National Aeronautics and Space Administration
Jet Propulsion Laboratory
California Institute of Technology

Shock Analysis and Testing

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6th Shock Working Group
5 March 2013

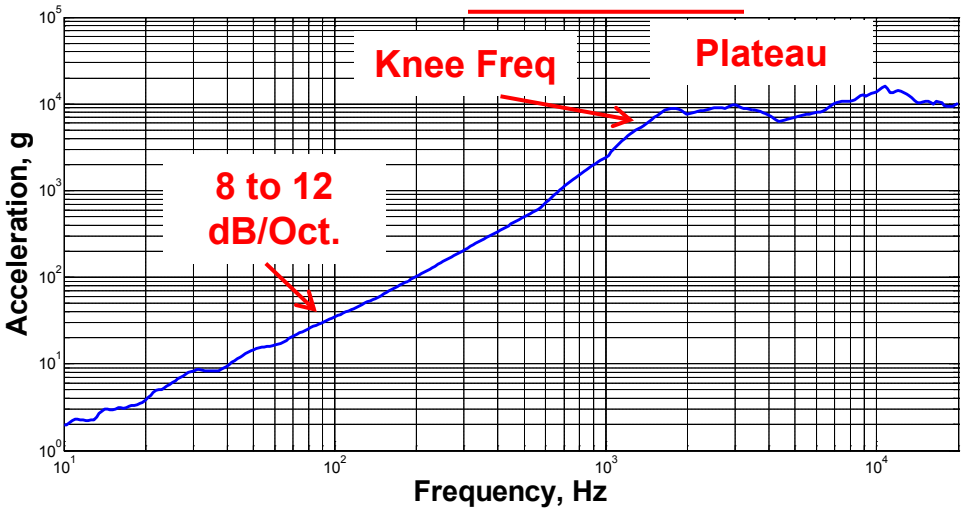
352G Dynamics Environments

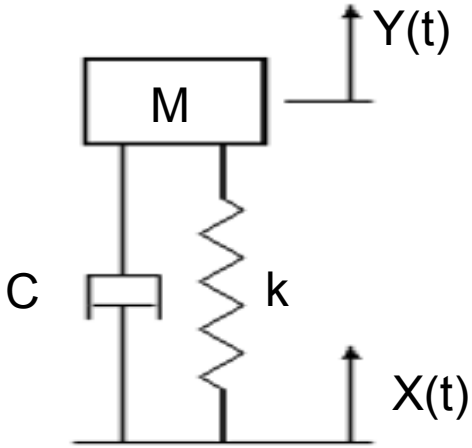
Outline

- SRS and PVSS data analysis discussed for the following cases
  - Separation Nut firings using flight hardware
    - Far- and mid-field
    - Near-field
      - High Frequency and high g levels
      - High frequency and relatively low g levels
  - 3-D Shock Simulation Test Data
    - One-shock application to obtain 3-axis shock requirements
      - Reduces unnecessary exposure to shock environment
  - High-frequency and High-g shock
    - Discuss failure mode
- Discussion on the applicability of SRS and PVSS on shock testing

Shock Response Spectrum (SRS)

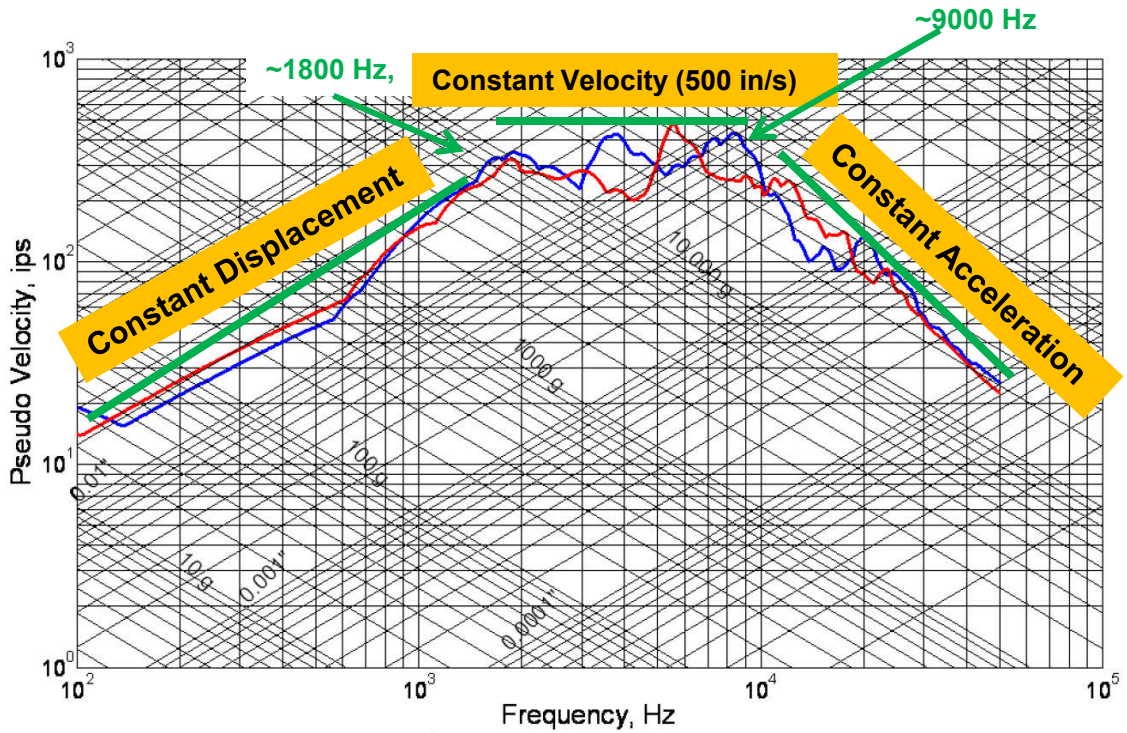
- Based on maximum accelerations in SDOF oscillators; the acceleration time history is converted into a response spectrum
- Many acceleration histories have same SRS
- Does not account explicitly for duration of transient, curve shape, or multiple exposures
- Typically a conservative approach for MDOF systems





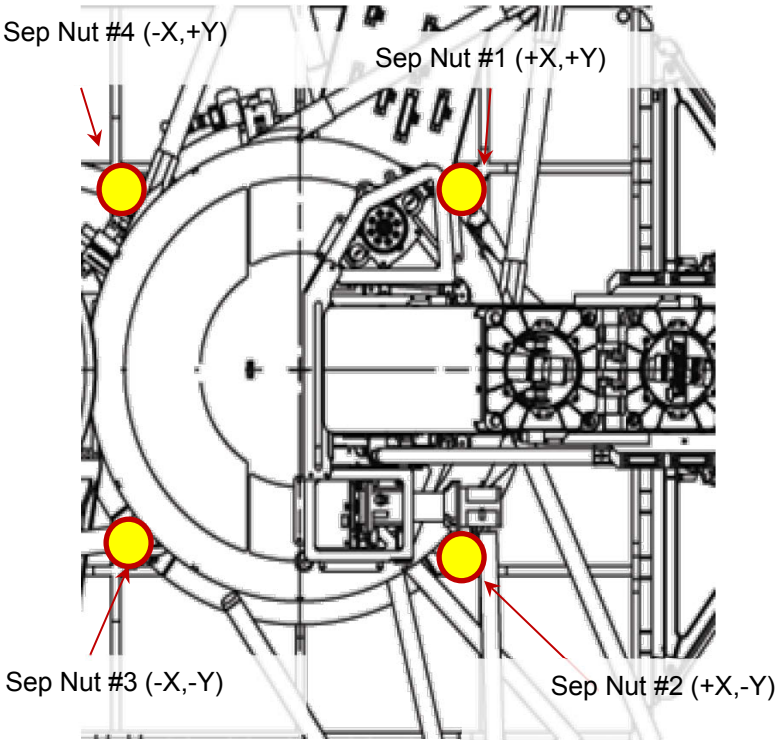
Pseudo-Velocity Shock Spectrum (PVSS)

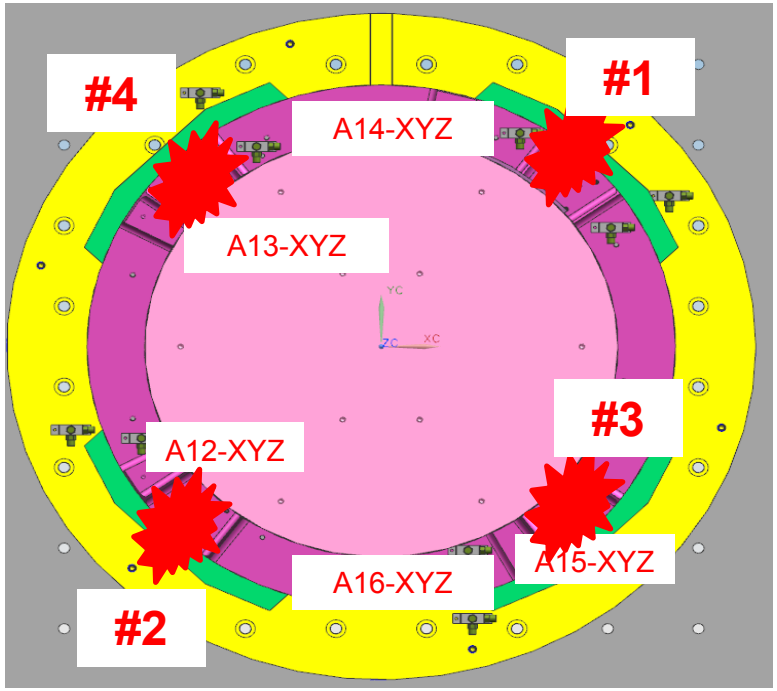
- Pseudo-Velocity is product of natural frequency, ω_n, and spring displacement, $(Z(t) - Y(t))$, in SDOF system
- Pseudo-Velocity Shock Spectrum (PVSS) plots peak pseudo-velocity versus natural frequency for given input motion
- Plateau in PVSS indicates shock severity (damage potential)?
  - ~400 in/sec for this example



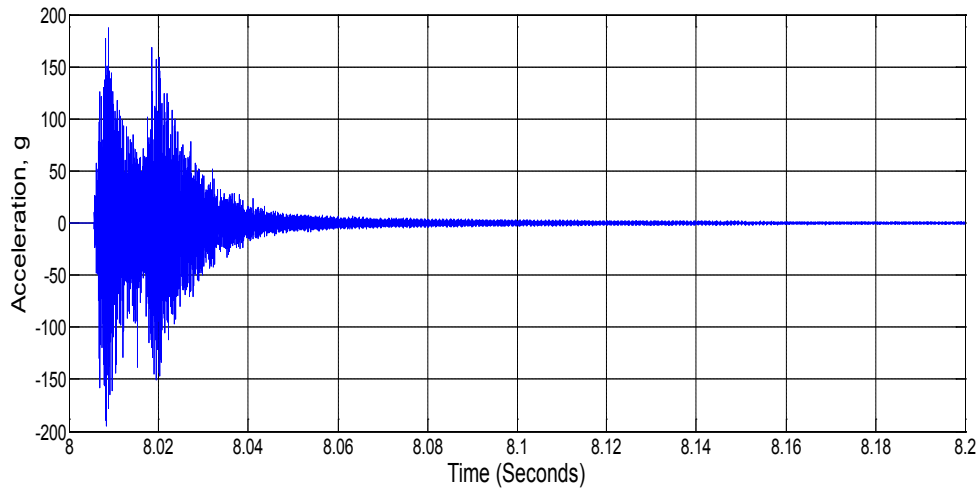
Far Field Sep Nut Data

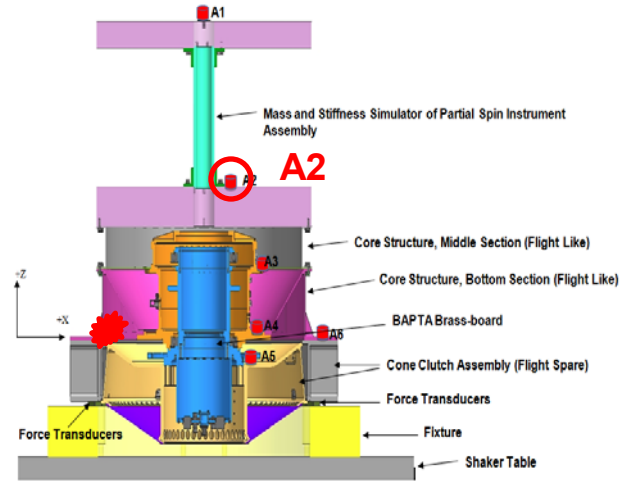
Sep Nut Test Setup

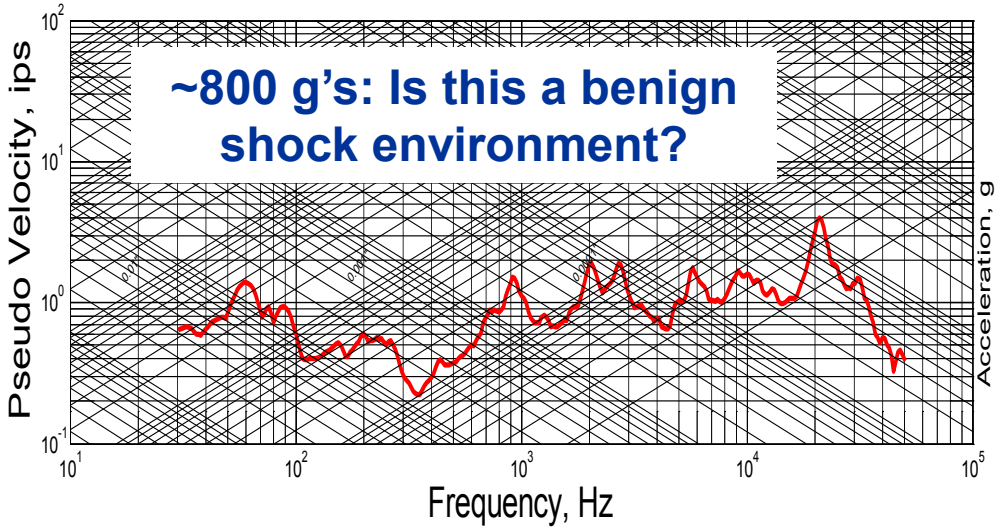


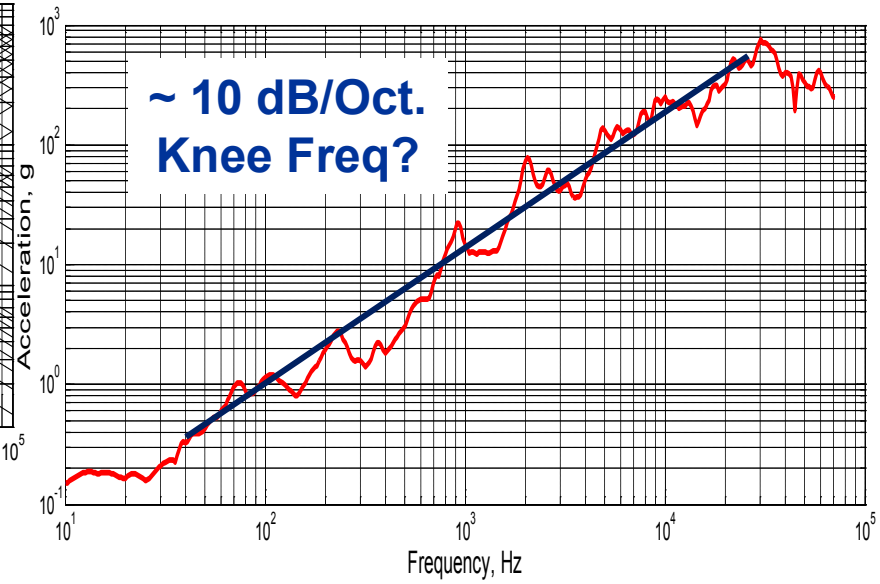


Far Field: Accelerometer on Mass Simulator

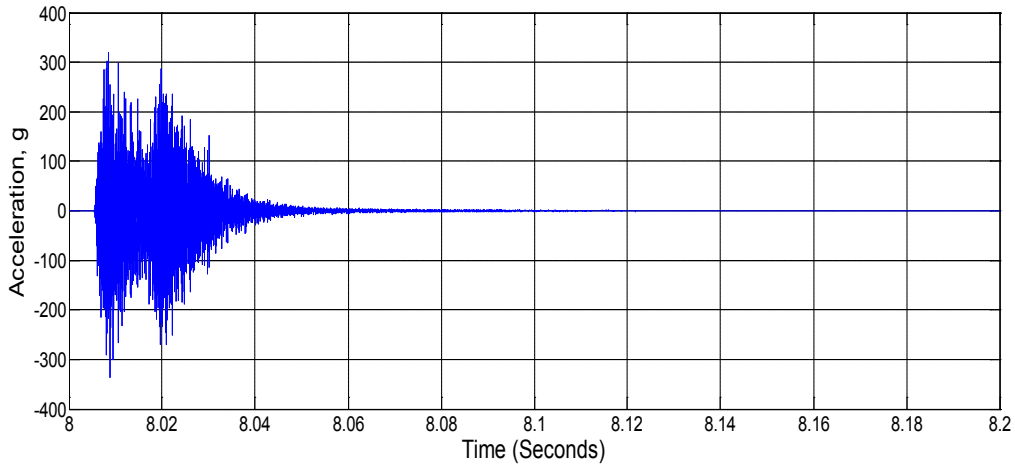


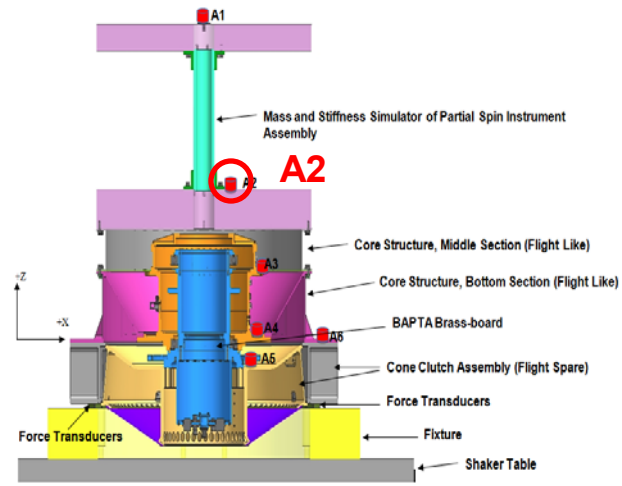




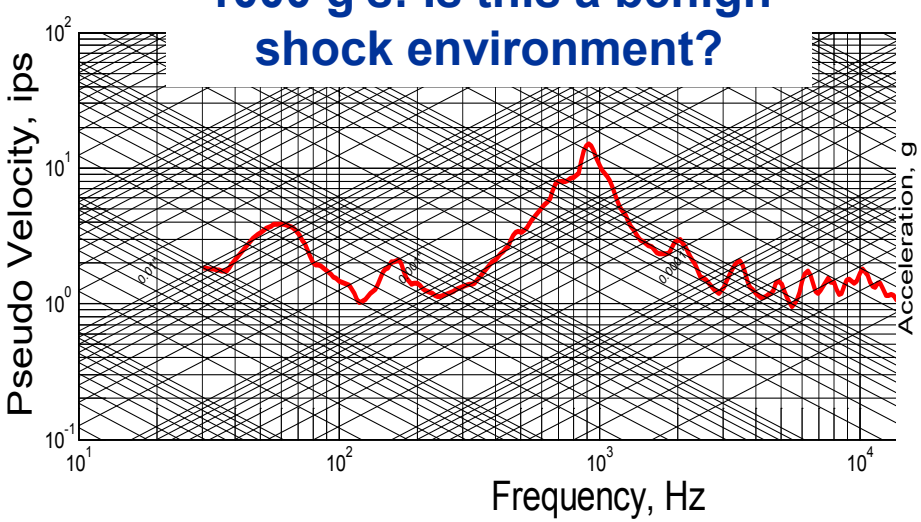


Far-field: Accelerometer on Flight HArdware

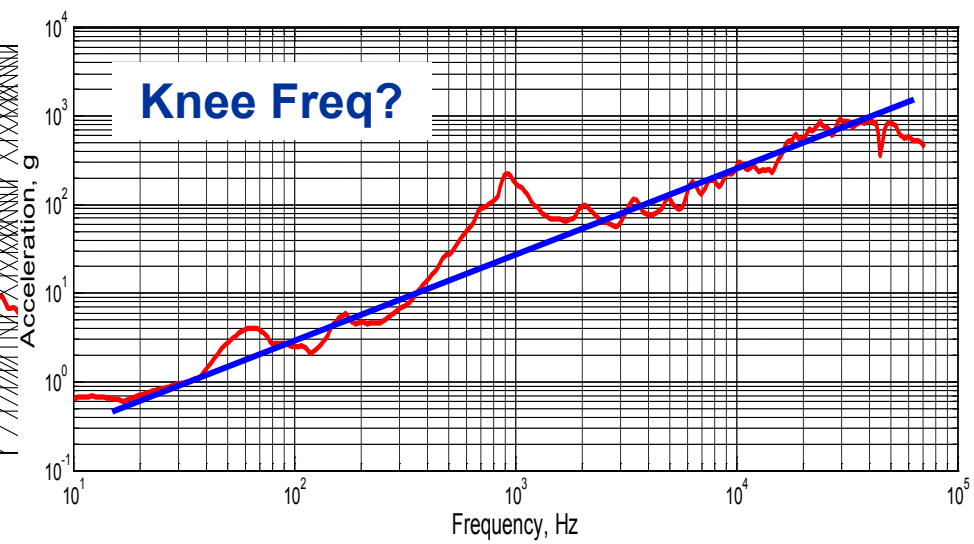




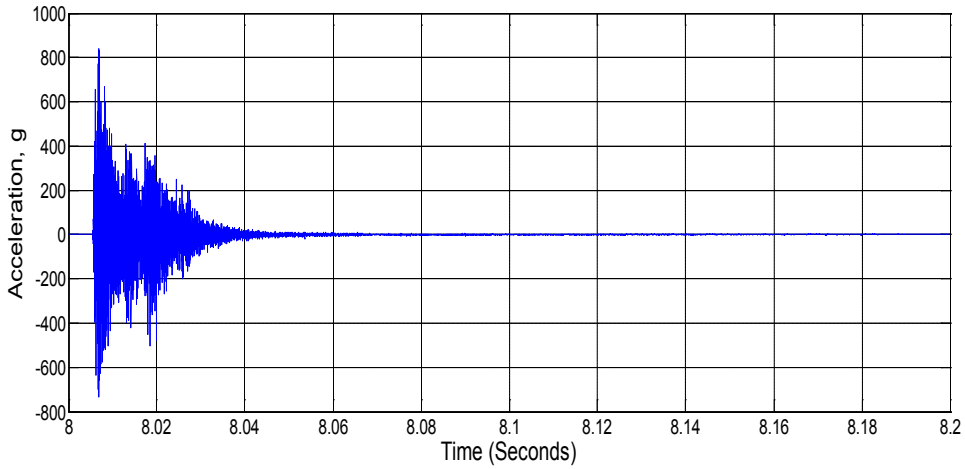
1000 g's: Is this a benign shock environment?

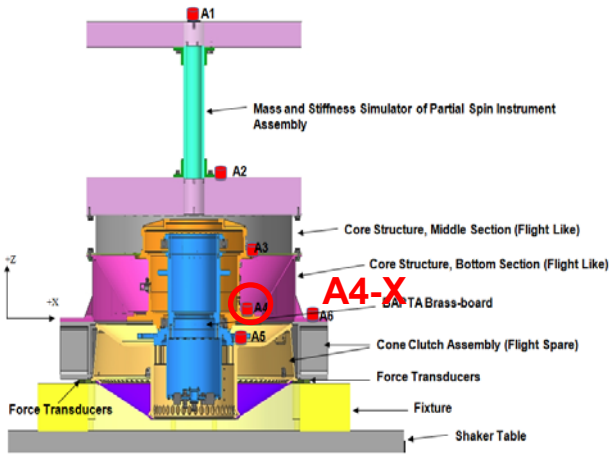


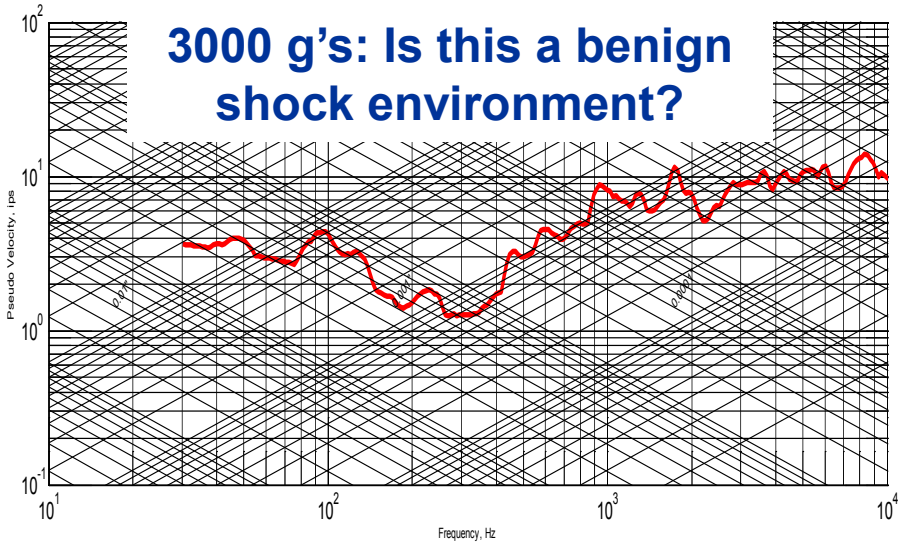
Knee Freq?

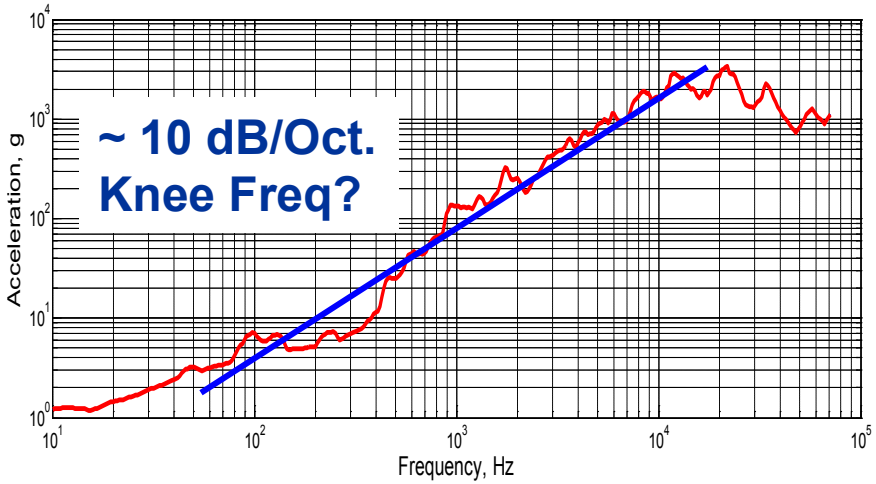


Far/Mid-field: Accelerometer on Flight Hardware

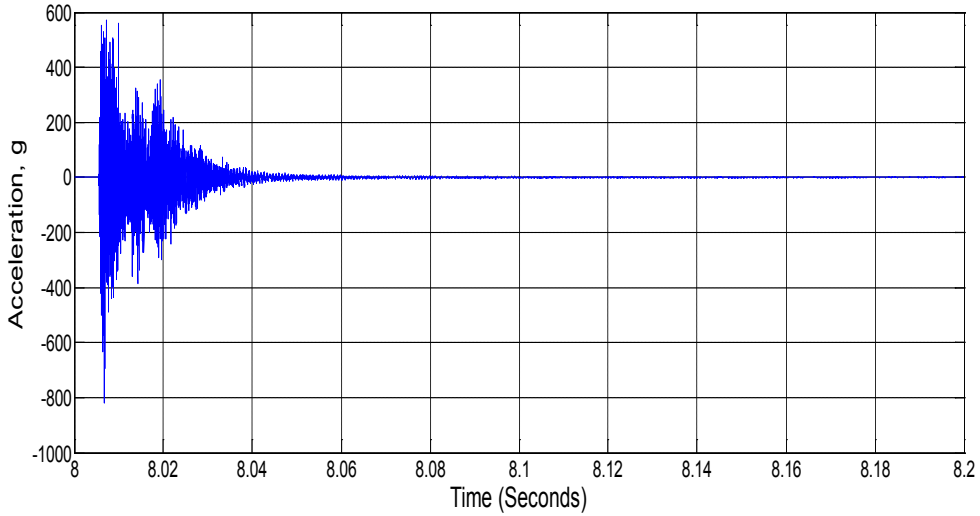


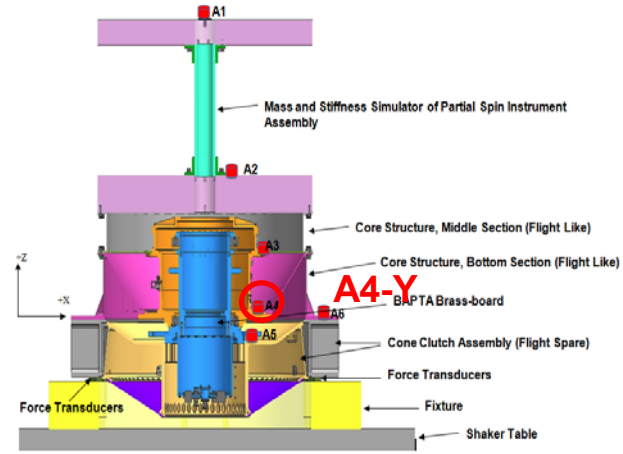


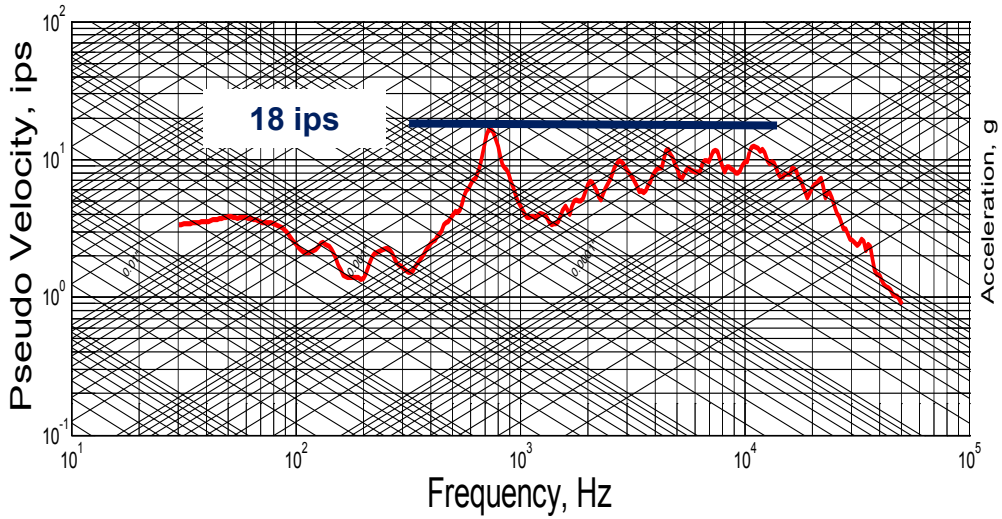


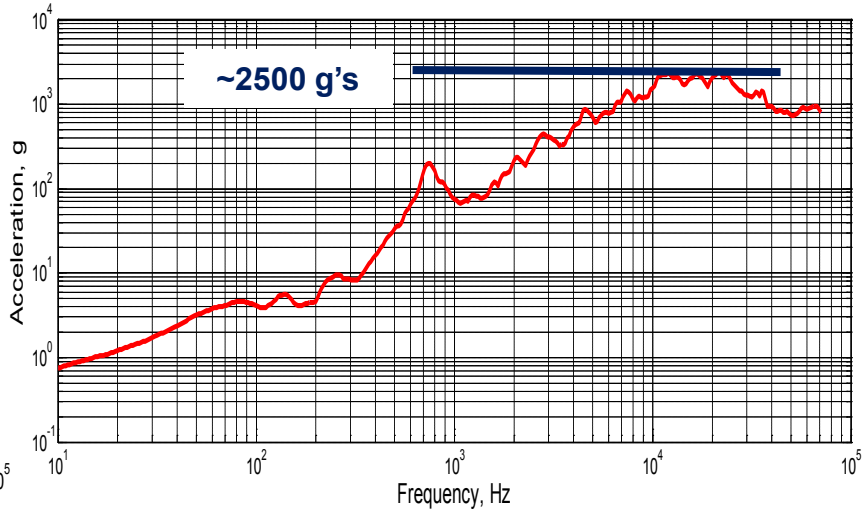


Mid/Far-field: Accelerometer on Flight Hardware

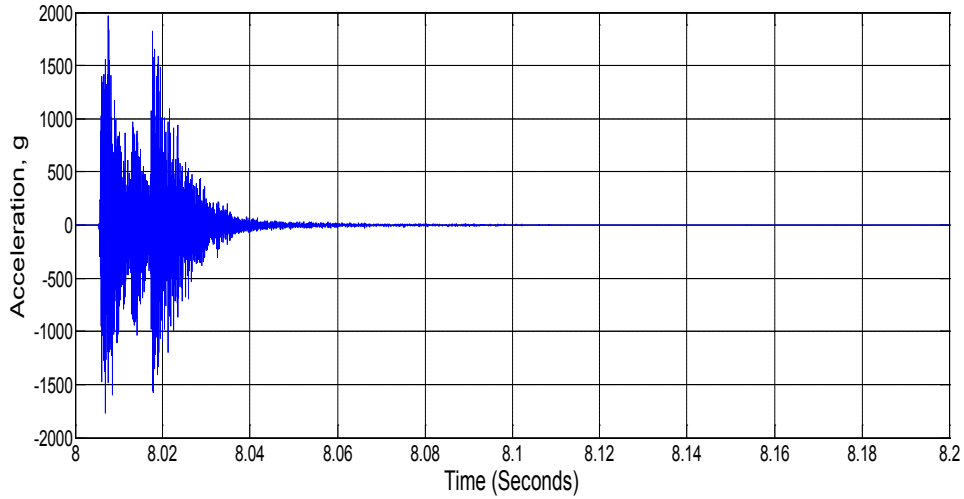


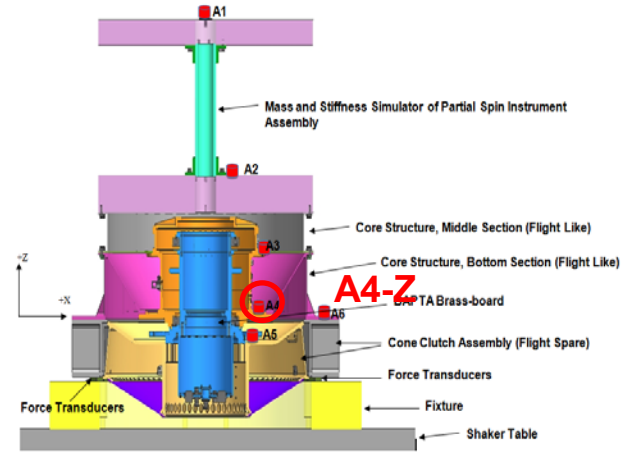


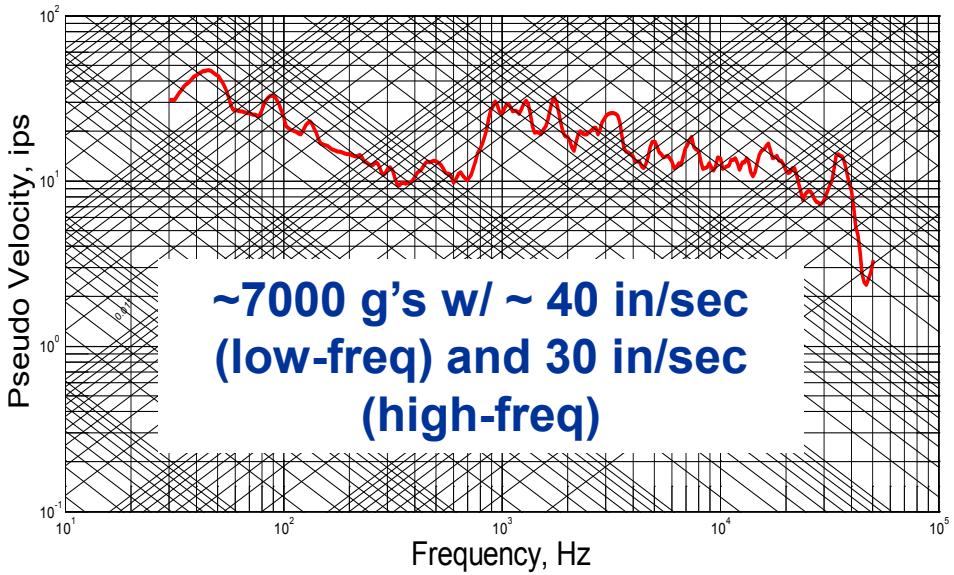


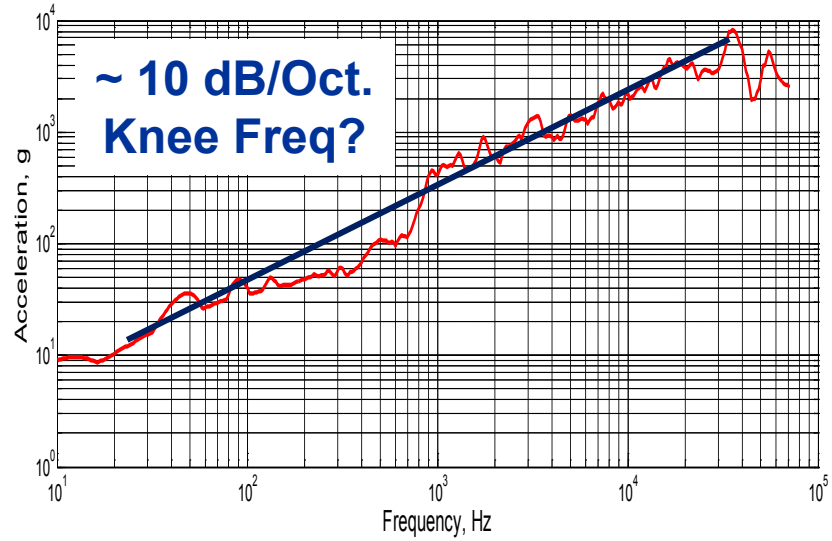


Mid/Far-field: Accelerometer on Flight Hardware



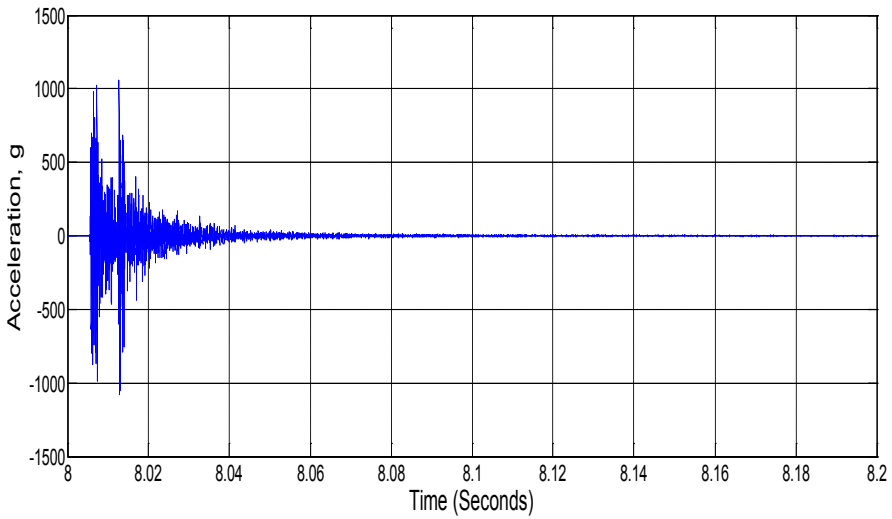


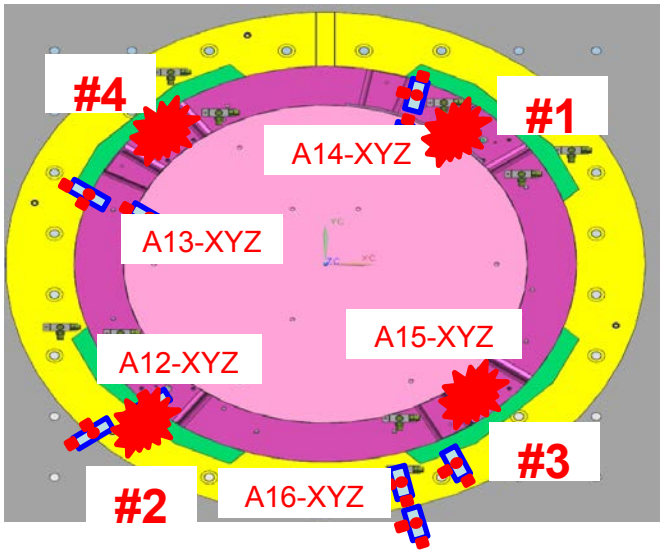


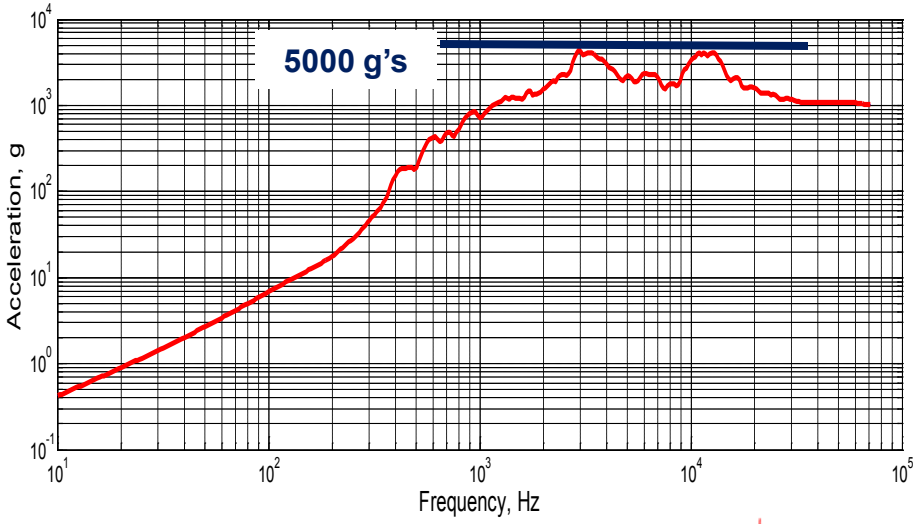


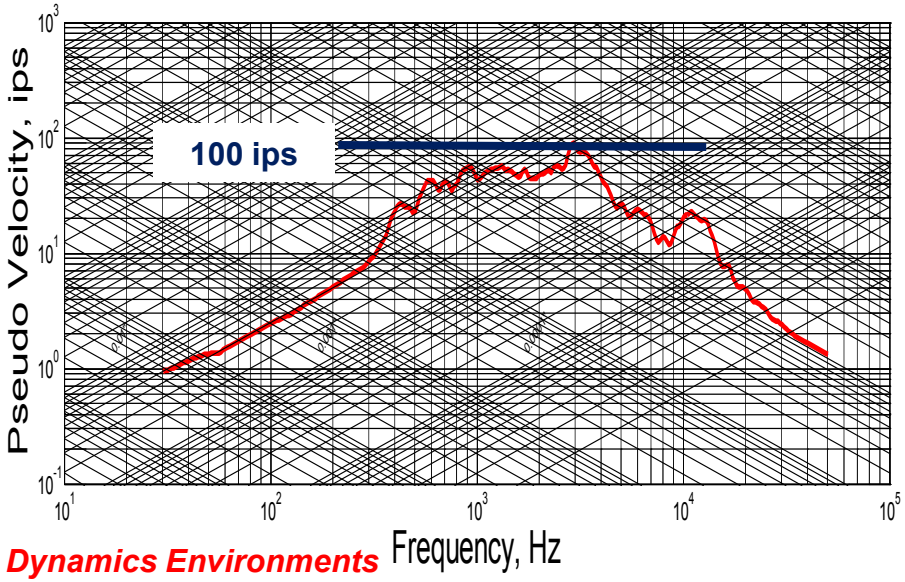
Near Field Sep Nut Data

Near Field: A12-R on Flight Hardware

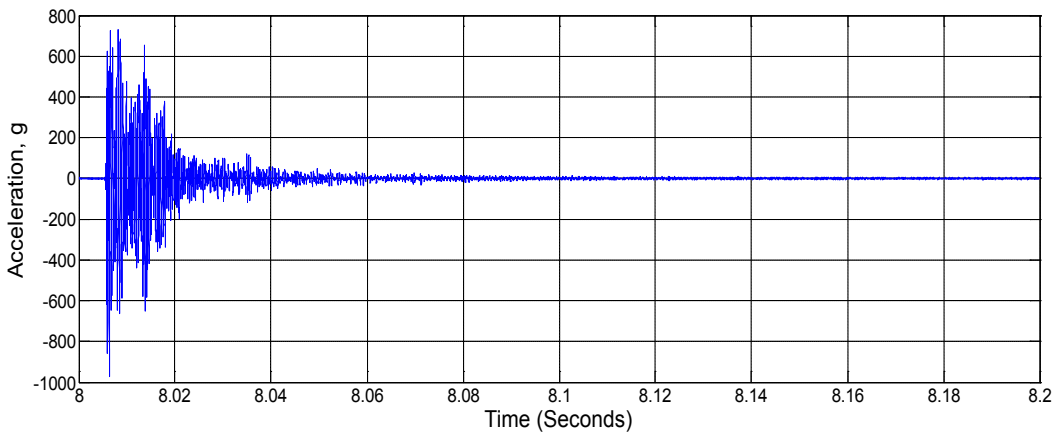


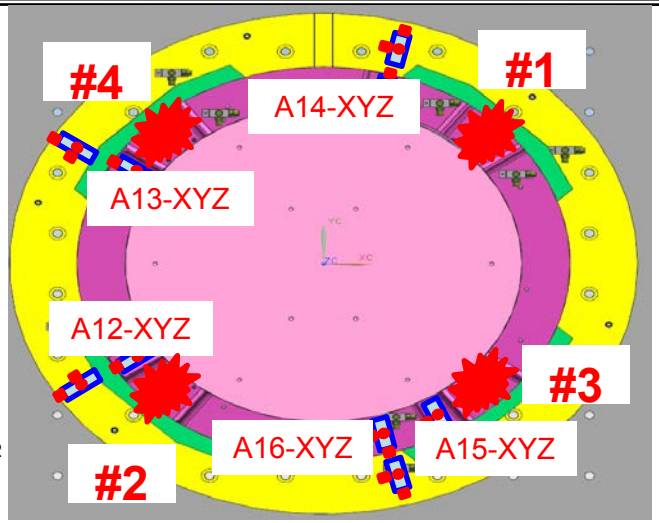


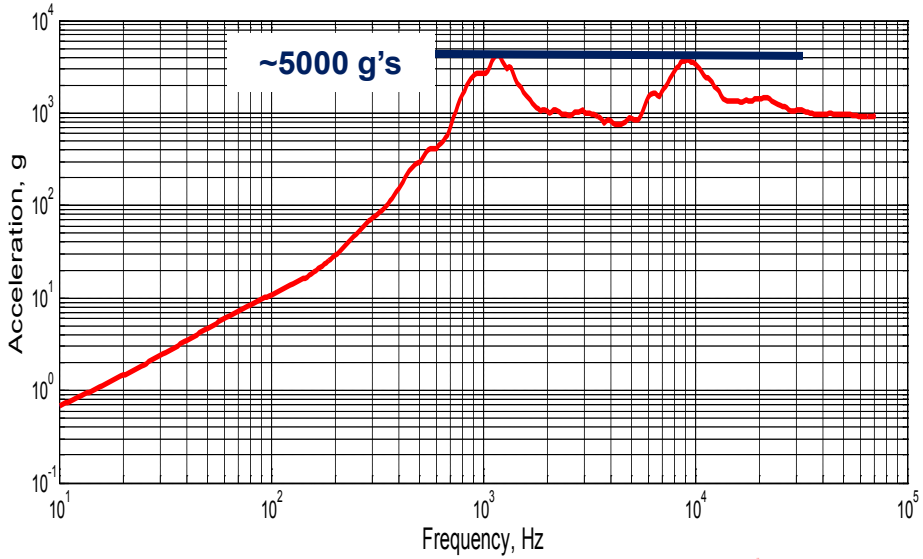


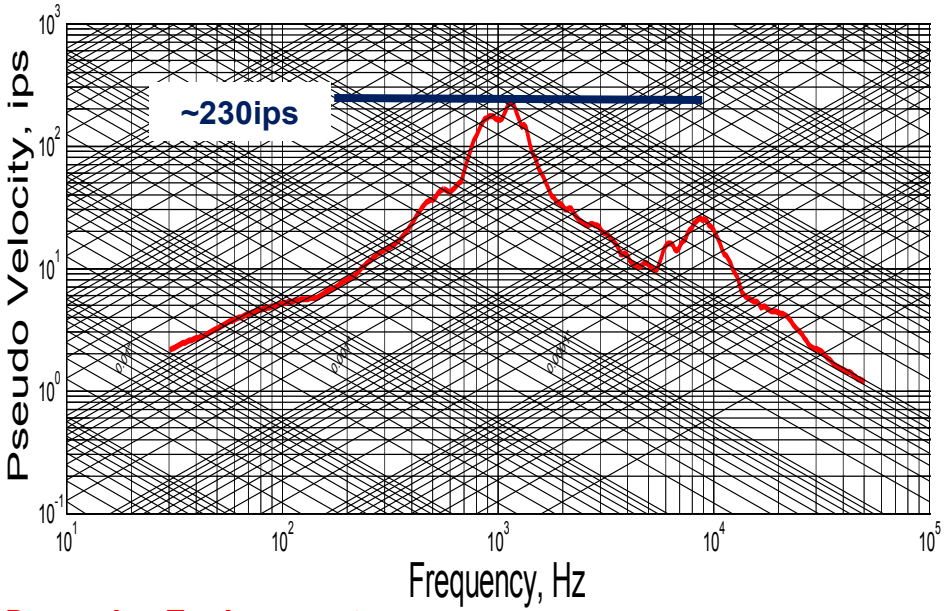


Near Field: A12-T on Flight Hardware

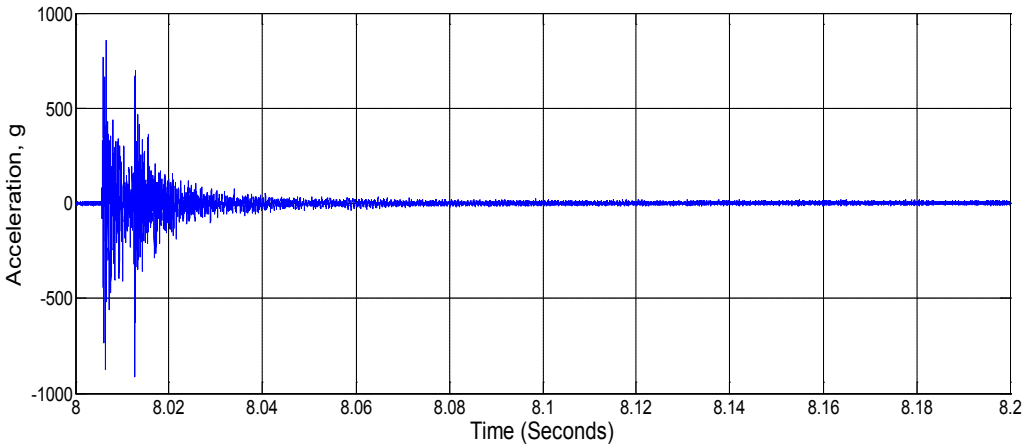


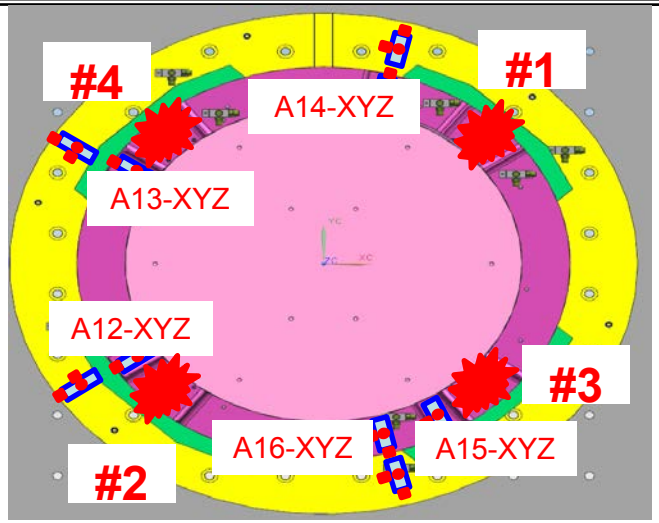


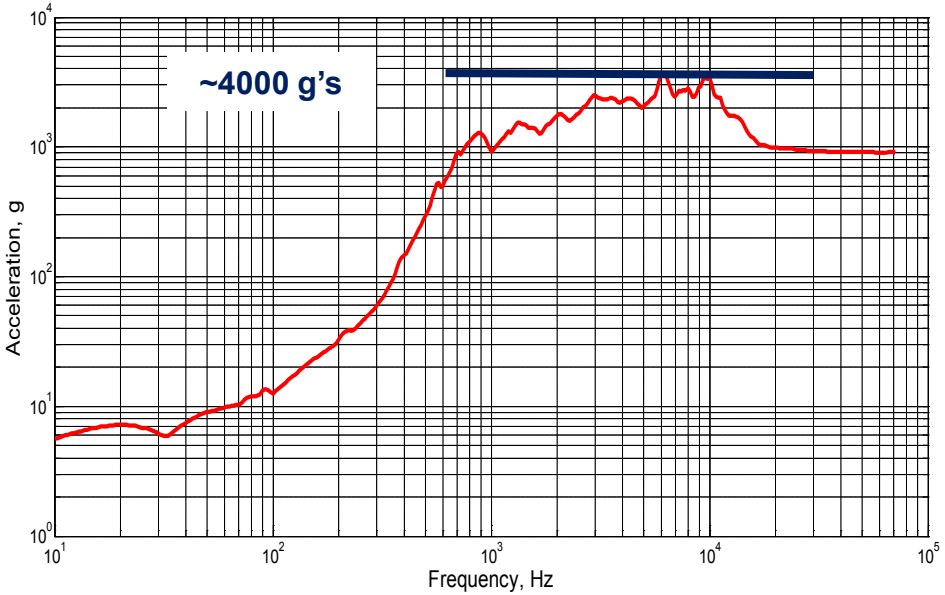


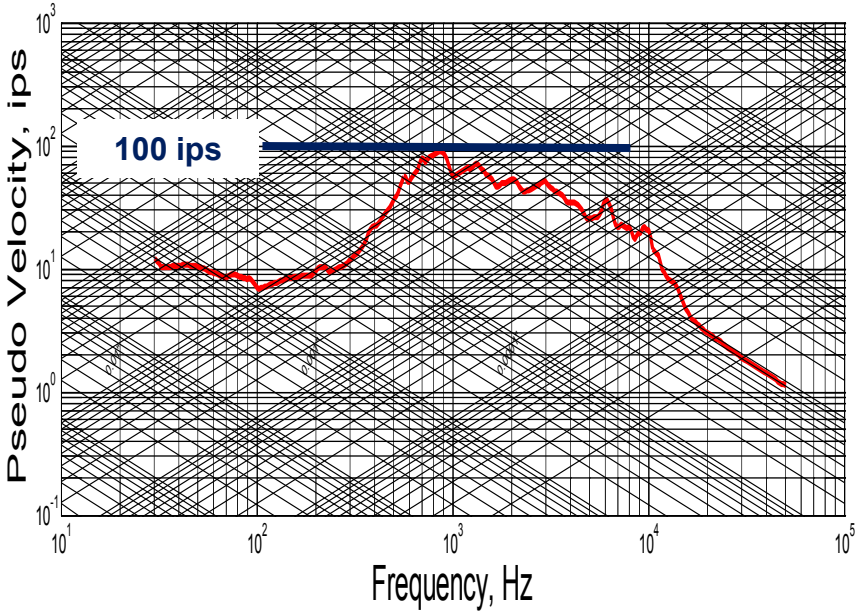


Near Field: A12-Z on Flight Hardware



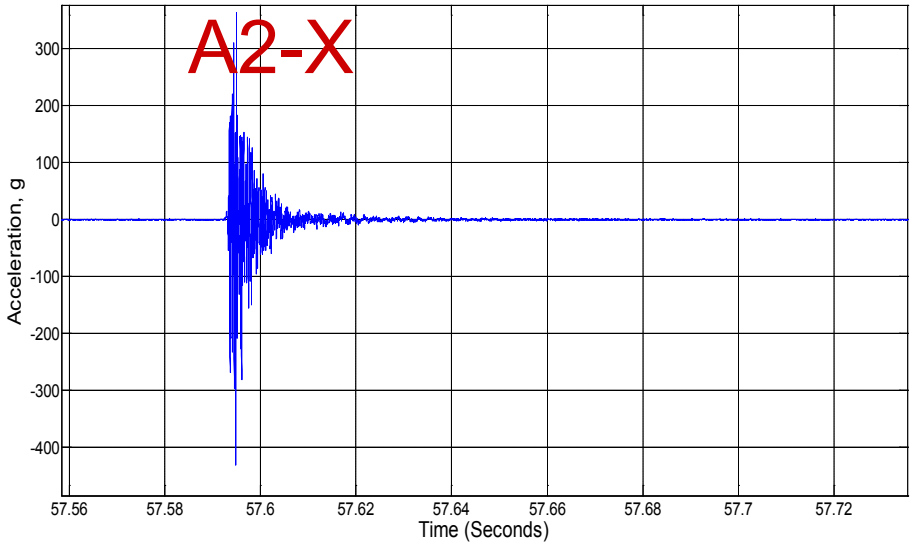


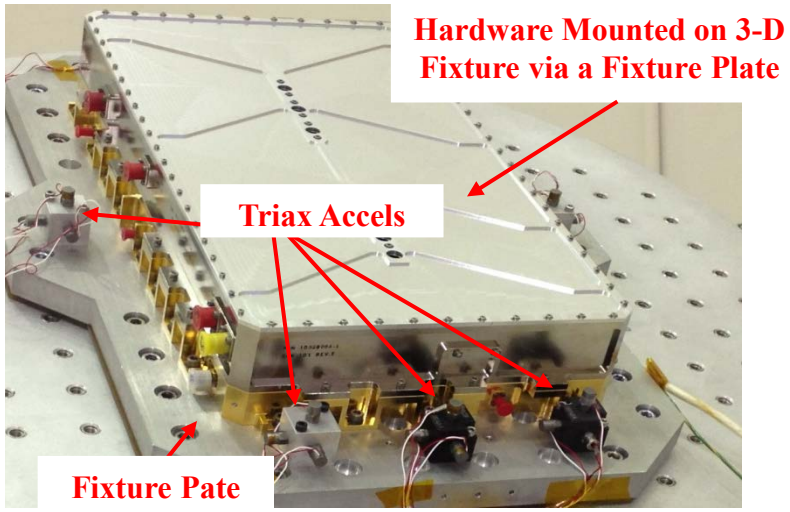


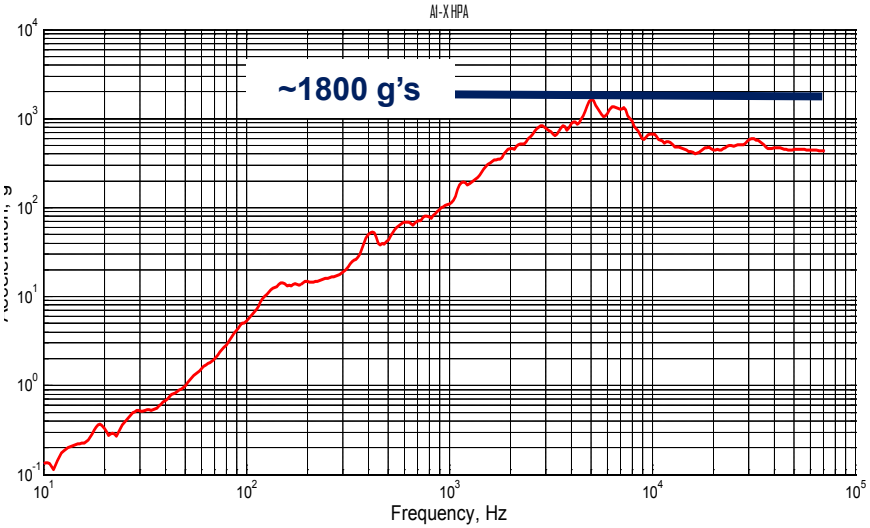


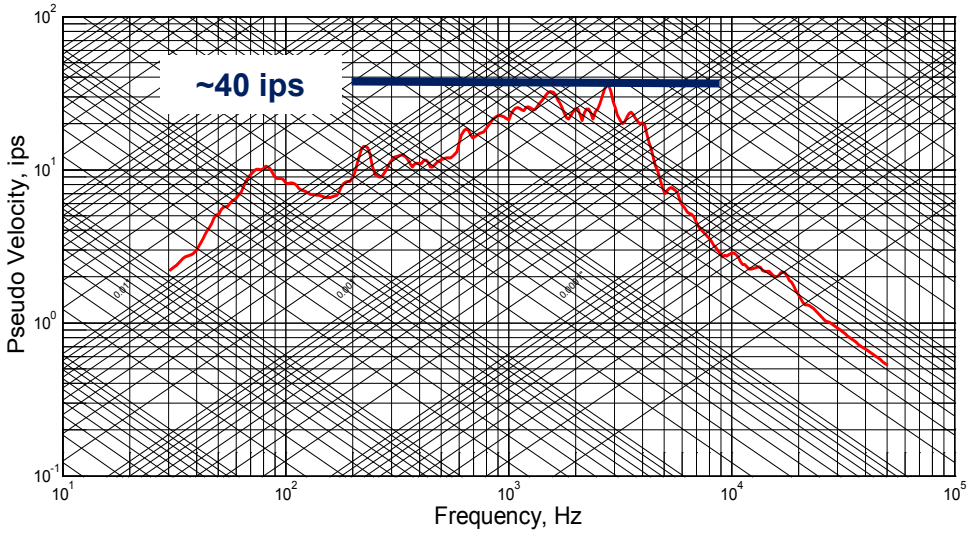
Shock Simulation Data

3-D Fixture Electronic Hardware Shock Simulation Test

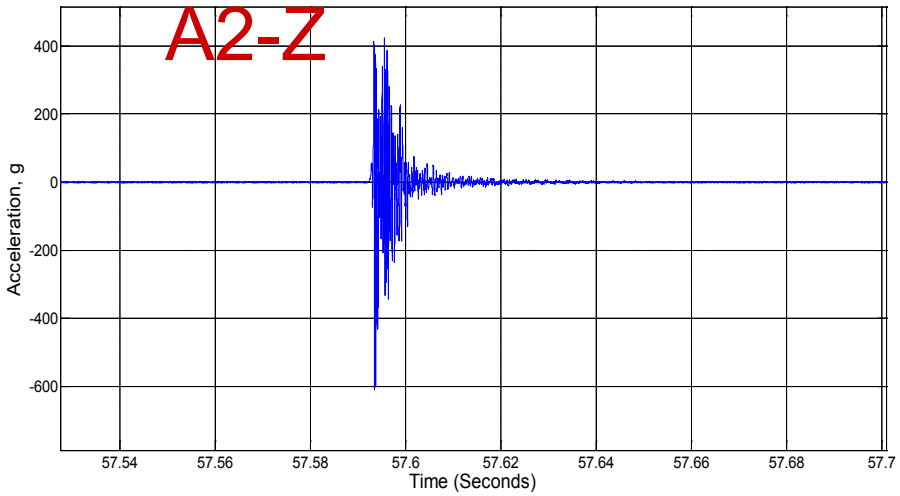


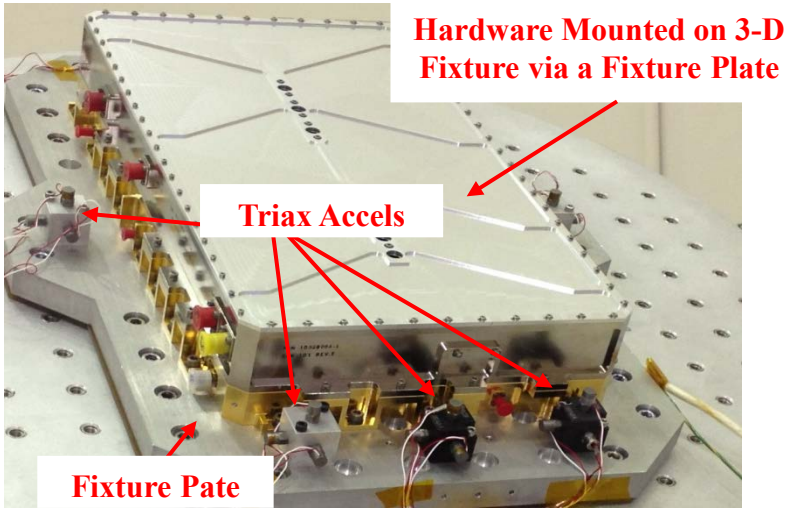


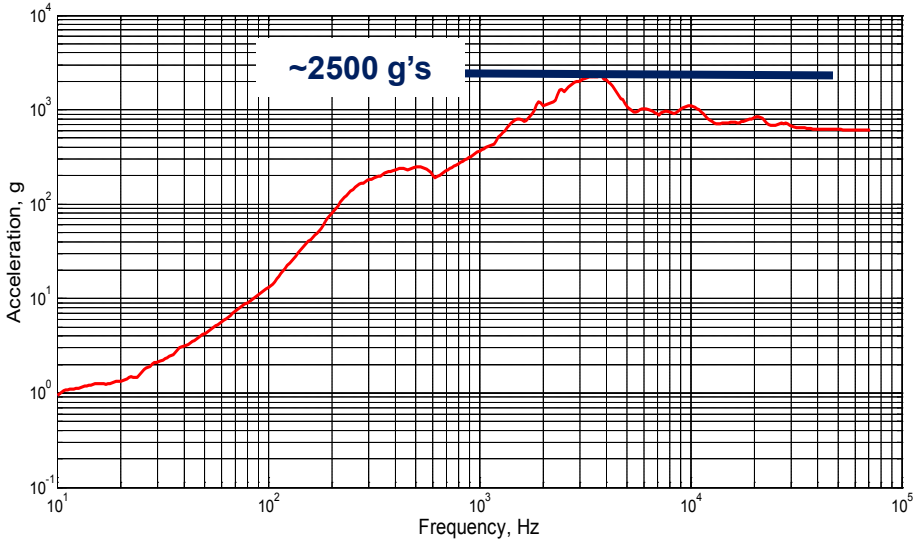


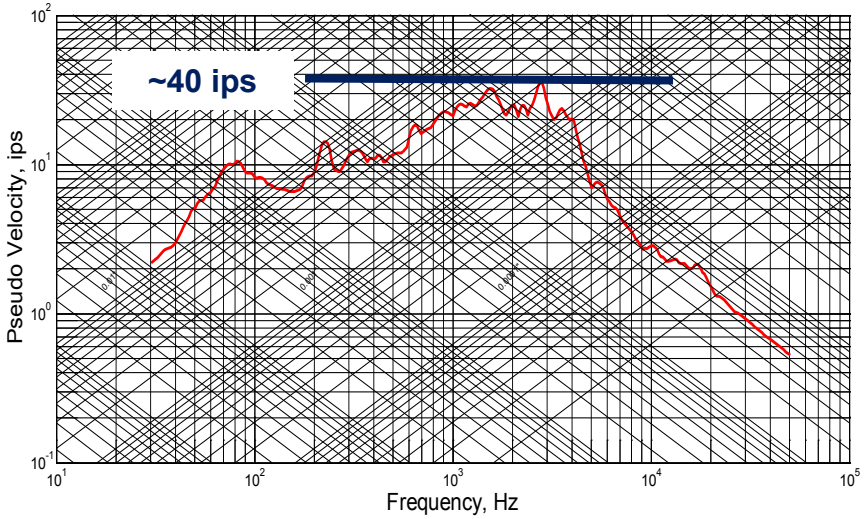


3-D Fixture Electronic Hardware Shock Simulation Test

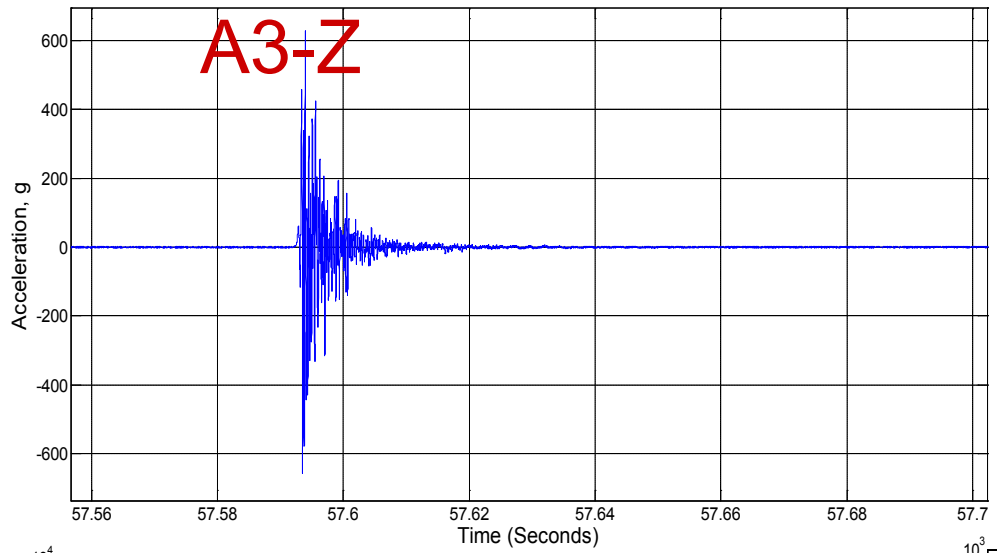


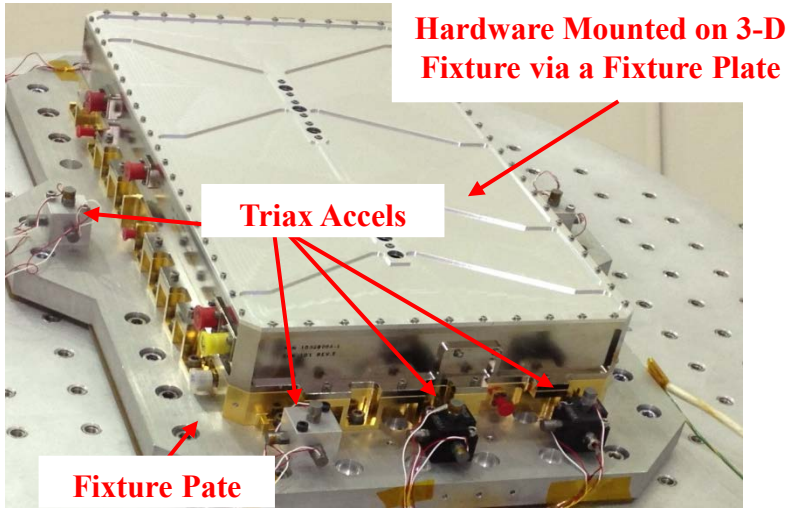


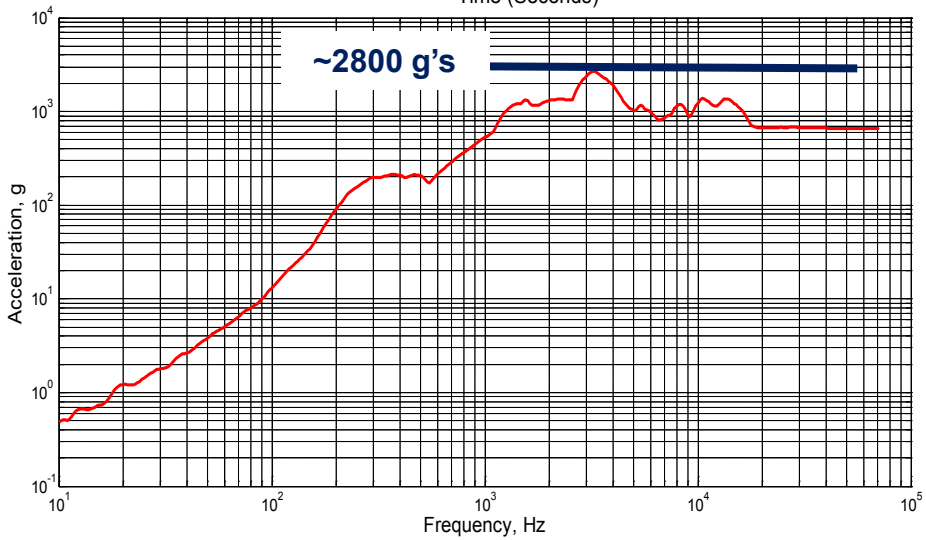


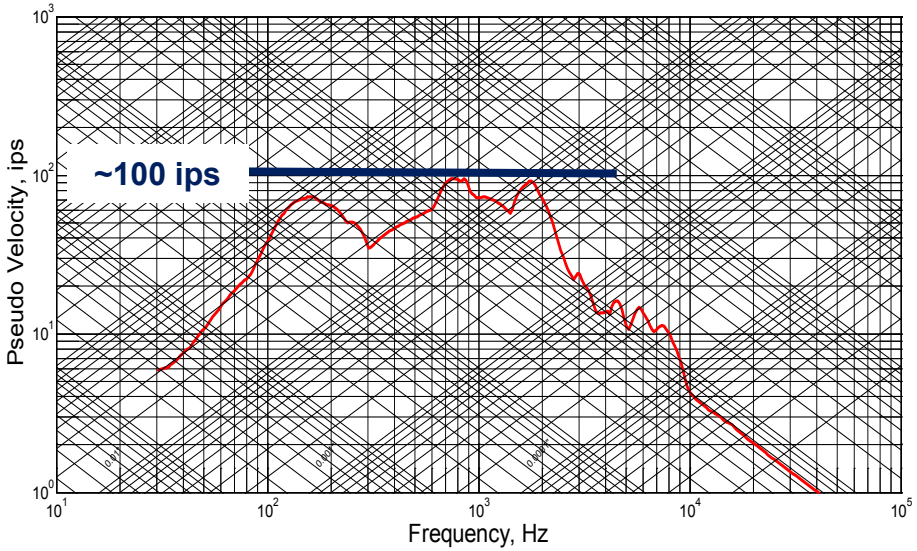


3-D Fixture Electronic Hardware Shock Simulation Test



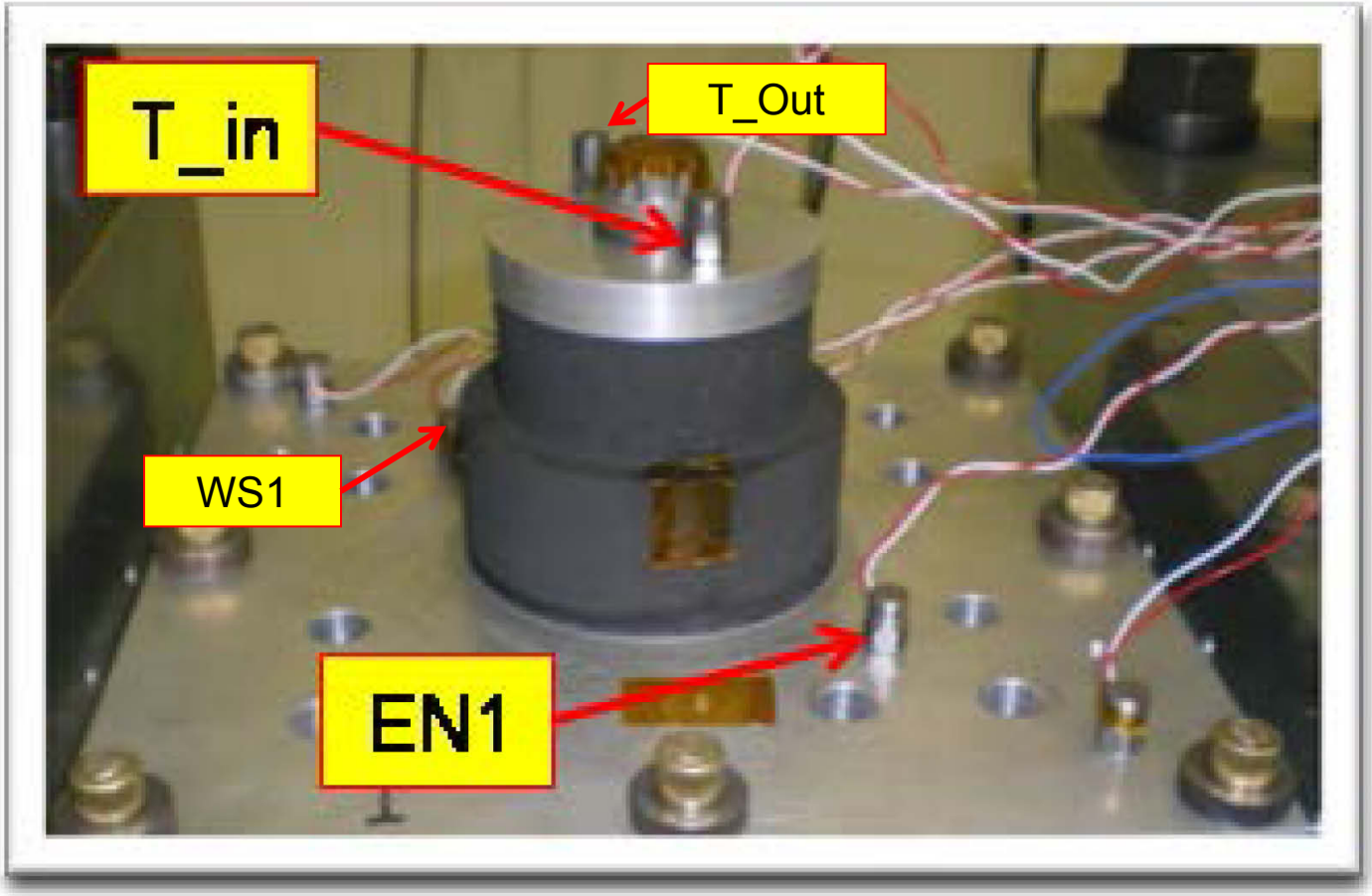






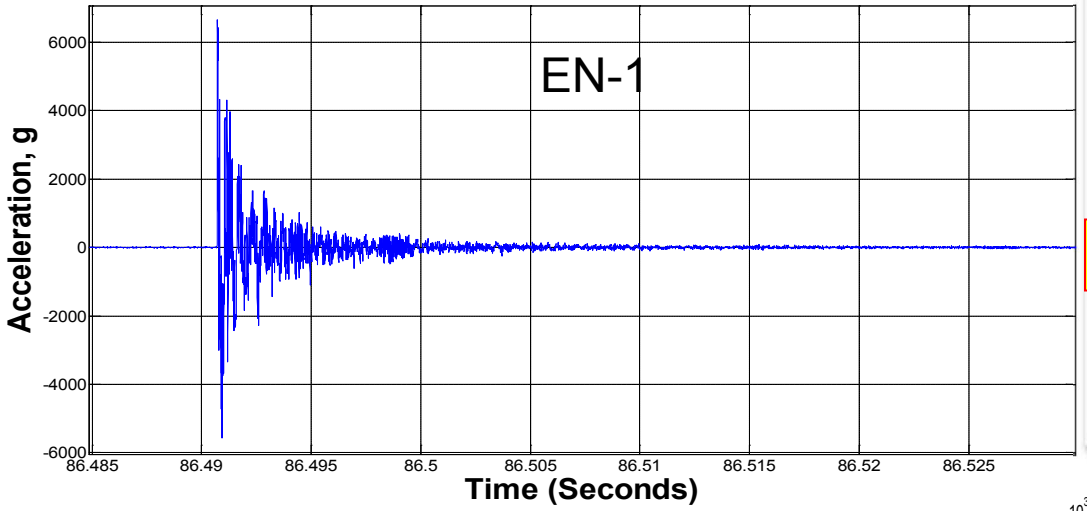
Sock Simulation Data
High Frequency High g

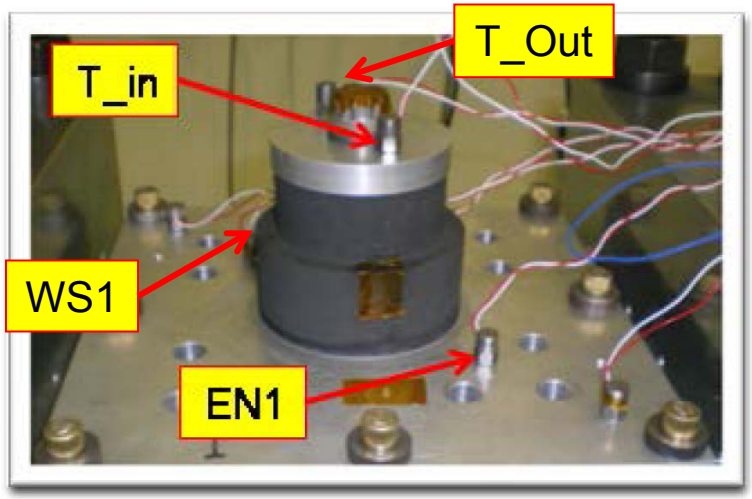
Test Setup

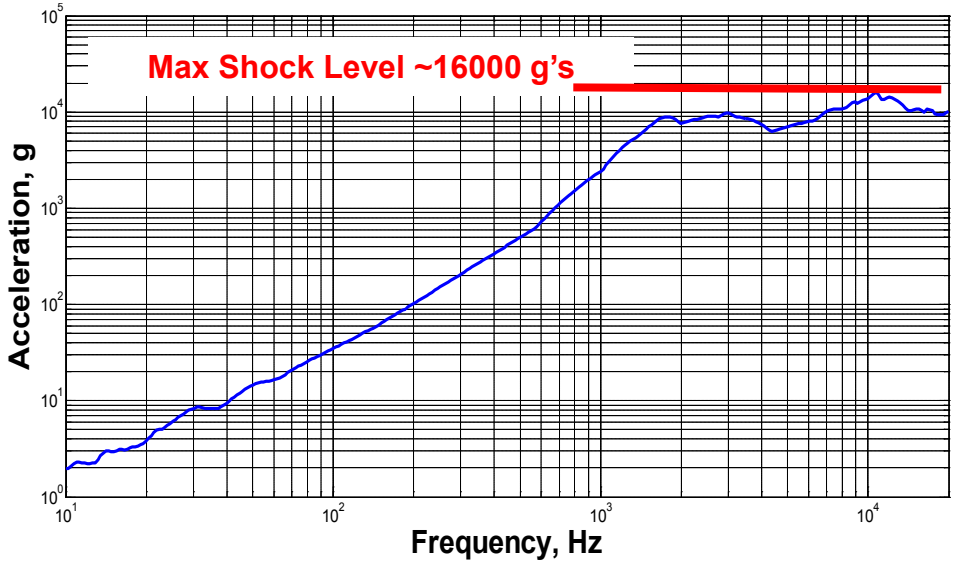


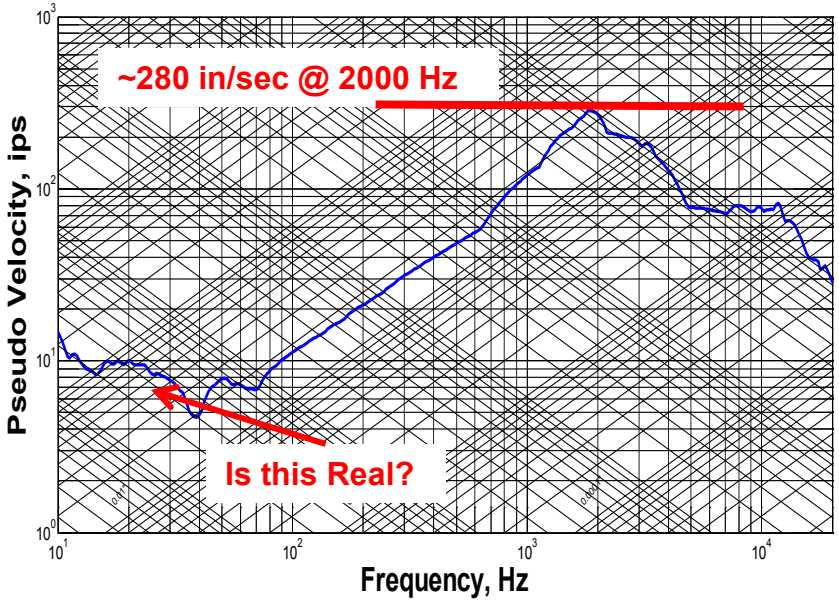
Goal: Exposure to 40k+ g's

High Shock Environment Simulation Test

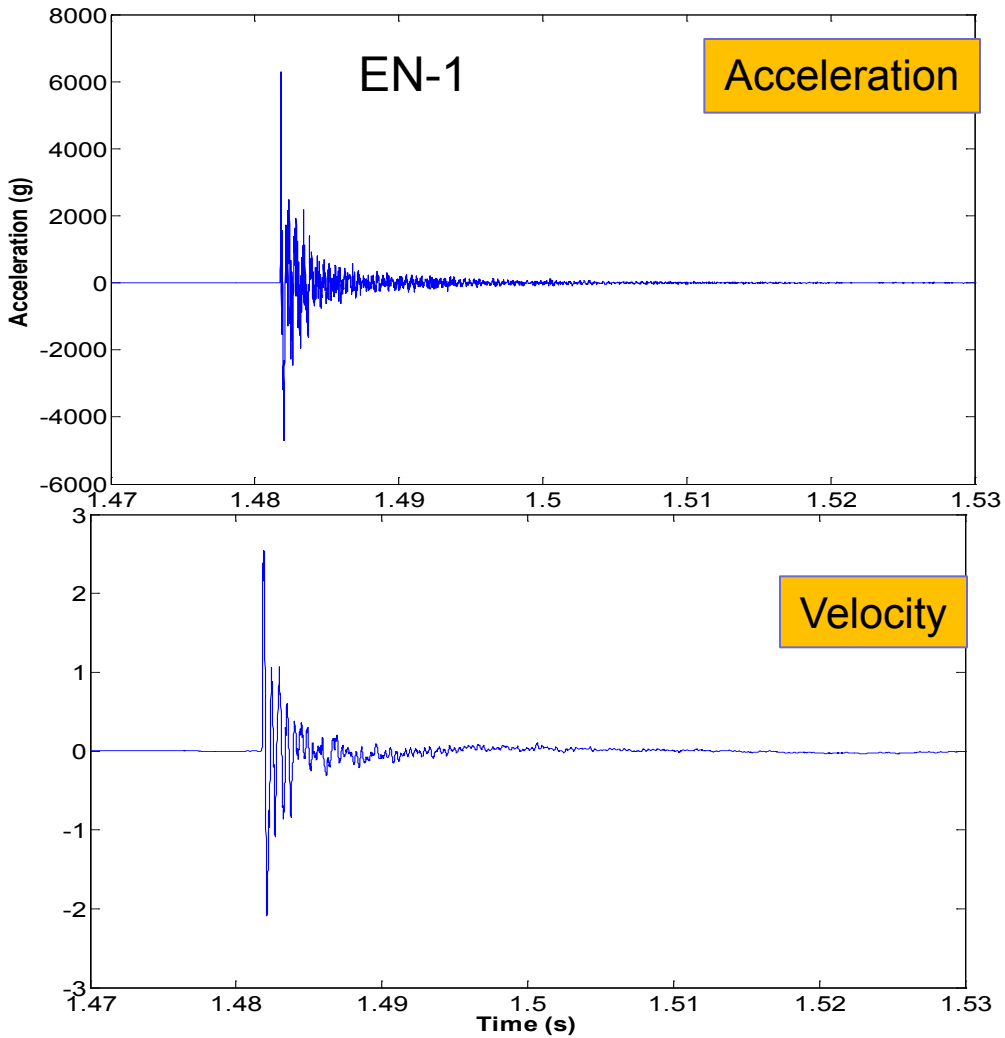






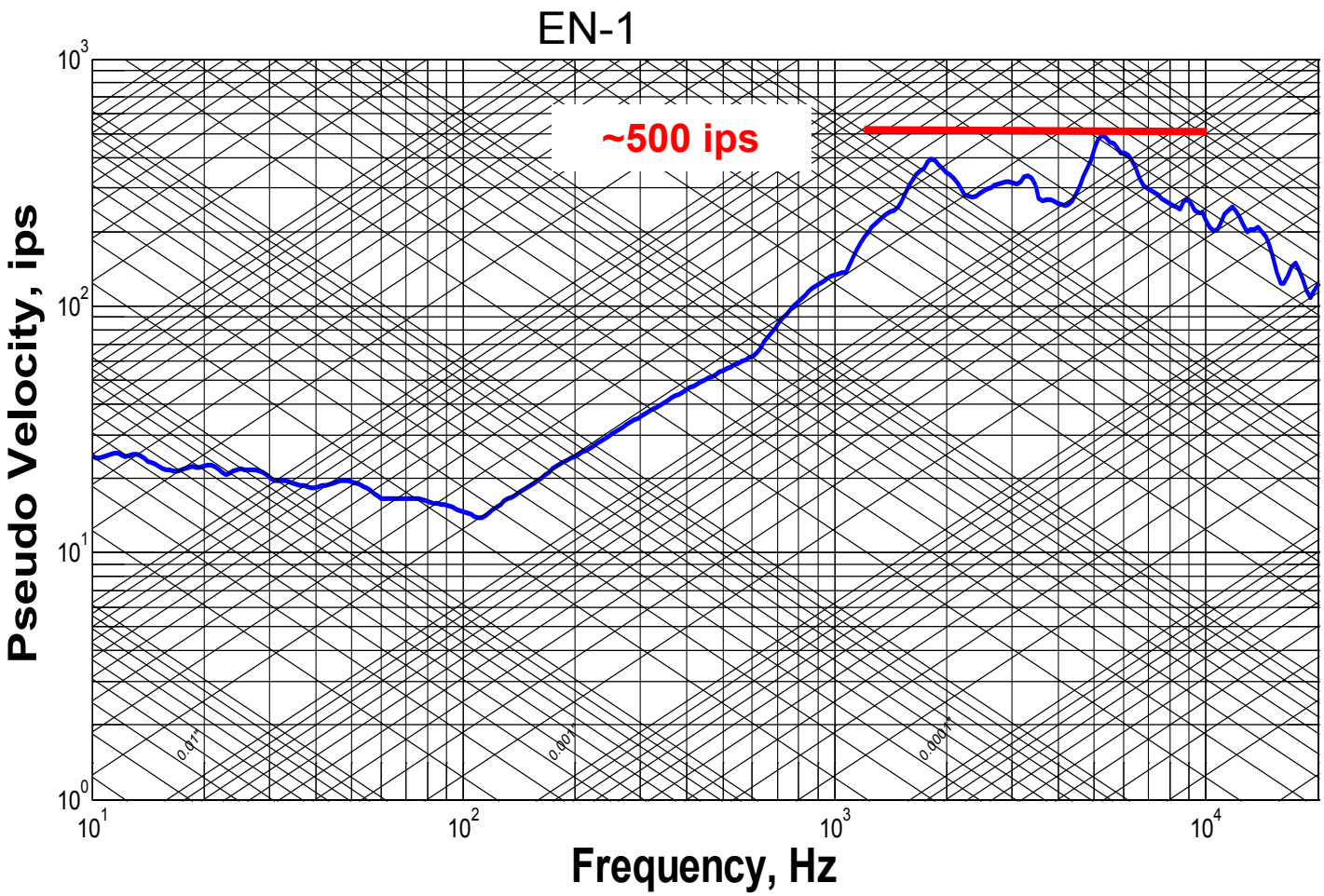


Data Quality

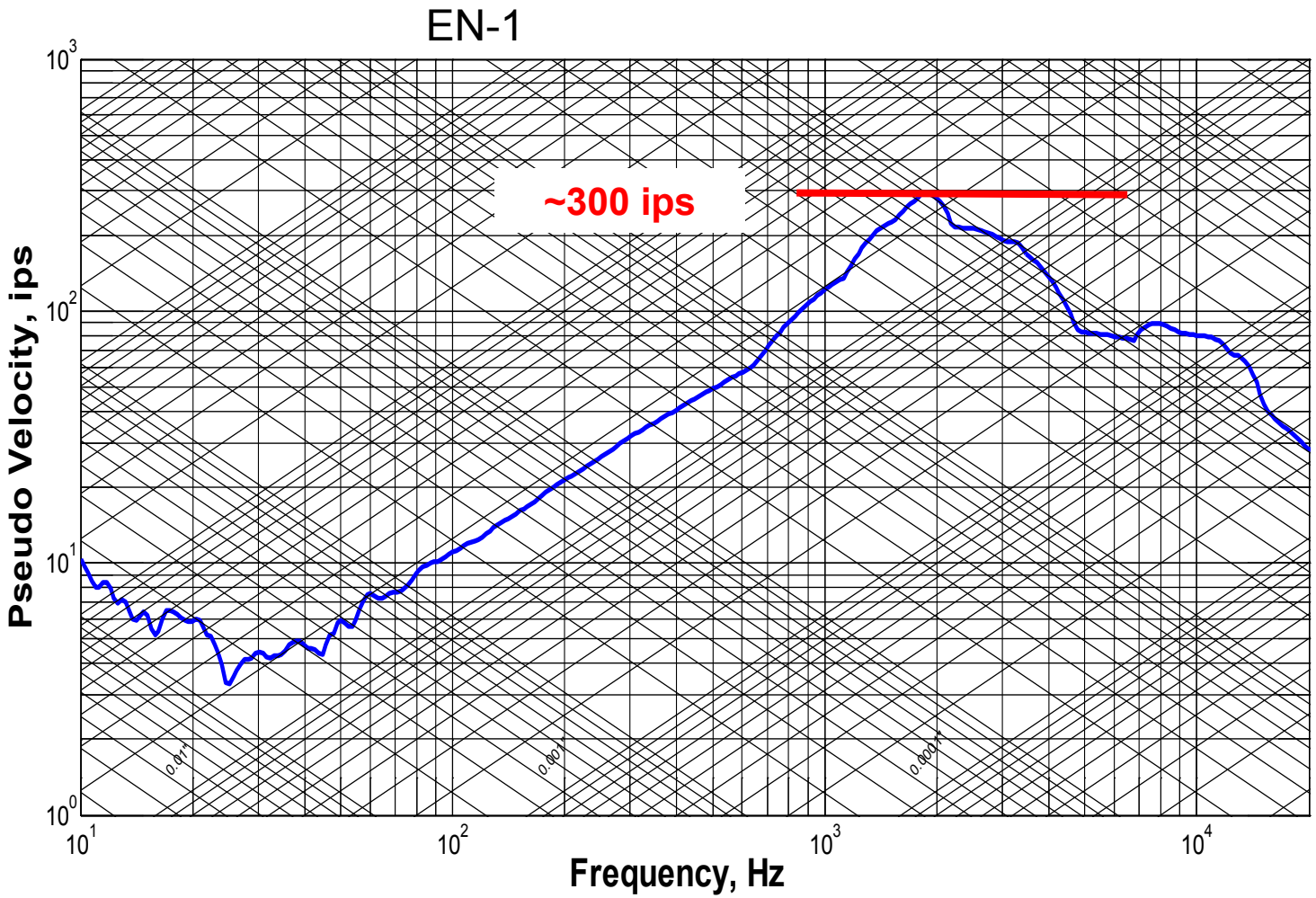


1. The transient oscillatory velocity indicate good shock data quality
2. Shock signature satisfies NASA requirements

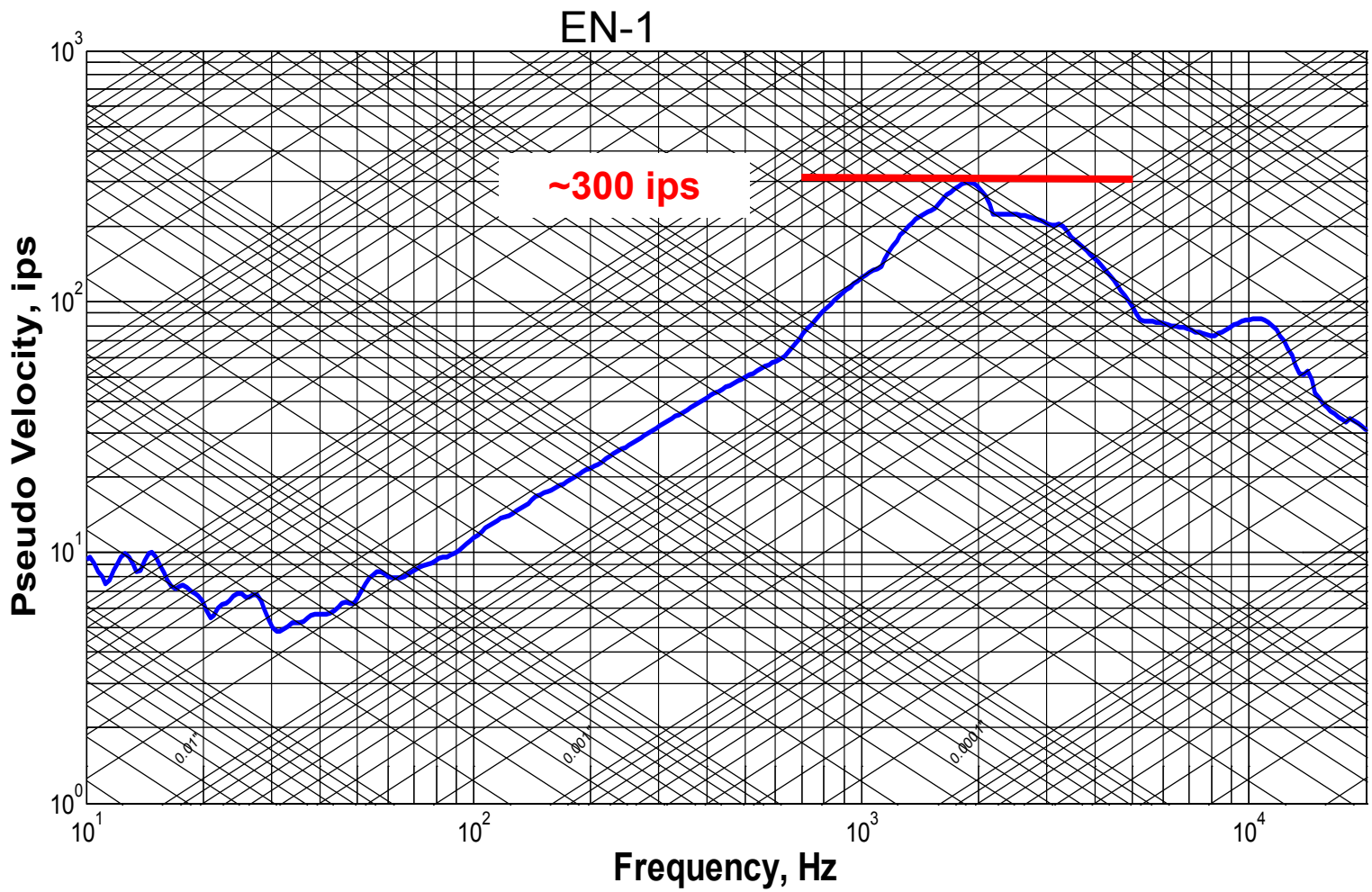
PVSS: Nominal Preload



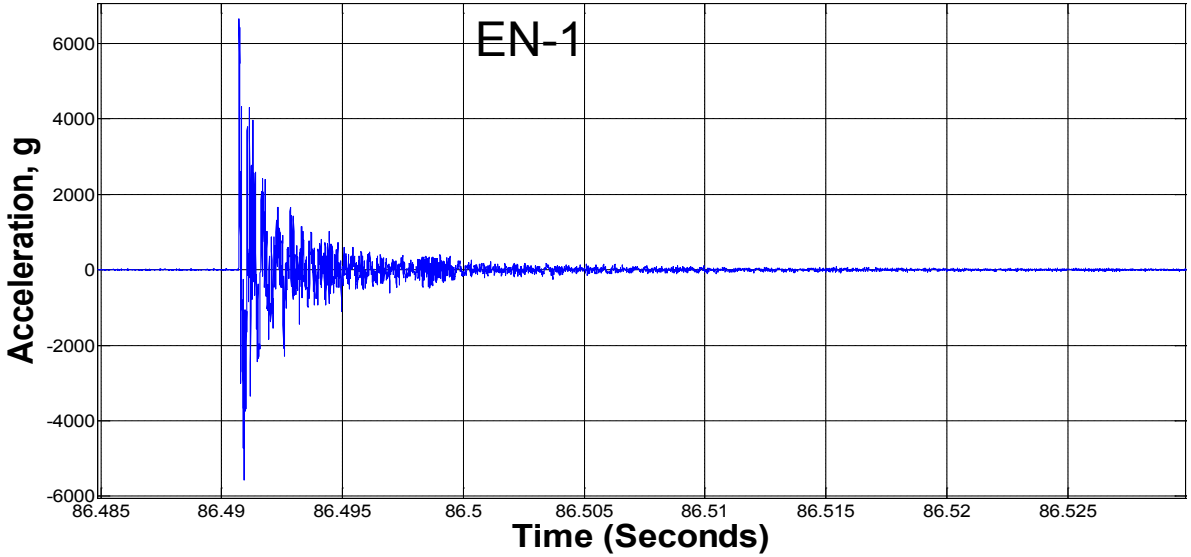
PVSS: 50% Reduction in Preload

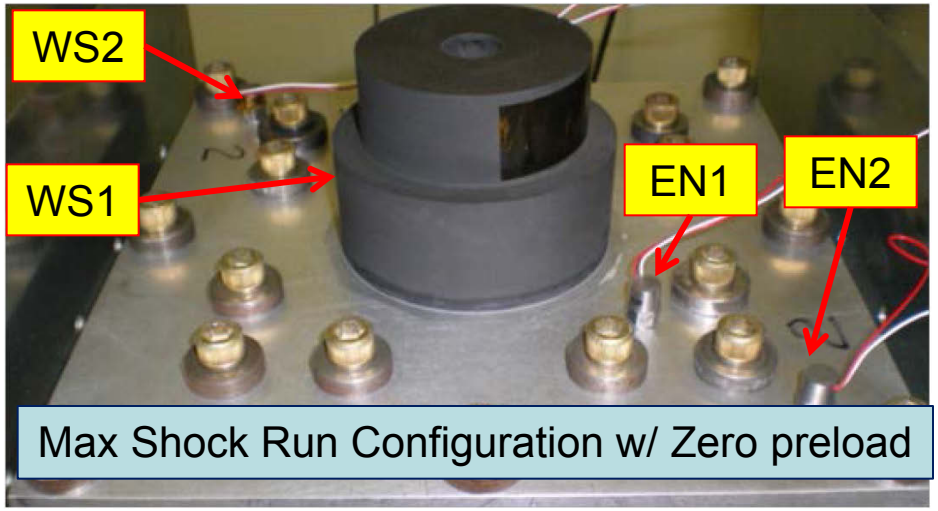


50% Increase in Preload



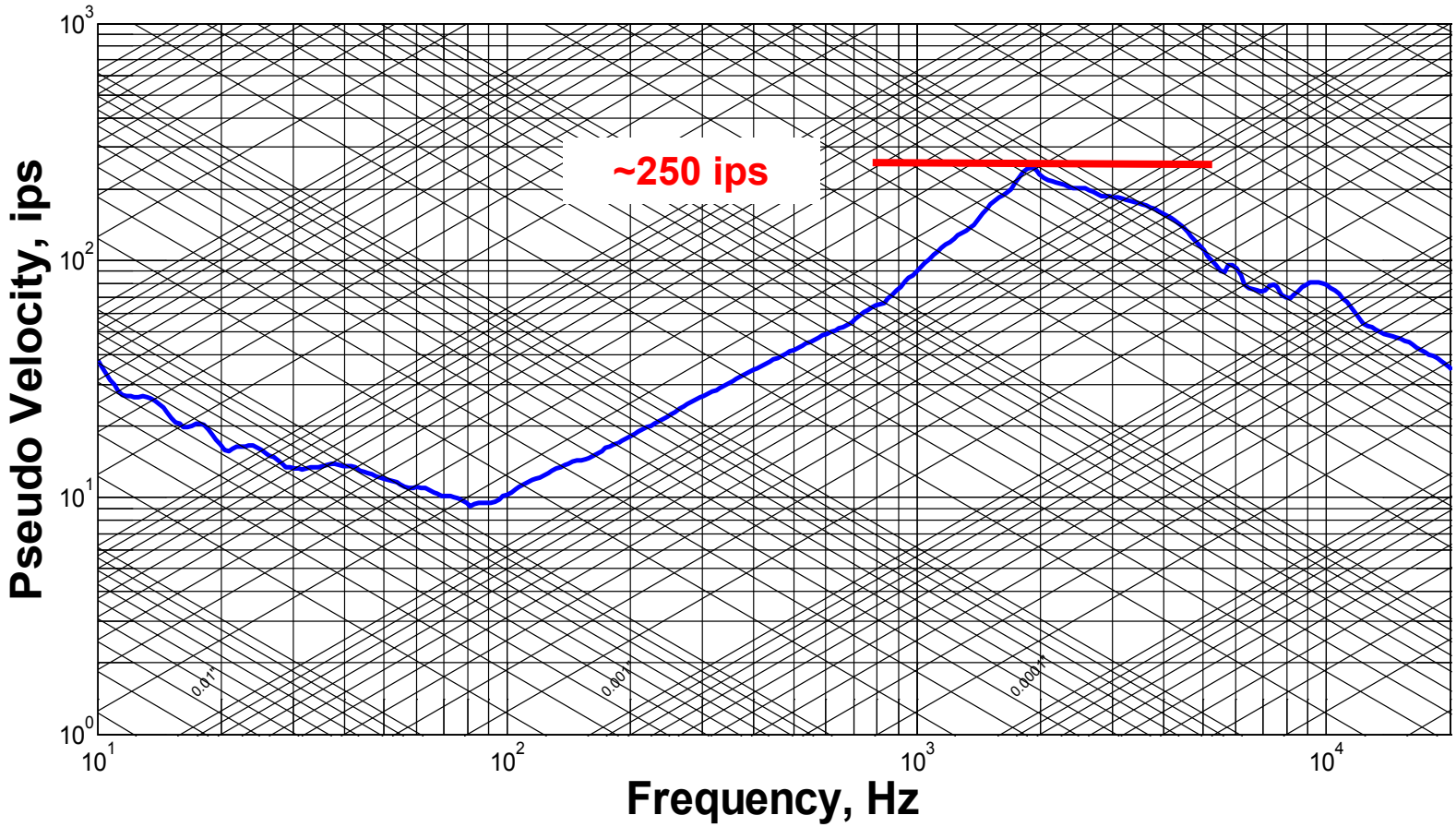
No Preload



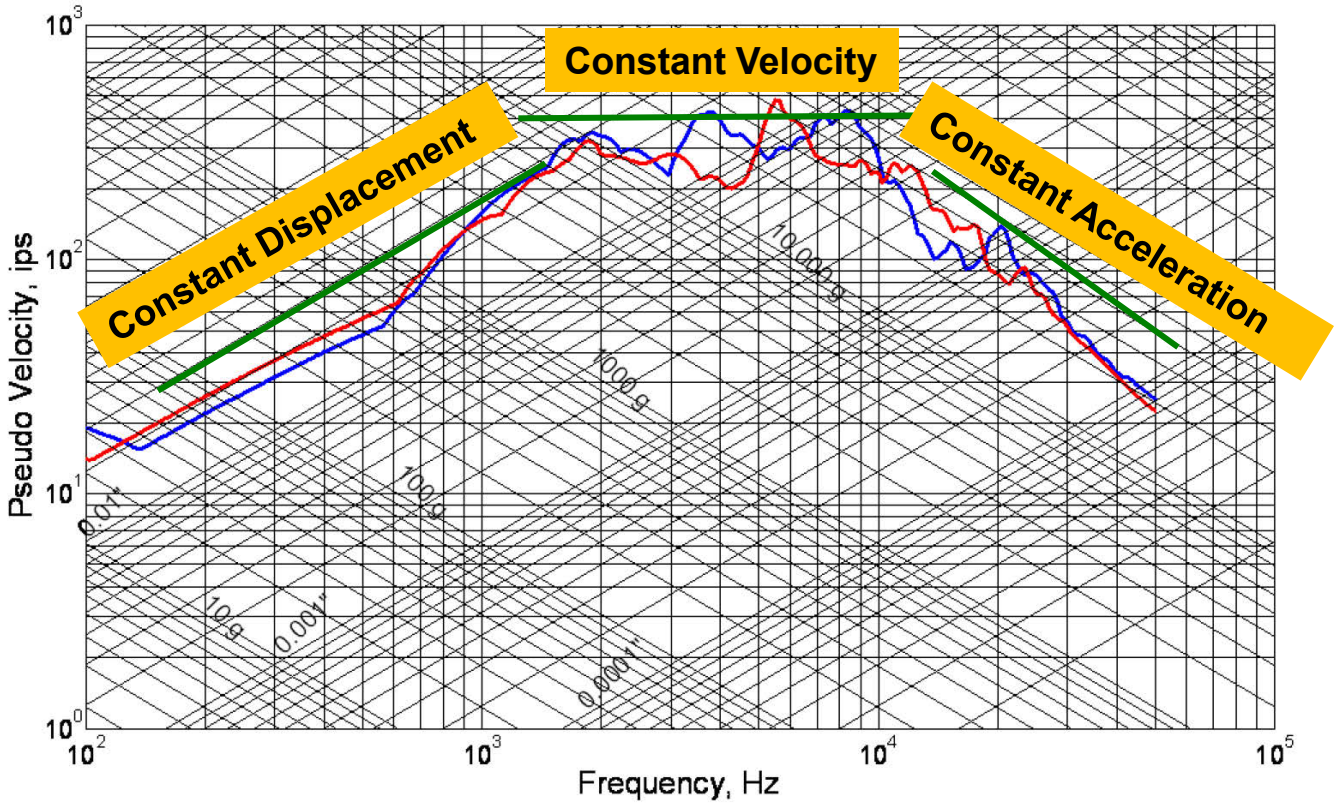


Max Shock Run Configuration w/ Zero preload

Sample without Failure



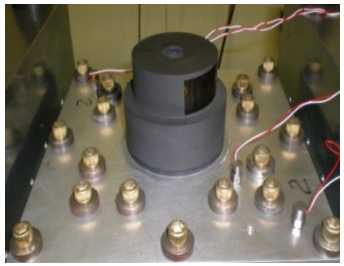
Two Identical Samples

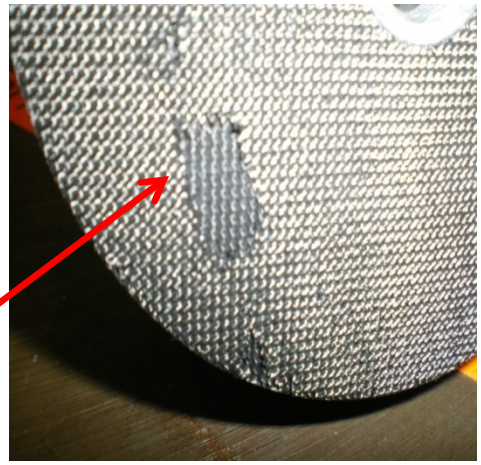


- The first test sample was subjected to multiple high-g shock loads.
  - Failed after exposure multi exposures
- No failure with identical sample exposed to one shock
- Neither SRS nor PVSS are the indicator of the test failure for these samples

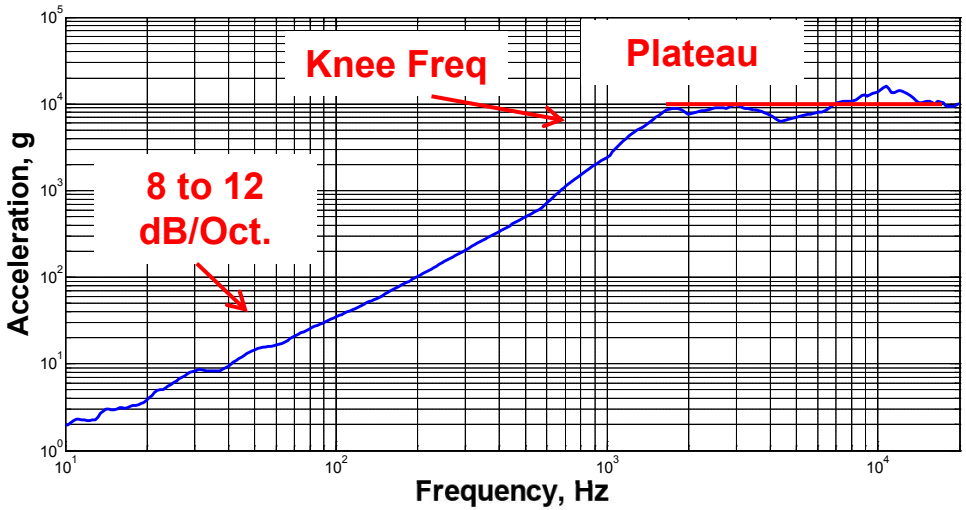
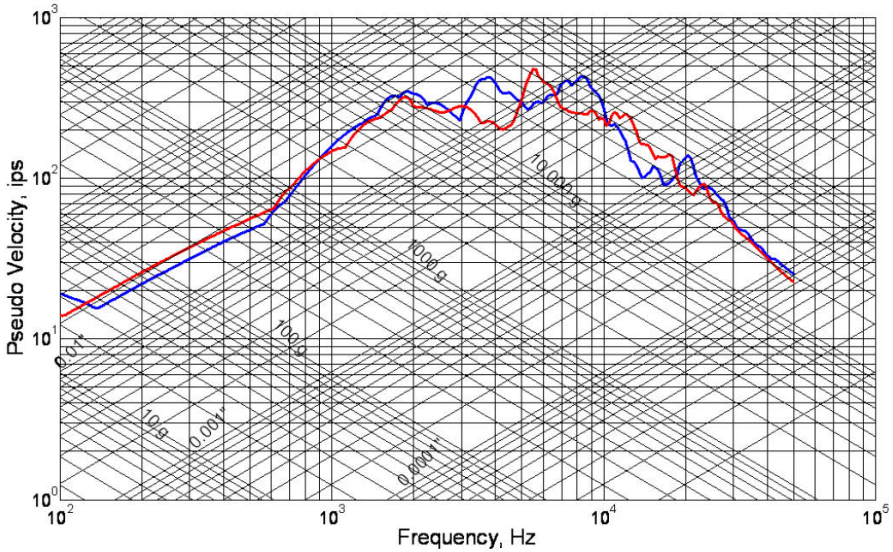
Failure Under High Shock Level

Remaining layer on the fixture plate





Failed test sample

SRS and PVSS (Discussion)

- **SRS**
  - Many acceleration histories have same SRS
  - Does not account explicitly for duration of transient, curve shape, or multiple exposures
  - SRS applicability to higher frequencies?
    - High frequency wave propagate with group velocity (Dispersive and non-dispersive waves)
  - Is Q of 10 applicable to all structures including composite and brittle structures and frequency bands?
  - How do we define Knee frequency?
  - Do we need to consider shock levels below 100 Hz and above 10,000 Hz for flight qualification?
- **PVSS**
  - Is this a severity indicator?
    - Low- and High-frequency severity not the same
  - Low-frequency material failures caused by exceeding a threshold stress or strain (energy), not acceleration
  - If PVSS provides useful information do we need to consider for flight hardware qualification tests?
- **Shock Modeling**
  - Open issue