

Discussion on the Impact of Acoustic Standing Waves on Structural Responses

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JPL

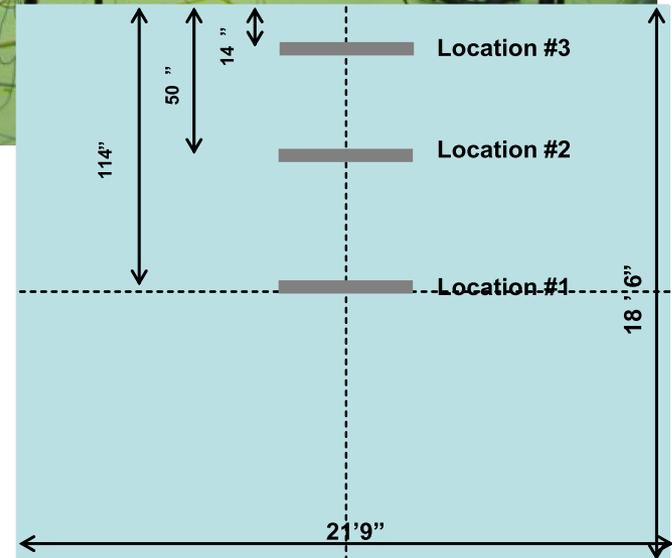
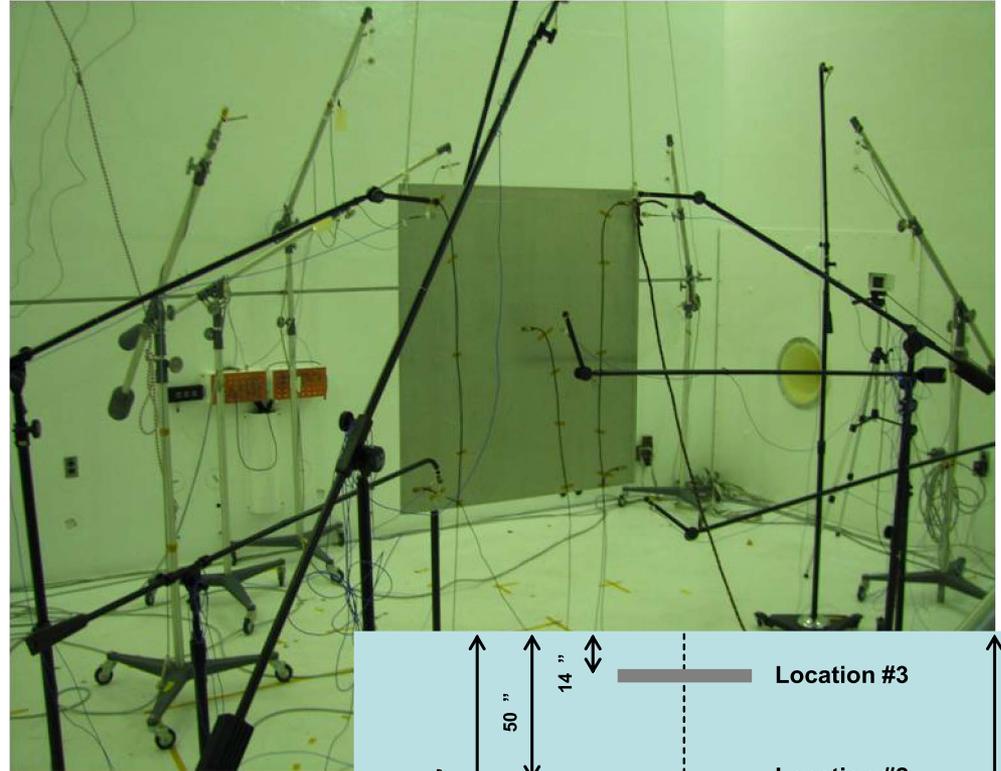
 **AEROSPACE**

OUTLINE

- Light-weight structures are very responsive when their modes are coupled with acoustic standing waves within an enclosure
- Coupling may occur in any enclosures such as
 - *Flight: Acoustic standing waves inside fairings interacting with panels, reflectors, etc.*
 - *Reverberant chambers and direct field acoustic testing of flight and development hardware*
- The coupling phenomenon first considered after a failure occurred during an acoustic flight qualification test; since then the following cases were considered to examine this issue:
 - Flight hardware acoustic tests
 - CloudSat was subjected to PF reverberant chamber acoustic test and a PF direct field acoustic test (Reference: O'Connell and Hausle, SCLV 2005)
 - DAWN Flight Spacecraft was subjected to workmanship reverberant chamber acoustic test and PF direct field acoustic test, and the DAWN HGA was subjected to assembly PF reverberant chamber test (Reference: Kolaini et al., ATS 2009)
 - Aquarius reflector subjected to PF acoustic tests performed in two different size reverberant chambers (Reference: Kolaini et al., ATS 2009)
 - *Al panel forced to couple with acoustic standing waves ((Reference: Kolaini et al., ATS 2009)*
 - *Aquarius DTM reflector has recently gone through acoustic tests in reverberant chamber placed in various locations parallel to chamber walls*
- The coupling phenomenon is further discussed in this presentation with suggestions provided on ways to reduce the structural responses when coupling occurs

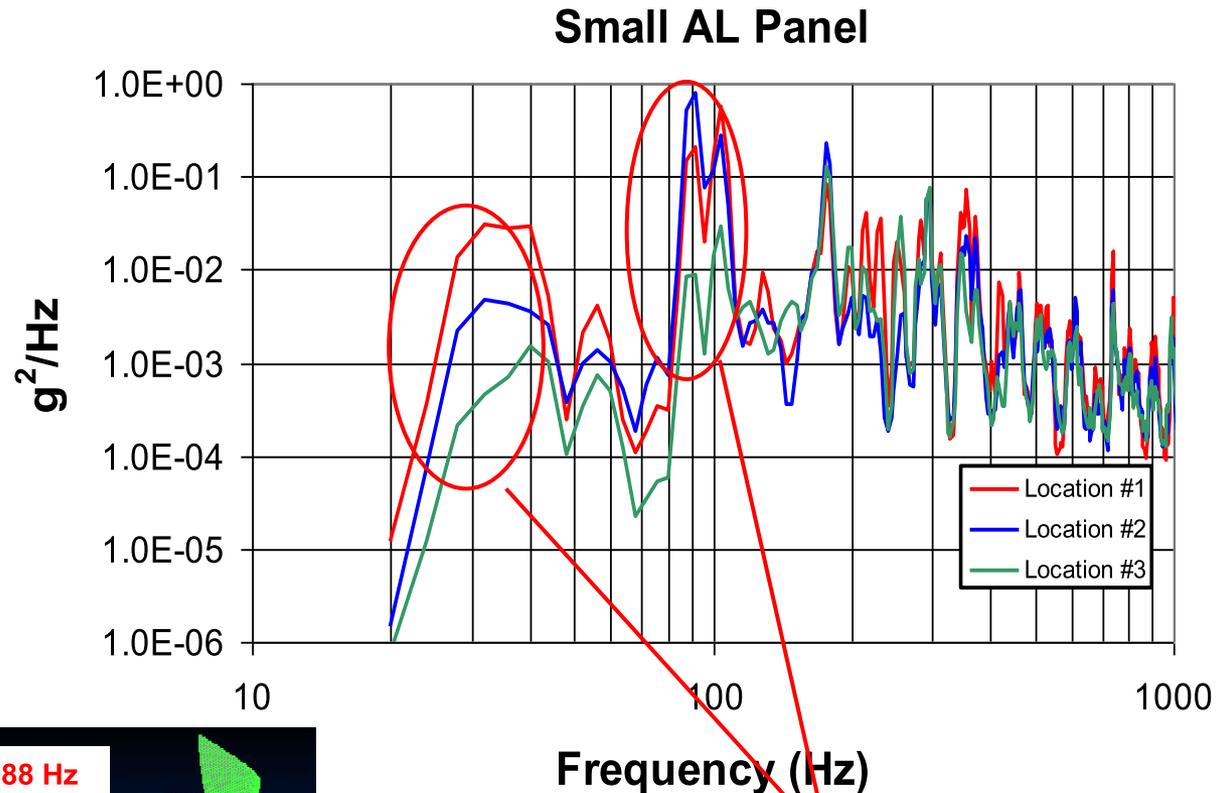
Panel Acoustic Test

- $\frac{1}{4}$ inch 37.5" x 41" AL panel suspended from reverberant chamber ceiling
- Panel was positioned in three locations as shown
- Instrumentation
 - *Eight control mics (stationary)*
 - *Several response microphones, some placed closer to the panel, moved with panel location*
 - *Five accelerometers mounted on panel*
- OASPL: 142.7 dB

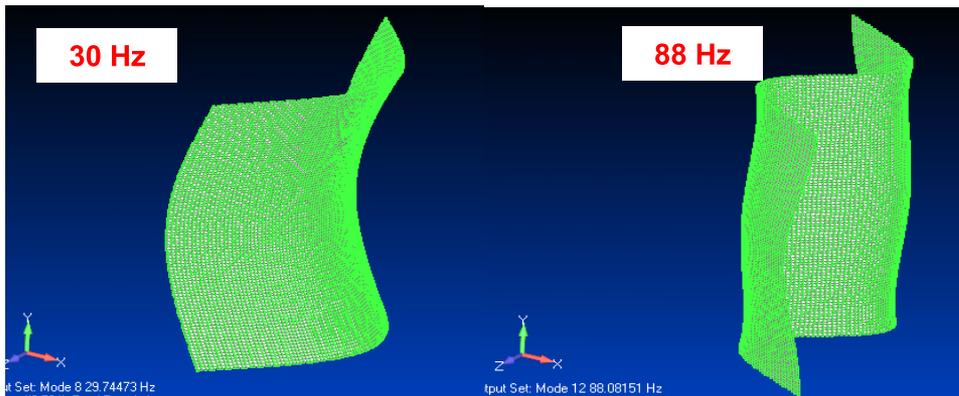


Reverbrant Chamber/Panel Modal Coupling (Panel Responses)

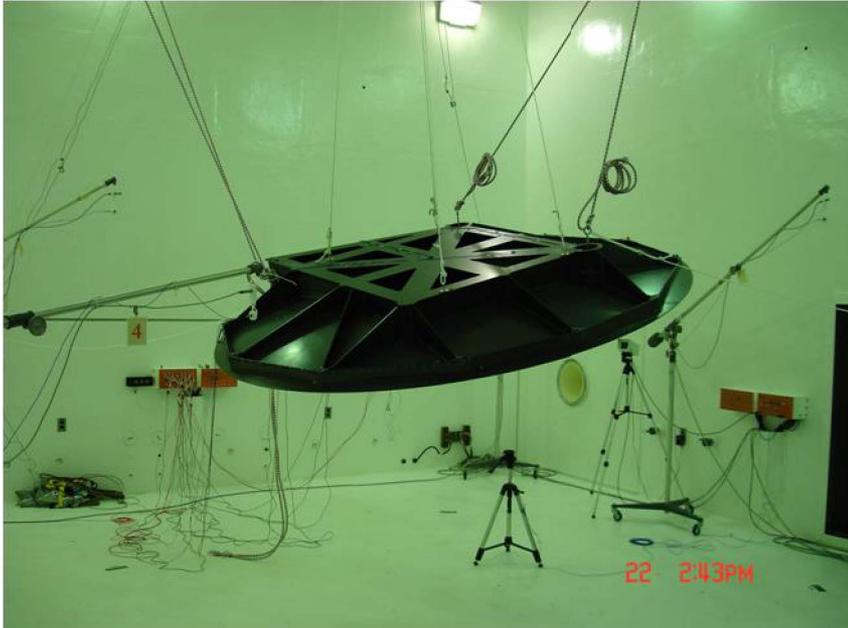
- **Acoustic/Structural Coupled Frequencies:**
 - *~30 Hz and 90 Hz (coupled with chamber mode perpendicular to the panel)*
 - 30 Hz: 10 dB difference in pressure levels and 18 dB in structural responses
 - 90 Hz: ~ 2 dB difference in pressure levels and 20 dB in structural responses
 - *56 Hz and 104 Hz coupled with chamber other modes in two other directions*
 - *Structural responses of the mode at 176 Hz unchanged*



Evidence of chamber acoustic/structural modal coupling phenomenon; more than 20+ dB increase in structural responses @ ~ 90 Hz and 10+ dB @30 Hz



Aquarius Reflector Acoustic Tested in Two Different Chambers



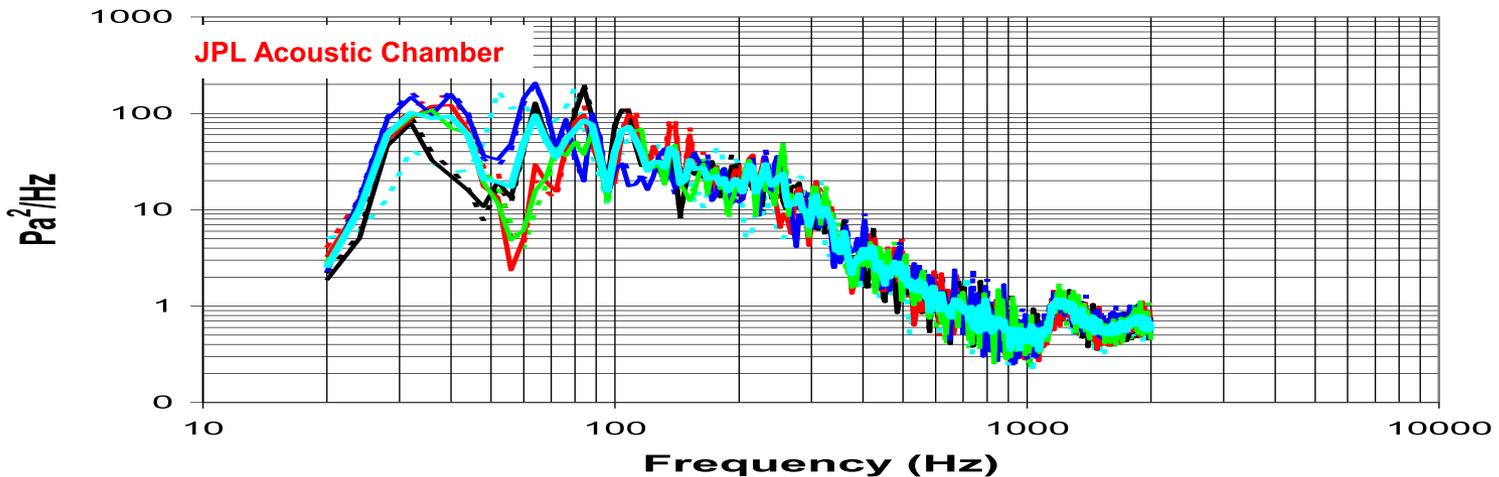
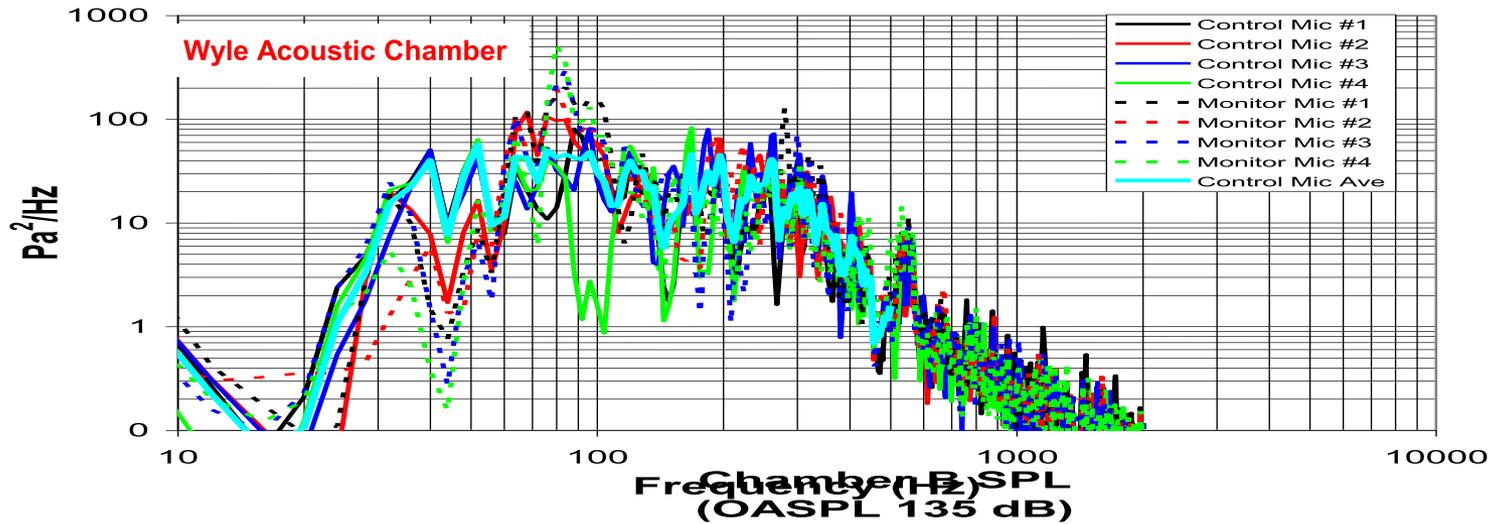
JPL: 21.75'(L)x18.5'(W)x26.5'(H)



Wyle: 18'(L)x14'(W)x10'(H)

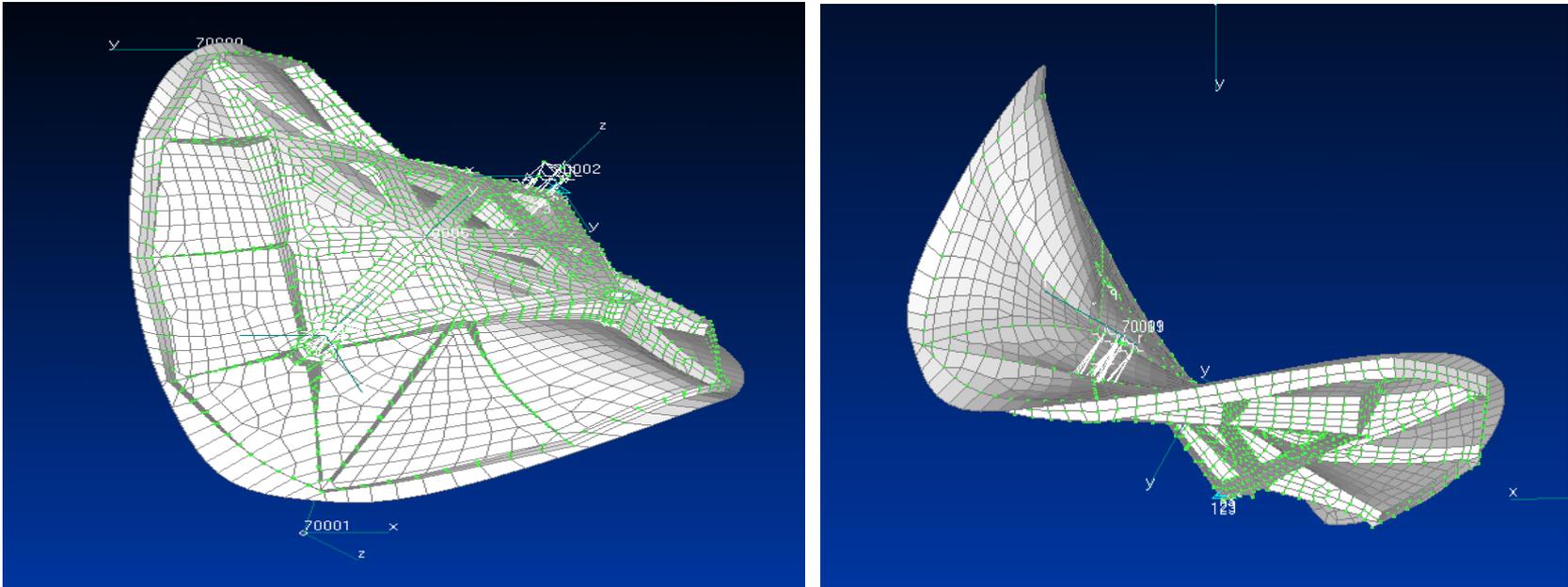
Sound Pressure Spectral Densities in Two Difference Reverberant Chambers

Chamber A SPL
(OASPL 135 dB)



Monitor M
Monitor M
Monitor M
Monitor M
Control M
Control M
Control M
Control M

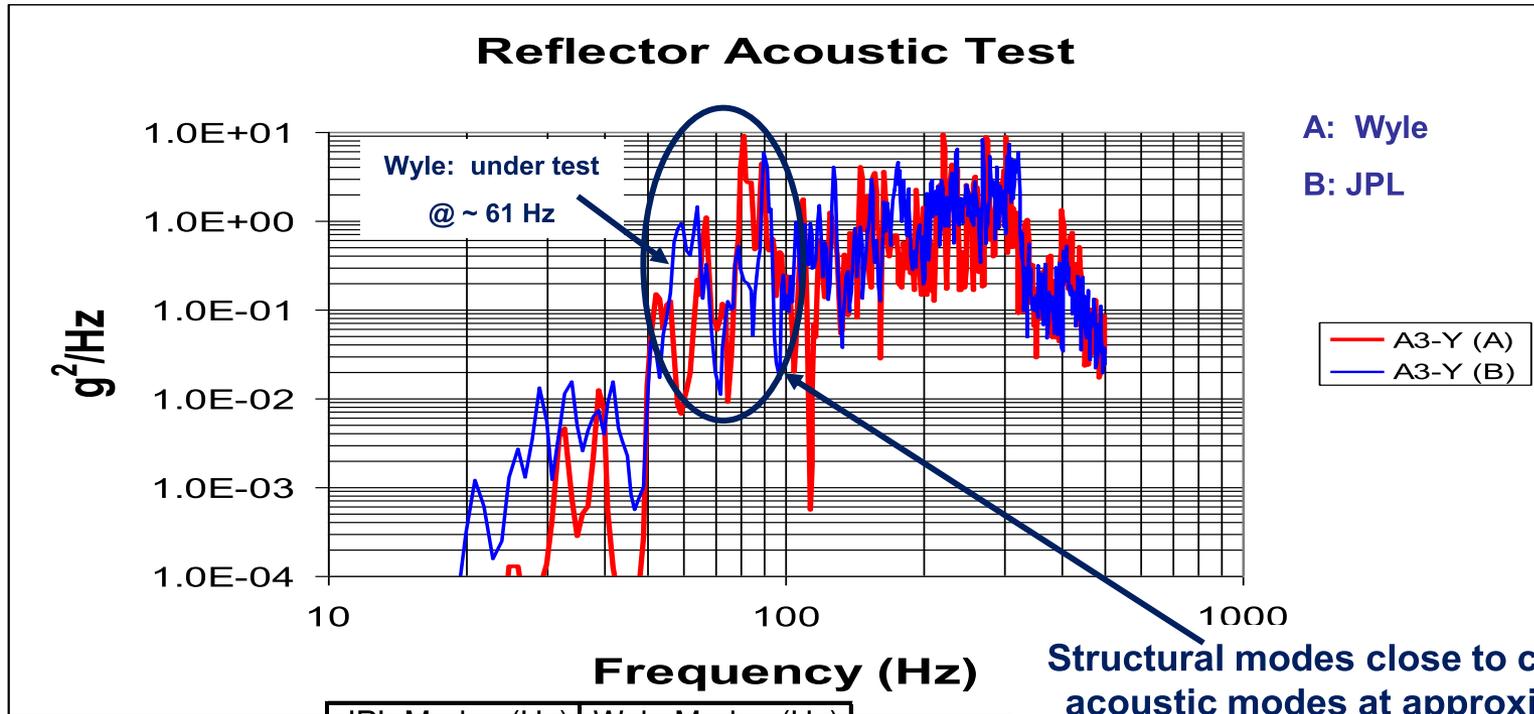
Reflector's Predicted Fundamental mode at ~ 61 Hz (potato chip mode)



This mode strongly coupled with one of the JPL reverberant chamber modes

Aquarius Reflector Acceleration Responses

(JPL and Wyle Test Comparisons)



Structural modes close to chamber acoustic modes at approximately 61 Hz, 64 Hz (JPL) and 81 Hz (Wyle)

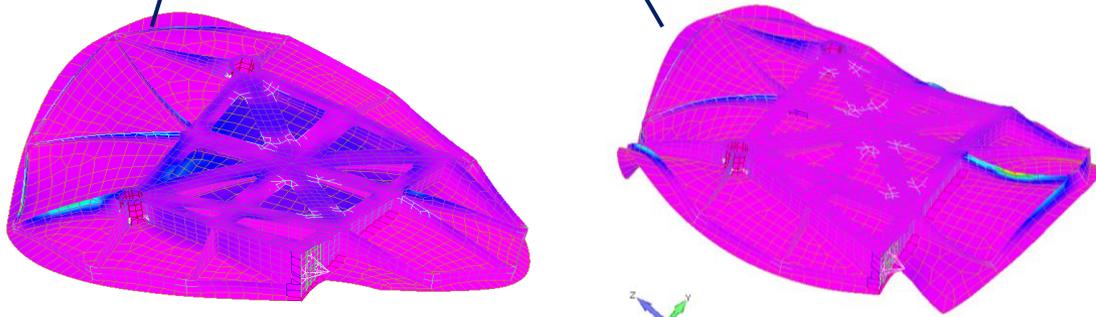
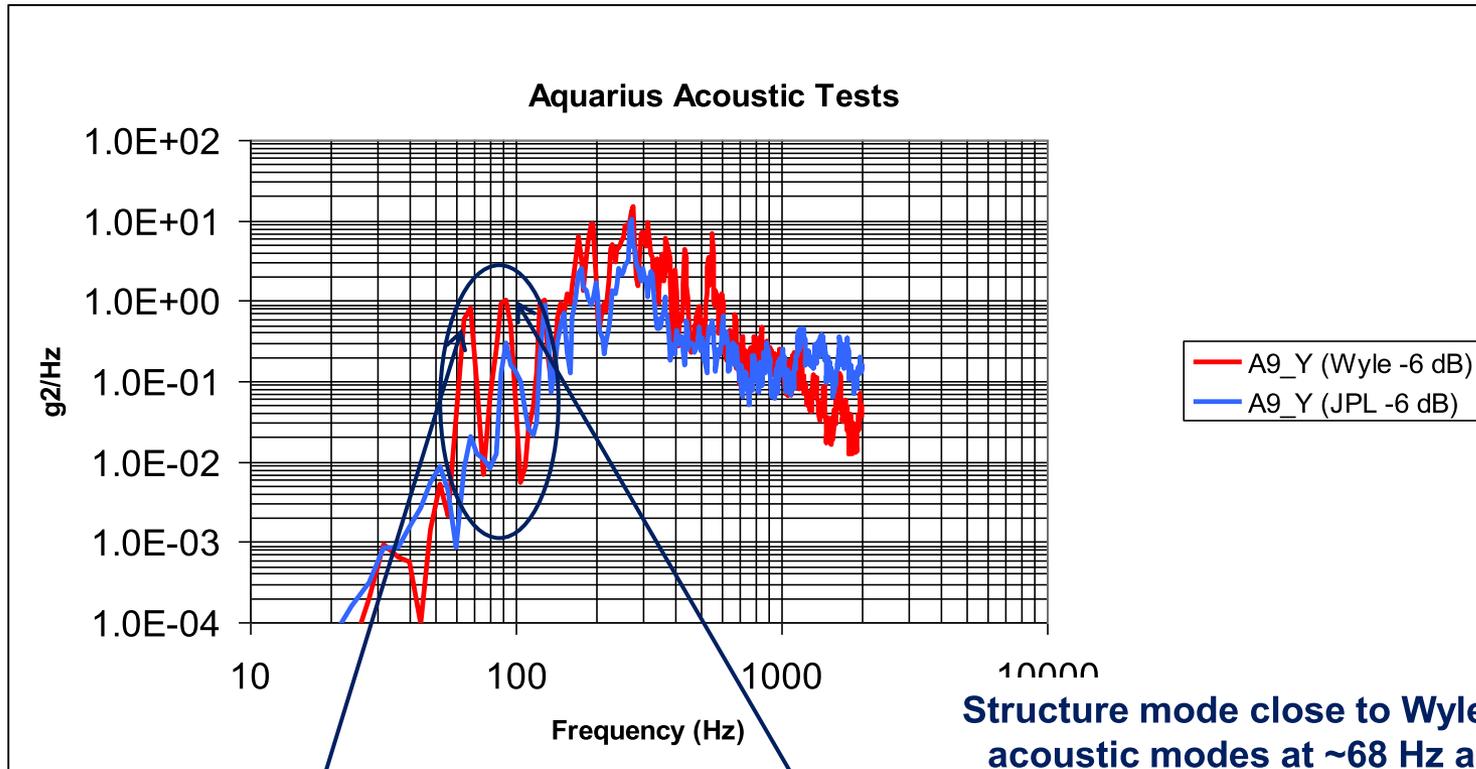
JPL chamber acoustic modes coupled with reflector's modes

JPL Modes (Hz)	Wyle Modes (Hz)
21	28
26	36
29	51
42	57
51.5	73
57	85
63	102
77.5	109
86	153

Wyle chamber acoustic modes coupled with reflector's modes

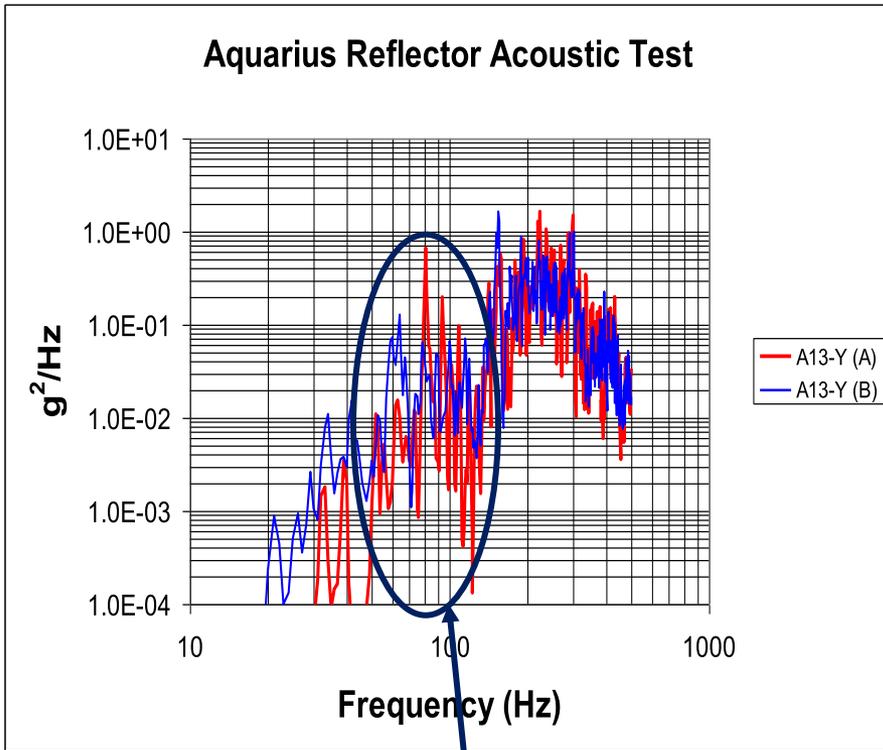
Aquarius Reflector Acceleration Responses

(JPL and Wyle Test Comparisons)

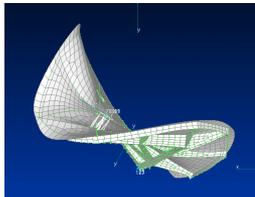
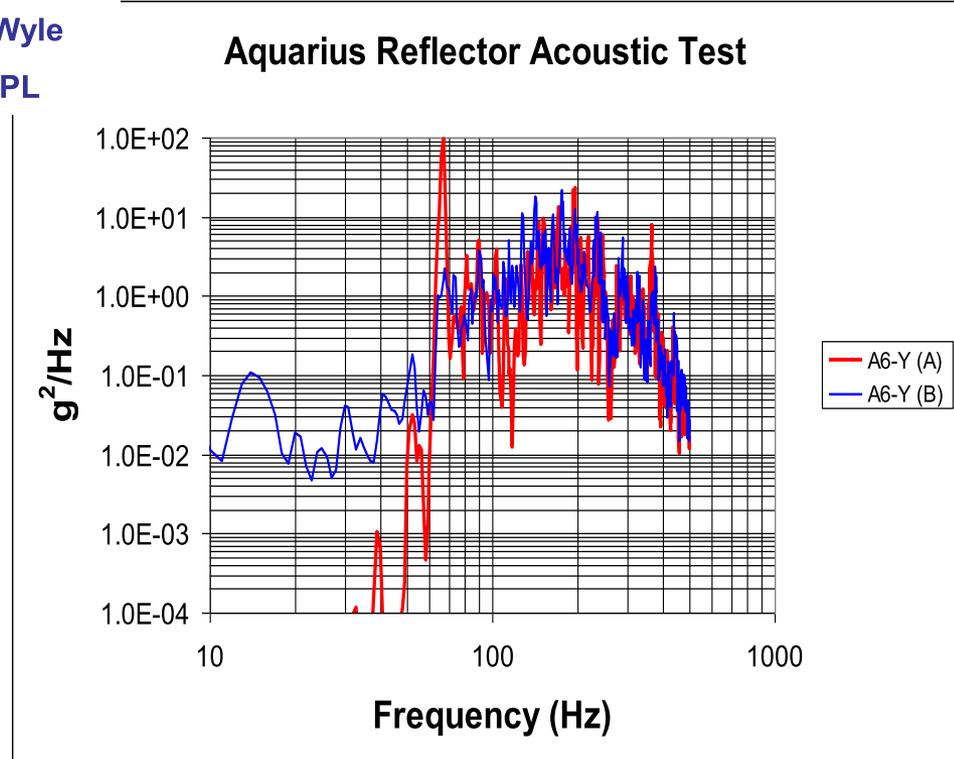


Aquarius Reflector Acceleration Responses

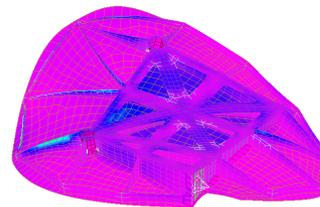
(JPL and Wyle Test Comparisons)



Wyle
JPL

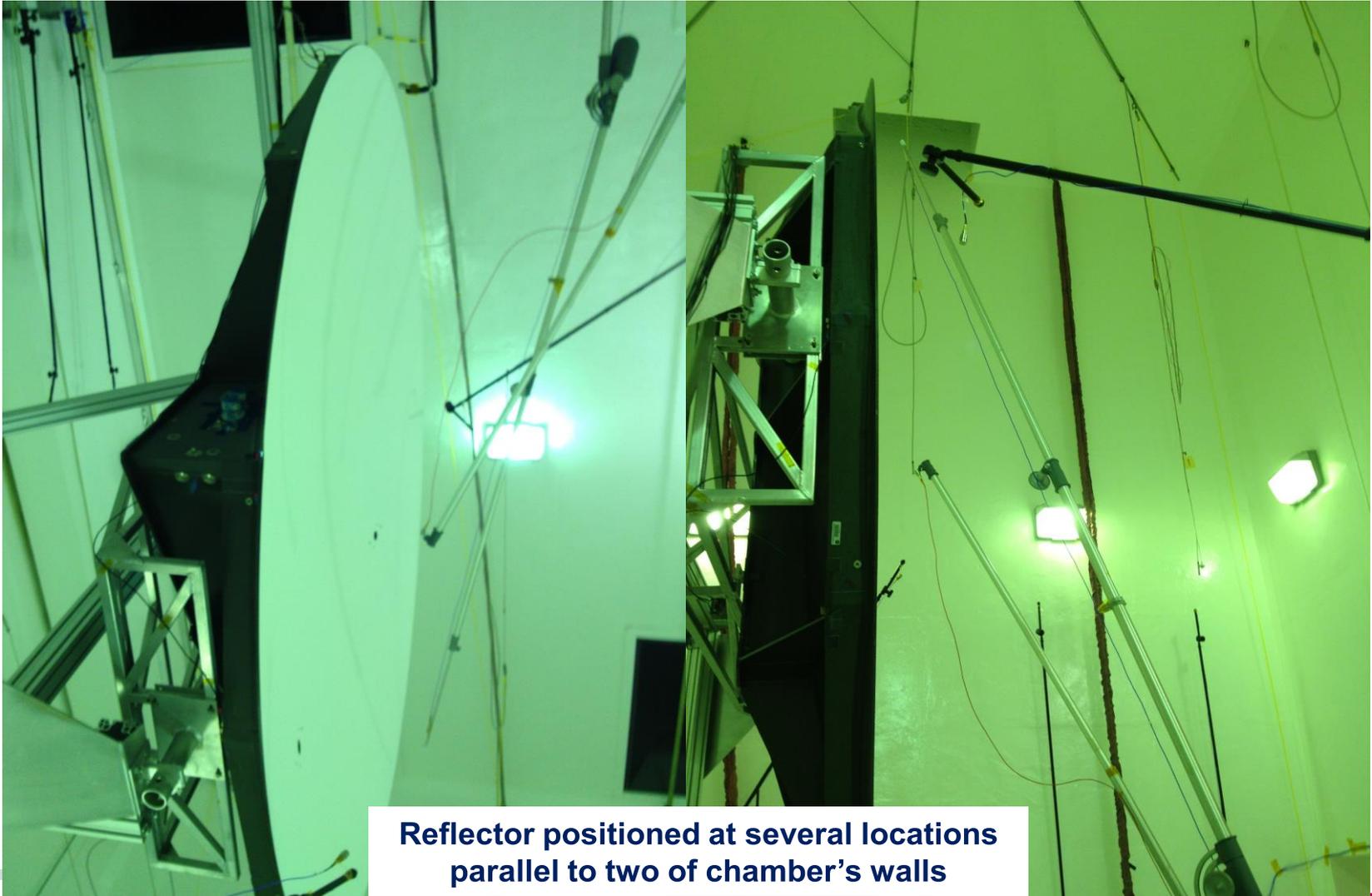


Structure modes close to chamber acoustic modes at approximately
61 Hz and 64 Hz (JPL)
81 Hz and 93 Hz (Wyle)



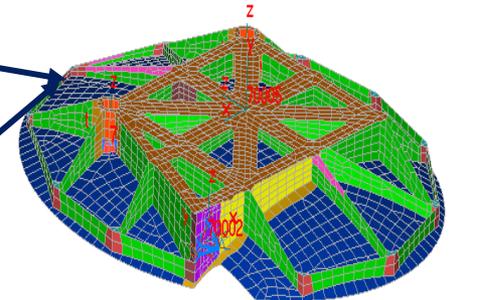
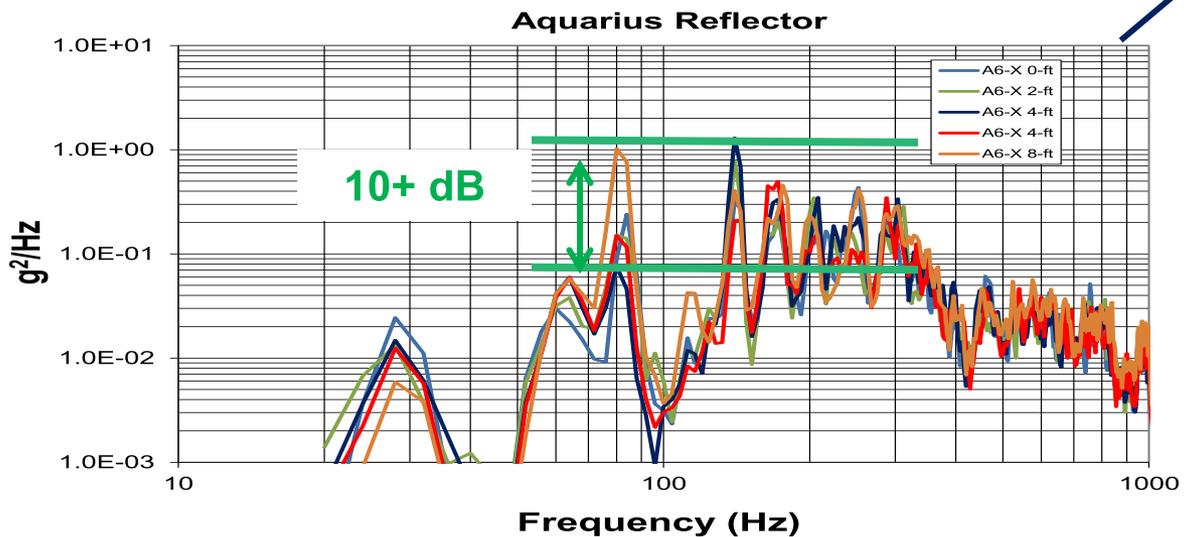
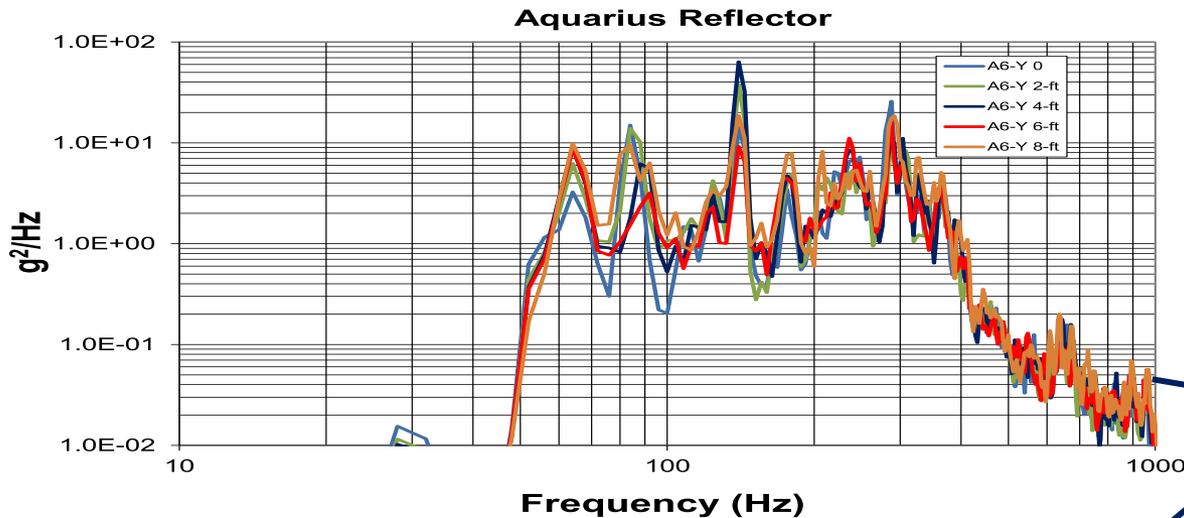
Structure mode close to chamber acoustic modes at ~ 67 Hz

Recent Aquarius Acoustic Reverberant Test at JPL Reverberant Chamber



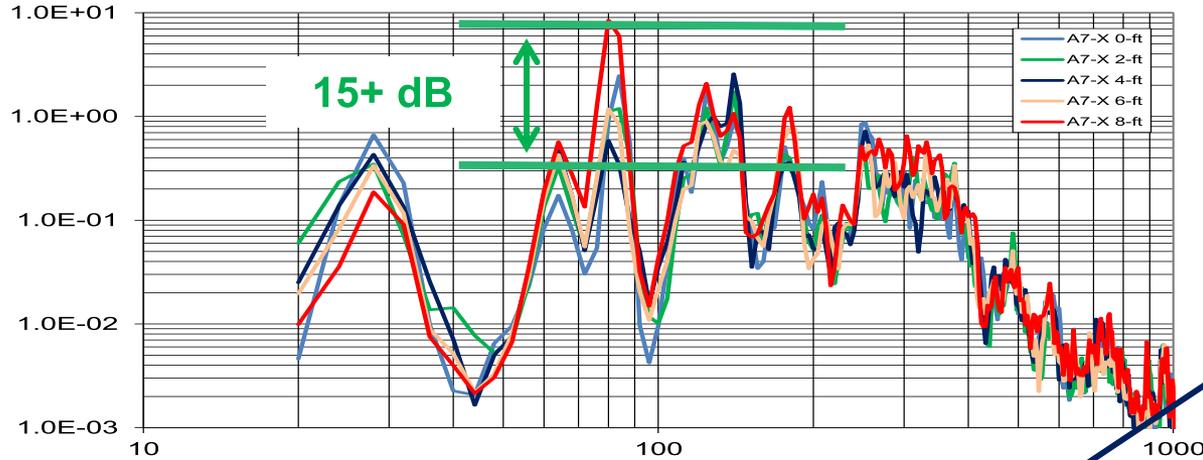
**Reflector positioned at several locations
parallel to two of chamber's walls**

Aquarius Reflector Responses: More evidence of acoustic structural coupling

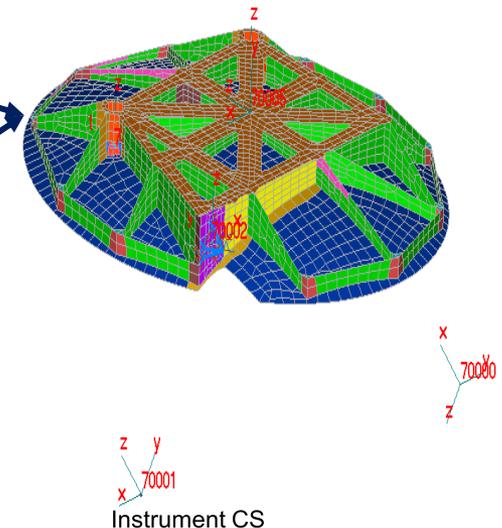
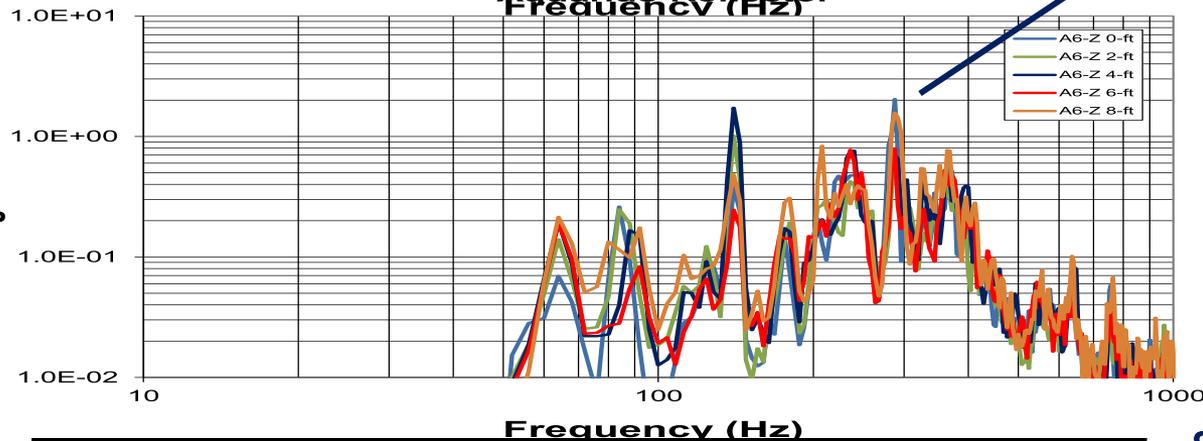


Aquarius Reflector Responses: More evidence of acoustic structural coupling

Aquarius Reflector



Aquarius Reflector



	0-ft	2-ft	4-ft	6-ft	8-ft
cm rms	4.04	3.51	2.33	3.14	8.07

~80 Hz the displacement is a factor of ~2 higher due to coupling!

Summary

- Acoustic standing wave/structural mode coupling is real and may occur in flight and ground tests using Reverberant chambers and DFAT
 - *Can be detrimental to the health of light-weight and responsive structures if not understood prior to testing*
- Suggested ways to minimize this effect during the qualification testing are:
 - *A complete acoustic characterization of the reverberant chamber and/or DFAT volume*
 - *Use a high-fidelity FEM model and vibro-acoustic prediction prior to acoustic testing to examine if coupling is going to pose problems*
 - *Re-position the flight hardware within the reverberant chambers and DFAT volume to minimize the coupling effect*
 - *Avoid smaller reverberant chamber size and DFAT volume*
- Response limit to remove conservatism if structural and acoustic standing wave coupling occurs
 - *Acoustic impedance is maximum when stranding waves occur and is probably the cause of the structures excessive excitation*
 - *This is analogous to mismatch in shaker testing impedance*
 - *The notched responses must not affect acoustic field and other components during testing*
- For light-weight structures inside fairings vibro-acoustic analysis should be performed to insure that such coupling will not pose a structural issue inside fairings during flight

SCIM

Thank you

