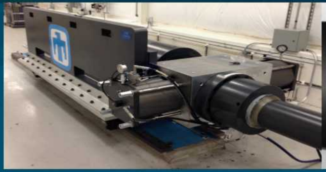
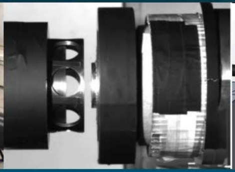
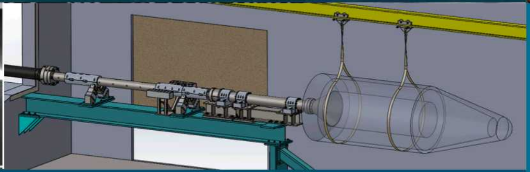
SAND2019-13085C

Development of Non-Destructive "Alternative Pyroshock" Simulation for Extremely Large Systems







PRESENTED BY:

Patrick Barnes, Sandia National Laboratories

90th Shock and Vibration Symposium, November 2019

ADD SAND #

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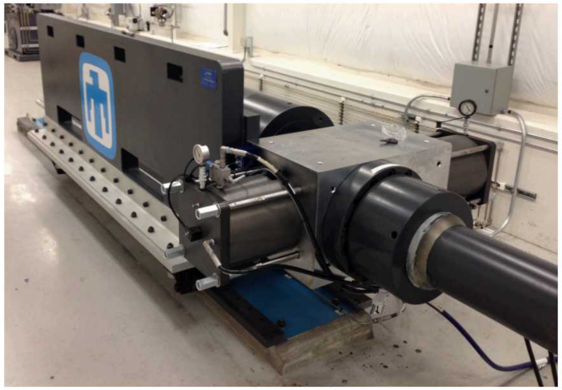
Mechanical Shock Facility – 6” Gas Gun Overview

Technical Specifications:

- Mounted permanently in the Mechanical Shock Facility (Bldg. 6570 / Tech Area III)
- Motive Source: Compressed Nitrogen Gas (up to 6000 psi)
- Bore Diameter: 6 in [152.4 mm]
- Max Velocity: 1140 ft/s [347.5 m/s]
- Velocity/Weight: 0 - 100 lb up to 1140 ft/s [45.4 kg up to 347.5 m/s]
  Heavier projectiles at lower velocities
- Projectiles up to 6 ft [1.8 m] in length
- Barrel sections 20 ft [6.1 m] long each (3 barrel sections - typical)
  - Projectiles may be breech or muzzle loaded depending on desired impact velocity
  - Barrel extensions / muzzle brakes may be added based on test parameters

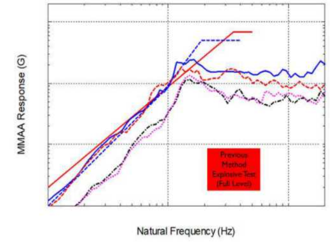
Intended Uses:

- Shock, penetration, or fragmentation tests
- Free-flight between muzzle and target allows for full real-time and high-speed video coverage of entire test event



Pyroshock Testing for Rocket Stage Separation

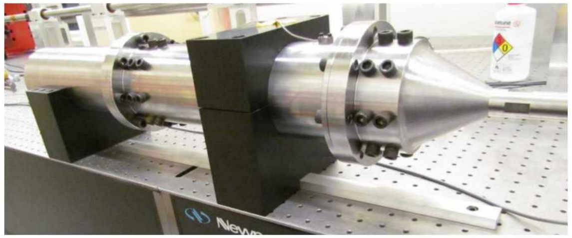
- Sandia previously used mild detonating fuse (MDF) to conduct qualification pyroshock tests (conducted by a different group)
- This was the accepted practice for many years, but with some drawbacks:
  - Use of explosives increased cost, planning time, and environmental impact
  - Explosive-based tests only had one attempt to get everything right
  - Test units had to undergo major reconfigurations after the destructive pyroshock tests were completed
- Sandia needed a new method to simulate pyroshock environments with the following requirements:
  - No explosives used
  - Non-destructive (i.e. minimal re-configuration required between test types)
  - Tunable (i.e. multiple test amplitudes possible)
  - Repeatable
  - Test unit systems must be able to function before, during, and after the simulation



NASA Ares I-X Separation Test

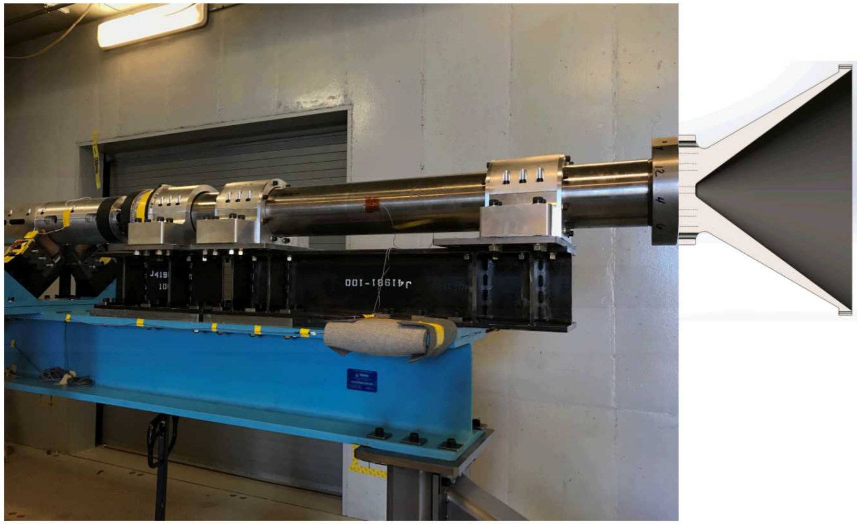
https://blogs.nasa.gov/wp-content/uploads/sites/127/2013/03/1002807main_frustrum_550.jpg

Sandia TA-1 Small-Scale / Proof of Concept Tests



Mechanical Shock Team with Alternative Pyroshock Setup

Alternative Pyroshock Test Setup

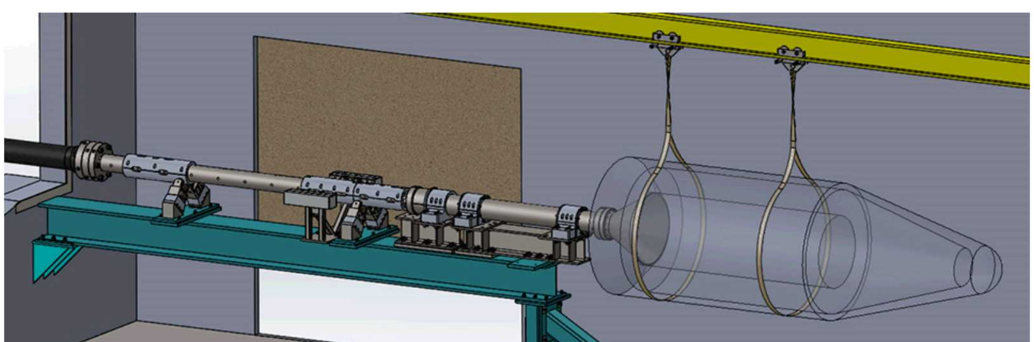


Resonant Bar Assembly:

- 8" Diameter, 36"/87" Long Steel Bar
- 30° Cone with Constant Cross-Sectional Area (Bolted to Bar)
- Bearing / Support Structure
- Energy Absorber (Alum. Honeycomb)

Rocket Part Test Unit (Approx):

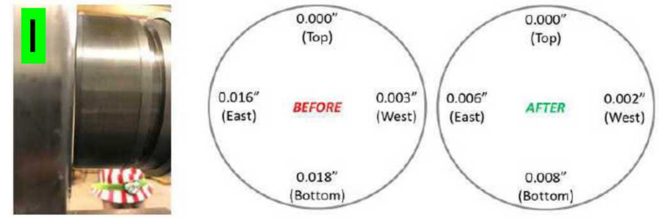
- 5-ft Diameter, 14-ft Long
- 2000 pounds
- 61 Instrumentation Channels

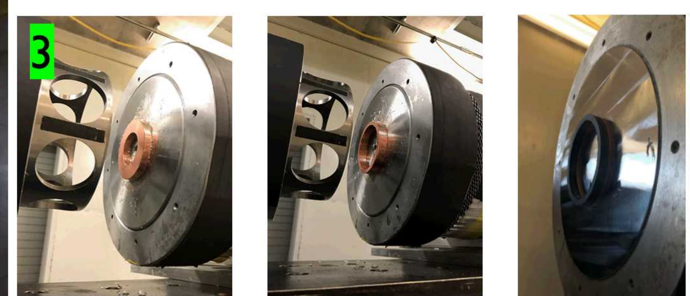


How Does an Alternative Pyroshock Test Work?

Test Overview:

1. Construct test setup and align projectile face to resonant bar (programmer compliance helps account for any misalignment or flatness variations)
2. Initially loaded projectile at breech – began loading at muzzle to increase consistency when firing at very low velocities
3. Install programming material (we used annealed copper, felt, cardboard, and mounting board with various thicknesses and geometries based on convenience for us to build and use)
4. Calibration tests to dial-in gas gun fire chamber pressure to impact velocity
5. Pyroshock calibration series with mock test unit (30-50 shots)
6. Pyroshock series with actual test unit (3-5 shots)





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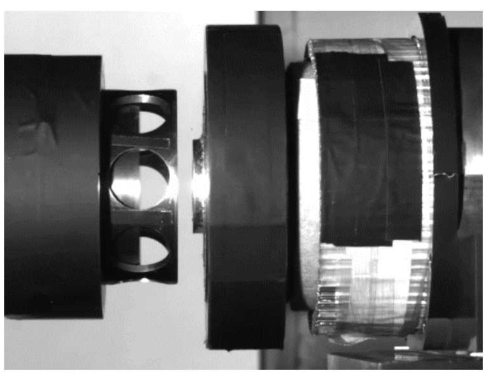
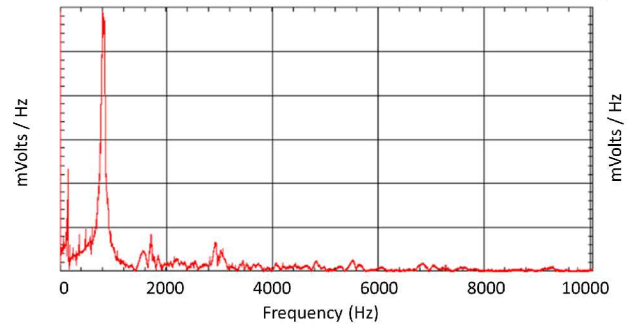
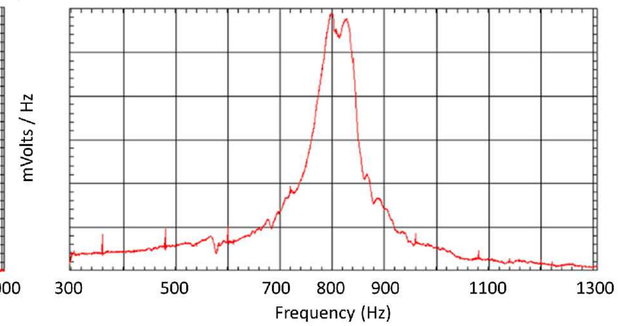


Methods Used to Tailor Pulse to Specification

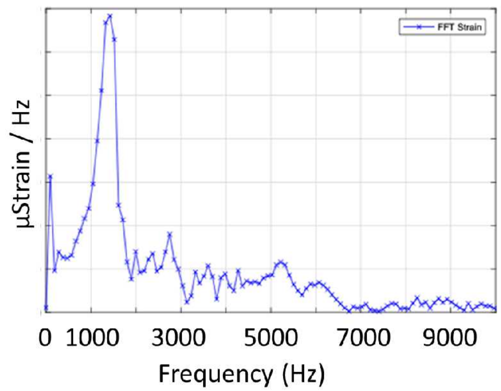
- Copper pulse programmer, felt programmer, mounting board programmer (little effect)
- Different length resonant bar (large effect)
- Various impact velocities (minor effect)
- Customer reconfigured internal hardware based on predicted resonance

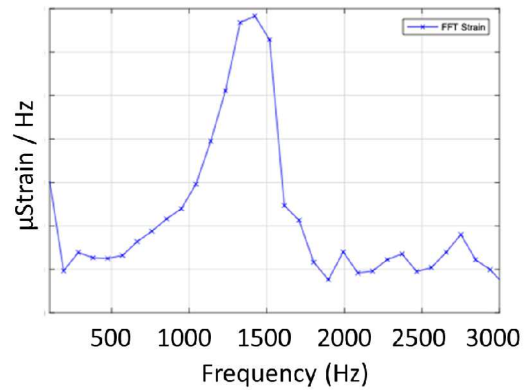




87" Bar and Cone:
Driving Frequency ~ 800 Hz

After redesign to closer approach ~ 1000 – 2000 Hz test spec. knee frequencies

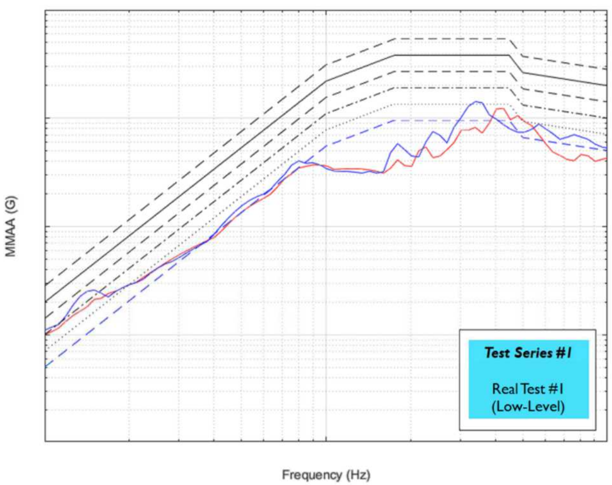


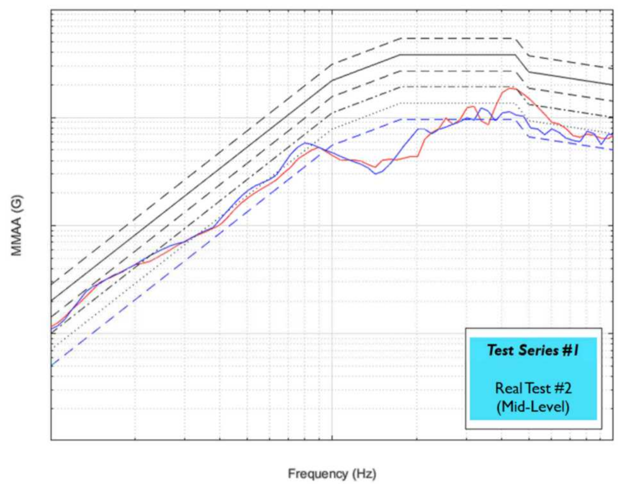


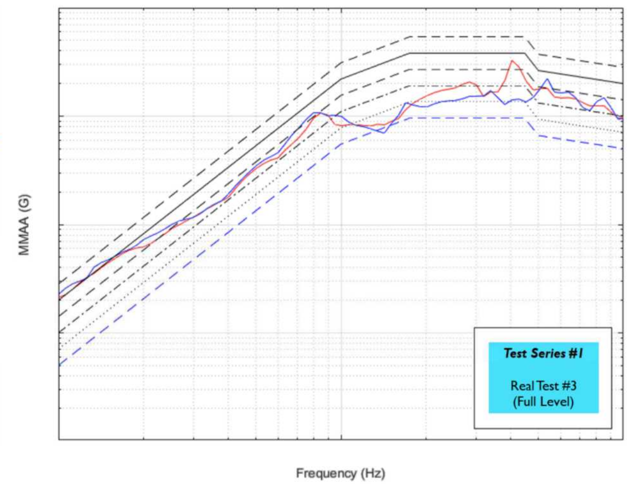
36" Bar and Cone:
Driving Frequency ~ 1400 Hz

Overall Results from Alternative Pyroshock Testing

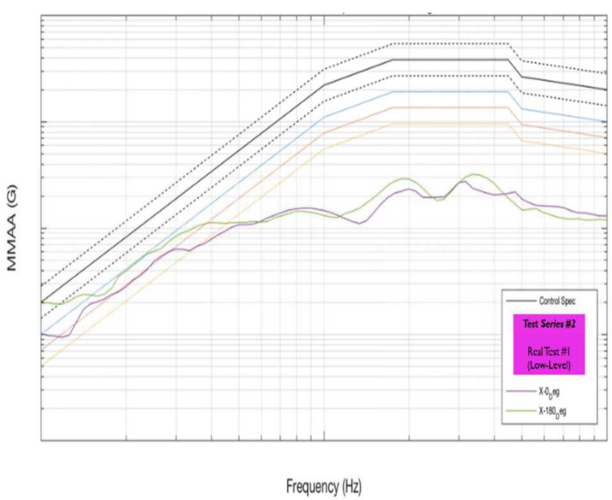
Initial Development Test Series: Low-Level, Mid-Level, and Full Level

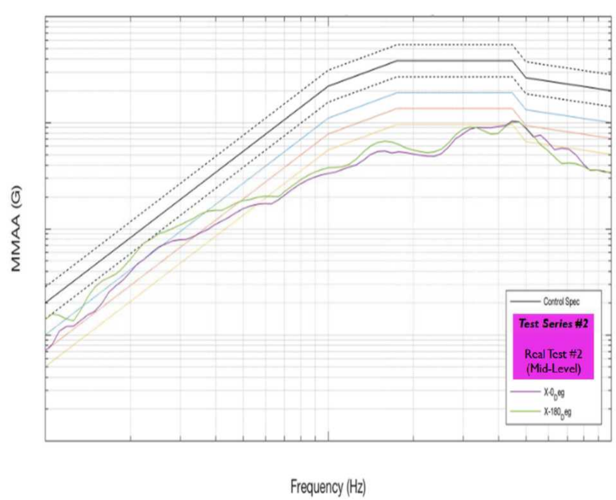


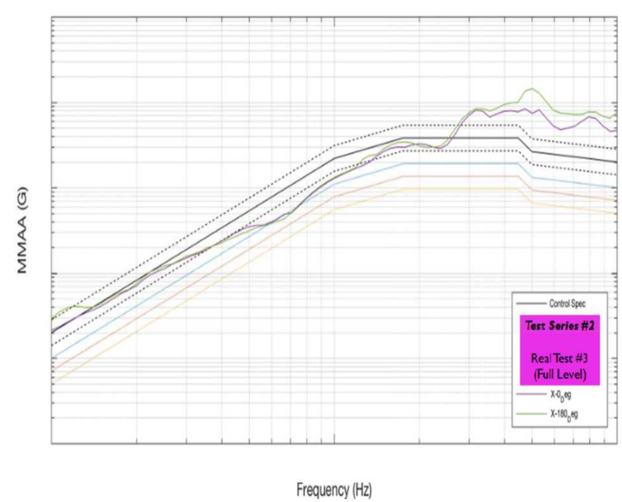




Second, More Refined Test Series: Low-Level, Mid-Level, and Full Level







Challenges and Future Improvements

Challenges:

- Hitting new test levels without a large calibration effort
- Ability to move the SRS curve through programming material are limited
- Test setup is not easily changed between one bar size to another

Future Improvements:

- Run simulations in advance to better predict expected results
- Conduct additional characterization tests to better understand the effects of the following:
    - Projectile length / weight
    - Resonant bar length / frequency
    - Bolted interfaces (i.e. multiple resonant bars to change length in a modular fashion)
    - Programming materials
    - Small-scale tests with various test article sizes, weights, geometries

Thank you!   Questions?

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