Fiscal Year:	FY 2020	**Task Last Updated:**	FY 01/14/2020
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		
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:	(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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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:	04/01/2019	**End Date:**	12/31/2019
No. of Post Docs:	0	**No. of PhD Degrees:**	0
No. of PhD Candidates:	0	**No. of Master' Degrees:**	1
No. of Master's Candidates:	1	**No. of Bachelor's Degrees:**	0
No. of Bachelor's Candidates:	2	**Monitoring Center:**	NASA JSC
Contact Monitor:	Williams, Thomas	**Contact Phone:**	281-483-8773
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Flight Program:			
Flight Assignment:			
Key Personnel Changes/Previous PI:	Personnel changes (January 2020 report): Principal Investigator (PI) Prof. Stirling moved from MIT to the University of Michigan in fall 2019; grant will be transferred there in early 2020. Prof. Dave Miller (MIT, Co-Investigator) left the project and Prof. Ella Atkins (University of Michigan, Co-I) was added. Mr. Jonathon Blossom (Jet Propulsion Laboratory-JPL PI) took over lead at JPL as the previous JPL PI, Mr. Victor Luo, and Co-I, Mr. Alex Menzies, have left JPL.		
COI Name (Institution):	Blossom, Jonathon (NASA Jet Propulsion Laboratory) Liu, Andrew Ph.D. (Massachusetts Institute of Technology) Atkins, Ella Ph.D. (University of Michigan)		
Grant/Contract No.:	80NSSC19K0703		
Performance Goal No.:			
Performance Goal Text:			

Task Description:	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 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:	In this reporting period, an initial simulation environment was developed aligning with Aim 1. While the larger study proposed includes the research question examining the effect of display (standard 2D camera images on a computer screen, 2D projection of a 3D reconstruction on a computer screen, and 3D AR) on task performance, an initial pilot study was performed to assess the simulation environment created. The Microsoft HoloLens, a gesturally-controlled AR headset, was used to display a simulated space station and satellite environment. Twelve subjects inspected the exterior of the space station using a simulated free-flying robot to detect surface anomalies. The subjects used gestural commands to control the satellite in three operation modes: satellite body (local) reference frame control, station (global) reference frame control, and waypoint control (markers are placed for the inspector to follow). Anomalies occurred in areas with high or low risk of satellite contact with the station structure. Subjects were instructed to prioritize their performance based on the following: (1) avoid station collisions, (2) locate anomalies, and (3) inspect the full exterior as quickly as possible. Subjects performed the inspection in both fixed command mode (in each of the three operation modes, order randomized) and in free mode (with free choice of when and how often they utilized different operation modes). Performance measures included percentage of station inspected, number of collisions, and accuracy in anomaly detection. Workload was evaluated using the NASA Task Load Index (TLX) method. Interactions with the simulated environment were logged to characterize subject strategies for utilizing the interface (i.e., moving the viewpoint, changing scale and position of virtual models). Manually controlling the satellite in the global and local frames maximized the percentage of the station that was inspected, while using waypoints led to fewer collisions between the satellite and the station. There was no significant difference in anomaly detection across the various command modes for the anomaly frequency and type selected. When operating with free choice of command mode, subjects preferred to remain in a single mode, typically either the global or local control. Subject feedback and NASA TLX scores suggest the global and local modes required less workload and were more usable than waypoint control as currently implemented. One subject was observed to select strategies that did not comply with our instructed task priorities as they appeared to prioritize speed over anomaly detection. The AR interface enabled users to manipulate the virtual models to alter their viewpoint and move around the virtual model in the real-world space throughout the inspection task. The design of waypoint navigation enabled better collision avoidance as it encouraged planning, but was more suited to single-point inspection tasks as currently implemented. The global and local modes were more suited to the patrol task in this study, enabling easier navigation at close proximity. Based on the initial pilot evaluation, we are in the process of updating the simulation environment. While the initial pilot study focused on robotic system control and inspection, the follow-on study simulation incorporates two different tasks across the visual modalities, an inspection-only (IO) task, where the images are pre-recorded, and a robotic control and inspection (RCI), where the operator must both obtain the images and inspect within the same trial. We have also enabled an automated mode where the robot performs an edge following task. In the manual modes, the operator can still control in local or global mode. While waypoint navigation provides a mid-level form of automation, it was determined that this control mode was not appropriate for the perimeter inspection task. When the operator manually stops the edge following, they would switch into manual control mode. During the next year of the program, the simulation study comparing the visual modalities will be performed. [EDITOR'S NOTE 4/15/2020: Due to Principal Investigator Stirling's move to University of Michigan, the project was transferred there with a new grant number 80NSSC20K0409 and a new period of performance, 12/4/2019-12/3/2023. See the continuation project for subsequent reporting.]
Bibliography Type:	Description: (Last Updated: 11/09/2023)

Abstracts for Journals and Proceedings	Todd JE, Liu A, Stirling L. "Investigation of augmented reality in enabling telerobotic on-orbit inspection of spacecraft." Presented at the 2020 NASA Human Research Program Investigators’ Workshop, Galveston, TX, January 27-30, 2020. Abstracts. 2020 NASA Human Research Program Investigators’ Workshop, Galveston, TX, January 27-30, 2020. , Jan-2020
Abstracts for Journals and Proceedings	Marquez J, Stirling L, Fanchiang C, Selva D, Lee J, Schreckenghost D, Robinson S. "Overview of the virtual NASA specialized center of research (VNSCOR)-'Human capabilities assessments for autonomous missions' (HCAAM)." 2020 NASA Human Research Program Investigators’ Workshop, Galveston, TX, January 27-30, 2020. Abstracts. 2020 NASA Human Research Program Investigators’ Workshop, Galveston, TX, January 27-30, 2020. , Jan-2020
Abstracts for Journals and Proceedings	Stirling L. "Emergent behaviors when defining a gesture interface for controlling a robotic arm." Presented at the ErgoX Symposium 2019, Seattle, WA, October 28, 2019. ErgoX Symposium 2019, Seattle, WA, October 28, 2019. , Oct-2019