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Critical Team Composition Issues for Long-Distance and Long-Duration Space Exploration

A Literature Review, an Operational Assessment, and Recommendations for Practice and Research

Suzanne T. Bell
Shanique G. Brown
Neal B. Outland
Daniel R. Abben

Correspondence should be directed to Suzanne T. Bell, Department of Psychology, DePaul University, 2219 N Kenmore Ave, Chicago, IL 60614, USA; (t) 773.325.4246, SBELL11@depaul.edu

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Johnson Space Center
Houston, Texas 77058

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It is good that we have this kind of relationship.
This mission is so easy, since we are of like personality and thought.[1]

Introduction

Prevailing team effectiveness models suggest that teams are best positioned for success when certain enabling conditions are in place (Hackman, 1987; Hackman, 2012; Mathieu, Maynard, Rapp, & Gilson, 2008; Wageman, Hackman, & Lehman, 2005). Team composition, or the configuration of member attributes, is an enabling structure key to fostering competent teamwork (Hackman, 2002; Wageman et al., 2005). A vast body of research supports the importance of team composition in team design (Bell, 2007). For example, team composition is empirically linked to outcomes such as cooperation (Eby & Dobbins, 1997), social integration (Harrison, Price, Gavin, & Florey, 2002), shared cognition (Fisher, Bell, Dierdorff, & Belohlav, 2012), information sharing (Randall, Resick, & DeChurch, 2011), adaptability (LePine, 2005), and team performance (e.g., Bell, 2007). As such, NASA has identified team composition as a potentially powerful means for mitigating the risk of performance decrements due to inadequate crew cooperation, coordination, communication, and psychosocial adaptation in future space exploration missions.

Much of what is known about effective team composition is drawn from research conducted in conventional workplaces (e.g., corporate offices, production plants). Quantitative reviews of the team composition literature (e.g., Bell, 2007; Bell, Villado, Lukasik, Belau, & Briggs, 2011) are based primarily on traditional teams. Less is known about how composition affects teams operating in extreme environments such as those that will be experienced by crews of future space exploration missions. For example, long-distance and long-duration space exploration (LDSE) crews are expected to live and work in isolated and confined environments (ICEs) for up to 30 months. Crews will also experience communication time delays from mission control, which will require crews to work more autonomously (see Appendix A for more detailed information regarding the LDSE context).

Given the unique context within which LDSE crews will operate, NASA identified both a gap in knowledge related to the effective composition of autonomous, LDSE crews, and the need to identify psychological and psychosocial factors, measures, and combinations thereof that can be used to compose highly effective crews (Team Gap 8). As an initial step to address Team Gap 8, we conducted a focused literature review and operational assessment related to team composition issues for LDSE. The objectives of our research were to:

(1) identify critical team composition issues and their effects on team functioning in LDSE-analogous environments with a focus on key composition factors that will most likely have the strongest influence on team performance and well-being, and

[1] Astronaut diary entry in regards to group interaction aboard the ISS (p.22; Stuster, 2010)

(2) identify and evaluate methods used to compose teams with a focus on methods used in analogous environments.

The remainder of the report includes the following components: (a) literature review methodology, (b) review of team composition theory and research, (c) methods for composing teams, (d) operational assessment results, and (e) recommendations.

Literature Review

Literature Search

We conducted a thorough literature search to obtain studies focused on team composition in LDSE-analogue environments. Our primary focus was on Earth-based analogues, such as space simulations in hyperbaric chambers (e.g., MARS-105), Antarctic teams, and polar expeditions, where the crews were in an ICE for long periods of time. These analogue environments are thought to mimic somewhat the realities of LDSEs and are often used to help identify important issues for long-duration space flight (Palinkas, Gunderson, Johnson, & Holland, 2000).

When generalizing from analogues, it is important to note the differences between Earth-based analogues and space flight. In terms of context, for example, space teams may experience monotony during low-workload periods, whereas Antarctic teams often have to cope with changing conditions more frequently (Lebedev, 1998). Further, different analogue environments (e.g., hyperbaric chambers, polar expeditions) elicit varying levels of psychological reactions, such as anxiety (Sandal, 2000). Even so, analogue environments provide a closer approximation to the unique LDSE context. Research in analogue environments can be used to identify team composition factors of interest for LDSE, and reveal basic principles of individual and team functioning that allow for a more informed generalization process of research conducted in traditional settings.

To begin, we searched 72 databases across multiple disciplines. A full list of the databases searched and keywords used are listed in Appendix B. In addition, the websites of the major space agencies were reviewed and, when identified, space agency databases (e.g., NASA technical report repository) were searched for reports related to crew selection, staffing, and composition. Several specific journals were also searched (see Appendix C for a full list of specific journals searched). Further, once identified, the reference lists of literature reviews on team composition in space flight or analogue environments (e.g., Kanas, 1998; Palinkas, Keeton, Shea, & Leveton, 2011) were reviewed to identify additional sources. Specific simulations (e.g., EXMSEI, ISEXMI, MARS-500) were also used as search terms. Finally, several researchers who have published frequently in areas related to team composition in space flight or space analogues (e.g., Vinokhodova, Kanas, Sandal, Bishop, Leon) were contacted regarding in-press and unpublished work that could lend insight into the topic.

Based on an initial review of article abstracts, more than 400 articles were obtained and reviewed further. We focused on articles that provided data from studies conducted in LDSE analogue environments, space simulations, or from actual space flights, and that examined some aspect of team composition, team member compatibility, or strategies or methods for composing teams in such environments. Of the 400 articles that we reviewed, 24 reported information about the relationship between some aspect of team composition and an outcome (e.g., performance, deviance, subgroup formation). Although we were intentionally inclusive of the articles that we reviewed, we did not formally review articles that looked at the relationships between team members' individual differences and individual-level outcomes. Such articles are the subject of other individual crewmember-focused NASA reports (e.g., Palinkas et al., 2011), as well as IRP Team Gap 4. Similarly, we did not formally review articles that provided only anecdotal information. Many of these articles, however, are cited in narrative parts of the technical report. A summary of the articles that reported data on team composition effects in space or analogue environments is provided in an Excel spreadsheet (attached or available from the first author). We relied more heavily on these articles for our review; throughout this report, we describe research conducted on teams from non-LDSE analogues as teams in "traditional" settings.

Articles were coded on the following categories: fidelity, study design, team composition variable, team composition operationalization, outcome, and observed effect. Fidelity ratings help to communicate the extent to which analogue research can be confidently applied to LDSE (Palinkas et al., 2011). Similar to Palinkas et al. (2011), we rated the degree of similarity between each study's characteristics and the projected characteristics of LDSE missions. Specifically, we assessed the studies' similarity to space flight, expected characteristics of LDSE astronauts, mission duration, and crew size (see Table 1). We also reviewed information about additional contextual features that might impact team functioning in LDSE, including the presence of periods of high and low workload, whether the crew was supported by a larger team (e.g., mission control), and the level of crew autonomy. Because this information was reported less consistently, however, it was not included in the fidelity score.

Table 1.
Fidelity scoring system from Palinkas et al. (2011)

Fidelity Category	**Coding and score**
Similarity to space flight	Analogue setting (e.g., polar, undersea) (1)
	Space simulation (2)
	Space flight (3)
Similarity of participants to long-duration expedition astronauts	Similar age (average age of 30+), but not gender, education, or cultural diversity (1)
	Similar age (30+) and education (at least college degree), but not gender and cultural diversity (2)
	Similar age (30+), education (college +), gender (mixed or all male) and possibly cultural diversity (3)
Duration of mission	30 days or less (1)
	31 to 365 days (2)
	365+ days (3)
Crew Size	Large (16+) crews (1)
	Moderately small (9 -15) crews (2)
	Small (1-8) crews (3)

Study design was coded as: (a) descriptive, (b) correlational, (c) quasi-experimental, and (d) experimental. For each study, the composition variable and team-level operationalization was noted, as were any observed effects. We included relatively enduring composition variables, such as personality traits, values, demographics, and interests. We also included team size as a composition variable, but we did not include crewmember transient states (e.g., mood). We were inclusive in terms of outcomes; as long as a team composition effect was investigated, we reviewed the relationship between team composition and the reported outcome.

Similarity of Reviewed Studies to Expected Characteristics of LDSE

Fifty-eight percent of the coded articles (n = 14) reported data collected in analogue environments (e.g., Antarctic research stations, polar, Greenland), 38% (n = 9) reported data from space simulations (e.g., EXSEMI, Mars-105), and one article reported data across both space flight and analogue environments (4%, n = 1). Overall, fidelity ratings can range from 4 to 12. Fidelity ratings of the crew composition studies included in our review (mean = 8.38; range = 6–10) suggest that, on average, study environments were moderately similar to LDSE.

We assessed the similarity between study participants and astronauts expected for LSDE in terms of age, gender, education, and cultural background. The majority of studies collected data using samples that were somewhat similar to those expected in LDSEs. The exception was experimental studies (e.g., Altman & Haythorn, 1967) that examined composition in controlled, ICE settings. These studies tended to include younger and more homogenous participants than the studies conducted in other contexts. For the most part, participants in the analogue studies were confined for only a fraction of the 30 months expected for Mars missions (DRM Summary, 2013). In only a few of the studies were participants in isolation for 1 year or more (Doll & Gunderson, 1971; Gunderson & Ryman, 1967; Gunderson, 1968; Nelson, 1964). Finally, we assessed fidelity in terms of team size. The planned crew size for a Mars mission is currently 6 people (DRM Summary, 2013). Most of the analogue studies that we reviewed had fewer than 6 crewmembers (Range = 2–196). Crew sizes in space simulations (Median = 4; Range = 3–7) were most similar to the crew sizes expected for Mars missions. A number of the studies included in our review provided information on dyads (e.g., Altman & Haythorn, 1967; Haythorn, Altman, & Meyers, 1966; Leon, Sandal, Fink, & Ciofani, 2011).

In addition to fidelity, we coded studies based on their research design. While a few of the studies included in our review were experimental (*n* = 3, Altman & Haythorn, 1967; Haythorn et al., 1966; Smith & Haythorn, 1972), most were correlational or descriptive. Predictors included a mix of surface-level characteristics (e.g., Bishop, Grobler, & SchjØll, 2001; Dudley-Rowley, 2000; Nelson, 1964; Rosnet, Jurion, Cazes, & Bachelard, 2004; Sandal, 2004) deep-level characteristics (e.g., Altman & Haythorn, 1967; Bishop et al., 2005; Haythorn et al., 1966; Leon et al., 2011), and team size (e.g., Doll & Gunderson, 1971; Gunderson, 1968a; Nelson, 1964; Smith & Haythorn, 1972). Most studies examined team members' heterogeneity on the attribute of interest. The outcome variables examined in these studies included team performance (Altman & Haythorn, 1967; Doll & Gunderson, 1971; Gunderson & Ryman, 1967; Leon & Sandal, 2003; Watters & Miller, 1971), group processes (Bishop et al., 2001; Leon & Sandal, 2003; Leon et al., 2011; Sandal, Bye, & van de Vijver, 2011; Watters & Miller, 1971), subgroup formation (Bishop et al., 2005; Sandal et al., 2011), compatibility (Doll & Gunderson, 1971; Gunderson & Ryman, 1967; Nelson, 1964), deviance (Dudley-Rowley, 2000), and stress and coping (Haythorn et al., 1966; Kjaergaard, Leon, & Fink, in press; Leon & Sandal, 2003; Smith & Haythorn, 1972).

Overview of Team Composition Research

In this section, we provide an overview of team composition research. We provide a review of the literature regarding specific attributes of interest when composing teams, as well as configurations of member attributes.

Team composition refers to the unit-level configuration of team members' attributes (Bell, 2007). Team composition is important to the extent that configurations on specific variables predict organizationally desired outcomes. To use team composition when designing teams, one must first identify both the specific attributes (e.g., personality, values, abilities, demographics) and the team-level configurations (e.g., uniformly high, heterogeneous) that predict desired outcomes (e.g., team performance, well-being). These identified attributes and configurations can then be used to establish teams that, as a unit, should be successful. When operational constraints limit the ability to design teams in this manner, knowledge of how team composition affects team functioning can be used to design organizational interventions (e.g., training, countermeasures) that can mitigate the risks associated with the team's composition.

Enduring Deep-Level and Surface-Level Characteristics

Team composition research generally focuses on team members' relatively enduring attributes, such as peoples' abilities, personalities, values, and demographics, or characteristics that are difficult to train, such as professional (e.g., functional) background. This narrow focus on enduring attributes can help identify critical composition considerations; more malleable traits and skills can be developed through the extensive training provided to astronaut candidates and crews.

Research indicates that despite the extreme environments that analogue teams face, enduring attributes such as personality and values can remain consistent (e.g., Butcher & Ryan, 1974; Sandal et al., 2011; Vinokhodova & Gushin, 2014). In one study of Antarctic explorers, for example, crewmembers' personality profiles remained consistent when tested midwinter and at the end of winter (Butcher & Ryan, 1974). Likewise, crewmember values have been found to be relatively stable during the MARS-105 simulation (except for benevolence; Sandal et al., 2011) and during ISS missions (Vinokhodova & Gushin, 2014). However, research from a polar expedition indicated changes in values for some crewmembers but not others, with a more experienced crewmember showing less change than his counterpart who had been on fewer previous expeditions (Leon et al., 2011). Basic needs (e.g., need for achievement, need for affiliation) and attitudes have also been studied as composition variables in analogue environments (e.g., Nelson, 1964). It should be noted, however, that needs and attitudes may be somewhat less enduring in space environments. For example, in one study that used publicly accessible records (i.e., diaries, interviews), a researcher found that astronauts' in-flight standings on need for affiliation and need for achievement were higher than their pre-flight standings (Brcic, 2010).

Team composition variables have been described as deep-level and surface-level variables. Enduring deep-level variables are underlying psychological characteristics thought to shape an individual's behaviors, thinking, and affect across many situations (Bell, 2007); examples include personality traits, values, and abilities. Surface-level composition variables are overt characteristics of team members that can reasonably be estimated after brief exposure to the team member; examples include age, race, education-level, and professional background (Bell, 2007; Harrison, Price, & Bell, 1998; Harrison et al., 2002). Because surface-level characteristics are easy for others to estimate, they are typically the basis for early judgments, assumptions, and stereotypes.

In general, research conducted on traditional teams indicates that deep-level composition variables, as compared to surface-level composition variables, have a stronger and longer-lasting influence on team performance (Bell, 2007; Bell et al., 2011). Similarly, research consistently shows that the effect of surface-level differences, such as sex, age, and race, on team processes (e.g., group cohesion, conflict) diminish over time, whereas the influence of deep-level differences, such as personality, values, and attitudinal differences, increase over time (Harrison et al., 1998; Harrison et al., 2002; Mohammed & Angell, 2004; Pelled, Eisenhardt, & Xin, 1999). As team members collaborate over time, they have more opportunity for interpersonal exchange and to observe other team members' behaviors (Gruenfeld, Mannix, Williams, & Neale, 1996). These exchanges allow the stereotypes and assumptions associated with surface-level differences to become less important. At the same time, deeper-level differences between team members begin to have a greater impact on social integration and performance (Harrison et al., 2002).

Research conducted in analogue environments supports the increased importance of deep-level differences over time (e.g., Kraft et al., 2002; Sandal et al., 2011). Contrary to the diminished effect observed for surface-level variables in traditional teams, however, research in analogue environments suggests that surface-level composition variables can maintain their influence on team functioning (e.g., Nelson, 1964; Rosnet et al., 2004). As such, both surface- and deep-level composition variables may be relevant for the effective composition of long-duration and long-distance space crews, and both will be considered further.

Configurations of Member Attributes

With team composition, the combination of team members' attributes is important. Specific configurations are represented by distributional properties of the team (e.g., team averages, team diversities) or by other, more complex configurations such as when multiple types of diversity contribute to faultline strength (faultlines will be discussed in more depth later in this report; Mathieu, Tannenbaum, Donsbach, & Alliger, 2014). Choice of configuration is guided by the theoretical reasoning behind how team member attributes combine to affect team functioning in a particular context. Mathieu et al. (2014) summarizes different configurations into those that weight each team member equally (called the team profile model) or those that more heavily weight the characteristics of a particular team member or a subset of team members (called the relative contribution model). These are briefly described in the following paragraphs.

Team profile models take the overall distributional profile of the team into account; examples are team diversity, the relational approach, and team-requisite KSAO. Team diversity research is concerned with issues such as how team-level variability on surface- or deep-level attributes affects team processes and performance (Bell et al., 2011; Harrison & Klein, 2007) or how these differences create faultlines that promote subgroup formation and influence performance (e.g., Lau & Murnighan, 1998). The relational approach is a variation of team diversity research. The relational approach considers a team member's similarity or dissimilarity to the profile of the team (usually represented as a diversity index) and uses that to predict individual-level processes (e.g., social integration) or individual-level outcomes (e.g., performance, well-being). Team-requisite KSAO is used when at least one team member needs to have the KSAO of interest, but the KSAO is not necessarily tied to a given position (Mathieu et al., 2014). For example, it may be important for one team member, regardless of position, to be a peacemaker.

The relative contribution model considers the composition of the team but accounts for the idea that overall team performance may depend on the characteristics of some team members more so than others (Mathieu et al., 2014). First, the relative contribution model is used when the weakest or strongest standing on a particular trait is likely to influence overall team performance more than team members who have average standings on that trait. For example, minimum team member agreeableness relates positively to team performance (Bell, 2007) suggesting that one disagreeable team member can disrupt team performance. Second, the relative contribution model is used when a specific team member or subset of team members (e.g., commander, and deputy commander) fill a critical role that exerts more influence on team performance. The attributes of these team members may be more important for team performance than the remainder of the team (e.g., Pearsall & Ellis, 2006).

The different models are means for translating how team member attributes combine to influence team performance and well-being. Though there are many possible configurations of team member attributes, important configurations can be identified by considering the context within which teams operate and the theoretical path through which team composition is expected to relate to valued outcomes (e.g., team performance and well-being).

Team performance, which is defined as the extent to which a team accomplishes its goals or mission objectives (Devine & Phillips, 2001), is important for LDSE crews (Schmidt, Keeton, Slack, Leveton, & Shea, 2009). NASA seeks to optimize team performance as a means of reducing the likelihood of mission failures (Schmidt et al., 2009). The extreme environment within which space crews live and work (e.g., isolated and confined spaces, dangerous environment) and the length of expected missions can have a significant impact on both social (e.g., team cohesion, psychosocial adaptation) and tactical (e.g., cooperation, coordination, communication) processes. This impact can undercut team performance (Schmidt et al., 2009). As such, effective cooperation, coordination, communication, cohesion, and psychosocial adaptation serve as proximal markers of team effectiveness and, in addition to team performance and well-being, are valued outcomes. Next, we discuss the primary mechanisms through which team composition is expected to affect these proximal markers of effectiveness, and ultimately mission success.

How Team Composition Relates to Mission Success

There are two primary paths through which team composition is likely to affect mission success. First, team composition can affect success by influencing team members' general ability to live and work together as a group. Living together for an extended period of time in an isolated and confined space requires a level of interpersonal compatibility that keeps conflicts between team members manageable and allows team members to rely on one another for support. Conflict and a lack of crew cohesion can impact team performance and crewmember well-being (e.g., Natani & Shurley, 1974; Stuster, Bachelard, & Suedfeld, 2000; Taylor, 1987). Second, team composition can also influence the team's ability to complete dynamic, complex, and highly interdependent tasks during high workload periods through its effect on more tactile processes such as the team's ability to coordinate, cooperate, and communicate with one another and with mission control. It is worth noting that these two paths are not mutually exclusive. For example, better social integration and cohesion is also related to better coordination (Orasanu, Fischer, Tada, & Kraft, 2004). Interpersonal conflict can also escalate to the point where it disrupts the team's ability to complete team taskwork (Sandal, 2004).

Path 1: By Affecting Social Integration

There is ample evidence that interpersonal relations among members of space crews can be challenging (e.g., Chaikin, 1985; Kanas, 2004). Interpersonal problems were rated as the top issue for American astronauts in critical incident logs from the Shuttle/Mir program (Kanas, 2004). As one cosmonaut noted in his diary, the "hardest thing during a flight is keeping good relations going with the ground crew and among the crew" (Chaikin, 1985, p. 24). Issues surrounding interpersonal compatibility are likely to become more apparent over time (Sandal et al., 2011). As another cosmonaut noted, "the effect of psychological compatibility arises after approximately one month of staying under conditions of group isolation. The longer the flight, the more strongly the effect appears" (Bluth, 1984, p. 32).

LDSE space crews will be particularly challenged in that crews will be diverse in a number of aspects (i.e., gender, culture, functional background). Surface- and deep-level differences between team members can affect social integration, which in turn affects team performance and well-being. Social integration is the degree to which a team member is psychologically linked to others in a group (Blau, 1960; O'Reilly, Caldwell, & Barnett, 1989). It is a multifaceted construct that reflects attraction to the group, satisfaction with other group members, and social interaction among group members (Katz & Kahn, 1978; O'Reilly et al., 1989). In space crews, social integration is important because it allows the team as a whole to form a cohesive unit. Examples of poor social integration include when crewmembers are more psychologically linked to a subgroup or when an individual does not socially integrate into the crew, resulting in withdrawal or alienation. Subgroups or alienated team members can become the target of crewmember hostilities, which is known as scapegoating. Subgroup formation, alienation, and scapegoating are three problems noted in space and analogue environments (Kanas et al., 2009; Kanas, 1998).

Problems in Space Flight Associated with Poor Unit-Level Social Integration

Subgrouping occurs when crewmembers identify more strongly with a subset of crewmembers than with the crew as a whole. Although subgrouping is not always problematic (Kraft et al., 2002; Le Cruff et al., 1997), there is consistent evidence from analogue environments that subgrouping can occur and that the formation of subgroups during missions may result in conflicts that threaten mission success or put crewmember well-being at risk (Kanas, 1998). For example, a secondary analysis of Antarctic teams observed that teams with a clique structure, which had identifiable subgroups based on areas of the station (e.g., biomed, library), reported higher levels of mood disturbance as compared to core periphery groups where the majority of members identified with the station as a unit. The members in the different structures (e.g., clique, core periphery) varied in the amount of support they gave one another (Palinkas et al., 2000).

Space and analogue studies have reported that subgroups can form around nationality, gender, values, and familiarity. Analogue studies have found that conflict can arise when nationality-based subgroups interact (Rivolier, Cazes & McCormick, 1991; Sandal, 2004). Biosphere 2, which involved a crew that was isolated for two years, saw the development of gender subgroups that resulted in intense conflict (Walford, Bechtel, MacCallum, Paglia, & Weber, 1996). Subgrouping also occurred around values during the MARS-105 simulation (Sandal et al., 2011); crewmembers who were perceived as less similar indicated more tension (Vinokhodova, Gushchin, Eskov, & Khananashvili, 2012). In the SFINCSS '99 simulation, conflict between subgroups resulted in the shutting of a hatch and no communication between subgroups for a month (Sandal, 2004; Vinokhodova, Bystritskaya, & Eskov, 2002). Further, familiarity was tied to the development of group cohesion in a sample of small-unit Navy officers (Bartone, Johnsen, Eid, Brun, & Laberg, 2002). If a subset of a LDSE crew is familiar with one another (e.g., as a result of training together or previous flight experience), subgrouping may be more likely to occur. The host-guest problem, observed in Russian missions, is another illustration of the effect of familiarity (Kanas et al., 2009). Specifically, in these cases, new crewmembers ("guests") join more permanent "host" crews on missions. The host-guest problem is associated with delayed performance and increased tension (Kanas et al., 2009).

Feelings of isolation and scapegoating are additional problems associated with poor crew-level social integration. For example, during the Saylut 6 mission, a visiting Czech astronaut felt socially isolated and indicated that he was kept from doing work by the Russian cosmonauts who were concerned that he would make an operational error (Kanas et al., 2001). Personnel in the Antarctic reported being socially isolated from the group because of language and cultural differences among group members (Sandal, 2000). Being excluded may have significant consequences for a crewmember's well-being; for example, an excluded crewmember might develop "long-eye" (e.g., insomnia, depression, agitation; Rohrer, 1958, as cited in Kanas, 1998). Isolated members may also be the target of scapegoating, particularly when they are unlike the majority of the crew and if they advocate divergent ideas (Kanas, 1998). Scapegoating has been reported during Antarctic expeditions (Rivolier et al., 1991) as well as in chamber-isolation space simulations (Gushin, Efimov, Smirnova, Vinokhodova & Kanas, 1998).

Team Composition Related to Social Integration

In general, social integration is thought to occur when team members are attracted to and approachable to one another (Blau, 1960). For surface-level variables (e.g., sex, race, age), team members tend to be attracted toward demographically similar others (Byrne, 1971). For deep-level variables, team members are more compatible with other team members when they are allowed to express themselves in trait-consistent ways. Personality traits and values are needs

(Allport, 1951), and the inability to express these needs can lead to anxiety (Cote & Moskowitz, 1998; Wiggins & Trapnell, 1996). For some deep-level variables (e.g., values, need for affiliation), a similar other allows for trait-consistent expression (called supplementary fit). For other deep-level variables (e.g., need for dominance), a dissimilar other better allows for trait-consistent expression (called complementary fit).

Research on traditional teams has linked surface- and deep-level diversity to both social integration and individual- and team-level outcomes, such as performance (e.g., Guillaume, Brodbeck, & Riketta, 2012; Harrison et al., 2002; Kristof-Brown, Barrick, & Stevens, 2005). Analogue research, which has explored social integration in relation to crew heterogeneity and social compatibility, has also examined surface- and deep-level differences. These studies are reviewed below.

Values

Values are beliefs about desirable behaviors that transcend specific situations, guide the evaluation of behaviors, and are ordered in an individual in terms of relative importance (Schwartz & Bilski, 1987). Values are thought to have a strong motivational component (Rokeach, 1973) and influence both daily actions (e.g., working hard or working with others) and lifelong objectives (e.g., personal goals and achievements). Values are studied as personal values (e.g., hedonism) but also as cultural values (e.g., Power Distance, Uncertainty Avoidance, Individualism versus Collectivism; Hofstede, 2001). Individuals tend to endorse the cultural values of their home country (Hofstede, 2001), and for this reason, sometimes nationality is used as a surface-level marker of underlying cultural values. However, it should be noted that there is some level of intra-country variation even within the cultural values.

Analogue studies have examined how individual-level value differences, as well as nationality, affect team functioning. Nationality heterogeneity was associated with increased tension between the crews in SFINCSS ’99; language problems and different attitudes toward gender relations were suggested to have a major impact on crew relations (Sandal, 2004; Fidelity Score [FS] = 10). On the other hand, members of the MARS-105 crew had tensions with those crewmembers perceived to be dissimilar on value orientations and assessments of the surrounding social environment rather than on cultural characteristics (Vinokhodova et al., 2012; FS = 10). Additional analysis of the MARS-105 crew indicated that subgroups were formed around homogeneity of values, specifically in terms of hedonism, benevolence, and traditionalism, values within Schwartz and Bilsky’s (1987) framework. These subgroups experienced increased tension over time as the crew was given more autonomy (Sandal et al., 2011; FS = 10). Finally, analysis of crew diaries across 10 space missions and analogues suggests that crews heterogeneous on nationality experience less deviance (e.g., acts of aggression; acts of deliberation such as violating safety rules; unusual or bizarre behavior; Dudley-Rowley, 2000). Thus, there is evidence that national diversity may lead to positive or negative outcomes but that underlying value differences may provide a stronger basis for subgrouping and tensions.

Personality

Evidence from analogue research indicates that crewmembers may better integrate with similar others in terms of personality. Expedition teams with similar personalities were more resistant to declines in motivation (Leon & Sandal, 2003; FS = 7). In another analogue study, both crewmembers had well-adjusted personalities and were extraverted, to which their ability to be supportive of each other was attributed (Leon et al., 2011; FS = 9). Similarities between crewmembers' anticipation of and approach to dealing with expedition stressors were thought to be helpful in reducing tension (Leon & Sandal; 2003, FS = 7) and useful for succeeding in challenging tasks (Leon et al., 2011; FS = 9). Homogeneity in conscientiousness among team members was related to more compatibility in Antarctic stations over 12 months (Gunderson & Ryman, 1967; FS = 7). In depth analysis of data from the HUBES and ECOPSY simulations suggested that differences in personality were the basis for a crewmember having an outsider status (Gushin et al., 1998; FS = 9). In both simulations, the outsider (as regarded by himself and other crew members) had problems cooperating with the other crewmembers; the disintegrated psychological climate produced tension and subgrouping. Finally, heterogeneous, as compared to homogenous, dogmatic dyads in confinement were more likely to turn inward (e.g., emotional symptomatology; Haythorn et al., 1966; FS = 6). It seems that personality compatibility may be important; however, given the methodology of the studies, it is not clear what specific dimensions of personality compatibility may be important.

Needs

Hypothetically, compatibility of needs involves both complementary and supplementary fit. Team members are thought to be more compatible on the need for dominance when their needs are complementary (e.g., when an individual high on the need for dominance interacts with an individual low on the need for dominance). Team members are thought to be more compatible on the need for achievement and the need for affiliation when their needs are similar. Results of a series of analogue studies, which will be discussed below, suggest the importance of compatibility on dominance but are less consistent regarding the importance of team member compatibility on other needs.

Compatibility on the need for dominance (as well as the related need for prominence) seems to have an impact on teams in isolation. Dyads that were incompatible on the need for dominance (high/high) were more territorial over time in isolation (Altman & Haythorn, 1967; FS = 6) while compatible (high/low) dyads became less territorial. In another study, dyads that were heterogeneous on the need for dominance reported less stress as compared to both high/high dominance dyads and low/low dominance dyads (Haythorn et al., 1966; FS = 6). In a study of Antarctic work groups, teams that were homogenous and high on the need for prominence were the most incompatible (as rated on a sociometric measure of compatibility) as compared to teams that were homogenous and low or teams that were heterogeneous (Nelson, 1964; FS = 9). In the ISEMSI 90 simulation, there was lasting antagonism between three dominant crewmembers, resulting in unpopularity and eventual isolation of one of the dominant crewmembers (Sandal, Vaernes, & Ursin, 1995; FS = 10). Another pattern was observed, however, between dominant members in the EXESMI simulation. The commander aligned himself with a dominant crewmember who was also low in task motivation. This alliance seemed to reduce competition, although there was lasting antagonism between the low task motivation dominant team member and a third crewmember. Taken together, it seems that there may be some difficulties associated with multiple dominant members in isolated teams that potentially may be problematic for team functioning.

Other needs show less consistent effects. Dyads that were heterogeneous in the need for affiliation tended to withdrawal from one another in isolation (Altman & Haythorn, 1967; FS = 6), as did dyads that were low in the need for affiliation (Altman & Haythorn, 1967; FS = 6). Dyads in which both members were high in the need for affiliation spent more time with each other (Altman & Haythorn, 1967; FS = 6). Dyads that were heterogeneous in the need for achievement reported more emotional disturbance (Haythorn et al., 1966; FS = 6). A study on teams in the Antarctic over a 12 month period, however, reported no effect between heterogeneity on the need for achievement and perceived compatibility (Nelson, 1964, FS = 9), suggesting a less conclusive effect. Another study on teams wintering over in the Antarctic found a negative relationship between variability on need for autonomy and compatibility (Gunderson & Ryman, 1967; FS = 7). Finally, a study that looked at combined compatibility on the need for achievement, need for control, and need for affect found that the hypothetically incompatible groups had more hostility, but found no difference on team members' levels of stress or state anxiety (Smith & Haythorn, 1972; FS = 6). In sum, the importance of compatibility between team members in terms of other needs (e.g., need for affiliation) seems less conclusive.

Attitudes, Interests, and Other Variables

Analogue studies have also examined deep-level differences in terms of interests, attitudes, and some other variables. There is evidence from the HUBES and ECOPSY simulations that perceived dissimilarity on attitudes was related to crew disintegration (Gushin et al., 1998; FS = 9). In a series of 10, short-duration (12-d to 20-d) missions run in Tektite II, shared interest between scientists and engineers was related to better relations and performance (Watters & Miller, 1971; FS = 10). In a 12-month study conducted at Antarctic stations, differences in the self-rated importance placed on hobbies and recreational activities, as well as diversity on rural as compared to urban backgrounds, were predictive of less compatibility (Gunderson & Ryman, 1967; FS = 7). Finally, differences on other attributes have been examined, but researchers have found little support regarding their importance. Specifically, occupational rank, sociocultural background (e.g., size of hometown, parents' occupation), and current interests were all unrelated to social compatibility (Nelson, 1964; FS = 9). Likewise, dissimilarity on skills was unrelated to deviance (Dudley-Rowley, 2000). In sum, some shared attitudes, interests, and background characteristics seem to influence outcomes, social integration, and performance.

Sex

Several analogue studies reported potential issues for sex-diverse crews, but often these issues were tied to a secondary composition variable (e.g., age, culture). Rosnet et al. (2004) examined the psychosocial adaptation of men and women in mixed crews that had spent the winter at a French polar station. The authors observed that while the inclusion of women seemed to improve the overall team climate, the women were subjected to inappropriate behavior and harassment. These inappropriate behaviors were more prevalent when women were also young (Rosnet et al., 2004; FS = 7). Similar difficulties were observed in the SFINCSS '99 simulation during which a male made advances toward a female crewmember (Sandal, 2004; FS = 10). As was mentioned, the issues associated with sex composition could have been due, in part, to cultural differences. For example, differences in reactions to gender-related situations and how these situations were resolved (e.g., involving mission control, mission control's lack of response) were attributed to cultural differences (Sandal, 2004). Analysis of the three main crews in SFINCSS '99 (Gushin et al., 1997) indicated that a culturally homogeneous crew (crew 1) had positive attitudes toward a culturally heterogeneous second crew (crew 2), even though they perceived the crew to be different from themselves. However, the first crew was not able to bond with the third crew, which was culturally diverse and had male and female members; the first crew perceived this crew to be psychologically distant. While sex may have contributed to these differences, linguistic analysis suggested that there was incompatibility between crews 1 and 3 on task-orientation and social-emotional orientation. Greater task orientation from crew 1 allowed it to bond with crew 2 over successful performance but not with the sex-diverse crew 3, which was more socially-emotionally oriented. Finally, in a study of 10 space flights and analogue expeditions, researchers found higher levels of deviance among mixed-sex crews (Dudley-Rowley, 2000). The author did note, however, that sex-homogenous crews had more members from military backgrounds, which may have reduced the deviance in all-male crews. Taken together these results suggest that the potential problems with sex diversity may be compounded by or a function of other composition variables (e.g., age, culture, military background).

Age

Crews that included members from the extreme ends of the age distribution were observed to have poor integration, possibly because of value differences. Specifically, a comparison of shorter-duration simulations at MDRS and FMARS suggested that generational differences resulted in poor social integration (Cusak, 2010; FS = 10). Generation Y crewmembers preferred to work solo, did not care for menial tasks, and had a greater level of self-interest as compared to a team focus, which led to poor integration. Members of the Silent Generation were reported to be more rigid and had difficulty understanding younger members, which led to poor integration. One study of Antarctic teams indicated a negative relationship between age heterogeneity and social compatibility in winter months (Nelson, 1964; FS = 9). However, during the summer months and in another study of Antarctic teams, age heterogeneity was unrelated to compatibility (Nelson, 1964; FS = 9; Gunderson & Ryman, 1967; FS = 7). At the same time, in a study of 10 space flight and analogue teams, age heterogeneity was associated with less deviance (Dudley-Rowley, 2000). Finally, a comparison of six Arctic-station crews observed that average age was inversely related to depression and anxiety in the short term and to hostility in the long term (Palinkas, Gunderson, & Burr, 1989; FS = 7). Overall, these results suggest that a mature, less age-diverse crew may have fewer problems.

Summary

In sum, much of the research from space simulation and analogue environments has used a social integration perspective to explore how differences between team members affect team functioning. The observed effects suggest that there is a lasting influence for both deep- and surface-level variables. Specifically, teams diverse on surface-level variables such as cultural background and sex have more difficulty with social integration; however, it is often difficult to determine if this is due to a particular trait (e.g., sex) or the result of other co-varying differences (e.g., age, values). For deep-level differences, homogenous crews in terms of values, needs, interests, and personality had better social integration with the exception of the need for dominance. Teams with more dominant team members appeared to be more incompatible than those with fewer dominant team members. Potential implications of these findings will be discussed later.

Path 2: By Affecting Team Process and Emergent States Related to Team Task Completion

LDSE will involve the completion of complex, dynamic, and highly interdependent tasks, particularly during high workload periods. This requires team members with diverse professional backgrounds and specialized expertise to integrate information among crewmembers, among mission control team members, and between the crew and mission control. Team composition can directly influence available expertise, the development of important team emergent states (e.g., shared cognition), and the critical team processes (i.e., coordination) needed for LDSE success. Emergent states are "properties of the team that are typically dynamic in nature and vary as a function of team context, inputs, processes, and outcomes" (Marks, Mathieu, & Zacarro, 2001; p. 357). Team processes are "members' interdependent acts that convert inputs to outcomes through cognitive, verbal, and behavioral activities directed toward organizing taskwork to achieve collective goals" (Marks et al., 2001; p. 357).

Highly interdependent tasks require team members to integrate their KSAs and efforts by simultaneously and sequentially performing multiple processes in order to orchestrate goal-directed taskwork (Marks et al., 2001). In space crews, transition phase processes (i.e., mission analysis, goal specification, strategy formation and planning; Marks et al., 2001) that focus on evaluation or planning related to goal accomplishment would most likely occur during low workload periods, while action phase processes (i.e., monitoring progress toward goals, systems monitoring, team monitoring and backup behavior, and coordination activities; Marks et al., 2001) that lead directly to goal attainment would most likely occur during high workload periods (Marks et al., 2001). Both transition phase and action phase processes have moderate to strong relationships with team performance, team member satisfaction, cohesion, and potency (LePine, Piccolo, Jackson, Mathieu, & Saul, 2008). Further, the team process and team performance relationship has been found to be stronger for teams that have higher task interdependence (LePine et al., 2008). A "nearly fatal incident" reported in Bluth (1984) onboard the Apollo-Soyuz test project illustrates a situation that could benefit from backup behavior among crewmembers.

> There had been a number of cockpit errors on this mission, and these included forgetting to set two critical switches for entry which would have prevented automatic

> devices from deploying the chutes and from dumping excess fuel and oxidizer from the attitude-control rocket engines. Commander Tom Stafford apparently was distracted and neglected to call for them at the proper time, and the rookie astronaut, Vance Brand, also missed them. As the capsule reentered the atmosphere, the crew began to choke, gag, and gasp as highly corrosive nitrogen oxide gas filled the cockpit. Brand passed out cold, and it took five minutes for Slayton & Stafford to break out the oxygen masks. The effect of such a toxic mixture on the lungs could have been fatal (p. 33).

A few studies from analogue environments have examined how team composition relates to team processes or performance. During the recent MARS-105 simulation, perceived similarity in values as rated through the PSPA (i.e., not tied to culture) affected preference for whom crewmembers communicated with and lead to subgrouping that resulted in less efficient completion of interdependent tasks (Vinokhodova et al., 2012; FR = 10). Homogeneity in conscientiousness, homogeneity in need for autonomy, homogeneity in self-rated importance placed on hobbies and recreational activities, and homogeneity on urban and rural background among team members were all related to more task accomplishment in Antarctic stations over 12 months (Gunderson & Ryman, 1967; FS = 7). In a series of 10, short-duration (12-d to 20-d) missions run in Tektite II, performance was better for groups in which scientists and engineers shared interests and activities (Watters & Miller, 1971; FR = 10). In an MDRS simulation, an all-female crew (also higher in conscientiousness and agreeableness and lower in competitiveness) was more vested in mission goals than was an all-male crew; rather than complying with reporting deadlines, the all-male crew continued EVAs and individual projects (Bishop et al., 2005; FR = 8). Finally, in a 10-d ICE experiment in which dyads completed team tasks, heterogeneity on needs (e.g., dogmatism, achievement, dominance) did not have consistent effects across performance on a series of team tasks. There was one exception: dyads heterogeneous on the need for affiliation seemed to perform worse than homogeneous dyads (Altman & Haythorn, 1967; FR = 6). Taken together, results from teams in analogue environments provide initial, but limited, support for the importance of deep-level composition variables as a means to optimize mission-related team performance for LDSE.

Network Team Composition Issues: Crews within a Multi-Team System

It is important to note that while the focus in the preceding review has been on crew composition, team composition issues can extend to the larger network (e.g., mission control). In the ISS, mission success requires crew coordination, but it also requires coordination, cooperation, and communication between the crew and mission control and within mission control. Mission control works with space crews in what has been described as *distributed supervisory coordination,* which acknowledges the idea that mission operations are coordinated and negotiated rather than dictated as seen in command and control environments (Caldwell, 2005). Specified positions work as liaisons between the interacting systems. For example, the flight director and the CAPCOM coordinate the ground-vehicle teamwork. Liaisons such as the Russian Interface Officers (RIO) coordinate between US and foreign mission operations on joint efforts (Caldwell, 2005). Expertise, information sharing, and shared cognition are thought to be critical for success (Caldwell, 2005; Rouse, Cannon-Bowers, & Salas, 1992). LDSE crews will likely enjoy more autonomy from mission control, particularly at longer distances, but they will still participate in a multi-team system (i.e., ground and crew).

There is currently no analogue research that directly speaks to the relationship between crew composition, mission control composition, and the interactions between the two. However, an analysis of the communication between space crews and mission control of the HUBES and ECOPSY simulations indicated that the crew and especially the commander shared a different amount of information and engaged in a different level of psychological closing (i.e., avoiding sharing feelings to mission control) across mission control groups (Gushin et al., 1997). Gushin et al. (1997) indicated that there may have been more rapport between the commander and one of the mission control teams. Although specific compositions were not examined in this study, the study results support the notion that the compatibility with mission control may have consequences for team functioning.

Given the limited team composition research pertaining to the broader mission team (i.e., mission control and space crew), conceptualizing the mission team as an information processor may lend insights into critical team processes and emergent states needed for effective performance, which in turn may implicate important team composition variables. “At the group level, information processing involves the degree to which information, ideas, or cognitive processes are shared, and are being shared among group members, and how this sharing of information affects both individual- and group-level outcomes” (Hinsz, Tindale, & Vollrath, 1997, p. 43). In information-heavy contexts such as high workload periods, what information and the degree to which information is shared ultimately determines group effectiveness (Stasser, Taylor, & Hanna, 1989). For teams to effectively process information, team members must have a shared objective, minimize distractions such as off-task conflict, develop a shared understanding of the task (i.e., shared mental models), and have an understanding of where information is stored (i.e., transactive memory system; Hinsz et al., 1997).

Research conducted on traditional teams has found that team composition is related to shared cognition (shared mental models, transactive memory systems). For example, high general mental ability (GMA) dyads were found to outperform low and mixed ability dyads, in part due to their ability to develop accurate team mental models (Edwards, Day, Arthur, & Bell, 2006). In a study that included students collaborating over time in a top management team simulation, team mean cooperation was positively and team racial diversity was negatively related to development of team shared mental models, which were ultimately related to implicit coordination and team performance (Fisher et al., 2012). There is also a broad literature base regarding how team composition affects information sharing in teams. For example, team mean agreeableness, extraversion, openness, and conscientiousness were all related to information sharing in R&D teams (Hsu, Wu, & Yeh, 2011). Finally, in a command and control situation, critical team member assertiveness was related to enhanced transactive memory systems, satisfaction, and team performance (Pearsall & Ellis, 2006).

As mentioned, distractions need to be minimized in order for teams to effectively process information. Tensions between crewmembers and mission control have been reported, mostly around scheduling issues (Stuster, 2010). Whether one is an expert or a novice may contribute to these issues. In medical teams, novice physicians were reported to overly rely on objective data, use linear thinking, and discount and explain away data that did not "fit" the frame, whereas experienced physicians drew on expertise to recognize cues and patterns while leaving room for altering or even changing their initial diagnoses (Schubert, Denmark, Crandall, Grome, & Pappas, 2013). Divergent cognitive styles related to expert and novice status are likely to inhibit shared understanding and mission team effectiveness. Further, tensions between space crews and mission control may suggest the importance of compatibility between key members (i.e., Commander, CAPCOM) in areas such as work style, communication style, and approach to conflict management (De Dreu, Evers, Beersma, Kluwer, & Nauta, 2001; Munduate, Ganaza, Peiró, & Euwema, 1999). These styles vary greatly over culture, suggesting compatibility in work styles may be complicated by the fact that individuals from some cultures may prefer different styles than others (Chua & Gudykunst, 1987).

Finally, tension between crewmembers and mission control may also result because of a well-integrated crew displacing hostility or frustration outward. Kanas (1990) noted several simulations that observed more conflict between mission control and crews when there was less conflict within the crew, and vice versa. Further, if mission control and crews are well integrated, this hostility and conflict may shift toward management. During the EXEMSI simulation, mission control personnel and crewmembers were similar on background, age, occupation, and feeling of "belonging to the same family." Crews maintained good relations with mission control but had strained relationships with management (LeScanff, Bachelard, Cazes, Rosnet, & Rivolier, 1997). Hostilities were first directed toward the organization and were later directed toward the specific ESA management representative, who was not prepared to become a scapegoat. Thus, although crew social integration is an important goal, the potential consequences of a socially integrated crew, or a socially integrated crew and mission control staff, must be accounted for via additional preparations and support for the individual or individuals who are most likely to serve as the scapegoat (LeScanff et al., 1997).

In sum, crew composition issues are likely to influence and be influenced by mission control. Identifying critical relationships (e.g., flight director and commander) between crews and mission control may help identify compatibilities that are important for crew performance and well-being. For example, the commander and the flight director may be the primary link for sharing information between mission control and the crew. In this example, the compatibility between the commander and the flight director may be more important than the compatibility between the entire space crew and mission control team members. Regardless, LDSE will participate in a multi-team system; a consideration of network factors as they relate to team composition issues is prudent.

Summary

The purpose of the preceding literature review was to identify critical issues surrounding team composition and the effect that composition has on team functioning. We focused particularly on the composition factors likely to affect team performance and well-being. The two primary theoretical paths through which team composition is expected to relate to team performance and well-being are summarized in Table 2. Anecdotal information and research conducted in analogue environments suggests that deep- and surface-level team composition variables are related to outcomes such as group processes, subgroup formation, compatibility, deviance, and stress and coping. Identified attributes and configurations can be used to staff teams that, as a unit, should be successful. Accordingly, the next section of this report describes methods for composing teams.

Table 2.
Summary of How Team Composition Relates to Mission Success

Overview: Team composition refers to the unit-level configuration of team members' attributes. There are two general paths through which team composition can affect mission success: (1) by affecting social integration, and (2) by affecting team processes and emergent states related to team task completion. These paths are not mutually exclusive. In addition, it is important to consider the extent to which composition issues within the larger network (e.g., the compatibility between the crew and the flight director) influence team performance and well-being.

<u>Path 1: By affecting social integration</u>

- Social integration allows the crew as a whole to form a cohesive unit. Examples of poor social integration include subgrouping or when an individual does not socially integrate into the crew, resulting in withdrawal, feelings of isolation, or alienation. Subgrouping does not always lead to problems but it may result in conflicts that threaten mission success or put crewmember well-being at risk (Kanas, 1998). Social isolation can have significant consequences for a crewmember's well-being. Isolated member may also be the target of scapegoating (Gushin et al., 1998; Rivolier et al., 1991).
- Social integration is thought to occur when team members are attracted to and approachable to one another.
    - For surface-level variables (e.g., sex, race, age), team members tend to be attracted toward demographically similar others (Byrne, 1971).
    - For deep-level variables, team members are more compatible with other team members when they are allowed to express themselves in trait-consistent ways. For some deep-level variables (e.g., values, need for affiliation), a similar other allows for trait-consistent expression (called supplementary fit). For other deep-level variables (e.g., need for dominance), a dissimilar other better allows for trait-consistent expression (called complementary fit).

- The majority of team composition research in analogue environments has taken a social integration approach.
- The following team composition variables have been tied social integration in studies from analogous environments: value similarity (specific dimensions unclear); personality compatibility (specific dimensions less clear), dominance (problems with multiple dominant team members); similarity in attitudes, interest, background in terms of urban or rural; sex diversity (typically co-varying with a second variable such as culture); age diversity; national diversity (mixed results), and other needs (e.g., need for affiliation; mixed results).

Path 2: By affecting team processes and emergent states related to team task completion

- Crew members with diverse professional backgrounds and specialized expertise will be required to integrate information among crewmembers, among mission control team members, and between the crew and mission control in order to complete complex, dynamic, and highly interdependent tasks seen in high workload periods.
- Team composition can directly influence available expertise, the development of important team emergent states (e.g., shared cognition), and the critical team processes (i.e., coordination) needed for LDSE success.
- Little research conducted in analogue environments has examined team composition in relation to team processes, emergent states, or task performance. However, the limited research shows that the following are related to better team performance: homogeneity in areas such as conscientiousness, rural and urban background, need for autonomy, shared interests and activities, values, need for affiliation; and the use of all-female crews.
- A large body of team composition research conducted on traditional teams implicates other composition variables related to shared cognition (Edwards et al., 2006; Fisher et al., 2012), information sharing (Hsu et al., 2011), and transactive memory systems (Pearsall & Ellis, 2006).

Methods for Composing Teams

Team-Level Composition Considerations in Crew Staffing

A team member's individual competence and teamwork skills are important components of team staffing; at the same time, it is important for the team as a whole to be well-positioned for success. In their integrative framework of team composition models, Mathieu et al. (2014) describe both individual- and team-based composition models. Individual-based models "focus on either individual and job requirements, or on member's generic team-related [knowledge, skills, abilities, and other characteristics] KSAOs" (p. 113). In other words, individual-based models focus on what it means to be a "good worker" in terms of traditional person-job fit (position-specific KSAOs), or in terms of working within a team-based environment (position specific KSAOs plus the addition of generic teamwork competencies). Individual-based methods in team staffing tend to rely on a classic selection model, which utilizes job analysis and team task analysis to identify individual-level skills that drive performance in team settings. These models rely on individual-level predictors of individual-level performance, even though the individual works within a team (e.g., Zaccaro & DiRosa, 2012). The “right stuff” approach (Santy, 1994) is an example of an individual-based method that has been used to staff space crews. Other examples of individual-based methods include assessments designed to evaluate the extent to which a team member will be a “good team player,” such as the teamwork knowledge test (Morgeson, Reider, & Campion, 2005) or a situational judgment test on team role knowledge (Mumford, Van Iddekinge, Morgeson, & Campion, 2008). Although both tests have been found to predict individual team member performance, these (and other) tests do not account for the combination or compatibility of team members.

An exclusive focus on individual-based methods provides a limited view of crewmember suitability for LDSE. Specifically, individual-based methods focus on the compatibility between a crewmember and his or her job, role, and some aspects of the context. However, the social context in terms of a team member’s compatibility with crewmembers, or between crewmembers and mission control is, at best, only considered linearly in individual-based methods. This is problematic because as discussed in the preceding sections, LDSE provides a particularly salient social context in which team members: (a) are required to live with one another in isolated and confined spaces for long-durations, (b) are likely to be more autonomous than in previous space missions, which allows individual differences to have a greater impact on behavior (Sandal et al., 2011), and (c) coordinate with one another, particularly during high workload periods during which crewmembers will have to complete interdependent tasks. Together, these conditions provide a context within which crews operate and implicate the importance of crew compatibility.

Team-based composition methods formally take team member compatibility into account and thus take into consideration the rich social context of LDSE. In doing so, these methods can be used to compose crews that are better positioned for mission success. Team staffing experts widely acknowledge the importance of team-based methods and urge practitioners to consider the combination of team members and how these combinations can be tailored to specific task and team parameters when making team-staffing decisions (Mohammed, Ferzandi, & Hamilton, 2010; Zaccaro & DiRosa, 2012).

Considering team-based methods when composing teams does not diminish or reduce the importance of individual-based methods. Taking unit-level composition into account allows one to acknowledge that the efficacy of some predictors may be a function of the other crewmembers’ standing on those predictors. For example, individual-level values may not relate to individual-level task execution; however, subgroups that form around values may limit team-level efficiencies or lead to social dynamics that are detrimental to mission success (Sandal, 2004; Vinokhodova et al., 2012), necessitating that a team be composed of individuals who share key values.

Indirect and direct assessment of compatibility can be used to compose teams. These assessments are likely most efficient when they are used as part of a multiple-hurdle selection process. For example, an indirect assessment of compatibility can be used during the early stages of selection or for initial crew assignment. The compatibility of potential crews can be directly assessed in the later stages of selection (i.e., for mission assignment). Indirect and direct assessments of crew compatibility are described in the following sections, and, when possible, information from analogue environments is included. Additional detail on the assessments and methodologies (e.g., reliability information, costs) is available in a spreadsheet from the first author. Interestingly enough, although compatibility has long been identified as one of the most important behavioral characteristics among crews in extreme environments (Doll & Gunderson, 1970), little information is provided on how crew composition and compatibility has been handled in analogue environments (Dudley-Rowley, 2000). For example, O'Donnell (2002) indicated that now-defunct Unocal took interpersonal compatibility into account when staffing crews for their oiling drilling teams. However, O'Donnell did not provide information about how this was done.

Indirect Assessments of Crew Compatibility

Indirect assessment methods seek to identify validated traits that predict crew compatibility with the goal of selecting new team members who will supplement or complement the make-up of the existing team so as to maximize fit. During the early stages of the selection process, candidates can be assessed individually via traditional methods (e.g., personality inventories) to gauge their standing on traits that are relevant for team-level composition. Then, the compatibility of a hypothetical crew can be determined by examining the extent to which the combination of team members is consistent with a preferred composition (e.g., homogenous, uniformly high). Candidates are determined to be compatible to the extent that their inclusion on the team moves the team toward the ideal configuration on the team composition variable of interest. Specific configurations of team composition variables are weighted by how well the configuration predicts the outcomes of interest (i.e., by their predictive validities); this weighting is taken into account in the overall selection algorithm. For example, if complementary fit on extraversion and supplementary fit on team goal priority are tied to critical team processes, a candidate who increases team extraversion variability and decreases team goal priority variability would be given a higher compatibility score than a candidate who does not do so. There is limited information available regarding the use of indirect assessments in analogue environments. However, a similar approach was suggested in an Army-sponsored technical report (Donsbach, Tannenbaum, & Alliger, 2009) and is utilized in staffing and developing traditional teams in the private sector.

When using indirect assessment methods, candidates are first individually assessed via personality inventories, structured interviews, or individual assessments. Examples of inventories used to assess stable personality traits include the Minnesota Multiphasic Personality Inventory (MMPI); the Hogan Personality Inventory (HPI); the NEO Personality Inventory/Five Factor Inventory (NEO-FFI), and the Personality Characteristic Inventory (PCI; Chidester, Helmreich, Gregorich & Geis, 1991). The NEO-PI (Costa & McCrae, 1995) assesses five major factors including emotional stability, extraversion, openness to experience, conscientiousness, and agreeableness. The PCI has been validated in a number of settings, including both space and military crews. The traits that are assessed by this instrument (e.g., expressivity, concern) have been shown to predict job competence, group living, and coping (McFadden, Helmreich, Rose, & Fogg, 1994; Sandal et al., 1998). The PCI also has been used in analogue studies (e.g., Atlis, Leon, Sandal & Infante, 2004; Sandal, Endresen, Vaernes & Ursin, 1999) and to assess astronaut applicants (Musson, Sandal, & Helmreich, 2004). Measures of values include the Portrait of Crew Vales Questionnaire (PCVQ) used by Sandal et al. (2011) in an analogue environment. This measure is often preferred over the Schwartz Value Survey (SVS) because the intent (i.e., to measure values) is less obvious to the individual completing the measure. Both scales generate scores with moderate to high test-retest reliabilities.

Two issues are associated with using self-report measures during astronaut selection: social desirability, or faking, and the stability of traits in space. The concern regarding social desirability and faking plagues traditional staffing environments and may be an issue when staffing space crews (Krins, 2011). Social desirability is defined as a test-taker's tendency to provide responses that are perceived as being culturally acceptable or desired (Ganster, Hennessey, & Luthan, 1983). Data from a sample of astronauts and pilots indicated higher levels of socially desirable responding on the NEO-FFI as compared to the PCI (Sandal, Musson, Helmreich & Gravdal, 2005), further supporting the use of the PCI for astronaut assessment.

Several interventions have been developed to reduce socially desirable responding, including indirect questions, forced-choice response options, neutral questions, item-randomization, bogus-scale items, proxy subjects, and the reduction of item transparency (Dilchert & Ones, 2011; Fisher, 1993; Nederhof, 1985). An example of a bogus item might read, "How familiar are you with the *NASA Space Flight Best Practices Booklet*?" which is impossible to endorse because such a booklet does not exist. Individuals who endorse bogus items can thus be identified as having a positive response distortion. Bogus-item measures are not correlated with personality traits. Because of this, these measures provide a promising means of detecting socially desirable responding and positive response distortion in personality inventories (Harvel, 2012; Pannone, 1984). A more "fake resistant" personality assessment was recently developed to assess US Army recruits (Drasgow et al., 2012), which includes several methods to reduce socially desirable responding. Thus, although socially desirable responding is a potential concern for self-report personality inventories, there are potential interventions that can help reduce socially desirable responding.

Alternatively, other methods, such as interviews and psychological assessments, can be used to assess individual differences. These options are more expensive per applicant and would best be used during a later stage of the selection process. Meta-analytic results indicate that observer ratings of the Big Five personality factors (i.e., openness, conscientiousness, extraversion, agreeableness, emotional stability) have a strong relationship with self-report ratings of personality, although the ratings are not redundant (Connolly, Kavanaugh, & Viswesvaran, 2007). Observer ratings of personality traits such as those made by interviewers have the potential to explain unique variance in job performance beyond the variance explained by self-report ratings (Connelly & Ones, 2010; Oh, Wang, & Mount, 2011). Alternative methods to self-report or a triangulation of methods might provide optimal insights into applicants' standing on deep-level traits such as personality. A final note regarding faking is that for team-based composition methods, the ultimate ideal candidate profile may be more difficult for the applicant to identify, because ideal is partially a function of the other crewmembers' standings on the traits of interest.

A second concern regarding trait-based crew selection is the possibility that people might change while they are in space. For example, salutogenic effects have the potential to give people a completely different outlook on life (Ritsher, Ihle, & Kanas, 2005). Likewise, the development of psychopathology is a possibility, as seen in studies using data from Antarctic teams (Palinkas, Glogower, Dembert, Hansen & Smullen, 2001). In a study that used diaries and other publicly available archival material (e.g., interviews), Brcic (2010) found that 46 astronauts' in-flight ratings of the need for affiliation and the need for achievement were higher than their pre-flight ratings of those needs. Hypothetically, values and personality traits should not change as a function of time spent in space. For example, Antarctic explorers' personality profiles measured using the MMPI and the Personality Research Form were consistent when tested midwinter and at the end of winter (Butcher & Ryan, 1974). Likewise, crewmember values were relatively stable in the MARS-105 simulation (except for benevolence; Sandal et al., 2011) and in ISS missions (Vinokhodova & Gushin, 2014). Thus, although it is likely that team members will evolve as they are in space, many individual-difference variables that are typically the focus of team composition are likely to have at least some stability.

In sum, a first step to approaching crew compatibility using indirect methods is to determine the candidate's standing on identified traits. A candidate can be assessed via an inventory, a structured interview, an individual assessment, or a combination of methods. Concerns with socially desirable responding can be mitigated by using well-designed measures and by triangulating methods. Once a candidate's standing on crew-relevant traits is identified, the extent to which the candidate would improve the team's composition can be estimated via an algorithm. The algorithm requires development and validation; specific configurations of member attributes are weighted by how well the variables predict the outcomes of interest. The indirect approach can be flexible if developed properly. The estimated compatibility of hypothetical crews can be determined before crew staffing decisions are made, and various staffing strategies can be used. For example, one team staffing strategy is to first identify critical team members (e.g., the commander) and to assess the remaining crewmembers' compatibility with those critical members (Mathieu, Tannenbaum, Donsbach, & Alliger, in press). Alternatively, the compatibility of all crewmembers can be considered simultaneously, and individuals who contribute to the compatible crew can be selected. Either the single best crew can be selected using this method, or multiple crews can be formed and subjected to direct assessments of crew compatibility, as discussed next.

Direct Assessment of Crew Compatibility

A few approaches for directly assessing interpersonal compatibility have been suggested for use in analogue environments. Some assessments can be administered on their own such as peer nomination for suitability for living together (Doll & Gunderson, 1970; McFadden et al., 1994; Nelson, 1964), survey assessment (Doll & Gunderson, 1971), and clinical evaluations by psychiatrists or psychologists (Santy, 1994). For example, sociometry has been used in the Air Force to select compatible flying partners (Zeleny, 1947). This method first requires participants to rate or nominate desired flight partners. Then a compatibility index is calculated. Interpersonally oriented tests have also been used in assessment centers and other simulations (Rivolier et al., 1991; Vaernes, 1990). Finally, interviewing and testing were used to predict crew incompatibility in the Ben Franklin submersible experiment (Ferguson, 1970).

In terms of space crews, Russia has long paid attention to issues of interpersonal compatibility (Bluth, 1981; Benson, 1996). For example, in 1971 a 3-man crew prepared to inhabit the Salyut 1 space station for three weeks by touring the USSR for a month; the goal of this activity was to determine whether the crewmembers could get along with one another (Bluth, 1981). Additionally, scientist Norman Thagard, who was one of the first Americans to spend time onboard the MIR space station, noted in an interview that the Russians were always concerned with how crewmembers got along (Benson, 1996). The Russians have used methods such as Homeostat to assess crew compatibility in research (Gushin et al, 1998; Kanas et al., 2009). They suggest an assessment center can be designed to assess interpersonal compatibility by including group tasks and analyzing team interaction systematically using measures such as Homeostat (Gushin et al., 1998). More recently, Russian researchers have utilized a set of methods in the MARS-105 simulation, as detailed later, that can be used to evaluate group behavior, diagnose interpersonal problems, and improve crew selection (Vinokhodova et al., 2012).

Assessment Centers and Simulations

Assessment centers are a selection technique in which multiple assessors observe candidates across various simulated job tasks (Joiner, 2000). Candidates (whether individuals or potential crews) are observed and rated on several dimensions (e.g., communication, teamwork) across exercises. Well-designed assessment centers are standardized; they are based on a job analysis, use multiple techniques, rely on well-trained assessors, and document detailed behavioral observations (Joiner, 2000). The criterion-related validity of assessment center ratings ranges from .25 to .39 (Arthur, Day, McNeally, & Edens, 2003). The criterion-related validity of assessment centers is related to various methodological features associated with the technique (Woehr & Arthur, 2003). Higher predictive validity occurs when: (a) psychologists as compared to managers or supervisors serve as assessors, and (b) assessors are extensively trained. These and other best practices should be incorporated into an assessment center in order to best systematically assess interpersonal compatibility.

Assessment centers and simulations can be designed to examine interpersonal compatibility. An assessment center was used to select the final team for the 60-d EXEMSI ‘92 simulation

(Manzey, Schiewe, & Fassbender, 1995, as cited in Krins, 2011). The technique was reported to be effective, and the authors suggested that tools such as assessment centers could be used to help reduce the risk of interpersonal tensions.

An assessment center designed to assess interpersonal compatibility would involve group tasks and include the systematic analysis of team interaction (Gushin et al., 1998). Group tasks could include critical incidents (i.e., incidents believed to be critical for LDSE crew success as identified by the critical incident technique; Flanagan, 1954). Team interaction has been assessed in analogue environments with measures such Fundamental Interpersonal Relations Orientation-Behavior (FIRO-B; Kanas et al., 2009) and other assessments of crew compatibility.

Approaches such as ego change (Kraft et al., 2002) and the FIRO-B look at individuals' expressed and desired behaviors (Paul, Mandal, Ramachandran, & Panwar, 2010). The FIRO-B (Schutz, 1958) determines compatibility based on the fit between expressed and wanted affection, inclusion, and control among crewmembers. The dimensions include reciprocal compatibility (i.e., relationship between expressed and wanted behaviors between two parties), originator compatibility (i.e., extent to which an individual desires interpersonal behaviors), and interchange compatibility (i.e., a team's expression of inclusion, control, or affection; Kay & Dolgin, 1998). Attempts to validate the FIRO-B are decades old (e.g., Kramer, 1967) and have seen mixed support (Kay & Dolgin, 1998). In some cases, the FIRO-B has been criticized for having poor validity. However, more recent evidence from a sample of students supports both the construct and discriminant validity of the instrument (Salminen, 1991).

A more thorough team interaction analysis likely includes the triangulation of several measures. Recently, Vinokhodova et al. (2012) used several methods to assess interpersonal compatibility in the MARS-105 simulation study, including: (a) a relaxometer to assess the capacity for individual self-regulation and stress resistance, (b) a Homeostat device to assess crew compatibility via efficiencies of interpersonal interaction, (c) the PSPA to assess interpersonal values, self-perceptions, perceptions of others' values and relationships in the group, and (d) sociometry, with questions focused on preferences in professional and leisure activities. The authors suggest that the set of methods can provide an efficient evaluation of crew behavior, be used in the diagnosis of interpersonal problems, and should be considered in the crew staffing for LDSE. While these methods show promise, to date there is limited published validation evidence available for some of them (e.g., Homeostat) in terms of predicting long-term team success.

Finally, critical incidents and a team interaction analysis can also be applied to long-term simulations. Analogue environments, especially hyperbaric chamber simulations, may provide optimal simulations for the final stages of crew selection (Sandal et al., 1996). Although they would likely be more difficult to implement and be expensive, concerns expressed by Kanas (1998) regarding analogue studies' generalizability to space missions may suggest the importance of at least a moderate-length hyperbaric chamber simulation. Earth-bound analogues do not reproduce many of the stressors and dangers observed in space (e.g., microgravity, potential danger with little hope of rescue). Likewise, issues such as perceptual sensitivity can change group dynamics (e.g., crew communication; Kelly & Kanas, 1992; Kanas, Weiss, & Marmar, 1996). Further, integration of critical incidents and a team interaction analysis may be easier in controlled simulations rather than analogue settings (i.e., polar expeditions).

Summary

The objective of the previous section was to identify and provide a preliminary assessment of methods for composing teams in analogous environments. LDSE crews can be better positioned for success when team-based selection methods are used as a complement to more traditional individual-based approaches to staffing crews (i.e., individually assessing a candidate for the "right stuff"; Santy, 1994). Indirect and direct assessment methods of assessing crew compatibility are summarized in Table 3. To the extent that operational constraints limit the ability for an ideal team composition to be achieved through staffing, knowledge of how team composition affects team functioning can be used to inform the development and strategic application of other organizational interventions (e.g., training, countermeasures) that can mitigate the risks associated with the team's composition.

Table 3.
Summary of Methods for Composing Teams

Overview: Team-based composition methods formally take team member compatibility into account and, by doing so, can be used to compose crews that are better positioned for mission success. Indirect and direct assessment of compatibility can be used to compose teams. In general, information on methods regarding composing team in analogue environments is extremely limited.

Indirect Assessment Methods

Indirect assessment methods seek to identify validated traits that predict crew compatibility with the goal of selecting new team members who will supplement or complement the make-up of the existing team so as to maximize fit.

- Candidates are assessed individually via traditional methods (e.g., personality inventories) to gauge their standing on traits.
- The compatibility of a hypothetical crew can be determined by examining the extent to which the combination of team members is consistent with a preferred composition (e.g., homogenous, uniformly high).
- Candidates are determined to be compatible to the extent that their inclusion in the team moves the team toward the ideal configuration on the team composition variable of interest.
- Specific configurations are weighted by how well the variables predict the outcomes of interest; this weighting is taken into account in the overall selection algorithm.

Direct Assessment Methods

Direct methods of assessing interpersonal compatibility are used in later stages of selection. Potential crews can be formed and assessed in terms of interpersonal compatibility or effectiveness in short- or long-term simulations.

- Assessment centers are a selection technique in which multiple assessors observe candidates or crews across various simulated job tasks (Joiner, 2000). An assessment center designed to assess interpersonal compatibility would involve group tasks and include the systematic analysis of team interaction (Gushin et al., 1998).
- Russian researchers have suggested that the following methods (used in the MARS-105 simulation) can provide an efficient evaluation of crew behavior, be used in the diagnosis of interpersonal problems, and should be considered in the crew staffing for LDSE.
    - a relaxometer to assess the capacity for individual self-regulation and stress resistance
    - a Homeostat device to assess efficiencies of interpersonal interaction
    - the PSPA to assess interpersonal values, self-perceptions, perceptions of others' values and relationships in the group
    - sociometry, with questions focused on preferences in professional and leisure activities
- Though expensive and difficult, analogue environments, especially hyperbaric chamber simulations, may provide optimal simulations for the final stages of crew selection.
- While assessment centers and simulations tend to generate high predictive validities, there is little validity information available on some methods of assessing interpersonal compatibility such as Homeostat.

Operational Assessment

Subsequent to our literature review, we conducted an operational assessment to:

- gain additional insights into key composition variables related to LDSE mission success;
- understand the extent to which a subset of team members are more interdependent with one another or have a disproportionate influence on team effectiveness; and
- understand astronaut and mission team selection and training with an emphasis on:
    - the extent to which interpersonal compatibility or team composition are considered in the processes
    - current plans for LDSE missions
    - operational constraints within which team composition strategies will need to operate

A total of 11 subject matter experts (SMEs) were interviewed between April 23, 2014, and August 25, 2014. The SMEs included astronauts, individuals from the mission operations directorate (e.g., flight directors, CAPCOM, flight controllers), an individual from the Jet Propulsion Lab (JPL) who is currently working with Mars exploration initiatives, and individuals from behavioral health who are involved with training, selection, and astronaut support. All SMEs were male. Interviews were conducted by teleconference, and each interview lasted approximately one hour. Interviewees were oriented to the focus of the interview (e.g., team composition and leadership issues for long duration space flight) and asked about their current and previous roles within NASA. The specific topics that were discussed varied based on each interviewee's expertise.

Interviews were conducted jointly with a research group focused on leadership. At least two note takers were present during each interview; these notes were then independently coded by two research assistants, both of whom identified key takeaways from each interview. Discrepancies were resolved via consensus and by referencing notes taken by other individuals present on the call. During the next section of the report, we further discuss the key takeaways that were identified by the coders. We organize the takeaways by topic, based on the objectives identified previously. Additional detail is available in the interim report.

Key Composition Variables Related to Mission Success

Our first objective was to gain additional insight into the key composition variables related to LDSE mission success. During our analysis of the interview data, we identified three themes: (a) differences among team members are typically tolerable for short flights but may result in more significant compatibility issues for LDSE missions; (b) key composition variables linked to LDSE success include cultural differences; values, experience, and backgrounds; gender; and personality; and (c) effective communication, conflict resolution, trust, and a shared understanding of mission objectives are thought to be central to LDSE mission success. The themes are discussed in more detail in this section.

There was general consensus that while astronauts have experienced frustration as a result of issues traditionally associated with team composition, crews have been able to tolerate interpersonal differences, manage interpersonal relationships, and act professionally for shorter space flights. Several reasons were provided for why team composition issues do not typically affect crew performance and well-being during shorter-duration flights (e.g., 2 weeks). First, shorter flights are often busy and are task focused; crewmembers do not have time to let interpersonal differences become a major issue. Second, incompatibilities can be ignored because crewmembers know that the mission is short. Third, crewmembers are able to retreat to private chambers in the ISS, which helps diffuse conflicts. Fourth, crewmembers are able to rely on emotional support from the ground (e.g., mission control, confidential calls with psychologists, family members), which helps mitigate issues related to crewmember incompatibility. Fifth, crewmembers get to know one another during crew training. Thus, while crewmembers might identify people with whom they have differences ("I know this person well; s/he has a tendency to do this."), they are able to overlook the differences in order to achieve mission goals.

In contrast, there was strong consensus that ensuring crew compatibility will be extremely important for LDSE missions. Interviewees identified several composition variables, detailed in the following section, which might affect crewmembers' ability to get along with one another. Several individuals suggested that the best LDSE crews would likely be homogenous in terms of cultural background, values, military background, and sex. Homogenous crews were thought to result in less friction and were seen as helpful for forming a shared crew identity. At the same time, the interviewees acknowledged the practical constraints regarding selecting crewmembers based on crew homogeneity on certain dimensions (e.g., cultural background, sex).

In the next section of the report, we discuss specific composition variables that surfaced during the operational assessment.

Cultural Differences

In general, crewmembers from different national and cultural backgrounds were perceived to be "professional" and primarily interested in "getting the job done"; however, cultural differences have resulted in crew subgrouping, crewmembers feeling isolated, conflict, and frustration, all of which were thought to be more problematic for LDSE. The cross-cultural tensions that were identified by the interviewees were a result of differences between astronauts and Russian cosmonauts. For example, there are generally two functioning subgroups on the ISS; one subgroup is comprised of Japanese, European, and Americans who are strongly integrated, and one is comprised of Russian cosmonauts. Differences in cultures and preferences regarding communication with mission control resulted in feelings of isolation in an astronaut who was flying with two cosmonauts. Differences in language, cognitive styles, problem solving, and worldviews, particularly in regards to the treatment of women (i.e., patriarchal vs., egalitarian), were also mentioned as concerns. Cross-cultural differences were the most frequently mentioned concern regarding crew compatibility and team functioning.

Values, Experiences, and Background

Shared values, shared experiences, and similar backgrounds were reported to help bridge crewmember differences and help crewmembers form a bond; they were also suggested as being important to LDSE mission success. One astronaut reported that his Russian counterpart was "the most Russian you could get," but that both crewmembers respected each other's patriotism; they were able to form a bond around that. The same astronaut noted that other shared values (e.g., similar family values, military background) and doing recreational activities together prior to space flight helped the crew build cohesion and ease working relations. He further suggested that becoming familiar with other people's value systems during recreational activities (e.g., being on time versus a casual attitude toward being on time to social gatherings) helped prevent conflict during space flight. Finally, other interviewees suggested that all-military or all-civilian crews might be best for LDSE because of differences between the military and civilian crewmembers' perspectives on leadership, decision-making, and general outlook.

Sex

Gender issues do not seem to be an issue for short-term missions; crews generally remain task-focused, which minimizes gender and sexual issues. Astronauts and BHP support staff alike indicated several issues that might arise if mixed-sex crews are used for LDSE missions. First, interviewees mentioned potential logistical and bioethical concerns about women in space (e.g., birth control, menstruation management). Second, the need for explicit management of sexual relations in space was raised. Specifically, interviewees raised concerns about issues related to group functioning that could surface if romantic or sexual relationships develop during an LDSE mission. People suggested that such relationships could create mistrust among crewmembers, compromise fairness in decision making, result in excluded crewmembers feeling lonely or uncomfortable, or result in crewmembers competing for the attention of others. These outcomes were suggested to be particularly likely for configurations such one woman and two men or two women and one man. Third, there was also concern regarding how female astronauts might be treated or accepted in crews that include members from largely patriarchal societies.

Personality

Several additional team-composition variables were suggested to play a key role in LDSE success, although interviewees provided less detail about them. Interviewees reported that past missions were successful when crewmembers had "compatible personalities," but they were not able to describe the key factors that were important, with the exception of dominance and extraversion. Interviewees pointed out that having crews composed of "a bunch of alpha individuals" might be problematic. On the other hand, one astronaut felt some friction between his more subtle and introverted interaction style and the "bombastic" commander with whom he flew. Finally, interviewees suggested certain personality types (e.g., cultural sensitivity, high in self-monitoring), without regard to the overall composition of the crew, would likely foster mission success.

Critical Team Processes and Emergent States

Identifying critical team processes, emergent states, and stressors can provide information about additional composition variables critical for LDSE success. In addition, this process will help determine the importance of all the various composition variables. Communication, conflict management, trust, and a shared understanding of task and mission objectives were frequently mentioned as being important. Stressors expected in LDSE were also suggested.

Communication

The ISS is managed from the ground. Communication from mission control to the crew is often directive, and usually there are no issues. On occasion, however, issues have emerged as a result of mission control's inability to understand the experience of the crew or communication between astronauts and mission control being misconstrued. Typically such incidents are followed by a rapid period of self-correction. Thus, while incidents have caused resentment and hurt feelings, they did not influence overall mission success. Communication is expected to be different for LDSE in terms of content (i.e., crews will operate more autonomously), frequency (e.g., due to time delays), and mode (e.g., text-based communication will be utilized more), which could contribute to misunderstandings as well as disrupt the process of self-correction.

Conflict Management

Differences of opinion were reported to occur within the crew, between the crew and mission control, and within mission control. Within-crew conflicts are primarily related to interpersonal frustrations, as discussed previously. Conflict between mission control and the flight crew was most often attributed to the different parties not appreciating each other's perspectives and were often about scheduling. The commander and the flight director often play a role in ameliorating these tensions. In LDSE, there may be less conflict around scheduling if the crew operates more autonomously. Given NASA's current hierarchical structure, conflict within mission control is mostly limited to the planning stage. Various stakeholders involved in the planning stages (i.e., operations, engineering, crew representatives) have different interests and opinions, which sometimes results in conflict. The mission management team was reported to make the final decision when these conflicts emerge. Finally, interviewees reported some inter-agency conflict, which often centered on new procedures such as the implementation of just-in-time training. Taken together, effective conflict management for LDSE may be necessary within crew, between the crew and mission control, within mission control during the mission planning stages, and between the different space agencies.

Trust

Trust was reported to play a critical role in crew and mission control relations. Astronauts want to receive information from trustworthy peers on the ground, particularly when things are not going well. Interviewees reported that building rapport between the flight director and the crew helped them better work together. Training, such as the National Outdoor Leadership School (NOLS), was reported to be helpful in cementing relations between the flight director and the crew; however, non-training, pre-flight social experiences such as "getting a beer" were thought to be as helpful for building camaraderie. Further, building trust and solidifying the relationship between the commander and the flight director was thought to be helpful, as both individuals serve as the key influencers for the two groups (e.g., mission control, crew). Given that trust is often based on familiarity and building rapport prior to space flight, maintaining continuity of trust between the crew and different members of mission control over time was noted as a potential challenge for LDSE missions. Further, time delays in the past have allowed crewmembers time to ruminate and become suspicious or resentful (e.g., "What isn't the ground telling me?"). This further implicates trust as being important for LDSE.

A Shared Understanding of the Task and Mission Objectives

A shared understanding of the task and mission objectives between the crew and mission control, as well as between mission control team members was suggested to be critical to LDSE success. First, LDSE crews are expected to function more autonomously than ISS crews. A shared understanding of mission objectives between the crew, the flight director, and mission control was suggested as critical to ensuring that crews make autonomous decisions that are consistent with the overall mission goals. One suggestion made for developing a shared understanding between the crew and flight director is to involve the crew in the mission planning process. In mission control's early days, there were small teams of pilots assigned to missions. During the mission, one person would become the pilot and the other person would act as the flight director. These team members were able to develop a shared understanding of the mission because they were deeply involved in putting the mission together. Second, a shared understanding within the larger mission team was also noted as critical to success, particularly if a multi-team structure is used. Interviewees noted that the overall mission goals should always be considered in and paramount to decision making.

Stress

Stress can directly affect crewmember well-being; it can also interfere with crewmembers' ability to process information effectively, develop shared team mental models, and perform effectively (Ellis, 2006). A number of key stressors in the LDSE context were identified. Specifically:

- Maintaining relationships with family or missing significant family events and developments on Earth
- Crew friction and skewed dynamics that might cause performance issues
- Periods of under- or over-work
- Conflict with the ground crew which may result in the flight crew ignoring the ground and making decisions that are inconsistent with recommendations
- Slow development of depressive or anxiety-related disorders
- Sense of foreboding
- Insidious effects of deep-space radiation affecting concentration, memory, the ability to perform, and reaction time

Key Roles and Interdependencies

Our next goal was to determine the extent to which a subset of mission team members are more interdependent with one another or have a disproportionate influence on team effectiveness. This information can be used to identify key composition configurations and shape team composition staffing priorities. For example, ensuring team member compatibility may be more important for subsets of mission team members that are more interdependent (e.g., flight director and commander) as compared to those that are less interdependent.

Within Crew

For the most part, all crew roles were thought to be important and highly interdependent with one another, although a few exceptions were noted. First, unplanned or planned subgrouping (e.g., the two sides of the ISS) results in limited interaction and less interdependence between crewmembers of the different subgroups. Second, a handful of crew roles were noted as possibly being more critical for LDSE missions including the commander, the physician, and the "entertainer."

Within Mission Control

The mission control team members are all dependent on one another. Some positions interact with others more often; however, at some point all team members have critical interactions with the others. The flight director, mission control positions related to infrastructure, and mission control positions central to particular program objectives were perceived to be more critical to mission success.

Between the Crew and Mission Control

The flight director and CAPCOM are central to the relationship between mission control and the crew. For the most part, communications between the crew and mission control either involve the flight director or are governed by the flight director. The flight director and the crew commander tend to negotiate some power dynamics during a mission. Because of this, it was considered essential that crews, and particularly commanders, are able to trust decisions made by the flight director. Another influential position for mission control and crew relations is the CAPCOM. This is not leadership position, as the CAPCOM does not have the authority to make decisions. The CAPCOM influences mission team and crew relations by serving as a liaison and facilitating communication between the two, the crew's advocate in mission control, and a psychological bridge between the crew and mission control. In some cases, a CAPCOM might be permanently assigned to a particular crew. The CAPCOM role is expected to evolve or disappear altogether for LDSE missions. In the event that the CAPCOM role disappears, flight crew advocacy may be handled in an offline fashion rather than in real time.

Finally, it was suggested that, particularly evident during shuttle flights, some types of individuals rely on mission control more than others. Astronauts who were less confident or who shied away from taking responsibility tended to look for more direction from mission control. An interviewee suggested that such individuals would not cope well on LDSE.

Astronaut Selection and Training

Our next objective was to understand astronaut and mission team selection and training, with a particular understanding of the extent to which interpersonal compatibility or team composition is considered in the processes, whether there are current plans for LDSE missions, and the operational constraints within which team composition strategies will need to operate.

Current ISS crews are composed of international crews that include members from different space agencies. NASA governs the selection, training, and crew assignment process for US astronauts. Other agencies (e.g., JAXA, RFSA, and ESA) govern their selection, training, and crew assignment processes. Once a crew is assigned, international partners spend time training the crew on the sections of the ISS that they govern. The following section details NASA's selection and training processes.

The astronaut selection process is competitive. Applicants are recruited through a call on the USA Jobs website, which typically results in more than 5,000 applications. Applicants are screened, and approximately 500 applications are further reviewed by a panel that ranks them based on the applicants' qualifications. A shortlist of applicants is invited to the Johnson Space Center for a first round of interviews at a rate of about 20 applicants per week. The first round of assessments includes psychological testing, an interview, and a medical history. Approximately 50 people are invited, at a rate of 10 applicants per week, for a second round of assessments that includes a flight physical, an interview with the selection board, an in-depth psychological interview, and a week of experiential exercises and challenges such as a low-ropes course. Approximately 8 individuals are selected to become astronaut candidates based on factors believed to be important for LDSE, including the ability to work in a team, lead others, and follow others when necessary. The astronaut candidates enter astronaut candidate (ASCAN) training, which includes training on space systems, expeditions, historical missions, space suits, T-38 training, and space flight resource management (SFRM) training (e.g., communication, cross-cultural issues, conflict management, and teamwork). An astronaut candidate must successfully complete ASCAN training and related assessments before being selected as an astronaut. Once selected, astronauts are assigned to desk jobs, assessed based on performance criteria related to their assigned jobs, and given continuing education.

For an astronaut to become a commander, there are additional considerations. For example, an astronaut is required to first spend at least 3 months as a mission specialist. Interested candidates are then assigned to the commander role on the ground, are given the opportunity to perform in training exercises, and are assessed for suitability.

The Astronaut Office assigns astronauts to particular mission crews using individual-level criteria such as tenure, job performance, technical expertise, and medical readiness. Crew-level composition issues are not formally considered when assembling a mission crew, although sometimes decisions include “knowing who will work well together.” Once selected for a mission, astronauts engage in 30 months of advanced training, which includes training in the US as well as at international partner sites (e.g., Russia, Japan). While all international partners agree upon and know the training schedule, individual countries establish their own objectives. Training tends to be informed by mission objectives (e.g., planned activities require training on how to use the robotic arm). Crew composition is not formally considered in determining training needs, although interviewees noted that Russia tends to be more concerned than NASA with how well people get along during crew training. In a few instances, incompatible crewmembers were reassigned to later missions if substantial interpersonal compatibility was noted during the pre-mission training. For example, a Russian commander did not like an astronaut and wanted him to be removed from the crew. The astronaut was reassigned to a later mission and the reason given to the public was “medical concerns.”

The astronauts and mission support staff who were interviewed agreed that interpersonal compatibility was less likely to influence mission success for short-duration missions (for the reasons noted previously). Accordingly, they believe that the current strategy (i.e., staffing crews with individuals who have high person-job fit and generic teamwork competencies, attending to crew interaction in pre-mission training) is sufficient. They also noted that the ability to formally consider crew composition in mission assignment might be less feasible for currently planned ISS missions because there is a constant flow of scheduled missions and a limited pool of astronauts who are mission-ready.

There was strong consensus during the interviews, however, that interpersonal compatibility would greatly influence LDSE mission success. Accordingly, they felt that team composition issues will need to be considered formally when staffing and training LDSE crews. Several reasons for the increased importance of crew compatibility for LDSE were provided, including:

- The vehicle used for LDSE missions will likely not allow as much personal space as the ISS, which will limit the extent to which an individual can “get away” from other crewmembers.
- Expected communication delays between mission control and the crew will require that a crew operate more autonomously and have the ability to self-correct. The crew must be able to adapt, manage conflict, and effectively perform with less guidance and limited real time support from Earth. This requires the crew to have the needed competencies, as a unit, to manage conflict and self-correct.
- Although there will likely be a designated commander selected by the country investing the most funds in the mission, every LDSE crewmember will need leadership skills. Crewmembers with relevant expertise will need to take a leadership role (e.g., serve as a deputy commander) in different mission contexts. A shared leadership structure was expected to be more difficult for certain compositions (e.g., a crew with too many “alpha” types).
- There were several instances were crewmembers had animosity toward one another but were able to ignore or suppress related conflict because of the short duration of the mission. Within-crew animosity is expected to be a major issue for a LDSE because of the length of the training, the length of the mission, and the difficulty of the mission.
- For current missions, crewmembers have weekly, private, one-on-one conferences with a psychologist or psychiatrist to discuss issues such as sleep, fatigue, crew dysfunction, family issues, mood, and interaction with the ground. This countermeasure is a means of defusing conflict, mitigating interpersonal incompatibility, and ensuring crewmember well-being. In its current form, these conferences will be more difficult to utilize in LDSE missions because of expected communication delays.
- During LDSE missions, periods of low workload might lead to boredom. There may be conflicts over the few meaningful responsibilities. In this way, extended low workload may result in poor cohesion and additional opportunities for conflict.

Mission Control Selection and Training

Mission control is staffed by ad hoc teams. Individuals have been selected into and have completed a multi-year training program. The selection of mission control team members follows a systematic process that involves the targeted recruitment of new college graduates who have degrees in engineering, mathematics, physics, or similar fields. Preference is shown toward individuals with a minimum GPA of 2.8, but selected individuals generally have much higher GPAs. Selected individuals tend to be “space geeks” who have good teamwork skills and a positive attitude toward teamwork, the ability to handle stress, and the ability to commit to the project (e.g., flexible work hours). People are hired for a particular position, are given a general 2–3 month orientation to NASA, 9–12 months of training for their specific position, and 6–9 months of team training, beginning with low-fidelity simulators and progressing to high-fidelity simulators. The console is staffed with operators, who can handle basic emergencies, during nights and weekends when specific operations are not planned. After operators have gained experience and received additional training, they staff the console during the day, when specific operations are planned. Some of these people later complete additional training to become instructors. Certain mission control positions, such as RIOs, flight directors, and CAPCOMs, all work their way up through these ranks; however, individuals for these positions are selected and assigned to mission teams using additional considerations. For example, flight directors are required to have a high level of technical expertise (e.g., experience managing a life-support system), and a history of effective leadership. CAPCOMs are expected to be able to understand the astronaut experience and are assessed using a situational judgment test.

Functional group (e.g., SPARTAN, CHRONOS, and ETHOS) leaders assign individuals to mission team roles, with the exception of a few positions (e.g., flight directors). Compatibility between mission team specialists is not considered in the staffing process. Instead, training is highly standardized with the goal that any person who is trained for a specific role should have the necessary skills to function properly as a member of the mission control team. Compatibility between members of the mission team and crew is also not formally taken into account; however, flight directors are often familiar with the crew or commander given the close-knit nature of NASA's culture.

It was noted in several interviews that the mission control paradigm would need to shift for deep-space missions. A more adaptable and flexible system was suggested for LDSE mission control. Further, some interviewees speculated that mission control teams would likely work virtually to some extent because of potential international collaboration. Given the suggested paradigm shift, interviewees indicated that their suggestions for selection and training for LDSE mission control were highly speculative. Based on the current mission control paradigm and their ideas about LDSE mission constraints, the interviewees suggested additional training for flight directors and CAPCOMs, particularly in regards to text-based communication, effective communication strategies, and empathy. Finally, given the potential paradigm shift for mission control, it was suggested the Jet Propulsion Lab (JPL), which is currently involved with Mars exploration (e.g., Mars Curiosity), might provide a more feasible mission control structure.

Operational Constraints

The final goal of understanding the selection and training processes was to identify key operational constraints that could influence the ability to implement team composition strategies. Two constraints were identified: the need for international collaboration to implement certain composition strategies and the existence of a limited pool of astronauts.

The ability to contribute financial resources to the LDSE mission is anticipated to influence the cross-cultural composition of the team. For example, the commander may be from the country that contributes the most, financially, to the project. Because a crew is likely to be multinational, fully utilizing team-based composition approaches to staffing teams requires collaboration from international partners. Specifically, information about potential crewmembers would need to be shared by international partners, or international partners would need to buy-in to crew-level assessments of compatibility to fully utilize team-based composition approaches in the selection process. Currently there is little international coordination in the selection process other than the use of an international medical board. It should be noted, however, that Russia seems to already consider crew compatibility issues. Interviewees were hopeful that the significance and novelty of LDSE missions might override political strife and other cultural differences and allow for international partners to cooperate in implementing team composition strategies.

International partners already collaborate to train crews. For example, crew training schedules are negotiated and agreed upon. While training objectives are created by individual agencies, there is a high likelihood that a LDSE crew (and even a back-up crew) could train together, which would ensure that crewmembers know one another before takeoff. Further, NASA has some flexibility regarding training content; crew training could be individualized to align with the needs of the specific crew 's composition. That being said, there are cultural differences associated with training, such as differing perspectives on the value of just-in-time training. While there may be some challenges with new collaborations, at a minimum, a shared and collaborative training schedule is expected for LDSE.

A second potential operational constraint is the limited pool of astronauts from which crews can be assigned. Family reasons (e.g., birth of a child), medical health, and needed technical expertise reduce the pool of astronauts that can be assigned to a particular mission. Considering interpersonal compatibility in crew assignments may be difficult when staffing the constant flow of ISS missions. It is not clear whether this operational constraint will be a concern for LDSE crew composition, however, because fewer crews are likely to be utilized for LDSE and there will likely be longer lead-up times. Regardless, a limited pool of qualified and available astronauts has the potential to limit implementing crew composition strategies.

Summary

A summary of key operational assessment findings is provided in Table 4.

Table 4.
Summary of the Operational Assessment Results

Overview: Eleven subject matter experts were interviewed in 2014 including astronauts, individuals from the mission operations directorate (e.g., flight directors, CAPCOM, flight controllers), an individual from the Jet Propulsion Lab (JPL) who is currently working with Mars exploration initiatives, and individuals from behavioral health who are involved with training, selection, and astronaut support.

- Three themes emerged related to identifying key composition variables most likely to be related to LDSE mission success
    - Differences among team members are typically tolerable for short flights but may result in more significant compatibility issues for LDSE missions

- Key composition variables linked to LDSE success include cultural differences; values, experience, and backgrounds; gender; and personality
  - Effective communication, conflict resolution, trust, and a shared understanding of mission objectives are thought to be central to LDSE mission success
- Some mission team members are more interdependent with one another or have a disproportionate influence on team effectiveness.
  - Within crew, all crew roles were thought to be important and highly interdependent with one another, although a few exceptions were noted. First, unplanned or planned subgrouping (e.g., the two sides of the ISS) results in limited interaction and less interdependence between crewmembers of the different subgroups. Second, a handful of crew roles were noted as possibly being more critical for LDSE missions including the commander, the physician, and the "entertainer."
  - Within mission control, the flight director, mission control positions related to infrastructure, and mission control positions central to particular program objectives were perceived to be more critical to mission success.
  - The flight director and CAPCOM are central to the relationship between mission control and the crew.
  - Some types of crewmembers (e.g., less confident) rely on mission control more than others.
- Currently, crew-level composition issues are not formally considered when assembling mission crews. There is a focus on individual-level criteria such as tenure, job performance, technical expertise, and medical readiness, although sometimes decisions include "knowing who will work well together."
- There was strong consensus that interpersonal compatibility would be more important for LDSE mission success; several reasons were provided.
- Compatibility between members of mission control and crew is not formally taken into account; however, flight directors are often familiar with the crew or commander given the close-knit nature of NASA's culture.
- The mission control paradigm will need to shift for deep-space missions. The Jet Propulsion Lab (JPL), which is currently involved with Mars exploration (e.g., Mars Curiosity), might provide a more feasible mission control structure.
- Key operational constraints for the effective composition of teams include a) the need for international collaboration, and b) a limited pool of flight-ready astronauts.

Recommendations

The literature review and operational assessment were consistent in indicating that surface- and deep-level differences are likely to influence team functioning in LDSE. Key composition factors that are most likely to have a strong influence on team performance and well-being of LDSE crews are cross-cultural issues; sex; values, attitudes, and interests; personality, especially assertiveness and extraversion; professional and military background; and specialized expertise. Composition issues that are not relevant to the operational context will not be discussed in our recommendations. For example, though crews uniformly high on GMA are likely to have improved shared mental models and better team performance (Edwards et al., 2006), the utility of recommending teams composed of high-GMA individuals is limited given that astronauts tend to be highly intelligent. Similarly, although there is evidence that mature, less age-diverse teams are more effective in analogue environments, most astronauts are 34 and there is already little variability in age; this will likely limit issues associated with age-diverse crews. A significant change in operations may lead to changes in the importance of team composition issues. In this final section, we provide recommendations surrounding team composition issues for LDSE.

Key Composition Variables Most Likely to have the Strongest Influence on Team Performance and Well-Being in LDSE

Cultural and Sex Differences

A failure in crew-level social integration (e.g., subgrouping, feelings of isolation, conflict) is a significant risk to LDSE team performance and well-being. Cross-cultural differences, particularly between astronauts and cosmonauts, were frequently tied to poor social integration. For these reasons, cross-cultural differences are the most significant team composition issue for LDSE. Future LDSE, such as a mission to Mars, will be an inspiring global achievement that will occur as a result of collaboration among international partners. Because of this, a crew that is comprised of members who have the same national background is not likely or desirable. In addition, crews are expected to be mixed-sex, which may affect social integration. Our first set of recommendations is focused on the effective management of crews diverse in national background and sex.

1. Some diversity configurations are more problematic than others. Avoiding particular diversity configurations that are more prone to subgrouping and alienation is a potential means of mitigating the risks associated with poor social integration while also allowing for the existence of nationality and sex diversity. Specifically, crews should be strategically staffed to avoid: (a) strong faultlines across sex and nationality (e.g., salient subgrouping characteristics should crosscut), and (b) token representation of "minority" team members. These approaches are explained in more detail below. The efficacy of managing diversity using these compositional approaches should be investigated in analogue environments.
    a. Research conducted on teams in traditional settings suggests that subgrouping is more likely to occur when "faultlines" are activated. Faultlines are "hypothetical dividing lines that may split a group into subgroups based on one or more attributes" (Lau & Murnighan, 1998, p. 328). Faultlines are activated when a subset of group members' attributes are salient and similar and are strongest when differences across several attributes (i.e., nationality, sex) correlate highly (Lau & Murnighan, 1998). An example of a team with a strong faultline would be a team in which all the women are also of the same nationality and all the men

are from nationalities different from the women. Teams with activated faultlines are more likely to form coalitions, have high levels of conflict, and have lower levels of satisfaction and performance (Jehn & Bezrukova, 2010). Strong faultlines result in fewer but more tightly knit subgroups, which may increase the chance of inter-group conflict and reduce communication (Lau & Murnighan, 2005). Further, faultlines are more disruptive to team functioning when teams have high autonomy (Molleman, 2005), a situation expected for LDSE.

An effective means of managing diversity and lowering the likelihood of subgroup formation due to faultlines is to crosscut a variable where subgrouping is likely to occur (i.e., sex) with a second variable (i.e., nationality). An example of a team in which sex and national diversity are crossed would be when the crew composition includes one female astronaut and one male astronaut who are both American and at least one female astronaut and one male astronaut from a different country. This crosscutting will result in a composition that has weaker faultline strength than a composition comprised of two female, American astronauts and four male, non-American astronauts. Decreasing the faultline strength reduces the likelihood that subgrouping will occur across sex or nationality. A crosscut diversity structure (e.g., where racial and job-function subgroup boundaries were crossed) weakened faultlines, enhanced information sharing, and improved decision-making in a sample of business students (Sawyer, Houlette, & Yeagley, 2006). The efficacy of crosscutting as a means to decrease the likelihood of subgroup formation along demographic status should be researched in analogue environments.

b. Token representation occurs when members of a particular group (e.g., people who have low sociostatus status) comprise less than 15% of the total group (Kanter, 1977). An example would be a crew comprised of one woman and six men. Missions with only one woman have been reported to be successful (e.g., Vostok 6 (Oberg, 1981); ISS, Kanas & Manzey, 2003), however, isolation of a particular crewmember and scapegoating may be more likely to occur when a crewmember is seen as a token representative. Challenges associated with token representation relate to the interaction between those in the 'dominant' and 'token' groups and include performance pressures, boundary heightening and isolation, and role entrapment (Kanter, 1977), all of which have been observed for minority members in space flight and analogue environments (see Leon, McNally & Ben-Porath, 1989, p. 176 for an example). Assigning token representatives to LDSE crews could put that person's well-being at risk and might affect overall team performance (Dion, 2004).

   Space flight may create additional hierarchies in terms of dominant as compared to token groups. For example, problems noted with a host-guest dichotomy parallel the effects observed in tokenism (Gushin et al., 1998; Gushin, Pustynnikova, & Smirnova, 2001; Lebedev, 1988). "Guests" are often treated as tokens (see Kanas et al., 2000a; Kanas et al., 2000b). Similar problems were indicated in our operational assessment interviews for an US astronaut in the minority status of a crew (i.e., flying with two cosmonauts). Future research could investigate which traits are associated with lower sociostatus among specific crews.

   c. It should be noted that the compositions described above should not be avoided to the extent that they result in barriers to entry for minority astronauts or are difficult given the specific functional expertise needed. The literature implicates additional means in which faultlines may be bridged, such as emphasizing the value of diversity (Homan, van Knippenberg, van Kleef, & De Dreu, 2007) or having strong leadership that creates a focus and commitment to shared objectives (van Knippenberg, Dawson, West, & Homan, 2011). The efficacy of these alternative solutions for managing LDSE should be explored through additional research.

2. While US astronauts interact with people from various countries (e.g., Japan, Canada, Russia), interviewees who participated in the operational assessment noted that cross-cultural issues arose when interacting with cosmonauts. The following factors may magnify cross-cultural differences and promote subgrouping between astronauts and cosmonauts: the amount of time spent together during training, language (i.e., astronauts speaking English together, cosmonauts speaking in Russian), the current structure of the ISS (two functioning subgroups), specific diversity configurations related to national backgrounds, and differences in space agencies' cultures and policies such as pay. Effective social integration for an LDSE multicultural crew will likely be contingent on how effectively these contributing factors are managed. For example, training astronauts and cosmonauts separately might result in subgrouping, whereas having astronauts and cosmonauts train together could potentially reduce subgrouping. Identifying and modifying situational factors and practices that contribute to failures in crew-level social integration among multicultural teams should be a priority.
3. Cross-cultural frustrations can be the result of more overt behavioral differences such as personal hygiene and housekeeping practices. These differences were suggested to be partially responsible for incidents of miscommunication and interpersonal conflict before, during, and after ISS missions (Tomi, Rossokha, & Hosein, 2001). The best way to resolve these differences may be to attend to crewmembers' cross-cultural understanding (e.g., selecting individuals with an interest in other cultures, providing cross-cultural training, encouraging shared experiences) and to establish agreed-upon living standards. For example, cross-cultural training and exposure to multicultural issues can help prepare teams for situations that may otherwise produce conflict (Matveev & Milter, 2004; Santy, Holland, Looper, & Marcondes-North, 1993).
4. Language differences will need to be actively managed. Although language differences do not seem to be a challenge for every crew (Sandal et al., 2011), language differences might be more of a problem when intra-crew tensions are high. Consistent with this, one of the astronauts who participated in the operational assessment noted that he experienced tension with the Russian commander of his mission; the commander made several disparaging comments to the press about the astronaut's Russian language skills. As mentioned, language differences can facilitate subgroup formation if subsets of

the crew share a dominant language. Finally, most cosmonauts and astronauts endorse the need for a common language in space crews (Kelly & Kanas, 1992). For these reasons, language differences need to be actively managed via agreed upon standards and training.

5. The distinction between culturally held values and individually held values has extremely important implications for the effective staffing of LDSE crews. Although individuals from certain cultures tend to endorse certain values, the values that people endorse at the individual-level serve as the deep-level differences that impact crew functioning (Sandal et al., 2011; Vinokhodova et al., 2012). Crews that share individual-level values should be able to form a bond around those values, which may significantly minimize the risk of subgrouping based on issues such as national background. Further research should be conducted to identify the specific shared individual-level values, attitudes, interests, and experiences that play a role in effective social integration in LDSE. These composition factors could then be integrated into LDSE staffing decisions while still allowing for a crew that is comprised of people from various national backgrounds.
6. Familiarity prior to missions was a consistent theme in terms of facilitating crew cohesion and positive relations. Familiarity can influence team effectiveness by having a positive impact on team processes and emergent states. For example, interpersonal knowledge can facilitate the development of efficient communication, coordination, and transactive memory systems (Stasser, Stewart, & Wittenbaum, 1995). However, familiarity can also result in some negative outcomes as a result of its effect on social integration. Specifically, new team members may have a difficult time adjusting to an already-cohesive unit and can become targets of scapegoating (Kanas et al., 2009; Kanas, 1998). An example of this can be seen with pre-mission training and current subgrouping in the ISS. US astronauts typically have more pre-mission interaction and training with astronauts from Japan, Europe, and Canada; there is less pre-flight interaction with cosmonauts. Varying levels of familiarity between crewmembers that are the result of differences in pre-mission training may contribute to the poor social integration sometimes observed between astronauts and cosmonauts. The extent that familiarity moderates team composition and outcome relationships over time in analogue environments is in need of research.
7. Although mixed-sex crews are not problematic for short-duration missions, a number of concerns were raised regarding mixed-sex crews in LDSE that will need to be addressed. The use of mixed-sex crews in LDSE is likely to benefit from agreed-upon standards regarding the treatment of women and acceptable sexual behavior; bioethical and logistical concerns (e.g., birth control) will also need to be resolved. Further, other composition variables that may help mixed-sex crews succeed can be managed at the point of team staffing. For example, Rosnet et al. (2004) found that women were subjected to inappropriate behavior and harassment more so when the women were also young. Because mixed-sex crews are expected in the LDSE, the interactive effects between sex composition and other composition variables and configurations should be researched in analogue environments. A summary of recommendations related to cultural and sex differences is provided in Table 5.

Table 5.
Summary of Recommendations: Cultural and Sex Differences

Cultural and Sex Differences

LDSE crews are expected to be diverse in nationality and sex. A failure in crew-level social integration (e.g., subgrouping, feelings of isolation, conflict) is a significant risk to LDSE team performance and well-being. Future research and practice should promote crew-level social integration.

Research Recommendations

- Some diversity configurations promote subgrouping and alienation. The efficacy of managing diversity by crosscutting salient subgroup differences and avoiding single or token representation of low socio-status characteristics should be investigated in analogue environments. Future research should also examine which traits are associated with lower socio-status among specific crew compositions.
- Research in analogue environments should be conducted to identify the specific shared individual-level values, attitudes, interests, and experiences that play a role in effective social integration of crews diverse in nationality and sex.
- Familiarity prior to missions was a consistent theme in terms of facilitating crew cohesion and positive relations. The extent that familiarity moderates team composition and outcome relationships over time in analogue environments is in need of research.
- The interactive effects between sex composition and other composition variables and configurations should be researched in analogue environments.

Practical Recommendations

- Identifying and modifying situational factors and practices (e.g., more pre-mission time spent with astronauts from some space agencies as compared to others) that contribute to failures in crew-level social integration among multicultural teams should be a priority.
- Cross-cultural frustrations can be the result of overt behavioral differences such as personal hygiene and housekeeping practices; these should be addressed by attending to crewmembers' cross-cultural understanding (e.g., selecting individuals with an interest in other cultures, providing cross-cultural training, encouraging shared experiences) and establishing agreed-upon living standards.
- Language differences need to be actively managed via agreed upon standards and training.
- The use of mixed-sex crews in LDSE is likely to benefit from agreed-upon standards regarding the treatment of women and acceptable sexual behavior; bioethical and logistical concerns (e.g., birth control) will also need to be resolved.

Personality

8. The effects of personality composition on team performance are understudied in LDSE analogues. Most analogue studies examined the effect of team personality composition in regards to compatibility and its effect on social integration and psychosocial adjustment (e.g., coping). While these outcomes are important, team personality composition also affects goal attainment, team processes, and emergent states that are needed during high workload periods. As such, personality composition provides a potentially fruitful but overlooked means for optimizing team performance in space crews. Future research should explore team composition on specific personality traits and how these may be helpful in the execution of highly interdependent team tasks, the transition between low and high interdependence tasks (called team task switching), and crew self-sufficiency.
9. There is some indication that assertiveness, extraversion, and the need for dominance influence team functioning and crewmember well-being in analogue environments and space flight and that the effects of these variables may be different from those observed in traditional teams (see below). Future research in analogue environments is needed to better understand acceptable ranges and optimal configurations on these variables.
    a. Extraverted individuals can be described as sociable, fun-loving, friendly and talkative (McCrae & Costa, 1987). In traditional teams, research suggests that teams composed of members high on extraversion are better performers than those composed of members low on extraversion (Barrick, Stewart, Neubert, & Mount, 1998; Bell, 2007). While traditional teams composed of extraverted individuals may do well, it may not be as desirable to staff crews who live and work in ICEs with extraverted astronauts. For example, introverted individuals are more tolerant of isolation (Francis, 1969, operational assessment interviews). Further, although the positive emotions associated with extraversion help crewmembers to provide support for one another (Leon et al., 2011), the activity level associated with this personality trait may be undesirable in a confined environment (Rosnet, LeScanff, & Sagal, 2000; Suedfeld, Steel, & Palinkas, 1992; operational assessment interviews). Crew compatibility issues may further complicate this issue. Research conducted on traditional teams suggests that individuals with complementary fit (an introverted individual with a more extraverted team, an extraverted individual with a more introverted team) are more attracted to their teams (Kristof-Brown et al., 2005); while teams whose members have different levels of extraversion have experienced friction in analogue environments and in space (Sandal, 2001, operational assessment). Thus, in ICEs, extraverted and introverted crewmembers may not appreciate their differences as has been observed in research on traditional teams.
    b. More recent team research has explored how facets of extraversion, such as assertiveness, are related to team functioning. Individuals high on assertiveness tend to be outspoken, forceful, and direct in their communications; they voice their opinions clearly and with confidence (Judge, Rodell, Klinger, Simon, & Crawford, 2013). In general, leaders who have moderate levels of assertiveness

have better social outcomes (Ames & Flynn, 2007). Some of the people who participated in the operational assessment suggested that there might be a need to move toward a shared leadership model in which different crewmembers will take a leadership role as warranted by their expertise. This may further implicate the importance of assertive behaviors but will also require crewmembers to successfully negotiate power and status dynamics. Further, closely related to assertiveness may be the need for dominance (Ray, 1981, cf. Jentsch & Smith-Jentsch, 2001). There is evidence from research in analogue environments as well as our operational assessment that multiple dominant members in isolated teams may be problematic for team functioning (Altman & Haythorn, 1967; Nelson, 1964; Sandal et al., 1995). This suggests that unless power dynamics are managed successfully, there is the potential for strained relationships among assertive crews or between assertive pairs in key leadership roles (i.e., commander and flight director).

Abilities, Expertise, Background

The DRM (2013) suggests that LDSE crews will be composed of a pilot, a geologist, a physician, a biologist, a mechanical engineer, and an electrical engineer. Further, astronauts currently come from both civilian and military backgrounds. Both of these have implications for effective team composition.

10. Crews composed of members who are both scientist and non-scientists may have competing priorities and friction. For example, during an oceanic research cruise, seamen were more interested in the crew and the operation of the vessel, and the scientists were most interested in data collection. Conflicts escalated to the point where some crewmembers intentionally destroyed data (Bernard & Kilworth, 1973, 1974; cited in Finney, 1991). Crewmember roles may also have an impact on psychological health. Scientists have reported fewer psychological problems than non-scientists in analogue settings since they can use free time to write up scientific work (Gunderson, 1968, cited in Kanas, 1998). Given the high and low tempo workloads expected in LDSE, ensuring crewmembers such as the pilot and the physician are also engaged in and value science may help reduce difficulties and facilitate a shared understanding of mission objectives and priorities among crewmembers.
11. Team composition should ensure that more than one team member could cover critical roles; for some roles (i.e., physician) it may be necessary to have multiple backup crewmembers. The results of our operational assessment suggest that the leadership (including a shared deputy commander which would rotate accordingly to needed expertise for the primary task), physician, and entertainer roles are important for LSDE success.
12. Self-sufficiency and the related adaptability needed by LDSE crews may require a shift in focus from specific KSAs to aptitudes. As plans for LDSE crystalize, critical competencies needed by the team as a unit should be systematically determined and included in team composition considerations. On a related note, the need for crews to be more adaptable

may implicate additional important team composition variables (e.g., LePine, 2005). Research in analogue environments should examine the team composition and team performance relationship when crews are required to be adaptable.

13. Astronauts can come from either civilian or military backgrounds. During our operational assessment, participants reported a mismatch between the military culture and the culture NASA will need for LDSE success. For example, leadership approaches consistent with military practices (i.e., autocratic leadership) was mentioned as being less effective for LDSE astronaut crews. Instead, more democratic, collective or shared leadership approaches were mentioned as being more ideal. If NASA shifts toward shared leadership and allows more autonomy to LDSE crews, the composition of the crew in terms of military background as well as its match with the culture of the broader mission team may have implications for LDSE crew performance and well-being. Additional research is needed to examine the role of diversity in terms of civilian and military background on LDSE team performance and well-being.

Team Size

14. The current DSM (2013) suggests a crew size of 6. Appropriateness of the crew size should be determined by operational constraints and the type of expertise needed during high workload periods. Larger crews are likely to have more task expertise and be more productive (Dudley-Rowley, Nolan, Bishop, Farry, & Gangale, 2001; Dudley-Rowley, Whitney, Bishop, Caldwell, & Nolan, 2002). They also have higher task mental efficacy (i.e., stronger beliefs in their capabilities to solve challenging problems and make good decisions; Hirschfeld & Bernerth, 2008), which could be important for LDSE crews because of their need to be self-sufficient. Crew size should not be maximized, however, to the extent that comfort (see Smith, 1969) and other basic needs are limited (e.g., privacy; creates competition for available resources such as treadmills). Further, decision-making rules to avoid deadlock should be put in place if even-numbered crews are used (Harrison, 2001).

Network Factors

15. Crew compatibility issues may also extend to relationships among the larger mission team. Our operational assessment indicated that compatibility between the crew and the flight director, between the crew and the CAPCOM, and between the commander and the flight director may influence team performance and well-being, particularly if compatibility influences communication, conflict resolution, trust, or shared mental models. A complete understanding of how team composition relates to mission success will involve integration of these network factors. Given the limited amount of research on team composition issues in multi-team systems (Millikin, Hom, & Manz, 2010), more research on how these network factors influence crew functioning is needed. A summary of recommendations pertaining to network factors as well as personality, abilities, expertise, background, and team size is provided in Table 6.

Table 6.
Summary of Recommendations: Personality; Abilities, Experience, and Background; Team Size; Network Factors

Personality

Research Recommendations

- The effects of personality composition on team performance are understudied in analogue environments. Future research should explore team composition on specific personality traits and how these may be helpful in the execution of highly interdependent team tasks, the transition between low and high interdependence tasks, and the crew's ability to be self-sufficient.
- There is some indication that assertiveness, extraversion, and the need for dominance influence team functioning and crewmember well-being in analogue environments and space flight and that the effects of these variables may be different from those observed in traditional teams. Future research in analogue environments is needed to better understand acceptable ranges and optimal configurations on these variables.

Abilities, Expertise, and Background

Practical Recommendations

- Given the high and low tempo workloads expected in LDSE, ensuring crewmembers such as the pilot and the physician are also engaged in and value science may help reduce difficulties and facilitate a shared understanding of mission objectives and priorities among crewmembers diverse in functional background.
- Effective composition will include individuals who can take on roles identified as important for LDSE success; namely, leadership (including a shared deputy commander which would rotate accordingly to needed expertise for the primary task), physician, and entertainer roles. It may be necessary to have strategic redundancies among crewmembers for critical roles such as physician.

Research Recommendations

- Self-sufficiency and the related adaptability needed by LDSE crews may require a shift in focus from specific KSAs to aptitudes. Research in analogue environments should examine team composition and team performance relationships when crews are required to be adaptable.
- Additional research is needed to examine the role of diversity in terms of civilian and military background on LDSE team performance and well-being, particularly if a shared leadership approach is planned for LDSE.

Team Size

Practical Recommendation - Appropriateness of the crew size should be determined by operational constraints (e.g., privacy, competition for resources) and the KSAs needed during high workload periods and self-sufficiency.

Network Factors

Research Recommendation - Crew compatibility issues may extend to relationships among the larger mission team. Given the limited amount of research on team composition issues in multi-team systems, more research is needed on how network factors such as the compatibility between the crew and the flight director influence crew functioning.

Methods of Composing Crews within Operational Constraints

16. Individual-based composition models are currently used to staff crews. While this approach is adequate for ISS missions, interpersonal compatibility and other composition factors should be considered when staffing LDSE crews. Team-based composition approaches, which account for interpersonal compatibility among crewmembers, are a necessary complement to individual-based methods.
17. Assessments of crew compatibility should be standardized and formally integrated into crew staffing. Informal, unstandardized approaches of assessment are more likely to be influenced by irrelevant information such as issues associated with organizational politics (Harris, Smith, & Champagne, 1995; Longenecker, Sims, & Giola, 1987) or applicants' personal characteristics such as age, race, or sex (Rudman & Glick, 1999; Shaw, 1972; Ziegert & Hanges, 2005). Informal assessment procedures also may result in data that are statistically unreliable (Viswesvaran, Ones, & Schmidt, 1996).
18. Future research is needed to develop and validate a team composition model that ties team composition to social integration, cooperation, coordination, communication, and psychosocial adaptation over time. Data collected from this research could inform a composition algorithm that could be used to make more informed staffing decisions, identify training needs, and anticipate the likelihood regarding whether certain problems (e.g., subgrouping) will occur. If such problems are identified, countermeasures could be developed.
19. Team-based models will be most effectively utilized if space agencies involved with an LDSE mission collaborate. First, research across space agencies would be used to develop a selection algorithm. Second, space agencies would need to assess potential crewmembers on key composition variables and allow the data to be used to make selection decisions. Third, an international committee would consider the compatibility of all crewmembers simultaneously (via the results of the selection algorithm or direct methods of assessment), and select the crewmembers composing the most compatible

crew. Russian researchers have already begun to explore the role of individual-level values in team functioning at the ISS (Vinokhodova & Gushin, 2014). Similarly, a team of international researchers explored individual-level values and crew functioning during the MARS-105 simulation (e.g., Sandal et al., 2011). Using interagency collaborative research programs to explore team composition issues and including research from other agencies in the development of the selection algorithm may help facilitate buy-in regarding team-based composition strategies. Team-based strategies can still be used, however, with varying levels of, or even little, interagency collaboration. For example, selection algorithms can be designed to assess whether potential crewmembers will be compatible with crewmembers that have already been selected.

20. Direct methods for assessing interpersonal compatibility could be integrated into the later stages of the selection process or used during team training simulations to examine the interpersonal compatibility and effectiveness of crews with different configurations. There is a need to further develop direct measures of crew compatibility that can be used to predict social integration, cooperation, coordination, communication, and psychosocial adaptation over time. For example, an assessment center or simulation could be designed to assess interpersonal compatibility using critical incidents and a team interaction analysis. This approach could also be extended to hyperbaric chamber simulations in the final stages of crew selection (Sandal et al., 1996). Methods that provide insights into social integration, efficient leadership structures, critical team processes, and emergent states (e.g., observation, relaxometer, Homeostat device, sociometry, mapping of shared team mental models), could be triangulated to determine which teams are more compatible. There is limited validation evidence for many of these methods; future research is needed to determine which methods lend critical insights into team functioning for LDSE crews.
21. Team composition information can inform training needs and guide countermeasure development. For example, an all-introverted crew may require assertiveness training to effectively engage in shared leadership. Although, it should be noted that personality traits and values are needs (Allport, 1951); when people are unable to express these traits, they may experience anxiety (Cote & Moskowitz, 1998; Wiggins & Trapnell, 1996). Thus, the efficacy of training interventions as a means of mitigating compositional risks in the long-term is needed. Personalized medicine acknowledges that not all humans have the same needs; these individualized needs should provide the basis for countermeasures in human space flight (Schmidt & Goodwin, 2013). In the same way, not all crews have the same needs. In-flight countermeasures could be mapped to specific crew compositions and risks. For example, for crews that are at risk for subgroup conflict, mission control could provide “critical” work that specifically calls on different subgroups to work interdependently.
22. Astronauts rely on psychologists and interaction with home as a means of coping with frustrations and managing conflict between crewmembers and with the ground. In its current form, this important countermeasure will be difficult or impossible to utilize due to expected time delays in communication. The development of a suitable alterative for LDSE is needed, particularly as interpersonal frustrations are anticipated to increase. A

summary of recommendations related to composing crews within operational constraints appears in Table 7.

Table 7.
Summary of Recommendations: Methods of Composing Crews within Operational Constraints

Practical Recommendations

- Team-based composition approaches, which account for interpersonal compatibility among crewmembers, are a necessary complement to individual-based methods when staffing LDSE crews.
- Assessments of crew compatibility should be standardized and formally integrated into crew staffing. Informal, unstandardized approaches of assessment are more likely to be influenced by irrelevant information such organizational politics and be statistically unreliable.
- Personalized medicine acknowledges that not all humans have the same needs; these individualized needs should provide the basis for countermeasures in human space flight (Schmidt & Goodwin, 2013). In the same way, not all crews have the same needs. Training needs and in-flight countermeasures should be linked to specific crew compositions and risks.

Research Recommendations

- Future research is needed to develop and validate a team composition model that ties team composition to social integration, cooperation, coordination, communication, and psychosocial adaptation over time. Data collected from this research could inform a composition algorithm that could be used to make more informed staffing decisions, identify training needs, and anticipate the likelihood regarding whether certain problems (e.g., subgrouping) will occur.
- Team-based models will be most effectively utilized if space agencies involved with an LDSE mission collaborate. Using interagency collaborative research programs to explore team composition issues and including research from other agencies in the development or validation of the selection algorithm may help facilitate buy-in regarding team-based composition strategies.
- Direct methods for assessing interpersonal compatibility could be integrated into the later stages of the selection process or used during team training simulations to examine the interpersonal compatibility and effectiveness of crews with different configurations. There is a need to develop direct measures of crew compatibility such as an assessment center or simulation that includes group tasks informed by critical incidents expected during LDSE and assesses interpersonal compatibility via a team interaction analysis. Methods that provide insights into social integration, efficient leadership structures, critical team processes, and emergent states (e.g., observation,

relaxometer, Homeostat device, sociometry, mapping of shared team mental models), could be triangulated to determine which teams are more compatible. This approach could also be extended to hyperbaric chamber simulations in the final stages of crew selection (Sandal et al., 1996). Validation is needed, particularly for some of the measures of team interaction.

- Astronauts rely on psychologists and interaction with home as means of coping with frustrations and managing conflict between crewmembers and with the ground. In its current form, these important countermeasures will be difficult or impossible to utilize due to expected time delays in communication. The development of a suitable alterative for LDSE is needed, particularly as interpersonal frustrations are anticipated to increase.

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Appendix A - Overview of LDSE Context

Table A1.

Overview of LDSE Context

	Description
Who?	The space crew works in conjunction with ground crew in order to complete mission objectives. Crew size is expected to be 6 members, likely determined by vehicle social density parameters. Crew is expected to be cross-functional and involve individuals with specialized knowledge including a pilot, a physician, geologist, a biologist, a mechanical engineer, and an electrical engineer. While the specific nationalities of crewmembers is not yet clear it will likely be a combination of astronauts from different countries such as the US, Russia, Europe, Canada, and Japan. The gender mix will be variable, although a specific composition has not been specified. Other crew composition factors are yet to be determined. Crews are composed from the pool of qualified astronauts who have been selected into and have completed astronaut training programs. In the US, admittance into the training program is highly selective, and astronauts are required to be college educated. Although not a requirement, astronauts often have a military background and an average age of 34. Historically, crews have had a specific designated leader (i.e., commander). The crew works collaboratively with mission control. Mission control is an extensive support staff of experts. A flight director and flight engineers constitute a primary flight controller team ("front room"), but additional experts are brought in for specific expertise ("back room"). Mission control coordinates with other space agencies, historically through a designated liaison (e.g., Russian Interface Officer).
What?	Crews will have both high- and low-tempo workloads. Planned high-tempo workloads are expected to be in sets of 2–3 and take place immediately, 6 months out, 24 months out, and 30 months out. The crew works interdependently with mission control, but autonomy will likely increase over the course of the expedition.
When?	Expeditions are long-duration. For Mars, the expected length is 30 months. Target dates for expeditions involve a several year cushion allowing for extensive training of crewmembers. Training is expected to be multiple years.
Where?	Crews will operate in isolated and confined space within a dangerous environment (e.g., outer space). Expeditions are likely long-distance, which has implications for the quality of the communication between the crew and mission control. Long-distances also suggest limited abort capabilities. Audio will likely have a delay of up to 22 minutes one way.
Why?	Mission planners decide on specific mission objectives. However, the general goal of human space exploration is to advance human presence in outerspace. Goals for Mars explorations include: (a) gaining new scientific knowledge of Earth and Mars, (b) supporting technological and economic growth, and (c) and inspiring global achievement via a collaboration of international partners.

Note. Taken from: Caldwell, 2005; DRM, 2013; NASA Voyages, 2014; “NASA Astronaut Selection”, 2014.

The unique context creates operational constraints to composing teams. First, team size is likely to be determined in part by vehicle size and social density, determined by the crew to vehicle ratio, and is currently set at 6 crewmembers. Crews will be diverse in terms of functional background (e.g., pilot, geologist, biologist), nationality, and sex. Constraints are also likely to influence staffing strategies used. For example, low abort capabilities, and extreme distance will make personnel changes mid-mission extremely difficult or impossible, implicating the importance of proper crew composition at the outset. An extensive astronaut candidate training program and other planned training of crewmembers suggests substantial opportunity to affect team processes (and possibly mitigate or capitalize on team composition effects) through training. International collaboration suggests that crew-level team composition staffing or training strategies will need to be a collaborative effort across agencies.

Table A2.
Salient Contextual Features Likely to Influence Team Functioning

Task context	Physical context	Social context
High and low workload	Confined space	High social density
High autonomy, likely to increase over mission duration	Long-distances traveled resulting in communication delays with ground control	Isolation from "home" and possibly other crewmembers at times
Mundane at times	Surrounded by a hostile environment	Living and working together
Small team supported by larger team on different schedules	Deep space radiation, which can affect concentration, memory, boredom, the ability to perform, and reaction time	Working with crewmembers from other cultures
Planning challenges given the unpredictability associated with longer-duration missions	Working in an environment with no gravity can make simple tasks more difficult to complete.	Living and working with crewmembers from different cultural and professional backgrounds and with mixed-sex crews
		Different agency objectives and organizational cultures
		Conflict with the ground where the ground crew is unable to understand the effects of zero gravity

Note. As summarized by Johns (2006), the task context originates from the specific work requirements inherent in the completion of performance objectives such as the degree of autonomy, uncertainty, and accountability faced by individuals, in addition to the presence or absence of available resources for task completion. The social context includes factors that emerge as a result of having to work with others such as the social density or social structure. The physical context reflects the arrangement of the physical environment in which the completion of mission-related tasks occurs.

Appendix B – Databases Searched

Database	Dates	Content
Academic Search Complete	1887-Present	Articles
Business Source Complete	1996-Present	Articles, Company and Industry Profiles
CINAHL Complete	1980-Present	Articles
Communication Abstracts	1977-Present	Articles
Communication and Mass Media		Articles
Education Research Complete		Articles
General Science Full Text		Articles
Military & Government Collection	1970-Present	Articles
PsychArticles	1884-Present	Articles
PsychCritiques		Articles
PsychInfo	1887-Present	Articles, Dissertations and Theses
Sociological Abstracts	1952-Present	Articles, Dissertations and Theses
ABI/Inform	1971-Present	Articles
Applied Social Sciences Index and Abstracts		Articles
Proquest Dissertations and Theses Full Text	1637-Present	Dissertations and Theses
ERIC		Articles
Proquest Nursing and Allied Health Source		Articles
Proquest Social Sciences		Articles
Army Publishing Directorate		Technical Reports
Defense Technical Information Center		Technical Reports
FDsys		Government Documents
Library of Congress Technical Reports		Technical Reports

and Standards		
NASA Technical Reports		Technical Reports
National Technical Information Service		Technical Reports
National Technical Reports Library		Technical Reports
Science.gov		Articles and Technical Reports
Technical Report Archive & Image Library		Technical Reports
US Army Medical Department: Medical Research and Material Command		Technical Reports
Books 24x7		E-books
E-print Network		Articles
Google Scholar		Articles, Books, Reviews
International Bibliography of the Social Sciences		Articles
JSTOR	1900-Present	Articles, Reviews
Sage Journals		Articles
Science Direct	1996-Present	Articles
Social Science Research Network		Articles
Social Sciences	1983-Present	Articles, Reviews
Web of Knowledge	1980-Present	Articles
Wiley Online		Articles

Appendix C – Search Terms

	Search Terms
Cluster 1	Team OR Crew
Cluster 2	composition OR staffing OR selection OR personality OR values OR demographics OR diversity OR "member attributes" OR KSA OR ability OR abilities OR fault-line OR "human capital" OR "member attributes" OR size OR culture OR experience OR motivation OR role OR resiliency OR intelligence
Cluster 3	"isolated work" OR isolation OR "confined space" OR "cross cultural" OR "extreme environment" OR Antarctica OR aviation OR "environmental medicine" OR confinement OR "extreme distance" OR "high-fidelity environment" OR high-risk OR long-duration OR long-distance
Cluster 4	exploratory OR exploration OR space flight OR missions OR NASA OR astronaut OR cosmonaut OR Mars OR lunar OR ISS OR "Greenland station" OR "Russia 520" OR "remote weather station" [All simulations (e.g., SFINCSS ’99); were search separately as well]

Appendix D – Journals Searched

Academic Emergency Medicine: Official Journal of the Society for Academic Emergency Medicine
Academic Medicine
Academy of Management Proceedings
Academy of Management Review
Acta Astronautica
Acta Psychologica
Administrative Science Quarterly
Advances in Space Research
Aerospace Research Central
African Journal of Business Management
Annual Review of Psychology
Applied Ergonomics
Aviation, Space, and Environmental Medicine
CA Magazine
Communications of the ACM
Computers & Industrial Engineering
Computational Intelligence
Current Directions in Psychological Science
Ergonomics
European Journal of Operational Research
European Journal of Personality
European Journal of Work and Organizational Psychology
Group dynamics: Theory, Research, and Practice
Group & Organizational Studies
Group & Organization Management
Human-Computer Interaction
Human Factors
Human Resource Management Review
Human Resource Management
International Journal of Aviation Psychology
International Journal of Cross Cultural Management
International Journal of Human-Computer Studies
International Journal of Industrial Ergonomics
International Journal of Productivity Management and Assessment Technologies
International Journal of Selection and Assessment
Journal of General Psychology
Journal for Healthcare Quality: Promoting Excellence in Healthcare
Journal of Applied Psychology
Journal of Applied Social Psychology,
Journal of Business and Psychology
Journal of Management Information Systems
Journal of Occupational and Organizational Psychology
Journal of Organizational Behavior
Journal of Personality and Social Psychology
Journal of Research in Personality
Journal of the American College of Surgeons
Journal of Work and Organizational Psychology
The Lancet
Management Science

McGill Journal of Medicine
National Productivity Review (Wiley)
Occupational Psychology Review
Organization Science
Organization Studies
Organizational Behavior and Human Decision Processes
Organizational Dynamics
Performance Improvement Quarterly
Personnel Psychology
Personnel Review
Project Management Journal
Psychologist-Manager Journal
Planetary and Space Science
Quality & Safety in Health Care
Research in Organizational Behavior
Research in Personnel and Human Resources Management
Safety Science
Small Group Research
Team Effectiveness and Decision Making in Organizations
The Mount Sinai Journal of Medicine
Theoretical Issues in Ergonomics Science
Translational Behavioral Medicine
World Journal of Surgery

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13. ABSTRACT *(Maximum 200 words)*
Team composition, or the configuration of team member attributes and their relations, is a key enabling structure of effective teamwork. A large body of research supports the importance of team composition; however, much of it is based on teams that operate in traditional workplaces. Given the unique context within which long-distance space exploration (LDSE) crews will operate (e.g., isolation, confinement), we sought to identify psychological and psychosocial factors, measures, and combinations thereof that can be used to compose highly effective crews. We conducted a focused literature review and operational assessment related to team composition issues for LDSE. Our goals were to: (1) identify critical team composition issues and their effects on team functioning in LDSE-analogous environments with a focus on key composition factors that will most likely have the strongest influence on team performance and well-being, and (2) identify and evaluate methods used to compose teams with a focus on methods used in analogous environments. We summarize results in terms of the two primary paths through which team composition relates to mission success, indirect and direct methods of assessing compatibility, and the themes from our operational assessment. Recommendations for research and practice regarding effective team composition for LDSE are provided.

14. SUBJECT TERMS

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