Spacecraft Internal Acoustic Environment Modeling

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Background

The acoustic noise environment has been identified by the Astronaut Office, Habitability and Environmental Factors Division, and the SHFE Gap Analysis as one of the top habitability concerns, and a key area for improvement, regarding Constellation spaceflight vehicles, including the Orion, Altair, Lunar Habitat, and Mars vehicles. The “Acoustic Modeling” directed research project has been established to provide vehicle acoustic environment models and institutional capability to assist the Constellation Program with design and oversight tools aimed at avoiding acoustics-related problems.

Risk of Reduced Safety and Efficiency Due to Poor Human Factors Design

A high-noise environment may increase the risk to safety, health and productivity of the crew, reduced communication effectiveness, and increased risk of temporary and permanent hearing loss. For example, the project is helping to define an Orion CM (Crew Module) Snorkel Fan requirement to ensure adequate post landing crew voice communications.

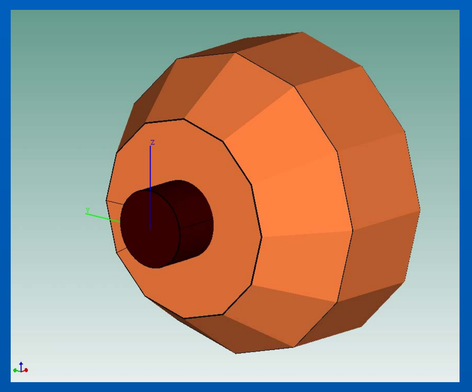
Objective

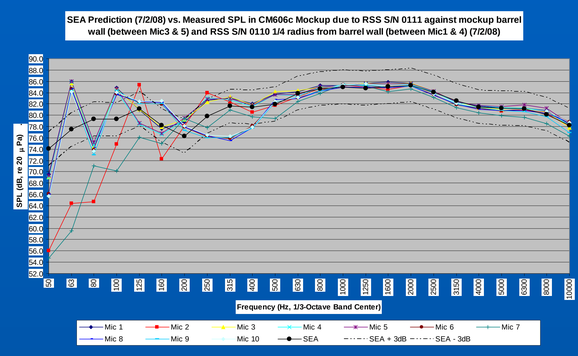
The objective of the project is to develop an acoustic modeling capability, based on commercial off-the-shelf software, to be used as a tool for oversight of the future manned Constellation vehicles. The use of such a model will help ensure compliance with acoustic requirements. Also, this project includes modeling validation and development feedback via building physical mockups and conducting acoustic measurements to compare with the predictions.

Products/Deliverables

- A two-layered MDF mockup, with an interior geometry shape similar to Orion CM IML (Interior Mode Line), was developed in FY08.
- A SEA (Statistical Energy Analysis) acoustic model with CM mockup geometry was developed and ten (10)-microphone SPL (Sound Pressure Level) measurements inside the mockup were used to validate the model. SPL predictions by the model match well with measurements in the mockup.
- Placing a sound source on the axis of symmetry of the mockup tends to focus the reflections from mockup wall on the axis of symmetry. SPL along the axis exceeded SEA prediction significantly. The deviation was reduced significantly when the focusing effect was removed. As the mockup fidelity increases and more asymmetrical reflecting surfaces are added into the mockup, the focusing effect will diminish.
- A SEA vehicle model based on the geometry from CM606 Rev C CAD model was also developed in FY08
  - » The model includes eleven (11) acoustic cavities and structural panels of ECLS wall and backbone (secondary structure).
  - » Sound absorption from reverberation time measurements of ISS US Lab and average of historic data of various space vehicles was used.
  - » The model has been used to develop sound power allocations for Snorkel Fan and ECLSS case/duct-borne radiated noise.
- Thinsulate acoustic absorber was attached to the mockup walls to reduce the reverberation time of the mockup interior to match the reverberation inside the ISS US Lab in the speech frequency bands. An noise simulation facility was then developed for evaluating various levels of background noise in the mockup and its effects on speech interference.
- Future Products/Deliverables will include:
  - » Snorkel Fan Acoustic Demonstration and Requirements inputs for fair crew voice communications in FY09 using the vehicle model and performing MRT (Modified Rhyme Test) in the mockup.
  - » Increase in the fidelity of the mockup by installing ECLS wall and ventilation system mockup components. Modeling and validation will also be performed.

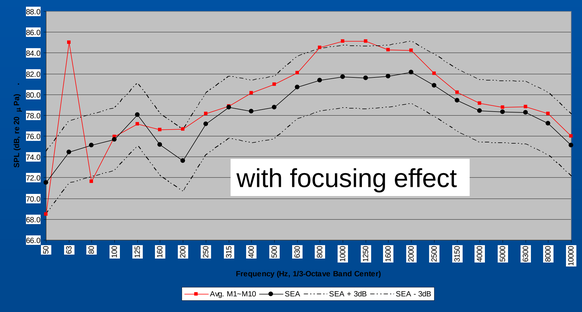
Orion Crew Module Acoustic Mockup @ JSC B49 and Model

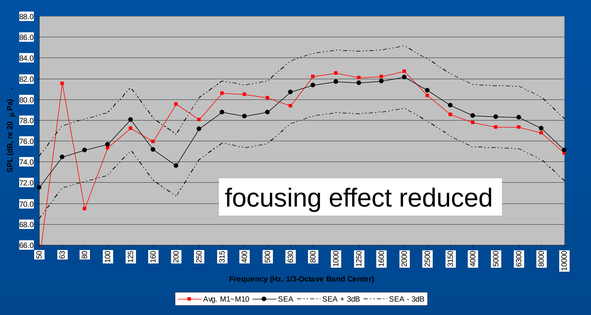




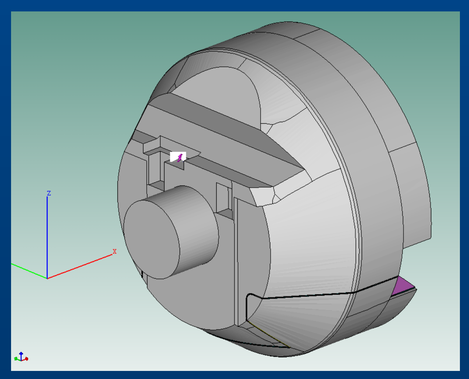
SEA Prediction (6/12/08) vs. Measured SPL in CM606c Mockup due to RSS S/N 0111 @ center of mockup deck (6/10/08)

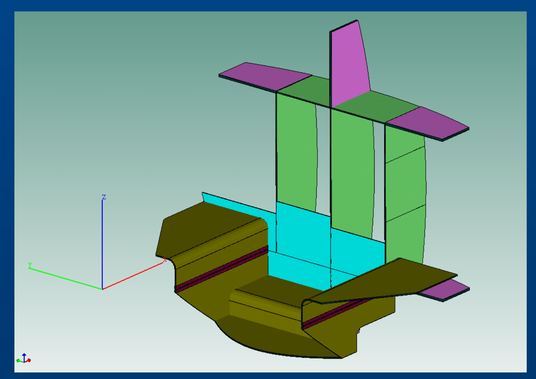
SEA Prediction (6/12/08) vs. Measured SPL in CM606c Mockup due to RSS S/N 0111 @ center of mockup deck with 3-sided box (7/3/08)





Orion Crew Module Model





Orion Crew Module Snorkel Fan Requirement Development