A Comprehensive Look Behind Team Composition for Long Duration Spaceflight

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BACKGROUND: How to determine team composition is one of many key topics when developing humanity's next deep space exploration programs. Behavioral health and performance among spaceflight teams are key aspects impacted by team composition and cohesiveness.

METHODS: This narrative review highlights areas of consideration for building cohesive teams in long duration spaceflight environments. The authors gathered information from a variety of team-behavior related studies that focused on team composition, cohesion, and dynamics, as well as others topics such as faultlines and subgroups, diversity, personality traits, personal values, and crew compatibility training.

RESULTS: The literature suggests that team cohesion occurs more easily when individuals are similar to one another, and deep-level variables such as personality and personal values have a greater impact on crew compatibility than surface level variables such as age, nationality, or gender. Diversity can have both positive and negative impacts on team cohesiveness.

CONCLUSION: Team composition, as well as pre-mission conflict resolution training can greatly impact group cohesion. This review aims to map areas of concern and assist with crew planning for long duration spaceflight missions.

KEYWORDS: human spaceflight, extreme environment, team composition, subgroup, gender.

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Humanity is entering an exciting new era of space exploration. With the introduction of the U.S.-led Artemis Program, the Chinese Lunar Exploration Program, and growing commercial activity in human space exploration, humanity's presence in outer space is expanding. While development is ongoing for these proposed activities, questions remain regarding who will be sent on these exploration-class missions.

Compatible crew teams are imperative to ensure the success of long-duration missions. Investigations across the literature have been explored to better understand the intricacies behind team composition and the most promising variables, some of which are listed below, that can predict a team's behavior.

- Deep-level variables take time to emerge, but they highly contribute to team cohesion.
- Mixed-gender crews display some advantages to team cohesion compared to all-male crews.
- Subgroup formation and groupthink pose threats to crew performance.
- Individualistic and collectivistic orientations of an individual play an important role in forming their personality and personal values.

This paper will discuss many such variables by examining findings reported across spaceflight literature as it relates to team composition and conflict resolution training.

Team cohesion is affected by both surface level (e.g., age, race, gender) and deeper level (e.g., personality traits, personal values) characteristics, which must be considered when composing long duration spaceflight (LDSF) crews. As outlined in the NASA Human Research Roadmap,[27] there are further descriptors to consider in crew compatibility assessments. Several deep-level psychological factors can be predictors of team performance,[2] but the driving elements of these factors are poorly understood. Elements such as communication tendencies, team cohesion and coping strategies, cultural diversity, individualism vs. collectivism, personality traits and personal

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values, and the dynamics between insider and outsider groups are all elements that affect team performance. Even when composing highly compatible crews, pre-mission training is highly important to further foster group compatibility.[11,21]

METHODS

This manuscript serves to outline some of the most prominent categories impacting team cohesion for LDSF crews. We began this analysis by reviewing topics related to developing teams for space exploration provided under the NASA Human Research Roadmap.[27] This provided keywords and topic categories to explore through our wider survey across various digital repositories containing prior works in these areas (including PubMed, Google Scholar, and ResearchGate).

This review discusses emerging topics such as the potential issues associated with the development of romantic relationships in long-term isolated groups and their implication in future LDSF missions. It also discusses how established topics such as groupthink, subgrouping, scapegoating, and other social phenomena should impact the selection criteria for LDSF crews. It further discusses pre-mission training strategies, which can help with addressing group conflict before it becomes unmanageable. Included are several analog studies of polar environments, as these are widely considered to be analogous to spaceflight environments, as well as several spaceflight simulation studies, including SIRIUS-19, Mars-105, Mars-500, and HI-SEAS II, III, and IV.

No environment on Earth is a perfect analog to spaceflight, and isolation study participants are not subjected to as stringent selection criteria as astronaut crews. These studies, however, provide valuable insight into potential pitfalls which may be experienced by future LDSF crews.

RESULTS

Team Cohesion

The psychological function of individual members of a crew is highly impactful to mission success. Although many factors in LDSF environments will impact the crew's psychological well-being, prime among them is crew composition and its impact on team cohesion.[25] In past missions, astronauts were selected on an individual basis.[10] Highly skilled individuals were selected based on their ability to perform a task, with little regard given to their interactions in a team setting.[35] In NASA astronaut culture, self-confidence became a central characteristic early in crewed spaceflight, and behavioral problems were not prioritized by NASA for this reason.[41] This contrasts with the selection process of Russian cosmonauts. Psychological problems caused by the isolated environment of space have long been recognized by the Russians, who have a history of psychological training and testing before flight.[19,21] Since the construction of the International Space Station (ISS), NASA, the European Space Agency (ESA), and other agencies have increasingly recognized the importance of psychological factors and of astronauts' abilities to work as a team.[10,26] Individual-based methods of determining crew selection, such as "the right stuff", are good at predicting individual performance, but do not account for how individual skill and team dynamics will combine to impact the desired mission outcomes.[3] Team composition researchers have demonstrated that traditional selection methods, which are focused on selecting the best person for each role, may not produce the most successful crews.[6,30,35] Selecting compatible crewmembers will become increasingly important as spaceflight duration increases. Mission planners ought to assemble teams of individuals that have compatible personality traits.[31] Cohesion will be more easily obtained by assigning compatible members to a team instead of forcing harmony between incompatible individuals.

Cohesion in a crew can be defined as "the degree to which group members desire to remain in the group". This term can be divided into two camps: 1) interpersonal cohesion, and 2) task cohesion.[25] Interpersonal cohesion refers to the individuals' attachment and relationships with each other. LDSF will require a certain amount of interpersonal cohesion among crewmembers due to the isolated and confined conditions. Task cohesion refers to the individual team members' commitment to a shared goal and is generally considered to have more impact on team success than interpersonal cohesion.[25] In tasks measuring team performance under temporal stress, Zaccaro and Lowe found that groups with a high degree of task cohesion performed better than other teams, but that interpersonal cohesion had no effect on team outcome.[25,46] However, in a simulated survival experiment where teams were tasked with ranking 15 items in order of importance to the situation, Zaccaro and McCoy found that groups that ranked high in both task and interpersonal cohesion outperformed any other team cohesion combination.[25,47] A crew ranking highly in both interpersonal and task cohesion will likely perform best in LDSF missions because they will demonstrate a "shared commitment to the task" while also satisfying the social needs of the group.[25] Both surface-level variables and deeper-level variables can contribute to group cohesion.[3,6] Cohesion is more easily obtained when individuals are similar to one another. Initially, surface-level attributes detract from group cohesion.[6] These variables increase demographic faultlines (hypothetical dividing lines that split groups into homogeneous subgroups based on aligning demographics or values), and subgroups (smaller groups of individuals with similar attributes within the larger group) may form.[6] Any individual difference can create faultlines, but gender and racial diversity have been found to increase faultline strength more than diversity in other categories.[3] However, surface-level differences are less impactful with time and group exposure, and they are found to have less significance on team cohesion than deeper-level variables in closely knit groups.[37] Cohesion can also be encouraged through group training and pre-mission contact.[21] Individuals tend to form close relationships with those they frequently encounter[3] and this tendency can be used to strengthen relationships between crewmembers before crew

departure. Although cohesion is found to improve group performance in tasks that require coordination, rely on communication, or take place in complex task environments, it can also cause problems within isolated groups.[3,25] Cohesion can encourage groupthink, a social phenomenon that occurs when a group's desire for harmony causes members to agree to popular in-group decisions without critical evaluation, leading to faulty decision-making outcomes. In some cases, individual behaviors that do not contribute to productivity can become a group norm and reduce overall performance.[25] LDSF is a prime environment for the development of groupthink behaviors due to the space crew's small size and separation from outside personnel.[10] Characteristics of groupthink include illusions of invulnerability, reluctance to disagree with decisions made within the group, and stereotyped views of people outside the group. Groupthink often develops as a coping mechanism used to "ensure cohesion and group agreement" within small and isolated groups.[39] It can also lead to disharmony between the spaceflight crew and mission control (MC) due to a tendency for the isolated group to displace negative emotions onto MC personnel rather than to fellow crewmembers.[6] Thus, groupthink poses a substantial threat to crew performance[26] and indicates that "promoting group cohesion" and "maintaining positive relationships within a group" will not necessarily result in successful mission outcomes.[39]

Subgroup Formation

Space analog studies have found that subgroups can form based on surface-level variables such as gender and nationality, as well as on nondemographic characteristics such as values.[6,34] Subgrouping is not always harmful, but it can result in conflict that could be detrimental to mission success.[6] Members of a subgroup generate beliefs and attitudes about insiders and outsiders of the group, which can be a barrier to communication and acceptance of ideas between subgroups.[37] Surface-level characteristics such as race, gender, and profession are immediately evident, and are an easy basis for faultlines, which could lead to the formation of homogeneous subgroups.[37] The alignment of multiple subgroups strengthens faultlines, further separating the subgroup from the whole. Subgroups can have a disruptive effect on crew performance because when a group or individual does not integrate into the crew, it can result in "withdrawal or isolation".[6] Furthermore, the isolated group or individual is then at risk of becoming the subject of group hostilities and is often the "scapegoat" blamed for problems experienced within the group.[6] Crosscutting subgroups to ensure that individuals belong to multiple subgroups within the overall team helps to promote individual- rather than subgroup-based interactions.[37] Mars-105 tested several hypotheses regarding the efficiency of several new criteria for group and individual psychology for a crewed mission to Mars.[44] One hypothesis under study was that culturally heterogeneous crews are a risk factor for the development of group cohesion.[45] This hypothesis was made on the basis that individuals in culturally diverse groups may differ in value-orientation and may hold preconceived ideas of one another's values.[45] The study consisted of six participants: four Russians and two representatives of ESA. It was found that the group fractured into stable subgroups by the end of the isolation period. By the midpoint of the isolation period, there was a decrease in crew cohesion, resulting in pairs forming among the group who preferred to communicate with each other rather than with the group as a whole. Closer relationships between some subjects and tension between others were based on mutual perceptions of similarity. In other words, subgroups formed among individuals who perceived other members to be similar to themselves.[45] The data were found to be "in close agreement with the hypothesis" that culturally heterogeneous groups are a risk to a well-consolidated crew. However, some of the pairs formed were among crewmembers from diverse cultural backgrounds, and these pairs formed more on the basis of similar value orientations than on any cultural characteristics. The study also found that the development of pairing was related to the lack of a functional role structure and the lack of a strong leader who could unite the crew as a whole.[45] Though the risk of subgroup formation may be higher among culturally heterogeneous crews, the fracturing of the crew into subgroups could potentially be mitigated by defining crewmembers' roles, including a group leader who encourages unity and group participation among crewmembers. In spaceflight, values such as "working hard", "working with others", "personal goals and achievements", "hedonism", and values within "collectivism vs. individualism" are all important variables that can form the basis of a subgroup.[4,6] LDSF crews will spend an extensive amount of time together, so compatible deeper-level variables are likely to be very important to compatible crew composition. During crew training and preparation, cultural and gender stereotypes often contribute to crewmates' perception of each other's values.[6,32] Surface-level differences provide clues for quick categorization, but time and exposure tend to neutralize the negative effect of surface-level differences.[37] Conversely, although deep-level variables take time to emerge, their impact on group cohesion strengthens as crews gain more experience interacting with one another.[37]

Gender Composition

There are several aspects to consider regarding sex and gender and its impact on LDSF. Here we will focus on the impact of gender on crew composition and cohesion. Several analog studies have found that the addition of women to isolated groups has either a positive or neutral effect on team cohesion.[25] Women were first permitted in U.S Antarctic stations in 1969.[40] Captain Brian Shoemaker, a former commander of U.S Support Force Antarctica led all-male crews early in his career and later commanded integrated crews. He observed that women had a stabilizing force in the winter-over parties.[40] More importantly, he found that male-female integrated crews were more productive than male-only crews from the past. Other experienced Antarctic managers supported this observation.[40]

Although mixed gender crews have been found to be more cohesive and productive than all male crews,[40] there are concerns to be considered. Romantic relationships have been found

to have a disruptive effect on crew interaction and cohesion.[40] Persistent, unwanted attention has occurred and has a negative impact on the pursued party. Gender can be a stressor for both men and women when the groups are of a similar age, and interpersonal problems related to sexual tension in mixed gender crews can negatively affect crew performance.[25] For example, in HI-SEAS II, III, and IV (i.e., HM4, HM8, and HM12), the crews were not provided with guidelines regarding crew relationships and were given the freedom to decide on relationship boundaries as a team. As a result, romantic relationships formed in "at least one" of the studies. To protect crew privacy, the number of relationships and the specific studies in which each relationship occurred were not disclosed. But it was recorded that "at least one" relationship ended during the course of a study that resulted in strain among the crew. The end of this relationship led to "at least one" additional romantic relationship in the crew, which caused further distress. Although several crewmembers were opposed to romantic relationships among the crew, most were supportive of, or indifferent to, potential romantic relationships. Further, "at least one" stable relationship formed in a crew that lasted through the end of the experiment, with both participants remaining integrated with the rest of the crew, which helped to "stabilize group dynamics and provide comfort".[16]

The possibility of romantic relationships among crewmates in heterogeneous and homogeneous crews should not be ignored when composing LDSF crews. These relationships can have a disruptive effect in crew interactions, but whether romantic relationships should be prohibited between crewmates or if crews should be allowed to use their own discretion in LDSF missions is yet to be determined.[16,25] Further study of the effects of romantic relationships in isolated crew environments on team moral would likely help determine the necessary guidelines for crew romantic interactions in LDSF environments. The increased stability observed in mixed-gender crews in analog environments suggests that pitfalls associated with sexual tension can be avoided in properly trained crews.[40]

The intersection of gender and cultural background is also a source of contention in mixed-gender crews.[6,39] According to Goel et al. "some space-faring cultures have lower expectations and hold negative stereotypes about the role and ability of women".[12] Different cultures have varying expectations about appropriate interactions between genders. These expectations can lead to division between crewmembers.[28] However, it is important to remember that cultural and gender sensitivity training can mitigate these misunderstandings.[22] Stuster notes in "Bold Endeavors Lessons from Polar and Space Exploration" that "problems appear to have been not directly attributed to mixed crews, but rather to the behavioral consequences of immaturity, faulty personnel selection, and inadequate pre-mission training for both male and female members of the crew".[40]

Several analog studies of mixed gender groups in extreme or isolated environments have been conducted, but studies of all-female crews in environments comparable to spaceflight are less common. Here we will examine four studies: one mixed gender confinement campaign and three all-female analogs:

1. SIRIUS-19, a confinement campaign lasting 4 mo that studied the nonverbal and verbal behaviors of a Russian-American crew of six individuals: three men and three women.[39,43]
2. A team of six British military women who completed an expedition to traverse the Antarctic continent.[8]
3. A multinational four-woman crew engaged in a 6-wk trek across Greenland.[29]
4. A four-woman Antarctic expedition team who successfully skied to the South Pole, but failed to meet their original goal of traversing the Antarctic Continent.[17]

In the SIRIUS-19 study, nonverbal and verbal data collected from six test subjects, three men (two Americans, one Russian) and three women (Russian), were analyzed to determine behavioral patterns between crewmates in isolation.[43] Factors such as facial expressions, visual/body/object interactions, interaction and lack of interaction between subjects, etc., were recorded to investigate the differences between male and female coping strategies in isolated environments. The data showed that female subjects ranked highly in facial expressions, such as smiling and laughing, compared to men, who were more interactive than female subjects. Collateral actions, which are indicators of discomfort, were more prevalent in male subjects (453 demonstrations) compared to female subjects (361 demonstrations). These data suggest that: 1) collateral actions could be a cause of stress on group interactions, and 2) women's expressive behavior could indicate an action that facilitates involvement in group life.[43]

In SIRIUS-19 the 'tend-and-befriend' stress response was also monitored in participants.[39] "Tend-and-befriend" is an alternative stress response to fight-or-flight characterized by an increase in prosocial behavior expressed by providing support to others (tend) then seeking support from them in turn (befriend). The study found that both men and women displayed high levels of emotional energy, supporting the hypothesis that tend-and-befriend behavior is displayed by both genders. These results were also found to be true in Mars-500, an all-male study where emotional energy was found to gradually increase during the entire study.[39]

Both men and women invest in social relationships during confinement, but in past studies women have been found to display more concern for the well-being of crewmates than men. Stress is compounded for women in mixed-gender groups as opposed to all female groups.[28] Leon explains in "Men and Women in Space"[28] that, "while men confided problems and concerns to women in the group, there was not a reciprocal expectation or encouragement for women to share their concerns with their male teammates." This stands in contrast to what was observed in SIRIUS-19, where both male and female participants exhibited high levels of emotional investment in crewmates. Leon also explains that in all-male expedition teams, members rarely share personal concerns with teammates and have shown "patterns of strong competitiveness" between members. But observations made of mixed-gender

Antarctic work groups show that women will sometimes take on the role of "peacemaker" in small groups, which helps to reduce competition and tension between male participants.[28,29]

The all-female military trek displayed investment in crew interaction and viewed "honesty in communication" as essential to the group's success.[8] A leading source of conflict in the group's dynamic was a disagreement about the "pace vs. distance" strategy for completing the trek.[8] The group held evening meetings to plan a strategy for the following day's trek where members stated their opinions, although the group leader decided the final strategy. Tension grew in the group during the second half of the expedition in which two crewmembers wanted to ski for longer periods each day to achieve a greater daily distance, while the remainder of the group wanted to continue with the leader's plan to maintain a steady pace and avoid injury.[8] The conflict was resolved by the leader who called members to discuss "personal goals vs. team goals" to determine shared team goals they could agree to. Tension was noted between the team's leader and a subordinate member of the team; however, the leader's effective communication strategy helped to avoid the creation of faultlines within the group.[8] This suggests that an effective leader can encourage group cohesion. As discussed in the case of Mars-105, the pairing of study participants began at the midpoint of the study and communication between the group as a whole was reduced due to participants' preference for communication within their subgroups.[45] Within the all-female military trek, a strong faultline could have formed on the basis of different pace vs. distance strategies. Communication between the crewmembers encouraged by the group leader helped to dilute the possibility of subgroup formation on this emerging faultline.

Both the nonmilitary all-female Antarctic trek and the Greenland trek expressed concern for the well-being of teammates as a primary stressor in the group.[17,29] This contrasts with findings in mixed-gendered crews, where interpersonal concerns were second to environmental concerns. Overall, female crewmembers express more concern than men about maintaining interpersonal relationships. Evaluations of Antarctic groups accumulated over 10 yr have indicated that interpersonal tension negatively impacts both men and women, but lack of group cohesion has a greater impact on women than men.[13,29] Both nonmilitary female crews reported social support as a primary coping mechanism in times of stress.[17] The hypothesis under investigation in the all-female Antarctic trek was that an all-female group in an isolated and extreme environment would be comparable to a mixed-gender group, but would display more sensitivity to emotional concerns. This hypothesis was supported in the study and there is favorable evidence for the all-female trek in Greenland to support this claim as well. The all-female military trek placed a high value on group communication and group members outside of the leader's conflict with a subordinate crewmember claimed to have been affected by the conflict and the group mood. With few studies conducted on all-female groups, these findings may be group dependent rather than universal.

Examinations of mixed-gender groups in isolated environments have indicated that heterogeneous crews are more productive and cohesive than all-male crews of past decades.[40] More studies are needed on crews composed entirely of female participants to reach definitive conclusions about female crews operating in extreme environments. Although there could be issues inherent in mixed-gender crews, including sexual tension and jealousy, they can be mitigated by proper training and careful crew selection.

Diversity in Cultures, Nationalities, Values, and Personalities

Cultural diversity, diversity in nationalities, and diversity in personality traits and personal values are significant factors regarding crew composition.[18]

Cultural diversity. When looking at cultural diversity, one important topic is collectivism vs. individualism. Collectivism gives priority to the group and individualism gives priority to the individual. These two cultural styles have huge implications for communication behavior, self-guiding goals, and an individual's outward perception.[14] Characters with individualistic values tend to value achievement and independence, personal responsibility, and their personal goals over those of the group.[7] Collectivist individuals value group goals over individual goals and avoid seeking competition and personal recognition in groups.[14]

All individuals fall somewhere on the 'individualism-collectivism continuum'.[14] Palinkas et al. conducted a study on individualistic-collectivistic cultures stemming from distinct nationality groups (United States, Russia, Poland, China, and India) participating in an 8-mo isolation and confinement study.[33] It was found that in more collectivist cultures (Russia and China), individuals avoided burdening team members with emotional stresses (Chinese team), but also sought support from fellow team members (Russian team). Individuals from more individualistic national cultures (United States) were less likely to seek emotional or material support from others.[33]

Diversity can be divided into three subcategories: separation, variety, and disparity.[7,15] These subcategories serve as the basis for understanding more typical variables in diversity (e.g., culture, race/ethnicity, and gender).[7,15] It can be unclear what should be considered a "diversity variable of interest". Clear and universally accepted definitions for diversity variables are lacking.[7,15] Bell et al. argues in "Getting specific about demographic diversity variable and team performance relationships: a meta-analysis" that the reason for so many ambiguities and inconclusive results reported in other work regarding diversity is due to the oversimplification of diversity within these studies.[7]

Diversity in nationalities. Diversity of nationalities in team composition merits additional investigation.[5] Organizations worldwide (NASA, Roscosmos, Japan Aerospace Exploration Agency, ESA, Canadian Space Agency, Chinese National Space Administration, etc.) have all contributed astronauts toward

space-based activities. The degree of cross-nationality interaction is a key consideration for future space exploration programs. Nationality can be used as a surface-level indicator of personal values, as individuals tend to uphold the cultural values of their nations.[6] Personal values are a deeper-level variable that can affect team cohesion.[6] As such, diversity of nationalities can have a negative effect on team cohesion when personal values among the crew do not align.[6] However, Bell et al. state that a review of crew diaries across 10 space-missions/analogs have suggested that nationally heterogeneous crews experience less deviant behavior than homogeneous crews.[6] This evidence indicates that diversity of nationalities in LDSF missions can have either a positive or negative affect on crew cohesion.[6]

In the early years of spaceflight, one nation's space agency would host crewmembers from other nations.[42] These missions of multinational crews were fraught with dissatisfaction and frustration on the part of the "guest" nations. Division was not only based on nationality but also on the status of "host crews" and "guests". Guests were rarely granted full coworker status by hosting crews and they were often prevented from doing meaningful work. Although the host typically spoke well of their foreign colleagues, they distrusted their competence operating the "home team's" spacecraft. This changed with the creation of the ISS. Multinational crews are now the norm rather than the exception.[12] Space exploration benefits from multinational collaboration, which supplies a larger pool of talent, encourages diplomacy between nations and defers a great deal of expense. But if one nation leads the expedition to Mars it will be important to avoid an insider-outsider dichotomy among multinational crews, both in the ship and with ground control. International crewmembers occasionally have had language barriers with a foreign nation's MC or felt isolated due to lack of support from an MC that had different expectations from that of their home nation.[24] A truly international Mars mission should consist of not only a multinational flight crew, but also a mission control with representatives from multiple nations.

One study looked at the values and interpersonal perception of other crewmembers from the perspective of cosmonauts.[44] This study showed emergent features of certain individual traits and personal values and showed that the cosmonauts tended to idealize their foreign counterparts while being more critical of their fellow cosmonauts.[44] More research is needed on multinational-mixed crews, especially those containing crewmembers from countries with fast-growing space capabilities.

Personality traits and personal values. Introversion vs. extroversion, adherence to tradition, individualism vs. collectivism, self-direction, and many other character attributes affect the dynamics of a team. This section will explore two categories: personality traits and personal values.[1]

Personality traits at the team-level (such as "agreeableness") should be highly considered when selecting astronauts for LDSF missions.[6] Anania et al. expresses a dichotomy of 'selecting in' vs. 'selecting out' candidates, which emphasizes the need to understand team-based personality considerations.[1] In "Psychology and culture during long-duration space missions", the authors argue that selection of astronauts should not only consider individual personality traits, but also interpersonal skills, with recognition that "agreeableness" and "low aggressiveness" have led to higher performing teams.[18] Individual crewmember selection must be considered in the context of how a given member will perform on the team. One disagreeable team member can disrupt the performance of the entire crew.[6]

Corneliussen et al. conducted an analysis of 10 Danish military personnel deployed to Greenland on a 26-mo rotation to study personality traits, personal values, and the development of conflict in isolated and confined environments (ICE) to evaluate their relevance to potential LDSF crews.[9] The participants completed a variety of assessments/questionnaires (e.g., Portrait Values Questionnaire, Triarchic Psychopathy Measure, structured interviews, and the NEO PI-R) and it was determined that the most successful individuals displayed a "dominance of positive traits and a low propensity for callous and emotionally dysregulated behavior".[9] Positive traits included high levels of boldness (adventurous, emotionally resilient, socially poised), benevolence (being well meaning), consciousness (a desire to do all tasks well and to place importance on obligations to others), and agreeableness (kind, sympathetic, cooperative, etc.).[9] Personal values held by individuals may contribute to their adjustment to ICE. Subjects who self-identified and displayed "stability over time with values of hedonism (enjoyment), self-direction, and benevolence" tended to perform well in ICE.[9] The value of benevolence was also found to contribute to a sense of camaraderie within the group, which Corneliussen et al.[9] suggests may be of particular importance for maintaining cohesion in small groups in ICE. This field study helps to identify positive personality traits that may be useful in LDSF crews. However, it must be noted that the subjects of this study "were not comparable to astronauts/cosmonauts in academic and professional level".[9] In addition, the group studied was all men, and thus may not be fully applicable to mixed-gender or all-female groups.

Personal values are a broad set of goals which motivate a person's actions and serve as their guiding principles. There have been several studies regarding the analysis of personal values in teams.[36,38,45] In a 105-d simulated space mission with six men (two Russian cosmonauts, one Russian medical doctor, one Russian sports physiologist, one German mechanical engineer, and one French airline pilot), the individuals were given a portrait-value questionnaire once a month and certain personal values were rated higher than others.[36] The entire crew was divided into three subgroups that were centered on certain personal values (one subgroup valued hedonism, the second subgroup valued tradition, conformity, and benevolence, and the third subgroup had less distinct personal values overall).[36] The investigation found that personal values tended to become more heterogeneous among the crew over time and argues that personal values are important for understanding interpersonal compatibility.[36]

A study looking at interpersonal perceptions of cosmonauts across several ISS missions found values of motivation,

intellectual level, knowledge, self-discipline, sociability, and friendship as some of the most important values among the crewmembers.[44] Self-direction, stimulation, universalism, and benevolence are among the highest rated values among crews.[38] Values of tradition, security, achievement, and power were rated low among participants.[38] Some values may be situationally dependent and not universally applicable.[36] These studies point to similar trends in benevolence and self-motivation as some of the most important personal values to hold when considering space exploration class missions.

Dynamic Crew Training

Deep-level values take time to emerge in teams who work closely together, but it is unlikely that selected crewmembers possess all the optimal characteristics in the ideal proportions.[20] Even within highly compatible and cohesive crews, some degree of conflict will be unavoidable. Even though selecting compatible individuals for LDSF may help reduce the potential for irreconcilable conflicts, this does not reduce the need for group training in conflict resolution practices.[19,21] Kass et al. suggests that from the time of crew selection to flight, dynamic group training sessions should be a part of astronaut preflight training, as this will provide crews with experience and strategies to maximize team effectiveness and resolve conflict.[19]

Kass and Kass suggest that there are essential areas of group processing that lead to developing an effective team.[20] These areas include morale, norms, decision-making, handling conflict, and power and leadership struggles.[20] Groups who have been trained in group processing "tend to promote greater psychological health and intragroup management, increased ability to cope with stress and adversity, and increased ability to work toward a shared goal".[20] Such groups also display increased tolerance and appreciation for cultural differences and the advantage of having differing perspectives available to solve a problem.[20] In addition, in the all-military Antarctic trek discussed in "Gender Composition", it is evident that the presence of a strong leader capable of leading the group in decision-making discussions to resolve conflict was effective in preventing the formation of a potential faultline, suggesting that a leader and crew who are effective in these areas are less prone to subgrouping than groups less versed in decision making, handling conflict, and power and leadership struggles.[8] However, it has been shown that leaders have the ability to "contribute stability or add stress" to the group environment.[22] And studies undertaken by Kass et al. have indicated that group reactions to situations do not tend to shift from pre- to post-mission assessments, indicating that changes in handling conflict and communication styles do not occur naturally and need to be trained in crews to achieve the desired results.[22,23]

In a 264-d spaceflight simulation that analyzed conflict handling models of three crews of four people, it was found that all crews scored highly for "accommodating", and lower in "collaborating", with middling scores in "competing, avoiding, and compromising".[23] There was no statistically significant change in these behaviors in the pre- to post-isolation portions of the experiment.[23] Accommodating behavior is used to maintain a cooperative environment among crew, but can be over relied upon and discourage collaboration.[23] Collaborative crews will "merge perspectives and integrate solutions"[23] while accommodation is an expedient way to avoid immediate conflict.[23] An overreliance on accommodation can lead to problems not being addressed and a buildup of tension both within the flight crew and between the flight crew and MC.[23] Crews trained in conflict management may be able to better handle conflicting ideas among crewmembers and promote collaboration rather than accommodation.[22,23] A crewed mission to Mars will require coordination between multiple teams. Conflict will arise within and between these teams, but it is possible for groups to identify and resolve potentially serious conflicts before they become unmanageable.[21,23]

In conclusion, as humanity ventures beyond low Earth orbit, it will become increasingly important to assemble not just competent, but compatible crews. A crewed mission to Mars will necessitate longer periods of isolation and confinement than were experienced by spaceflight crews in the past. With communication delays from the spacecraft to Earth lasting up to 40 min, crewmates will need to rely on one another during times of crisis and boredom alike. It will be essential to provide careful consideration to crew selection to maximize compatibility and cohesion.

This paper discussed the impact of surface- and deep-level variables on team cohesion and determined that deeper level variables such as personality and personal values will have a greater impact on crew compatibility overall than surface level variables such as nationality and profession. A cohesive group will operate as a unit and not fracture into subgroups. Characteristics such as gender, race, nationality, and profession will impact crew cohesion and can be foundations for subgroups, but there is no evidence with regard to crew compatibility to suggest that diversity in these categories is inherently incompatible. Even in highly compatible crews, dynamic group training sessions pre-mission are advisable to maximize the crew's ability to manage conflict.

A final note of consideration is the importance of social support and enthusiasm for an endeavor as monumental as a crewed mission to Mars. Space agencies are already renewing exploration outside of low Earth orbit. Many space agencies and even private organizations are likely to participate in LDSF ventures in the coming decades. Collaboration between nations has occurred throughout the history of spaceflight and is likely to intensify as humanity takes its next steps out into our solar system. Group compatibility and cohesion can be achieved across demographic lines. When composing future LDSF crews, we ought to remember that the triumph of exploration need not be owned by one nation, gender, or race, but shared by all humanity.

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REFERENCES

1. Anania EC, Disher T, Anglin KM, Kring JP. Selecting for long-duration space exploration: implications of personality. IEEE Aerospace Conference; March 4-11, 2017; Big Sky, MT. New York: IEEE; 2017:1–8.
2. Bell ST. Deep-level composition variables as predictors of team performance: a meta-analysis. J Appl Psychol. 2007; 92(3):595–615.
3. Bell ST, Brown SG. Selecting and composing cohesive teams. In: Team cohesion: advances in psychological theory, methods and practice research on managing groups and teams. Vol. 17. Bingley (UK): Emerald Group Publishing Ltd.; 2015:181–209.
4. Bell ST, Brown SG, Abben DR, Outland NB. Team composition issues for future space exploration: a review and directions for future research. Aerosp Med Hum Perform. 2015; 86(6):548–556.
5. Bell ST, Brown SG, Mitchell T. What we know about team dynamics for long-distance space missions: a systematic review of analog research. Front Psychol. 2019; 10:811.
6. Bell ST, Brown SG, Outland NB, Abben DR. Critical team composition issues for long-distance and long-duration space exploration a literature review, an operational assessment, and recommendations for practice and research. Houston (TX): NASA Johnson Space Center; 2015. Report No.: NASA/TM-2015-218568. [Accessed April 12, 2023]. Available from https://ntrs.nasa.gov/citations/20140016953.
7. Bell ST, Villado AJ, Lukasik MA, Belau L, Briggs AL. Getting specific about demographic diversity variable and team performance relationships: A meta-analysis. J Manage. 2011; 37(3):709–743.
8. Blackadder-Weinstein J, Leon GR, Norris RC, Venables NC, Smith M. Individual attributes, values, and goals of an all-military women Antarctic expedition. Aerosp Med Hum Perform. 2019; 90(1):18–25.
9. Corneliussen JG, Leon GR, Kjærgaard A, Fink BA, Venables NC. Individual traits, personal values, and conflict resolution in an isolated, confined, extreme environment. Aerosp Med Hum Perform. 2017; 88(6):535–543.
10. De La Torre GG, van Baarsen B, Ferlazzo F, Kanas N, Weiss K, et al. Future perspectives on space psychology: recommendations on psychosocial and neurobehavioural aspects of human spaceflight. Acta Astronaut. 2012; 81(2):587–599.
11. Dinges DF. Behavioral health and performance: an overview. In: Young LR, Sutton JP, editors. Encyclopedia of Bioastronautics. New York: Springer International Publishing; 2019:1–3.
12. Draguns JG, Harrison AA. Spaceflight and cross-cultural psychology. In: Vakoch DA, editor. Psychology of space exploration: contemporary research in historical perspective. Washington (DC): NASA; 2012: 177–194.
13. Goel N, Bale TL, Epperson CN, Kornstein SG, Leon GR, et al. Effects of sex and gender on adaptation to space: behavioral health. J Womens Health (Larchmt). 2014; 23(11):975–986.
14. Gundlach M, Zivnuska S, Stoner J. Understanding the relationship between individualism-collectivism and team performance through an integration of social identity theory and the social relations mode. Hum Relat. 2006; 59(12):1603–1632.
15. Harrison DA, Klein KJ. What's the difference? Diversity constructs as separation, variety, or disparity in organizations. Acad Manage Rev. 2007; 32(4):1199–1228.
16. Heinicke C, Poulet L, Dunn J, Meier A. Crew self-organization and group-living habits during three autonomous, long-duration Mars analog missions. Acta Astronaut. 2021; 182:160–178.
17. Kahn PM, Leon GR. Group climate and individual functioning in an all-women Antarctic expedition team. Environ Behav. 1994; 26(5): 669–697.
18. Kanas N, Sandal G, Boyd JE, Gushin VI, Manzey D, et al. Psychology and culture during long-duration space missions. Acta Astronaut. 2009; 64(7–8):659–677.
19. Kass J, Kass R, Samaltedinov I. Psychological considerations of man in space: problems & solutions. Acta Astronaut. 1995; 36(8–12):657–660.
20. Kass R, Kass J. Group dynamics training for manned spaceflight and the capsuls mission: prophylactic against incompatibility and its consequences? Acta Astronaut. 1995; 36(8-12):567–573.
21. Kass R, Kass J. Psycho-Social Training for Man In Space. Acta Astronaut. 1999; 45(2):115–118.
22. Kass R, Kass J. Team-work during long duration isolation. In: 52nd International Astronautical Congress; 1-5 Oct. 2001; Toulouse, France. Paris (France): International Astronautical Federation; 2001:1–5.
23. Kass R, Kass J, Binder H, Kraft N. Conflict-handling mode scores of three crews before and after a 264-day spaceflight simulation. Aviat Space Environ Med. 2010; 81(5):502–505.
24. Kraft NO, Lyons TJ, Binder H. Intercultural crew issues in long-duration spaceflight. Aviat Space Environ Med. 2003; 74(5):575–578.
25. Kring JP, Kaminski MA. Gender composition and crew cohesion during long-duration space missions. In: Vakoch DA, editor. Psychology of space exploration: contemporary research in historical perspective. Washington (DC): Government Printing Office; 2012:125–139.
26. Landon LB, Slack KJ, Barrett JD. Teamwork and collaboration in long-duration space missions: going to extremes. Am Psychol. 2018; 73(4): 563–575.
27. Landon LB, Vessy WB, Barrett JD, Schmidt LL, Keeton K, et al. Risk of performance and behavioral health decrements due to inadequate cooperation, coordination, communication, and psychosocial adaptation within a team. Human research roadmap. 2016. [Accessed April 12, 2023]. Available from https://humanresearchroadmap.nasa.gov/risks/risk.aspx?i=101.
28. Leon GR. Men and women in space. Aviat Space Environ Med. 2005; 76(6, Suppl):B84–B88.
29. Leon GR, Sandal GM. Women and couples in isolated extreme environments: applications for long-duration missions. Acta Astronautica. 2003; 53(4–10):259–267.
30. Mathieu JE, Tannenbaum SI, Donsbach JS, Alliger GM. A review and integration of team composition models: moving toward a dynamic and temporal framework. J Manage. 2014; 40(1):130–160.
31. Nakushian A, Deaton JE. Issues facing crew selection for long duration space flight missions. International Journal of Aviation Research. 2020; 12(1):20–34.
32. Palinkas LA. Psychosocial issues in long-term space flight: overview. Gravit Space Biol Bull. 2001; 14(2):25–33.
33. Palinkas LA, Johnson JC, Boster JS, Stanislaw R-S, Klopov VP, et al. Cross-cultural differences in psychosocial adaptation to isolated and confined environments. Aviat Space Environ Med. 2004; 75(11): 973–980.
34. Palinkas LA, Suedfeld P. Psychosocial issues in isolated and confined extreme environments. Neurosci Biobehav Rev. 2021; 126:413–429.
35. Salas E, Tannenbaum SI, Kozlowski SWJ, Miller CA, Mathieu JE, Vessey WB. Teams in space exploration: a new frontier for the science of team effectiveness. Curr Dir Psychol Sci. 2015; 24(3):200–207.
36. Sandal GM, Bye HH, van de Vijver FJR. Personal values and crew compatibility: results from a 105 days simulated space mission. Acta Astronaut. 2011; 69(3–4):141–149.
37. Sawyer JE, Houlette MA, Yeagley EL. Decision performance and diversity structure: comparing faultlines in convergent, crosscut, and racially homogeneous groups. Organ Behav Hum Decis Process. 2006; 99(1):1–15.
38. Smith N, Sandal GM, Leon GR. Examining personal values in extreme environment contexts: revisiting the question of generalizability. Acta Astronaut. 2017; 137:138–144.

39. Šolcová I, Vinokhodova A, Gushin V, Kuznetsova P. Tend-and-befriend behaviour during spaceflight simulation. Acta Astronaut. 2022; 191:79–87
40. Stuster J. Group interactions. In: Stuster J. Bold endeavors: lessons from polar and space exploration. Annapolis: Naval Institute Press; 2011: 175–181.
41. Stuster JW. Behavioral challenges of space exploration. In: Young LR, Sutton JP, editors. Handbook of bioastronautics. Cham: Springer; 2021.
42. Suedfeld P, Wilk KE, Cassel L. Flying with strangers: post reflections of multinational space crews. In: Vakoch DA, editor. Psychology of space exploration: contemporary research in historical perspective. Washington (DC): Government Printing Office; 2012:143–175.
43. Tafforin C. Behaviors of a mixed gender and culture group during a 4-month confinement (SIRIUS-19). Antrocom Online Journal of Anthropology. 2020;16(1):5–19. [Accessed April 12, 2023]. Available from http://www.antrocom.net/archives/2020/volume-16-number-1-2020.html.
44. Vinokhodova AG, Gushin VI. Study of values and interpersonal perception in cosmonauts on board of International Space Station. Acta Astronaut. 2014; 93:359–365.
45. Vinokhodova AG, Gushchin VI, Eskov KN, Khananashvili MM. Psychological selection and optimization of interpersonal relationships in an experiment with 105-days isolation. Hum Physiol. 2012; 38(7):677–682.
46. Zaccaro SJ, Lowe CA. Cohesiveness and performance on an additive task: evidence for multidimensionality. J Soc Psychol. 1988; 128(4):547–558.
47. Zaccaro SJ, McCoy MC. The effects of task and interpersonal cohesiveness on performance of a disjunctive group task. J Appl Soc Psychol. 1988; 18(10):837–851.