Fiscal Year:	FY 2019	**Task Last Updated:**	FY 02/18/2019
PI Name:	Hayman née Anderson, Allison Ph.D.		
Project Title:	Interactive Space Vehicle Design Tool with Virtual Reality		
Division Name:	Human Research		
Program/Discipline:			
Program/Discipline--Element/Subdiscipline:	HUMAN RESEARCH--Space Human Factors Engineering		
Joint Agency Name:		**TechPort:**	No
Human Research Program Elements:	(1) **HFBP**:Human Factors & Behavioral Performance (IRP Rev H)		
Human Research Program Risks:	(1) **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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Zip Code:	80309-5004	**Congressional District:**	2
Comments:	NOTE: name change to Hayman née Anderson (Ed., March 2025). PI moved to University of Colorado from Dartmouth College in early 2017.		
Project Type:	Ground	**Solicitation / Funding Source:**	2016-2017 HERO NNJ16ZSA001N-Crew Health (FLAGSHIP, OMNIBUS). Appendix A-Omnibus, Appendix B-Flagship
Start Date:	11/09/2017	**End Date:**	11/09/2019
No. of Post Docs:	0	**No. of PhD Degrees:**	0
No. of PhD Candidates:	1	**No. of Master' Degrees:**	0
No. of Master's Candidates:	1	**No. of Bachelor's Degrees:**	1
No. of Bachelor's Candidates:	4	**Monitoring Center:**	NASA JSC
Contact Monitor:	Williams, Thomas	**Contact Phone:**	281-483-8773
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Flight Program:			
Flight Assignment:	NOTE: End date changed to 11/9/2019; grant number changed sometime in late 2018 per NSSC information (Ed., 1/31/19)		
Key Personnel Changes/Previous PI:	February 2019 report: There are no Key Personnel changes.		
COI Name (Institution):	Klaus, David Ph.D. (University of Colorado - Boulder)		
Grant/Contract No.:	80NSSC18K1734 ; 80NSSC18K0198		
Performance Goal No.:			
Performance Goal Text:			

Task Description:	Objective: To evaluate the spectrum of visualization tools (i.e., virtual reality, hybrid reality, augmented reality, physical reality) in their ability to facilitate rapid mock-up and flexible design of microgravity vehicles and habitats. Research Product Description: To enable efficient and rapid mock-up of vehicle concepts, the spectrum of visualization tools can be used earlier in the design process to achieve improved system design. We will define, characterize, and establish metrics by which these tools can be used, with focus applications in early-stage spacecraft habitat design. From the results of this initial definition phase, an experimental evaluation of the proposed methodologies will be performed. Specific Aim 1: We will characterize and define the four categories of design tools noted above (physical, augmented, hybrid, and virtual) and establish a set of high-level guidelines from the literature for how each approach is typically used, to be documented as a table of advantages, disadvantages, and comments. This characterization will include specific definitions of these categories, metrics by which to evaluated them, and system requirements. To the extent possible, we will also project into future technology development on the horizon from interaction with experts in academia, government, and industry, such that this benchmark assessment is not limited to current state-of-the-art. Specific Aim 2: Working in conjunction with NASA personnel, we will down-select a subset of tasks described in Aim 1 from which to conduct evaluations, with the intent to experimentally investigate our findings. This subset may be to evaluate specific design tools or paradigms in which the design tools are used, to be determined from the highest utility to achieve NASA objectives. This experimental work will leverage software, hardware, and previously developed NASA tools as well as the facilities within the University of Colorado (CU)-Boulder Bioastronautics Laboratory, as outlined in the original proposal. NASA Relevance: This proposal addresses the Risk of Incompatible Vehicle/Habitat Design. Specifically, it addresses the Gap HAB – 05 to identify technologies and create a tool to enable the design and assessment of space vehicles.
Rationale for HRP Directed Research:	
Research Impact/Earth Benefits:	Alternative reality technologies have been used successfully in other engineering and design fields and are rapidly advancing commercially. In the automotive industry, many companies continue to adopt new paradigms for design visualization and assessment. Virtual reality for product design and assembly has been widely studied, with virtual versions of physical hardware demonstrating high utility. It has been used successfully in psychological training, military applications, and entertainment. In building design and construction, architects have adopted Building Information Management and virtual visualizations of designed spaces as a means by which to capture all elements of the design evaluation. This research is the first to performs a side-by-side assessment of technology implementations across the full spectrum of alternative reality technologies. We evaluate the benefits and potential pitfalls of virtual, hybrid, augmented, and physical reality.
Task Progress:	This study evaluates the spectrum of virtual reality (VR), hybrid reality (HR), augmented reality (AR), and traditional physical reality (PR) mockups in spacecraft habitat design evaluations. In our first year, we accomplished all of our primary research goals, as this was a study funded for a single year. Data analysis is ongoing, but is nearing completion. We developed a framework by which spacecraft habitat designers and evaluators can identify alternative reality technologies best suited for their specific applications. This was enabled by merging two constructs: a theoretical taxonomy of the elements needed to create alternative realities, and the technical requirements needed to achieve alternative realities through human sensing modalities. One advantage to this methodology is that it identifies technical requirements from a sensory perspective, thus allowing it to remain relevant as computational and display hardware continues to advance. The evaluation was directed toward the specific application of spacecraft vehicle and habitat design from the perspective of evaluators in Program Management, Human Systems Integration, Operations and Training, Engineering, and Manufacturing and Assembly. We identified existing tools used within these stakeholder groups and established a set of high-level guidelines for how each approach could be used. The results were summarized in a series of tables to document the advantages, disadvantages, tools, and applicable phases within the design process. The research also identified current state-of-the-art uses in other disciplines and, to the extent possible, projects expected future technology development. The framework contributes to our understanding of alternative reality technologies and their applicability to all stages of spacecraft habitat design and evaluation. This research will assist in evaluating requirements and can be used to improve habitability, ergonomics, and space allocation, and to meet engineering constraints. We also performed an experimental evaluation across the four defined extended reality (XR) environments. Each environment models a low-fidelity cis-lunar habitat in the CU Bioastronautics Laboratory. The habitat includes a galley, sleeping quarters, stations for scientific experiments, communication, controls, and extravehicular activity. The Physical Reality (PR) environment is a physical habitat mockup. The Augmented Reality (AR) environment was projected onto the physical mockup to replicate switch and display interface functionality, presented on the Microsoft Hololens. The Hybrid Reality (HR) and Virtual Reality (VR) environments visually present the habitat in the HTC Vive Pro head mounted display. For the HR environment, the physical mockup was outfitted with sensors such that the visual field represented direct interaction with the physical habitat. The VR environment allows for interactions through two hand-held controllers. A set of functionally-grouped task lists were created across the XR environments. Each subject (n=36) completed lifestyle, science, and emergency tasks in one of the alternative reality environments, with dependent variables for these trials including the number and type of errors made, task completion time, and subjective analysis of the environment's usability. In addition, subjects completed a volumetric assessment across environments to determine how spatially accurate the virtual presentations of the physical environment are. The volumetric assessment requires the subject to estimate whether boxes of varying sizes will fit through a hatch door. Users will assess the spacecraft habitat design while completing these tasks. We hypothesized there would be no overall significant difference in the perception of and interaction with the habitat across the alternative reality environments. This was not the case. Subjects perceived the spacecraft volume to be smaller in AR, and also made the most errors in volumetric assessment in this environment. For the functional tasks, subjects performed their tasks the most poorly in HR, followed by AR. In both experiments, subjects performed the most consistently with the PR environment while assessing volume and performing tasks in the VR environment. Further, we also tracked the development effort required for each alternative reality category. The HR environment took more than twice the amount of time to develop as the other environments. Hardware limitations in AR also may have contributed to the results in these experimental studies and additional exploration of other

	implementations of these alternative reality technologies should continue to be explored. In this work, we identify ways in which alternative reality technologies can be used as one of many tools available to achieve the greatest utility in spacecraft habitat design evaluation. Future work includes finalizing the statistical analysis associated with our experimental findings. We are also preparing two manuscripts for publication (one each for the framework and the experiment). We have submitted the report from Phase 1 of the project, the framework, to NASA, and that document will be transitioned to a NASA technical report so it can be widely distributed. Future areas of investigation include going beyond volumetric assessment to include more traditional measures of human factors, such as situational awareness, workload, stress, and psychophysiological response of working in the habitat for long duration. We may also explore the microgravity simulation capabilities that are available in alternative realities and explore their utility for spacecraft habitat design evaluation.
Bibliography Type:	Description: (Last Updated: 03/26/2025)
Abstracts for Journals and Proceedings	Anderson A, Banerjee N, Boppana A, Baughman A, Lin S, Witte Z, Wall R, Klaus D. "Spacecraft Habitat Design Evaluation Using Alternative Reality Technologies." 2019 NASA Human Research Program Investigators' Workshop, Galveston, TX, January 22-25, 2019. 2019 NASA Human Research Program Investigators' Workshop, Galveston, TX, January 22-25, 2019. , Jan-2019
Abstracts for Journals and Proceedings	Banerjee N, Baughman A, Lin S, Witte Z, Klaus D, Anderson A. "Development of Alternative Reality Environments for Spacecraft Habitat Design Evaluation." 2019 NASA Human Research Program Investigators' Workshop, Galveston, TX, January 22-25, 2019. 2019 NASA Human Research Program Investigators' Workshop, Galveston, TX, January 22-25, 2019. , Jan-2019
Awards	Lin M. (Michelle (Shu-Yu) Lin) "Brooke Owens Fellowship (Awarded), February 2019." Feb-2019