InSight System Acoustic Requirement Evolution

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ABSTRACT

The InSight Mars lander is to be launched to Mars in 2018 on a rocket, contained within an aeroshell designed for Mars entry. The primary mission objective is to deliever an ultra-sensitive seismometer to the Martian surface for scientific investigations. The preliminary InSight PF acoustic requirement (the heritage Phoenix environment, 139.8 dB overall SPL maximum expected environment) was reduced significantly when the Launch vehicle was selected as the InSight launch vehicle (134.5 dB overall SPL maximum expected environment). This reduction would have resulted in a very low Lander Deck random vibration at SEIS, and other instruments inside the aeroshell, during the system Protoflight (PF) acoustic test with questionable workmanship value. To mitigate this concern JPL and Launch vehicle contractor agreed to increase the InSight PF acoustic test requirement to enhance workmanship testing for science instruments and assemblies inside the aeroshell. The actual InSight system acoustic test vibration responses at the SEIS instrument are compared to the predicted responses.

KEY WORDS: InSight, acoustic requirement, system acoustic test response, SEIS instrument vibration, Aeroshell acoustic attenuation, workmanship vibration

SYMBOLS

dB = decibel, 20 micro bars reference
JPL = Jet Propulsion Laboratory
PF = Protoflight (maximum predicted environment + 3 dB)
SPL = Sound Pressure Level

INSIGHT ACOUSTIC REDUCTION FOR LAUNCH VEHICLE

The InSight spacecraft dynamics test program included a system acoustic test, but no system vibration test. The system vibration test was waived by the project though a system vibration test was strongly recommended. Therefore, the system acoustic test was intended to play a more important role in screening for workmanship issues than is typical for a JPL project.

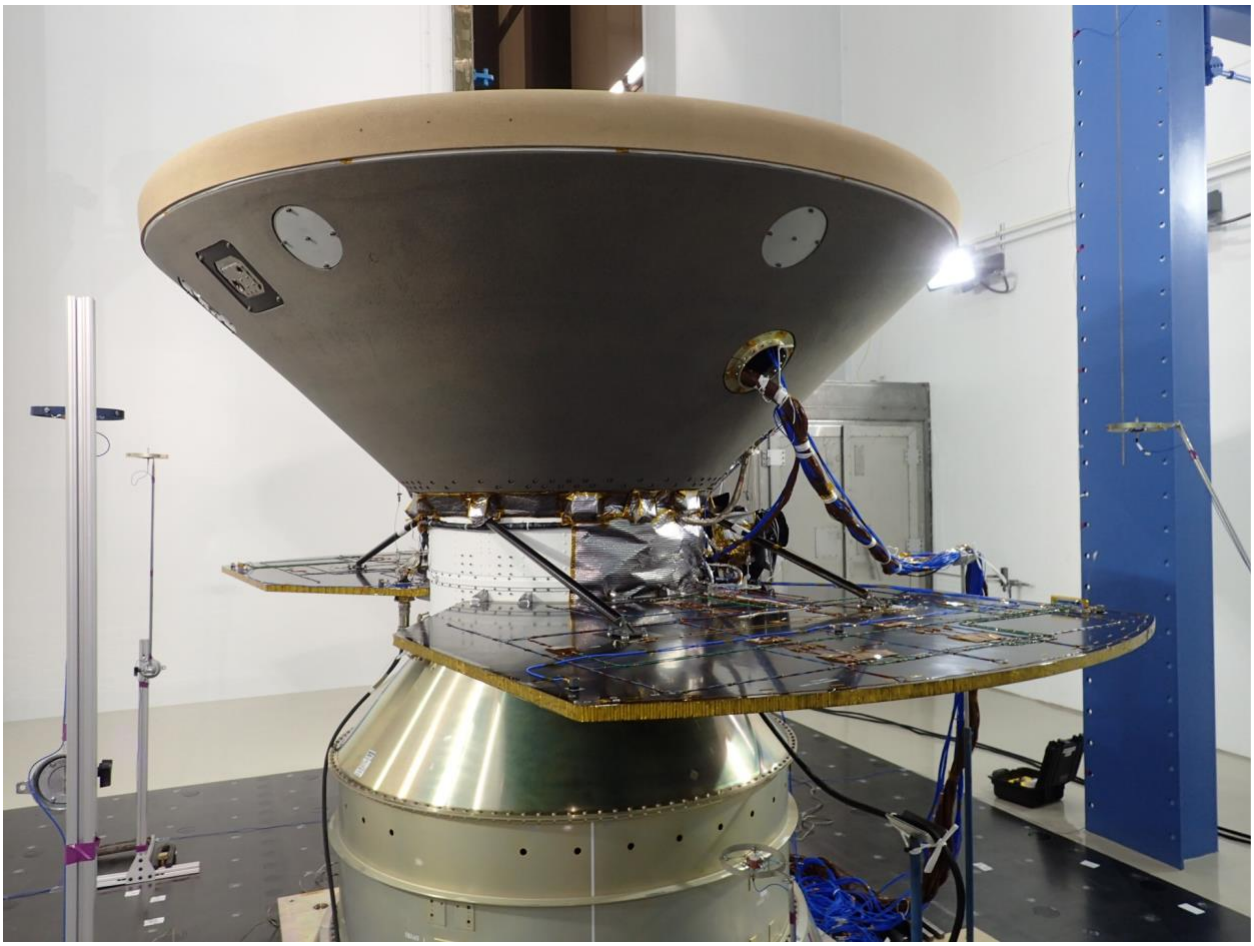
After selection of the launch vehicle, the InSight Protoflight (PF) Environmental Requirements Document acoustic requirement was reduced by the project to 138.3 dB OA SPL, Reference 1. The acoustic requirement was previously 142.8 dB OA SPL, in the original Environmental Requirements Document, which was the Phoenix requirement. The lowered acoustic requirement was 6-8 dB lower than the original acoustic spectrum between 70-400 Hz, Figure 1.

Typically, tailoring the test environment to the actual expected environments is a good practice. But, the most critical InSight equipment is inside an aeroshell at launch. Phoenix acoustic test data

indicated, Figure 3, that the reduced acoustic test requirement would result in minimal vibration response of the flight system. The Phoenix Lander Deck response data and P95-50 expected maximum environment (heavy red curve) are shown on Figure 3 compared to the NASA minimum workmanship specification.

A waiver of the InSight system vibration test was assessed as a high risk for equipment inside the aeroshell for an acoustic test only to the Launch vehicle acoustic PF requirement. Given the low expected acoustic test vibration responses, References 2 and 3, the possibility of exposing workmanship flaws for hardware inside the aeroshell would have largely been eliminated. This included the Mars Lander and all its equipment. Furthermore, none of the secondary structure, cabling, etc. would have been subjected to vibration with significant displacements, or with the compliant flight boundary conditions.

Figure 1. InSight in the acoustic chamber with lander contained in aeroshell

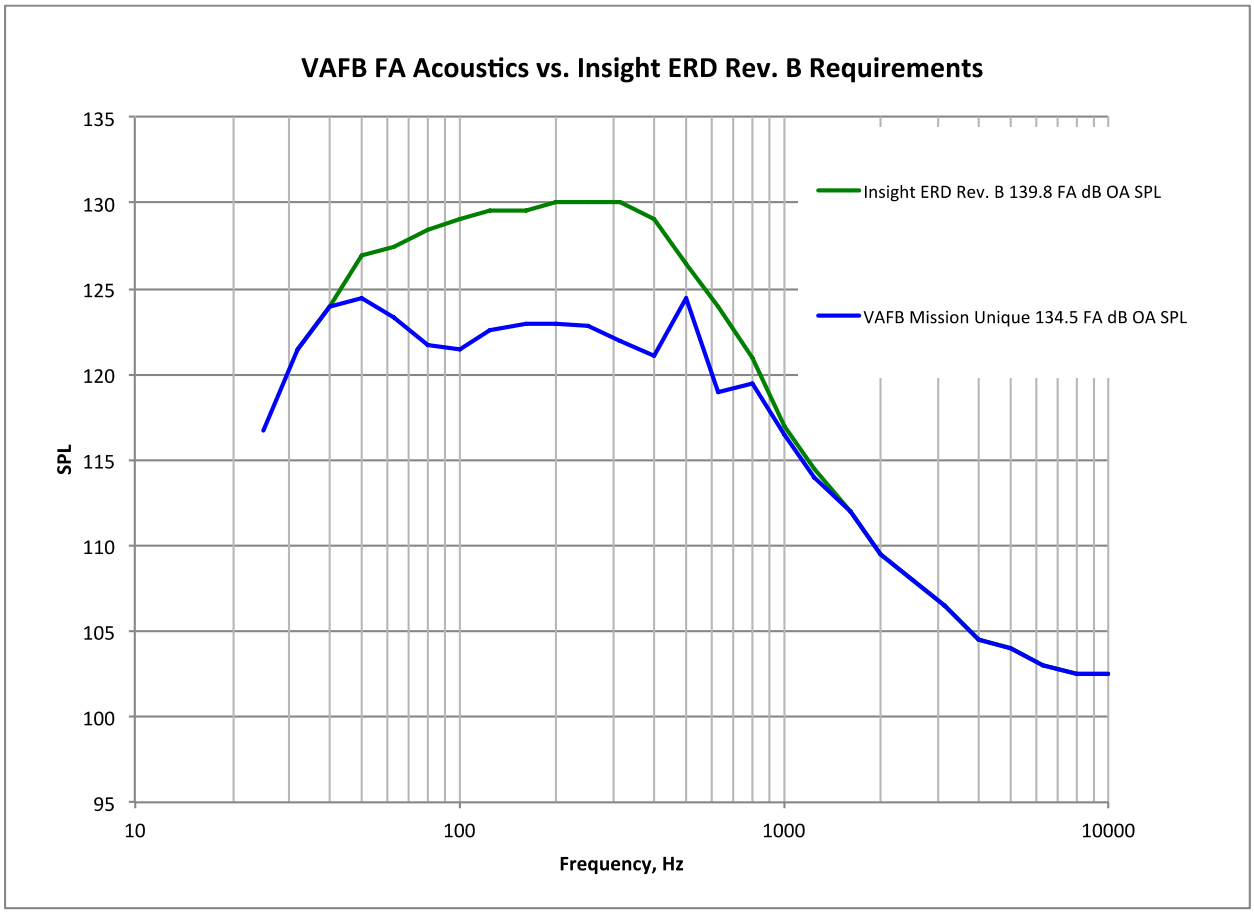


For this reason, vibration specifications for equipment inside the aeroshell on the Lander had been based on minimum workmanship requirements (plus a 3 dB Protoflight margin).

REVISED ACOUSTICS

JPL's dynamics environments group recommended returning to the original requirement to reduce the risk of missing workmanship flaws during the InSight PF acoustic test, Reference 3. This is the Delta II acoustic spectrum in Figure 1 (green).

Figure 2. Launch Vehicle Contractor Proposed PF Acoustics vs. Reduced Acoustics and Phoenix Acoustics



The Phoenix Science Deck vibration and a P95-50 calculated from the data are shown in Figure 3. Then the Phoenix Science Deck vibration was scaled to the new Launch vehicle contractor acoustic spectrum in Figure 4 (thin black dashes). The reduced InSight acoustic specification would have resulted in vibration responses significantly lower than those measured during Phoenix as can be seen in Figure 4. The wide difference between the NASA minimum workmanship and the predicted responses on the Science Deck can also be seen in Figures 3 and 4.

In a compromise JPL and Launch vehicle contractor agreed on the acoustic specification of Figure 5, dashed green curve. This acoustic spectrum would result in responses that were not much reduced from those on Phoenix, Figure 4.

It was known that the ‘enhanced’ acoustic requirement would not be ideal for Lander equipment, but there was a reduced risk of missing workmanship flaws compared to using the Reduced acoustic requirement. The increase in the acoustic test requirement reduced the mission risk from ‘high risk’ to ‘moderate’, as in the original assessment of the system vibration test waiver.

Figure 3. Phoenix Instrument Deck Data With P95-50 Curve

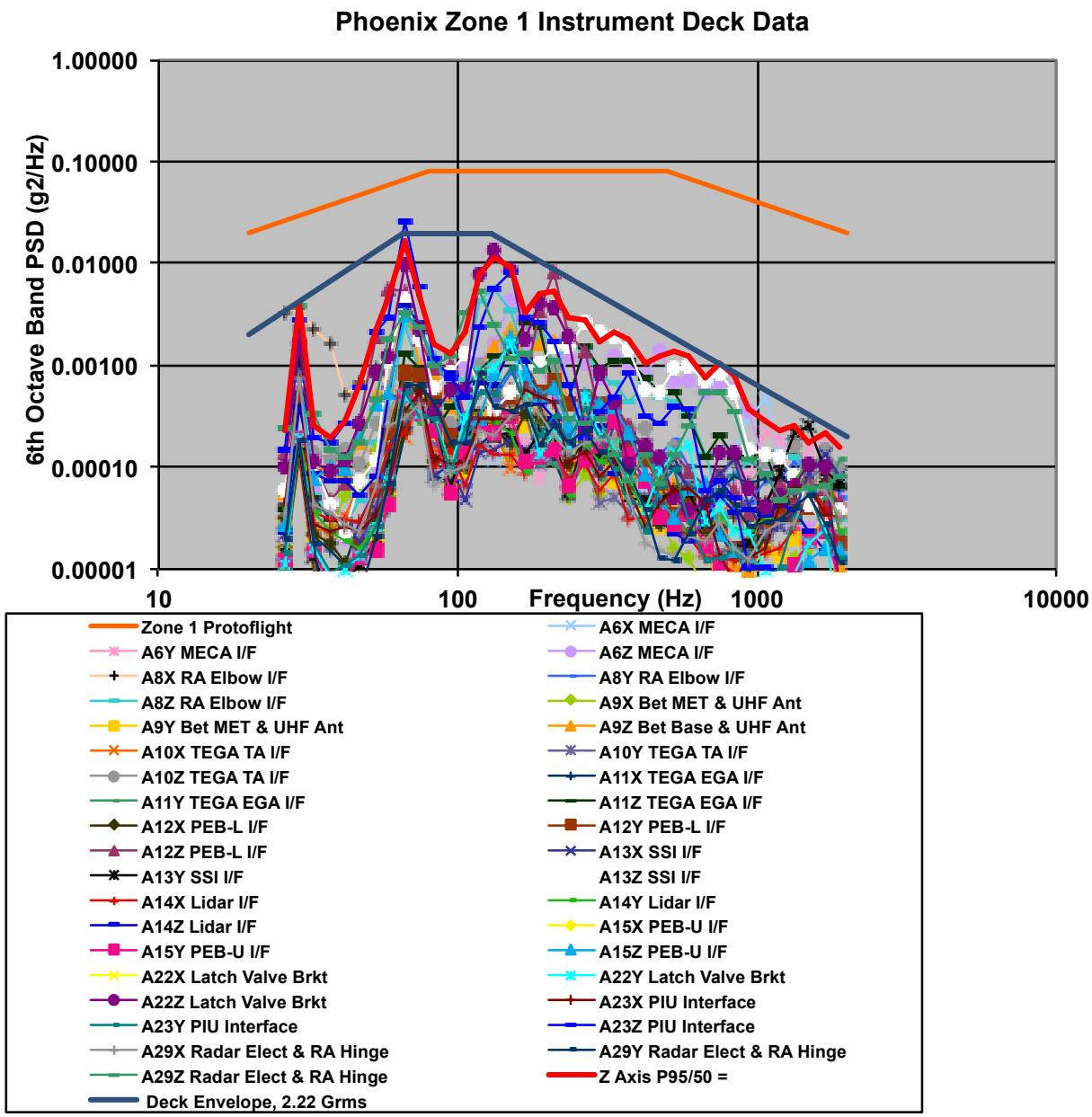


Figure 4. Phoenix P95-50 Curve Scaled to Launch Vehicle Contractor and JPL Proposed Acoustics

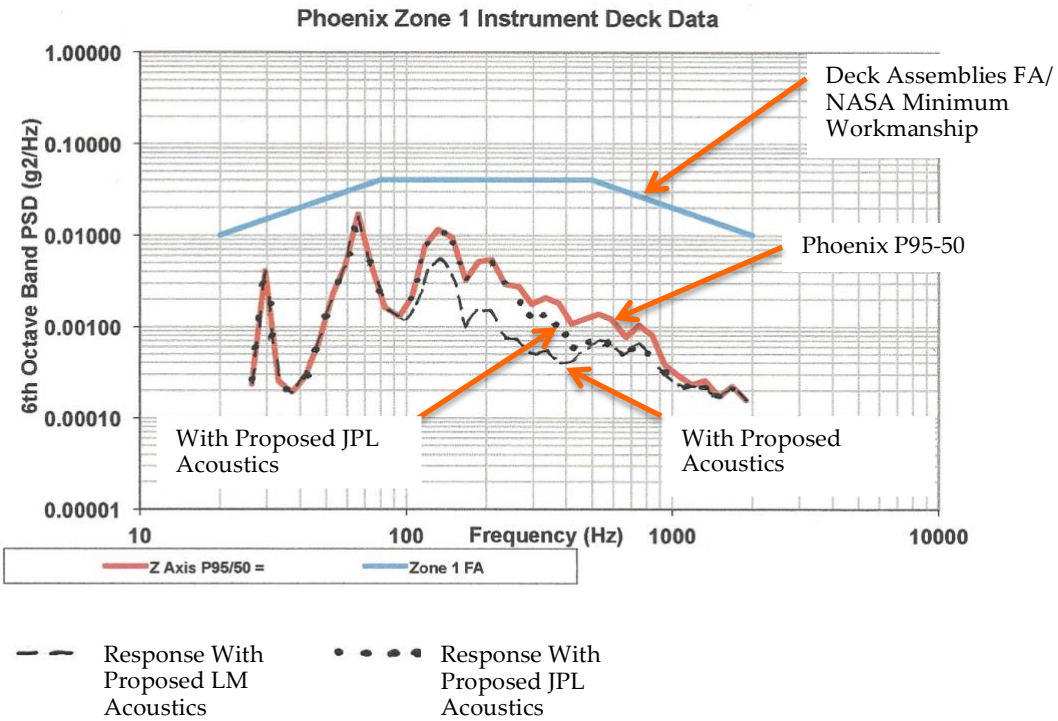
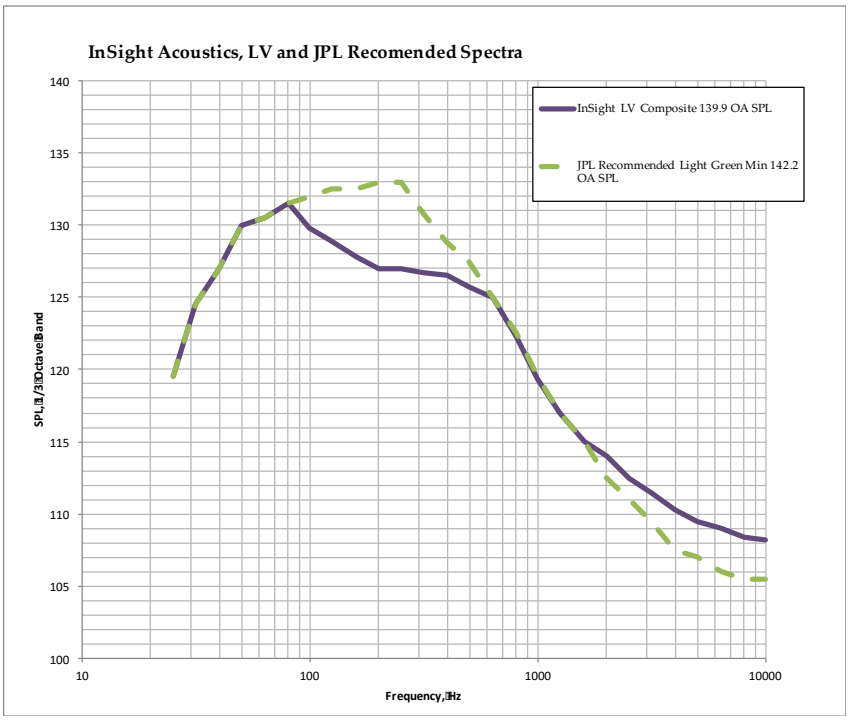


Figure 5. Launch Vehicle Contractor Proposed Acoustics and Alternate JPL PF Acoustics



Frequency, Hz	JPL Recommended Minimum FA Acoustics	JPL Recommended PF Acoustics
31.5	121.5	124.5
40	124	127
50	127	130
63	127.5	130.5
80	128.5	131.5
100	129	132
125	129.5	132.5
160	129.5	132.5
200	130	133
250	130	133
315	127.8	130.8
400	125.8	128.8
500	124.4	127.4
630	122	125
800	119.5	122.5
1000	116.5	119.5
1250	114	117
1600	112	115
2000	109.5	112.5
2500	108	111
3150	106.5	109.5
4000	104.5	107.5
5000	104	107
6300	103	106
8000	102.5	105.5
10000	102.5	105.5
OA SPL	139.2	142.2

INSIGHT ACOUSTIC TEST RESULTS

The actual acoustic test input for InSight is shown below in Figure 6. A notch of 3 dB was introduced into the acoustic spectrum to protect the cruise stage solar arrays per launch vehicle contractor's request.

This was an unusual step for an acoustic test, but with the enhanced acoustic input there was significant margin above the actual Launch vehicle acoustic environment. The input at 100 Hz was still 6 dB higher than the launch vehicle's reduced specification plus 3 dB at 100 Hz. With a couple of minor exceptions (80-100 Hz at the notch) each microphone was within the test tolerances for all frequencies below 3150 Hz. Therefore, the notched input did not result in increased launch risk for the spacecraft and it was deemed that the acoustic input met the objectives of the test.

The SEIS instrument interface vibration requirement had been reduced (Figure 3, tailored to the actual Lander Deck environment with margin) due to concerns about the fragility of the instrument, an ultra-sensitive seismometer. However, the InSight Lander Deck vibration was still substantially lower than the reduced PF SEIS instrument random vibration specification, Figure 7. InSight Lander Deck instrument responses to PF Acoustics (0.008 g2/Hz or less, 0.74 grms) were 5 dB and more below the reduced SEIS PF Lander Deck specification, Figure 7. This illustrates the low acoustic test responses that one can expect on equipment within an aeroshell.

This demonstrates that system acoustics testing alone is not typically adequate for workmanship, especially when equipment is contained within an aeroshell at launch. This result reinforces the view that a system vibration is typically required for adequate spacecraft workmanship testing for dynamics environments.

Figure 6. Final InSight Acoustic Requirements

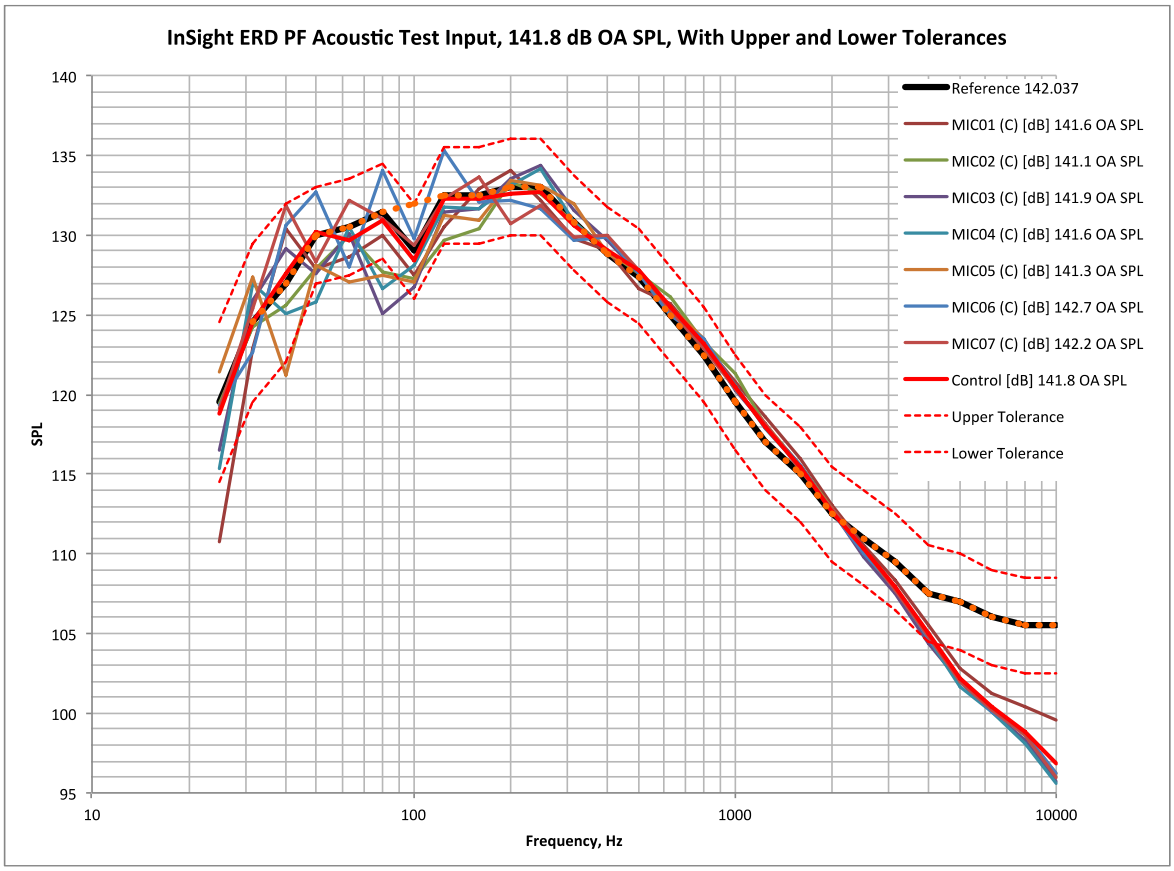
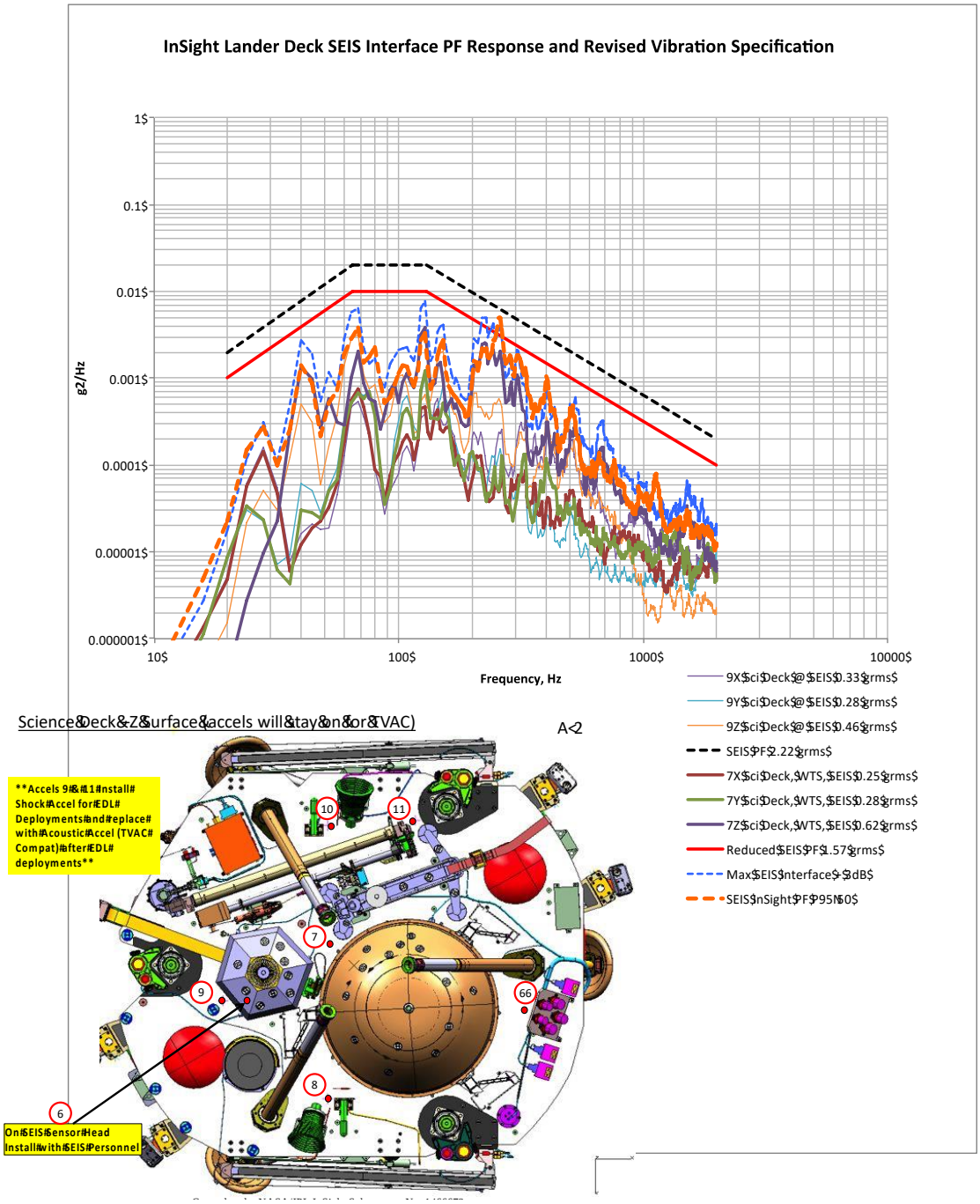


Figure 7. InSight Acoustic Test SEIS Interface Vibration



CONCLUSIONS, RECOMMENDATIONS

In many cases, a tailored PF spacecraft acoustic test may not be sufficient to provide workmanship vibration at assemblies, particularly for equipment inside an aeroshell.

Therefore, it is recommended that future missions with hardware inside an Aeroshell to maximize the workmanship value of the acoustic test as was done for InSight.

It is also recommended that a system random vibration test be performed since acoustics by itself does not provide adequate system workmanship for the low to mid frequency loads, and Deck/ hardware deflections.

ACKNOWLEDGEMENT

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BIOGRAPHIES

Michael O'Connell is a graduate of Purdue University and has worked at JPL in the mechanical engineering section since 1980 with a year and a half stint at Boeing Delta II. He has been in the field of dynamics environments since 1975 with experience in vibration, shock and acoustic analysis and test requirement development and with resolving design and test issues related to dynamics environments. He has extensive experience in environmental prediction, force limited random vibration testing, pyro shock testing and acoustic testing of science spacecraft.