Fiscal Year:	FY 2023	**Task Last Updated:**	FY 09/29/2022
PI Name:	Stirling, Leia Ph.D.		
Project Title:	HCAAM VNSCOR: Responsive Multimodal Human-Automation Communication for Augmenting Human Situation Awareness in Nominal and Off-Nominal Scenarios (80NSSC20K0409)		
Division Name:	Human Research		
Program/Discipline:			
Program/Discipline--Element/Subdiscipline:			
Joint Agency Name:		**TechPort:**	No
Human Research Program Elements:	(1) **HFBP**:Human Factors & Behavioral Performance (IRP Rev H)		
Human Research Program Risks:	None		
Space Biology Element:	None		
Space Biology Cross-Element Discipline:	None		
Space Biology Special Category:	None		
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City:	Ann Arbor	**State:**	MI
Zip Code:	48109	**Congressional District:**	12
Comments:	NOTE: PI moved to University of Michigan in fall 2019; previous affiliation was Massachusetts Institute of Technology		
Project Type:	Ground	**Solicitation / Funding Source:**	2017-2018 HERO 80JSC017N0001-BPBA Topics in Biological, Physiological, and Behavioral Adaptations to Spaceflight. Appendix C
Start Date:	12/04/2019	**End Date:**	12/03/2023
No. of Post Docs:	0	**No. of PhD Degrees:**	0
No. of PhD Candidates:	3	**No. of Master' Degrees:**	2
No. of Master's Candidates:	0	**No. of Bachelor's Degrees:**	2
No. of Bachelor's Candidates:	4	**Monitoring Center:**	NASA JSC
Contact Monitor:	Whitmire, Alexandra	**Contact Phone:**	
Contact Email:	alexandra.m.whitmire@nasa.gov		
Flight Program:			
Flight Assignment:			
Key Personnel Changes/Previous PI:	Co-I Ella Atkins moved from University of Michigan to Virginia Tech in August 2022. This change in location will not affect the proposed effort and collaboration continues with Prof. Atkins co-advising a graduate student with Prof. Stirling.		
COI Name (Institution):	Blossom, Jonathon (NASA Jet Propulsion Laboratory) Atkins, Ella Ph.D. (University of Michigan, Transitioned to Virginia Tech) Liu, Andrew Ph.D. (Massachusetts Institute of Technology)		
Grant/Contract No.:	80NSSC20K0409		
Performance Goal No.:			
Performance Goal Text:			

Task Description:	[Ed. note April 2020: Continuation of "HCAAM VNSCOR: Responsive Multimodal Human-Automation Communication for Augmenting Human Situation Awareness in Nominal and Off-Nominal Scenarios," grant 80NSSC19K0703, with the same Principal Investigator (PI) Leia Stirling, Ph.D., due to PI move to University of Michigan from Massachusetts Institute of Technology in fall 2019] This task is part of the Human Capabilities Assessments for Autonomous Missions (HCAAM) Virtual NASA Specialized Center of Research (VNSCOR). Crew extravehicular activity (EVA) is limited on spaceflight missions. Multiple, small robotic spacecraft with varying levels of autonomy are needed to perform tasks that might have been completed by an astronaut (e.g., an exterior surface inspection or repair). Crews on long duration exploration missions (LDEM) will have less access to ground support during task operations. As a result, they will need to process more information and communicate with autonomous robots effectively to ensure tasks are progressing safely and on schedule. The objective of these studies is to investigate the use of augmented reality (AR) multimodal interface displays and communication pathways for improving human-robot communication, situation awareness (SA), trust, and task performance. This will lead to developing guidelines for designing human-robot system interactions that enable operational performance for crews on spaceflight missions. The specific aims are to: 1) Develop a simulation testbed for examining communication between human-robot teams. 2) Develop a hardware testbed for examining communication between human-robot teams. 3) Evaluate human SA, trust, and task performance within a short duration and long-duration ground-based study (simulation and/or hardware) through testing various interface communication modalities and information displays. 4) (Option) Perform additional studies for alternate parameters of interest that could be tested using the study testbeds. Additional parameters include timing and persistence of information, gesture command mapping, varying the levels of robot automation, evaluating precision enabled by each command mode.
Rationale for HRP Directed Research:	
Research Impact/Earth Benefits:	Augmented Reality (AR) has the opportunity to support decision making across a variety of use-case scenarios, including but not limited to manufacturing, automated vehicles, military training, and entertainment. This research compares AR to other visual modalities for telerobotics applications, specifically considering robotic control and anomaly inspection. Results from this study can inform how AR is integrated for task-specific applications, as there may be tasks that have increased benefit from AR, whereas others may have additional considerations that emerge.
Task Progress:	The objective of these studies is to investigate the use of augmented reality (AR) multimodal interface displays and communication pathways for improving human-robot communication, situation awareness (SA), trust, and task performance. This will lead to developing guidelines for designing human-robot system interactions that enable operational performance for crews on spaceflight missions. During this reporting period, our team supported the NASA Human Exploration Research Analog (HERA) Campaign 6 missions in data collection and performed data analysis for the missions completed. This study used the Unity-based simulation testbed for evaluating the aims of assessing visual presentation modality across two tasks. The visual modalities considered were: (1) 2D camera images from fixed cameras placed externally on a simulated space station, (2) 3D reconstruction shown on a 2D projection, and (3) 3D reconstruction shown in an Augmented Reality environment using the HoloLens v2 platform. The reconstruction simulates using 2D camera images from the inspector to create the 3D object. The tasks evaluated are Synchronous and Asynchronous inspection tasks. In the Synchronous task, participants fly an inspector robot around the spacecraft to identify any surface anomalies that require closer inspection. The inspector can be flown in automatic mode along a predetermined path or manual mode to move off the assigned path. The robot is controlled with a 3-DOF joystick. In the Asynchronous task, participants analyze the imagery from a previous inspection flight to identify the potential anomalies on the spacecraft exterior. In both tasks, detected anomalies are captured by taking a picture of the anomaly within the viewpoint. Initial HERA results support that detection accuracy was the highest for the 2D display for the Synchronous Inspection task. Additional interactive 3D viewpoints decreased detection accuracy and increased task completion time. Augmented Reality provided no significant improvement to local navigation, i.e., minimum distance to station or portion of time within two meters, suggesting that the technology did not enhance the perception level of situation awareness. Based on these findings, mission planning operations, when applicable, should include synchronous human-in-the-loop presence for telerobotic inspection of spacecraft. Additional details on the single session study are available in Weiss et al. (2021) and on the initial HERA findings in Liu et al. (2022). During the reporting period, our team also continued to develop a hardware-based implementation of the anomaly-detection task. We previously built a scaled physical mock-up of a space station and configured a quadcopter for a hardware-based ground evaluation. During this report period, pilot testing was performed to examine the hardware testbed and communication between human-robot teams. Additional details on these tests are reported in Weiss et al. (2022). Localization of the quadcopter for the automated mode is performed with motion capture, while the manual mode is performed using a handheld controller. Effort continues on the automation algorithms to support coverage mapping and real-time object reconstruction using this testbed. Finally, our team began our effort to compare augmented reality task performance with physical task performance to support new knowledge for the NASA Human Integration Design Handbook (HIDH). Tasks selected align with sensorimotor and neurovestibular assessment and include a Fitts' Law task examining precision and accuracy, as well as dynamic and operational balance assessments that make use of the virtual environment. This reporting period included software development and initial user studies. Human studies testing has begun and will continue into the next reporting period.
Bibliography Type:	Description: (Last Updated: 05/15/2025)

Abstracts for Journals and Proceedings	Liu AM, Weiss H, Stirling L. "Effects of visual display modality on simulated on-orbit inspection performance: Initial results from Human Exploration Research Analog Campaign 6. " 66th International Annual Meeting of the Human Factors and Ergonomics Society, Atlanta, GA, October 10-14, 2022. Abstracts. 66th International Annual Meeting of the Human Factors and Ergonomics Society, Atlanta, GA, October 10-14, 2022. , Oct-2022
Abstracts for Journals and Proceedings	Weiss H, Stirling L. "Methods for evaluating neurovestibular and sensorimotor performance using augmented reality and wearable sensors. " 13th International Conference on Applied Human Factors and Ergonomics (AHFE 2022), New York, NY, July 24 - 28, 2022. Abstracts. 13th International Conference on Applied Human Factors and Ergonomics (AHFE 2022), New York, NY, July 24 - 28, 2022. , Jul-2022
Abstracts for Journals and Proceedings	Weiss H, Patel A, Liu A, Stirling L. "Evaluation of human-in-the-loop presence on an anomaly inspection task using a quadcopter." 2022 NASA Human Research Program Investigators' Workshop, Virtual, February 7-10, 2022. Abstracts. 2022 NASA Human Research Program Investigators' Workshop, Virtual, February 7-10, 2022. , Feb-2022
Papers from Meeting Proceedings	Weiss H, Patel A, Romano M, Apodoca B, Kuevor P, Atkins E, Stirling L. "Methods for evaluation of human-in-the-loop inspection of a Space Station mockup using a quadcopter. " 2022 IEEE Aerospace Conference (AERO), Big Sky, MT, March 5-12, 2022. Proceedings from the 2022 IEEE Aerospace Conference (AERO), Big Sky, MT, March 5-12, 2022. http://dx.doi.org/10.1109/AERO53065.2022.9843466 , Mar-2022