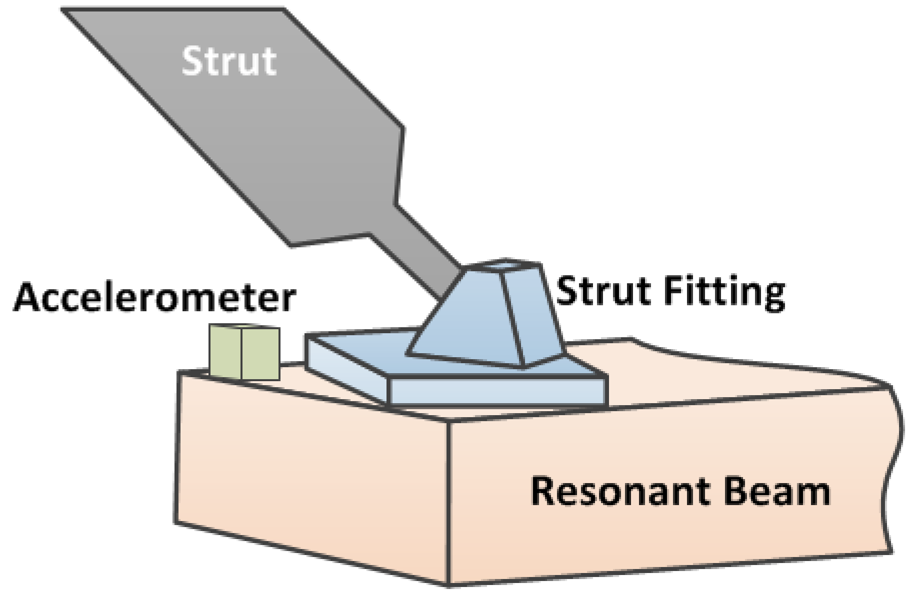
- Almost a decade ago, Sandia National Laboratories conducted shock tests on a satellite payload
  - Resonant beam test to simulate the SRS of a pyroshock
- This presentation gives an overview of the level of attenuation seen at various parts of the payload
- Agenda
  - Payload Description
  - Input SRS
  - Shock Attenuation Factors
  - Shock Attenuation Data
  - Summary Observations

Payload Description

- The structure tested was spacecraft payload with struts attaching it to the main structure
- Shocks were applied at 3 foot pads independently



Satellite Payload

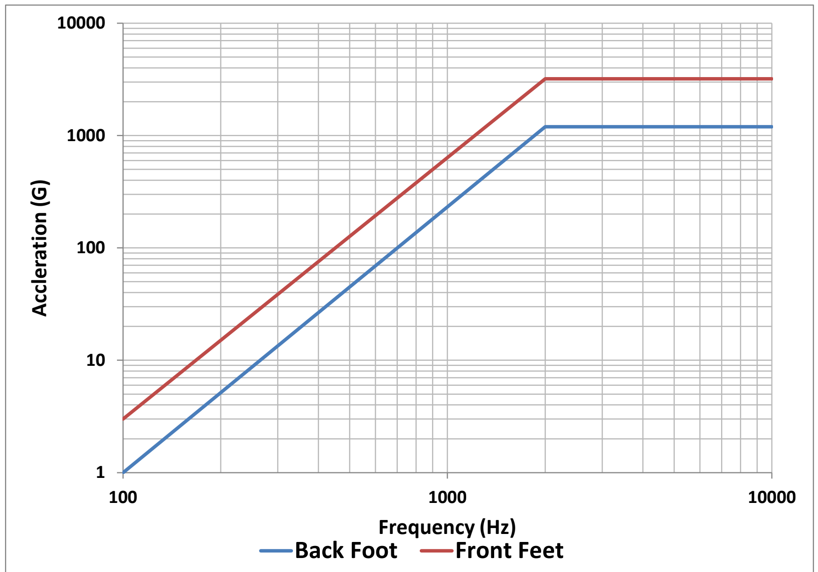


Resonant beam was bolted to a foot pad
Accelerometer was attached to the beam near the pad

Shock Environment

- Different shocks were applied to the front feet and the back foot

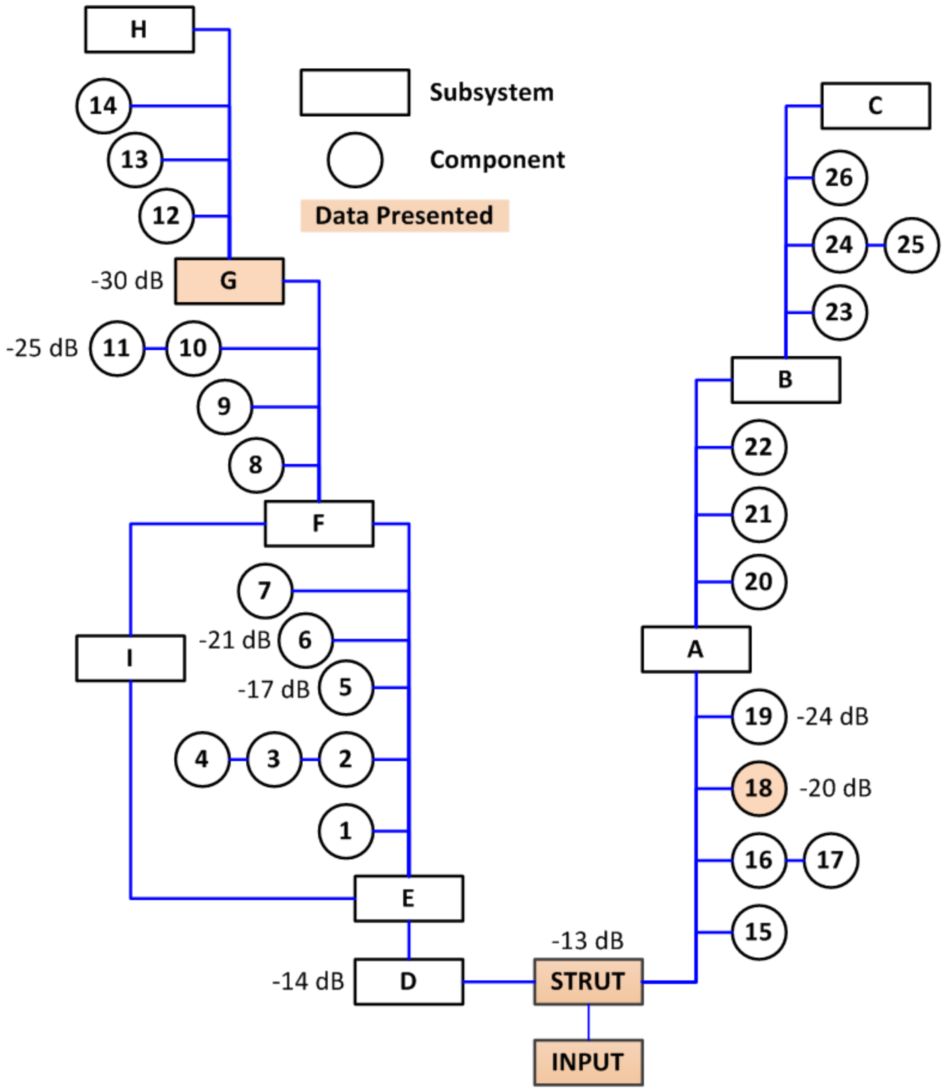
SRS Breakpoints (Q = 10)	
Back Foot	
Frequency (Hz)	**G**
100	1
2000	1200
10,000	1200
Front Feet	
Frequency (Hz)	**G**
100	3
2000	3200
10,000	3200



Vertical Orientation

Shock Actuator SNL Air Gun

Shock Attenuation Factors



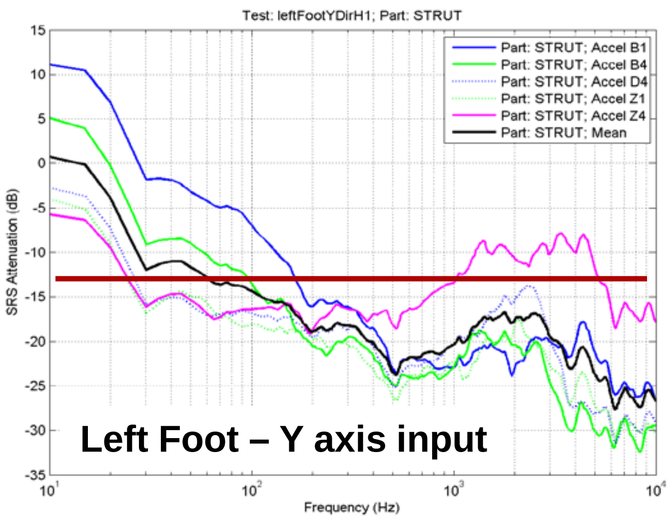
Load Path Tree

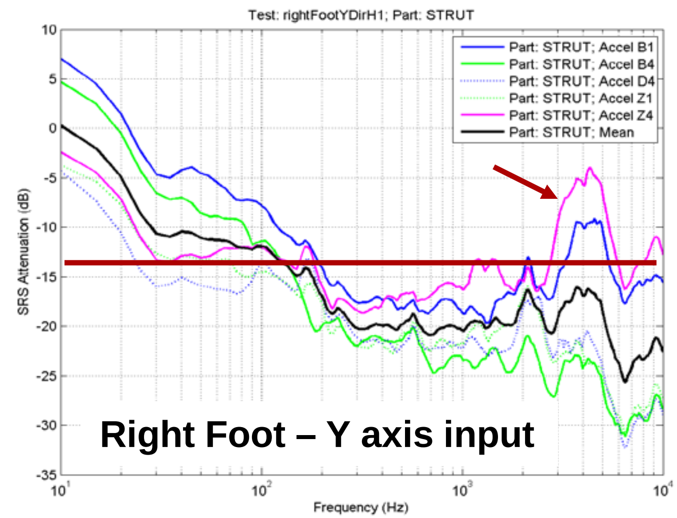
- Design Attenuation Factors
  - Rotational Joint: -3dB
  - Distance: -3dB
  - Right Angle: -0 dB
  - Bolted Joint: -3dB
  - Bonded Joint: -1 dB
  - Flexure: - 0 dB
  - Material: -1 dB
- Attenuation plots shown for Struts, Subsystem G, and Part 18

Shock Attenuation Analysis

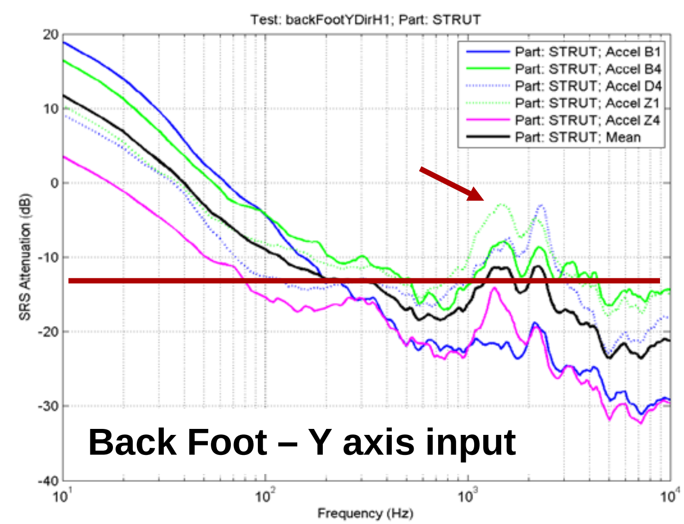
- Shock attenuation assessment is based on SRS
  - Compute a "Shock Attenuation Spectrum"
    - Ratio of the Response SRS to the Input SRS
    - dB ($20\log_{10}(X)$) vs Frequency
  - Due to ambiguity of accelerometer frames, the input and response X, Y, Z SRS are each RSS'd first
- All sensors associated with a part or subsystem are grouped together
  - Shock Attenuation Mean Spectrum is calculated when there is more than one sensor

Shock Attenuation Results – Across Struts Y-Axis





- Design attenuation factor for the struts was -13 dB
- May not have been conservative enough for parts located close to the ends of some struts
  - The design factors should be conservative



Shock Attenuation Results – Across Struts X-Axis

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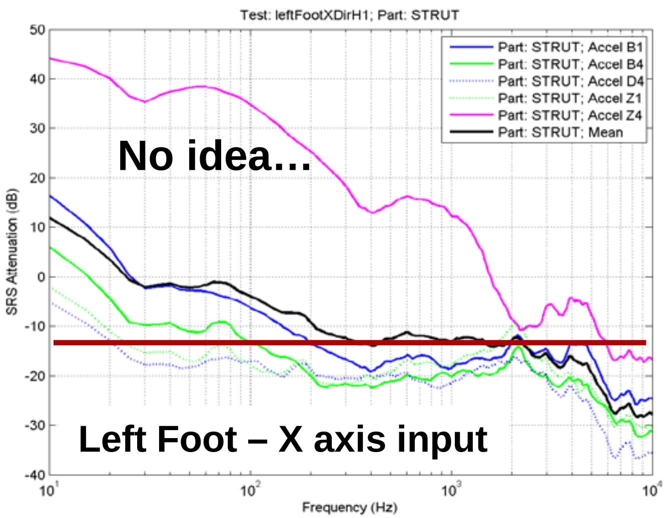

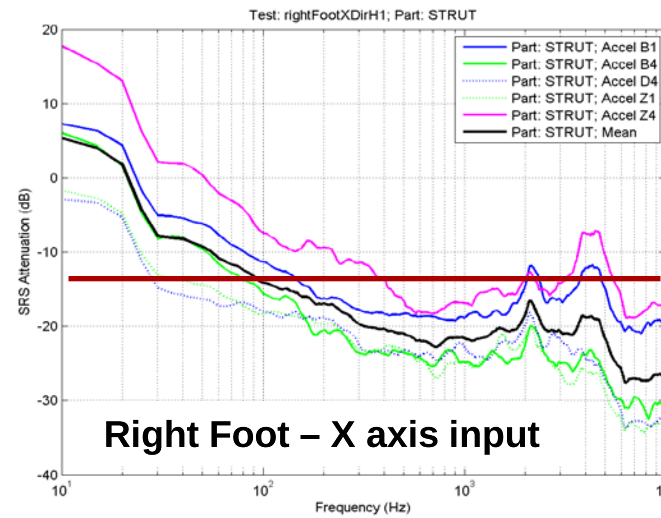

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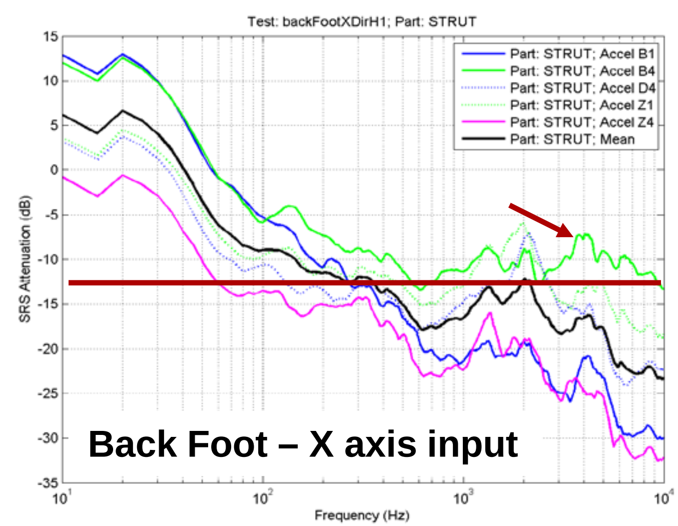
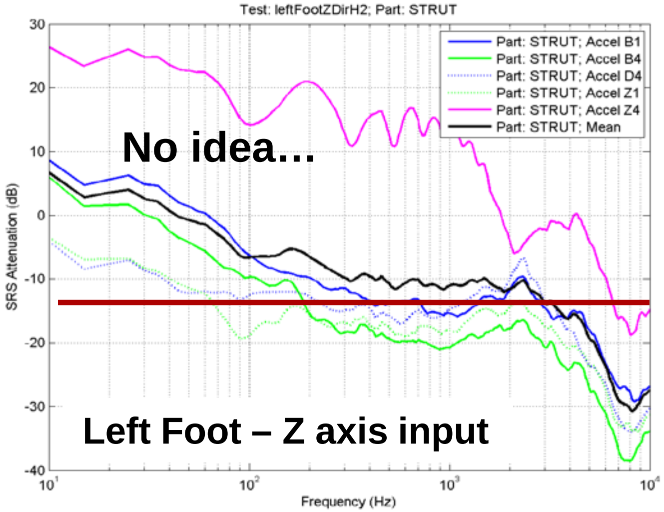


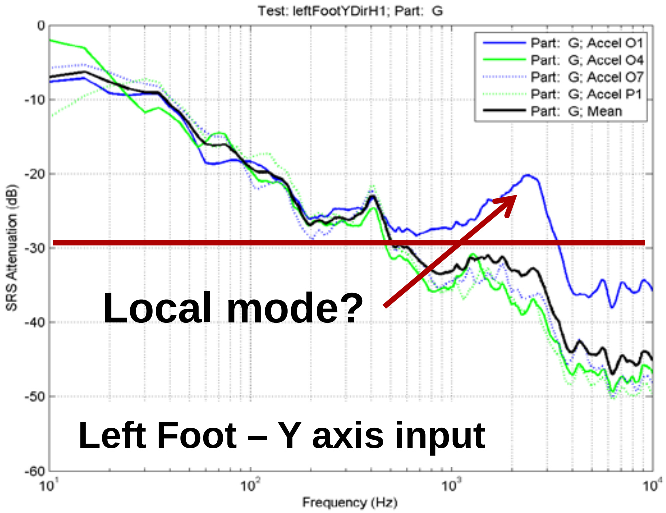
Shock Attenuation Results – Across Struts Z-Axis

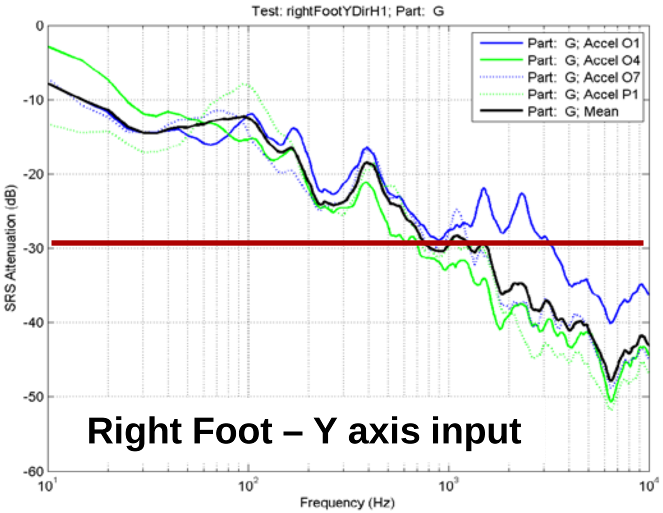


No Z-axis shocks at the right foot and the back foot

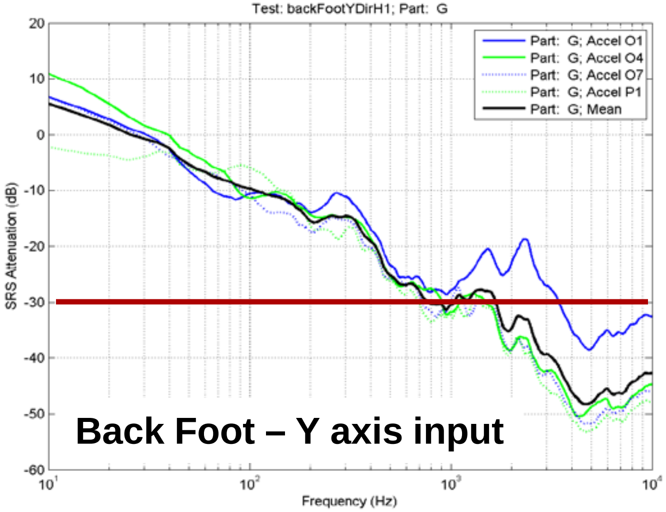
- Design attenuation factor for the struts was -13 dB
- May not have been conservative enough for parts located close to the ends of some struts

Shock Attenuation Results – Subsystem G Y-Axis

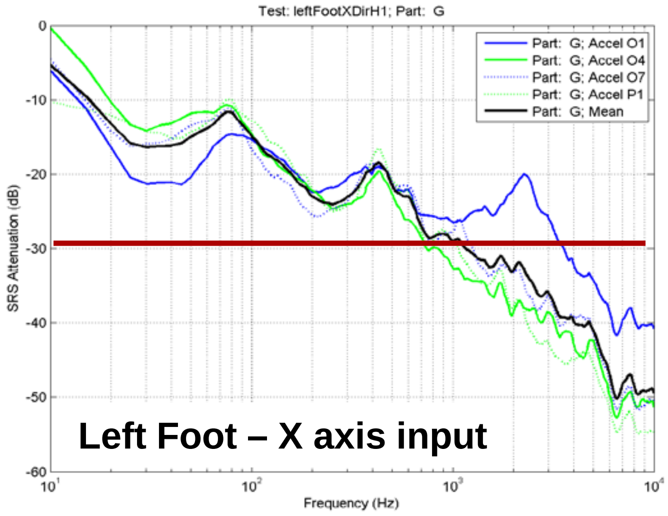


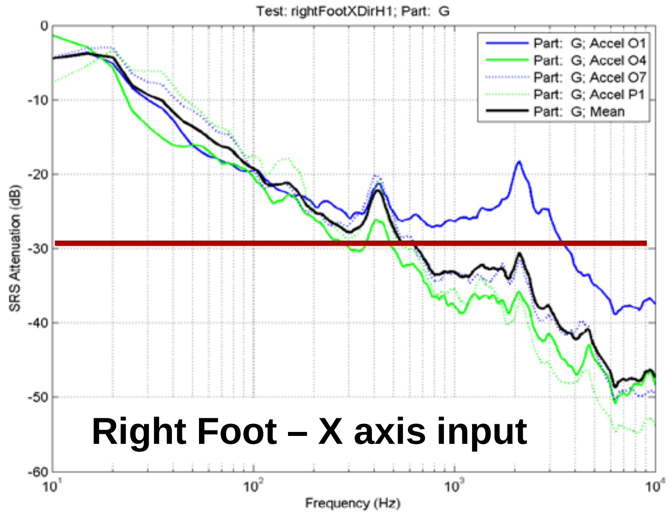


- Design attenuation factor for Subsystem G was -30 dB
- Attenuation was much less locally (near accelerometer O1)
- Overall prediction was good



Shock Attenuation Results – Subsystem G X-Axis





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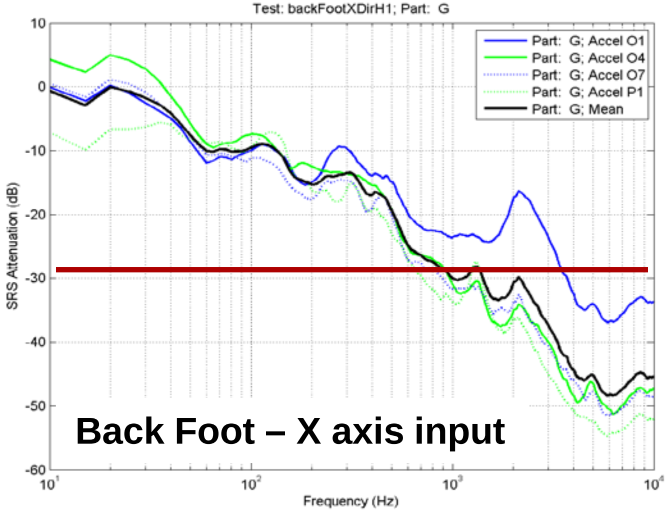
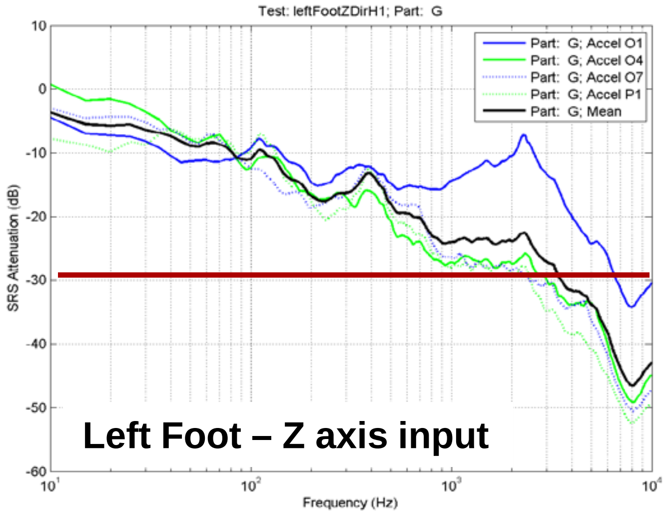


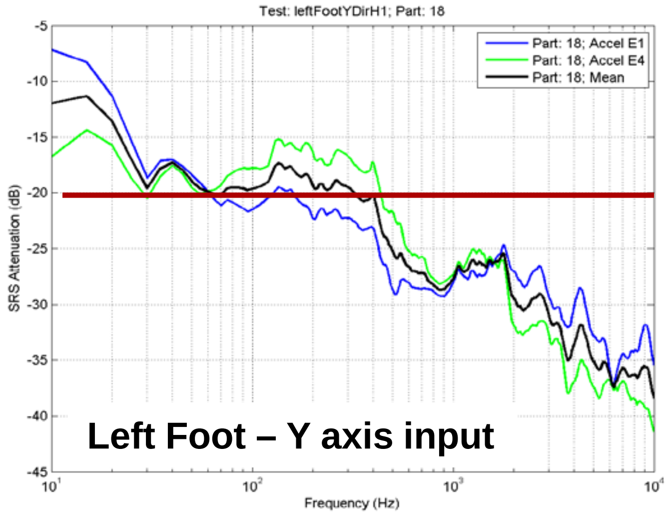
Shock Attenuation Results – Subsystem G Z-Axis

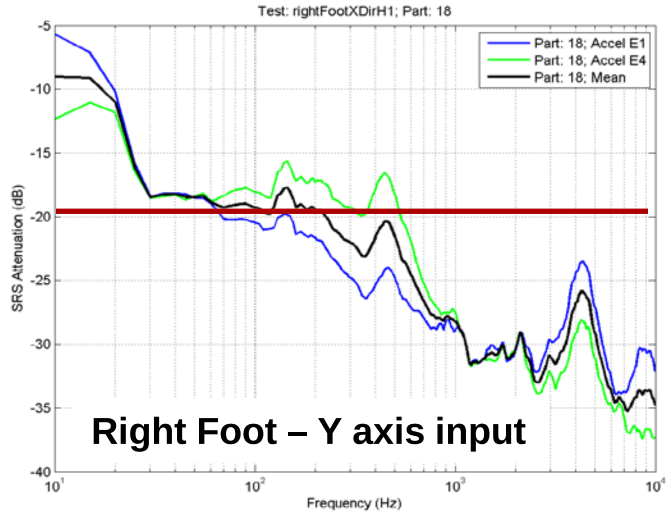


No Z-axis shocks at the right foot and the back foot

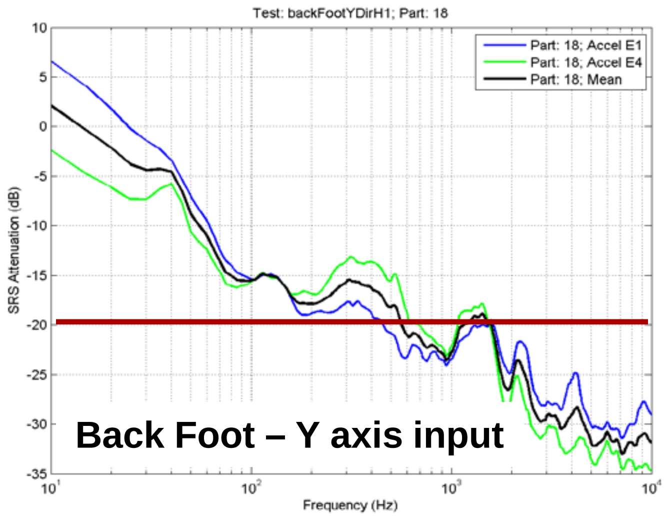
- Design attenuation factor for Subsystem G was -30 dB
- Attenuation was much less locally (near accelerometer O1)
- Overall prediction was good

Shock Attenuation Results – Part 18 Y-Axis

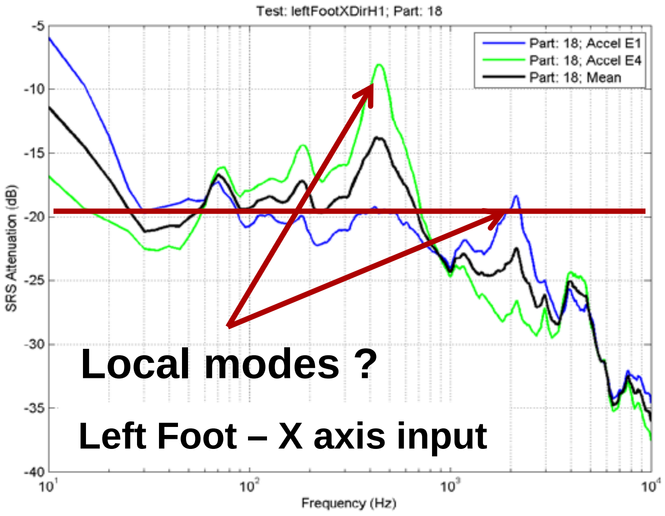


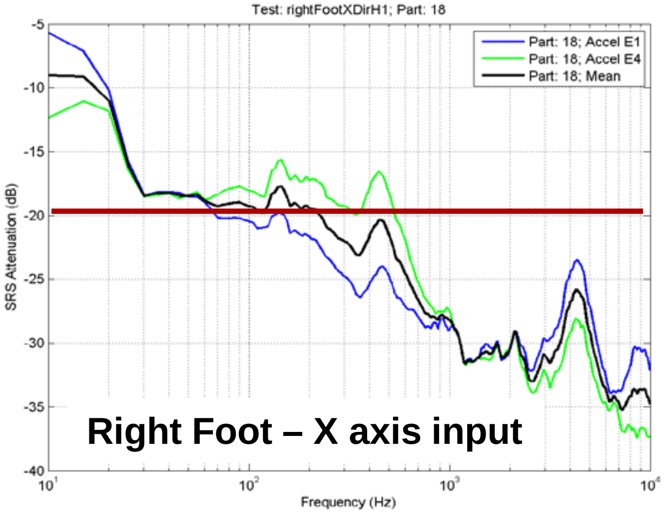


- Design attenuation factor for Part 18 was -20 dB
- Overall prediction was conservative
  - Best result above 1000 Hz

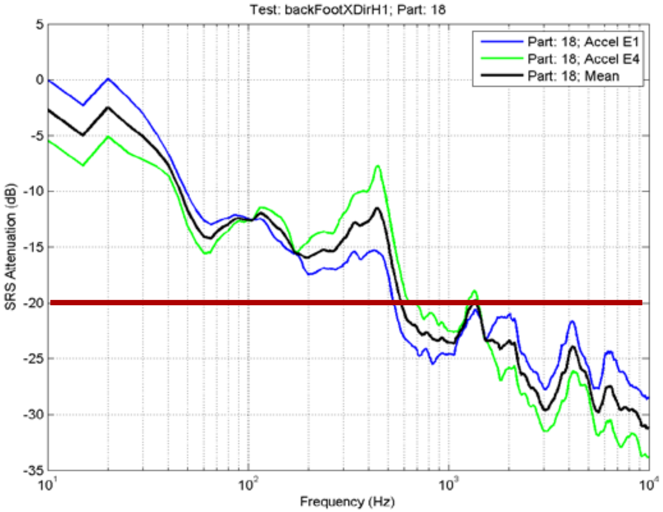


Shock Attenuation Results – Part 18
X-Axis

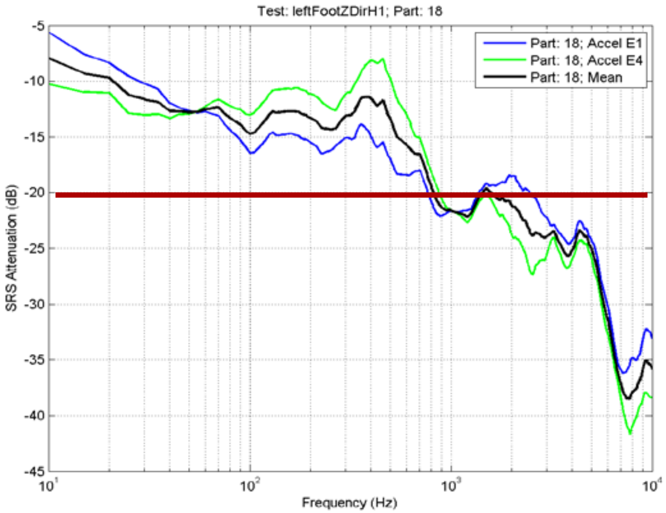




- Design attenuation factor for Part 18 was -20 dB
- Overall prediction was good
  - Not as conservative as the Y-axis



Shock Attenuation Results – Part 18
Z-Axis



No Z-axis shocks at the right foot and the back foot

- Design attenuation factor for Part 18 was -20 dB
- Overall prediction was good
  - Not as conservative as the Y-axis

Summary Observations

- Shock attenuation factors were generated by the systems engineering team to provide guidance to designers on satellite component shock levels
  - Took into account:
    - Distance, Right Angles, Rotational Joints, Bolted Joints, Bonded Joints, Flexures, and Material
  - Cascaded theses features through the load path
    - Did not follow NASA 7005 guidelines, such as the “3-joint rule”, strictly
- The attenuation factors backed-out from the shock test were remarkably consistent with the systems engineering design factors
  - Local modes reduced the attenuation factors at some frequencies for some components

Design attenuation factors were consistent with attenuation observed in test