
# Guidance on Shock Qualification and Acceptance Test Requirements

*Ali R. Kolaini [1], Teresa Kinney [2], and Dexter Johnson [3]*

*[1] Jet Propulsion Laboratory, Pasadena, California*
*[2] Kennedy Space Center, Florida*
[3] NASA Engineering Safety Center */Langley Research Center, Hampton, VA*

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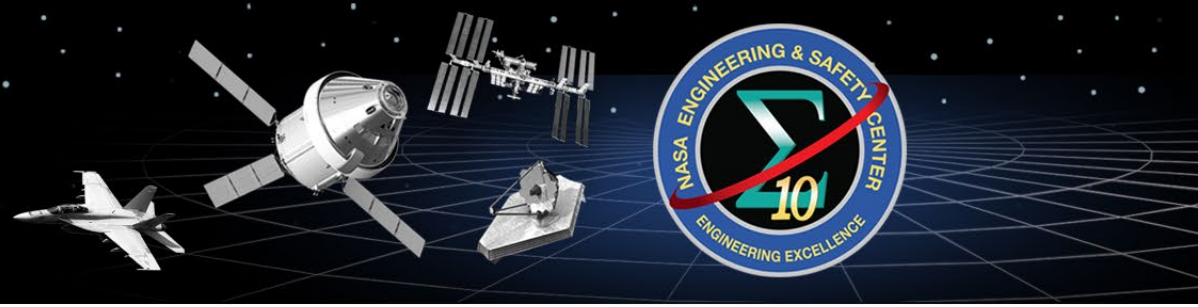
# Background 1/3

- Several years ago, a team of Subject Matter Experts (SMEs) prepared a memo for the Constellation Program Environmental Qualification and Acceptance Test Requirements (CEQATR) per request by NASA Chief Engineer
  - The memo covered only shock
  - Tailored for the Constellation Program
  - A few recommendations were made
- CEQATR recommendations are reviewed and compared with NASA-STD-7003B

# Background 2/3
# CEQATR- Recommendations

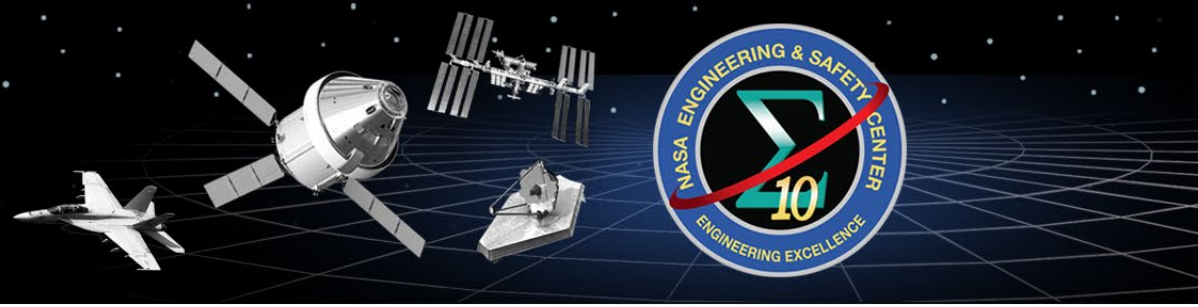



- ***Unit qualification*** *testing is required (R) for all units. The unit must be a flight-like unit. A qualification test margin of 3 dB above the P95/50 maximum predicted environments (MPE) shock response spectrum (SRS) level is required with a test tolerance of -3dB/+6 dB. The program may specify a higher confidence level by using a larger qualification test margin (e.g., 6 dB). This increased confidence is recommended when:*
  - *The shock source levels have not been measured several times at the full level of assembly in flight.*
  - *The shock transmissions into zones of interest are based on analysis.*
  - *For flight termination system hardware, the increased test margin should be 4.5 dB per the Air Force Space Command Manual 91-710 Volume 4.*
- *Two shock in each coordinate direction are required.*
- *Unit acceptance testing is not required. Random vibration acceptance tests have been found to be effective at precipitating failures associated with latent defects and workmanship that would occur due to pyrotechnic or mechanical shock. Therefore, additional unit shock acceptance tests are not generally required provide there is a rigorous unit acceptance random vibration test program.*

# Background 3/3
# CEQATR- Recommendations

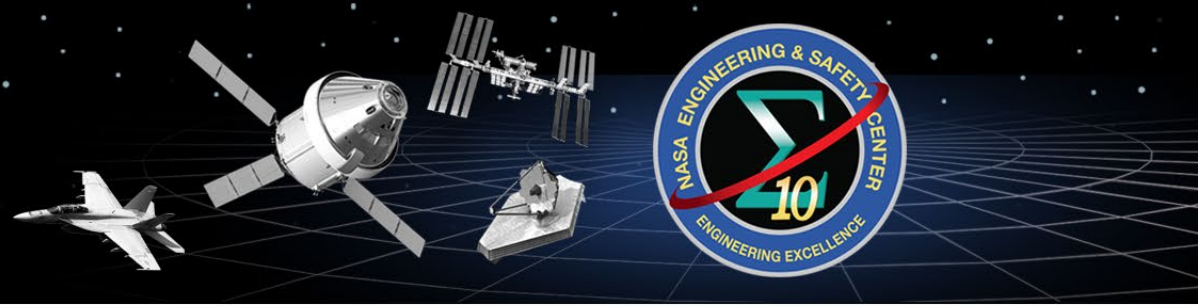
- ***Major assembly level qualification*** *testing is required (R) although it is recognized that MPE and design margin cannot be demonstrated at the system level. Therefore, the following system test objectives are recommended:*
  - *Functional Demonstration: The electrical and mechanical function of the shock source device shall be demonstrated. Mechanical motion of the hardware (for example, interferences and tip-off rates) shall be verified as appropriate. At a minimum, a flight-like shock source and supporting hardware shall be used in the functional demonstration.*
  - *Validation of Flight Assembly: The assembly shall be in a flight configuration.*
- *Flight-like qualification units shall be mounted with all associated support hardware (harness, brackets, pluming, and assorted parts). Units that are powered during flight shall be present and in their operational mode applicable to the flight shock event. The assembly shall be exposed to the shock event a minimum of two times.*
- *Multiple tests may be performed in order to meet the system test objectives as identified above.*
- *Major assembly acceptance testing is not required.*

# CEQATR- Recommendations #1
## Unit Qualification Test



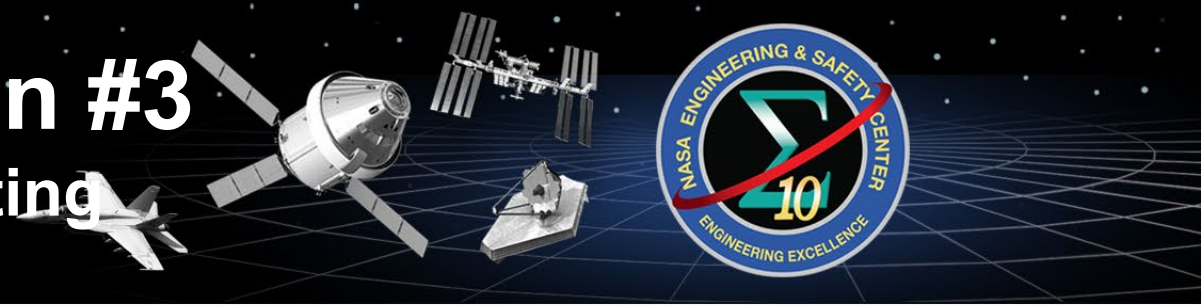

- The NASA Standard 7003 requires that all units go through shock qualification testing, with the exception of type II Class D projects.
  - The Technical Standard calls for pyroshock qualification testing of non-flight hardware for externally induced environments to be performed with a 3-dB magnitude margin added to the MPE with two shocks per each orthogonal axis.
  - Qualification tests are performed on hardware that will not be flown but is manufactured using the same drawings, materials, tooling, processes, inspection methods, and personnel competency as used for the flight hardware.
  - The purpose of a qualification test is to verify the design integrity of the flight hardware.
  - Protoflight (PF) test may be performed on flight hardware when there is no qualification hardware is available.
    - Type I Classes B-C
- **CEQATR recommendation is in line with the NASA Standard 7003B**.

# CEQATR Recommendation # 2
# Unit Acceptance Test



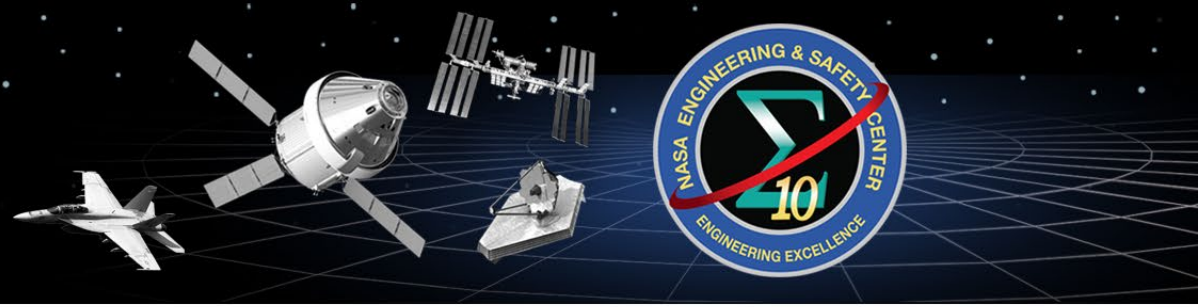

- **The CEQATR memo recommends not performing unit acceptance (FA) shock testing**
  - Emphasized unit to go through rigorous acceptance random vibration (RV) test program to uncover the precipitating failures associated with latent defects and workmanship.
  - The 7003 Technical Standard does not explicitly refer to unit acceptance shock test as a requirement. However, it specifies if acceptance-level testing is part of a test plan for flight hardware the levels shall be MPE and one shock per axis shall be applied in all three orthogonal axes.
    - This includes spare(s), where the hardware design integrity has already been verified by a qualification test.
- CEQATR is in line with the 7003B Standard; recommends to add guidance to future 7003 revision on workmanship screening test
  - RV may be used as workmanship screening up to 2000 Hz and will not be an adequate screening test above 2000 Hz.
  - Workmanship screening tests of unique and sensitive hardware shock acceptance level tests need to be dealt with on a case-by-case basis and approved by an expert in pyroshock dynamics.

# CEQATR Recommendation #3
## Major Assembly Qualification Testing



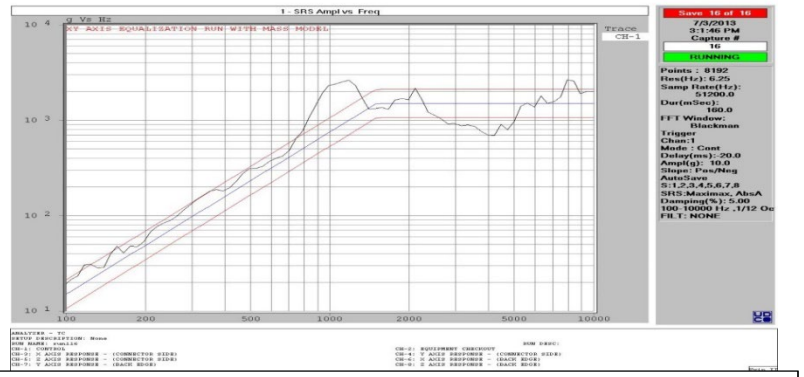

- **The CEQATR memo requires major assembly qualification testing .**
  - MPE and design margin cannot be demonstrated at the system-level tests.
  - Three objectives discussed
    - The functional demonstration of shock separation devices.
    - The validation of the unit shock environments.
    - Transfer functions (TFs) that may help to estimate the attenuation, and in **some cases structural amplifications**, throughout the system with all assemblies in flight configuration.
- The Standard 7003B has similar discussions for the first two major assembly qualification test objectives and there are no discussions on the third recommendation related to the TFs.
  - The TFs may be used to assess shock propagation paths and attenuations/amplifications at joints and interfaces.
  - The attenuation is highly dependent on the materials and joints constructions and may be significantly different if there are changes in the system configuration.
  - **Recommendation:** Add guidance on TFs to be used as qualitative information rather than using them for assessing the attenuation in the structural shock paths.
- The CEQATR memo is in line with the Standard 7003B to not perform major assembly acceptance testing.

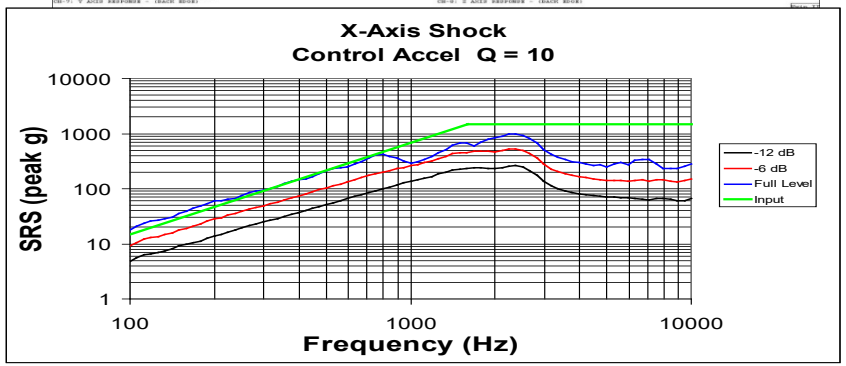
# Shaker Shock Test

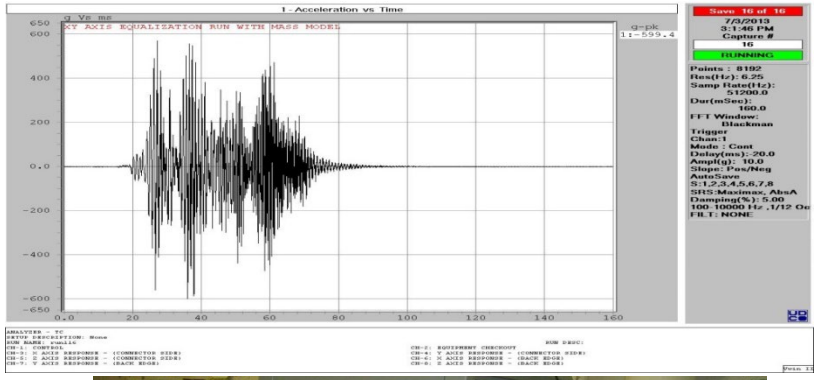


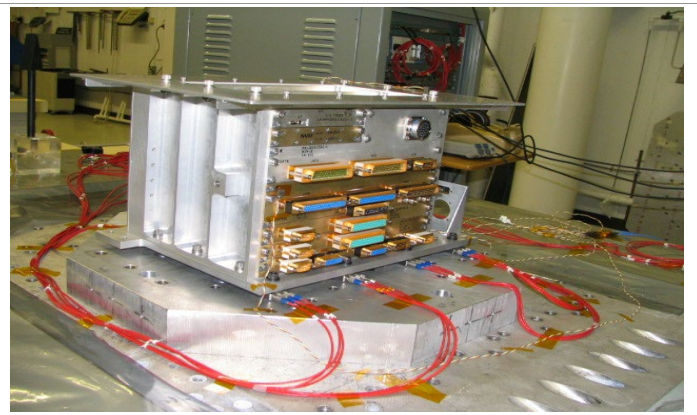

- Shaker shock test was discussed in the CEQATR memo an option for qualifying flight hardware for shock environments.
- Even though shaker shock testing has been used in the past and are still being used for flight hardware qualifications, there are two major technical issues:
  - Provides severe shook environments below roughly 2000 Hz.
  - Most shakers are not able to generate SRSs above a couple 1000 Hz, therefore, shaker shock test is deficient in meeting the shock requirement up to 10 kHz frequency requirement.
- The NASA Standard 7003B does not recommend the shaker method of testing due to the above limitations.
  - Under unique situation shaker shock simulation test may be acceptable such as lower-level shock requirements.
    - Unacceptable methods should not be used to force into meeting SRS requirements (such as having fasteners rattle/chatter, use digital signatures such as wavelet, etc.)
- **This is one of the areas we depart from the CEQATR memo.**
  - Shaker shock simulation may be used if both SRS/time history mimic shock signatures generated by separation systems

# Shaker Shock Examples



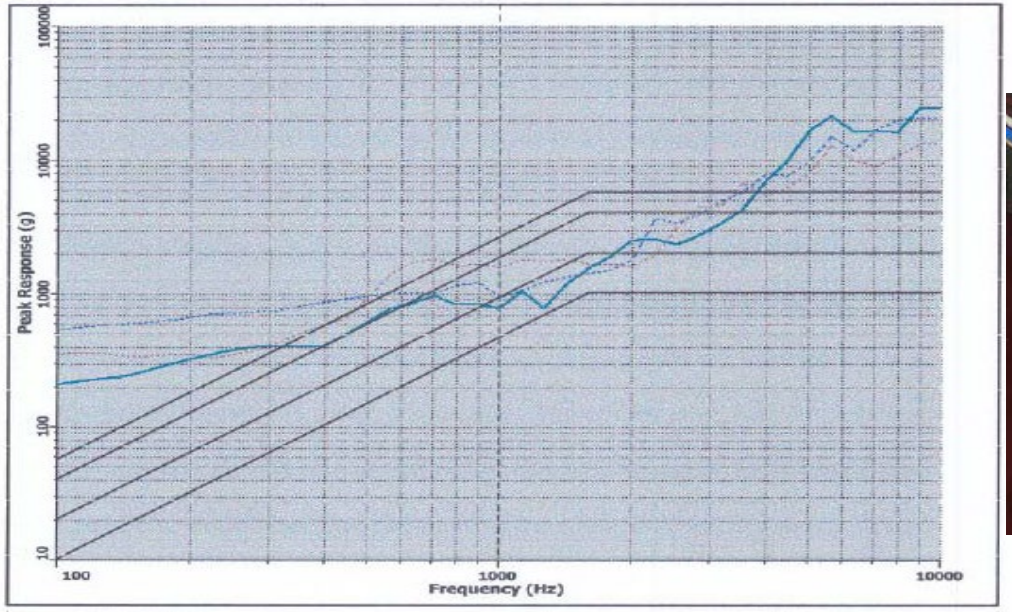



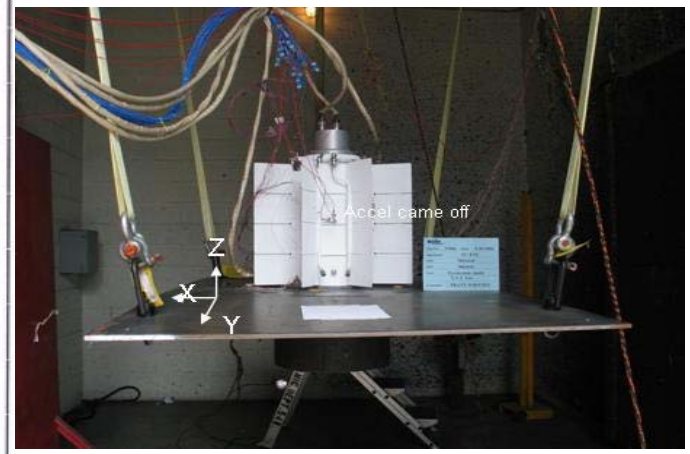



Shaker shock simulation system has the following limitations:

1. In general, a very severe test for flight hardware qualification.
2. Not able to generate shock levels above 1000 Hz for most cases.
3. Not recommended for space applications, where high-frequency shock levels are required.

# AN Example of Detonator Shock Simulation SRS




An example of pyro-shock simulation tests. The pyro firing simulation systems usually have the following issues:

- They often are not controllable and repeatable.
- In general, they provide severe shock levels at low and high frequencies.
- Challenges in investigating the flight hardware failure modes.

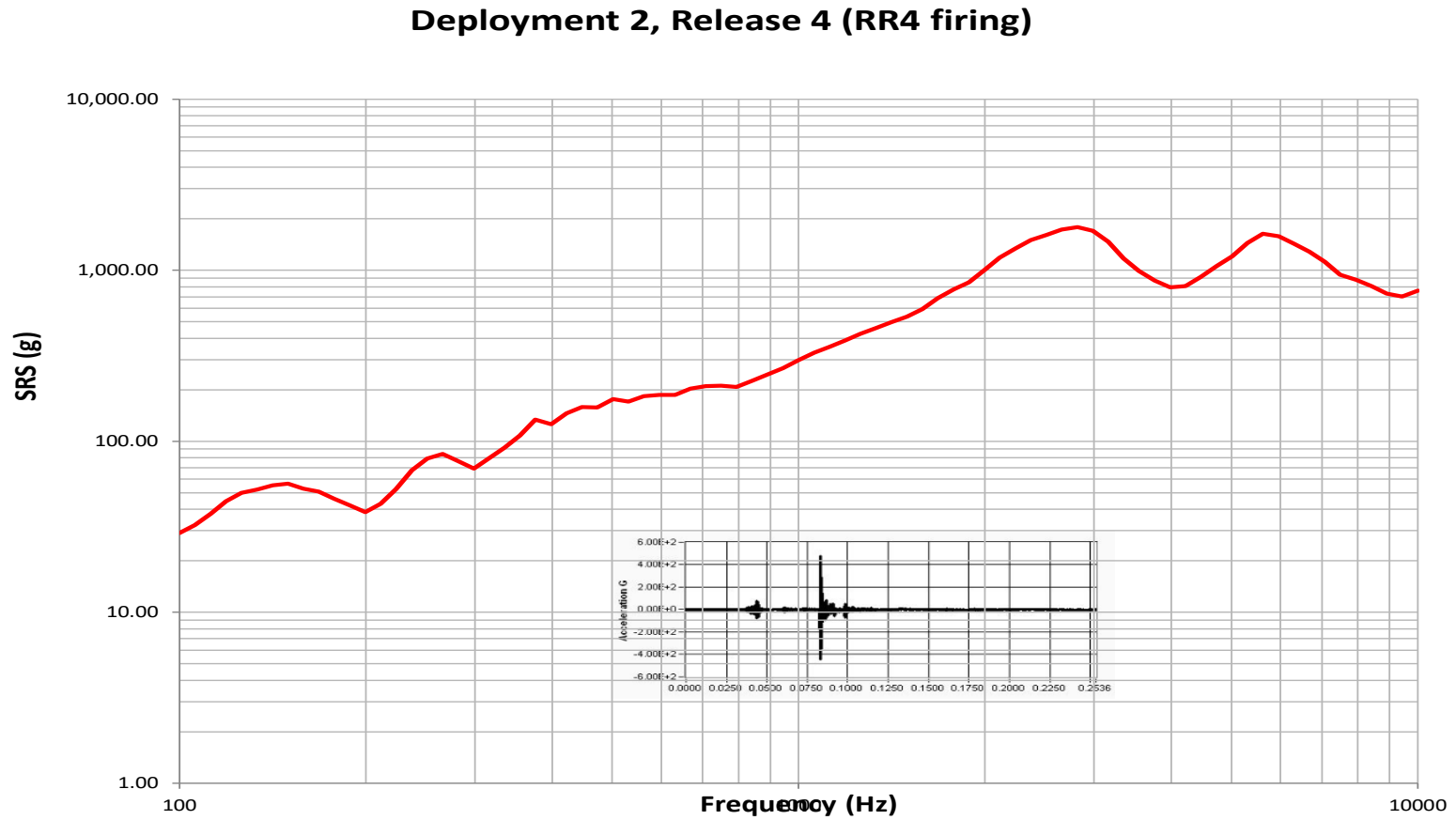
# Shock Test Tolerances


- The shock tolerance specified in the 7003 Standard is +/- 6 dB from 100 Hz to 3000 Hz and +9 dB/- 6 dB above 3000 Hz.
- The shock tolerance specified in the CEQATR memo is -3 dB/+6 dB across all frequencies.
- Recommendation: Use shock tolerances to be +/- 6 dB across all frequencies.
  - The constant tolerance bandwidth across all frequencies are possible as many existing shock simulation systems are able to simulate shock signatures that fall within these tolerances without difficulties.
  - The tightening of the +/- 6 dB tolerances should be dealt with on a case-by-case basis when dealing with a sensitive flight hardware and is recommended to be assessed by a SME in shock testing before implementing the changes.
  - For detonator or explosive shock simulation systems the shock tolerances above 3000 Hz may be kept at +9 dB/- 6 dB.
    - Care must be taken to calibrate the system for sensitive flight hardware with structural modes that may undergo sustained excitation and possibly lead to failures.

# Mechanical Shock vs. Pyroshock

- The CEQATR memo refers to classic mechanical shocks to be low-frequency shocks with energy concentrated at frequencies below 2 kHz.
- Measurements from many different pyro/non-pyro separation systems have broader shock signatures and do not support the applicability/usage of mechanical shock in the low to mid frequency range only.
- The Standard 7003 discusses this topic; however, a future revision should clarify the applicability of the mechanical shocks to be broader and not to be limited to 2 kHz and below.
- **The mechanical shock is another topic that we differ from the CEQATR memo.**

# Mechanical Shock




An example SRS obtained from a of mechanical shock separation system indicting the signature produced is broad as is the case with pyro shock devices.

# Summary


- Unit Qualification Test is discussed in NASA Standard 7003B.
  - No changes are recommended.
- Unit Acceptance Test also discussed in NASA Standard 7003B.
  - Will consider adding recommendation on using RV as workmanship screening test up to 2000 Hz and above this frequency for unique and sensitive hardware shock acceptance level tests need to be dealt with on a case-by-case basis.
- Shaker shock simulation is not recommended as this is already discussed in 7003B.
  - May be used if both SRS/time history mimic shock signatures generated by separation systems.
- Consider changing shock test tolerances in 7003B from +/- 6 dB up to 3000 Hz and +9/-6 dB above this frequency to +/- 6 dB across all frequencies.
- Recommend clarifying the applicability of the mechanical shocks to be broader and not to be limited to 2 kHz and below in the next 7003 revision.