Fiscal Year:	FY 2009	**Task Last Updated:**	FY 05/04/2010
PI Name:	Allen, Christopher S M.S.		
Project Title:	Space Craft Internal Acoustic Environment		
Division Name:	Human Research		
Program/Discipline:	HUMAN RESEARCH		
Program/Discipline--Element/Subdiscipline:	HUMAN RESEARCH--Space Human Factors Engineering		
Joint Agency Name:		**TechPort:**	No
Human Research Program Elements:	(1) **SHFH**:Space Human Factors & Habitability (archival in 2017)		
Human Research Program Risks:	(1) **Hab**:Risk of an Incompatible Vehicle/Habitat Design (2) **HSIA**:Risk of Adverse Outcomes Due to Inadequate Human Systems Integration Architecture		
Space Biology Element:	None		
Space Biology Cross-Element Discipline:	None		
Space Biology Special Category:	None		
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City:	Houston	**State:**	TX
Zip Code:	77058	**Congressional District:**	22
Comments:			
Project Type:	GROUND	**Solicitation / Funding Source:**	Directed Research
Start Date:	10/02/2006	**End Date:**	09/30/2011
No. of Post Docs:	0	**No. of PhD Degrees:**	0
No. of PhD Candidates:	0	**No. of Master' Degrees:**	0
No. of Master's Candidates:	0	**No. of Bachelor's Degrees:**	0
No. of Bachelor's Candidates:	0	**Monitoring Center:**	NASA JSC
Contact Monitor:	Woolford, Barbara	**Contact Phone:**	218-483-3701
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Flight Program:			
Flight Assignment:	NOTE: End date supposed to be 9/30/2011, per A. Foerster/JSC (5/2010)		
Key Personnel Changes/Previous PI:			
COI Name (Institution):	Chu, S. Reynold (Lockheed/NASA Johnson Space Center)		
Grant/Contract No.:			
Performance Goal No.:			
Performance Goal Text:			

Task Description:	Acoustic modeling can be used to identify key noise sources, determine/analyze sub-allocated requirements, keep track of the accumulation of minor noise sources, and to predict vehicle noise levels at various stages in the development, first with estimates of noise sources, later with experimental data. Bench testing of isolated systems alone is not sufficient as the installation effects are often not known. Acoustic modeling will be used to determine installation effects, reverberation (room geometry) effects, and will be used to identify propagation paths and possible noise controls, as well as develop an understanding of the resulting acoustic levels in the composite environment. Finally, acoustic modeling will be used to assist with the development and implementation of spaceflight acoustic materials and to predict their effectiveness including sound containment, absorption and vibration isolation. Prior to this project, NASA did not have institutional acoustic modeling capability in regards to space flight vehicles. Through this project, acoustic modeling capability is being developed for application to the Cx (Constellation) Program and its new spaceflight vehicles to ensure a sufficiently quiet environment in which the astronaut crews can work and live. In general, modern acoustic modeling techniques such as Statistical Energy Analysis (SEA), Ray-tracing techniques, and Finite Element Methods have been used effectively to reduce interior noise in automotive, aircraft, and some spacecraft designs. Each method has its own strengths depending on the type of noise being modeled and the assumptions used, but it is clear that these methods have been effective; automotive and aircraft noise levels have been substantially reduced in recent years. Also, the continued development, current sophistication, and rising sales of off-the-shelf acoustic modeling software are indicative of their applicability and success, otherwise the companies that build automobiles and aircraft would not purchase these. See reference 1 for a recent article describing the state of the art in acoustic modeling capabilities, including off-the-shelf acoustic modeling software tools. The objective of this project will be to develop an acoustic modeling capability, based on off-the-shelf software, to be used as a tool for oversight of the future manned Constellation vehicles to ensure compliance with acoustic requirements and thus provide a safe and habitable acoustic environment for the crews. During FY'07, the project's first year, this project: 1. Determined the acoustic modeling requirements for Constellation vehicles, in terms of frequency range, source type, and model type, and leased an off-the-shelf software package that is well-suited for the modeling task. 2. Developed a simple-geometry acoustic model and validated the model using a physical mockup and acoustic measurements. Tools for modeling the effects of absorptive wall treatments and the resulting reverberation environment were developed as part of this work. Limitations of the modeling technique were also investigated and documented.
Rationale for HRP Directed Research:	
Research Impact/Earth Benefits:	Discoveries/advancements on how best to model certain geometrical/physical aspects of enclosed spaces (such as flight vehicles) will be shared with the acoustic modeling community.
Task Progress:	In FY'09, significant progress was made with validation and development of the acoustic modeling technique. This included: • Modified the acoustic reverberation time of the CM mockup to match the reverberation time inside the ISS US Lab in the speech bands, i.e. 0.5, 1, 2, and 4 kHz, for evaluating CM Snorkel Fan noise on post-landing crew communications. Thinsulate© sound absorption material was attached to the interior surface of the mockup to achieve this purpose. An SEA acoustic model of the CM mockup was used to predict the amount of acoustic treatment required, and reverberation time measurements were made to verify the match to the desired reverberation environment. • Validated the SEA model in predicting mockup interior SPLs (Sound Pressure Levels) due to the emissions of realistic ventilation fan sources. The sound power levels of these fan sources were unknown a priori. Sound power levels of these fan sources were estimated using a sound intensity measurement technique. This is opposed to prior studies where a RSS (Reference Sound Source) with known calibrated sound power was used. A measurement grid system of rectangular box shape was built for sound intensity measurements. The grid system enclosed the source to be measured with five surfaces, i.e., front, right, back, left, and top. Sound intensity at the center of each segment of the grid system was measured and time averaged for 15 sec. Sound intensity at the bottom surface reflected most of the incident sound energy so that it was accounted for at the other measured surfaces. Non-stationary background noise of the Chamber was of concern because it could introduce some net error on estimated fan sound power. The technique of estimating sound power via sound intensity measurements can cancel out only stationary background noise sources outside the grid system. Acoustic testing was performed in the Orion CM mockup, and comparisons were made with acoustic modeling predictions. The comparisons showed very good agreement, plus or minus 3 dB above the Schroder frequency (where SEA is expected to give good results). The case studied was very realistic as the sound absorption material covered only part of the wall (i.e., 30% of the area of conical and vertical wall). The effect of such sound absorption material was predicted by: • mockup cavity absorption predicted from measured mockup interior reverberation times and then using Sabine equation, or • a two-layered Thinsulate© layup model, which attaches to the face (i.e., the interior wall surface) of the mockup cavity. The lay-up model was developed based on the results of impedance tube absorption testing. Furthermore, the effect of air absorption, which is notable in high frequencies (> 1 kHz), was also included. Currently, the mockup only includes the bare pressure shell. The development of a fairly high-fidelity ECLS wall closeout panel was completed in FY'09. Installing the closeout panel into the mockup, updating the mockup acoustic model with the closeout panel, and validating the model with sound pressure measurement in the mockup will be performed. In addition to the modeling development described above, other significant achievements were made with respect to Orion acoustics work. In particular, the Orion acoustic mockup, built as part of this acoustic modeling project, was used in demonstrations to protect the acoustic requirements (and the resulting Orion crew acoustic environment). Hamilton Sundstrand had indicated that the acoustic requirements were too strict and that they were not going to meet them. This included the continuous noise requirement, and the noise requirement for the Snorkel Fan (used after landing in a

contingency situation). The Orion acoustics mockup was used to demonstrate to high level CxP management what the effects of higher noise levels would mean to Orion crews. As a result, a new commitment was made to hold to the acoustic requirements. An Acoustic Noise Control Plan will now be developed, and additional resources are being used to control noise during design of the vehicle. As part of this effort, the Snorkel Fan noise requirement was re-evaluated and updated to ensure adequate crew voice communications during a contingency landing situation.

| **Bibliography Type:** | Description: (Last Updated: 08/31/2018) |