American Psychological Association

American Psychologist

0003-066X/18/$12.00

2018, Vol. 73, No. 4, 563–575
http://dx.doi.org/10.1037/amp0000260

Teamwork and Collaboration in Long-Duration Space Missions: Going to Extremes

Lauren Blackwell Landon
KBRwyle, National Aeronautics and Space Administration, Houston, Texas

Kelley J. Slack
University of Houston and National Aeronautics and Space Administration, Houston, Texas

Jamie D. Barrett
Federal Aviation Administration, Oklahoma City, Oklahoma

The scientific study of teamwork in the context of spaceflight has uncovered a considerable amount of knowledge over the past 20 years. Although much is known about the underlying factors and processes of teamwork, much is left to be discovered for teams who will be operating in extreme isolation and confinement during a future Mars mission. Special considerations must be made to enhance teamwork and team well-being for multi-year missions during which the small team will live and work together. We discuss the unique challenges of effective teamwork in a Mars mission scenario, and the difficulties of studying teamwork using analogs of the space environment. We then describe the National Aeronautics and Space Administration's current practices and research on teamwork, which includes team selection and composition, teamwork training, countermeasures to mitigate risks to effective team performance, and the measurement and monitoring of team functioning. We end with a discussion of the teamwork research areas that are most critical for a successful journey to Mars.

Keywords: teamwork, space exploration, astronaut, extreme team

Teamwork has been an integral aspect of American spaceflight from the earliest days of the space race; starting with the National Aeronautics and Space Administration's (NASA's) engineering and technology teams, and progressing to the manned spaceflight programs that took teams of astronauts to the Moon. Future manned exploration-class missions such as a Mars mission will require periods of isolation and confinement that will last years rather than months. NASA recognizes that the success of these future space missions will rely on effective teamwork (both in a task-oriented and an interpersonally oriented sense). NASA support for psychological research has increased, particularly in the 21st century. NASA's Human Factors and Behavioral Performance Research Element funds a dedicated stream of research that is focused on mitigating the "Risk of Performance and Behavioral Health Decrements Due to Inadequate Cooperation, Coordination, Communication, and Psychosocial Adaptation within a Team" (Landon, Vessey, & Barrett, 2016). NASA teamwork research is rooted in the broader organizational behavior literature and operating from a common description of teamwork as "interdependent acts that convert inputs to outcomes through cognitive, verbal, and behavioral processes directed toward organizing taskwork to achieve collective goals" (Marks, Mathieu, & Zaccaro, 2001, p. 357). The isolated, confined, and extreme (ICE) environment of spaceflight is a new frontier for teamwork research.

Challenges of Studying Teamwork in Space Exploration

The very nature of space makes it a difficult environment in which to study teamwork. Space is the quintessential ICE environment (cf. Palinkas & Suedfeld, 2008, for one review of the psychological effects of ICE environments). Irrespective of the inhospitable nature of the environment, humans

Editor's note. This article is part of a special issue, "The Science of Teamwork," published in the May–June 2018 issue of *American Psychologist*. Susan H. McDaniel and Eduardo Salas served as guest editors of the special issue, with Anne E. Kazak as advisory editor.

Authors' note. Lauren Blackwell Landon, KBRwyle, Human Factors and Behavioral Performance Element, National Aeronautics and Space Administration, Houston, Texas; Kelley J. Slack, Department of Health and Human Performance, University of Houston, and Behavioral Health and Performance Operations, National Aeronautics and Space Administration; Jamie D. Barrett, Office of Aerospace Medicine, Aerospace Human Factors Division, Federal Aviation Administration, Oklahoma City, Oklahoma.

Correspondence concerning this article should be addressed to Lauren Blackwell Landon, KBRwyle, 2400 NASA Parkway, Houston, TX 77058. E-mail: laurenblandonphd@gmail.com

Lauren Blackwell Landon

have been venturing into space since the middle of the 20th century. In fact, the International Space Station (ISS) has been continuously occupied since Expedition 1 launched in 2000.

Characteristics of the Space Environment

The ISS is located in low Earth orbit, approximately 250 miles from Earth (see Table 1). The design of the ISS supports psychological health because the ISS is quite large (i.e., the size of a four-bedroom house), with private crew quarters, and a large window or cupola from which to view the Earth. Crewmembers also have the option to evacuate the ISS if there is an unrecoverable emergency. ISS astronauts have real-time space-to-ground communications with the flight controllers, flight surgeons, and psychological support personnel in the Mission Control Center, and they can interact with family and friends. This social, psychological, and medical support helps maintain individual health and well-being of the astronauts, and promotes team cohesion during these remote ISS missions. Crewmembers can also participate in discretionary events such as public speaking from the ISS, they exercise for 2 hr per day, and they receive care packages and resupplies. These support systems reduce the feeling of isolation and provide support during a fast-paced and stressful a space mission. NASA is now planning missions beyond low Earth orbit for the first time since the Moon missions, and many of the conveniences of low Earth orbit ISS missions will be unavailable to crews of these exploration missions, placing the individual and team functioning at greater risk. The psychological and physical factors in these extreme environments will amplify the stress inherent to spaceflight.

It is necessary that we understand the impact that such long-duration exploration missions will have on crews and those supporting them from the ground. Researchers who examine the psychological factors of a Mars mission must carefully consider study participants, study scenarios and tasks, and experimental environments to ensure findings will apply to a future Mars mission environment.

Psychological Fidelity of Spaceflight Analogs

Many aspects of research on how teams perform in organizational settings can be applied to spaceflight teams. For example, a meta-analysis of team debriefs have found improved team performance of 25% for those teams employing debriefs (Tannenbaum & Cerasoli, 2013). Related research investigating the effectiveness of debrief techniques in space mission simulations found similar performance improvements (Tannenbaum, Mathieu, Alliger, Donsbach, & Cerasoli, 2016). Psychological research is robust in many areas, and NASA leverages this foundational work, particularly in the field of industrial-organizational (I-O) psychology, to ensure training and countermeasures are rooted in scientific evidence.

Some aspects of long-duration exploration missions must be studied in environments analogous to spaceflight. Although a strong physical similarity does not ensure that the psychological fidelity of the analog would be akin to that of

Table 1
Comparison of Low Earth Orbit, Cislunar, and Mars Missions

Mission characteristic	Low Earth orbit (the ISS)	Cislunar	Mars
Distance from Earth	~250 miles	~250,000 miles to moon	~141,000,000 miles
Return to Earth	Hours	Days	Months
Size of vehicle	4-bedroom house	Small RV	Mid-sized RV
Length of mission	6–12 months	1.5–12 months	2–3 years
Crew size	6	4	4
Communication delay (round-trip)	1–2 s	3–4 s	Up to 45 min
Autonomy of crew	Low	Low	High
View of Earth	Yes	Distant but visible most of the time	No
Resupply possible	Yes	Yes	No

Note. Source: nasa.gov. ISS = International Space Station; RV = recreational vehicle.

Kelley J. Slack

spaceflight, the physical fidelity is often an indicator of the psychological fidelity. Fortunately, even with a disconnect between the physical environments of analogs and spaceflight, psychological fidelity can be achieved. When talking to the astronaut corps about his recent trip searching for meteorites on the surface of Antarctica, Don Pettit, an astronaut with experience on two ISS missions, stated that although the "physics" of Antarctica might be "wrong," the psychological "mind-set" was right (Pettit, 2007).

NASA researchers examine teams in several mission-simulation analogs (see Table 2), including the Human Exploration Research Analog (HERA) at NASA's Johnson Space Center. The HERA missions are carefully controlled, 45-day simulated spaceflight missions in which researchers can study a four-person crew in small habitable volume. During these missions, crew members perform team-oriented operational tasks such as emergency simulations that can be manipulated experimentally. The crew members have restricted access to family, friends, and the Internet, and they communicate with the supporting Mission Control team with the time delays that are anticipated for Mars mission. Military teams or personnel living at an Antarctic research station during the isolated winter-over period is a good field analog for studying psychological effects of isolation similar to those of spaceflight. Although mission simulation analogs allow for more experimental controls and manipulations, they fall short of field analogs on factors such as degree of real danger. The best analog NASA has for future long-duration space missions is the ISS; however, team research is not often collected on the ISS because time in the daily schedule reserved for data collection is limited. Ground analogs are used to capture many of the most important psychological factors that influence team performance and functioning because team research does not rely on the microgravity environment.

Data Limitations in Spaceflight Research

Psychological research in spaceflight or spaceflight analogs is limited, particularly with regard to teams, for several reasons. First, few astronauts that have participated in long-duration space missions, and there is a limited number of analog missions per year. For example, HERA has four 4-person missions per year and Hawai'i Space Exploration Analog & Simulation (HI-SEAS) includes teams of six for missions up to 1 year. Second, researchers and astronauts from different cultures may use disparate models. Third, astronauts have a heavy nominal workload, leaving little time for answer-

Table 2
Comparison of Commonly Used Spaceflight Analog Environments

Analog characteristic	HERA	HI-SEAS	Russian IBMP chamber	NEEMO	Submarine	Antarctica (small station)	Antarctica (large station)
Analog type	Mission sim	Mission sim	Mission sim	Mission sim	Field	Field	Field
Mission duration	45 days	4–12 months	4–12 months	<2 weeks	3–6 months	4+ months	4+ months
Real danger	No	Yes	No	Yes	Yes	Yes	Yes
Size of vehicle	Mid-sized RV	Mid-sized RV	House	Small RV	Cruise ship	House	University
Astronaut-like crew (rigorous selection process)	Yes	Yes	Yes	Yes, astronauts on crew	Yes	No	No
International crew	No	Yes	Yes	Yes	No	Yes	Yes
Spaceflight-like mission control	Yes	Yes	Yes	Yes	No	No	No
Crew size	4	6	6	6	50–200	4–20	50–1,000
Communication delay (round-trip)	Up to 20 min	Up to 45 min	Up to 45 min	Up to 20 min	No	No	No

Note. HERA = Human Exploration Research Analog; HI-SEAS = Hawai'i Space Exploration Analog & Simulation; IBMP = Russian Institute for Biomedical Problems; NEEMO = NASA Extreme Environment Mission Operations; Mission sim = mission simulation; RV = recreational vehicle. Information adapted from Dunn (2017) and Schneiderman and Landon (2015).

Jamie D. Barrett

ing surveys or participating in teamwork research related to mission experiences. Fourth, there is a lack of standard measures, both in spaceflight studies and spaceflight analog studies, further restricting total sample sizes and the comparison of findings across isolated, confined, extreme environments. Due to lack of data from spaceflight and spaceflight analog environments, meta-analysis is simply not a viable option for examining many of the different factors that will be critical to teams on a Mars mission.

Researchers have recently begun to address many of these limitations and build a more comprehensive and robust database that will help them understand and mitigate risks related to long-duration exploration missions, but years remain before many of these projects come to fruition. For example, the NASA Human Research Program is currently funding several projects aimed at creating a standard set of measures to be deployed on the ISS and in ground analogs, with aspects specifically targeted to psychological and team factors (e.g., Williams, Landon, Vessey, Schneiderman, & Basner, 2017). Increased international partnerships between space researchers, along with efforts to compare and integrate data collection tools, have resulted in cross-agency projects—projects of interest to psychologists outside of NASA as globalization and multinational organizational research increases. Additionally, the number of acceptable analogous populations for long-duration exploration missions (e.g., teams from elite military units, aviation, health care, Antarctic stations) has prudently, yet steadily, grown over recent years. These environments can also be used as test beds for developing and validating teamwork training and other interventions to support team performance.

Psychological Constructs in the Context of Spaceflight Teams

Many best practices from psychology can be used to compose a team of astronauts who have the capabilities to engage in effective teamwork throughout the course of a long-duration mission. Individuals with the aptitude and skill for teamwork, and a personality suited for working and living in a high-consequence environment, are carefully selected and then trained in teamwork processes over the course of many years. This training and preparation extends beyond specific teamwork skills such as collaborative problem solving to include factors that may enhance teamwork, such as psychological resilience and team orientation.

Team-Oriented Selection and Composition

Astronaut selection processes. The two major considerations for selecting an astronaut are (a) the suitability of the applicant to the demanding and complex job of astronaut, and (b) the suitability of the applicant to working as part of a team in an extreme environment. NASA has historically paid more attention to the former consideration, whereas focus on the latter has only recently been considered as part of the astronaut selection process. NASA's Behavioral Health and Performance (BHP) group conducts the psychiatric and psychological assessment of astronaut applicants, and results of these tests are classified as medical data. BHP uses the term *suitability* to indicate clinical judgment is included with the less subjective measures traditionally used by I-O psychologists. However, BHP does use some best practices from I-O psychology, including job analysis, psychometrically sound measures, and multitrait/multimethod assessments.

Before the ISS mission program started, a nontechnical, behaviorally oriented job analysis identified critical psychological factors and skill sets that would be required for both long- and short-duration missions on the ISS (i.e., ISS and Shuttle; Galarza & Holland, 1999a). Teamwork, communication, leadership capability, and group living were among the team-oriented proficiencies that were identified as critical for ISS missions. In 2015, NASA psychologists conducted an astronaut job analysis with experienced astronauts who had participated in ISS missions lasting 3 to 6 months (Barrett, Holland, & Vessey, 2015). The experienced astronauts and other spaceflight behavioral subject matter experts (SMEs) rated teamwork and competencies enhancing team functioning (e.g., small group living, judgment, motivation, and adaptability) as highly important for the success of Mars-like missions. Additionally, the job analysis participants regarded team-oriented competencies among the top requirements needed "at hire." Regardless of whether an astronaut spends 3 months on the ISS or up to 3 years on a Mars mission, it is clear that teamwork is essential to mission success.

From the early 1990s, personality tests have been included in suitability assessments of astronaut candidates. Unsurprisingly, emotional stability has been identified as a critical trait for an astronaut (note that emotional stability is a facet in the 2015 competency of self-care). Researchers have found that American and European astronauts and military pilots are more emotionally stable than normative samples (Maschke, Oubaid, & Pecena, 2011; Mittelstädt, Pecena, Oubaid, & Maschke, 2016; Musson & Keeton, 2011). A meta-analysis showed that a team members' average emotional stability had a small to medium effect on team performance (Bell, 2007). This result is reflective of the more limited findings of spaceflight analog research, such as data from the Mars 500 simulation, in which greater anxiety was related to more negative interpersonal communications and interactions (Tafforin, Vinokhodova, Chekalina, & Gushin, 2015). Other findings related to the five-factor model of personality in spaceflight research and analog studies suggest that there is no one "perfect" scoring pattern for an individual; that is, successful astronauts have a range of scores, and cohesive teams may be comprised of individuals with complementary scores from this pool of well-selected astronauts.

One recent review of spaceflight and analog research suggested a personality profile that can be used to select team members who will likely work successfully together during long-duration exploration missions (Landon, Rokholt, Slack, & Pecena, 2017). The suggested personality profile includes high emotional stability, moderately high to high agreeableness, moderate openness to experience with a range of acceptable scores, a range of acceptable conscientiousness scores that are above a determined minimum value, and a range of low to moderately high extraversion that avoids very high scores. Similarly, the spaceflight SMEs participating in the astronaut job analysis reported that extreme high or low values for any personality factor indicated that the individual was not suited to be an astronaut (Barrett et al., 2015). However, given the incredible desirability and competition to become an astronaut, detailed knowledge of exact scores, profiles, and selection methods are kept confidential to all but a few individuals who select the astronauts.

Barrett et al. (2015) identified additional personality traits and skills that both benefit an astronaut as an individual and indicate that he or she will work successfully in an isolated team environment. For example, data from a long-duration spaceflight-mission simulations and from teams stationed in the Antarctic indicate that individuals with greater resilience, adaptability, and team orientation used appropriate stress- and problem-coping strategies, allowing them to adapt to changing events, integrate successfully into a group, and function well in a team (Bishop et al., 2006; Kanas et al., 2009; Vanhove, Herian, Harms, & Luthans, 2015). In anticipation of beginning long-duration missions on the ISS in 2000, the BHP astronaut selection team devised a behaviorally based, semistructured interview process to assess an individual's suitability for a long-duration mission. This interview included sections targeting team-oriented skills (teamwork and team care skills that ensure teammates remain physically and psychologically healthy) and communication (Galarza & Holland, 1999b). Applicants were asked about past experiences, with a focus on experience in extreme environments.

NASA has increasingly recognized how important successful teamwork will be for long-duration exploration missions and has added a series of low-physical-fidelity, high-psychological-fidelity experiential team exercises to the selection process, with performance of applicants rated by SMEs (Slack, 2016). The finalists of the astronaut class of 2009 participated in team exercises derived primarily from military field exercises. Each team was given a problem, assigned a leader for that problem, and given a set amount of time and supplies to solve the problem. This process was repeated with each team member leading an exercise. Best practice methods were used to develop behaviorally anchored rating scales to assess each team-oriented competency being assessed. Applicants for the 2013 and 2017 astronaut selection also participated in series of exercises to test teamwork and other team-oriented skills that were more integrated with mission and task goals than the previous tests. For the astronaut class of 2017, performance on the teamwork skills was assessed using behaviorally anchored scales that were updated to reflect the results of the 2015 job analysis; a second team exercise was added to the battery of selection tests. This new exercise focused on assessing teamwork skills in an environment with moderate physical fidelity to spaceflight (a mock Mission Control Center with communication via headsets, as occurs during flight) and high psychological fidelity. Additionally, this exercise was based on simulations given to flight controllers and Astronaut Candidates (i.e., newly hired astronauts) as part of a larger curriculum to teach nontechnical teamwork skills at NASA. The results from the two team exercises were aggregated with other measures of teamwork to determine overall suitability scores for teamwork, and these scores fed into an overall suitability score across all competencies.

Emerging research on spaceflight team composition. Teamwork skills and team-orientation selection tests will help NASA select a Mars mission team from the pool of highly qualified, team-oriented astronauts. Past research and observational studies of spaceflight crews, test subjects in space analogs, and other teams in ICE settings also provide indicators of the team composition factors that are most critical for exploration missions. For example, one review of these studies identified five variables that are important to consider when composing teams for long-duration exploration missions: cultural and gender differences; personality; abilities, expertise, and background; team size; and network factors such as compatibility, communication, and trust (Bell, Brown, Abben, & Outland, 2015). This review also recommended that "faultlines," hypothetical dividing lines that split a group into two or more subgroups, be avoided whenever possible, particularly if those faultlines could form as a result of deep-level diversity such as values and personality. Faultlines, compounded by poor teamwork skills, may affect team performance by disrupting processes such as communicating, maintaining a shared mental model, and supporting behaviors. Studies of teams in HERA have found that, over time, deep-level characteristics related to values and knowledge become more important than surface-level or demographic characteristics (Antone, Contractor, Bell, & DeChurch, 2017).

Recent findings from a 3-year study of teams who were isolated in the Antarctic for the winter found that individual personality traits influenced perceptions of team processes (Webb, Olenick, Ayton, Chang, & Kozlowski, 2017). For example, the more conscientious team members reported higher team performance ratings. Findings suggest that high levels of conscientiousness should be used to select individuals for ICE teams, whereas negative traits such as lower emotional stability should be used as an exclusion factor.

Humor, which stems from personality and may be influenced by cultural factors, is often cited as a benefit by spaceflight and analog teams, although sometimes it can cause friction. Crews in HERA and astronauts aboard the ISS report that appropriate affiliative humor is a key factor in crew compatibility, conflict resolution, and coping—"humor and joking around continue to be huge assets and quickly defuse any problems" (astronaut journal entry from Stuster, 2016, p. 34; Weiss, Outland, Bell, DeChurch, & Contractor, 2017). Astronauts find value in their ability to handle the more negative aspects, relatively speaking, of other cultures, and the ability to adapt to the values, cultures, and preferences of others (Barrett et al., 2015). Groups, particularly those in isolation, tend to develop their own cultures, complete with internal jokes, which bind them together (Dunn, 2017), and in some cases, this results in conflict with other groups such as between astronauts and Mission Control personnel.

Given that nuanced and deep-level characteristics of values, culture, and humor are important for successful long-term teamwork, more research is needed into long-duration, international teams and data-driven methods of team composition that may be applied across cultures. A team living together for multiple years will be required to not only perform task assignments effectively but also fulfill social roles within the team (Burke et al., 2017).

NASA currently does not use a scientifically based approach to composing teams, but this knowledge gap is scheduled to be filled by the 2020s. However, there is no cross-agency approach to blending team members from different space agencies, and there is less attention given to filling this gap. As such, predicting friction points and training in teamwork skills becomes important to overcome the frictions that are likely to occur within teams.

Training to Maximize Teamwork While Living and Working Together

After they are selected, astronauts undergo an intensive 2-year training program, and although high levels of proficiency are required for selection, NASA selection experts also recognize that these high levels are just the foundation upon which to build. Many astronaut candidates enter the corps with experience and skills in leadership; however, the leadership role is shared during a long-duration mission, even if a formal mission commander has been assigned (Burke, Shuffler, Wiese, Hernandez, & Flynn, 2017). Thus, new astronauts with typical leadership skills at selection may need training on aspects of followership and shared leadership in concert with team orientation.

Current training of spaceflight teamwork skills. Long-duration exploration missions inherently require teamwork skills among both the team in space and the teams in Mission Control. Two primary models are used by these teams: the Spaceflight Resource Management (SFRM) model and the Crew Expeditionary Skills model. Although elements certainly overlap within these models (e.g., both models incorporate teamwork, communication, and leadership skills), the SFRM model is more applicable to teamwork itself, and the Crew Expeditionary Skills model adds a layer of attributes accounting for the "living together" aspect of long-duration exploration missions.

Astronauts learn tasks and acquire technical information by following many best practices typical of other organizations; that is, pretraining (with a mix of lecture and practice with feedback), refresher training, and just-in-time training. Historically, much of this training was created organically, responding to the needs of changing space vehicle designs and mission objectives. More recently, training development has leveraged the science of learning. For example, the SFRM model is used to train flight controllers in teamwork skills using classroom lecture, demonstration through examples and the shared experience of certified flight controllers, practice during simulations and other nontechnical job tasks (e.g., active listening during meetings), and feedback employed during initial training team debriefs (O'Keefe, 2008). If SFRM training debriefs are organized by the competency or skill being taught (vs. chronologically), flight controllers are certified quicker (Bedwell, Smith-Jentsch, Sierra, & Salas, 2012).

Whereas SFRM teamwork skills are taught by specially trained instructors, some of the Crew Expeditionary Skills are taught by astronauts who have flown on the ISS (Barrett et al., 2015). This model of teamwork skills was created by astronauts, for astronauts, with input from I-O psychologists and other experts familiar with the NASA context. Crew Expeditionary Skills are composed of leadership/followership, communication, self-care, team-care, teamwork, and small group living skills. NASA's Astronaut Office has increasingly incorporated this training into technical training events to optimize the busy training schedule of an astronaut. For example, when astronauts are trained on geosciences during a series of field events, they also engage in an outdoor leadership course as a team for approximately 12 days (Smith-Jentsch & Sierra, 2017). These multiday overnight events take place away from friends and family and typically involve facilitated learning challenges provided by expert support staff members that accompany the astronaut teams. Astronauts also receive unique training experiences related to small-group living, which includes tolerance, constructive conflict, seeking to understand differences, and cooperation and support of their roommates in space. However, these training events and the Crew Expeditionary Skills model have not been validated and do not currently collect data on the effectiveness of this training. Anecdotal statements from the astronauts provide a measure of the perceived efficacy of the training and whether the astronauts believe their skills are enhanced. However, despite some trainee reaction measures being collected, systematic evidence of training effectiveness is lacking (Smith-Jentsch & Sierra, 2017).

Training research to enhance teamwork. True study of teamwork skills training is in its early stage at NASA. Initial training needs analyses of general teamwork competencies and a review of existing training in context of a long-duration exploration training has been completed in the past few years (Noe, Dachner, Saxton, & Keeton, 2011; Smith-Jentsch & Sierra, 2017). However, drivers of potential team performance decrements on an exploration mission such as cross-cultural differences have been addressed through training to various degrees for many years. The existing cross-cultural training emphasizes teaching each culture's core values as the basis for classroom content (Barrett, Slack, Holland, & Sipes, 2014), although future initiatives will examine how to make cultural training more flexible across cultures.

A Mars mission will require the integration of teamwork skills and technical skills to perform highly complex tasks. The autonomous astronaut team, under communication delay, may need to draw on technical skills trained months or even years earlier. Training retention is a major concern for crew on long-duration missions because skills degrade with the mission duration. Crewmembers "consistently comment that they do not recall being trained on specific hardware or payloads, they don't remember specific briefings, and/or they have a hard time remembering training that was at times over two years prior" (Barshi & Dempsey, 2016, p. 12). Excellent execution of teamwork skills and processes may bolster technical skills and mitigate issues stemming from degradation of technical skills. Unfortunately, current technical and teamwork skills training for astronauts has not been evaluated for effectiveness, and teamwork skills suffer from similar problems related to long lag times between premission training and mission deployment. This is particularly concerning because ISS crewmembers have stated that they required assistance from experienced teammates to complete a critical task (Barshi & Dempsey, 2016). Because all crewmembers of the first Mars mission will be inexperienced to that mission profile, training premission and refreshers during mission will be a key to success.

Individual-level, computer-based training may also have indirect effects on team functioning. The preliminary findings of the Stress Management and Resilience Training for Optimal Performance (SMART-OP) study of stress management for flight controllers and flight directors suggests that participants rated as most useful the behavioral skills training associated with effective communication and strategic problem solving (Rose et al., 2017). The overall SMART-OP training program was found to be highly useful for managing stress and building resilience.

Training is an extensive, time-consuming part of every astronaut's off-mission workload. Once an astronaut is assigned to a particular ISS expedition, their training, called "assigned training" or "increment-specific training," typically takes 2.5 years to complete (Barrett, 2015). Although three astronauts are assigned to each ISS mission, crewmembers complete most of their training independently, and only a few sessions are scheduled in which the three crewmembers practice teamwork skills together as an intact team. ISS missions last approximately 6 months, and missions overlap by 3 months, so at any given time, two teams are onboard the ISS, forming a crew of six. Even fewer opportunities exist for astronauts to train with the larger crew of six. ISS crews also have few opportunities before their mission to engage with the team in Mission Control who will support them during their mission. That is, the teams and individuals across the multiteam system (MTS) have little opportunity to practice teamwork skills.

Building a cohesive team requires engaging as a team. Teams in environments that are analogous to spaceflight, such as some military teams, undergo typical team phases of forming, storming, norming, and performing, which indicates that astronaut teams that are selected for a long-duration exploration mission will need several weeks to complete this cycle if they are to reach the performing phase before launch (Schmidt, 2015). To ensure effective team performance during the extensive duration and in the extreme isolation of a Mars mission, it is likely the mission team will need more training as an intact team than ISS crewmembers in areas of team stability and understanding of teammates' individuality. The following excerpt was recorded in an ISS astronaut's journal:

> There were a couple very short tempered exchanges . . . I have come to recognize these moments as relating to stress and I saw them often in training too. The good thing is they don't have a lasting effect. All it takes is a little direct communication and a couple jokes to clear the air. (Stuster, 2016, p. 35)

Performance support tools, such as guided team debriefs, were designed to address both the task performance and the dynamics of teams living together, but teamwork skills are critical. One astronaut stated, "Task disruptions may happen more often; but interpersonal [disruptions are] more problematic and they need more discussion to overcome" (Maynard & Kennedy, 2016, p. 33). Successfully negotiating conflict, planning together as a team, making decisions as a team, and practicing shared leadership should receive extensive attention long before a team launches on a space mission.

Countermeasures to Mitigate Risk to Teamwork

Over the decades, NASA has learned a great deal about providing psychological support to astronauts. As a result, current missions to the ISS include a number of risk mitigation strategies, or countermeasures, to support individual and team behavioral health and well-being, but many of the current countermeasures will be insufficient or not available for the Mars mission.

Because there is no delay in communication between Mission Control and the ISS, there is no countermeasure in place for delays in communication. Research into mitigating risks related to communication delays has focused on understanding the risks and creating training and tools that can prevent performance decrements related to poor teamwork between the crew and ground support personnel. NASA experts have noted that information withholding, usually between teams, and for fear of negative repercussions, may be dangerous during spaceflight (Shuffler, Kramer, Savage, & Verhoeven, in press). Implementing clear, overarching goals, building trust between teams prior to launch, designating and training communication norms, and debriefing may help alleviate some conflict and motivate teams to overcome fears of negative repercussions. Other issues stem from poor communication structures and the nature of the task being performed (e.g., novel vs. familiar), and these may be more straightforward to address through the design of communication protocols. An ISS study found that a 50-s time delay of audio communications led to increased stress and frustration and lowered communication quality (Kintz, Chou, Vessey, Leveton, & Palinkas, 2016). Astronauts also reported that delays in communicating with Mission Control had negative effects on their efficiency in completing a task. One astronaut stated, "Things you could do independently were fine, things where you relied on [Mission Control personnel] resulted in lots of time lost and frustration, which is just not going to work [for Mars]" (Kintz et al., 2016, p. 196). Crewmembers in this study identified potential countermeasures to help communications flow smoothly, such as training crew and ground teams to announce calls twice if it they were deemed important, and they suggested using text or video-based communications for long-duration exploration missions so that the complete message is received without an additional communication delay. A study of communication delay in HERA and NEEMO analog missions found that structuring communications can help reduce misunderstanding (Fischer & Mosier, 2015). The following were identified as the most important elements to enhance effectiveness of communication under 5- to 10-min delay: stating the topic early, repeating critical information, tracking timing and the conversation thread in a log, and forewarning the other team of incoming messages. Text messaging was rated more effective for routine communications, and voice messaging was rated more effect for team building. The HERA crew trained on these communication protocols for only 30 to 60 min before the mission, but compliance was high (approximately 90%), which shows that this straightforward protocol is effective and useful. Other team factors were also reported as important for improving communication, including joint training with both analog mission crews and the habitat's Mission Control teams.

The increased autonomy that will be characteristic of Mars missions has led to research examining debriefing as an effective tool for ensuring that teamwork does not suffer throughout the mission. Tannenbaum and colleagues (2016) developed a debrief tool that was tested during HERA and NEEMO missions, and found that guided team debriefs enhanced resilience, psychological safety, and team processes to improve team performance. Additionally, this research found that resilience is more highly related to performance over time. Astronauts stated that this debrief tool, which steps each team member through a short series of questions and generates an anonymized discussion guide of topics prioritized by what is most salient for team functioning at that time, "allows everyone to be honest" and is "a great way to encourage people to bring forward points that they otherwise wouldn't" (Tannenbaum et al., 2016), allowing the team to constructively address conflict.

Teamwork Across the Spaceflight Multiteam System

A team of astronauts in space is just one piece of a much larger MTS that connects the Mission Control Center in Houston, Texas, payload communicators in Huntsville, Alabama, and mission controls from the other space agencies around the world. As with many other MTSs, NASA's MTS is a large, geographically dispersed, functionally diverse team, with changing membership (Shuffler, Jimenez-Rodriguez, & Kramer, 2015). However, NASA implements a centralized command structure (i.e., the Mission Control “front room,” with a representative from each functional specialization or “discipline,” which, in turn, is each supported by a “back room” team) led by each mission’s flight director, and a structured training and certification program for both technical and teamwork skills. Shared understanding between disciplines and space agencies are enhanced initially in the classroom and followed by simulation training, and most importantly, experienced flight controllers provide novice flight controllers with on-the-job training. During training, the transactive memory system is built as flight controllers are introduced to the different responsibilities of the different discipline areas and disciplines learn to work together, and shared mental models are formed through common training in ISS procedures and teamwork skills. However, according to NASA experts, these shared team cognitions may be harder to develop during long-duration exploration missions than during low Earth orbit missions on ISS (Shuffler et al., in press). All communication between the crew in space and the ground support teams in Mission Control is coordinated through a single capsule communicator, or CapCom. The role of CapCom may switch between individuals as demanded by specific tasks. NASA Mission Control personnel also communicate with other space agencies. The risks of coordinating across an MTS include process loss and distractions from goals (Davison, Hollenbeck, Barnes, Sleesman, & Ilgen, 2012). An ISS crewmember noted, “[The ISS] is really five mission controls connected at the crew with the crew as the ‘integrating force’” (Shuffler et al., in press, p. 33). Demands on ISS crew from performing this central role may cause conflict as the crew works to mitigate tensions and balance competing goals between teams on Earth.

In addition to this complex environment of communication and coordination, there will be a one-way delay of up to 22 min for all data and voice communications during a Mars mission. This communication delay will likely cause the Mars crew to act autonomously, especially during time-critical events (Rubino & Keeton, 2010). Astronauts interviewed on the topic of MTSs have stated that mixed motives may create disagreements and interfere with connections between teams (Shuffler et al., in press). Because crew autonomy will be greater during exploration missions, NASA experts propose that leadership will need to be shared between Mission Control and the Mars crew, but acknowledge that this will be challenging. These experts also suggested the need for cross-training across the MTS to ensure awareness of competing goals and functions between teams. Flight directors and psychological support staff often serve as a bridge between space and ground teams, but this support will be reduced when communication delays are in place. A final issue that may influence teamwork is the reduced availability of personal communications. ISS astronauts are currently able to phone home to family and friends each day, conference with psychological support staff, and chat in real time with special “guests” such as celebrities and childhood heroes, all of which often serve to boost morale and mood (e.g., “It was a nice surprise and added a little relaxation to the day”; Stuster, 2016, p. 31). Again, interactions in real-time will not be possible on a Mars mission and eliminating a major countermeasure related to individual well-being, and indirectly harm team functioning could potentially result in negative moods or prolonged withdrawal from the team.

If teams in MTSs use the same shared leadership style, teamwork is improved, improving cohesion, improving the work environment, and allowing autonomy of teams while retaining support between teams (Gonzalez, Mosier, Lam, & Fischer, 2015). Training in similar models and protocols, and training with other teams across the MTS, may ultimately enhance overall performance of the MTS.

Measurement and Monitoring Teamwork

Astronauts are among the most monitored and measured populations on Earth. However, current monitoring techniques will need to adapt with the advent of long-duration exploration missions.

Unobtrusive measures. Psychologists conducting research, in field and lab settings, find benefit from data collection that does not interfere with natural processes of human behaviors and interactions. It is particularly important to avoid disturbing astronauts while they conduct highly complex team tasks such as spacewalks; monitoring team behaviors without distracting from the task at hand may be the difference between life and death. Unobtrusively collecting data and feeding that data back into a near-real-time analysis may allow team members to recognize impending negative outcomes, and prompt team members or automated processes to intervene with a countermeasure to mitigate that potential negative outcome. This localized feedback loop will be particularly important for a long-duration exploration mission because of communication and data delays.

NASA is currently developing several technologies to assist unobtrusive measurement of team factors and other factors that may influence teamwork (e.g., fatigue and physical health). Sociometric badges, worn on the chest, measure the proximity of individuals and whether they are facing each other, as well as vocal intensity (i.e., a marker of emotions and stress). These badges provide important information regarding the quality of team interactions such as frequency of interaction between team members (Kozlowski, 2017). Video and facial analysis could be collected that will provide information related to team behavioral interactions and psychosocial states (Dinges et al., 2017). Lexical analysis of speech and text, collected from crew journals and communication logs, could also indicate stress and psychosocial states at both the individual and team levels (Driskell, Salas, Driskell, & Iwig, 2017). For example, valence of chosen words denotes emotional states, and usage of individual pronouns or collective pronouns indicates group affiliation (Gonzales, Hancock, & Pennebaker, 2010). All of these unobtrusive measures will enable teams to monitor whether team members may be withdrawing or whether the team is maintaining communication, coordination, and cohesion. Data from diaries and open-ended survey responses about team processes that were collected from several deployed Antarctic research teams indicate that social and task cohesion was predictive of performance; positive emotion words predicted good performance, whereas word counts predicted team cohesion (Olenick et al., 2017). Another set of studies conducted in bed-rest facilities and mission simulations used journals and an interactive task dialog to establish that lexical techniques correlate with the results of surveys, which are typical obtrusive, and lexical techniques provide a richer mood state assessment than surveys (Miller, Wu, Schmer-Galunder, Ott, & Rye, 2016). That is, it is possible to go beyond simply detecting an increase in negative emotions and to determine the cause of the emotional changes over time.

Anecdotal reports show that astronauts and participants of studies in simulated spaceflight prefer unobtrusive measurement techniques over traditional survey data collection because they reduce their workload. However, crews value their privacy in this highly monitored environment, so psychologists must maintain an open dialogue to navigate the boundary between obtaining candid data and being intrusive. One method of lessening perceived privacy violation is to make all the data available to crewmembers. If the data are available to the crew and they can use it for self-monitoring and self-correction, they may be more accepting of this monitoring.

Integrating teamwork research with physiological research and technology. Physiological processes and corresponding metrics, which are traditionally assessed at the individual level, are increasingly being applied to assess team factors. Researchers are using spaceflight analogs to investigate the validity, usability, and feasibility of implementing physiological measures to monitor team inaction during long-duration exploration missions. Measures include galvanic skin response, brain waves, heart rate variability, and biological molecules found in bodily fluids and hair samples (Dunn, Landry, & Binsted, 2017). Investigating how these physiological measures and unobtrusive measures compare with self-report measures will also help inform the design of health and psychological monitoring systems. Some of these measures could be obtained from a small, wearable device such as a sociometric badge, whereas other measures would be more invasive (e.g., blood draws to also assess biomarkers related to social support and affiliation, resilience, and stress hormones).

Cortisol, a stress hormone, has perhaps been the most studied biomarker for assessing individuals in extreme settings. A recent review of the biological basis of social support suggests that social support may buffer an individual from stress and from the harmful damage that cortisol can do to synapses in the brain (Whitaker-Azmitia, 2016). Cortisol can negatively affect cognitive processes and resilience. Higher cortisol levels have been reported in sleep-deprived military personnel and in NEEMO crewmembers. Oxytocin plays a strong role in social bonding, and also works to buffer against harm caused by cortisol. During collaboration, oxytocin synchronizes physiological processes including those taking place in the brain. Oxytocin may also influence social bonding and social behaviors and possibly enhancing team performance. However, oxytocin has also been linked to hostility aimed at an out-group, as was found in the Mars 500 mission simulation in which the crew displaced negative mood to Mission Control personnel (Gushin, Shved, Ehmann, Balazss, & Komarevtsev, 2012).

A small but growing niche of interdisciplinary research related to future exploration missions focuses on how sleep and fatigue affect team performance. Extensive studies of fatigue and performance in analogous populations, such as those in aviation and the military, have shown that sleep loss is a serious risk to safety and mission objectives, and to overall health (Shattuck & Matsangas, 2015). Sleep restriction can cause impaired judgment and mood disturbance; risky decisions and actions affect teamwork and team cohesion. Recent findings from spaceflight analog studies show decreased sleep quality at the mission midpoint, with longer and more frequent wake periods, corresponded to a decrease in positive affect (Abeln, 2017). Spaceflight analogs also reported increased neurobehavioral disorders (e.g., increased memory lapses and errors, anger, and depression) during total sleep deprivation (Dennis, Ecker, & Goel, 2017). There were individual differences between participants, which may have implications for teamwork; however, a link between sleep and teamwork has not yet been well-established through research (Roma & Bedwell, 2017).

Obviously, there is no perfect team, but data-driven methods of monitoring crews can be used to predict potential points of friction between team members and indicate when teamwork processes may be affected. In-mission monitoring technologies that capture near-real-time data on team states and performance, such as cohesion and coordination behaviors, can be used to activate timely countermeasures that could mitigate team breakdown. Crewmembers on the ISS have stated, “We all need a break from each other at times,” and have related stories of discord, such as taking a group photo that devolved into conflict (Stuster, 2016, pp. 34–35). One crewmember in the photo reported, “I thought we were going to lose a member of the crew during that one.

Six cooks in the kitchen, all brewing up their own ideas." Aggregate data collected during crew monitoring could be used to detect potential problems and inform task schedulers that the crew may need to focus on individual tasks to alleviate group tensions, initiate refresher training on team communication, or complete a guided team debrief to work through tensions.

Future Directions for Space Teamwork Research

Astronauts acknowledge it will be a challenge to maintain effective teamwork during a Mars mission. Teamwork skills are critically important to the success of these future missions, especially because the teams are isolated from real-time support from Mission Control personnel on Earth. One understudied area of spaceflight teams involves coordinating communication across an MTS under conditions of communication delay. Relatedly, more scientifically rigorous research and development of training and countermeasures are required to ensure that the remote, highly autonomous spaceflight team is able to maintain teamwork skills throughout a mission lasting 2 to 3 years with reduced support from Mission Control. Finally, if information about teamwork processes and physiological factors that may impact teamwork (e.g., reduced sleep negatively influencing team decision making and other cognitive processes) are integrated, it will better enable strategic and timely implementation of supporting countermeasures. Monitoring tools with feedback mechanisms and intelligent support approaches (e.g., adaptive training) need to be developed and scientifically validated to provide data-driven technological support for spaceflight teams. These tools will enable high-performing teams to succeed in the ICE environment of long-duration space exploration missions.

References

Abeln, V. (2017, January). *Psychophysiological changes during 30-days of isolation in the Human Exploration Research Analog (HERA)*. Presented at the NASA Human Research Program Investigators' Workshop, Galveston, TX.

Antone, W. B., Contractor, N. S., Bell, S. T., & DeChurch, L. A. (2017, January). *Faulty analysis: Analyzing the validity of different faultline measurement algorithms for long-duration space exploration*. Presented at the NASA Human Research Program Investigators' Workshop, Galveston, TX.

Barrett, J. D. (2015, April). *Team skills training: Evidence from spaceflight and ground teams*. Presented at the 31st Annual Conference of the Society for Industrial and Organizational Psychology, Anaheim, CA.

Barrett, J. D., Holland, A. W., & Vessey, W. B. (2015, April). *Identifying the "Right Stuff": An exploration focused astronaut job analysis*. Presented at the 30th Annual Conference of the Society for Industrial and Organizational Psychology, Philadelphia, PA.

Barrett, J. D., Slack, K. J., Holland, A. W., & Sipes, W. (2014, August). *Training the 8-balls: Psychological readiness preparation for the 2013 U.S. astronaut class*. Presented at the Annual Convention of the American Psychological Association, Washington, DC.

Barshi, I., & Dempsey, D. L. (2016). *Evidence report: Risk of performance errors due to training deficiencies*. Retrieved from https://humanresearchroadmap.nasa.gov/

Bedwell, W. L., Smith-Jentsch, K., Sierra, M. J., & Salas, E. (2012, February). *Team dimensional training validation: A field study with flight controllers*. Presented at the NASA Human Research Program Investigators' Workshop, Galveston, TX.

Bell, S. T. (2007). Deep-level composition variables as predictors of team performance: A meta-analysis. *Journal of Applied Psychology, 92,* 595–615. http://dx.doi.org/10.1037/0021-9010.92.3.595

Bell, S. T., Brown, S. G., Abben, D. R., & Outland, N. B. (2015). Team composition issues for future space exploration: A review and directions for future research. *Aerospace Medicine and Human Performance, 86,* 548–556. http://dx.doi.org/10.3357/AMHP.4195.2015

Bishop, S. L., Dawson, S., Rawat, N., Reynolds, K., Eggins, R., & Bunzelek, K. (2006). Assessing teams in Mars simulation habitats. In J. D. Clarke (Ed.), *American Astronautical Society science and technology series* (pp. 177–196). San Diego, CA: Univelt.

Burke, C. S., Driskell, J. E., Howell, R., Marlow, S., Driskell, T., & Salas, E. (2017, January). *Team roles revisited*. Presented at the NASA Human Research Program Investigators' Workshop, Galveston, TX.

Burke, C. S., Shuffler, M., Wiese, C., Hernandez, C., & Flynn, M. (2017, January). *Shared leadership in isolated, confined environments (ICE)*. Presented at the NASA Human Research Program Investigators' Workshop, Galveston, TX.

Davison, R. B., Hollenbeck, J. R., Barnes, C. M., Sleesman, D. J., & Ilgen, D. R. (2012). Coordinated action in multiteam systems. *Journal of Applied Psychology, 97,* 808–824. http://dx.doi.org/10.1037/a0026682

Dennis, L. E., Ecker, A. J., & Goel, N. (2017, January). *Individual differences in neurobehavioral and affective responses to stress and sleep loss HERA mission crewmembers*. Presented at the NASA Human Research Program Investigators' Workshop, Galveston, TX.

Dinges, D., Metaxas, D., Zhong, L., Yu, X., Wang, L., Dennis, L., . . . Basner, M. (2017, January). *Optical computer recognition of stress, affect and fatigue in space flight*. Presented at the NASA Human Research Program Investigators' Workshop, Galveston, TX.

Driskell, T., Salas, E., Driskell, J., & Iwig, C. (2017, January). *Inter- and intra- crew differences in stress response: A lexical profile*. Presented at the NASA Human Research Program Investigators' Workshop, Galveston, TX.

Dunn, J. (2017, July 27). *HI-SEAS mission*. Presentation of the WISE Series, Houston, TX.

Dunn, J., Landry, S., & Binsted, K. (2017, January). *Trajectories of health and stress in long-duration Mars analog crews*. Presented at the NASA Human Research Program Investigators' Workshop, Galveston, TX.

Fischer, U., & Mosier, K. (2015). Communication protocols to support collaboration in distributed teams under asynchronous conditions. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting, 59,* 1–5. http://dx.doi.org/10.1177/1541931215591001

Galarza, L., & Holland, A. W. (1999a). *Critical astronaut proficiencies required for long-duration space flight* (SAE Technical Paper 1999-01-2096). http://dx.doi.org/10.4271/1999-01-2096

Galarza, L., & Holland, A. (1999b). *Selecting astronauts for long-duration space missions* (SAE Technical Paper 1999-01-2097). http://dx.doi.org/10.4271/1999-01-2097

Gonzales, A. L., Hancock, J. T., & Pennebaker, J. W. (2010). Language style matching as a predictor of social dynamics in small groups. *Communication Research, 37,* 3–19. http://dx.doi.org/10.1177/0093650209351468

Gonzalez, K., Mosier, K. L., Lam, J., & Fischer, U. (2015). Characteristics impacting teamwork and performance for space operations. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting, 59,* 936–940. http://dx.doi.org/10.1177/1541931215591272

Gushin, V., Shved, D., Ehmann, B., Balazss, L., & Komarevtsev, S. (2012, October 1–5). *Crew-MC interactions during communication delay in Mars-500*. Paper # IAC-12-A1. 1.2. Proceedings of the 63rd International Astronautical Congress, Naples, Italy.

Kanas, N., Sandal, G., Boyd, J., Gushin, V., Manzey, D., North, R., . . . Wang, J. (2009). Psychology & culture during LDSMs. *Acta Astronautica, 64,* 659–677. http://dx.doi.org/10.1016/j.actaastro.2008.12.005

Kintz, N. M., Chou, C.-P., Vessey, W. B., Leveton, L. B., & Palinkas, L. A. (2016). Impact of communication delays to and from the International Space Station on self-reported individual and team behavior and performance: A mixed-methods study. *Acta Astronautica, 129,* 193–200. http://dx.doi.org/10.1016/j.actaastro.2016.09.018

Kozlowski, S. W. J. (2017, April). *More than just average: Novel approaches to measurement in teams*. Panelist at the 32nd Annual Conference of the Society for Industrial and Organizational Psychology, Orlando, FL.

Landon, L. B., Rokholt, C., Slack, K. J., & Pecena, Y. (2017). Selecting astronauts for long-duration exploration missions: Considerations for team performance and functioning. *REACH—Reviews in Human Space Exploration, 5,* 33–56.

Landon, L. B., Vessey, W. B., & Barrett, J. D. (2016). *Evidence report: Risk of performance and behavioral health decrements due to inadequate cooperation, coordination, communication, and psychosocial adaptation within a team*. NASA Human Research Program. Retrieved from http://humanresearchroadmap.nasa.gov/Risks/risk.aspx?i=101

Marks, M. A., Mathieu, J. E., & Zaccaro, S. J. (2001). A temporally based framework and taxonomy of team processes. *Academy of Management Review, 26,* 356–376.

Maschke, P., Oubaid, V., & Pecena, Y. (2011). How do astronaut candidate profiles differ from airline pilot profiles? Results from the 2008/2009 ESA astronaut selection. *Aviation Psychology and Applied Human Factors, 1,* 38–44. http://dx.doi.org/10.1027/2192-0923/a00006

Maynard, M. T., & Kennedy, D. M. (2016). *Team adaptation and resilience: What do we know and what can be applied to long-duration ICE contexts (NASA/TM-2016–218597)*. Retrieved from https://ston.jsc.nasa.gov/collections/TRS/_techrep/TM-2016-218597.pdf

Miller, C. A., Wu, P., Schmer-Galunder, S., Ott, T., & Rye, J. M. (2016, January). *AD ASTRA: Automated detection of attitudes and states through translation recordings analysis*. Presented at NASA Human Research Program Investigators' Workshop, Galveston, TX.

Mittelstädt, J. M., Pecena, Y., Oubaid, V., & Maschke, P. (2016). Psychometric personality differences between candidates in astronaut selection. *Aerospace Medicine and Human Performance, 87,* 933–939. http://dx.doi.org/10.3357/AMHP.4548.2016

Musson, D., & Keeton, K. (2011). *Investigating the relationship between personality traits and astronaut career performance: Retrospective analysis on personality data collected 1989–1995 (NASA/TM-2011–217353)*. Retrieved from https://ston.jsc.nasa.gov/collections/TRS/_techrep/TM-2011-217353.pdf

Noe, R. A., Dachner, A. M., Saxton, B., & Keeton, K. E. (2011). *Team training for long-duration missions in isolated and confined environments (NASA TM-2011–216162)*. Retrieved from https://ston.jsc.nasa.gov/collections/TRS/_techrep/TM-2011-216162.pdf

O'Keefe, W. S. (2008, September). *Space flight resource management training for international space station flight controllers*. Presented at AIAA Space Conference, San Diego, CA.

Olenick, J., Morrison, M., Dixon, A., Dishop, C., Harvey, R., Kamer, J., . . . Kozlowski, S. (2017, January). *Using linguistic analysis tools to study teams in ICE environments*. Presented at the NASA Human Research Program Investigators' Workshop, Galveston, TX.

Palinkas, L. A., & Suedfeld, P. (2008). Psychological effects of polar expeditions. *The Lancet, 371,* 153–163. http://dx.doi.org/10.1016/S0140-6736(07)61056-3

Pettit, D. R. (2007, May). *Presentation on Antarctic Expedition for Meteorites*. Presented at NASA Johnson Space Center, Houston, TX.

Roma, P. G., & Bedwell, W. L. (2017). Key factors and threats to team dynamics in long-duration extreme environments. In E. Salas, W. B. Vessey, & L. B. Landon (Eds.), *Team dynamics over time* (pp. 155–187). Bingley, UK: Emerald. http://dx.doi.org/10.1108/S1534-085620160000018007

Rose, R. D., Zbozinek, T., Smith, S., Leveton, L., Schneiderman, J., Arias, D., . . . Craske, M. (2017, January). *Autonomous multimedia stress management and resilience training for flight controllers*. Presented at the NASA Human Research Program Investigators' Workshop, Galveston, TX.

Rubino, C., & Keeton, K. E. (2010). *Autonomy report* [Internal NASA report]. Washington, DC: National Aeronautics and Space Administration.

Schmidt, L. A. (2015). *A model of psychosocial factors for long duration spaceflight exploration missions* (NASA/TM-2015–218582). Retrieved from http://ston.jsc.nasa.gov/collections/TRS/_techrep/TM-2015-218582.pdf

Schneiderman, J., & Landon, L. B. (2015, April). *Behavioral research in spaceflight analogs*. Presented at the University of Houston, Houston, TX.

Shattuck, N. L., & Matsangas, P. (2015). A 6-month assessment of sleep during naval deployment: A case study of a commanding officer. *Aerospace Medicine and Human Performance, 86,* 481–485. http://dx.doi.org/10.3357/AMHP.4140.2015

Shuffler, M. L., Jimenez-Rodriguez, M., & Kramer, W. S. (2015). The science of multiteam systems: A review and future research agenda. *Small Group Research, 46,* 659–699. http://dx.doi.org/10.1177/1046496415603455

Shuffler, M. L., Kramer, W. S., Savage, N. M., & Verhoeven, D. C. (in press). *Review of multiteam systems related to long-duration exploration missions (NASA/TM)*. Washington, DC: National Aeronautics and Space Administration.

Slack, K. J. (2016, April). *Selecting astronauts and composing crews: Lessons applicable to earth-bound organizations*. Presented at the 31st Annual Conference of the Society of Industrial/Organizational Psychology, Anaheim, CA.

Smith-Jentsch, K., & Sierra, M. J. (2017). *Teamwork training needs analysis for long-duration exploration missions* (NASA/TM-2017–219294). Retrieved from https://ston.jsc.nasa.gov/collections/TRS/_techrep/TM-2017-219294.pdf

Stuster, J. (2016). *Behavioral issues associated with long duration space expeditions: Review and analysis of astronaut journals experiment Phase 2* (NASA/TM-2016–218603). Retrieved from https://ston.jsc.nasa.gov/collections/TRS/_techrep/TM-2016-218603.pdf

Tafforin, C., Vinokhodova, A., Chekalina, A., & Gushin, V. (2015). Correlation of etho-social and psycho-social data from "Mars-500" interplanetary simulation. *Acta Astronautica, 111,* 19–28. http://dx.doi.org/10.1016/j.actaastro.2015.02.005

Tannenbaum, S. I., & Cerasoli, C. P. (2013). Do team and individual debriefs enhance performance? A meta-analysis. *Human Factors, 55,* 231–245. http://dx.doi.org/10.1177/0018720812448394

Tannenbaum, S. I., Mathieu, J. E., Alliger, G. M., Donsbach, J. S., & Cerasoli, C. P. (2016, January). *Team-led debriefs: A countermeasure for LDSE crews*. Presented at the NASA Human Research Program Investigators' Workshop, Galveston, TX.

Vanhove, A. J., Herian, M. N., Harms, P. D., & Luthans, F. (2015). *Resilience and growth in long-duration isolated, confined and extreme (ice) missions* (NASA/TM-2015–218566). Retrieved from https://ston.jsc.nasa.gov/collections/TRS/_techrep/TM-2015-218566.pdf

Webb, J. M., & Olenick, J., Ayton, J., Chang, C.-H., & Kozlowski, S. W. J. (2017, January). *An examination of the relationships between the big five* *personality factors and team processes*. Presented at the NASA Human Research Program Investigators' Workshop, Galveston, TX.

Weiss, J. A., Outland, N. B., Bell, S. T., DeChurch, L. A., & Contractor, N. S. (2017, January). *Interpersonal compatibility in HERA*. Presented at the NASA Human Research Program Investigators' Workshop, Galveston, TX.

Whitaker-Azmitia, P. M. (2016). *Biological basis of social support* (NASA/TM-2016–218598). Retrieved from https://ston.jsc.nasa.gov/collections/TRS/_techrep/TM-2016-218598.pdf

Williams, T. J., Landon, L. B., Vessey, W. B., Schneiderman, J., & Basner, M. (2017, January). *Developing behavioral health and performance standard measures for the Team, Sleep, BMed risks*. Presented at NASA Human Research Program Investigators' Workshop, Galveston, TX.

Received January 24, 2017
Revision received November 2, 2017
Accepted November 3, 2017 ■