Fiscal Year:	FY 2011	**Task Last Updated:**	FY 09/30/2011
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
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Flight Program:			
Flight Assignment:	NOTE: End date is 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.:	Directed Research		
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 spaceflight vehicles. Through this project, acoustic modeling capability is being developed for application to Orion and other 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 spaceflight vehicles to ensure compliance with acoustic requirements and thus provide a safe and habitable acoustic environment for the crews. Reference 1. von Estorff, Otto, "NUMERICAL METHODS IN ACOUSTICS: FACTS, FEARS, FUTURE," 19th INTERNATIONAL CONGRESS ON ACOUSTICS, Madrid, September 2007.
Rationale for HRP Directed Research:	
Research Impact/Earth Benefits:	• Demonstrated the development of spacecraft cabin acoustic models and a model validation technique using acoustic mockups with incrementally increasing fidelity. • Observed great utility and capability of the Statistical Energy Analysis (SEA) acoustic modeling method both in the accuracy of the results (in the applicable frequency range), and in the geometrical complexity that can be accommodated. • Reversed the Orion team decision to push back (up) the Orion cabin noise limit. • Prompted the formation of the Orion Acoustic Working Group for resolving Orion cabin acoustics related issues. • Prompted Lockheed Martin to hire a vibro-acoustics engineer for crew module (CM) cabin acoustic environment modeling and analysis. • Developed Level 2 requirements for the CM Snorkel Fan and the Waste Management System. The Snorkel Fan requirement is to limit pre-launch and post-landing Speech Interference Levels. • Initiated a collaborated effort with Lockheed Martin staff for Orion CM cabin acoustic environment modeling and analysis. The findings described in this report were provided to Lockheed Martin staff, helping to promote and validate similar system-level noise treatments for the actual Orion vehicle. This resulted in the acceptance of a mass allocation for the system-level noise treatments, which were then assigned to various Orion system teams for implementation.
Task Progress:	The activity of this research implements acoustic modeling for design purposes by incrementally increasing model fidelity and validating the accuracy of the model which predicts the sound pressure levels (SPLs) produced by sources under various conditions. An International Space Station (ISS) US Lab mockup and an Orion Crew Module (CM) acoustic mockup were used for modeling validation. For the ISS US Lab mockup, three mockup interior reverberant environments were modeled and validated successfully using single and dual airborne sound sources with known sound power levels. Two methods were developed to model the mockup interior absorption: one was based on the measurement of mockup interior reverberation time; the other was based on impedance tube measurement of sound absorptive material used to cover the interior surfaces of the mockup. The effect of source location on the accuracy of the model predictions under a highly absorptive mockup interior was observed. Furthermore, strategy was developed to model the SPL distribution in a large mockup with a highly absorptive interior. The modeling of the Orion CM acoustic mockup involved more complex geometrical shape and ventilation fan with unknown sound power levels beforehand. Sound power levels of the ventilation fans were estimated from sound intensity measurements. The fidelity of the mockup and the model were increased from an empty interior in the beginning to include an ECLSS (Environmental Control and Life Support System) wall and ECLSS bay with open/sealed gaps between the ECLSS wall and the mockup wall. There were two configurations of sound absorptive Thinsulate attached to the surfaces of the ECLSS wall panels. An effective method of deploying sound absorptive material in reducing cabin SPL was discovered by modeling and validated by measurement. The effect of sealing the gaps to prevent noise from leaking into the cabin was also modeled and validated. Lastly, a bare Orion CM mockup with aluminum interior walls was also modeled and validated. The purpose of the study was to increase the mockup interior reverberation time to the level typical of a spacecraft pressure vessel interior. Also, lessons were learned regarding the problem of absorption coupling between adjacent cavities, e.g., cabin and ECLSS bay in the CM mockup, and the problem of Damping Loss Factor sensitivity when modeling structure-borne noise.

Bibliography Type:	Description: (Last Updated: 08/31/2018)
Abstracts for Journals and Proceedings	Dandaroy I, Chu SR. "Cabin Noise Studies for the Orion Spacecraft Crew Module." Presentation at the Spacecraft and Launch Vehicle Dynamic Environments Workshop, The Aerospace Corporation, El Segundo, Calif., June 7-9, 2011. Spacecraft and Launch Vehicle Dynamic Environments Workshop, The Aerospace Corporation, El Segundo, Calif., June 7-9, 2011. , Jun-2011
Abstracts for Journals and Proceedings	Chu SR, Allen CS. "Spacecraft Internal Acoustic Environment Modeling." Space Human Factors and Habitability Poster Session. Poster Presentation at the NASA Human Research Program Investigators' Workshop, Houston, TX, February 3-5, 2010. NASA Human Research Program Investigators' Workshop, Houston, TX, February 3-5, 2010. , Feb-2010
Abstracts for Journals and Proceedings	Chu SR, Allen CS. "Spacecraft Internal Acoustic Environment Modeling." Poster Presentation at Inadequate Design Risk Session, NASA Human Research Program Investigators' Workshop, League City, TX, February 2-4, 2009. NASA Human Research Program Investigators' Workshop, League City, TX, February 2-4, 2009. , Feb-2009
Abstracts for Journals and Proceedings	Chu SR, Allen CS. "Spacecraft Internal Acoustic Environment Modeling." Poster Presentation at the Space Human Factors and Habitability Poster Session, NASA Human Research Program Investigators' Workshop, League City, TX, February 4-6, 2008. NASA Human Research Program Investigators' Workshop, League City, TX, February 4-6, 2008. , Feb-2008
Papers from Meeting Proceedings	Chu SR, Allen CS. "Spacecraft Cabin Acoustic Modeling and Validation with Mockups." 41st International Conference on Environmental Systems, Portland, Oregon, July 17-21, 2011. (Presentation on July 19). 41st International Conference on Environmental Systems, Portland, Oregon, July 17-21, 2011. Paper AIAA-2011-5112. http://arc.aiaa.org/doi/abs/10.2514/6.2011-5112 ; accessed 7/7/15. , Jul-2011