NASA/TM-2015-218586

Issues in Maintaining Team Motivation over Long-Duration Exploration Missions

Frederick P. Morgeson, Ph.D.
fred@morgeson.com
(517) 381-0811

Prepared for:
Behavioral Health and Performance Research Element
NASA Human Research Program

National Aeronautics and
Space Administration

Johnson Space Center
Houston, Texas 77058

August 2015

NASA STI Program ... in Profile

Since its founding, NASA has been dedicated to the advancement of aeronautics and space science. The NASA scientific and technical information (STI) program plays a key part in helping NASA maintain this important role.

The NASA STI program operates under the auspices of the Agency Chief Information Officer. It collects, organizes, provides for archiving, and disseminates NASA's STI. The NASA STI program provides access to the NASA Aeronautics and Space Database and its public interface, the NASA Technical Report Server, thus providing one of the largest collections of aeronautical and space science STI in the world. Results are published in both non-NASA channels and by NASA in the NASA STI Report Series, which includes the following report types:

- TECHNICAL PUBLICATION. Reports of completed research or a major significant phase of research that present the results of NASA Programs and include extensive data or theoretical analysis. Includes compilations of significant scientific and technical data and information deemed to be of continuing reference value. NASA counterpart of peer-reviewed formal professional papers but has less stringent limitations on manuscript length and extent of graphic presentations.

- TECHNICAL MEMORANDUM. Scientific and technical findings that are preliminary or of specialized interest, e.g., quick release reports, working papers, and bibliographies that contain minimal annotation. Does not contain extensive analysis.

- CONTRACTOR REPORT. Scientific and technical findings by NASA-sponsored contractors and grantees.

- CONFERENCE PUBLICATION. Collected papers from scientific and technical conferences, symposia, seminars, or other meetings sponsored or co-sponsored by NASA.

- SPECIAL PUBLICATION. Scientific, technical, or historical information from NASA programs, projects, and missions, often concerned with subjects having substantial public interest.

- TECHNICAL TRANSLATION. English-language translations of foreign scientific and technical material pertinent to NASA's mission.

Specialized services also include creating custom thesauri, building customized databases, and organizing and publishing research results.

For more information about the NASA STI program, see the following:

- Access the NASA STI program home page at *http://www.sti.nasa.gov*

- E-mail your question via the Internet to help@sti.nasa.gov

- Fax your question to the NASA STI Help Desk at 443-757-5803

- Phone the NASA STI Help Desk at 443-757-5802

- Write to:
  NASA Center for AeroSpace Information
  7115 Standard Drive
  Hanover, MD 21076-1320

NASA/TM-2015-218586

Issues in Maintaining Team Motivation over Long-Duration Exploration Missions

Frederick P. Morgeson, Ph.D.
fred@morgeson.com
(517) 381-0811

Prepared for:
Behavioral Health and Performance Research Element
NASA Human Research Program

National Aeronautics and
Space Administration

Johnson Space Center
Houston, Texas 77058

August 2015

Available from:

NASA Center for AeroSpace Information
7115 Standard Drive
Hanover, MD 21076-1320

National Technical Information Service
5301 Shawnee Road
Alexandria, VA 22312

Available in electric form at http://ston.jsc.nasa.gov/collections/TRS

Abstract

This review was commissioned by the Behavioral Health and Performance Research Element (BHP-R) of the NASA Human Research Program (HRP) in order to review the issues that might arise in maintaining team (crew) motivation over long durations. The team and spaceflight literatures were reviewed and ten interviews were conducted with a variety of spaceflight experts. This review is organized by the five distinctive crew motivational challenges (CMCs) that were identified in the interviews, including (1) the presence of motivational challenges, (2) mission preparation, (3) crew autonomy, (4) workload, and (5) team composition and individual differences. For each of the CMCs, the results of the expert interviews are provided, followed by the results of the literature review. Each section concludes with potential solutions to the CMCs identified. The report concludes with a summary of the results and suggestions for future research.

Table of Contents

Abstract i
Executive Summary 1
Operational Recommendations 1
Research Recommendations 2
Background 3
Understanding Team Motivation 4
Expert Interviews 5
Literature Review 6
Crew Motivational Challenge #1:
Presence of Motivational Challenges 9
Expert Interview Results 9
Literature Review Results 10
Potential Solutions 11
Crew Motivational Challenge #2:
Mission Preparation 12
Expert Interview Results 12
Literature Review Results 12
Potential Solutions 13
Crew Motivational Challenge #3:
Crew Autonomy 15
Expert Interview Results 15
Literature Review Results 17
Potential Solutions 20
Crew Motivational Challenge #4:
Workload 23
Expert Interview Results 23
Literature Review Results 24
Potential Solutions 25
Crew Motivational Challenge #5:
Team Composition and Individual Differences 27
Expert Interview Results 27
Literature Review Results 28
Potential Solutions 29
Summary and Suggestions for Future Research 30
References 32

Executive Summary

This review was commissioned by the Behavioral Health and Performance Research Element (BHP-R) of the NASA Human Research Program (HRP) in order to review the issues that might arise in maintaining team (crew) motivation over long durations. The team and spaceflight research literatures were reviewed and ten interviews were conducted with a variety of spaceflight experts. These experts had considerable experience (27 years on average) in a variety of spaceflight domains, including mission planning, flight operations, astronaut selection and evaluation, and high fidelity analogous missions and environments.

Five distinctive crew motivational challenges (CMCs) were identified in the interviews and the literature review was organized around these challenges. First, the presence of motivational challenges reflected the question of how and why team motivation might become a problem on long-duration missions. Second, mission preparation involved the length and quality of mission preparation needed to effectively function on long-duration missions. Third, crew autonomy focused on issues of the amount of autonomy, challenges to autonomy, and changes in autonomy over the course of the mission. Fourth, workload concerned the amount of work done on mission and the extent to which the work is meaningful or motivational in nature. Fifth, team composition and individual differences focused on the specific astronaut competencies and mix of competencies needed to maintain high motivation levels.

The expert interviews and literature review identified a number of operational and research recommendations. They are summarized below.

Operational Recommendations

- Provide crew members realistic information about the mission.
- Explicitly address the fact that this might be the final mission for crew members and what motivational implications this fact would have.
- Train crews to tolerate the mission constraints, including performing long simulations of the mission under real confinement.
- Train crews together with members of mission control.
- Build intrinsic motivation into the mission goals (including personal goals) as well as emphasize the importance of the mission goals.
- Ensure there are autonomy-supportive systems in place.
- Conceptualize the types of autonomy that will be feasible.
- Understand the predominant NASA ground control culture and how this will impact enhanced crew autonomy.
- Give crews a balance of things to do, including what to do during downtime.
- Create meaningful work.

Research Recommendations

- Conduct additional team-level research on the motivational issues that might arise during long-duration spaceflight.
- Conduct research on the specific forms of autonomy that are feasible given the mission constraints associated with long-duration spaceflight.
- Explore the range of ways meaningful work might be created and implemented over the course of a long-duration mission.
- Conduct research on team composition and individual differences.

Background

As part of its ongoing efforts of supporting and conducting research designed to identify and reduce the risks associated with long-duration spaceflight missions, the Behavioral Health and Performance Research Element (BHP-R) of the NASA Human Research Program (HRP) commissioned this review of the issues that might arise in maintaining team (crew) motivation over long durations. As noted in the Statement of Work (SOW):

> Future space exploration missions will be characterized by extended periods, in some cases up to 30 months, of isolation and confinement with a small team. Travel to and from objects of interest (e.g., planets, asteroids) will involve long periods of relatively little activity and the potential for prolonged boredom. These factors make it critical to understand team motivation in this context, particularly with regard to methods for maintaining motivation over long durations.

In order to understand issues of team motivation in this type of long-duration spaceflight context, I conducted a literature review on the critical issues surrounding team motivation and its effects on team functioning. This included a specific focus on methods used to maintain motivation in teams working in similar settings to the spaceflight context (this context includes small teams supported by larger teams on different schedules, teams performing in isolated, confined settings, and both high tempo and low tempo workloads, or in extended workload situations). Next, I conducted an operational assessment to determine what issues related to motivation are present during spaceflight. This was accomplished via semi-structured interviews with 10 spaceflight experts from different backgrounds (flight controllers, astronauts, mission planners, CapComs, etc.).

The remainder of this report details the results of the literature review and expert interviews. As discussed with BHP-R staff, the literature review is focused only on the subset of challenges and motivational issues identified via the expert interviews. As such, this report describes the expert interview methodology and uses the expert interview results as the organizing framework for the report. The experts identified a range of crew motivational challenges (CMCs) or problems associated with long-duration spaceflight. These CMCs represent broad themes that arose across multiple interviews.

In each section that follows, I first identify the problem described by the experts. Then I describe the academic research that addresses or otherwise speaks to the problem. This is followed by a discussion of the range of solutions offered by the experts and the research literature. The report concludes with a summary of the results and suggestions for future research.

Understanding Team Motivation

In order to understand issues of team motivation, it is first necessary to understand something about teams and their motivation. A team can be defined as:

> (a) two or more individuals who (b) socially interact (face-to-face or, increasingly, virtually); (c) possess one or more common goals; (d) are brought together to perform organizationally relevant tasks; (e) exhibit interdependencies with respect to workflow, goals, and outcomes; (f) have different roles and responsibilities; and (g) are together embedded in an encompassing organizational system, with boundaries and linkages to the broader system context and task environment (Kozlowski & Ilgen, 2006, p. 76).

This definition would encompass collectives that have been variously labeled groups, teams, and crews. Although some have made distinctions between groups, teams, and crews, any differences tend to be ones of degree rather than kind. As such, in this report I use the terms group, team, crew interchangeably (see also Morgeson, DeRue, & Karam, 2010).

In terms of motivational processes, scholars have distinguished between motivation in teams and motivation of teams. Motivation in teams concerns individual-level motivation in team contexts whereas motivation of teams reflects motivation at the team level of analysis. Given the spaceflight context and need for understanding crew motivation in long-duration missions, I will primarily focus on team-level motivation and the motivational processes that manifest themselves within the team. Having said that, for some areas the bulk of research and suggestions have been for individual-level motivational processes, so these will be discussed where needed. Team motivation has been defined as:

> *Goal generation* and *[goal] striving* behaviors among team members in which team and member *motivational* states interact dynamically and interdependently to include the direction, intensity, and persistence of member actions relevant to team goals (Ilgen, 2014, p. 55).

As described by Chen and colleagues (Chen & Gogus, 2008; Chen & Kanfer, 2006), motivational states involve beliefs regarding the work environment and one's interest in and capacity to operate effectively in that environment. Goal generation involves choosing where and how to allocate one's effort. Goal striving involves regulating one's effort during goal pursuit. This model is summarized in Figure 1. There are at least two interesting implications of this definition for the spaceflight context. First, long-duration spaceflight involves many constraints in terms of the tasks performed, the environment they are performed within, and the interpersonal context of their performance. These constraints reflect distinctive challenges or problems experienced by teams and individuals and are key influences (or inputs) on the motivational processes. Second, unlike many organizational contexts, the long-duration spaceflight context will have few boundaries between the "work" and "personal" domains.

Because team-level goal processes are fundamentally interpersonal in nature, the blending of work and personal domains will have important implications for team motivation.

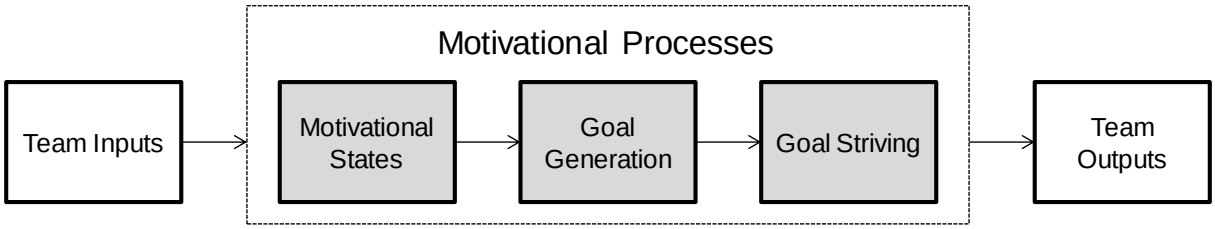

Figure 1. Team Motivation Framework

The expert interviews and literature review was guided by this overarching conceptual model, particularly in terms of understanding what can influence the motivational processes as crews embark upon long-duration missions.

Expert Interviews

From April to August, 2014, 10 spaceflight experts were interviewed. The goal of these interviews was to understand the range of motivational challenges experienced by crews on long-duration missions. For clarity, consistency, and a common frame of reference, the example long-duration mission discussed was a manned mission to Mars. The experts were generally familiar with the challenges and constraints of such a mission and were readily able to provide opinions about the motivational challenges that might be present during such an endeavor. Hour-long interview sessions were shared between myself and one other researcher. As such, my interviews lasted approximately 30 minutes. The other researcher and I alternated the order of the interviews such that in half the interviews she introduced the purpose of the interview and asked her questions first (focusing on team culture) and in the other half I introduced the purpose of the interview and asked my questions first (focusing on team motivation). Although my interviews were guided by a set of general interview questions, these questions were most commonly used to start the conversation. Once the conversation was started, I probed and explored the responses given, as well as verified and checked information given in earlier interviews. At the request of BHP-R, these interviews were not recorded to protect confidentiality and encourage open dialogue.

These experts had considerable experience (27 years on average) in a variety of spaceflight domains, including mission planning, flight operations, astronaut selection and evaluation, and high fidelity analogous missions and environments.[1] Experts included former astronauts with

[1] Analogous missions have been defined as "a fully integrated set of activities in support of, and/or simulating future exploration missions on the Moon or Mars" (Williamson, Hipkin, Lebeuf, & Berinstain, 2007; cited in Binsted, Kobrick, Griofa, Bishop, & Lapierre, 2010, p. 995) and analogous environments have been defined as "environments that share one or more salient features (e.g., temperature, remoteness, topology, mineralogy, etc.) with the target environment" (Binsted et al., 2010, p. 995).

considerable spaceflight mission experience (both as flyers as well as in supporting roles). In order to protect the confidentiality of interviewee responses, specific respondents are not identified in the summaries that follow. Instead, summarized and paraphrased comments will be provided.

An analysis of the themes that emerged across the interviews revealed five CMCs. These CMCs are summarized in Table 1. A detailed explanation of these interviews is provided in the remainder of the report.

Table 1. Summary of Crew Motivation Challenges

Number	Crew Motivational Challenge	Description
1	Presence of Motivational Challenges	How and why team motivation might become a problem on long-duration missions.
2	Mission Preparation	Length and quality of mission preparation.
3	Crew Autonomy	Amount of autonomy, challenges to autonomy, and changes in autonomy over the course of the mission.
4	Workload	Amount of work done on mission and the extent to which that work is meaningful or motivational.
5	Team Composition and Individual Differences	Specific astronaut competencies and mix of competencies needed to maintain high motivation levels.

Literature Review

A literature review was conducted to identify academic research conducted on issues of team motivation, with particular emphasis on research conducted in analogous settings. For purposes of this review, analogous settings include those that are *isolated* (i.e., remoteness from home, family, and organizational support; difficulty in communicating with home); *confined*, with a lack of privacy or some physical discomfort; have *variable workload* (i.e., "punctuated" or event-driven workload that might alternate between under- and over-load); involve *physical exertion*; have a *long duration* (i.e., long voyages to and from destination or long stay at a single destination); have *high consequences of error* (i.e., extreme, risky, and dangerous environments); and might produce certain *psychological issues* such as boredom, irritability, depression, and anxiety (Stuster, 1996; Suedfeld, 2010). These characteristics are summarized in Figure 2.

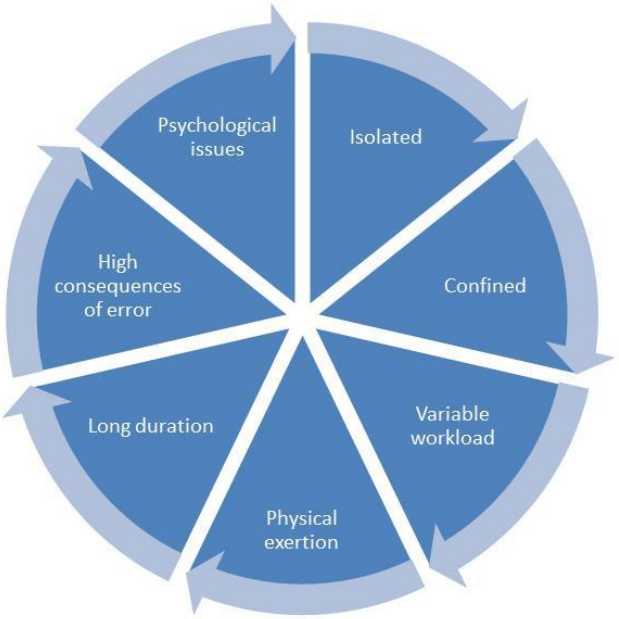

Figure 2. Characteristics of Analogous Settings

To identify articles, a search was conducted to identify as many published studies as possible. There were four search targets, including (1) computerized databases, (2) major psychology and management journals, (3) major planetary and environmental sciences journals, and (4) reference lists of key team motivation articles and books. See Table 2 for a summary of the various databases and journals searched. The search terms for these sources included: Team, teams, group, groups, crew, crews, and collective with the keywords motivation, motivating, and motivate(d).

Table 2. Databases and Journals Searched

Computerized Databases	Psychology and Management Journals		Planetary, Aviation, & Environmental Sciences Journals
• **ABI/Inform** • **EBSCO** • **ProQuest** • **PsycInfo** • **JSTOR** • **Web of Science**	• Academy of Management Journal • Academy of Management Review • Administrative Science Quarterly • Journal of Applied Psychology • Journal of Management • Journal of Organizational Behavior • Journal of Personality and Social Psychology	• Journal of Vocational Behavior • Management Science • Organization Science • Organizational Behavior and Human Decision Processes • Personnel Psychology • Psychological Bulletin • Small Group Research	• Acta Astronautica • Advances in Space Research • Aviation, Space, and Environmental Medicine • Environment and Behavior • Journal of Environmental Psychology • Planetary and Space Science

This search process yielded over 750 articles[2] that were subject to further review and evaluation. This subsequent review and evaluation yielded 277 articles that fit the initial review criteria. These articles were further reviewed to determine if they were conducted in settings analogous to the long-duration spaceflight setting or if they covered any of the five CMCs identified in the expert interviews. Table 3 reports the number of articles that included any potentially relevant information about the crew motivational challenges. This coding was deliberately inclusive and included a number of articles that were ultimately not included in the literature review. The articles were retained at this point in order to have as inclusive a starting point. In addition, if no research was conducted in analogous settings, I looked to other settings for potential insight into team crew motivational challenges.

Table 3. Number of Articles Found for Each Crew Motivational Challenge

Crew Motivational Challenge	Number of Articles[3]
Presence of Motivational Challenges	50
Mission Preparation	16
Crew Autonomy	41
Workload	38
Team Composition and Individual Differences	116

[2] I am using the term "articles" to refer to journal articles, government reports, edited book chapters, and books.
[3] Some articles cover multiple motivational challenges.

Crew Motivational Challenge #1:
Presence of Motivational Challenges

Expert Interview Results

A presumption of the team motivation project is that there will be motivational challenges among long-duration spaceflight crews. At least two of the ten experts interviewed questioned this premise by suggesting that they were not sure there would be any motivational issues. The basis of this suggestion is that astronauts will have volunteered for this mission and will want to participate in the mission. As such, they suggested, the astronauts will be highly motivated and you will get the "best of the best" for the mission. This would suggest that team motivation will not be a problem.

In probing experts about this issue, they typically acknowledged that this group will be highly motivated, but they might not be able to maintain that motivation over time (within a mission) or across missions (i.e., subsequent missions after the first). For example, one expert suggested that the first mission (at least) will likely not evidence motivational problems. The novelty of the mission, along with the fact that the crew on the mission will be the first of their kind will enable sufficient team motivation. It is only on subsequent missions that crew motivation might be a problem.

Other experts, however, were not quite as sanguine. They universally acknowledged that astronauts are a highly capable, trained, and motivated group. Yet, they also suggested that astronauts will overestimate the ease of long-duration flights. One can see how this might occur, in part because astronauts are likely to be highly confident in their own capabilities. In addition, another expert suggested that the situation (i.e., the duration, confinement, and low workload) will eventually wear them down, thus producing motivational issues. In addition, another expert suggested that small problems are likely to become bigger problems over time. Thus, astronauts or mission planners might acknowledge that there might be some potential problems, but then underestimate the severity of problems or the fact that a small problem can grow into a large problem over time.

The final idea in this CMC is the comment by one of the experts that in spaceflight crews, motivation is driven by two factors: (1) perfect mission performance and (2) getting another mission. This expert suggested that astronauts are not necessarily inherently cooperative and that it is this combination of factors that helps keep crews motivated to maintain good team dynamics and processes. Interestingly, in a long-duration mission, the first factor (i.e., perfect mission performance) would be present but the second factor (i.e., getting another mission) would likely not be present (i.e., this is likely the last flight for long-duration flyers). As this expert questioned, will people be on their best behavior if this is their last mission? This expert suggested that one of the reasons astronauts stay on their best behavior is because they want to

fly again. This suggests that the typically (positive) influences on crew motivation may not be present during long-duration missions, pointing to the likelihood of motivational issues arising.

Literature Review Results

Perhaps one of the most highly researched topics in the teams literature has focused on the range of motivation losses that can occur in team-based work (Shepperd, 1993). Also termed process loss (Steiner, 1972), this includes social loafing (Latané, Williams, & Harkins, 1979) and free-riding (Albanese & Van Fleet, 1985) effects. The basic idea is that as individual team member contributions become unidentifiable and diffused within the team, team members withhold their effort for a variety of reasons (Kidwell & Bennett, 1993). What results is a lack of motivation and lower levels of performance. Although some have suggested that such problems are not inevitable (van Dick, Tissington, & Hertel, 2009), the vast majority of research would argue that motivation loss is a key motivational problem in teams. Interestingly, however, the bulk of the research on this topic has occurred in short-term laboratory research with ad hoc teams composed of undergraduate students. Because this is quite different than a long-duration spaceflight context with highly trained and highly capable crews, it is an open question as to whether one would expect to find any motivational problems in these teams. A small body of research has considered this issue in the spaceflight context, which suggests that this has been a problem in many analogous and spaceflight situations.

Kanas (1985) reviewed a host of studies that concerned the psychosocial issues that have presented themselves in past missions analogous to long-duration spaceflight. A handful of them speak to crew motivation issues. For example, in 1958, the Nautilus submarine was submerged for one month during its historic transpolar cruise. According to Kinsey (1959), crew morale was high and few difficulties were experienced. As Kanas (1985, p. 807) suggests, “Undoubtedly, the historic nature of the mission helped to keep the motivation high.” This reflects a comment made in an expert interview, where the initial mission is less likely to be negatively impacted by motivational issues.

In 1960, during an 83-day cruise of the Triton submarine, crew members completed daily questionnaires concerning their mental state. Weybrew (1961) found that individual motivation and group morale began to decline after ten days but then increased during the last two weeks of the mission. This suggests that crew motivation is dynamic in nature, likely depending on both temporal indicators (e.g., time between mission phases) and key events (e.g., landing).

In 1953, 22 crew members and an officer took part in a 60-day confinement study aboard the U.S.S. Haddock. The goal of the study, in part, was to understand the effects of long confinement on performance, attitudes, and emotions. Weybrew (1957) found that as the confinement period increased, motivation declined, tension increased, and alertness decreased. Again, this early study suggests that such settings can produce motivational issues.

Allner and Rygalov (2008) analyzed the group dynamics that arose during the Lewis and Clark Expedition that began in 1803. This is thought to be a relevant analog for long-duration space missions because this was an extended mission (more than two years) that took place in, "a remotely confined and high-perceived risk environment that produced huge stresses and every day challenges for the crew" (Allner & Rygalov, 2008, p. 1958). In reviewing the literature on winter-over groups, Allner and Rygalov (2008) indicate that when crews are isolated and confined (two key characteristics of long-duration spaceflight), daily routines quickly take on a monotonous and boring quality that leads to depression and degrades team motivation.

In analyzing the Lewis and Clark Expedition, Allner and Rygalov (2008, p. 1964) identified an "intermediate phase" that lasted from months 4 to 6. This phase was characterized by a number of factors including crew fatigue resulting from heat and physical fatigue from the work and an incident where a crew member ran away (also referred to as a transcendent experience). Importantly, they also noted insubordination issues as reflected in decreasing motivation. The issue of motivation was particularly important because, "high crew motivation was a critical aspect in both group dynamic development and overall mission success" (Allner & Rygalov, 2008, p. 1968).

As these handful of studies suggest, it appears that motivation issues are likely to present themselves during extended long-duration missions. Although relatively few studies have been conducted in spaceflight contexts or their analogs, there is reason to believe that the same kinds of motivational issues present in most groups will manifest themselves during spaceflight. Some of the reasons for these motivational issues will be reviewed later in this report.

Potential Solutions

The question of whether there will be any motivational challenges at all is not a challenge that requires a solution per se. The subsequent challenges, however, do have a variety of solutions that will be discussed.

Crew Motivational Challenge #2:
Mission Preparation

Expert Interview Results

Another theme revealed during the expert interviews revolves around the preparation undertaken for the first long-duration mission and the uncertainties associated with the first mission. One expert suggested that for the first mission, crews will have spent an exceptionally long time preparing for the mission, undoubtedly with many changes occurring during the preparation. As such, the crews will be going to launch "tired, frustrated, and mad." In addition, there will be a brand new crew, brand new software, a brand new vehicle, a new ops context, and new procedures, all of which is likely to increase the frustration levels.

Another expert suggested that the training is likely to be bad, or at least not fully appropriate for their mission. For example, one expert mentioned the importance of providing teamwork skills training, even though that has not typically been a very strong focus of training. In addition, an expert mentioned that the crew might not get the vehicle or software expected and much of what will be put on board will be wrong. In short, there will be a lot of teething problems. Interestingly, multiple experts noted that this is how it has been for the initial missions for previous programs (e.g., International Space Station [ISS], Russian space station MIR). As such, they cannot imagine that it would be any different for the first Mars mission. This will lead to some unmet expectations, potentially leading to frustration and motivational challenges.

Literature Review Results

What is unexpected about the issues highlighted by the experts is that they are suggesting that the training itself will be too long or filled with incomplete or changing information. Of course, these two characteristics of training are related, in that in an effort to anticipate all the contingencies likely present during a long-duration mission, training will have to occur over an extended period of time prior to departure (and then continue during the flight to the destination). To the extent that the mission parameters change during mission preparation, this will only serve to either further extend training or make some of the previous training content obsolete. This will create the exhaustion and frustration reaction noted above.

The team training literature is voluminous (Salas et al., 2008). For teams with a defined mission, the training period is often of considerable length and complexity. For example, Navy Seal team members train extensively for two and a half years from boot camp until their first mission deployment (Official Naval Special Warfare Website, 2014). In addition to their initial candidate training period, Apollo 11 crew members trained exclusively for the July 16, 1969 launch for almost an entire year (Compton, 1989). As acknowledged by the spaceflight experts, the crews will undoubtedly go through an extensive and extended training period.

Although considerable research has focused on within-training motivation and post-training performance, very little research has focused on post-training team motivation. As such, there has been little published research that identifies this as a potential motivational challenge. Yet, the published research does have something to say about how to design training so as to avoid these problems. I highlight these suggestions below.

Potential Solutions

The spaceflight experts had two suggestions for how to adequately prepare crews for the inevitable frustrations they would experience. First, they suggested that crew members be provided realistic information about the mission. This would include information about both the positive aspects of the mission as well as all the inevitable frustrations that they are likely to experience. Such a strategy would be consistent with providing new job applicants realistic information about their prospective job (Breaugh, 2013). Providing such information is likely to help crew members develop accurate expectations about the mission and its preparation. It is also likely to build trust between the mission planners and the crew. Such trust is critical for long-term motivation and mission success.

Second, the spaceflight experts suggested that mission preparation explicitly address the fact that this might be the final mission for crew members and what motivational implications this fact would have. This information could inform crew member selection, in that certain types of crew members might be more prone to maintain motivation even with the knowledge that this is their last mission. This information could also be used in the mission training itself, where this issue is directly addressed and countermeasures developed to avoid potential motivational issues.

Two broad suggestions were offered in the published literature that has implications for mission preparation and team motivation. The first revolves around preparation realism and difficulty. Recognizing the difficulties inherent in long-duration missions, Ursin, Comet, and Soulez-Larivière (1992, p. 308) suggest that crews must be trained to tolerate the mission constraints. Specifically, they suggest that, "In addition to individual training, crew training and simulation of long-duration confinements are necessary. Common training in difficult environment [sic] should have two interests: the first will be to test the crew compatibility and coherence, the second will be to train the crew members themselves." They go on to offer three primary recommendations:

1. Perform long simulations of the mission (2 months or longer) with or without a difficult environment, but under real confinement.
2. Train the crew for diagnosis and management for interpersonal frictions and conflicts.
3. Investigate to which extent the combined characteristics of the crew reflect the individual characteristics and capabilities of each crew member.

Kanas et al. (2009) offer similar recommendations, suggesting that crews undergo survival training in a variety of extreme conditions (e.g., polar wintering-over, desert expeditions).

Importantly, they suggest, crews should train together during pre-launch training. In addition, some of this training should include members of mission control. This is thought to build the relationship between the crew and ground as well as enhance communication. Finally, they suggest that crew members should be involved in making operational decisions before and during space missions (see the autonomy CMC below). This would include seeking opinions on such things as, "…access to logistics, fair workload distribution, and leisure time, so that potential sources of quarrels can be identified and offset" (Kanas et al., 2009, p. 674).

Similar recommendations come from the non-spaceflight research. For example, in studying project teams, Ericksen and Dyer (2004, p. 467) note that, "…the duration and intensity of mobilization and launch activities appear not only to affect the actual amount of time project teams have to do their work but also serve as models of behavior that influence team members' perceptions of time and thus their collective motivation during the immediate post-launch period." Similarly, Edmonds, Tenenbaum, Kamata, and Johnson (2009) studied adventure racing teams and found that their preparation effort was related to initial levels of collective efficacy, an important motivational state that is related to performance.

The second recommendation from the literature revolves around issues of mission relevance in the preparation. As Lim et al. (2010, p. 924) note, "Fostering intrinsic motivation will orient astronauts towards continuous informal learning and a quest for mastery. The field science and exploration program should engender a sense of intrinsic motivation in the astronaut by stressing the need for a commitment to not only field science and exploration objectives, but also personal development objectives. This is an important factor in ensuring that (a) the individual is intrinsically motivated to learn and (b) that learning is focused on specific outcomes." This not only has implications for how to approach mission preparation, but also how to approach the tasks once the mission as begun.

In addition to building this sort of intrinsic motivation, it is also important to emphasize the importance of the mission goals. Key to this is to effectively communicate the importance of what the team was selected to do (Edmondson, Bohmer, & Pisano, 2001). This can help build a sense of task significance as well as significance of the mission to others. As we will see in the discussion of workload, building both internal and external sources of motivation are critical to ensuring crews have motivating work.

Crew Motivational Challenge #3:
Crew Autonomy

Expert Interview Results

In every interview, the experts spoke about crew autonomy. The issue of autonomy is important because of its strong and clear link to individual and team motivation. The expert comments revolved around three related issues: (1) the amount of autonomy long-duration crews will have; (2) potential challenges to autonomy; and (3) potential changes in autonomy over time.

Amount of autonomy. The primary autonomy issue discussed centered on the amount of autonomy crews will have from ground controllers. Most experts agreed that long-duration mission crews "will have a bit more autonomy than the ISS" mission crews. In general, they see this as a consequence of the communication lag that will slowly increase as the vehicle approaches Mars and that will slowly decrease as the vehicle returns and approaches Earth. As one expert suggested, once the communication delay is beyond a short interval (30 seconds), crews will have to start acting autonomously. Another expert suggested that the time delay will push the boundary in terms of crew autonomy (more than it has been on previous missions). The basic idea is that the crews will have to assume more autonomy and responsibility because they will not be able to communicate in real time with mission controllers.

There was also some suggestion, however, that the amount of autonomy might vary. One factor that might produce variability is mission phase. When crews engage in highly critical activities, they are likely to have lower amounts of autonomy. When engaging in low criticality (or more routine) activities, crews are likely to have higher amounts of autonomy.

Despite the likely presence of autonomy, other experts suggested that dependency will exist for a variety of reasons, including the fact that ground has much more information than the crew. Because the crew needs to have access to this data, they are dependent upon the ground. In addition, when problems occur, ground has the manpower (and knowledge) to develop solutions that the crew does not have. Finally, one expert noted that it will be difficult for the crew to build a schedule given the constraints they will be facing (e.g., power, communications) unless they have knowledge of the constraints (i.e., all the pieces of the puzzle). Because this knowledge will be maintained by ground, the crew will be dependent upon them.

One expert, however, did not think that crews will receive additional autonomy (when compared to shorter-duration missions). A number of reasons were given for this opinion, including the reality of how much knowledge is needed for the mission, the fact that training only gives the crew enough knowledge to operate the equipment, the fact that ground control has literally hundreds of years of combined experience, the likelihood that so much of what is put on board will be wrong, the fact that a Mars mission will have more software and that this software is extremely hard to master, and finally that the crew will not have access to more or better knowledge (when compared to the knowledge possessed by ground control).

Challenges to autonomy. Despite the general recognition that long-duration crews are likely to experience higher levels of autonomy, many experts identified a number of issues that might challenge or threaten the autonomy crews are likely to experience. Perhaps the biggest challenge (identified by multiple experts) concerned the strong ground control culture currently in place. The experts noted that the ISS was designed to be run from the ground, the flight director is in charge of the mission, and most (if not all) missions are controlled from the ground. One expert expressed the hope that crews would be autonomous, but acknowledged that this would be a cultural challenge given the history with ground control. All of this creates a strong set of cultural norms (within NASA) oriented toward a centralized command operational model, likely making it more difficult to grant crews additional autonomy.

Yet, as the experts noted, a Mars mission is completely different than ISS missions, and thus there will have to be a completely different modus operandi. One expert pointed out that early in the ISS program NASA tried to run it like a shuttle mission and this did not work very well. Another expert noted that due to the complexity of the ISS, the astronaut office had to adapt to high levels of ground control and there was initially a lot of resistance to this idea. This expert suggested that ground/mission control will eventually have to come around to the idea that they will not be able to control everything. The implication of these comments is that any attempt to run a long-duration mission like an ISS mission is not likely to work either. Particularly when there is a considerable communication delay, the experts noted that crews cannot depend on ground controllers. The experts noted that this will be difficult for ground controllers and could be a source of tension between the ground and crew. Change and adaptation is needed for the unique requirements of long-duration missions.

Changes in autonomy. Although only mentioned by a couple of experts, the idea that autonomy might change during the course of the mission is another autonomy-oriented challenge of long-duration missions. On a long-duration mission to Mars, the communication delay will steadily increase. On the return trip to Earth, the communication delay will steadily decrease. The experts suggested that there might be a tendency for ground to exert more control early in the flight (when the communication delay is less) and autonomy to increase gradually on the trip to Mars. It is likely that the crew will become accustomed to the increased autonomy. Upon return, however, ground may wish to reassert control (thus reducing autonomy) as the communication delay decreases. One expert suggested that changing autonomy could be a big problem, prompting the crew to question the legitimacy of such a change. This is likely to be problematic because control or autonomy is given, people generally do not like to relinquish it. This is likely to be particularly true for a crew that has spent quite a bit of time together and has shown their competence and had various successes. Reducing autonomy negatively impacts a crew's agency and demonstrates a lack of trust, two factors sure to reduce motivation. Although the expert who made this point did not elaborate on what specifically might happen, it seems logical to expect that crew members would at a minimum behave in a passive-aggressive manner or simply ignore directives from ground control.

Literature Review Results

The issue of team autonomy has a long history in the area of work and team design as well as the spaceflight literature. To organize the review of this area, I first briefly describe the non-spaceflight literature in order to provide key definitions and outline the issues associated with team autonomy. I then review the spaceflight literature and the unique team autonomy considerations that have been identified.

Non-spaceflight literature. The idea that giving or increasing team autonomy or discretion will have positive motivational implications has a long history. The seminal studies at the Harwood Manufacturing Company showed that when groups of employees have increased responsibility for, and control over, their job and work environment, motivation and performance increased (Lewin, 1948). In this research, the "motivation was believe to come…largely from the opportunity to use skills, learn and teach, and to take responsibility" (Bucklow, 1966, p. 65).

In the same time frame, scholars at the Tavistock Institute in Great Britain began to study the British coal mining industry. This industry and the work of coal miners has some similarity to spaceflight contexts in that workers routinely find themselves in isolated, confined, and extreme environments. They began to study the variety of motivational and performance decreases as coal mining shifted from "hand got" techniques (which involved considerable worker autonomy) to "long wall" techniques (which reduced autonomy by simplifying and automating the work; see Trist & Bamforth, 1951). This research focused attention on the, "responsible autonomy of the multiskilled individual miner, and on the organization of the small, underground work group. Responsibility for the work and for supervision rested with the men themselves, requiring a high level of interdependence between members, rotation of roles and tasks, and sharing in a common paynote" (Bucklow, 1966, p. 69). This research led to what has been termed the "sociotechnical systems theory" approach, of which the autonomous team occupies a central role. Interestingly, this research showed that when team autonomy is taken away it has a deleterious effect on team motivation, which has potential implications for the changes in crew autonomy mentioned by the experts.

As research progressed, a variety of different terms have been used to describe these teams, including semi-autonomous teams, self-managing teams, and self-designing teams (Banker, Field, Schroeder, & Sinha, 1996). Regardless of the label used, these kinds of teams have been shown to yield higher levels of motivation and performance than less autonomous forms of work organization (Cohen & Ledford, 1994; LePine, Piccolo, Jackson, Mathieu, & Saul, 2008).

It is thought that these kinds of teams yield high levels of motivation and performance for at least three reasons. First, they enable team member self-regulation and control over the work, particularly if they are facing changing conditions. This is a key principle in socio-technical systems, which is to design work (and enable team autonomy) to control variance at its source (Cherns, 1978). In other words, if the environment is likely to produce unexpected events and

this variance cannot be eliminated, it should be controlled as close as possible to its origin, suggesting that work be designed with sufficient autonomy or control (Morgeson & Campion, 2003).

Second, the work and organizational designs of autonomous or semi-autonomous teams is inherently motivating. Autonomous team work is high in what has been termed motivational work design (Campion & Thayer, 1985), which includes such things as autonomy, task variety, task identity, task significance, and feedback from the work itself. These kinds of work designs foster internal work motivation which leads to high performance and satisfaction (Humphrey, Nahrgang, & Morgeson, 2007).

Third, autonomous team designs augment or replace hierarchical control with peer-based control. Peer-based control is, "an emergent motivational state in self-managing teams that replaces hierarchical control to coordinate the direction and persistence of individual and collective efforts of team members" (Stewart, Courtright, & Barrick, 2012, p. 435). Peer-based control is potentially more powerful than hierarchical control because of the significant rational and normative pressures that can exist within the team (Barker, 1993).

The motivational benefits of team autonomy have been well-established. There has been, however, less clarity around what is meant by the term "autonomy." Research by Breaugh (1985); Wall, Jackson, and Davids (1992); Wall, Jackson, and Mullarkey (1995); and Morgeson and Humphrey (2006) has shown that autonomy is composed of three interrelated aspects centered on freedom in (1) work scheduling (i.e., controlling the timing of one's work), (2) decision making (i.e., the ability to make decisions at work), and (3) work methods (i.e., controlling how the work is performed). Similar distinctions have been made in the context of team autonomy (Janz, Colquitt, & Noe, 1997). Understanding these different forms of autonomy is important because they suggest different ways in which autonomy might be designed into the work if some forms are not feasible.

Spaceflight literature. Those writing in the long-duration spaceflight literature are clear in their view that crew autonomy is essential. As Ursin et al. (1992, p. 308) state, "The most important principle is the autonomy of the crew." Similarly, De La Torre, van Baarsen, Ferlazzo, Kanas, Weiss, Schneider, and Whiteley (2012, p. 595) indicate, "One of the most promising aspects we have noted in the field of human space research is autonomy." There are numerous reasons why long-duration missions will require heretofore unseen levels of crew autonomy.

For example, in reviewing the literature relevant to determining the ideal psychological profiles for long-duration space mission **crews**, Ursin et al. (1992, p. 303) noted, "When considering Mars mission constraints (long distance from Earth, delayed communications, no escape possibilities…) it is obvious that the crew becomes more responsible for its survival, and will have to be more autonomous then ordinary space travelers." Implications of this include the fact that crews will need to be responsible for both normal and emergency situations as well as

having a different relationship with ground than presently exists. Decisions will often have to be made in real time without the input of ground control, partly because ground support might not be fast or efficient enough, or even possible at all (Ursin et al., 1992).

Kanas et al. (2009) and De La Torre et al. (2012) echo this sentiment, also pointing to the considerable communication delay (up to 22 minutes for one-way communication depending on distance between Earth and Mars and their relative orbital positions) and the fact that there is no possibility for emergency re-supply or rescue flights. "As a consequence, crews on a Mars mission will be exposed to a much higher level of autonomy and long-term confinement and isolation than any previous space crew" (Kanas et al., 2009, p. 661).

In addition, Kanas et al. (2009, pp. 673-674) suggest that the relationship between crew members and mission control will be affected by this autonomy. As they note, "In all likelihood, crews will need to plan most of their day-to-day activities without mission control input, and should a problem occur they would have to deal with it themselves. This planning extends to leaving time to sleep, eat and exercise…in addition, crew members will have to trust their on- board resources for monitoring life support and providing them with the information they will need to carry out their mission, so the human-machine interface will become even more important. It is time to start thinking about the issue of increased crew autonomy and the role of mission control during such non-orbital activities beyond the Earth's immediate environment."

Kanas, Harris, Neylan, Boyd, Weiss, Cook, and Saylor (2011) directly studied high versus low crew member autonomy during a simulated 105-day Mars mission (as part of the Mars 500 study). In reviewing the extant research, they summarized two previous autonomy studies at the NASA Extreme Environment Mission Operations (NEEMO) and the Haughton-Mars Project (HMP) 2008 and concluded that, "The findings from both studies suggested that the high autonomy condition was well received and that the subjects were able to complete the mission goals safely and successfully" (Kanas et al., 2011, p. 241).

With respect to their original research, Kanas et al. (2011) participated in a pilot study which involved a 105-day simulation conducted from March to July of 2009. The study involved a "crew" of six men (two Russian cosmonauts, a Russian medical doctor, a Russian sports physiologist, a German mechanical engineer, and a French airline pilot). Eighteen Russian monitoring personnel worked in shifts outside the simulated habitat as "mission control." The low autonomy condition occurred during the first ten weeks of isolation where mission control planned the work schedule. The high autonomy condition occurred during the last five weeks, where crew members took over more planning for their own activities. In addition, a 40-minute communication delay was implemented (to simulate a Mars-like delay). Perhaps not surprisingly, no adverse results were encountered in the high autonomy condition and during post-mission debriefings the crew members indicated they liked the freedom enjoyed in the high autonomy condition. As Kanas et al. (2011, p. 243) conclude, "Taken along with the findings from our

earlier NEEMO and HMP 2008 studies, the results from this Mars 500 105-day pilot study suggest that high crew autonomy is well received by crew members working in isolated space analog settings. The mission goals were accomplished, there were no adverse effects, and crew member mood, self-direction, and freedom to plan work were rated as being higher."

Potential Solutions

The beneficial effects of autonomy are well-established and both the spaceflight experts and the spaceflight research literature indicate that long-distance missions will be characterized by higher levels of autonomy. With these assumptions, the question arises as to how to best implement higher levels of crew autonomy. Based on the expert interviews, the literature review, and the demands of long-duration spaceflight, there are three primary issues: (1) ensuring there are autonomy-supportive systems in place, (2) conceptualizing the types of autonomy that will be feasible, and (3) understanding the predominant NASA culture and how this will impact enhanced crew autonomy.

Autonomy-supportive systems. Two types of autonomy-supportive systems emerged from the interviews and literature review. First, there is considerable evidence that crews and mission control will require preparation and training to adequately leverage and support crew autonomy. Beyond technical training, both crew and mission control will need to be trained on how to interact given enhanced crew autonomy. Critically, this will call for the training of mission control and other ground support to foster and support crew autonomy, even in the presence of what might seem like unreasonable complaints and demands (Ursin et al., 1992). In addition, De La Torre et al. (2012, p. 595) suggested that, "…countermeasures to sustain crew-ground communication under…conditions [of time delay] need to be developed and tested. For example, it is possible that the suggested negative impact of time delays can be countered by training crew members to include a number of potential responses to their questions at the end of each communication to which their contacts on Earth can respond directly, thus decreasing the need for frequent back-and-forth interactions." Finally, any potential changes in autonomy during the mission (i.e., less autonomy early in the mission and more autonomy later) should be planned and clearly communicated to crew and mission control. Yet, it is important to recognize that once autonomy is provided, if such autonomy is taken away, crews are likely to react negatively (see Trist and Bamforth, 1951).

Second, systems will need to be developed and implemented to support autonomous action. As De La Torre et al. (2012, p. 595) note, "This high autonomy environment demands new tools for astronauts, so that they can detect and treat possible problems, especially during long-term missions. These tools may be used to monitor, assess and treat psychological and neuropsychological variables or deficits due to the different hazardous sources present in space missions of these characteristics." As several experts noted, autonomy is good provided that you can resolve the problem yourself. The vehicle will need to be designed to be autonomous and expert systems will need to be developed to support and enable problem solving and decision

making (Ursin et al., 1992). Of course, as one expert noted, if the crew knows it does not have the right training or tools for that day's work, then they also need to know that they should seek help from mission control.

Types of autonomy. As described earlier, there are different types of autonomy (i.e., work scheduling, decision making, and work methods). Understanding these different types can inform the form crew autonomy might take. For example, although the experts acknowledged that it would be important to give crews more autonomy, the specific type of autonomy granted will depend on the day-to-day work schedule and experiments or activities to be conducted. Scheduling forms of autonomy were the most commonly discussed types of autonomy. The basic idea as expressed by one expert would be to give the crew flexibility to design a day's work given their intimate knowledge of the immediate environment, but recognizing that the crew will still likely need some help to put together a successful schedule. One way to foster such successful work scheduling would be to provide crews with needed timeline training and tools (see above).

As one expert noted, the provision of these types of autonomy has precedent in the MIR missions. This expert noted that, unlike the ISS, there was no continuous contact with mission control on MIR. One implication of this is that the MIR crew was much more interdependent and dependent on each other. Because of the limited ground contact, crews were in charge of their own life. They had to make adjustments and used the mission control timeline as a general guide. It was suggested that being in charge of their day was very empowering, making them more productive. This observation is echoed in the work of Kanas et al. (2011, p. 241), where they note, "It is not known how this increased autonomy will affect crew member performance and safety and what its impact will be on mission control operations on the Earth. However, astronauts are very competent and intelligent people who are used to organizing their activities in life. One might therefore theorize that during high autonomy space missions, where they are able to flexibly plan and schedule their workload with maximal efficiency, crew members would enjoy their work activities more, experience more positive mood states, and perform at a higher level than under conditions where their schedule is timelined and controlled by others."

Cultural influences. In different ways, many of the experts commented on the strong "mission control" NASA culture. The basic idea is that mission control exercises considerable power in dictating what happens on current spaceflight missions. This observation was also supported in the spaceflight literature review. Such a strong culture of centralized control is likely to pose significant challenges for missions with enhanced crew autonomy. Although some ideas for how to overcome these challenges have been offered, it is likely to continue to be a challenge. Recognizing this, one of the interviewed experts noted that mission control probably will not give up control entirely, but perhaps on a day-to-day basis they might be comfortable giving some general goals and objectives, letting the crew decide how to achieve them.

Yet, as noted earlier, astronauts are very competent and intelligent. Reflecting this, one of the experts noted that even on current missions, after a couple of months, astronauts rebel against a lack of autonomy. This expert characterized the astronaut mentality this way: “Just give me the skeleton and let me do it my way.” If autonomy is not formally granted and supported, the crew will undoubtedly take more autonomy, particularly as they become more distant from Earth. Recognizing this, the tendency might be to grant crews some nominal form of autonomy but retain control of the more significant functions. This might be tempting, but crews will readily see through this strategy. It is essential, of course, for teams to be truly given autonomy over meaningful aspects of their work. In a classic study, Morse and Reimer (1956) showed that simply granting teams nominal levels of autonomy was not sufficient to motivate workers. In fact, workers typically seek to expand the scope of their decisions and will grow frustrated if they cannot expand the scope. Thus, meaningful crew autonomy needs to be designed into the operating philosophy, training protocol, vehicle design, and mission specifications.

Crew Motivational Challenge #4:
Workload

Expert Interview Results

As with autonomy, the experts identified workload issues as a key team motivation issue. The workload challenge is important because of its strong and clear link to individual and team motivation. The expert comments revolved around two related issues: (1) the amount of work that would need to be done on a long-duration mission and (2) the type of work that would be performed on the mission.

Amount of work. All the experts interviewed identified the amount of work that would need to be done on a long-duration mission as a key team motivation challenge. Although the experts acknowledged there would likely be times of overwork and fatigue, there was unanimous agreement that there will be more times where the crew will not have enough work to do. Such an underwork situation is likely to produce significant levels of boredom and a lack of motivation. One expert made an analogy to driving a car: for short trips there are no problems, but over longer trips problems will arise. Another expert noted that a Mars mission will not have the same kind of daily task list as on the ISS, nor will you have the same diversity of exercise equipment, entertainment, payloads, experiments, communication options, location options (i.e., going to another module), or food variety. Another expert brought up the MIR 18 mission as an example of problems with boredom, where the U.S. astronaut (Norman Thagard) was scheduled to do some research experiments but the launch of the needed module (Spektr) was delayed, giving him little to do (as the first American aboard MIR).

Another expert noted that long-duration missions represent “a very different environment” because the crew may not have enough to do during transit. This expert noted that there was commonly not enough to do on early MIR missions, which led to depression and irritability, two outcomes with significant motivational implications. Related to this is the fact that the potential amount of work that needs to be done varies depending on the stage of the mission. The transit phases are more problematic, with the return to Earth most problematic (because there is little training needed for the return). Crucially, as one expert pointed out, two of the three forms of motivating work that are available pre-Mars landing are gone: There will be no landing training (because they will be landing in ocean) and there will be no science preparation. As this expert summarizes, the highlight of your life is behind you, so how motivated will you be? Another expert noted that boredom was a big problem in a long-duration simulation, where days were very routine and nothing new happened, particularly during the second half of the simulation. The expert likened it to being a prisoner.

Finally one of the experts suggested that procrastination might also be a problem. Because of the length of the transit and the relative lack of work, crews might feel no sense of urgency. For example, even if the crew knows they have to land and have to study the terrain, they may be

tempted to do it later. In addition, there might be a sense of "I've already done/studied" this, which will impact motivational states. Furthermore, given the long timelines, this expert suggested that everything will seem so much less urgent, thereby impacting day-to-day motivation. This expert suggested that additional simulation training will feel like busywork, also impacting the motivation to engage in it.

Type of work. In addition to concerns about a relative lack of work, virtually all of the experts commented on the type of work being done as a team motivation challenge. The key recurring question was, "will there be enough meaningful work?" As noted by one expert, crews on the ISS are much more functional when they are given a full day of "meaningful work" rather than "mundane work" (mundane work is much less interesting and more frustrating). As one might expect, meaningful work is far more motivational than mundane work. Another expert suggested that astronauts are motivated by spaceflight, the attention they get, and the achievement of being an astronaut. This motivation changes if there is no motivating work. A number of experts suggested that astronauts consider research to be highly meaningful work. In other words, if there is a complicated research activity that is focused on doing something unique, motivation is high and crews are fulfilled. Yet, according to another expert, crews are unlikely to do ground-breaking science on a Mars mission. This expert suggested that they would not be able to improve on the micro gravity science already being done in the ISS, but did acknowledge that they might be able to improve the human science.

Literature Review Results

Although there has been a considerable amount of research conducted on the negative impact of role overload or excessive workload, relatively little research has explored the impact of role underload or too little workload (Shultz, Wang, & Olson, 2010). In the interviews, the experts described what Fisher (1993) has termed "quantitative underload," which reflects the situation where individuals have nothing to do. Unfortunately, this aspect of boredom has not been studied in the work design or team literatures (Fisher, 1993). The consequences of boredom, however, has been identified, with Grose (1989) recounting a particularly salient incident where an airliner flying from the East Coast overflew its destination in Los Angeles. "The three-man crew of this major air carrier did not respond to radio communications until they had flown about 100 miles westward over the Pacific Ocean. Were they too busy? No, all three were asleep!" (Grose, 1989, p. 24).

In long-duration mission contexts, however, the impact of having too little to do has long been recognized. For example, Binsted et al. (2010) summarized human factors research conducted during a simulated four-month Mars mission on Devon Island. Most relevant to the current review concerns the motivational implications of such an analog, suggesting that, "…it is impossible for participants in HF [Human Factors] studies to maintain motivation in make-work over the long term" (Binsted et al., 2010, p. 997). This supports the view of the expert interviews, which suggests that work on any long-duration mission must be meaningful. As

Binsted et al. (2010, p. 1003) conclude, "No crew can fake motivation or play-act over the long-term. The work must be real, and genuinely important to the crew members."

Similarly, Allner and Rygalov (2008, p. 1967) noted that in the Lewis and Clark Expedition, in order to maintain high levels of morale and motivation, the crew was, "required to work on meaningful tasks daily, or whenever possible. Both Connors et al. (2005) and Stuster (1996) have identified this critical need for meaningful tasks inflight in helping to combat monotony, boredom, and possible depression associated with remote and confined environments."

Finally, Rohrer (1961) has described three time-dependent stages of reactions in Antarctic and submarine missions. Key for team motivation is the depression and boredom that has been found to arise during a long monotonous middle phase. This phenomenon has also been found during long-duration Russian space missions, "where a syndrome called asthenia has been described (frequently during the middle phase) which consists of irritability, dysphoria, hypoactivity, tiredness, sleep problems, poor appetite, and low energy" (Kanas et al., 2000, p. 648). This becomes critical because many of these factors have direct implications for team motivation in terms of direction, intensity, and persistence of crew member actions.

Potential Solutions

Given the two workload challenges identified (amount and type of work), a number of different strategies are possible. These are discussed separately.

Amount of work. As noted earlier, a key challenge for long-duration spaceflight missions is a distinct lack of work during the lengthy transit phases. The boredom that can result from such quantitative underload has negative motivational implications. As one expert noted, you need to give crews a balance of things to do, because if you fail to keep them busy, there are potential motivational problems. Yet, according to another of the interviewed experts, mission designers have not taken into account what to do during downtime. There seems to be at least three distinct strategies associated with ensuring there is enough work. First, en route to the destination crews can prepare for arrival. This could include any number of purposeful activities, including exercise, simulator training for landing, familiarization training on destination terrain, and computer simulation of operations on planet. Yet, as one expert noted, "you can only get so many lessons" on a given aspect of the mission, piece of software, or technology. In addition, these activities are generally not available on the trip back where there will be larger issues with boredom and isolation. Second, crew members could engage in personally relevant development. This could include learning a language, earning a degree, writing a book, receiving training (from another crew member) in another occupation, or many other developmental activities. The key would be for each crew member to set a goal around what to learn about during the mission. Third, crew members could bring any number of entertainment and leisure options. This could include video games, books, movies, or any other form of entertainment that would fit within the space and mass constraints likely to be present. As Allner and Rygalov (2008, p. 1967) note,

"We need to be careful not to underestimate the importance of having a variety of recreational opportunities for astronauts on a long sojourn to Mars."

Type of work. In addition to not having enough work, a key challenge revolves around how do you keep crews motivated and interested in the work that they are doing? Virtually every source (experts, literature review) identifies the importance of meaningful work as a solution to boredom and isolation. Yet, the experts also suggested that you cannot fool crews into thinking that "make-work" or "busywork" is meaningful. Because astronauts are high-intensity individuals, it is a significant risk to not have meaningful work for them. One solution is to invite crews into the planning process by having them describe what they would find meaningful. This could be seen as an early instantiation of crew autonomy. Given that there are more researchers and scientists than pilots among the astronaut ranks, they might have some good ideas about how to create meaningful work.

Another way to consider this issue is to understand what makes work meaningful. Traditionally, the focus has been on the tasks themselves. This would include the extent to which there is variety in the tasks performed, crew members are able to perform a whole piece of work from beginning to end, a variety of skills are used in the performance of the tasks, and the extent to which tasks can be performed autonomously. Yet, there are two other facets of meaningful work that are less frequently considered. First, the significance of the work for the self and others can play an important motivational role. Understanding how work can benefit others has been shown to be a powerful motivational force (Grant, 2008). Second, the social environment of work can also have positive motivational effects. This includes receiving feedback from others, working interdependently, and building in opportunities for social support, all of which are shown to be related to internal work motivation (Humphrey et al., 2007). Some of these social features will be naturally present because of the interdependent crew structure, but there are always opportunities to focus and enhance these features in order to bolster motivation.

Crew Motivational Challenge #5:
Team Composition and Individual Differences

Expert Interview Results

The final challenge identified by the experts revolved around the composition of the crew and what individual characteristics are needed to maintain high levels of team motivation.

The experts had a variety of thoughts about the individual differences needed to maintain motivation throughout a long-duration mission. These individual differences appear to reflect factors that are important for three different reasons. The first set of individual differences is important for the demands of the tasks crews will face. This included having crew members who can tolerate boredom (as describe earlier); those who are motivated by the mission structure; those who are interested in and motivated by doing good science; and those who are calm and levelheaded in emergencies.

The second set of individual differences is important for crew interaction and morale. This included having crew members who are motivated by a higher goal or purpose, those who are selfless; those who are self-aware and aware of their impact on others; those who work well with others and are emotionally and physically supportive; those who are flexible and willing to give and take; those who negotiate to win-win; those who can get along; those who have a good sense of humor and like to talk and laugh; those who enjoy life no matter the situation and are able to enjoy the moment; and those who are enablers of others. Interestingly, one expert noted that although NASA looks for a lot of different things, it is not clear that they take into consideration what is best for crew interaction. Of course, this is a potential problem if a crew is on a long-duration mission where there is no possibility for periodic replacement of members.

The third set of individual differences is important for crew adaptation as conditions might change. This included having crew members who make the best of any situation they are in; those who are comfortable in an environment where they are dependent on their own resources and pooling together their resources; those who are free-thinking enough to identify things to do; those who take a big picture in mind; and those who are stress-resilient.

In addition to these characteristics thought to be important for motivational maintenance, the experts also identified a handful of characteristics that should not be present among crew members. One expert noted that although astronauts are often quite brilliant, some do not interact very well with others. This expert was concerned about having them on a long-duration mission. Another expert noted that most current astronauts are “Type A” personality, which is necessary for 6-month ISS missions. For longer duration missions, however, this expert suggested that a “Type A” personality would not be helpful. In a similar vein, at least two experts noted that you would not want a narcissistic or egocentric person on a long-duration mission. Finally, one expert commented on the need for crews to have a mix of personalities in order to create a more harmonious group interaction.

Literature Review Results

The bulk of the research literature focuses on those individual characteristics that lead to enhanced job performance. There is a smaller body of research that has identified those personality characteristics that are linked to motivational states. There are, however, four studies that have potential relevance for understanding team motivation. In an early study of naval personnel, Broedling (1975) found that those with an internal locus of control (i.e., who feel in control of the things which happen) are more motivated to work than those with an external locus of control (i.e., who feel that life events are largely beyond their control), perform at higher levels, and see hard work as more instrumental in obtaining what they want.

Chen and colleagues conducted two studies that link individual differences to two different motivational states. In the first, Wallace and Chen (2006) found that conscientiousness (the motivationally oriented Big 5 factor) is related to motivational regulatory strategies of facilities maintenance workers, and those regulatory strategies (promotion and prevention focus) mediate the relationship between conscientiousness and different forms of performance. In the second, Chen, Farh, Campbell-Bush, Wu, and Wu (2013) found that research and development team member proactive personality, which is an individual tendency to promote change and take action to influence the environment, was positively related to role-breadth self-efficacy and intrinsic motivation, and these individual motivational states mediated the relationship between proactive personality and individual innovative performance.

Finally, Cole, Bruch, and Vogel (2012, p. 447) defined the new collective construct of "productive energy" as "the shared experience and demonstration of positive affect, cognitive arousal, and agentic behavior among unit members in their joint pursuit of organizationally salient objectives." This construct is thought to emerge from individual-level energy attributes via mutual dependence and individual interaction. Although an emergent collective phenomena, the individual-level components of productive energy might be important individual differences that contribute to crew motivation.

The subject of individual differences also has been examined in spaceflight analog contexts. Ursin et al. (1992, p. 305) made the observation that, "The commonality between the ideal personality traits for a short and long term mission is very narrow." This suggest that the "right stuff" for shorter duration missions is not necessarily appropriate for longer duration missions. They also suggested that long-duration crew members should have the, "social ability to provide and receive "group support" as well as social adaptability" and that, "To ensure the autonomy of the crew, high levels of skill and knowledge must be present in the crew. The trouble shooting capacity of the crew must be maximum [sic]" (Ursin et al., 1992, p. 307).

Kanas et al. (2011) found some differences in reactions to low versus high autonomy conditions in a 105-day simulation for Russian and European participants. This suggests some potential cultural differences in reactions to low versus high autonomy. As they reported, "…during the

high autonomy period, the four Russian crew members scored modestly higher in work planning freedom, work performance efficiency, and work performance accuracy. During high autonomy the two European crew members scored higher in negative emotions and awareness of autonomy, but lower in direction from the crew commander and in work performance efficiency and accuracy" (Kanas et al., 2011, p. 243). Although based on a small sample with a number of potential alternative explanations, these cultural differences might have implications for the composition of the crews and how different preferences for autonomy might impact crew motivation.

Finally, Sandal, Vaernes, Bergan, Warncke, and Ursin (1996) examined psychological predictors of adaption in three different analog settings. Sixty-seven subjects participated in the study, with 18 in experimental hyperbaric chambers isolation studies, 15 in polar crossings, and 34 stationed in the Arctic. Although there was fairly little variance in personality profiles for some of the groups, for crews in the hyperbaric chambers, Sandal et al. (1996) reported that the "right stuff" profile (i.e., those who have high scores on both instrumental and expressive traits) had higher well-being and lower anxiety in the first quarter of the isolation. They further suggested that strong expressive traits are the most important because they are, "probably associated with ability to give and receive social support, which may counteract the negative effects of stress" (Sandal et al., 1996, p. 232).

Potential Solutions

As this review shows, unfortunately there is limited research on what individual differences are linked to or produce stronger motivation in a team. This suggests that additional research is needed to identify those crew member competencies that are important for motivation in long-duration settings. In addition, I could find no studies that considered team composition issues and how team composition might relate to team motivation. In other words, it is simply not known what mix of competencies and individual differences are needed in a small crew in order to maintain high levels of motivation over an extended period. Future research is sorely needed to address these fundamental questions team composition issues.

Summary and Suggestions for Future Research

As this review shows, there are a number of crew motivational challenges in long-duration spaceflight contexts. The combination of spaceflight expert interviews and review of the psychological and spaceflight research literatures has yielded a number of important insights about crew motivation and how to address many of the potential challenges. In this final section, I offer some overall suggestions for future research. In some cases the suggestion focuses on a specific CMC and in other cases it is an overarching call for research.

Somewhat surprisingly, there is a comparatively small empirical database focused on team motivation issues in long-duration spaceflight or analogous contexts. Of course, there is a fairly large literature on teams, but more often than not the focus is on affective (e.g., satisfaction) or behavioral (e.g., performance) outcomes, not the motivational states of interest in the current effort. When team motivational issues are addressed, they are often in contexts that are not necessarily comparable to the kind of isolated, confined, and extreme context that characterizes long-duration spaceflight. Thus, my first suggestion for future research is to conduct more team-level research on the motivational issues that might arise during long-duration spaceflight. Given the specificity of this context, however, it is likely that this research will need to be commissioned rather than occur naturally.

In addition to the relatively small empirical database, the research conducted in long-duration contexts that does exist consists primarily of case studies or small samples. It is understandable why this would be the case, but this does not change the fact that it is difficult to develop strong evidence about the team motivation phenomena. Larger samples are needed to support inferential statistical testing and wider generalizations.

Additional research needs to be conducted on the specific forms of autonomy that are feasible given the mission constraints associated with long-duration spaceflight. The interview experts and research literature were very consistent in highlighting the need for and benefits of additional crew autonomy. Yet, it is not clear how crew autonomy can be operationalized given the technical and cultural constraints that will exist. In addition, research on how to address the cultural issues within NASA that might prevent or undermine crew autonomy is needed. This would include an analysis of the formal and informal systems that would need to be changed to accommodate additional crew autonomy.

The issue of quantitative underload (i.e., simply not enough tasks to perform) is a large threat to crew motivation. The provision of meaningful work appears to be a way to minimize the problems associated with this kind of boredom. Yet, it is not entirely clear how to provide enough meaningful work to address this challenge. Thus, future research should explore the range of ways meaningful work might be created and implemented over the course of a long-duration mission. As discussed earlier, there are a number of ways in which work can become

meaningful, so any future research should adopt an expansive and inclusive conceptualization in an effort to combat the boredom that is likely to be present.

Finally, additional research should be conducted on team composition and individual differences. The selection and assignment of the crew represents perhaps the most important non-technical facet of any long-duration mission. Although there are host of important factors to consider, selecting individual crew members who are likely to be (and remain) highly motivated should be high on the list of important crew member characteristics. Perhaps as important is the relative mix of members who will avoid the motivation losses so often observed in team settings. Despite its importance, we know relatively little about these composition and individual difference factors. Future research aimed at addressing these gaps should be a high priority.

References

Albanese, R., & Van Fleet, D. D. (1985). Rational behavior in groups: The free-riding tendency. *Academy of Management Review, 10,* 244-255.

Allner, M., & Rygalov, V. (2008). Group dynamics in a long-term blind endeavor on Earth: An analog for space missions (Lewis & Clark expedition group dynamic analysis). *Advances in Space Research, 42,* 1957-1970.

Banker, R. D., Field, J. M., Schroeder, R. G., & Sinha, K. K. (1996). Impact of work teams on manufacturing performance: A longitudinal field study. *Academy of Management Journal, 39,* 867-890.

Barker, J. R. (1993). Tightening the iron cage: Concertive control in self-managing teams. *Administrative Science Quarterly, 38,* 408-437.

Binsted, K., Kobrick, R. L., Griofa, M. O., Bishop, S., & Lapierre, J. (2010). Human factors research as part of a Mars exploration analogue mission on Devon Island. *Planetary and Space Science, 58,* 994-1006.

Breaugh, J. A. (1985). The measurement of work autonomy. *Human Relations, 38,* 551–570.

Breaugh, J. A. (2013). Employee recruitment. *Annual Review of Psychology, 64,* 389-416.

Broedling, L. A. (1975). Relationship of internal-external control to work motivation and performance in an expectancy model. *Journal of Applied Psychology, 60,* 65-70.

Bucklow, M. (1966). A new role for the work group. *Administrative Science Quarterly, 11,* 59-78.

Campion, M. A., & Thayer, P. W. (1985). Development and field evaluation of an interdisciplinary measure of job design. *Journal of Applied Psychology, 70,* 29-43.

Chen, G., Farh, J.-L., Campbell-Bush, E. M., Wu, Z., & Wu, X. (2013). Teams as innovative systems: Multilevel motivational antecedents of innovation in R&D teams. *Journal of Applied Psychology, 98,* 1018-1027.

Chen, G., & Gogus, C. I. (2008). Motivation in and of work teams: A multilevel perspective. In R. Kanfer, G. Chen, & R. D. Pritchard (Eds.), *Work motivation: Past, present, and future* (pp. 285-317). New York, NY: Routledge.

Chen, G., & Kanfer, R. (2006). Toward a systems theory of motivated behavior in work teams. *Research in Organizational Behavior, 27,* 223-267.

Cherns, A. (1978). The principles of sociotechnical design. *Human Relations, 29,* 783-792.

Cohen, S. G., Ledford, G. E., Jr. (1994). The effectiveness of self-managing teams: A quasi-experiment. *Human Relations, 47,* 13-43.

Cole, M. S., Bruch, H., & Vogel, B. (2012). Energy at work: A measurement validation and linkage to unit effectiveness. *Journal of Organizational Behavior, 33,* 445-467.

Compton, W. D. (1989). *Where no man has gone before: A history of Apollo lunar exploration missions*. Washington, DC: NASA.

Connors, M. M., Harrison, A. A., & Akins, F. R. (2005). *Living aloft: Human requirements for extended spaceflight*. Washington, DC: NASA.

De La Torre, G. G., van Baarsen, B., Ferlazzo, F., Kanas, N., Weiss, K., Schneider, S., & Whiteley, I. (2012). Future perspectives on space psychology: Recommendations on psychosocial and neurobehavioural aspects of human spaceflight. *Acta Astronautica, 81,* 587-599.

Edmonds, W. A., Tenenbaum, G., Kamata, A., & Johnson, M. B. (2009). The role of collective efficacy in adventure racing teams. *Small Group Research, 40,* 163-180.

Edmondson, A. C., Bohmer, R. M., & Pisano, G. P. (2001). Disrupted routines: Team learning and new technology implementation in hospitals. *Administrative Science Quarterly, 46,* 685-716.

Ericksen, J., & Dyer, L. (2004). Right from the start: Exploring the effects of early team events on subsequent project team development and performance. *Administrative Science Quarterly, 49,* 438-471.

Fisher, C.D. (1993). Boredom at work: A neglected topic. *Human Relations, 46,* 395–417.

Grant, A. M. (2008). The significance of task significance: Job performance effects, relational mechanisms, and boundary conditions. *Journal of Applied Psychology, 93,* 108-124.

Grose, V. L. (1989). Coping with boredom in the cockpit before it's too late. *Professional Safety, 34,* 24-26.

Humphrey, S. E., Nahrgang, J. D., & Morgeson, F. P. (2007). Integrating motivational, social, and contextual work design features: A meta-analytic summary and theoretical extension of the work design literature. *Journal of Applied Psychology, 92,* 1332-1356.

Ilgen, D. R. (2014). Work team motivation: Progress and perils. In J. K. Ford, J. R. Hollenbeck, & A. M. Ryan (Eds.), *The nature of work: Advances in psychological theory, methods, and practice* (pp. 51-67). Washington, DC: American Psychological Association.

Janz, B. D., Colquitt, J. A., & Noe, R. A. (1997). Knowledge worker team effectiveness: The role of autonomy, interdependence, team development, and contextual support variables. *Personnel Psychology, 50,* 877-904.

Kanas, N. (1985). Psychological factors affecting simulated and actual space missions. *Aviation, Space, and Environmental Medicine, 56,* 806-811.

Kanas, N., Harris, M., Neylan, T., Boyd, J., Weiss, D. S., Cook, C., & Saylor, S. (2011). High versus low crewmember autonomy during a 105-day Mars simulation mission. *Acta Astronautica, 69,* 240-244.

Kanas, N., Salnitskiy, V., Grund, E. M., Gushin, V., Weiss, D. S., Kozerenko, O., Sled, A., & Marmar, C. R. (2000). Social and cultural issues during shuttle/MIR space missions. *Acta Astronautica, 47,* 647-655.

Kanas, N., Sandal, G., Boyd, J. E., Gushin, V. I., Manzey, D., North, R, . . . Wang, J. (2009). Psychology and culture during long-duration space missions. *Acta Astronautica, 64,* 659-677.

Kidwell, R. E., & Bennett, N. (1993). Employee propensity to withhold effort: A conceptual model to intersect three avenues of research. *Academy of Management Review, 18,* 429-456.

Kinsey, J. L. (1959). Psychological aspects of the "Nautilus" transpolar cruise. *United States Armed Forces Medical Journal, 10,* 451-462.

Kozlowski, S. W. J., & Ilgen, D. R. (2006). Enhancing the effectiveness of work groups and teams. *Psychological Science in the Public Interest, 7,* 77-124.

Latané, B., Williams, K., & Harkins, S. (1979). Many hands make light the work: The causes and consequences of social loafing. *Journal of Personality and Social Psychology, 37,* 822-832.

LePine, J. A., Piccolo, R. F., Jackson, C. L., Mathieu, J. E., & Saul, J. R. (2008). A meta-analysis of teamwork processes: Tests of a multidimensional model and relationships with team effectiveness criteria. *Personnel Psychology, 61,* 273-307.

Lewin, K. (1948). *Resolving social conflict*. New York, NY: Harper.

Lim, D. S. S., Warman, G. L., Gernhardt, M. L., McKay, C. P., Fong, T., Marinova, M. M., . . . Williams, D. (2010). Scientific field training for human planetary exploration. *Planetary and Space Science, 58,* 920-930.

Morgeson, F. P., & Campion, M. A. (2003). Work design. In W. C. Borman, D. R. Ilgen, & R. J. Klimoski (Eds.), *Handbook of psychology: Industrial and organizational psychology* (Vol. 12, pp. 423-452). Hoboken, NJ: John Wiley & Sons.

Morgeson, F. P., DeRue, D. S., & Karam, E. P. (2010). Leadership in teams: A functional approach to understanding leadership structures and processes. *Journal of Management, 36,* 5-39.

Morgeson, F. P., & Humphrey, S. E. (2006). The Work Design Questionnaire (WDQ): Developing and validating a comprehensive measure for assessing job design and the nature of work. *Journal of Applied Psychology, 91,* 1321-1339.

Morse, N. C., & Reimer, E. (1956). The experimental change of a major organizational variable. *Journal of Abnormal and Social Psychology, 52,* 120-129.

Official Naval Special Warfare Website. (2014). *Navy Seals Frequently Asked Questions*. Retrieved from http://www.sealswcc.com/navy-seals-frequently-asked-questions-faq.html

Rohrer, J. H. (1961). Interpersonal relationships in isolated small groups. In B. E. Flaherty (Ed.), *Psychophysiological aspects of space flight* (pp. 263-271). New York, NY: Columbia University Press.

Salas, E., Diaz-Granados, D., Klein, C., Burke, C. S., Stagl, K. C., Goodwin, G. F., & Halpin, S. M. (2008). Does team training improve team performance? A meta-analysis. *Human Factors, 50,* 903-933.

Sandal, G. M., Vaernes, R., Bergan, T., Warncke, M., & Ursin, H. (1996). Psychological reactions during polar expeditions and isolation in hyperbaric chambers. *Aviation, Space, and Environmental Medicine, 67,* 227-234.

Shepperd, J. A. (1993). Productivity loss in performance groups: A motivation analysis. *Psychological Bulletin, 113,* 67-81.

Shultz, K. S., Wang, M., & Olson, D. A. (2010). Role overload and underload in relation to occupational stress and health. *Stress and Health, 26, 99-111.*

Steiner, I. D. (1972). *Group processes and productivity*. New York: Academic Press.

Stewart, G. L., Courtright, S. H., & Barrick, M. R. (2012). Peer-based control in self-managing teams: Linking rational and normative influence with individual and group performance. *Journal of Applied Psychology, 97,* 435-447.

Stuster, J. (1996). *Bold endeavors: Lessons from polar and space exploration*. Annapolis, MD: Naval Institute Press.

Suedfeld, P. (2010). Historical space psychology: Early terrestrial explorations as Mars analogues. *Planetary and Space Science, 58,* 639-645.

Trist, E. L., & Bamforth, K. W. (1951). Some social and psychological consequences of the longwall method of coal-getting: An examination of the psychological situation and defences of a work group in relation to the social structure and technological content of the work system. *Human Relations, 4,* 3-38.

Ursin, H., Comet, B., & Soulez-Lariviere, C. (1992). An attempt to determine the ideal psychological profiles for crews of long term space missions. *Advances in Space Research, 12,* 301-314.

van Dick, R., Tissington, P. A., & Hertel, G. (2009). Do many hands make light work? How to overcome social loafing and gain motivation in work teams. *European Business Review, 21,* 233-245.

Wall, T. D., Jackson, P. R., & Davids, K. (1992). Operator work design and robotics system performance: A serendipitous field study. *Journal of Applied Psychology, 77,* 353-362.

Wall, T. D., Jackson, P. R., & Mullarkey, S. (1995). Further evidence on some new measures of job control, cognitive demand and production responsibility. *Journal of Organizational Behavior, 16,* 431-455.

Wallace, C., & Chen, G. (2006). A multilevel integration of personality, climate, self-regulation, and performance. *Personnel Psychology, 59,* 529-557.

Weybrew, B. B. (1957). *Psychological and psychophysiological effects of long periods of submergence: Analysis of data collected during a 265-hour, completely submerged, habitability cruise made by the U.S.S. Nautilus* (Naval Medical Research Laboratory Report No. 281). Groton, CT: Naval Medical Research Laboratory.

Weybrew, B. B. (1961). The impact of isolation upon personnel. *Journal of Occupational Medicine, 3,* 290-294.

Williamson, M.-C., Hipkin, V., Lebeuf, M., & Berinstain, A. (October, 2007). *Exploration architecture validation through analogue missions – A Canadian perspective*. Poster presented at the Lunar Exploration Analysis Group Annual Meeting, Houston, TX.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

1. AGENCY USE ONLY *(Leave Blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	August 2015	Technical Memorandum

4. TITLE AND SUBTITLE
Issues in Maintaining Team Motivation over Long-Duration Exploration Missions

5. FUNDING NUMBERS

6. AUTHOR(S)
Frederick P. Morgeson, Ph.D.

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Lyndon B. Johnson Space Center
Houston, Texas 77058

8. PERFORMING ORGANIZATION REPORT NUMBERS
S-1201

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
National Aeronautics and Space Administration
Washington, DC 20546-0001

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
TM-2015-218586

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Unclassified/Unlimited
Available from the NASA Center for AeroSpace Information (CASI)
7115 Standard
Hanover, MD 21076-1320 Category: 53

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*
This review was commissioned by the Behavioral Health and Performance Research Element (BHP-R) of the NASA Human Research Program (HRP) in order to review the issues that might arise in maintaining team (crew) motivation over long durations. The team and spaceflight literatures were reviewed and ten interviews were conducted with a variety of spaceflight experts. This review is organized by the five distinctive crew motivational challenges (CMCs) that were identified in the interviews, including (1) the presence of motivational challenges, (2) mission preparation, (3) crew autonomy, (4) workload, and (5) team composition and individual differences. For each of the CMCs, the results of the expert interviews are provided, followed by the results of the literature review. Each section concludes with potential solutions to the CMCs identified. The report concludes with a summary of the results and suggestions for future research.

14. SUBJECT TERMS	15. NUMBER OF PAGES	16. PRICE CODE
teams; motivation; long duration space flight; preparation; autonomy; workloads	46	

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	Unlimited