34th ATS 2025

Advancements and Current Status of Direct Field Acoustic (DFA) Testing Since Inception

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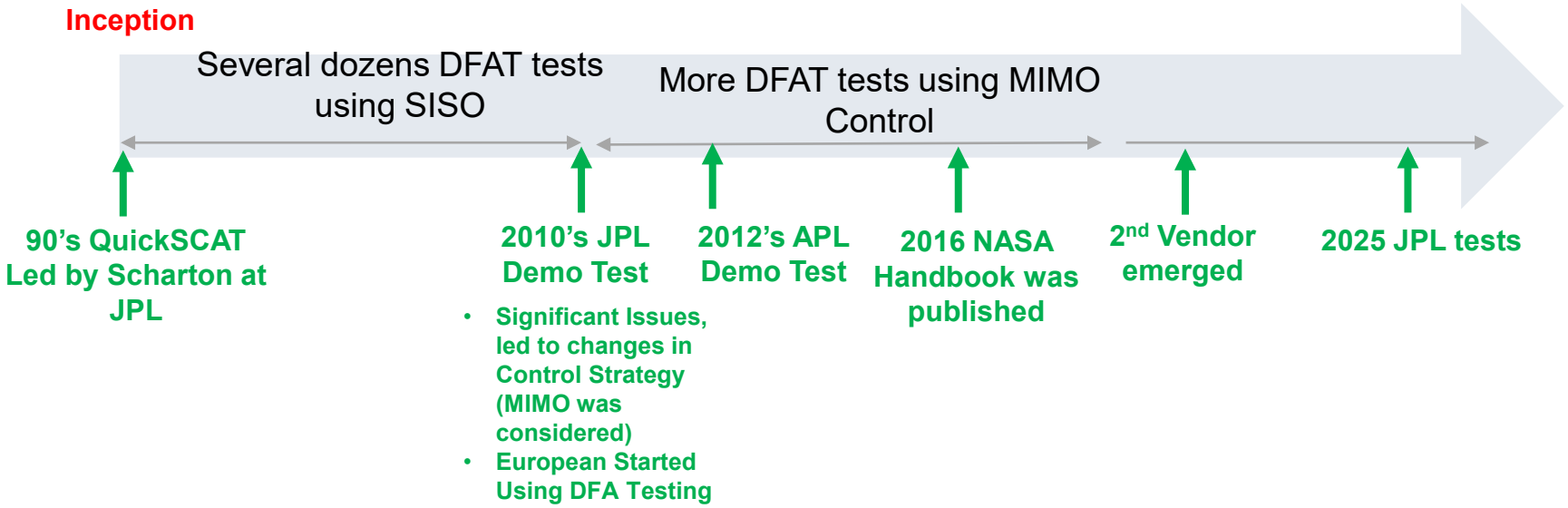
April 1th to 3rd, 2024

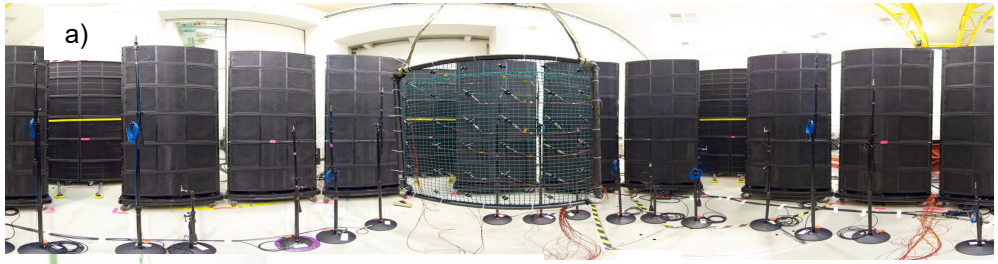
Jet Propulsion Laboratory
California Institute of Technology

INTRODUCTION (DFA Testing History)



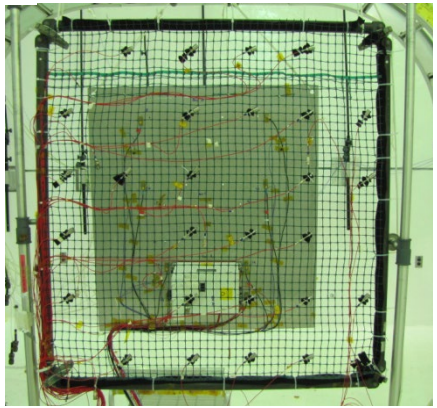
JPL DFAT Test (2009), 1/4

a)



b)

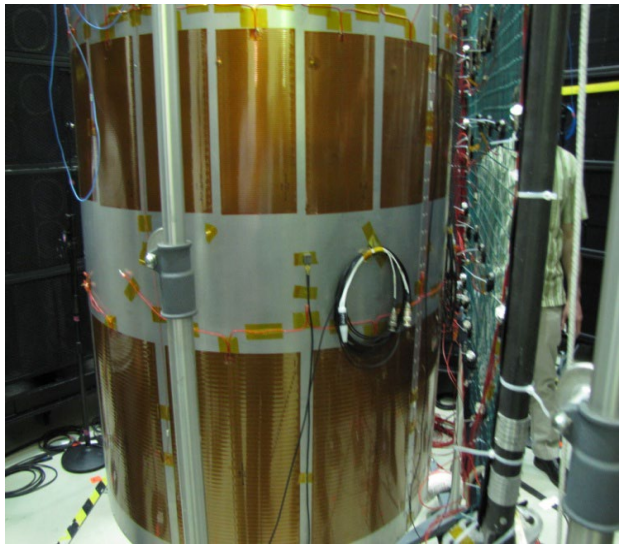
c)



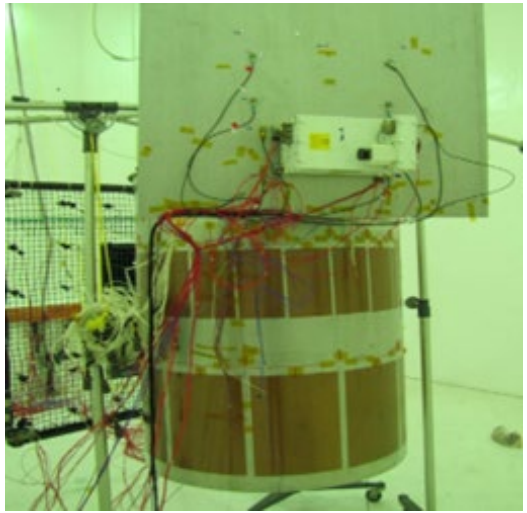
(a) Speaker and woofer arrangement captured with a wide-angle camera, (b) speaker testing volume used in JPL tests, and (c) microphone array setup

JPL DFAT Test (2009), 2/4

a)



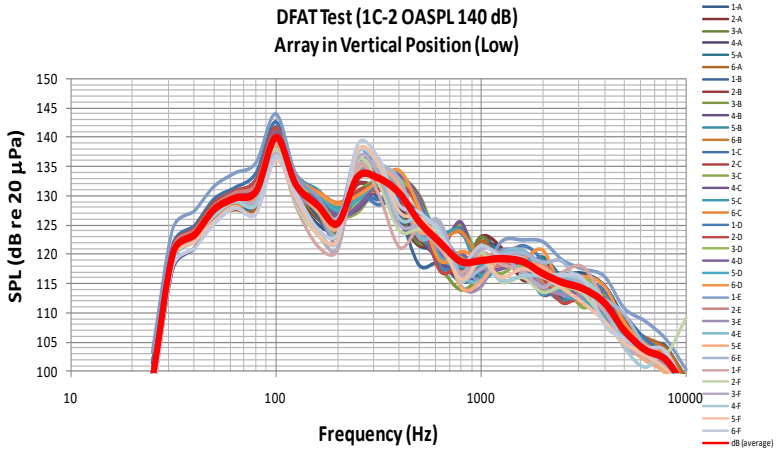
b)



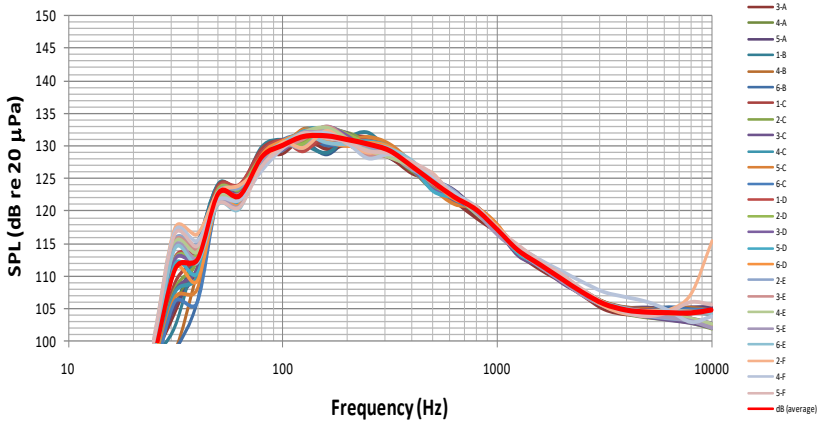
Aluminum panel with an electronics box and force gauges installed at the box/panel interfaces. A 3-ft cylindrical test article was also positioned within the speaker array for DFA testing (a) and later tested in JPL's reverberant chamber (b).

JPL DFAT Test (2009), 3/4

a)



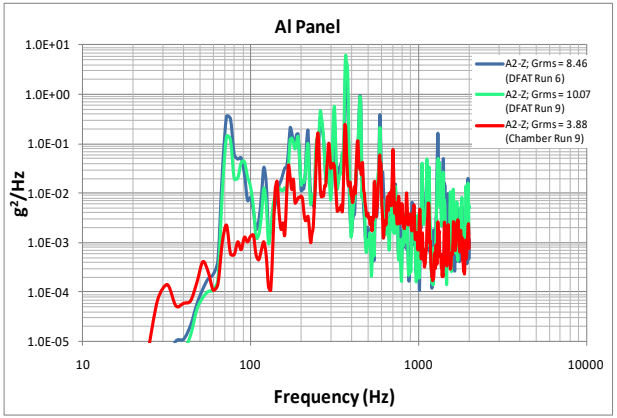
b)



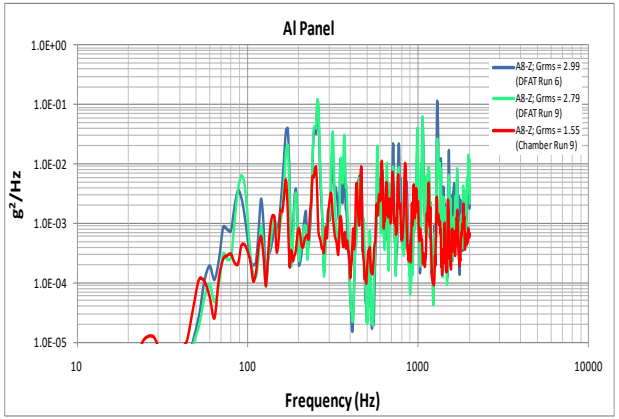
- SPLs measured in DFA (a) and RFA (b) tests. The average SPL across all microphones in the array is also shown. The array was positioned identically with respect to the test articles in both tests
- Two pronounced modes (standing waves) were observed at ~100 Hz and ~250 Hz

JPL DFAT Test (2009), 4/4

a)



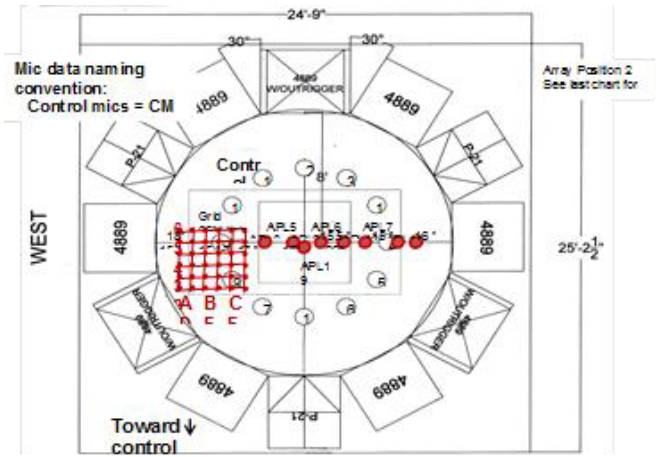
b)



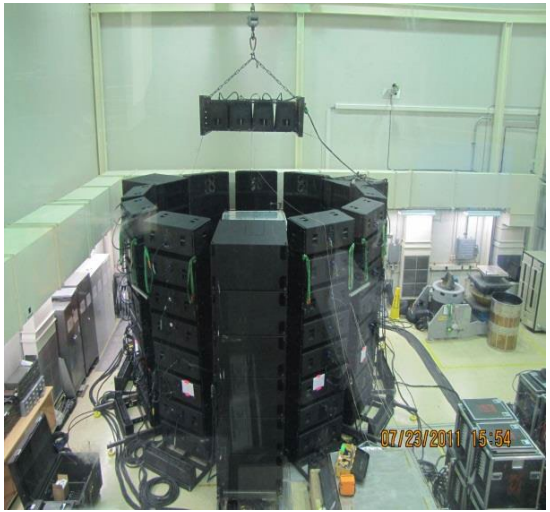
- Structural acceleration responses measured at two locations in DFA testing (green and blue curves) and RFA testing (red curves).
- Clear differences between the two test methods of testing under identical conditions are evident
- These responses led to a serios discussion to move away from SISO control system.

APL DFAT Tests (2011-12), 1/2

a)



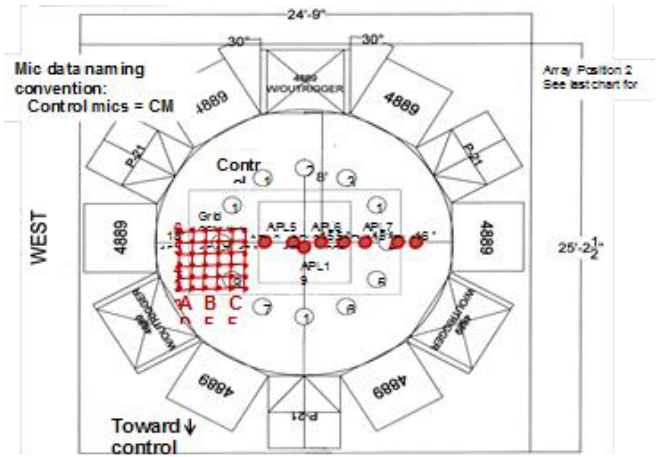
b)



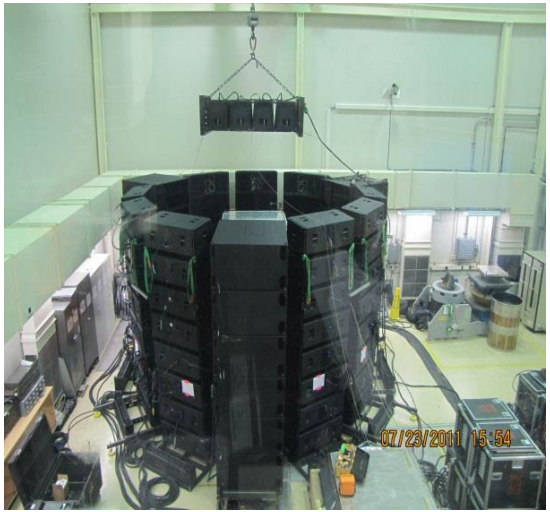
(a) APL speaker and woofer arrangement with control microphones, microphone array, and linear array. (b) Photograph of the APL DFA test setup

APL DFAT tests(2011-12)

a)



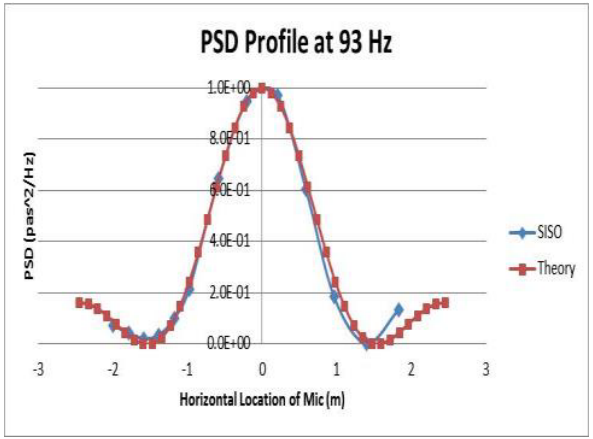
b)



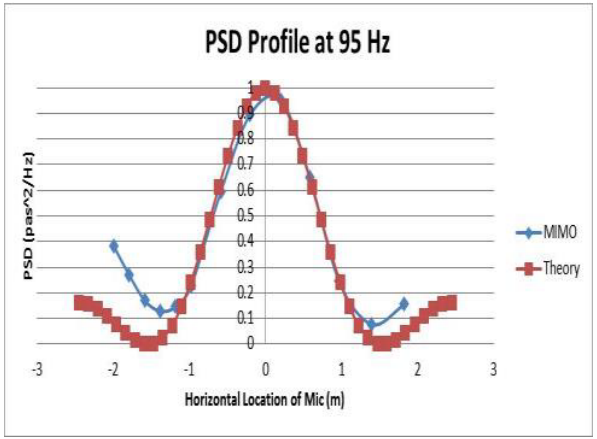
(a) APL speaker and woofer arrangement with control microphones, microphone array, and linear array. (b) Photograph of the APL DFA test setup

APL DFAT Tests (2011-12), 2/2

a)



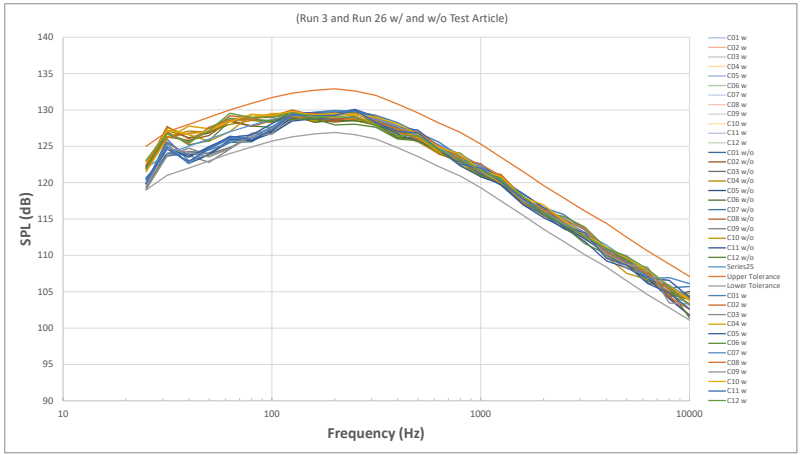
b)



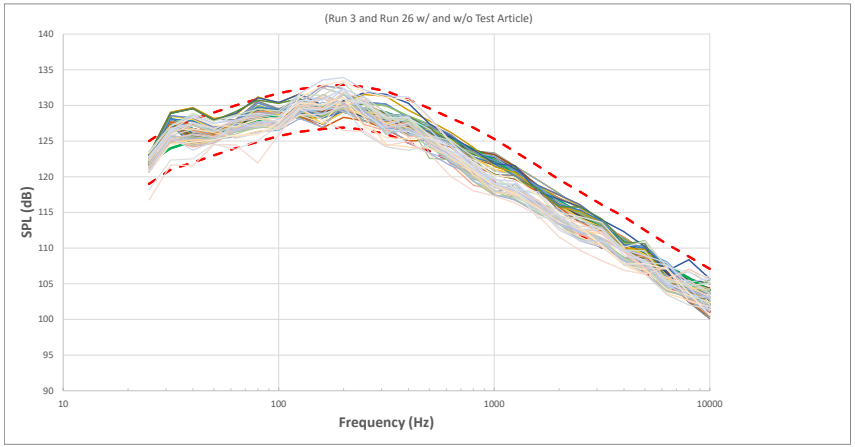
- Predicted radial acoustic mode shape (~93 Hz) correlated with DFA test data obtained using SISO and MIMO control schemes
- Much improvements in SPLs within the DFAT cavity, however still pronounced standing waves

DFA Testing at JPL, 2025, ¼ (Vendor 1)

a)



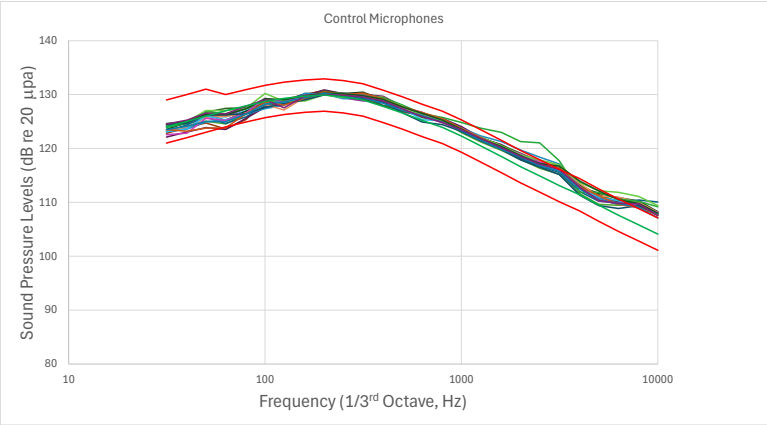
b)



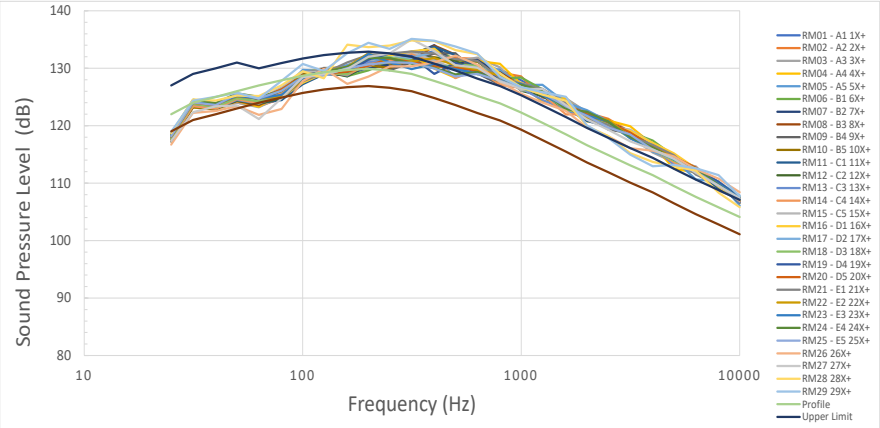
- SPLs measured using control microphones using Vendor 1's test setup. (b) SPLs measured using a microphone array positioned at various locations within the DFA test volume
  - Control SPL Scatter is tights, however below 100 Hz scatter is higher
  - Standing waves are minimized
- Array mic SPLs are scattered more than control mics and are in general lower than nominal SPLs.

DFA Testing at JPL, 2025, 2/4 (Vendor 2)

a)



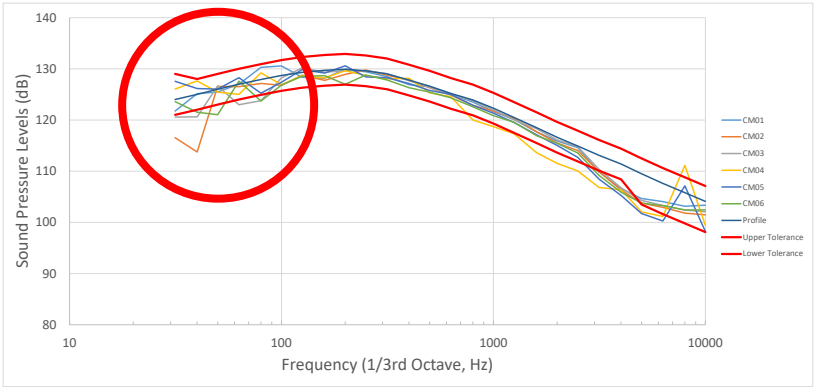
b)



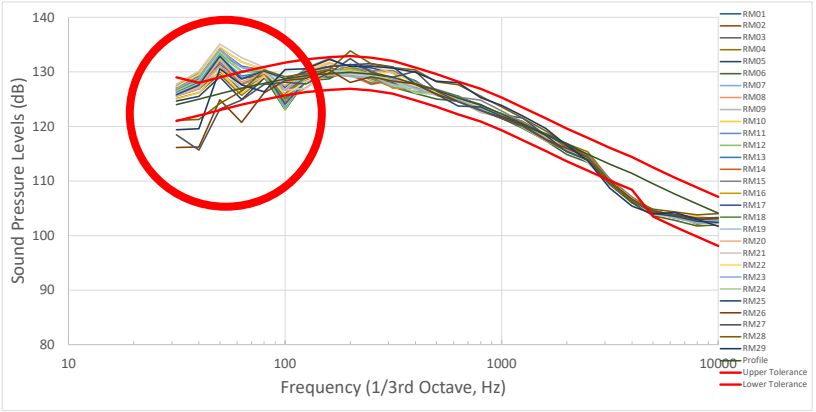
- SPLs measured using control microphones using Vendor 2's test setup. (b) SPLs measured using a microphone array positioned at various locations within the DFA test volume
  - Much tighter control microphone SPLs; above ~1000 Hz the SPLs are on the high side
  - Microphone array SPLs are tighter, but are on the high side of the nominal SPLs

DFA Testing at JPL, 2025, ¾ (JPL Reverberant Chamber)

a)

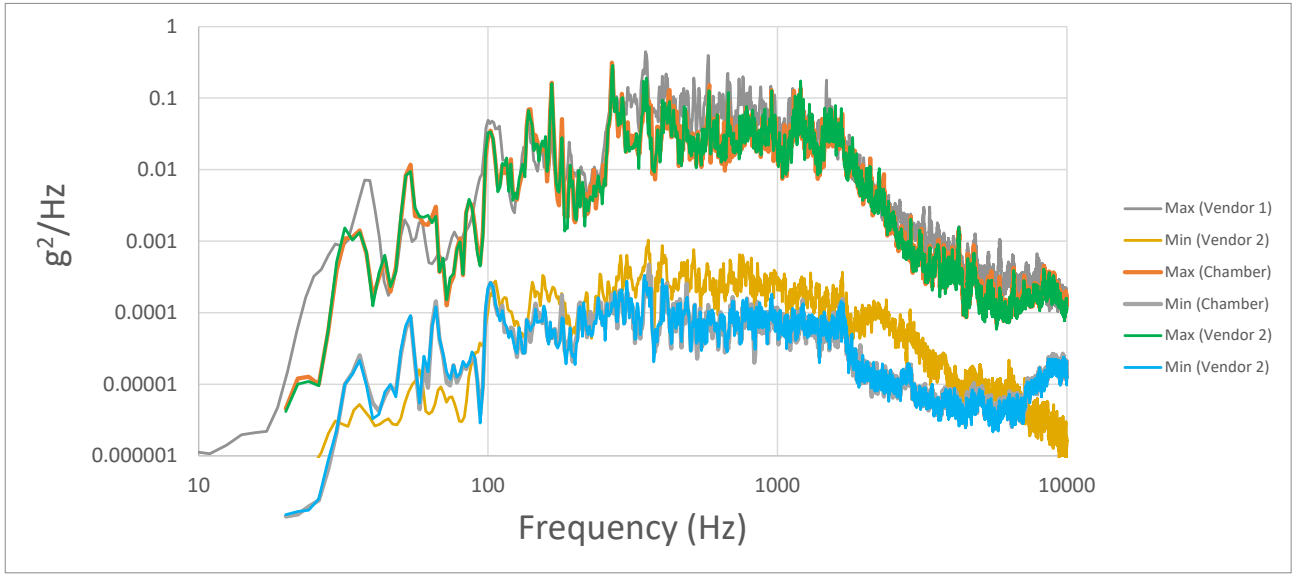


b)



- (a) SPLs measured using control microphones in JPL's reverberant chamber. (b) SPLs measured using the response microphone array.
  - Control and array microphone SPLs much tighter than DFA tests
  - Standing waves below ~150 Hz, DFA tests appears to have minimized this
  - Higher frequency above ~2000 Hz for this chamber SPL does not meet the requirements

DFA Testing at JPL, 2025, 4/4



- Maximum and minimum structural acceleration responses from Vendor 1, Vendor 2, and reverberant chamber tests.
- Even though there are differences in SPLs, the overall responses remain very similar!

Summary

- Since the inception of DFA testing, significant progress has been made in producing sound pressure levels (SPLs) that inspire confidence in using this method to qualify large flight hardware for acoustic environments.
- Advancements in MIMO control systems and speaker technologies since the JPL tests conducted several years ago have significantly improved DFA testing.
  - The SISO control system does not provide acceptable SPLs and should no longer be used by the community.
- One of the most notable improvements is the reduction of acoustic standing waves in DFA test setups when properly controlled, providing a key advantage over chamber testing, where minimizing standing waves remains a significant challenge.
- Another advantage of DFA methods is their ability to generate sound fields at higher frequencies that meet most test requirements, whereas chamber testing may require additional techniques to achieve the same high-frequency coverage.
- **In general a lot of progress has been made**; despite these advancements, a few key questions remain:
  - While chamber sound fields—despite their challenges—are well understood and typically diffuse above the Schroeder cut-off frequency, DFA-generated sound fields may not always provide the necessary level of diffuseness, and scattered sound fields may persist.
    - This will be rigorously assessed once results from these tests are analyzed
- No change in structural response remains a concern, as SPL variations have been observed in some cases without corresponding changes in structural response.
- As part of the ongoing revision of Handbook 7010, one or two key parameters are being considered to ensure consistent sound field and structural response characteristics across different control systems and test setups.
  - The evaluation will include coherence in the radial and vertical directions, as well as the diffuseness of the sound field.
- Data collected from three tests conducted at JPL will be made available to the community.
  - More detailed results, including SPLs and structural responses from these tests, will be provided to benefit the broader community.

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ACKNOWLEDGMENT

- MSI and ASR support for working with the JPL team in setting up and performing the DFA tests at JPL.
    - Special thanks to Michael Van Dyke, Michel William, and his team for conducting the DFA and acoustic chamber tests, as well as to the many others who contributed to the execution of these tests.
- Support of the NASA Engineering and Safety Center Loads and Dynamics Technical Team.

This research was carried at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration (80NM0018D0004).