Fiscal Year:	FY 2020	**Task Last Updated:**	FY 05/14/2020
PI Name:	Fischer, Ute Ph.D.		
Project Title:	Understanding Key Components of Successful Autonomous Space Missions		
Division Name:	Human Research		
Program/Discipline:			
Program/Discipline--Element/Subdiscipline:	HUMAN RESEARCH--Behavior and performance		
Joint Agency Name:		**TechPort:**	No
Human Research Program Elements:	(1) **HFBP**:Human Factors & Behavioral Performance (IRP Rev H)		
Human Research Program Risks:	(1) **BMed**:Risk of Adverse Cognitive or Behavioral Conditions and Psychiatric Disorders (2) **Team**:Risk of Performance and Behavioral Health Decrements Due to Inadequate Cooperation, Coordination, Communication, and Psychosocial Adaptation within a Team		
Space Biology Element:	None		
Space Biology Cross-Element Discipline:	None		
Space Biology Special Category:	None		
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Comments:	NOTE: The NSSC also lists the PI as Ute Fischer-Loss (Ed., March 2025).		
Project Type:	Ground	**Solicitation / Funding Source:**	2015-16 HERO NNJ15ZSA001N-Crew Health (FLAGSHIP, NSBRI, OMNIBUS). Appendix A-Crew Health, Appendix B-NSBRI, Appendix C-Omnibus
Start Date:	06/29/2016	**End Date:**	06/28/2021
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 changed to 6/28/2021 per NSSC information (Ed., 5/21/2020) NOTE: End date changed to 6/28/2020 per L. Juliette/HRP (Ed., 2/19/2020) NOTE: Element change to Human Factors & Behavioral Performance; previously Behavioral Health & Performance (Ed., 1/18/17)		
Key Personnel Changes/Previous PI:	May 2020 report: Dr. Tofighi withdrew as Co-I from the project effective July 1, 2019.		
COI Name (Institution):	Mosier, Kathleen Ph.D. (Teamscape LLC)		
Grant/Contract No.:	NNX16AM16G		
Performance Goal No.:			
Performance Goal Text:			

Task Description:	Exploration space missions will require that space crews manage tasks more autonomously than in current operations, although they will continue to be part of the multi-team system (MTS) comprised of members in space and on the ground. The overall goal of the proposed research is to develop countermeasures that will enhance the ability of MTS members to maintain effective team performance and manage autonomous operations during Long Duration Exploration Missions (LDEMs). We will use NASA Life Sciences Data Archive (LSDA) data collected in space analogs and the International Space Station (ISS) to develop models of the individual- and team-level relationships between crew autonomy, emergent states, and team performance. Additionally, several simulations will be conducted in space analogs to assess the impact of different autonomy implementations on MTS performance in long-duration missions. Data from this study will be used to refine the individual- and team-level models, and to create a MTS-level model of the autonomy-performance relationship. Our approach is comprehensive in that we will examine different implementations and levels of autonomy, experience with interdependent and autonomous operations, individual and team process variables as well as varying task constraints. A set of products to support space and mission control teams during long-duration exploration missions will be delivered. These include: a validated model of factors related to team autonomy and team performance in LDEMs; recommendations for how team autonomy should be managed within a MTS during LDEMs, including countermeasures to mitigate potential negative effects; and recommendations for future research on autonomous team functioning.
Rationale for HRP Directed Research:	
Research Impact/Earth Benefits:	Multiteam collaboration is not a unique feature of spaceflight operations but common to many organizations, as is the question of how best to implement task autonomy within a multiteam system. We therefore expect that our research findings not only generalize to other isolated and confined extreme (ICE) environments, such as Antarctica, but also apply to any organization that require the collaboration by different work units.
Task Progress:	Over the past year data collection was completed in two space mission simulations. The Scientific International Research In a Unique terrestrial Station (SIRIUS)-19 mission ended in July 2019, the last of the four Human Exploration Research Analog (HERA) C5 missions ended in March 2020. Preliminary findings of these studies will be summarized below. Our research was also selected for inclusion in two upcoming space simulations. Details on these missions will be provided in the second section of this report. HERA C5 consisted of four missions, each with a duration of 45 days. Missions involved communication delays (increasing from 30 seconds to 5 minutes, one-way) and were identical concerning objectives and schedule. The overall mission objective was to conduct geological operations at a near-Earth asteroid. In addition, each crew was to conduct scientific experiments, vehicle systems maintenance, and educational outreach. 16 astronaut-like participants were recruited as crewmembers (4 per mission); 12 members of NASA Johnson Space Center (JSC) Flight Analogs group acted as mission control personnel (HABCOMs). As HERA C5 missions did not involve any crew autonomy manipulation, they will serve as baseline conditions to simulations with crew autonomy: SIRIUS 19, and upcoming HERA C6 and SIRIUS 20/21 simulations. SIRIUS 19 was a 4-month simulation that involved a high level of crew autonomy as the crew was expected to solve problems largely independently of mission control and took place in the Russian NEK (Nezemnyy Eksperimental'nyy Kompleks) facility. SIRIUS simulated a lunar mission and involved docking with a lunar orbital station, orbital operations to identify a site on the lunar surface suitable for landing, and lunar landing of a crew of four—crewmembers moved to a different module for this part of the simulation where they lived for 7 days and simulated lunar surface operations. After the lunar crew's return to the orbital station there were 40 days of simulated lunar orbit during which crewmembers conducted remote rover operations. Transit to Earth was initiated on mission day MD111 with the crew reaching the Earth's orbit by MD118. Communication between crew and mission control was delayed by 5 minutes one-way on mission days 11 through 110. The official mission language was Russian. Crewmembers included four Russian and two U.S. participants. Mission controller participants were 24 medical staff members. Several unexpected (for the crew) events were built into a mission. These events served as our experimental tasks to examine teamwork both within a crew and the crew/mission control (MCC) multiteam system. There were eight tasks in a HERA mission, and 10 tasks in SIRIUS. Half of the tasks were demand events where MCC requested that the crew perform an unscheduled and time consuming task. Stretch events were off-nominal situations that challenged the crew's expertise and members had to decide on how best to respond; in particular, whether to resolve the issue and its impact on their task schedule autonomously or to seek assistance from mission control. The same set of surveys were employed in both simulations. For SIRIUS, Russian versions of the surveys were prepared by a professional translator and back-translated into English to verify their accuracy. Participants were given the choice to receive the surveys in English or Russian. Surveys were administered via Qualtrics. Surveys explored the team concept held by crewmembers and mission controllers, their perception of task and social cohesion among members of the space/ground multiteam system, and their assessment of the multiteam system's efficacy. Premission surveys included measures of participants' teamwork model and individual inclinations and attitudes. Task-related surveys concerned crewmembers' and mission controllers' evaluation of teamwork and task performance, and their ratings of the crew's and MCC staff's task contribution. Task-related surveys were not included in the crew's mission schedule to ensure that crewmembers had no prior indication of the experimental tasks; instead MCC sent survey links after task completion. Personnel manning MCC during an experimental task was asked to complete task-related surveys at the end of their shift. Analyses at the Level of the Crew/MCC Multiteam System (MTS): Analyses indicate that crewmembers and mission controllers in both HERA and SIRIUS simulations tended to define 'their team' narrowly as they predominantly referred to members of their own component teams rather than the space/ground multiteam system. Divergent perspectives were also apparent between SIRIUS crewmembers and mission controllers in their judgment of cohesion in the space/ground MTS and its efficacy. SIRIUS crewmembers perceived less unity with and closeness to mission controllers than vice versa and, more importantly, they also perceived less shared task commitment between members of the multiteam system than mission controllers. Likewise, crewmembers were less confident than mission controllers that their teams were able to communicate and collaborate effectively. In the HERA simulation, crewmembers and mission controllers appeared more aligned with respect to their perception of both MTS cohesion and MTS efficacy. Differences between them concerned their assessment of taskwork. Here we observed a tendency by each component team to think that they contributed more to task success than members of the other team (MCC or crew, respectively). In SIRIUS, in contrast, crewmembers and mission controllers agreed in their assessment of MTS members' taskwork and tended to give more weight to MCC and the commander than to the other

crewmembers.

Because these findings are based on two space simulations involving five teams of crewmembers and mission controllers, it is certainly premature to draw any conclusions about the impact of crew autonomy on the crew/MCC multiteam system. Nonetheless, it is worth pointing out that some of our observations, notably concerning MTS cohesion and efficacy, are consistent with the hypothesis that crew autonomy may disrupt common ground between crewmembers and mission controllers.

Analysis at the Level of the Crew Component Team: Our suite of surveys also included measures that targeted social and cognitive processes at the crew component team level. Specifically we focused on crewmembers' perception of their teamwork and team dynamics. Additional measures addressing within-crew cohesion, conflict, efficacy and performance will be obtained through a data-sharing agreement with NASA colleagues.

Analyses to-date explored crewmembers' models of teamwork to generate snapshots of the HERA and SIRIUS crews and to identify directions for further inquiry. These high-level analyses focused on crewmembers' teamwork models across experimental tasks, team roles, and teamwork components. While these analyses revealed considerable variability among the crews in the different missions, with no clear pattern of differences emerging between crews working under current vs. autonomous mission operation, they point to finer-grained analyses. Specifically, next analytic steps need to consider task characteristics –e.g., what aspects of teamwork were required?—and crewmember involvement in a given task in order to better address similarity in crewmembers' teamwork models. Future analyses will also need to unpack the differences in the "overall" teamwork models that we observed and focus on teamwork components; that is, they need to address whether crewmembers' agreement or disagreement was tied to specific teamwork behaviors; a consideration important for team training. Moreover, once additional crew data become available to us through data sharing agreements, we will be able to relate our measures of team mental models and team dynamics to team states and processes, such as cohesion, conflict, and team performance. Planned analyses of crew communication and task performance will provide additional process and outcome measures.

Upcoming Simulations

Our research project was selected for inclusion in two upcoming space simulation missions, HERA C6 and SIRIUS 20/21. The Principal Investigators (PIs) have participated in planning sessions for both missions and have submitted the Science Requirement Documents to NASA JSC Human Research Program (HRP). Both simulations are currently scheduled to start in November 2020.

SIRIUS 20/21 will be an 8-month space simulation with high crew autonomy and will replicate our study design of SIRIUS 19 mission. The HERA C6 campaign will include for missions, each with a duration of 45 days. Missions will follow the general study design we implemented in the preceding campaign; however, this time, missions will incorporate our crew autonomy manipulation of increasing autonomy. Crew autonomy will be gradually introduced with the onset of communication delay and after an initial period of no-autonomy (modeled after current mission operations as in previous HERA missions). The first phase of autonomy will involve limited crew autonomy – the crew will be able to self-schedule and -manage a certain number of tasks; however, the implementation of their plans will require pre-approval by MCC and the crew will be required to provide performance updates to MCC. High crew autonomy will be introduced once crew/MCC communication is delayed by 5 minutes. The crew will have the same responsibilities under limited autonomy but with fewer restrictions. They will not need to have their planned timeline pre-approved by MCC, nor will performance updates be prescribed. While the crew will be expected to transmit an evening daily planning conference (DPC), its content and level of detail will be at the crew's discretion. Mission control will be in a supportive role and crew/MCC communication will be initiated by the crew.

Both simulations will double the N for the high-autonomy condition, provide longitudinal data over a longer time frame (SIRIUS 20), and enable additional data analyses and modeling. The combined data sets will provide for empirically-based predictions of impact of autonomy on MTS team perceptions and team performance as well as changes in these variables over the course of a mission.

Bibliography Type:	Description: (Last Updated: 03/22/2024)
Books/Book Chapters	Fischer U, Mosier K. "Teamwork in spaceflight operations." in "The Oxford Handbook of Expertise." Ed. P. Ward, J.M. Schraagen, J. Gore, E.M. Roth. Oxford, UK: Oxford University Press, 2019. p. 830-849. https://doi.org/10.1093/oxfordhb/9780198795872.013.36 , Nov-2019