Task Book Report Generated on: 04/19/2024

Fixed   Years   FY 2011	Fiscal Year:	FY 2011	Took Last Undated	EV 00/30/2011
Project Title: Space Cnaft Internal Acoustic Environment  Division Name: Human Research  Program/Discipline: HUMAN RESEARCH  Program/Discipline: HUMAN RESEARCH  Program/Discipline: HUMAN RESEARCH-Space Human Factors Engineering  Liement/Subdispline: International Program Elements: CONTROLL (INTERNATIONAL PROJECT OF Mo. 1)  Human Research Program Riements: CONTROLL (INTERNATIONAL Program Risks: CONTROLL (INTERNATIONAL PROJECT OF MO. 1)  Human Research Program Risks: CONTROLL (INTERNATIONAL PROJECT OF MO. 1)  Human Research Program Risks: CONTROLL (INTERNATIONAL PROJECT OF MO. 1)  Human Research Program Risks: CONTROLL (INTERNATIONAL PROJECT OF MO. 1)  Human Research Program Risks: CONTROLL (INTERNATIONAL PROJECT OF MO. 1)  Human Research Program Risks: CONTROLL (INTERNATIONAL PROJECT OF MO. 1)  Human Research Program Risks: CONTROLL (INTERNATIONAL PROJECT OF MO. 1)  Human Research Program Risks: CONTROLL (INTERNATIONAL PROJECT OF MO. 1)  Human Research Program Risks: CONTROLL (INTERNATIONAL PROJECT OF MO. 1)  Human Research Program Risks: CONTROLL (INTERNATIONAL PROJECT OF MO. 1)  Human Research Program Risks: CONTROLL (INTERNATIONAL PROJECT OF MO. 1)  Human Research Program Risks: CONTROLL (INTERNATIONAL PROJECT OF MO. 1)  Human Research Program Risks: CONTROLL (INTERNATIONAL PROJECT OF MO. 1)  Human Research Program Risks: CONTROLL (INTERNATIONAL PROJECT OF MO. 1)  Human Research Program Risks: CONTROLL (INTERNATIONAL PROJECT OF MO. 1)  Human Research Program Risks: CONTROLL (INTERNATIONAL PROJECT OF MO. 1)  Human Research Program Risks: CONTROLL (INTERNATIONAL PROJECT OF MO. 1)  Human Research Program Risks: CONTROLL (INTERNATIONAL PROJECT OF MO. 1)  Human Research Program Risks: CONTROLL (INTERNATIONAL PROJECT OF MO. 1)  Human Research Program Risks: CONTROLL (INTERNATIONAL PROJECT OF MO. 1)  Human Research Program Risks: CONTROLL (INTERNATIONAL PROJECT OF MO. 1)  Human Research Program Risks: CONTROLL (INTERNATIONAL PROJECT OF MO. 1)  Human Research Program Risks: CONTROLL (INTERNATIONAL PROJECT OF MO. 1)			Task Last Opuateu.	1 1 09/30/2011
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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 Dasign (2) IISIA/Risk of Adverse Outcomes Due to Inadequate Human Systems Integration Architecture  Space Biology Cross-Element: None  Space Biology Cross-Element: None  Space Biology Special Category: None  PI Emailt: christophers allen@masn.gov Fax: FY  PI Organization Type: INDUSTRY Phone: 281.483.9710  Organization Name: Lockheed-Martin/ NASA Johnson Space Center  PI Address 1: 2101 Nasa Parkway  PI Address 2: Mail Code SF22  PI Web Page:  City: Houston State: TX  Zip Code: 77058 Congressional District: 22  Comments:  Project Type: GROUND Solicitation / Funding Nource: Directed Research Nource State: 1002/2006 End Date: 09/30/2011  No. of Post Docs: 0 No. of Master' Degrees: 0  No. of Master's Candidates: 0 No. of Master' Degrees: 0  No. of Master's Candidates: 0 No. of Monitoring Center: NASA JSC  Contact Monitor: Woolford, Barbara way  Flight Program:  Flight Assignment: NOTE: End date is 9/30/2011, per A. Foerster/JSC (S/2010)  Flight Assignment: NOTE: End date is 9/30/2011, per A. Foerster/JSC (S/2010)  Grant/Contract No.: Directed Research  Directed Research  NOTE: End date is 9/30/2011, per A. Foerster/JSC (S/2010)		HUMAN RESEARCHSpace Human Factors Engineering		
Human Research Program Risks: (2) Hab/Risk of an Incompatible Vehicle/Habitat Design (2) HSTA/Risk of Adverse Outcomes Due to Inadequate Human Systems Integration Architecture  Space Biology Cross-Element None  Space Biology Special Category: None  PI Email: christopher.sallen@inasu.gov Fax: FY  HOSPAIN ORGANIZATION NONE  PI Granization Type: INDUSTRY Phone: 281.483.9710  Organization Name: Lockheed-Martin/ NASA Johnson Space Center  PI Address 1: 2101 Nasa Parkway  PI Address 2: Mail Code SF22  PI Web Page:  City: Houston State: TX  Zip Code: 77088 Congressional District: 22  Comments:  Project Type: GROUND Solicitation / Funding Directed Research Source: No. of PhD Degrees: 0  No. of Post Docs: 0 No. of PhD Degrees: 0  No. of Post Docs: 0 No. of Master' Degrees: 0  No. of Master's Candidates: 0 No. of Master' Degrees: 0  No. of Master's Candidates: 0 No. of Bachelor's Candidates: No. of Master' Degrees: 0  No. of Master's Candidates: 0 No. of Bachelor's Candidates: No. of Master's Candidates: No. of Bachelor's Candidates: No. of Master's Candidates	Joint Agency Name:	Te	echPort:	No
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Space Biology Cross-Element Discipline:         None           Space Biology Special Category:         None           PI Email:         christopher, sallen@mass.gov         Fax:         FY           PI Organization Type:         INDUSTRY         Phone:         281.483.9710           Organization Name:         Lockheed-Martin/ NASA Johnson Space Center         Phone:         281.483.9710           PI Address I:         2101 Nasa Parkway         Provident         Provident         Provident           City:         Houston         State:         TX           Zip Code:         7058         Congressional District:         22           Comments:         Project Type:         GROUND         Solicitation / Funding Source:         Directed Research           Start Date:         1002/2006         End Date:         9/30/2011           No. of Post Docs:         0         No. of PhD Degrees:         0           No. of Marker'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           Contact Email:         barbara i woolford@mass.gov         Solicitation / Funding Cen	Human Research Program Risks:		an Systems Integration Archi	tecture
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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 Pst Docs:         0         No. of PhD Degrees:         0           No. of PhD Candidates:         0         No. of Master' Degrees:         0           No. of Bachelor'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           Contact Email:         barbara.i.woolford@nasa.gov         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)         Contact Center         Directed Research           Performance Goal No.:         Performance Goal No.:         Performance Goal No.         Performance Coal No.         Performance Coal No.	PI Address 2:	Mail Code SF22		
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No. of Master's Candidates:  0 No. of Bachelor's Degrees:  0 Monitoring Center: NASA JSC  Contact Monitor: Woolford, Barbara  Contact Email: barbara_i,woolford@nasa.gov  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.:	No. of Post Docs:	0	No. of PhD Degrees:	0
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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.

Task Description:

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:**

- 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.

## Research Impact/Earth Benefits:

- 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.

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.

Task Progress:

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.

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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
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