Comparison of Direct Acoustic Impingement of Avionics Equipment to Vibration Base Shake Response

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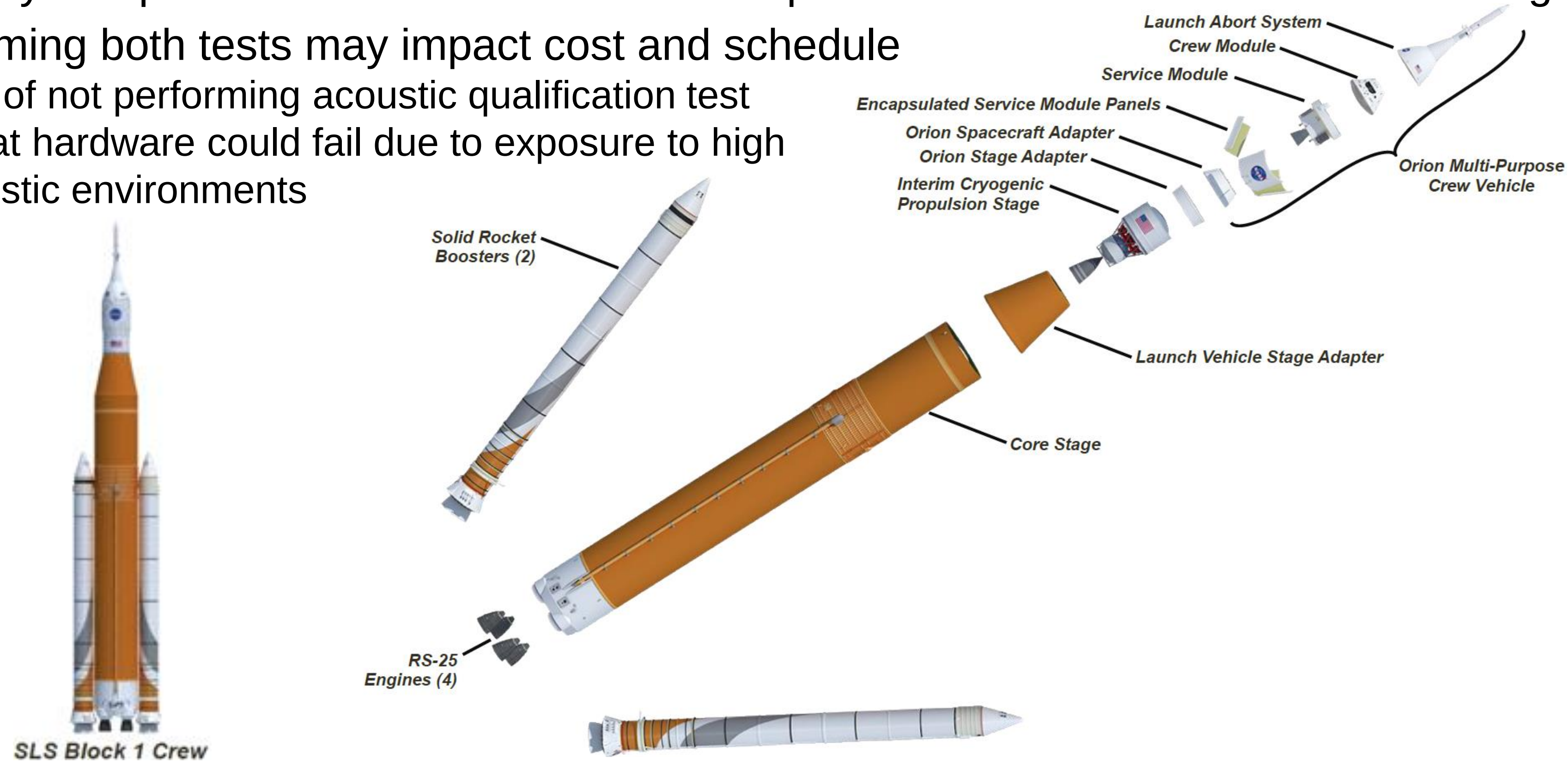
Spacecraft and Launch Vehicle Dynamic Environments Workshop
20-22 June 2017

Agenda

- Background
- Problem Statement
- Test and Observations
- Conclusions and Future Work

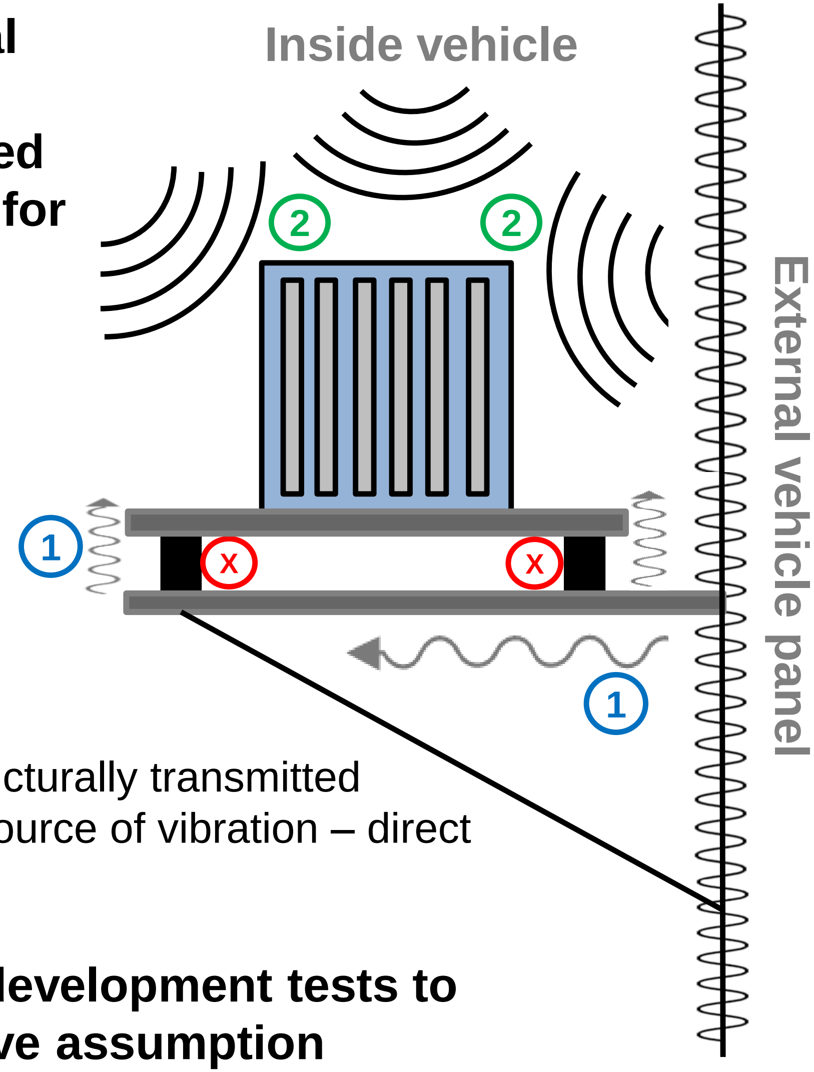
Space Launch System (SLS)

- Space Launch System (SLS)
  - NASA's future manned Mars launch vehicle
- Launch vehicle developers may put components on isolators inside the vehicle
  - For example, heritage hardware being used in new flight environments
- Typically components mounted on isolators require both vibration and acoustic testing
- Performing both tests may impact cost and schedule
  - Risk of not performing acoustic qualification test is that hardware could fail due to exposure to high acoustic environments



Direct Acoustic Impingement Concern

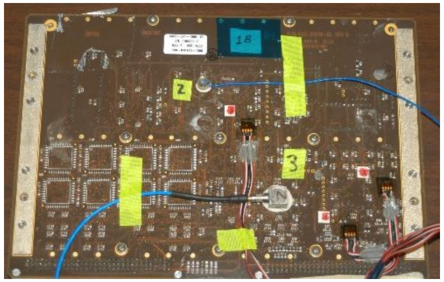
- **Vibration was assumed to be from external panels which is structurally transmitted through isolator mounts. This was assumed to be the predominant source of vibration for components.** 1
  - This assumes effect of direct acoustic impingement on components is not the predominant source of vibration 2
  - This assumption is generally valid for ***non-isolated*** components
  - However, isolation significantly mitigates structural transmission of vibration X
    - Acoustic impingement may then be the predominant source of vibration 2
  - For isolated components, only considering structurally transmitted vibration ignores the potentially predominant source of vibration – direct acoustic impingement

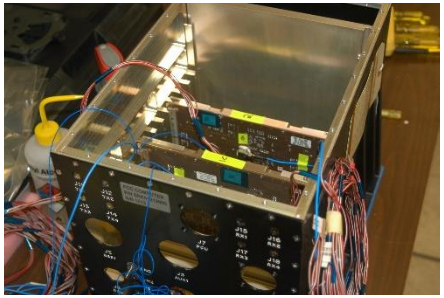


- **NASA Marshall Engineering conducted development tests to investigate this possibly non-conservative assumption**

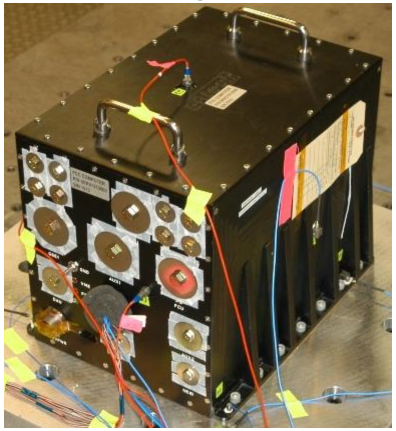
Test Background

- Three avionics boxes representative of launch vehicle components were put through an acoustic test series
  - Internal circuit boards and chassis were instrumented with accelerometers and strain gauges to measure vibration response
  - Small box is heritage SRB flight hardware
- Then each box was vibration tested on a shaker table
- Allowed for comparison of response data between the acoustic test and vibration shaker table test responses
- Strain gauge data allowed for insight to subcomponent load factor development





Large



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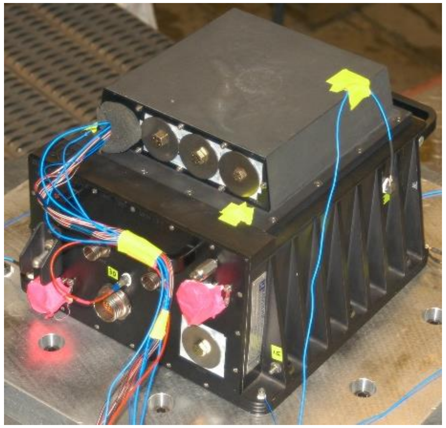
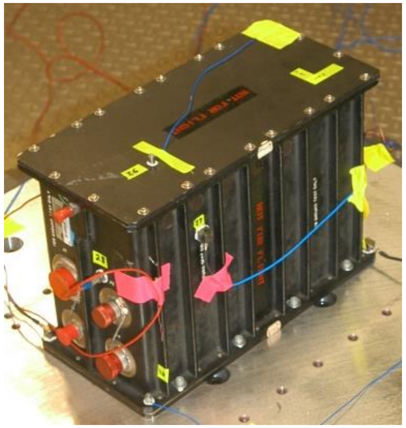


Small



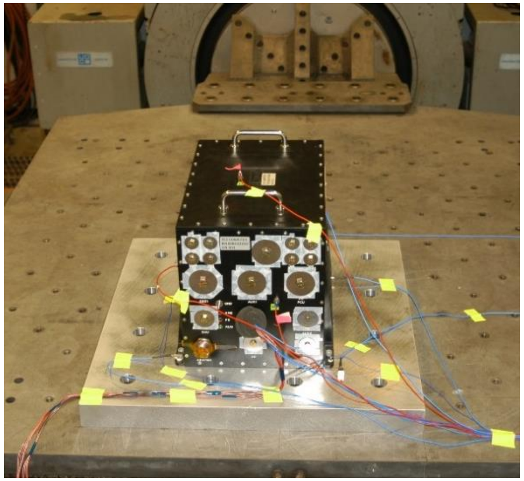
Vibration Testing

Vibration levels

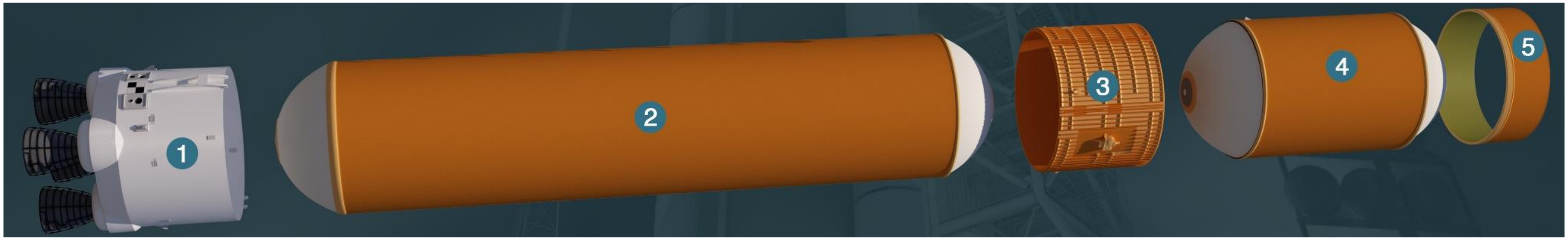
- Criteria 1 and 2 were generic test levels that were representative of compartment levels
- Criteria 3 was derived from SMC-S-016 minimum acceptance test +3 dB

Vibration responses

- Data collected for all 3 axes, however, data shown are only responses normal to circuit boards
- Same locations as acoustic test



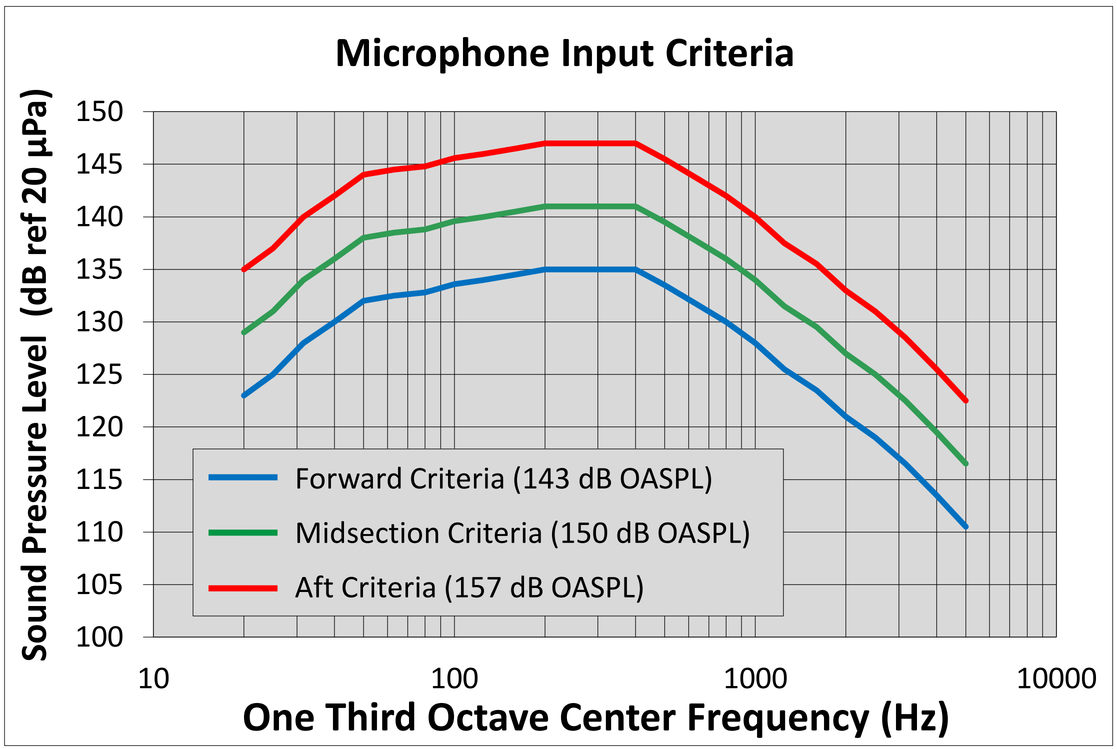
Vehicle Zone	Vibration Test Cases
Forward 5	Criteria 1, Criteria 3
Midsection 3	Criteria 1, Criteria 2, Criteria 3
Aft 1	Criteria 1, Criteria 3

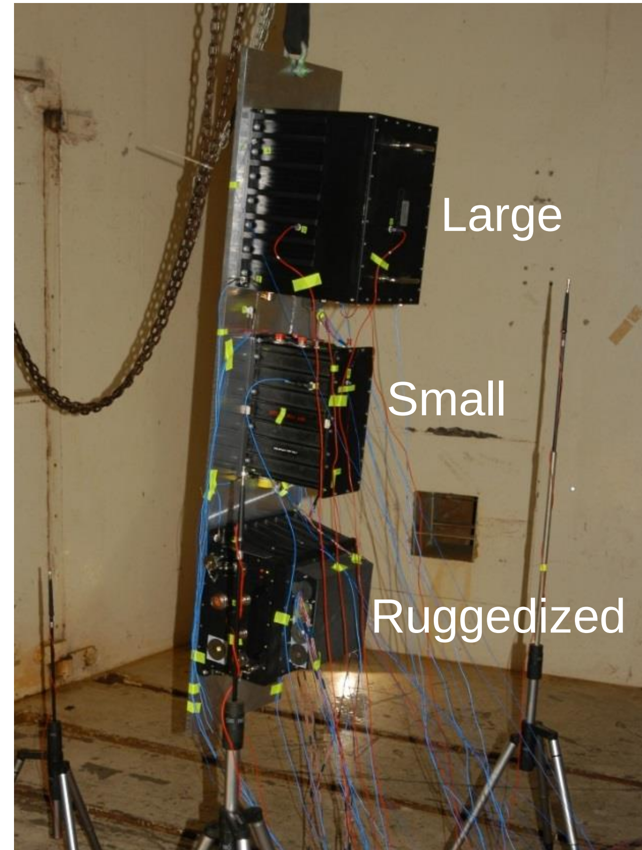


Acoustic Testing

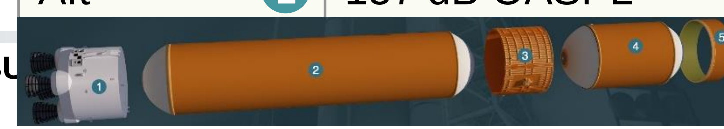
Acoustic levels

- 6 OASPL test cases: 140 dB, 143 dB, 147 dB, 150 dB, 153 dB, 157 dB
- Levels chosen representative of three sections of where launch vehicle avionics are located (Forward, Midsection, Aft)
- Panel dimensions: 60” x 14.25” x 0.7” aluminum





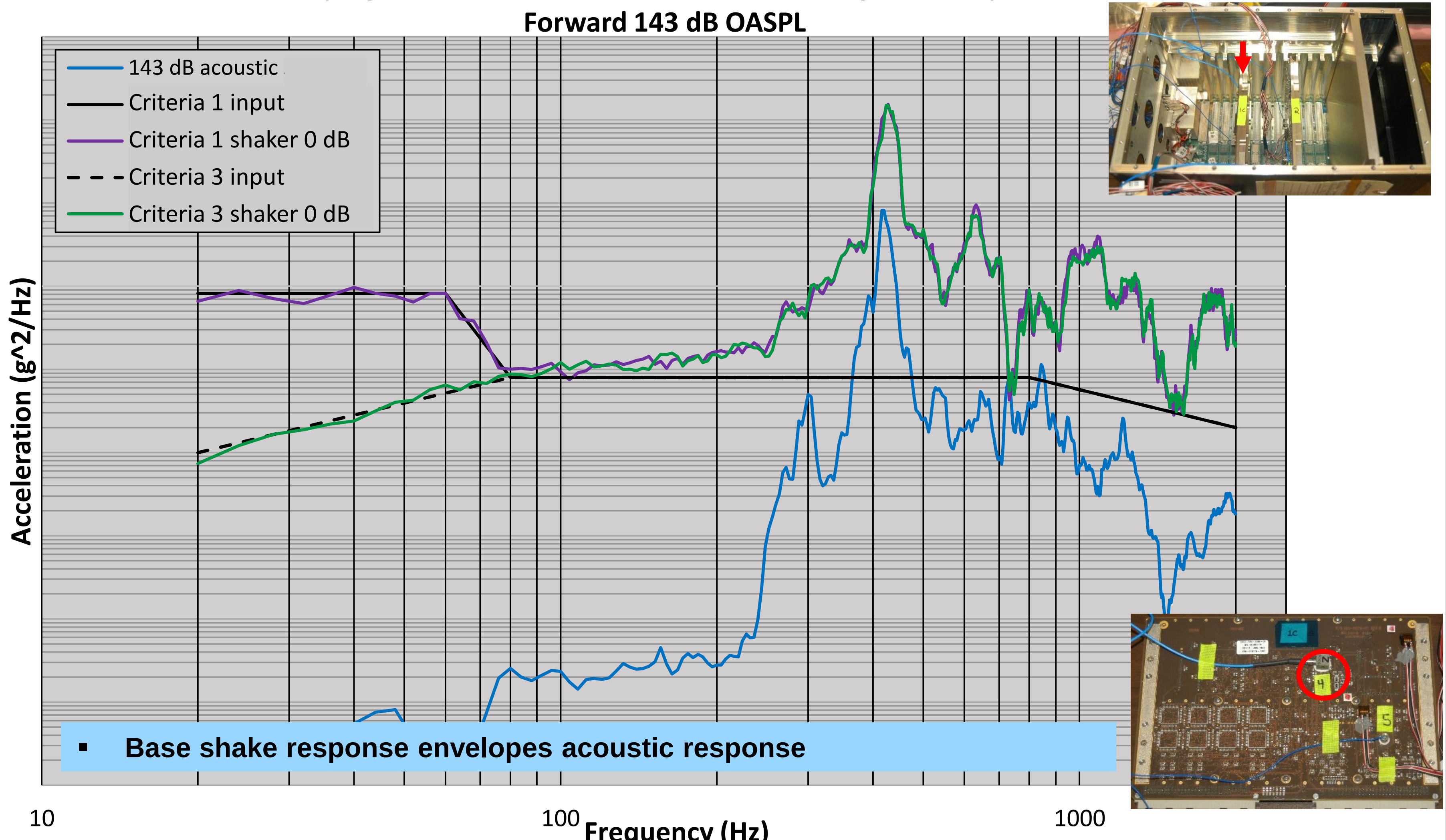
Vehicle Zone	Acoustic Test SPL
Forward 5	143 dB OASPL
Midsection 3	150 dB OASPL
Aft 1	157 dB OASPL



Test and Observations

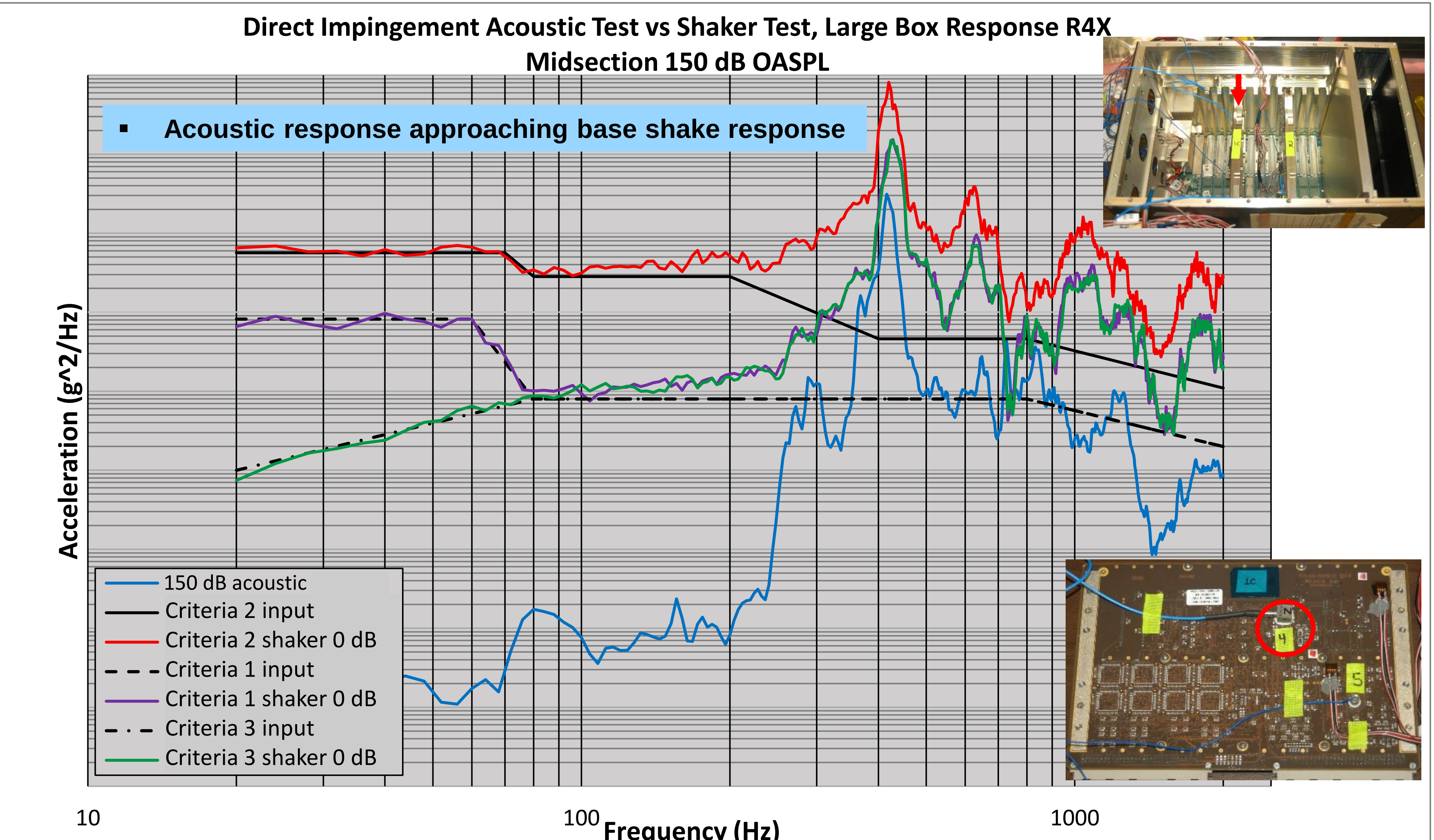
Forward (143 dB): Accelerometer R4X

Direct Impingement Acoustic Test vs Shaker Test, Large Box Response R4X
Forward 143 dB OASPL



(Data is typical response from all three boxes)

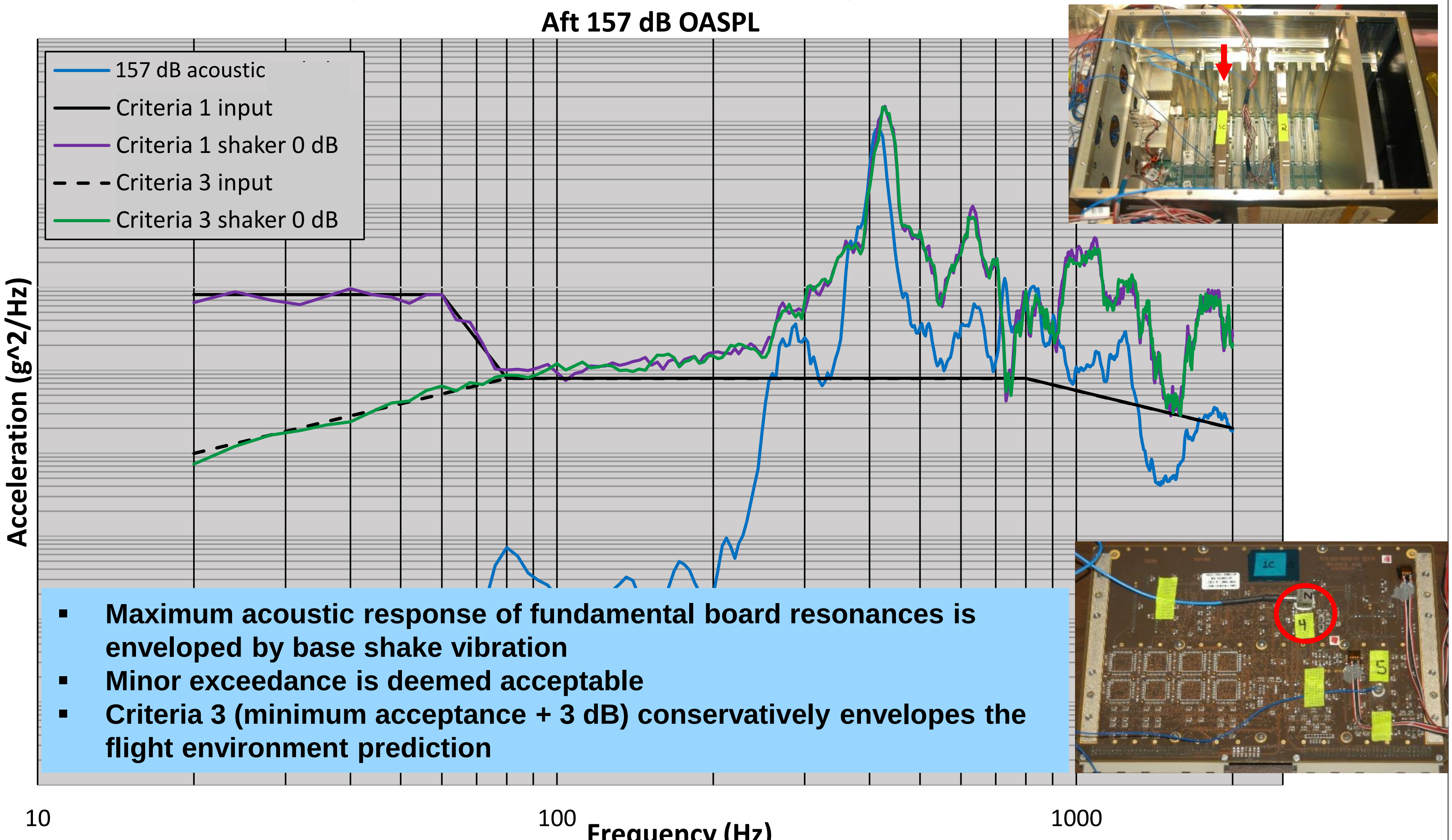
Midsection (150 dB): Accelerometer R4X



(Data is typical response from all three boxes)

Aft (157 dB): Accelerometer R4X

Direct Impingement Acoustic Test vs Shaker Test, Large Box Response R4X
Aft 157 dB OASPL



- **Maximum acoustic response of fundamental board resonances is enveloped by base shake vibration**
- **Minor exceedance is deemed acceptable**
- **Criteria 3 (minimum acceptance + 3 dB) conservatively envelopes the flight environment prediction**

(Data is typical response from all three boxes)

Conclusions and Future Work

Conclusions:

- Acoustic and vibration shaker table accelerometer responses were assessed and compared
- Test data showed base shake vibration response envelopes acoustic induced vibration response in Forward & Midsection zones
- Aft zone acoustic responses greater than vibration response at some higher frequencies; however, there is still adequate margin in test criteria

- **Structurally transmitted vibration is still the predominant source of vibration for isolated components of comparable size and construction as those tested in this series for acoustic levels up to ~157 dB OASPL**

General recommendation:

- Include a minimum random vibration criteria for qualification of *isolated hardware* on future programs to avoid acoustic qualification tests

Future Work:

- Analyze strain gauge data gathered in this testing to aid in FEM correlation of avionics

Backup

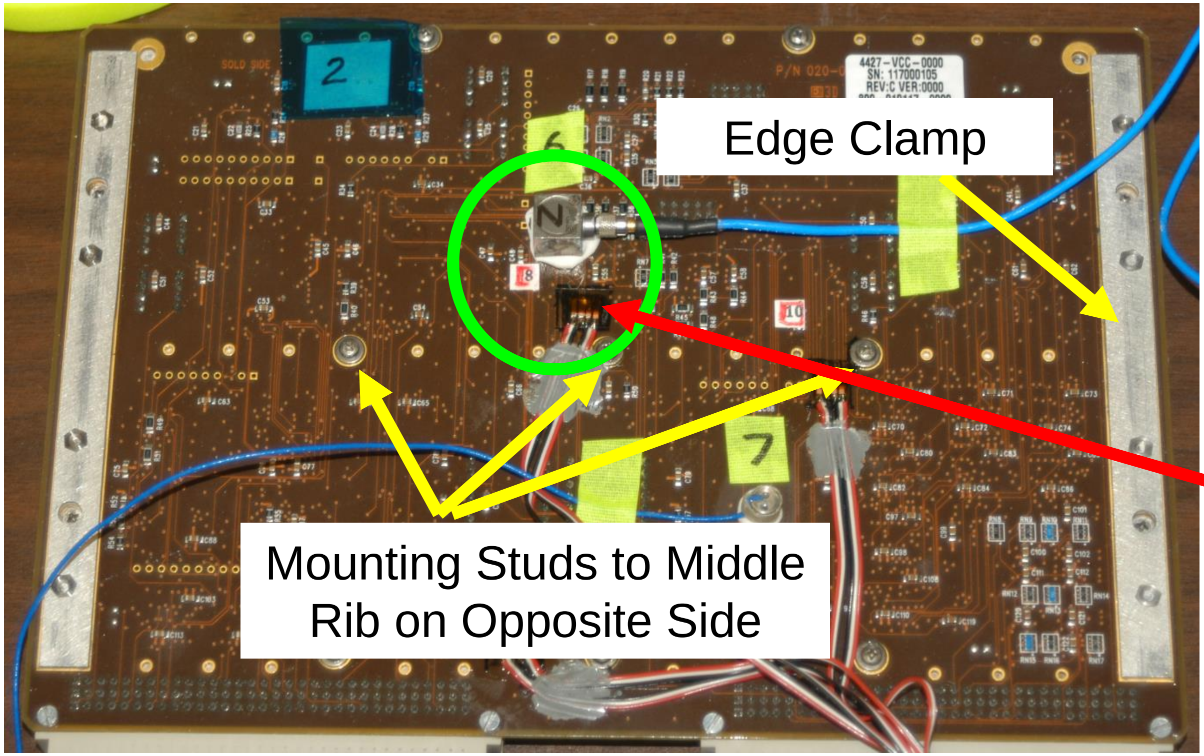
Strain Gauge Response Measurements

Strain measurements were collected on the boards at key interface locations

- Key interface locations were considered near a mounting stud or edge clamp

Vibration responses were also measured on the boards

- Measurement locations were taken near the center of the boards



Two orthogonal strain measurements

Strain Gauge Response Measurements

- Preliminary results reveal same correlation of cumulative RMS velocity and RMS strain as seen with larger secondary structures
- Forward work is to further interrogate board measurements and bring back design insights to 2018 SCLV
- Any analysis request from the community are welcome

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Thank you