Fiscal Year:	FY 2017	**Task Last Updated:**	FY 06/26/2017
PI Name:	Kozlowski, Steve Ph.D.		
Project Title:	Measuring, Monitoring, and Regulating Teamwork for Long Duration Missions		
Division Name:	Human Research		
Program/Discipline:	HUMAN RESEARCH		
Program/Discipline--Element/Subdiscipline:	HUMAN RESEARCH--Behavior and performance		
Joint Agency Name:		**TechPort:**	Yes
Human Research Program Elements:	(1) **HFBP**:Human Factors & Behavioral Performance (IRP Rev H)		
Human Research Program Risks:	(1) **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:	I moved from Michigan State University to the University of South Florida in August 2020.		
Project Type:	Ground	**Solicitation / Funding Source:**	2012 Crew Health NNJ12ZSA002N
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No. of Bachelor's Candidates:	1	**Monitoring Center:**	NASA JSC
Contact Monitor:	Williams, Thomas	**Contact Phone:**	281-483-8773
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Flight Program:			
Flight Assignment:	NOTE: New end date is 8/15/2018 per NSSC information (Ed., 3/14/18) NOTE: Element change to Human Factors & Behavioral Performance; previously Behavioral Health & Performance (Ed., 1/18/17) NOTE: End date changed to 12/31/2017 per NSSC information (Ed., 6/16/16)		
Key Personnel Changes/Previous PI:	June 2017 report: Co-Investigator Chu-Hsiang (Daisy) Chang's leave assignment to serve as NSF Science of Organizations Program Officer has been extended an additional year. June 2016 report: Co-Investigator Chu-Hsiang (Daisy) Chang will be starting a one-year leave to assume the role of NSF (National Science Foundation) Science of Organizations Program Officer.		
COI Name (Institution):	Biswas, Subir Ph.D. (Michigan State University) Chang, Chu-Hsiang Ph.D. (Michigan State University)		
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Task Description:	Teamwork processes – entailing cognitive, motivational, affective, and behavioral aspects – have been researched in the psychological and behavioral sciences for well over a half century. Several lines of systematic research, large scale literature reviews, and meta-analytic summaries have firmly established that team processes, as key indicators of psycho-social team health, are critical contributors to team effectiveness, especially for "action" teams performing complex, interdependent tasks. Disruptions to teamwork jeopardize, due to conflict, low cohesion, or poor collaboration, have the potential to threaten team effectiveness. This is particularly the case under the isolated, confined, and extreme (ICE) conditions that can be anticipated for long duration space missions. These difficult operating environments are further challenged by high team autonomy and time lagged communications with ground. For high reliability teams, a disruption in good teamwork, especially at an inopportune time when well-coordinated teamwork is critical, can have disastrous consequences. Thus, the capability for NASA to measure, monitor, and regulate good teamwork interactions for flight crews and ground control teams is essential for overall mission effectiveness for the NASA strategic plan for space exploration. Developing this countermeasure capability is the goal of this ongoing research program. This proposed ground-based research is designed to address the following Program Requirements Document (PRD) Risk and Behavioral Health and Performance (BHP) Integrated Research Plan (IRP; 2011). PRD Risk: Risk of Performance Decrements Due to Inadequate Cooperation, Coordination, Communication, and Psychosocial Adaptation within a Team. IRP Gap – Team1: We need to understand the key threats, indicators, and life cycle of the team for autonomous, long duration and/or distance exploration missions. The proposed research has three specific aims and associated deliverables that represent an integrated approach for measuring, monitoring, and regulating teamwork processes and long-term team functioning: (1) Benchmark long duration team functioning in ICE analog environments. This research uses Experience Sampling Methods (ESM; daily assessments) to assess team functioning in ICE environments. The product of this research aim quantifies the expected range of variation in key teamwork processes (e.g., cohesion, collaboration, conflict), identifies internal and external shocks that influence variation, and assesses dynamic effects on team functioning. Benchmark data in ICE analog environments are essential for developing standards to distinguish expected variation in teamwork from anomalies indicative of a threat to team functioning. Such standards are essential for triggering countermeasures / interventions. (2) Extend engineering development of an unobtrusive monitoring technology (i.e., a wearable wireless sensor package). The product of this research aim advances development of a prototype monitoring technology to capture dynamic multimodal (i.e., physical, physiological, and behavioral) data capturing team member and teamwork interactions. Initial validation demonstrated the reliability and accuracy of the monitoring technology sufficient to establish proof of concept. Extensions include making the system more robust (i.e., packaging, energy efficiency, hardware, algorithms, and software) and developing a Bluetooth module for integrating additional sensors. (3) Develop teamwork interaction metrics and regulation support systems. The monitoring technology provides high frequency data streams on a range of team interaction and individual-level indicators. The product of this research aim develops supporting components (metrics, data fusion, and information display) required for these dynamic data streams to be utilized as a countermeasure for teams to regulate teamwork interactions and psycho-social health. To accomplish the product objectives highlighted above we have developed a multidisciplinary research team composed of experts spanning team development, regulation, and effectiveness (Kozlowski); psychological measurement of motivation, affect, and stress (Chang); and wireless monitoring of team member interactions (Biswas). This research contributes to reducing the risk of team performance decrements due to poor teamwork interactions by (a) characterizing normative and anomalous patterns of team functioning; (b) monitoring team member interactions; and (c) providing regulation support to maintain teamwork and to trigger countermeasures when needed to aid team recovery.
Rationale for HRP Directed Research:	
Research Impact/Earth Benefits:	Team cohesion is not only a critical factor for astronaut teams and ground crews; cohesion is important to the effectiveness of all teams and especially those that operate in critical, high reliability settings. Of the many team process factors that support team effectiveness, team cohesion is the most studied with over a half century of research. Yet, remarkably, very little is known about the characteristics that promote its development and maintenance. For example, we know that experiencing work situations together is associated with cohesion formation and maintenance, but the mechanisms remain unknown. This research, which focuses on the dynamics of collaboration, cohesion, and effective team functioning, and is creating technologies to monitor team cohesion and guide interventions to restore it, has the potential for wide utility in aviation, military, medical, industrial, and other environments where society depends on the effective performance of high reliability teams.
	Project Activities Benchmark Long Duration Team Functioning in ICE Analog Environments A significant portion of research effort was invested in continuing the multiple benchmarking data collections we have developed for this project. We have ongoing data collections in the Antarctic (i.e., science teams camped on the ice during the Antarctic summer and station teams for winter over-missions) and in NASA mission simulations (i.e., an asteroid transit simulation and a Mars surface exploration simulation). Australian Antarctic Division (AAD) Stations. Our collaborative research with Dr. Jeff Ayton of the AAD was extended (see prior reporting) through the current deployment. In this reporting period, we concluded the 2015-2016 data collection of approximately 27 participants from Mawson, Davis, and Casey Stations, and Macquarie Island. Research protocols and IRB (Institutional Review Board) approvals with AAD, Michigan State University (MSU), and NASA were updated and extended. We are currently working with our collaborator to bring this data collection effort to closure. This research assesses daily teamwork processes using Experience Sampling Methodology (ESM), which captures a snapshot of key individual and team reactions to daily events. Although the absolute sample sizes tend to be small, the

primary focus of this research is on the dynamics of reactions over a period of nine months to one year (i.e., approximately 270 to 360 measurement periods), which yields insights into long duration individual and team functioning.

To date, we have collected data from 151 individuals who wintered over in the Antarctic. Participants spent between 9-15 months in their stations and reported a total of 5,738 daily survey data points. Descriptive results showed that individuals exhibit different characteristic patterns on different individual and team-level indicators over time. These patterns can be differentiated into four categories: rock solid, uni-varier, multi-varier, or stabilizer. Individuals with a rock solid pattern did not vary in their responses to most of the questions over time. Uni-variers primarily fluctuated on one variable, such as daily task or social cohesion. Multi-variers, conversely, varied in their responses across a range of indicators. This response, potentially, arose because of their heightened perceptions of and response to environmental factors. Finally, stabilizers varied initially on many variables, but then converged to equilibrium across the mission. These findings suggest that response pattern classification may be a useful way to characterize how different individuals adapt to the rigors of long duration missions.

Science Field Teams in Antarctica. We also extended our ongoing collaboration with science teams that deploy to the Antarctic ice. Marking the seventh season of data collection, we extended our research protocol, renewed MSU and NASA IRB approvals, and recruited participants. Originally, eight participants were recruited to provide daily ESM reports for the 2016-2017 season. However, the expedition experienced delays in federal grant funding (due to delays by in Congress passing a budget for fiscal year 2017) which required half of their team to return to the USA without deploying to the ice. Four participants did complete diaries as requested. However, the mix of respondents and small sample size make individual responses potentially identifiable. Thus, we are not reporting summary findings from those data, given the stipulations in the IRB protocols for this data collection.

In this reporting period we explored the use of linguistic analysis tools to transform previously collected qualitative responses (open-ended comments) collected as part of our protocol into quantitative measures. Our focus was on a tool called Linguistic Inquiry and Word Count (LIWC), which provides counts of the words that fall into linguistic categories. A number of these categories, such as first person singular pronouns (e.g., I, me) or first person plural (e.g., we, us) have, respectively, demonstrated promise for estimating team processes such as social conflict or cohesion. These results show that language use in communication may be a viable approach to the development of unobtrusive measures of team processes in ICE environments.

Human Exploration Research Analog (HERA). We continued benchmarking research in HERA, a NASA mission simulation located at the Johnson Space Center (JSC) that was initiated in 2014. HERA missions involve a crew of 4 members, selected from NASA volunteers. HERA simulates a transit mission for exploration of an asteroid. In Campaign 1, mission duration was approximately 7 days for 4 crews of 4 members each. Campaign 2, initiated in January 2015, extended the missions to 14 days for 4 crews of 4 members each. Campaign 3, initiated in January 2016, extended the missions to 30 days for 4 crews of 4 members each. Campaign 4, initiated in January 2017, extended the missions to 45 days for 4 crews of 4 members each. Campaign 4, mission 1 is currently about to conclude. This research involved extending our protocol, securing IRB approvals from NASA and MSU, training personnel, and coordinating research activities with several other investigator teams.

We also assumed the responsibility of coordinating the collection of several end-of-day measures across investigators and then compiling and sharing the data. Data analyses for Campaign 3, therefore, are in progress and are not reported here. This is largely because a substantial proportion of our time is devoted to data sharing, which has emerged as a significant investment of personnel resources. We share data with more than ten other research teams. Each data sharing effort requires the development of a joint data sharing agreement (MSU Technologies) with the provider or recipient institution, which necessitates extensive communication. The data then have to be parsed, encrypted, and shared in a secure manner. The considerable labor and time involved have diverted resources from primary research activities. This substantial load on research personnel was not anticipated when this research team originally agreed to coordinate the sharing of behavioral data and it has significantly impeded our ability to accomplish primary research tasks. Thus, we are behind schedule on efforts to analyze data from Campaign 3.

Hawai‘i Space Exploration Analog and Simulation (HI-SEAS). We continued our benchmarking research in a surface exploration simulation, HI-SEAS, which is located at 8200 feet on Mt. Mona Loa on the big island of Hawai‘i. We initiated our collaboration with HI-SEAS mission 2. This research involved extending our protocol, securing IRB approvals from the University of Hawai’i (under PI Kim Binsted), MSU, and NASA, and substantially aiding HI-SEAS mission design. We contributed to crew selection (we screened on the five factor model of personality and cognitive ability), the mission story / script, mission EVA (extravehicular activity) / scenario design, and problem-solving on a variety of issues that arose across the arc of the missions.

We have completed data collections from the five-person crew (1 team member withdrew shortly after the mission began) of mission 2 (4 months), the six-person crew of mission 3 (8 months), and the six-person crew of mission 4 (12 months). The M4 crew also used the MSU monitoring badge so that we can enlarge the pool of benchmarking data for interactions over time.

Task Progress:

Although it is difficult to draw firm conclusions based on these three case studies, we observed that the most significant anomalies affecting team functioning occurred in the two longer duration missions that exceeded six months. Teams in both longer duration missions developed relationship conflict patterns at approximately the six-month point in the mission. The nature of the problems across the crews were based on different issues, but the conflicts persisted to influence subsequent team functioning through the remainder of both missions. If either of these crews had had to respond to an emergency, it is the opinion of this research team that their effectiveness would have been impeded by their ongoing conflict patterns.

Conclusions can only be tentative at this point, but these observations suggest that mission duration in excess of six months is a contributing factor to problems in team functioning. If so, the findings suggest that the most informative analog missions will also be in excess of six months in duration.

Extend Engineering Development of an Unobtrusive Monitoring Technology

The monitoring technology under development has been successfully validated in the laboratory and is under evaluation in NASA mission simulations. Engineering activity was mainly focused on the integration of a Bluetooth hardware module and development of associated software.

Bluetooth (BT) hardware and software integration. When we started this project, wearable sensors were a novelty. However, over the course of technology development, wearable sensor technology has exploded across a variety of activity monitors (mostly wrist mounted) in the commercial marketplace. As sensors are proliferating, they are also becoming increasingly sophisticated. We anticipate that in the future, it is likely that commercial monitors will provide sensor data that are useful for our effort to diagnose team member psychosocial health. Thus, to provide flexibility for the technology platform, we have initiated an effort (with NASA concurrence) to integrate a BT module with the badge sensor processor.

During this reporting period, the engineering team chose a Bluetooth Low Energy (BLE) module, supplied by Laird Technologies Inc., for integration with the MSU badge system. The objective of this integration was to add BLE connectivity to the badge so that it can: (1) collect data from external sensors (e.g., heart rate from smart watches, galvanic skin resistance [GSR]) and (2) communicate with data aggregator devices such as mobile phones, tablets, and PCs. BLE development was accomplished in two phases. In the first phase, we used a BLE Chipset that allowed the badge to be connected to one peripheral device (e.g., external sensor) at a time. This development is now complete and we have a working prototype. Using this BLE connectivity, the badge is now able to communicate with an external Bluetooth heart rate sensor (Polar H7 http://www.polar.com/) for heart rate monitoring. Software for all the subsystems, namely, the badge, base station, and PC have been developed for end-to-end transportation of heart rate data from the H7 monitor over the BLE link, all the way to the PC-based badge dashboard software.

The next step of the BLE development is to use a more generalized chipset that will allow the badge to be able to communicate with many peripherals simultaneously. Work on this phase is underway.

Develop Teamwork Interaction Metrics and Support Systems.

Metrics. Depending on teamwork activity, interaction data streams can be dense (e.g., most members of the team are engaged in an intensive interaction) or quite sparse (e.g., members interact as dyads every so often but mostly work apart) or anywhere in between. Yet, even when team interactions are intensive, everyone on the team will not be interacting with everyone else at exactly the same time, which means that there will be many “holes” or “gaps” in the interaction data. At this point in the development of the system, we need to use standard statistical analyses to link the interactions and physiological indicators. Statistical software requires specific, dense data structures. Thus, in order to analyze interaction level data, the raw data collected by the badges have to be filtered to target those points in time when one member is interacting with another member and then the interaction and associated physiological data have to be parsed (i.e., extracted) and rewritten to a new data file without gaps that can then be analyzed with appropriate statistical tools (i.e., random coefficient models). Our ultimate aim is to accomplish the filtering process algorithmically. However, to develop appropriate algorithms, one needs to first develop the logic, instantiate it in code, and evaluate the integrity of the resulting data set. We have been working on this focus this reporting period.

Data filtering and parsing. We have previously developed computer code for our laboratory evaluation of the badges. That code was used to filter the raw data files from the badges and to parse and transform (i.e., recompile) it into a dataset that is appropriate for statistical analysis. During this reporting period, we have been systematically extending, generalizing, and evaluating the code for badge data collected in HERA and HI-SEAS.

In prior efforts, we extended the code to “test” our highly structured interactions in HERA and HI-SEAS. That is, participants worked on a task in which they followed a protocol specifying who interacted with whom and in what order the interactions occurred. That procedure allowed a phased validation of the badge as we transitioned it from the laboratory (3-person teams) to a controlled field setting (HERA; 4-person teams) and to a less controlled field setting (HI-SEAS; 6-person teams).

With that phased validation in place, the next major extension was to advance the code to assess dyadic interactions for fully unstructured or natural interactions. We have made preliminary progress and have a prototype algorithm under development and evaluation.

Data fusion. Having filtered, parsed, and transformed the badge data, the multivariate time series metrics need to be fused into a coherent assessment of ongoing individual and team functioning. As previously reported, we have preliminary evidence that positive and negative reactions based on interaction-level data can be predicted from heart rate (HR), HR variability (HRV), and their interaction. These data are collected by the badge system. As we continue to develop the badge technology system as a sensor integration platform (i.e., Bluetooth integration) that adds additional sensing modalities, the physiological data available for inferring psychological states will expand and reliability will improve.

Distributed networked dashboard. A system architecture is needed to integrate sensor information. A backend server infrastructure was developed during the prior reporting period for supporting the proposed distributed network dashboard. The server, which is hosted at MSU Engineering Building, has a JAVA based remote connection to the existing PC-based dashboard software. All data collected by the base station is pushed up to this remote server via the PC-based dashboard software. The server then makes the data available via a web service. This provides the opportunity for accessing badge-collected data to be exported to any remote web client running on PCs, tablets, phones, and other handheld devices.

During this reporting period, we have developed design concepts for a live dashboard 'app' that space crews could use to monitor and improve the functioning of their team based on badge data. This Team Dashboard will be designed track and improve targeted team interaction metrics deemed crucial for success on space missions by a panel of experienced astronauts (a future concept that is beyond the scope of the current project). The Team Dashboard will be designed using best practices in User Experience Design and the latest Gamification techniques to create a tool that space crews feel they can rely on and enjoy using.

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