International Journal of Aviation Research

Volume 12 | Issue 01 Peer-Reviewed Article

Issues Facing Crew Selection for Long Duration Space Flight Missions

Andrew Nakushian
Florida Institute of Technology

John E. Deaton
Florida Institute of Technology

This paper looks at the issues facing the selection and composition of a crew for a long-duration mission to Mars. It also considers the many psychological and physiological challenges that crew members will face on long-duration space flight. These factors are important because the United States has set ambitious goals of returning to the Moon and going to Mars. The United States has expressed that it intends to set up permanent settlements on both of these bodies. A thorough review is necessary to determine gaps in research that need to be addressed before a safe flight. After a review and discussion of previous research and industry practices, multiple areas of future research were identified. The areas of future research include crew personality, conflict resolution, and mental health. Previous research indicates that the use of the Antarctic as a research analog could aid in answering these and other questions regarding long-duration space flight. This topic of research is important because the United States has expressed interest in returning to the Moon for extended missions and eventually journeying to Mars.

Recommended Citation:

Nakushian, A., & Deaton, J. (2020). Issues Facing Crew Selection for Long Duration Space Flight Missions. *International Journal of Aviation Research, 12*(01), 20-34.

Introduction

The United States is involved in a new space race. However, this race is not between superpowers; it is between private companies. In 2018, the United States announced that the new priority for the space program was to send American astronauts back to the Moon by the year 2024 and eventually to Mars. This new goal is ambitious and rivals President John F. Kennedy's ambitious goal of landing a man on the Moon before the 1960s decade ended; a goal that was achieved with the landing of Apollo 11 in July of 1969. The challenges associated with sending a crew to Mars are even more immense than those related to sending a crew to the Moon. However, companies like SpaceX, Boeing, and Blue Origin are attempting to meet this challenge.

The trip to Mars is approximately six months in each direction, making the round trip at least a year (Munk, 1999). A technical report by Munk (1999) explains the primary goal for mission designers has been to reduce the amount of time in zero gravity conditions meaning a flight would have to occur when the two planets are at their closest. Between the cost of sending a crew up and the logistical challenges set by the orbits of both Mars and Earth, the time on the surface would be approximately 500 days. This would make the entire mission 860 days or just over two years. For this discussion, the length of a Mars mission will be operationally defined as an even two years. The Mars mission will be further defined as consisting of a six-month journey to Mars, a year spent on the surface of Mars, and a six-month return journey to Earth.

While the engineering challenges presented by this goal are immense, there is another set of challenges equally as crucial to mission success. This set of challenges involves crew selection. If the crew does not interact well, then the mission's success will be thrown in jeopardy. The purpose of this paper is to evaluate the existing literature from the past twenty years regarding the United States' space program and identify the major human factors related challenges facing the crew selection process of long-duration space missions. It also seeks to identify areas where further research is needed to develop a set of crew selection criteria for the long-duration missions of the future.

Status of Current Research

History of Astronaut Selection Criteria

In the past, astronauts were all Navy or Air Force Test Pilots, which resulted in them all being young men in their late 20s and 30s. This requirement was the result of a mandate from President Eisenhower that ordered that all astronauts must have been active military test pilots (Sandal, Sgobba, Clervoy, & Kanki, 2018). The National Aeronautics and Space Administration (NASA) took this mandate and required that all candidates have:

> A degree in science or engineering, be a graduate of a military test pilot program, have at least 1500 flying hours, be younger than 40 years old, be no taller than 5'11", be in superb physical condition, and possess specified psychological attributes (724-5).

Sandal et al. (2018) explain that while there was no explicit ban on women joining the astronaut corps, the strict requirements made it nearly impossible for women to join and impossible for civilians. It was not until the Space Shuttle program that women and civilians could apply and join NASA's Astronaut Corps.

With the launch of the Space Shuttle program, NASA still wanted the best of the best, but the mission profile had changed. As a result of the changing mission, the crew selection requirements had to be changed. The Space Shuttle missions required mission specialists who were crewmembers that aided in the conduct of experiments. These changing mission criteria led to the need for non-pilot crew members in addition to pilots (Sandal et al., 2018). As a result of the need for mission specialists, the requirement of high-performance jet experience was removed. While flight experience was no longer mandatory, there were strict requirements that Astronaut Corps candidates had to meet, which remain in effect to this day.

Current Astronaut Selection Criteria

Currently, there are medical requirements, academic requirements, and general requirements that must be met to be selected to be an astronaut. First and foremost, NASA Astronauts must be American citizens. Medically, applicants must be in good health and have a vision that is correctable to 20/20 in each eye separately. Applicants also must have a strong academic and professional background. NASA requires astronaut applicants to have at least a bachelor's degree in engineering, biological science, physical science, computer science, or mathematics (Dunbar, 2015). On top of this, NASA requires a minimum of three years of professional experience in a STEM-related field. Graduate school can qualify for the work experience requirements as well. A master's degree in an approved field of study can qualify as one year of work experience, and a doctorate can count for all three (Roemer, personal interview, 2019). One-thousand hours of jet pilot experience can also qualify for the work experience requirement. Additionally, NASA considers teaching experience, including K-12 education, as qualifying professional experience as they want educators to apply for the program (Sandal et al., 2018). Combinations of the two are evaluated on a case by case basis.

Once an applicant meets the initial requirements, the application is sent to a review board, consisting of NASA management and current astronauts, which reviews applicants in the second round of the application process (Roemer, personal interview, 2018). This review board assesses the applicant's educational preparation, work experience, technical skills, and teamwork experience. During this phase, the applicants are assessed as to which ones are most suitable for the current set of missions and openings in the program. After the evaluation board makes its decisions, applicants will be called in for an interview. An astronaut job interview is as unique as the position being applied for. The applicant finalist is brought down to Johnson Space Center in Houston, Texas, and the applicant is interviewed in person as well as undergoes multiple practical interviews. These practical interviews measure teamwork, technical skills, and decision making. If the interview team is satisfied with the applicant at that point, he/she is accepted into the program for training. At this point, the applicant is called an astronaut candidate or ASCAN (Sandal et al., 2018).

This lengthy three-phase application process was designed to ensure that only the best and most qualified applicants get accepted into the astronaut program. The job of an astronaut is very demanding, both cognitively and physiologically. Any mistake can be a catastrophic one in space, especially as long-duration missions become more common in the coming decades. NASA also wants to make sure that the candidates for the astronaut program will make it through the lengthy and costly training process that has to occur before the candidates are mission ready.

NASA also sets general requirements which are based on the training needed to become an astronaut. The medical, academic, and work requirements are used as a method of choosing astronaut candidates. In order to officially be selected as a member of the astronaut corps, a candidate must successfully pass intensive training that lasts approximately two years (Dunbar, 2015). The intensive training includes SCUBA as well as G-force training. If the candidates are pilots, they will maintain flight proficiency in NASA aircraft for the duration of this training. Should the candidate fail to complete the training process satisfactorily, he/she will be terminated from the program.

For commercial astronauts, the selection requirements are quite different. Since commercial astronauts are not government employees like NASA astronauts, for the purposes of regulation, they are treated as a regular civilian pilot. Like all pilots, the standards for certification are established by the Federal Aviation Administration (FAA). The FAA requires that all pilots of space flight vehicles hold a valid commercial pilot certificate and an instrument rating (14 CFR §460.5). The Instrument Rating was required since space flight vehicles pass through Class A airspace on launch and reentry (Human Space Flight Requirements for Crew and Space Flight Participants, 2005). Additionally, the FAA requires training and experience to allow the pilot to safely control the vehicle. The pilot will also have to hold at minimum a second-class medical certificate in order to exercise the privileges of their commercial pilot certificate pursuit to the Federal Aviation Regulations.

Beyond that, there are no additional FAA requirements to become a commercial astronaut. The remainder of the astronaut selection criteria is up to the individual companies. Currently, it appears all commercial astronauts have prior NASA experience, but that is not a legal requirement. In the eyes of the FAA, as long as a candidate passed a commercial pilot checkride and passes their annual medical, they are qualified to become a commercial astronaut. This presents an interesting safety issue since, legally speaking, a 250-hour commercial pilot with an instrument rating and a second-class medical would be eligible to start training to operate a commercial spacecraft. Private companies are permitted to set requirements exceeding the minimum standards set by the FAA, which it is almost certain that they will; however, there is no requirement to do so. While this may not currently be an issue as the number of commercial space flight operations increases over the next decades, it is something to keep in mind.

Crew Personality

Personality and crew dynamics are essential for the success of any complex mission. The commercial airline industry has focused on promoting crew resource management (CRM) to reduce accidents (Muñoz-Marrón, 2018). CRM is the process of "optimal use, by an aircrew, of all available resources (information, material equipment, and human resources) for the achievement of safe and efficient flight operations (Lauber, 1984)." CRM training has been used by airlines since the early 1980s and has been credited with preventing numerous accidents

(Muñoz-Marrón, 2018). NASA itself has been using a form of CRM called Space Flight Resource Management (SFRM) since the mid-2000s (Pruyn and Sterling, 2006.) One of the critical attributes of CRM and SFRM is communication. If the communication among the astronauts breaks down for any reason, it could result in the breakdown of SFRM. Candidates for long-duration space missions would have to be receptive to SFRM training.

Typical airline flights last a few hours at maximum, but long-duration space missions could very well last a few years. Keeping the crew dynamic harmonious for years on end will be a difficult task for mission planners to accomplish. Palinkas (2001) explains that previous research combined with anecdotal evidence from both American and Russian crews suggests that as mission length increases, the amount of interpersonal conflict inflight also increases. Failure to maintain a harmonious crew dynamic could very well prove to be catastrophic. The long-duration space flight environment is hard to replicate on Earth. The crew on long-duration space flights would have no ability to leave the vehicle and have limited communication with ground control.

As a result of the limited ground communication, crews need to be high functioning and self-sufficient (Harris, 2009). High functioning crews possess the following traits: high levels of commitment, competence, concern for completing tasks/achieving goals, and have high outputs. Additionally, a high functioning crew member is competitive against him/herself but not others. This trait is crucial in a multi-crew member system where the crew is expected to work together. Harris (2009) claims that the best way to make sure crewmembers possess these traits is only to recruit individuals who possess these traits. He also states that NASA should be recruiting the best of the best and use them as role models for new crewmembers.

Harris (2009) also explains that before departure, crewmembers should be trained in leadership and conflict resolution techniques. The crew will need to have synergy. During the mission-design process, planners should assign members to a crew that has compatible personality traits. It is easier to simply assign people who are harmonious together than it is to try to force synergy between people who are not.

An article by Musson et al. (2004) explains that the use of personality testing is essential for long-duration space flight since some personality profiles do better under stress than others. Additionally, candidates for space missions also need to be receptive to crew resource management (CRM) training. The Musson et al. (2004) study administered personality inventories to three classes of astronaut candidates. It found that astronaut candidates scored higher in conscientiousness, extraversion, and agreeableness. The authors explain that while these are traits that many candidates possess, merely possessing them does not predict final selection into the Astronaut Corps.

A study by Mittelstädt et al. (2016) looked at personality traits of astronauts selected by the European Space Agency (ESA) and found that successful astronaut candidates score higher on agreeableness and extraversion, which supports the findings of the Musson et al. (2004) study. Mittelstädt et al. (2016) also found motivation and instrumentality to be personality attributes of successful astronaut candidates. The authors explain that instrumentality was seen as a personality attribute that was related to the emotional stability of crews on Antarctic missions. The personality profile developed by Musson et al. (2004) and supported by

Mittelstädt et al. (2016) is called the "right stuff" personality. The authors explain the "right stuff" or the personality required to be a successful astronaut is not a single train but a combination of traits that together make a candidate successful in astronaut selection.

Astronaut applicants applying for NASA are currently required to take the NEO Five-Factor Inventory and the Personal Characteristics Inventory. This is to check for the "right stuff" attributes identified in previous literature (Anania et al., 2017). Anania et al. (2017) explain that one of the issues with personality assessments is that they are not always the most accurate. The authors explain that social desirability could result in applicants answering in a way that results in higher scores. This could explain how Musson et al. (2004) found no significant differences between successful astronaut applicants and unsuccessful astronaut applicants.

Crew Psychology

Maintaining the psychological health of the crew is essential. If a crew member has a psychological breakdown, the mission and safety of the remaining crew could be put in jeopardy. The main change regarding the addressing of the psychological concerns associated with long-duration space missions is that there are limited data as very few people have spent over a year in space/spacecraft (Basner et al., 2014).

An article by Lugg (2005) draws parallels between long-duration space flight missions and expeditions to Antarctica. Lugg explains that long-duration expeditions to Antarctica are similar to space missions in that crewmembers are isolated away from other people, the environment is harsh, and there is limited communication to back home (2005). Lugg also explains how, during the winter, there is little to no prospect for medical evacuation (2005). He argues that the psychological effects researchers in Antarctica have experienced could predict the psychological effects of a long-duration mission in space. Throughout the history of Antarctic exploration, there have been reports of psychological distress from the researchers and crew stationed there. Lugg also expresses how Antarctica does not have the radiation or microgravity of space. This reality prevents Antarctica from being an exact analog. However, it is a starting place in the absence of data from space.

A study by Basner et al. (2014) looked at the psychological changes of a crew involved in a simulated 520-day mission to Mars. The crew lived in a pressurized space station simulator and performed daily tasks as if they were in space. They also had to conduct experiments as if they were in space. The crew took a battery of tests that measured psychological and behavioral measures. The psychological battery consisted of the Social Desirability Scale, Visual Analog Scale, Profile of Moods Scale, Beck Depression Inventory, and a conflict questionnaire. (Basner et al., 2014).

The results of the study indicate that overall the crew did not suffer from depression as a result of the mission simulation (Basner et al., 2014). There was a slight uptick in the manifestation of the symptoms of depression but not to the degree that it could be claimed that the mission caused them. One participant did show high levels of psychological distress and symptoms of depression. The authors argue that this one participant's symptoms could explain the slight uptick in depression symptoms. However, the slight uptick could also be because the crewmembers did not report their actual depression symptoms due to social desirability. The study indicated that the crew became more sedentary and slept more throughout the mission. The authors explain that this is indicative of a need to develop coping mechanisms to avoid becoming sedentary over long missions. Two of the six participants showed no psychological or behavioral symptoms throughout the study. In comparison, the remaining four participants showed a varying range of symptoms. There were relatively few inter-crew conflicts, and most of the conflicts were between the crew and mission control.

Two of the limitations of the Basner et al. (2014) study were that the effects of radiation and microgravity could not be replicated in the simulated habitat. This meant that the main physiological stressors of the space flight environment could not be replicated. The authors explain how this limits the generalizability of the results. Additionally, the study used an all-male sample, which means it is not representative of potential all-female crews or mixed-gender crews. The single-sex sample is also a limitation because the researchers do not know whether the stress of long-duration space flight affects females differently than males. A final limitation of the study that the authors did not consider is that since the crew is on Earth, a quick rescue is possible in the event of an emergency. This possibility does not exist in the space flight environment. The knowledge of the fact that a rescue is possible could have a confounding influence on the behavior and stress levels of the crew.

A study by Wood et al. (2005) looked at data collected by a joint NASA and Australian Antarctic Division. The authors explain how the remote and extreme environment of Antarctica is considered a good analog for long-duration space flight as both are extreme environments. The study used a computer questionnaire that was developed in 1993. This was chosen as the method as the data could be transmitted back from Antarctica automatically as opposed to having to ship back paper forms. The NASA researchers administered the questionnaire to a six-man crew on a multi-week tractor train expedition. They did this during the 1993 and 1994 seasons. The data showed that leadership effectiveness decreased, and interpersonal tensions increased over the multi-week missions.

The primary limitation of Wood et al. (2005) study was that it had a small sample size. The authors only looked at a few six-person teams. This means that while the data can point to exciting results, it must be understood that the data cannot be effectively generalized to all Antarctic missions or space missions. However, what the Wood et al. results are good for is indicating an area for future research.

A study by Kraft et al. (2003) looked at intercultural issues among long-duration space flight crews. The authors explain that there is a lack of psychological data on spaceflight crews because astronauts/cosmonauts are concerned that information given in the course of the studies could negatively affect their careers. They explain that psychological issues in crewmembers could place the mission in jeopardy. The authors also report that there have been reports of interpersonal issues between members of space crews as well as between space crews and ground control personnel. The authors also cite Antarctic missions where psychological problems and issues with crew dynamics have nearly put the mission in jeopardy.

Crew Medical Factors

The long-term effects of the exposure to the radiation and micro-gravity are unknown.

NASA conducted a well-publicized twin study in 2015. NASA sent Scott Kelly to spend a year on the International Space Station while his identical twin brother Mark remained on Earth. This experimental design would allow a comparison between subjects with identical genetic structures to highlight the changes that occur due to exposure to the space environment (Garrett-Bakelman et al., 2019). The NASA Twins Study was a longitudinal study that consisted of a 340-day stay on the International Space Station and 25 months of follow up tests after the flight subject returned to Earth.

The researchers collected data on physiological, telomeric, transcriptomic, epigenetic, proteomic, metabolomic, immune, microbiome, cardiovascular, vision-related, and cognitive measures (Garrett-Bakelman et al., 2019). In total, they collected data from 317 samples taken from both subjects. Samples taken in flight were shipped back down to Earth onboard Russian Soyuz spacecraft. The data indicated that there were multisystem changes to the flight subject's body throughout the mission.

The flight subject had an increased telomere length as compared to the ground subject at the end of the mission (Garrett-Bakelman et al., 2019). They had similar length telomeres before the mission. The increase in telomere length has been found in other studies of astronauts, and the exact reason for this elongation is still unknown at this time. There also was evidence of more telomerase activity in the flight subject than the ground subject. However, the authors note that the telomerase was destroyed in transit from the ISS. The flight subject also showed changes in his immune system function after the 340-day mission. Researchers found increased levels of cytokines in blood plasma that remained elevated six months after the flight subject's return from space. Some of these cytokines are involved in "mediating inflammation, cell growth, and cell proliferation, as well as tumor proliferation and vascularization (Garret-Bakelman et al., 2019)." These results indicate an increase in inflammation in the flight subject throughout the 340-day mission.

The researchers in the NASA Twin Study found a decrease in cognitive performance in the flight subject (Garret-Bakelman et al., 2019). They explain that this could be a limiting factor in long-duration space flight missions because an increased cognitive performance decline could adversely affect flight and mission safety. However, the authors are not sure how much of the cognitive performance decline was the result of the mission itself or all of the media attention postflight. The authors identified this as an area that needs more research. The flight subject also had cardiovascular symptoms as a result of the flight. There was evidence of thickening of the blood vessels and increased cardiac output as well as a decrease in blood pressure. The researchers are still unsure if these changes increase the flight subject's risk of cardiovascular disease (Garret-Bakelman et al., 2019).

There is a significant chance that many of the long-duration space missions will occur in private spacecraft. As a result, the requirements set by NASA for choosing crew would not apply per se. Additionally, some of these missions could be carrying paying passengers as many of the companies currently in operation intend to start passenger-carrying operations shortly. This means that there is a high chance that occupants of the spacecraft are not in perfect physical condition. Since NASA requires near-perfect health and physical condition, there is limited data on how the space flight environment affects people who are not in perfect health.

An article by Jennings et al. (2006) describes a case study of an older participant with a history of smoking and emphysema who was slated to be a crew member on the International Space Station. A CT Scan indicated a mass on the patient's lung that needed to be checked out. The doctors placed the man on a series of inhaled medications and placed him in simulations of various mission conditions to see if he had any difficulties breathing. The results of the tests showed no difficulty in breathing during the simulations. After the mass on the lungs was taken care of, he was deemed fit to fly by the Russian Space Agency. He flew on the International Space Station at the age of 60 and had no difficulties in carrying out his duties. A postflight evaluation showed no medical changes as a result of the flight (Jennings et al., 2006). This study is significant because it shows that candidates with airway obstruction diseases such as COPD or emphysema can complete missions.

This is an important finding mostly for commercial missions, which will require the crew members to hold a valid FAA medical certificate, which has more flexible standards than traditional astronaut medical evaluations. While NASA makes it clear that no waivers are issued for medical conditions that are considered disqualifying, the FAA, on the other hand, gives waivers for its medical certification requirements quite frequently after further review by specialists at the Civil Aerospace Medical Institute. This means that with the increase of commercial space crews, there will be an increase in space flight participants with conditions that NASA previously has not allowed. Pilots with airway obstruction diseases can be issued medical certificates through either special or regular issue pathways (Jennings et al., 2006). Additionally, pilots are allowed to fly while on inhaled medications for lung conditions as the FAA deems the risk of side effects minimal. The spaceflight environment is significantly different from the on-Earth flight environment. Just because a medical condition is safe for traditional pilots does not mean it will be safe for the astronauts.

The primary limitation of the Jennings et al. (2006) study is that it is a case study. It only looks at one individual. More research needs to be done to determine if the results are generalizable to the population at large. Additionally, the single-subject study only gives insight into the conditions experienced by the one subject. There may be other medical conditions that affect crewmembers' ability to carry out their duties that are not known at this time.

A survey administered to all members of the U.S Astronaut Corps by Saluja et al. (2008) found that a majority of astronauts felt that a dedicated crew medical officer should be included in all long-duration space flight missions that have four or more crewmembers. The astronauts wanted a physician with training in general and emergency medicine as well as limited training in dentistry, psychiatry, and gynecology. This cross-training of the medical officer would allow a single crewmember to aid whatever issues the other crewmembers report.

Crew Training

The NASA training program lasts approximately two years plus mission-specific training. NASA currently trains astronauts specifically for each mission (Roemer, personal interview, 2019). This extensive process is because each mission is unique, and each crew member will have to interact with specific individuals in highly technical and complicated tasks. This mission-specific training will be continued with long-duration space missions run by NASA. NASA astronauts go through SCUBA and G-Training as well as procedures training for the system they are flying on. Pilots remain proficient by flying NASA T-38 Talon aircraft.

Commercial Space Operators, on the other hand, must meet requirements set forth by the FAA. As mentioned earlier, the crewmembers with a safety-critical role must possess at least "An FAA Airman Certificate with an instrument rating and second-class medical certificate (14 CFR §460.5)."

Additionally, each required crewmember must,

> Demonstrate an ability to withstand the stresses of space flight, which may include high acceleration or deceleration, microgravity, and vibration, insufficient condition to safely carry out his or her duties so that the vehicle will not harm the public
>
> Possess aeronautical knowledge, experience, and skills necessary to pilot and control the launch or reentry vehicle that will operate in the National Airspace System (NAS). Aeronautical experience may include hours in flight, ratings, and training.
>
> Train in procedures that direct the vehicle away from the public in the event the flight crew abandons the vehicle during flight; and
>
> Train for each mode of control or propulsion, including any transition between modes, such that the pilot or remote operator is able to control the vehicle. (14 CFR §460.5)

There is no other guidance from the FAA as to how these criteria are supposed to be met. Unlike the standards for FAA Airmen Certificates, there are no performance-based standards for commercial space crew training. It is up to the individual operator to ensure that the requirements of 14 CFR §460.5 are met. Additionally, there is a moratorium on the creation of new regulations for spaceflight crews until 2023 under the Commercial Space Launch Competitiveness Act of 2015 (Coffman, personal interview, 2019). The moratorium means that commercial space operators will be allowed to self-certify their crew until at least that date. The idea behind this is that the commercial operators know their systems the best, and each design is so different from the next that it would be impractical/impossible to create blanket training requirements until more data are received. However, this lack of standardization of training could pose numerous threats to flight safety.

Analysis of Current Research

Gaps in Existing Research

There are numerous gaps in the existing research regarding long-duration spaceflight and the selection of crews for long-duration missions. Very little is known about the long-term effects of microgravity and radiation on human performance. There are many barriers to conducting that type of research as the space flight environment cannot be easily replicated on Earth. There is little empirical data regarding the effects of long-duration isolation on the performance of a crew—most of the evidence indicating that there are issues are anecdotal examples. There is a need to find out which personality traits make good crewmembers for long-duration missions. While a few studies highlighted some traits, more research is needed. The main reason why there is a lack of data is because of the lack of long-duration missions. At this point, only a handful of individuals have been in space for longer than a year. The data are still being analyzed about the effects that those missions had on them.

Additionally, regarding psychological research on space crews, Kraft et al. (2003) suggest that fear of being taken off flight status as a result of reporting psychological issues that occurred during training or missions is an explanation for the lack of studies. If the culture surrounding aerospace psychology became more open to discussing the mental health of crewmembers, there would be more data on the issues crews face, and researchers could quite possibly find solutions to those issues. However, some issues like long term physiological effects on crew and crew performance will be unknown until an actual long-term space flight mission is launched.

A considerable gap in the literature is regarding the flight fitness of crew members for long-duration space flights. For commercial crew members, the FAA requires them to hold a second-class medical certificate. However, numerous medical conditions are either allowed under a standard-issuance medical or are waiver-able with a special issuance medical. For example, people with conditions like asthma, pre-diabetes, glaucoma, hypertension are all allowed standard issuance medical certificates provided their conditions are managed by a doctor (FAA, 2019). While the FAA has deemed them to be of little aeromedical importance on Earth, little research has been done to determine if those conditions will adversely affect performance in space. Those are just a handful of the many conditions pilots who hold second-class medical certificates could have.

Future Directions of Research

As the 2020's decade continues, the United States will see continued growth in commercial spaceflight, and long-duration space travel will become a regular occurrence. Private companies have already launched astronauts to the International Space Station. These companies hope to carry paying passengers within the next few years. The lack of research in many areas regarding spaceflight will become unacceptable from a safety standpoint. There is still much that needs to be learned about psychological and medical factors affecting crews and eventual passengers.

The areas of future research are nearly limitless. One area of future research could be to look at various personality attributes that make good crew leaders. Research here could aid in choosing an effective leader to be a mission commander. Another possible direction of research could look at the interaction of personality types in space flight situations. Research that would help mission planners create a balanced crew that can work well together over a long-duration mission. In terms of psychology, more research needs to be done on the psychological effects of long-duration space flight.

While it is not perfect, more research could be done using Antarctic crews as an analog for space flight as there will be no actual data until space agencies and private companies start launching long-duration missions. Studies conducted in the Antarctic analog could look at levels of depression, anxiety, and stress. These variables could be measured in winter staying crews in Antarctic research camps. Additionally, space crews could be sent to Antarctica (or the Arctic) for long-duration mission training. These simulations have delivered data that has helped the space program in the past.

For long-duration missions, it should be assumed that interpersonal conflicts will occur amongst the crewmembers. It would be advisable to develop conflict resolution techniques to diffuse crewmember-crewmember and crewmember-ground control conflict. It is essential to know that crews are adequately trained and qualified to diffuse any conflicts as not to put the mission and crew safety in jeopardy. Research must also be conducted into the current list of medical conditions permitted by the FAA and conditions that require special issuance medical certificates to see if those conditions have adverse effects in a space flight environment. If the conditions do, then the FAA will have to consider creating a new class of medical certificates for commercial space crews. Additionally, studies should be conducted looking at the effects of conflict and competition on human performance.

Conclusion

As the 2020s progress, space truly is becoming the final frontier. The idea of commercially traveling in space was once a theme of science fiction. Soon it will be a reality. Companies like Virgin Galactic and Space X will be attempting to launch paying passengers within the next few years. For decades, space transportation consisted only of government or military rockets. Currently, most of the rockets being launched are owned by private businesses. The rise of commercial space launches presents new challenges for operators and regulatory bodies. Operators must choose crewmembers who are qualified to operate complex systems for periods that may be years long for long-duration missions. Regulators must ensure that these operators are qualified to do that safely for themselves, possible paying passengers, other users of the national airspace system, and people on the ground. The crew must have the personality, mentality, medical fitness to undergo the stress of long-duration space flight as well as the technical skills to operate the spacecraft. Choosing the right crew for these long-duration public/corporate missions is imperative to the safety and success of these missions.

As operators try to decide who the right crew is for these extreme missions. It is important to remember that there is a lot that needs to be learned before missions like this are attempted. This paper sought to identify some of the critical areas of human performance that need to be addressed in order to have safe and successful long-duration missions.

References

Anania, E. C., Disher, T., Anglin, K. M., & Kring, J. P. (2017). Selecting for long duration space exploration: Implications of personality. 2017 IEEE Aerospace Conference, Aerospace Conference, 2017 IEEE, 1–8. https://doi.org.portal.lib.fit.edu/10.1109/AERO.2017.7943814

Basner, M., Dinges, D. F., Mollicone, D. J., Savelev, I., Ecker, A. J., Di Antonio, A., … Sutton, J. P. (2014). Psychological and behavioral changes during confinement in a 520-day simulated interplanetary mission to Mars. *PLoS ONE*, 9(3), e93298. https://doi.org/10.1371/journal.pone.0093298

Dunbar, B. (2015). Astronaut Requirements. Retrieved February 1, 2019, from https://www.nasa.gov/audience/forstudents/postsecondary/features/F_Astronaut_Requirements.html

Federal Aviation Administration (2019). Guide for aviation medical examiners, CACI conditions. Retrieved September 4, 2020, from https://www.faa.gov/about/office_org/headquarters_offices/avs/offices/aam/ame/guide/certification_ws/

Garret-Bakelman, F.E, et al. (2019). The NASA Twins Study: A multidimensional analysis of a year-long human spaceflight. *Science*. 363.

Harris, P. R. (2009). *Space enterprise living and working offworld in the 21st century*. Berlin: In association with Praxis Publishing.

Human Space Flight Requirements for Crew and Space Flight Participants, Vol. 71, Fed. Reg. No. 241 (December 15, 2005). (To be codified 14 CFR pts 401, 415, 431, 435, 440 and 460).

Jennings, R. T., et al. (2006). Medical qualification of a commercial spaceflight participant: Not your average astronaut. *Aviation, Space, and Environmental Medicine*, 77(5), 475-484.

Kraft, N. O., Lyons, T. J., & Binder, H. (2003). Intercultural crew issues in long-duration spaceflight. *Aviation, Space, and Environmental Medicine*, 74(5), 575-578.

Lauber, J. K. (1984). Resource management in the cockpit. *Air Line Pilot, 53,* 20-30.

Lugg, D. J. (2005). Behavioral health in Antarctica: implications for long-duration space missions. *Aviation, Space, and Environmental Medicine,76*(6), B74-B75.

Mittelstädt, J. M., Pecena, Y., Oubaid, V., & Maschke, P. (2016). Psychometric Personality Differences Between Candidates in Astronaut Selection. *Aerospace Medicine and Human Performance*, 87(11), 933–939.

Munk, M. M. (1999). Departure Energies, Trip Times, and Entry Speeds for Human Mars Missions. NASA Technical Report #AAS 99-103.

Muñoz-Marrón, D. (2018). Human Factors in Aviation: Crm (Crew Resource Management). *Papeles Del Psicólogo*, *39*(3), 191–199. https://doi.org/10.23923/pap.psicol2018.2870

Musson, D. M., Sandal, G., & Helmreich, R. L. (2004). Personality characteristics and trait clusters in final stage astronaut selection. *Aviation, space, and environmental medicine,* *75*(4), 342-349.

Palinkas, L. A. (2001). Psychosocial issues in long-term space flight: overview. *Gravitational and Space Biology, 2*(25).

Pruyn, P. W., & Sterling, M. R. (2006). Space Flight Resource Management: Lessons Learned from Astronaut Team Learning. *Reflections, 7*(2), 45–57

Saluja, I. S., Williams, D. R., Woodard, D., Kaczorowski, J., Douglas, B., Scarpa, P. J., & Comtois, J. (2008). Survey of astronaut opinions on medical crewmembers for a mission to mars. *Acta Astronautica, 63*(5), 586-593. doi: 10.1016/j.actaastro.2008.05.002

Sandal, G. M., Sgobba, T., Clervoy, J., & Kanki, B. G. (2018). *Space Safety and Human Performance*. Butterworth-Heinemann.

Space Crew Operators, 14 C.F.R § 460.5 (2019).

Wood, J., Schmidt, L., Lugg, D., Ayton, J., Phillips, T., & Shepanek, M. (2005). Life, survival, and behavioral health in small closed communities: 10 years of studying isolated Antarctic groups. *Aviation Space and Environmental Medicine*, 76(6), B89-B93.