BIOLOGICAL AND PSYCHOSOCIAL EFFECTS OF SPACE TRAVEL:

A CASE STUDY

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Dedication Page

This paper is dedicated to my mom June Kam Hu Chun who drove me towards this field of study, my father Martin Hsia, my grandfather Robert Chun, uncle Rodney, aunty Q, Tom, my grandfather Yujen Hsia, and of course my sister who is skeptical of everything I do, but will guide me towards the right decisions.

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ABSTRACT

BIOLOGICAL AND PSYCHOSOCIAL EFFECTS OF SPACE TRAVEL: A CASE STUDY

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This dissertation interviewed a single astronaut to explore psychosocial issues relevant to long-duration space travel and how these issues relate to the astronaut's training. It examined the psychological impact of isolation, crew interaction, and the experience of microgravity with the goal of increasing understanding of how to foster crew survivability and positive small group interactions in space (Santy, 1994). It also focused on how to develop possible treatments for crews when they transition back to Earth from the extreme environment of space missions. The astronaut's responses agreed with the literature and the predictions for long-duration space missions except the participant reported no temporary or permanent cognitive or memory deficits due to microgravity exposure. The dissertation identified five frequently endorsed themes including communication, environmental stressors, personal strengths, un-researched problems, and other. The agreement found between the literature and astronaut's responses offer a strong foundation of questions and data that needs to be further studied before conducting research in space or long-duration space missions.

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CHAPTER I

Introduction

Space exploration reached a zenith with the Apollo Program. A very select few individuals have had the opportunity to experience and study life in such an extreme habitat. In the coming age there will be an increase in human exposure to space via commercial endeavors and state-funded missions.

This dissertation examined the physical, psychological and social alterations that accompany long-duration space flight with a view toward improving training standards. It is important to determine what training standards and candidate characteristics will increase resistance to the myriad of stressors, promote mission success and decrease potential casualties in space exploration (Kanas & Manzey, 2008). There have been no published reports from empirical studies in space addressing psychosocial issues affecting long-duration international space crews (Kanas, 1998).

This dissertation interviewed a single astronaut to explore psychosocial issues relevant to long-duration space travel and how these issues relate to the astronaut's training. It examined the psychological impact of isolation, crew interaction, and the experience of microgravity with the goal of increasing understanding of how to foster crew survivability and positive small group interactions in space (Santy, 1994). It also focused on how to develop possible treatments for crews when they transition back to Earth from the extreme environment of space missions.

The published research to date that pertains to long-duration space flight emanates from similar extreme environments including submarines, scientific expeditions to the Antarctic, Biosphere 2 experiments and space station missions (Sandal, 2000). Isolation, crew interactions, somatic complaints, biological adaptations and perceptual processes are variables that have been studied in one or more of the scenarios listed above. These variables may all be relevant to foreseeable problems of long-duration space flight. However, no data exist for crews experiencing extended periods in microgravity (Kanas, 1998). Shayler (2000) notes that deep space conditions will most likely restrict communications; thus, studying different psychological stressors and coping mechanisms is essential to train the crews to treat themselves and maintain their own mental health.

The current study interviewed a male astronaut who spent 131 days in space while participating in four shuttle missions and stays on board the International Space Station. Single-case studies such as this one are virtually non-existent in the published literature on space travel. Through investigating this astronaut’s first-hand experience, it is hoped that this study can contribute to the understanding of physical, biological, psychological, and social problems arising from long-duration exposure to microgravity.

CHAPTER II

Literature Review

Overview

This literature review is divided into three sections. The first section will cover the development of selection criteria for astronauts and the pre-flight training that is meant to influence the success and survivability of missions in space. Selection criteria are developed to screen-in individuals with traits beneficial to mission success and to screen-out individuals with traits hazardous to mission success. During the earlier years of the National Aeronautic and Space Administration (NASA), psychological screening and testing were strenuous and extensive. As time went on, psychological testing became less extensive.

The second section will review in-flight treatments and interventions to cope with hazardous conditions. For example, Haddy (2007, p. 643) posited a situation regarding unknown stressors by asking, "Imagine a radiation sick, sleep-deprived astronaut stepping on Mars; muscle and bone weakened and dehydrated, he or she becomes hypotensive, faints, and breaks a leg. What now, Houston?"

It is well documented that biological functioning is affected by long-term exposure to microgravity. Cognitive processes are also heavily influenced. Research on these issues, as well as on Space Adaptation Syndrome (SAS), more commonly known as space sickness, will be presented in this section. Also included will be research on the psychological impact of isolation, confinement, repetitive tasks, and lack of possibility of rescue or aid from outside sources. Finally, research on variables that affect how crews interact, such as small group dynamics, decision-making processes, and cross-cultural differences, will be summarized.

The third and much briefer section of the literature review will touch on post-flight treatment of returning astronauts. It will consider issues of biological impairment, necessity of quarantine, and stressors that are currently unforeseeable.

It is largely unknown how to address problems associated with long-term exposure to radiation and microgravity. It is also unclear how the psyche will react to being reintegrated into mainstream society after long-duration space missions, for example, three years for a journey to Mars and back.

Pre-Flight

History of Psychological Selection Criteria

The selection process for astronauts is continually developing and changing as new technology and missions arise along with further understanding of human psychology.

At the beginning of the space program, astronauts were selected solely from military personnel with a focus on performance and experience rather than psychological functioning. However, in November, 1957, President Eisenhower decided that screening protocols caused inter-service rivalry between the military branches and established the President's Scientific Advisory Committee which led to the National Aeronautics and Space Act enacted by Congress in July, 1958. A Space Task Group (STG) chaired by

Robert Gilruth was founded the same year at Langley Field, Virginia to determine which individuals would function effectively in space.

In Santy's history (1994) of the criteria implemented to improve the selection process of astronaut candidates, she noted that as of World War II, psychiatrists would often over-predict failure and underestimate the ability of many individuals to adapt to stressful situations. Determining the characteristics that individuals would need in order to succeed in their missions began as a combination of pure conjecture and real experience with high performance aircraft operations (Santy, 1994).

The STG found that the primary task for an astronaut was to survive his/her mission, in other words, to be able to fly into space and return safely. A secondary objective was for the astronaut to demonstrate a capacity to act usefully under conditions of space flight. The astronaut would also need to function as a backup for automated controls so as to increase the reliability of spacecraft systems. The STG concluded that the astronaut should function as a scientific observer and go beyond what spacecraft instrumentation and unmanned satellites were able to observe and report (Atkinson and Shafritz, 1985).

The STG considered what type of prior occupations would best be suited for candidates for deep space travel. They included aircraft pilots, balloonists, submariners, deep-sea divers, mountain climbers, explorers, flight surgeons and scientists in their list. Originally, since the space agency was civilian and not military, it was expected that different industries including the Department of Defense would nominate candidates for consideration as astronauts. However, the White House forcefully interceded. Eisenhower wanted only active military test pilots as candidates. Because of the ongoing Cold War, he was concerned about national security issues. Therefore, by presidential decree, all astronaut candidates were required to be graduates of military test pilot school with a minimum of 1500 hours of flying time in high-performance jets. These requirements considerably decreased the heterogeneity of applicants (Santy, 1994).

To yield as much heterogeneity as possible, NASA asked the military services to screen 110 test pilots who met the 1500 hours of flight time requirement in order to select astronauts for Project Mercury. NASA's request for assistance was given to Air Force Command, which handed the task of doing psychological evaluations to the Aeromedical Research Laboratory (AMRL) and eventually to Dr. George Ruff. While Ruff was in charge, it was mandated that each military service was to be involved in all phases of the selection process. This included the Navy representative Dr. Robert Voas, a psychologist who worked in the STG, and the Army flight surgeon Dr. William Augerson. Santy (1994) reports that Ruff and his colleagues saw their task as one of great responsibility and opportunity since it afforded the chance to study men in perhaps the most hostile and unique environment. The work was thought to be a natural extension of prior research on pilot and crew isolation and adaptation.

Development of Psychological Selection Criteria in the 1950's

Ruff acknowledges today (Ruff & Levy, 1959) that the first evaluations were influenced both by Raymond Cattell's description and measurement of personality and Paul E. Meehl's work as elucidated in his seminal book, *Clinical vs. Statistical Prediction: A Theoretical Analysis and Review of the Evidence* (Santy, 1994). Meehl

(1954) noted that when predicting success, psychiatrists were slightly better than the statistical method (85%-80% versus 76% accuracy) but when predicting failure, psychiatrists were inferior to the statistical method (30%-50% versus 69% accuracy).

Ruff and his colleagues at the AMRL decided to improve prediction by insuring that both clinical and statistical approaches were used in screening. They also expressed the intention to refine the psychological selection battery over the years by use of outcome data, which would identify the factors most important in predicting success as an astronaut (Santy, 1994).

The statistical and clinical approaches both had shortcomings when applied to the problem of astronaut selection because there was no data yet available on space-crew performance. In addition, while scientists could make intelligent guesses via examining previous results from demanding missions, these results were not necessarily generalizable. A further disadvantage was that, especially at the time the initial astronaut selection was to be carried out, psychological variables were difficult to measure objectively.

Ruff and Levy opted to combine both statistical and clinical techniques on the reasoning that computers could interpret objective data more accurately than clinicians could and that clinicians could use information that could not be quantified for the computer.

The specific job of the astronaut had to be defined since the determination of the personal characteristics required would in part be based upon the job description. After the astronauts had been selected, their performance could be tracked and used to validate the original selection criteria or justify modification of these criteria.

For the Mercury program, the psychological selection contained four distinct tasks (Santy, 1994). These were: (1) determination of job duties and job conditions, (2) after the job requirements were defined, decisions had to be made on what physical and mental characteristics were desirable and undesirable for successful functioning on space missions, (3) determination of assessment methods, i.e., tests needed to be chosen or devised to determine optimal combinations of desirable characteristics and to rule out undesirable characteristics, and (4) validation of selection criteria, in other words, predictions would need to be checked against performance.

The job requirements included four major components called sequence monitoring, systems management, attitude control and research observations. In sequence monitoring, the astronaut is responsible for overseeing critical phases of the mission such as ensuring that the booster rocket functions properly to lift the space ship and corresponding parts high enough before separating as well as firing retrorockets to slow the descent and deployment of the parachutes. Systems management occurs when the astronaut operates all onboard systems and manages the crucial consumable supplies including oxygen and water to insure that out-of-tolerance conditions are rectified before becoming critical. Attitude control encompasses the astronauts maneuvering the vehicle during the mission. Research observations are special research-related functions and evaluation of the spacecraft during flight conditions.

The team identified the most obvious professional requirements for becoming an astronaut as the following: a high level of skill in the pilot's role, appropriate personal characteristics, a high level of physical fitness, a good knowledge of engineering and operational procedures of aircraft or missiles, broad scientific knowledge and research skills, high intelligence, and excellent psychomotor skills (Santy, 1994).

Psychologically, the candidate needed to demonstrate good stress tolerance, ability to make decisions, ability to work effectively with others, emotional maturity and strong motivation for the team's welfare as opposed to personal objectives. While these general psychological characteristics were warranted for astronauts, more requirements that are specific also needed to be drawn up to enhance the selection criteria.

Ruff and Levy (1959) listed the specific psychological requirements developed by the AMRL psychological team for the Mercury astronauts: (1) a high level of general intelligence including abilities to interpret instruments, perceive mathematical relationships and maintain spatial orientation; (2) sufficient evidence of drive and creativity to ensure positive contributions; (3) relative freedom from conflict and anxiety as well as a minimum of exaggerated and stereotypic defenses; (4) abilities to accept dependence upon others when required for mission success and to tolerate both close association with others and extreme isolation; (5) ability to function when not in familiar surroundings and when usual behavioral patterns are impossible; (6) predictable responsiveness in foreseeable situations in and flexible adaptiveness under unforeseen circumstances; (7) ability to control self-destructive wishes and behaviors to compensate for identity problems or feelings of personal inadequacy; (8) minimal impulsivity but rather ability to tolerate stress without engaging in undue motor activity to alleviate anxiety.

The AMRL psychological team then developed 17 psychological categories on which to rate each candidate in order to quantify clinical impressions. All interview and test information would be used. Santy (1994) lists the 17 psychological categories: drive; freedom from conflict and anxiety; effectiveness of defenses; free energy; identity; object relationships; reality testing; dependency; adaptability; freedom from impulsivity; need for activity; somatization; quantity of motivation; quality of motivation; frustration tolerance; social relationships; and overall rating of suitability for the mission.

NASA instructed the psychiatric evaluators to rate the candidates on the dimensions as (1) well qualified, (2) qualified or (3) not qualified rather than on a ten-point scale as originally planned. After the evaluations were complete, the candidates were ranked on psychological functioning and the seven eventually chosen came from the top nine.

Interview and test data were also utilized to determine a more clinical rating. The psychiatric interview process included one interview devoted to reviewing a candidate's life history and current life adjustment and a second open-ended and unstructured interview, which allowed the candidate to present himself as he wished (Ruff and Levy, 1959). Ruff and Levy pooled information and compared notes resulting in a combined psychiatric rating of each candidate.

The testing process incorporated both projective and objective personality tests. The projective personality tests included the Rorschach Ink Blot Test, Thematic

Apperception Test, Draw-a- Person, Sentence Completion Test, and Who Am I Test. The objective tests included the Minnesota Multiphasic Personality Inventory, Gordon Personal Profile, Edwards Personal Preference Schedule, Shipley Personal Inventory, Outer-inner Preferences, Pensacola Z and the Officer Effectiveness Inventory.

The candidates were also introduced to the complex behavior simulator where they simultaneously performed several psychomotor and cognitive tasks as well as an isolation test.

Ability and intelligence tests, both general and specific, included the Wechsler Adult Intelligence Scale, Miller Analogies, Raven Progressive Matrices, Doppelt Mathematical Reasoning Test, Minnesota Engineering Analogies Mechanical Comprehension, Air Force Officer Qualification Test, Aviation Qualification Test (USN), Space Memory, Spatial Orientation/Spatial Visualization, Gottschaldt Hidden Figures, and Guilford-Zimmerman Spatial Visualization.

In retrospect, the sheer quantity of tests and interviews administered to each candidate may seem somewhat excessive in terms of current evaluative methodology.

Contemporary Psychological Selection Criteria

The selection process will probably always need to undergo modification as space analog studies such as use of submariners and Biosphere 2 inhabitants have limited generalizability. This is due to multiple factors, which include contact with the outside world, larger areas to move about, presence of gravity, no long-term exposure to massive amounts of radiation, and means of escape, rescue and/or resupply of necessary materials.

The selection criteria of the past changed dramatically for later space missions. The field evolved from little consideration of psychological factors in the original selection of astronauts, to a heavy focus with the Mercury Project, and finally to a shift back towards minimal emphasis on psychological factors. This pattern was compiled by Santy (1994, p. 54) as shown in Table 1:

Table 1

Summary of Psychiatric and Psychological Selection Procedures in the U.S. Space Program (1959-1985)

	Mercury	Gemini/Apollo	Shuttle
# Hours of Evaluation	30	10	3
Written Standards	No	No	Yes
Selection Criteria	Intelligence	Emotional Stability	None
	Drive & Creativity	High Motivation	
	Independence	"Self" Concept	
	Adaptive Motivation	Interpersonal Relations	
	Flexible		
	Motivation		
	Lack of Impulsivity		
Screening Method	2 Psych Interviews	2 Psych Interviews	2 Psych Interviews
	25 Psych Tests	10 Psych Tests	None
	1 Stress Test	1 Stress Test	None
Outcome	1 Consensus	1 Consensus	2 Independent
Validation of Criteria	Data not available	Not done	Not done

Note. Taken from Santy (1994, p.54)

This fluctuating pattern of selection criteria over the years of space exploration has prompted contemporary research investigating what aspects might currently be optimal for international space programs.

At the individual level, there are two basic objectives of selection strategies: to eliminate unfit or potentially unfit applicants and to select qualified candidates who will perform and cope optimally based on their basic aptitudes, attitudes, prior experiences, and personality characteristics (Kanas, 2009). Research on the personality traits that have been correlated with astronaut effectiveness during short-term missions and training sessions indicate high "agreeableness" and low aggressiveness as general characteristics of high performers (Rose, Fogg, Helmreich, & McFadden, 1994). Kanas et al. (2009) suggests that optimal personality traits may differ as a function of mission duration.

Weighting of selection criteria should be based on systematic analyses of issues such as mission objectives, crew composition and duration of space flight. Since space missions will most likely have ethnically diverse and perhaps even multinational crews, cross-cultural competence as well as interpersonal skills with persons of one's own culture will probably be heavily weighted. Kanas et al (2009) states that political and public relation issues should not detract from the importance of psychologically-guided crew composition.

Assessment tools for selection purposes include performance tests, biographical data, personality questionnaires, behavioral observations, and interviews. A combination of several tools is likely to result in the most valid judgment. The emphasis might well be on development and validation of behavioral measures that can assess interpersonal skills, cross-cultural competence, and can predict the individual's reactions to stress, confinement and isolation. Kanas et al. (2009) found that, to date, the absence of opportunities to conduct research on astronaut performance in space, due to the rarity of space missions, has made it difficult to evaluate the validity of criteria used for selecting astronauts and forming compatible crews.

Studies addressing "the right stuff" for long-duration space missions have involved the analysis of personality factors as potential predictors of adaptation and performance in space analog environments like the research stations in Antarctica (Sandal, 2000). Kanas et al. (2009) report that several studies have linked superior performance to a personality profile characterized by a combination of high levels of expressivity and instrumentality as well as lower levels of interpersonal aggressiveness. Although the these characteristics have not been investigated in terms of adaptation and coping during long-duration space missions, the space analog studies represent a first step in providing empirical data.

Kanas et al. (2009) suggest that in multinational pools of applicants, the potential impact of cultural differences in type of scales used and in response styles must be considered in choosing personality measures. Due to differences in preferred methodology, a common selection procedure may be difficult to achieve even when the different national space agencies agree on criteria.

Psychosocial Factors

Selection criteria for psychological factors are an important pre-flight consideration but psychosocial studies are also necessary to insure that crews interact efficiently and safely throughout the in-flight portion of their mission.

Kanas (1998) reviews the literature regarding three major psychosocial factors: crew heterogeneity, language and dialects, and supportive leadership versus task leadership roles.

During the early years of space flight, crews were homogenous in that they were composed of males with professional backgrounds as engineers or test pilots. Currently, however, crews are more heterogeneous; future missions are likely to continue this trend. The International Space Station includes men and women with different career backgrounds who are from a number of countries yet need to interact in space for months.

When crews speak different native languages, issues arise which may affect how crewmembers interact and how they feel about each other. Norm Thagard commented that his feelings of cultural isolation were related to the fact that he was the only Russian speaker aboard the Mir and sometimes went up to 72 hours without speaking to someone in his native tongue (Kanas, 1991). Kelly & Kanas (1992) interviewed 54 astronauts and cosmonauts and found that 64% of them believed it was important for space crews to be fluent in a common language. They also report that astronauts, pilots and commanders scored higher on Likert scales assessing common language importance than cosmonauts and researchers. International astronauts on U.S. space missions rated the importance of having a common dialect significantly lower than did their American and Russian counterparts. This is possibly due to exposure to more languages over their lifetime.

Dealing with language differences during pre-flight training may help reduce faulty communication and misunderstandings during critical periods on the space flight itself.

Native language is not the only linguistic issue as crews must also be familiar with space terminology. NASA space terminology is derived from English synonyms, acronyms and neologisms whereas Russian space terminology utilizes different linguistic parameters based on Russian. This also can lead to tension between astronauts of different nations on the same crew.

Different leadership roles gain prominence at different times. Two major leadership roles have been identified: task (instrumental) leadership oriented towards accomplishing work goals and operational needs and supportive (expressive) leadership focused on morale and addressing emotional needs (Kanas, 1998). Sometimes both roles are served by the same person but often different people specialize in one or the other. Both task and supportive leadership roles are important for crew functioning. A study of a three-man crew confined in a Mir simulator for 135 days found that a measure of leader control (addressing task-oriented, instrumental characteristics) and leader support (addressing supportive, expressive qualities) correlated significantly with a measure of crew cohesion (Kanas, Weiss, & Marmar, 1996). Leon, Kanfer, Hoffman, and Dupre (1994) found that conflicts between the more experienced and conciliatory cosmonauts and the more stubborn and task-oriented astronauts was detrimental to overall cohesiveness of the group.

Interactions of Psychological, Psychosocial, and Cultural Factors

Psychological, psychosocial and cultural issues are all relevant to how crewmembers can interact optimally. International space crews have become the norm, as opposed to all male, all-white, all-American crews of the past, and thus culture is bound to play a prominent role in communication and cooperation. Cultural issues may influence the mission as differences in personality styles of coping with stress become manifest. Tensions may also arise from cultural differences in cognitive and decision-making styles, individual behavioral norms such as privacy and personal grooming, and social behavioral norms.

Kanas, Salnitskiy, Grund, et al. (2001) studied the stressful incidents during space missions conducted onboard Mir, a Russia space station launched in 1986 and manned until 2001. Their report chronicled how a tightly knit crew can displace frustrations with each other onto mission control, and was the first psychological study conducted in space published in a peer-reviewed journal. Kanas et al. commented on the inherent difficulties with attempts at conducting research due to astronauts' busy schedules but also because of their concerns that test results may deem them unfit for future missions.

Kanas et al. (2001) reported on a NASA-funded team which developed a 15-minutes assessment of crews and ground control workers' mental states utilizing items from the Profile of Mood States Scale, the Group Environment Scale and the Work Environment Scale. Thirteen astronauts and 58 mission control members completed weekly evaluations starting 4 weeks before mission onset and ending 2 weeks post mission. Kanas et al. (2001) found strong support for a displacement phenomenon as people under isolation displace their affect to an 'out group' from the 'in group' and such irrational anger at other spaceflight team members may lead to miscommunication or other barriers to collective problem-solving. These findings prompted researchers to recommend that NASA coordinate training of flight crew, mission control, and NASA management so groups perceive themselves as a unified cohesive unit, underscoring the importance of making everyone aware of the propensity to lay blame at other's feet.

Considerable evidence exists that many crewmembers experience psychological and interpersonal difficulties arising from the stressors in space (Shayler, 2000). Suedfeld (2003) found that psychological and behavioral reactions include lapses of attention, sleeping problems, psychosomatic symptoms, irritability towards crewmates and/or mission control staff, emotional lability and decline in vigor and motivation.

During space missions, psychological difficulties may not only affect an individual but also the entire crew and even have disastrous outcomes. Myasnikov and Zamaletdinov (1998) found adaptation to be an accommodation over time occurring in stages. They stated that the most serious problems are most likely to occur around the third quarter of the mission. Kanas et al. (2009) suggest that identifying critical periods in adaptation is important since this knowledge may enable crews and mission control to prepare for problems and intervene before these problems negatively affects operations. Long-duration space missions may include monotony and boredom due to low workload, hypo-stimulation, and restricted social contacts. Individual factors may influence coping ability, including individual experiences, personality, coping strategies, leisure activities, and the types of social and emotional support available.

Kanas & Manzey (2008) reported that, according to evidence originating from space or in isolated or confined settings, intra-crew tension, group dynamics, and leadership styles all are key factors responsible for exacerbating or ameliorating stress and impeding or facilitating coping and adaptation processes. Efficient strategies to ameliorate stress levels during short-term space missions may become impossible or impractical to implement. Suedfeld (2005) found anecdotal evidence that confinement of small groups leads to openness about a variety of personal matters. The disclosures stemming from this openness may produce discomfort and regret after missions. Social support factors operate differently for long-duration missions since the burden of support must stem from crewmembers due to the absence of a network of families and friends.

Santy (1993) surveyed nine American astronauts who had flown on international space missions and all endorsed the importance of having pre-flight cultural training. During a 61-day, Soviet-American, Bering Bridge expedition, one Russian member reported that many disagreements resulted from the fact that Soviets were accustomed to doing things collectively, whereas Americans approached tasks in a more individualistic manner. Kanas (1991) reported this collectivistic concern on the part of Russian space travelers via Dr. Myasnikov, a prominent member of the Psychological Support Group for cosmonauts.

Kanas, Salnitskiy, Grund, et al. (2000) suggested that interpersonal and cultural issues will impact the interactions of crews and mission control personnel during long-duration space missions. The study concluded that in future long-duration space missions, countermeasures should focus on providing support for crewmembers from a culture in the minority with crews including more than one representative from this culture. This should enhance the positive aspects of the interpersonal environment while needs of mission control personnel should be addressed as well as those of crewmembers.

Pre-Flight Training

Pre-flight training should be provided to space crewmembers and mission control personnel to prepare both groups for coping with psychological difficulties during long-term missions. Kanas et al. (2009) suggest that the greatest benefit can be expected if selection processes are combined with pre-mission training which focuses on further development of coping abilities, such as self-care, self-management, teamwork, group living, leadership, followership, and cross-cultural issues. It may be essential for pre-flight training to include simulations. These can provide hands-on training, evaluation, and coaching of crews under confinement and isolation conditions. Kanas et al. (2009) emphasize that it is crucial that pre-flight training include tailored regimens to meet the needs of individual crewmembers and specific crews due to differences in personality, culture, and previous training backgrounds. Santy et al. (1993) noted that astronauts acknowledged that conversational language training is important in missions composed of international crews.

Analog Experiments

Analog studies are the major source of evidence regarding what might happen to individuals and crews in outer space. This is because it is too expensive and logistically impossible to utilize deep space missions to gather empirical evidence.

Analog studies of space take place in analog simulators, polar expeditions, submarines, submersible simulators, land-based simulators, and under hypodynamia (bed-rest) conditions.

Kanas et al. (2009) noted that most strategies of ground-based support currently used to foster psychological well-being during orbital space missions might well be ineffective during long-duration expeditions. This is due to the increased psychological risks to individual crewmembers over time and to the fact that these expeditions are hypothesized to produce psychological challenges never experienced before.

One such challenge is referred to as the "Earth out of view phenomenon." Astronauts on long-duration missions to places like Mars will be the first humans put in a situation where their home planet is reduced to an insignificant dot in space (Kanas & Manzey, 2008).

Ihle, Ritsher, and Kanas (2006) found that looking at the earth while in orbit has a positive value for the astronaut's well-being. This provides some strength for the prediction that seeing the Earth as an insignificant dot in space when missions move into deep space will negatively impact the psyche of the astronauts. Long-duration stays aboard an orbital space station are the first step in the evolution of human space exploration and even these, with Earth well in view as a full orb, can produce psychological and interpersonal consequences (Kanas et al., 2009).

The Biosphere 2 experimental habitation experiment began with a crew of eight passing through an airlock in September 26, 1991. This crew emerged 2 years later in overall good health, having surmounted considerable odds against it. This marked the first long-duration habitation by humans in a closed environmental system.

MacCallum and Poynter (1995) noted that the Biosphere 2 crews reported that interpersonal relations were considered the biggest problem, which was consistent with reports about other isolated confined environments like Antarctica. Interactions between crew and mission control members were considered the largest factor affecting crew performance and safety in Biosphere 2. Specific variables seen to impact psychological well-being included group dynamics, leadership, privacy, stress relief mechanisms, organization of the crew and relationship with Mission Control. Environmental factors like caloric restriction, lowered oxygen, and internal structures also influenced psychological well-being in crewmembers. Analog studies are essential for knowledge about pre-flight therapeutic interventions. These studies can lead to devising interventions that are helpful in teaching crewmembers how to cope with long-duration isolation and closed environments before they embark on a space mission.

Candidates who demonstrate difficulties with living in an isolated closed environment, interacting with crewmembers appropriately, and performing optimally within the extreme environment should be reconsidered for selection. Monitoring of mood changes, performance decrements and fatigue during these experiments should be used to provide education about psychological states and coping mechanisms. Such information may help crews to become aware of psychological triggers and symptoms before they spiral out of control. They may teach the candidates how to assess and intervene to help other crewmembers in emergencies or when they are logistically out of contact.

Sandal (2001) conducted a study that showed increases in interpersonal tension in the beginning, during the middle, and towards the end of confinement. Three subjects were confined within the MIR space station simulator for 135 days in Moscow. Assessment occurred via communication analysis, peer ratings, interviews, and questionnaires to assess crew tension. The beginning period of confinement included competition for leadership. The middle period was characterized by decreases in crew cohesion and aggression towards mission control. The final weeks were marked by open conflict including social exclusion of one of the three subjects. Sandal also found that the process of adaptation occurs in stages independent of the duration of the mission. This has been verified by other researchers studying personnel in isolated and confined environments (ICE) settings such as Rohrer's (1961) polar station studies, submarine studies (Sandal, Endresen, Vaernes, & Ursin, 1999) and Russian space missions (Gushin et al., 1996).

Kanas et al. (2007) suggest a number of pre-launch training topics to counter psychosocial problems between crewmembers and mission control personnel. These topics include nature of the relationship between the two groups, crew tension, displacement and how to avoid it, and application of different leadership roles depending on situational factors.

Computer-based training may be available in space and on the ground during the mission to refresh and extend the psychosocial training received pre-launch. Commanders who have demonstrated strength in both supportive and task-oriented leadership should be selected.

One limitation to Biosphere 2, submarine, and other analog studies is that while they are relevant to human adaptation to isolation while on Earth, this relevance may not necessarily transfer to long-duration isolation in outer space.

Kanas et. al. (2007) caution extrapolating the findings to future missions beyond Earth's orbit because the extreme distances may change the mission profile considerably. Martian mission scenarios foresee an international crew of seven members undergoing a 3 year expedition with a majority of the time spent in transit. This would include years of being subjected to the "Earth out of view phenomenon." Analog studies, with the exception of the Biosphere 2 study, have not been of such a long duration and in the Biosphere 2 study, the subjects knew that they were on Earth all the time.

In-Flight

Psychological Studies

The psychological impact of stressors during the in-flight portion of the mission is important to research as deep space missions will require crews to detect, intervene and maintain their own mental health while channels of communication are limited.

Kanas et al. (2001) define asthenia as a nervous or mental weakness with symptoms of quick loss of strength, low sensation threshold, extremely unstable moods, and sleep disturbance. These can be caused by somatic disease, excessive mental or physical strain, prolonged negative emotional experience or conflict. Russian psychologists studied the cosmonauts stationed on the Salyut and Mir space stations for several months. Examples of psychosomatic symptoms included a Salyut 6 cosmonaut reporting that he was afraid of having an appendicitis attack and later experiencing pain in his teeth when dreaming about a toothache. A Mir cosmonaut experienced fatigue, physical complaints, and cardiac arrhythmia due to stressful events causing his work duties to be altered.

Such case studies can be utilized to help prevent problems during all the stages of flight but it must be noted that they are studies of astronauts on orbit mission near to Earth. These studies might not estimate so well the psychological impact of stressors on long-duration space flights far from Earth.

Long-duration Flight Influences

Isolation, crew interactions, somatic complaints, biological adaptations and perceptual processes are all pertinent issues that may have been studied in one or more of the scenarios listed above to examine foreseeable problems of long-duration space flight. Nonetheless, no data exist for extended periods in microgravity (Kanas, 1998).

Manzey (2004, p.781) states, “Our current psychological knowledge derived from orbital space flight and analogue environments are not sufficient to assess the specific risks of missions into outer space.” Cosmonaut Valery Polyakov holds the record for longest stay in orbit with 438 days in 1994-1995. His stay provides evidence that at least one human being is capable of enduring a demanding work schedule in isolation and a long-duration confinement in outer space.

Emurian & Brady (2007) estimate the duration of a viable Mars mission as being a minimum of 800 days including 200 days to reach Mars, 400 days on the surface, and 200 days en route back to Earth. Harrison (2005) warns that items that enhance psychological health are crucial on such long-duration missions and should not be omitted due to cost.

Kornilova and Kozlovskaya (2003) define space adaptation syndrome (SAS) as autonomic reactions during microgravity, which are a natural response. However, if these reactions manifest clinically to decrease professional efficiency, the state is then defined as space motion sickness (SMS). The abnormal reactions via exposure to microgravity are due to the interaction between the gravitational factor and the vestibular system, which are interrelated. These researchers found that from Day 60 of microgravity on, abnormal oculomotor responses such as orientation illusions, vertigo, difficulties tracking moving objects and difficulties focusing were regularly observed. These symptoms were indicative of changes in the vestibular and sensory systems that went through oscillating periods of abnormal and normal. This study included 31 cosmonauts, with some on prolonged missions between 76 and 438 days. Psychological education and discussion of these somatic symptoms, as well as interventions and/or training so that crewmembers can understand them, reduce their stigma and adapt appropriately to them may improve mood and interpersonal communication.

Manzey, Lorenz and Poljakov (1998) repeatedly assessed Valery Polyakov during his 438-day stay in space comparing his performance pre-flight, in-flight, immediately post-flight, and during two 6-month periods after the mission. The results indicated that the first 3 weeks of long-duration space flight and the first 2 weeks back on Earth represent critical periods, as adverse effects on mood, attention, and performance are induced via the demands to adjust to the gravitational changes. Based on Polyakov's reactions, it may be critical for psychologists to provide interventions, discuss mood issues, and address performance during these critical periods of high distress. During Polyakov's off-earth mission, he was able to communicate directly with Earth, but for missions beyond Earth's orbit, a psychologist or a psychologically trained crewmember will need to provide interventions.

Cognitive and Complex Performance Skills in Space

Cognitive and complex performance skills are impaired almost immediately as the human body adapts to microgravity and then oscillate throughout long-duration missions. A variety of tasks like operating complex technical systems, conducting scientific experiments and performing extravehicular activities are common work for astronauts. These tasks demand different cognitive and psychomotor functions and skills. Maintaining a high level of performance efficiency in-flight is an essential pre-condition of success and safety of long-duration missions.

The lack of gravity in space has been shown to affect different brain mechanisms, including disrupting congruence between the vestibular signal and other receptors. The otolith and semicircular receptors are also altered via microgravity (Kanas et al., 2009). Microgravity is directly responsible for mechanical and proprioceptive changes during the execution of movements. These changes cause a disruption of the usual relationship amongst afferent and efferent signals, which is referred to as a state of sensorimotor discordance (Bock, 1998).

In addition to specific microgravity effects, the working and living conditions of space can induce stress that may lead to degradation of cognitive and psychomotor performance (Kanas et al., 2009). Examples include decreased alertness, high workload, fatigue, emotional stress, interpersonal tension, and/or other long-term effects of confinement and isolation. Kanas et al. (2009) found that the main effect of changes in the vestibular system involves a sensory conflict that appears to be the basic mechanism underlying visual illusions of self and the environment; additionally, motions induced via head movement caused disturbances of spatial orientation and space motion sickness. The vestibular system and graviceptors provide information that affects different parts of the visual cortex, yet higher processes of visual perception and cognition remain unimpaired (Kanas et al., 2009). The microgravity effect discussed above (Kanas et al, 2009) produced various performance impairments. These included a loss of precision in voluntary movements, altered kinematics during execution of movements, and/or a slowing of movement times. Manzey (2000) noted that adaptation to most microgravity-induced changes in the sensorimotor system can be achieved rapidly in space; thus, the emergence of performance decrements is expected to be limited to the early phase of flight.

Performance in cognitive tasks such as logical reasoning, mental arithmetic, and memory search remain largely unimpaired in space, but significant disturbances have been found in perceptual-motor and attention tasks (Manzey & Lorenz, 1998). While impairments of perceptual-motor performance during the early phase of the mission are likely attributed to direct effects of microgravity on the sensorimotor system, most other effects appear to be related to non-specific stress due to physiological changes, sleep disturbance, inadequate work-rest schedules and other extreme living conditions inherent to space (Kanas et al., 2009).

A comprehensive performance monitoring study (Manzey & Lorenz, 1998) conducted during the 438-day stay on board Mir of cosmonaut Polyakov suggested a resiliency of elementary cognitive and perceptual motor functions to the impact of stressors related to space flight even during long-duration missions. Impairment of alertness, performance and subjective well-being was observed only during the first 2 weeks in space and when Polyakov was back on Earth (i.e., the critical phases of adaptation to changed gravitational forces also associated with high workloads). Manzey & Lorenz found that after the early phase, Polyakov's subjective mood and performance returned to pre-flight baseline levels and remained stable throughout the remaining 400+ days in space. Once again, it is necessary to note that this study had only one subject, Polyakov, and that he might happen to be an extremely resilient person. Thus, these results might not be generalizable to less resilient people. However, these results certainly warrant further exploration with other subjects.

Kanas et. al. (2009) found that, while adaptation occurs during exposure to microgravity, some processes do not return to baseline levels. Their study found considerable loss of skill after 3 months in space, including degradations of operational performance and decrements in operational task performance related to stress. Stress variables included high workload, disruption of sleep-wake cycle, and psychosomatic discomfort. They reported that systematic research addressing the acquisition and retention of complex cognitive and perceptual-motor skills in space is lacking. Research efforts have been limited to a few studies performed during ground-based simulations that did not provide consistent patterns in their results and suffered from methodological constraints such as persistent learning.

As previously discussed, performance may depend on the cultural background of astronauts. Whether lack of privacy, for example, is perceived as a stressor and thus lead to detrimental effects on mood and performance may depend upon cultural factors. Kanas et al. (2009) suggest a similar situation may be assumed for other potential psychological stressors including monotony, boredom, workload, and time pressure. Culture also has an effect on higher-order cognitive processes such as decision-making or information processing schemata.

In order to detect and provide support for these cognitive impairments, tools are needed to discern subtle performance decrements before they escalate into crises (Kanas et al., 2009). One approach to this is to monitor cognitive and psychomotor capabilities of astronauts while they are in-flight in space via repetitive assessments of their performance on specific screening tests and to compare the results with their pre-flight baseline.

The current focus on cognitive probing tasks must be expanded to include tasks measuring attention and psychomotor functions found to be sensitive to microgravity and stress-related effects of the space habitat. In-flight support and maintenance of acceptable performance emphasize the importance of sleep and appropriate work-rest schedules as significant for performance efficiency (Kanas et al., 2009). Furthermore, in-flight training of critical perceptual-motor tasks may become more important and even essential as mission duration increases. This became apparent with the severe accident that occurred on the Mir station when one module was hit and damaged during a manual re-docking of a supply flight. Kanas et al. (2009) identified the factors that contributed to this accident as including the failure to maintain the operator's docking skills throughout the mission and decrements in skill due to fatigue.

Astronauts will undoubtedly experience mental strain. Hoping to identify its effects to avoid critical mistakes, Harvard psychology professor Stephen Kosslyn developed a Palm Pilot-based program called MiniCog that could be used to measure cognitive abilities during space flight to compare to Earth-based scores or to population norms. MiniCog could possibly be used before working on a difficult task such as repairing equipment on the spacecraft outer hull where astronauts would use the device to see whether their spatial relations are sufficient for the task. In addition to spatial ability tests, the MiniCog can also evaluate level of attention, working memory, problem solving and motor control as Kosslyn commented that the goal was to create a blood-pressure cuff for the mind.

Kanas et al. (2009) reported that the range of cognitive performance assessment in space research has been restricted so far. Further, they maintain that to obtain a full description and monitoring of the nature of cognitive and psychomotor deficits due to microgravity, an integrated test battery needs to be designed and applied that will assess behavioral aspects of information processing as well as physiological and psychological variables. More research is required to discover the comparative influences on basic and complex cognitive and psychomotor functioning of stress from microgravity vs. stress from working and living in an isolated, confined, and potentially dangerous environment. Overall, more research needs to be generated to evaluate the many physiological, cognitive, psychomotor and complex skills that are influenced by microgravity, exposure to large doses of radiation, and the confined or isolated space habitat.

Isolation Studies

The studies summarized above have explored the different effects microgravity has on psychological and biological functioning but isolation also plays a pivotal role. Space crews may be separated for long periods from support, aid, and rescue. This separation can play havoc on psyche and morale.

Rohrer (1961) describes three stages of reaction to long-term isolation and confinement. Heightened anxiety and activity are paramount in the first stage, boredom and depression in the second stage, and hypomanic mood and aggressive behavior in the final stage as people anticipate their return. Kelly and Kanas (1994) note that the cosmonaut Psychological Support Group, a Russian team of psychologists responsible for emotional well-being of crews, was concerned with how to utilize free time effectively in order to minimize psychological problems such as hypersensitivity, interpersonal tension, emotional irritability and lability, and hypo-activity. These authors suggested that increased stimulation could counter these negative conditions, such as the cosmonaut Psychological Support Group monitoring and organizing on-board activities. Possible treatments for long-duration missions include scheduling leisure activities and improving interpersonal relations to counteract negative psychological functioning that occurs during critical periods.

Kanas et al. (2007) note that the extremes of planetary orbits encompass a 44-minute transmission time to ask a question and get a response from Earth, making it impossible to communicate in real time with family, friends, mission control, or other sources of support during a crisis. On a space flight to Mars, for example, the crew will have to be more autonomous and self-sufficient than any other crew ever to have participated in a space mission.

The resulting social monotony and isolation from support and loved ones may negatively influence morale and the psychological state of the crew, possibly leading to major psychiatric problems such as depression, psychosis, or suicidal behavior (Kanas et al., 2007). As conflicts incubate and mission control interactions become less prominent, tension can turn inward and displacement may arise. Displacement can lead to scapegoating and disruption to cohesion and even put the survival of the crew at risk (Kanas et al., 2007).

In-Flight Group Interaction Research

The isolation of being in space regardless of the duration of the mission forces crewmembers into close interactions with each other and as a group. Group interactions require the negotiation of in-group and out-group dynamics. The astronaut selection and training processes are intense, perceptions of the astronaut are rarified, and the astronaut's working environment is unique and dangerous. Tension can be expected to occur between groups with multiple team performances, including groups of astronauts and other professionals involved with operational management (Kanas & Caldwell, 2000), during mission training and actual mission phases.

The primary interaction source of tension is with flight controller teams.

Santy et al. (1993) surveyed nine astronauts who recorded 17 incidents of miscommunication, misunderstanding or interpersonal conflict that had a moderate or high impact on the mission. To optimize crewmembers interactions and functioning as a group, it is important to understand several issues that may interfere with crew cohesion. Kanas & Manzey (2008) found these issues included: (1) crew tension due to environmental stress and crew heterogeneity; (2) time-related decreases in cohesion; (3) poor leadership skills; and (4) stress due to cultural and language differences.

Kanas et al. (2009) report crewmembers in space or analog environments may experience psychological and interpersonal difficulties after the halfway point when a sense of relief that half the mission is over is marred by the realization that another half is upcoming. Rorher's (1961) time model consists of three sequential phases including: initial anxiety, mid-mission depression, and terminal euphoria. These issues can result in psychological problems such as: (1) decreased crew morale, (2) withdrawal or territorial behavior as crews cease to interact, (3) scapegoating, and (4) formation of competing subgroups with subsequent destruction of crew unity (Kanas et al., 2009).

Kanas & Manzey (2008) found that crews might need to be more autonomous in future space missions. They may need to plan their daily activities without input from mission control. Should a problem occur, crews would have to overcome the obstacle themselves. The planning would include time to sleep, eat, and exercise as Kanas et al. (2009) found that nutritional and physiological factors are important to the maintenance of crew health and well-being. These researchers report that crews will need to trust on-board resources for monitoring life support as well as providing the information necessary for a successful mission. Thus, the human-machine interface will take on a bigger role and this too can cause tension for the crewmembers.

Internationally sanctioned procedures for in-flight monitoring of crew interactions and group performance need to be created. Russia's mission control monitored their crew communication sessions. This monitoring included voice frequency analysis, content analysis and analysis of facial expression; these procedures allowed valuable information to be collected regarding psychosocial status of the crew. However, such intense monitoring will most likely be unavailable when inter-planetary distances cause delays in audio and video transmissions. These delays will hamper traditional supportive strategies dependent on real-time crew-ground communications. The distance itself will eradicate the hope and possibility of supplies being sent from Earth or a sick crewmember being evacuated (Kanas et al, 2009).

Kanas et al. (2009) recommend: (1) facilitating crew cohesion via undergoing survival training together in a variety of extreme environments; (2) crews training together pre-flight because the longer they train together, the smoother their future interactions; (3) pre-flight training involving mission control to enhance crew-ground cohesion; (4) group sensitivity training as this can reduce influences of personal, cultural, national and other peculiar behaviors during the in-flight portion of the mission; and (5) communication and conflict resolution training being tailored for the characteristics of the particular space crew involved.

Harrison (2001) suggested that psychological research has well documented how the stress of being in an enclosed space with a small group of people for long-duration can result in depression, interpersonal conflicts, and cognitive decline in an otherwise-well-adjusted group which can easily escalate into a disaster in an environment already fraught with dangers. NASA’s National Space Biomedical Research Institute (NSBRI) funded studies looking to develop methods to predict, identify, and cope with the behavioral and interpersonal problems which may arise. The NSBRI has conducted research on space mission stress, developed a handheld cognitive ability test and created a therapist computer program.

Psychosocial Studies

Tension in the crew can originate from a number of factors including misunderstandings, miscommunications, heterogeneity issues, and leadership or role competition, which has occurred in both space and analog extreme environments (Kanas, 1998).

Skylab 4 commander Gerald Carr reported interpersonal tension on his 84-day mission, believing a lack of privacy contributed to the tension and appetizing meals, a variety of activities, and interior furnishings helped alleviate it. Kanas (1998) reported a displacement of intra-crew tension and dysphoria to more remote people on the outside. Pre-flight or in-flight training on how to intervene could help when there are warning signs like rising tension during periods of no contact with Earth.

In a 135-day Mir space simulation (Kanas, Weiss, & Marmar, 1996), significantly less tension was observed during the last half of isolation than during the first. In contrast to this finding, the eight Biosphere 2 crewmembers who were isolated for two years reported more severe interpersonal problems during the third quarter of their isolation (Walford et al., 1996). The Biosphere scenario’s time length is almost comparable to a Mars expedition, but during the first biosphere mission the group split into two factions, and some members of these factions were barely on speaking terms.

Examples of displacement during a space mission are the work slowdown on Skylab 4 and Valentin Lebedev’s frustration with the ground crews during the 211–day

Salyut 7 mission. Santy et al. (1993) interviewed nine astronauts and found that three of them reported incidents of interpersonal conflict in flight crew-ground crew interactions.

While group interactions within the crew can prove problematic, some dealings with other groups can improve the crewmembers' mental health. Kelly & Kanas (1993) surveyed 54 astronauts and cosmonauts who endorsed the value of contact with loved ones on Earth. They felt it had a positive influence on their performance. With an astronaut's increase in contact with support networks, his/her ability to accomplish mission goals and deal with psychosocial stressors is improved. However, during long-duration missions, crews must attend to each other and be trained to detect and intervene since Earth-side support may become impossible to maintain due to the long distance.

Kanas (1998) found decreased team cohesion mentioned in the diaries of long-duration space travelers and scientists on Antarctic expeditions. Kanas (1991) describes asthenia via irritability, low energy, dysphoria, hypo-activity, problems with sleep and appetite that may lead to decreased cohesion. Valentin Lebedev reported withdrawing from his crewmates in space during his 211-day Salyut 7 mission. This pattern of withdrawal has been seen in space analog environments as well. Kanas (1991) suggests that in the extreme withdrawal from others can lead to territorial behavior, arguments, hypersensitivity towards personal space and property, and even fights. These unfortunate behaviors may destroy cohesion of a crew and lead to major decrements in performance and the loss of ability to accomplish mission goals. Crew heterogeneity, including sub-grouping and scapegoating, has been reported in space analog environments where crewmembers segregate along social, national or task-oriented lines. Formation of subgroups may reflect deep divisions and can lead to interpersonal difficulties. The 12-

man International Biomedical Expedition to the Antarctic segregated into subgroups along national lines (Rivolier, Cazes & McCormick, 1991). This resulted in inter-group conflicts characterized by aggressiveness, lack of mutual concern, and irritability. Walford et al. (1996) observed the 8-person crew of Biosphere 2 divide into two factions (each composed of two men and two women) where one faction was loyal to outside management and the other faction perceived outside influence as arrogant, abusive and inept scientifically. Sub-grouping is a common phenomenon and if subgroups do not interact with each other at least part of the time, a potential for miscommunication or misunderstandings can negatively affect the mission.

Scapegoating is also common; often the person most unlike the majority is set up, especially if he/she is espousing unpopular ideas. Kanas (1998) observed the "long-eye" phenomenon in isolated conditions, where an excluded person experiences insomnia, depression, agitation and may even exhibit psychotic symptoms such as auditory hallucinations and persecutory delusions. Scapegoating occurred during the International Biomedical Expedition to the Antarctic and reportedly during hyperbaric chamber isolation missions (Rivolier, Cazes, & McCormick, 1991). By training a crew pre-flight or in-flight to be prepared to assess, identify and intervene if warning signs of scapegoating, tension or deteriorating crew cohesion appear, the psychosocial well-being of the crews can be improved when Earth and other support networks are not functioning or unable to communicate.

Kanas et al. (2000) evaluated the impact on five astronauts, eight cosmonauts, and 42 American and 16 Russian mission control personnel who participated in either the Space Shuttle or Mir program. The personnel completed questions from the Profile of

Mood States, the Group Environment Scale, and the Work Environment Scale weekly throughout the mission. Russians scored higher on measures of task orientation, self-discovery, managerial control, physical comfort and leader support while Americans scored higher on measures of work pressure and vigor. Mission control personnel scored higher than crewmembers on dysphoric emotions whereas both scored significantly lower than published norms from other studies. Kanas et al. (2000) found significant interaction effects for subscales which measured leader support, expressiveness, and independence with American astronauts scoring lowest of all comparison groups for all three subscales.

Leadership Research

The manner in which leaders direct the activities of the crew and the mission can increase or decrease in-flight tension. As stated above, Kanas (1993) found that during space missions two major leadership roles emerge and can be identified: task or instrumental leadership and supportive or expressive leadership. The mission commander usually is the identified task leader but this is not always the case. For example, during the 96-day Salyut 6 mission, the commander was less experienced than his older crewmate in the engineering skills necessary to repair the space station so the two men agreed to share decision-making through mutual consensus.

Both supportive and task leadership roles are important for crew functioning and each may gain prominence during different situations. In the Antarctic, the task role of the identified leader dominates initially as a clear line of authority is followed, but during the wintering-over period when the teams are completely isolated, the most valued leader utilizes a democratic style demonstrating concern for the well-being and emotional state of the crew (Gunderson & Nelson, 1963). Kanas, Weiss, and Marmar (1996) studied a three-man crew confined in the Mir simulator for 135 days using both a measure of leader control (addressing task-oriented, instrumental characteristics) and a measure of leader support (addressing supportive, expressive qualities) and found leadership style correlated significantly with a crew cohesion measure. Leon et al. (1994) found that conflicts between the more experienced and conciliatory Soviet leader and the more task-oriented and stubborn U.S. leader upset group cohesion.

Work Experience and Motivation

Previous experience, professional careers, and motivation will determine the manner in which individuals approach the mission and their tasks. Astronauts and cosmonauts find meaningful work important especially during long-duration space missions. Kanas (1998) cites several examples including: Valeri Ryumin reporting in his diary that he utilized excess work to avoid troublesome thoughts related to disappointment that fellow cosmonauts aborted their visit to Salyut 6 during his 175-day mission; crew commander of the 84-day Skylab mission Gerald Carr said it was important for him to keep busy with an active work schedule; Valentin Lebedev described keeping busy by using photographic activities to advance his professional career during his 211-day Salyut 7 mission; Norm Thagard commented that he felt underworked which made him feel bored and which created awkward situations when he perceived his Russian crew mates as overworked. Work seems to serve a number of functions for astronauts and cosmonauts in space.

However, people vary in their work motivations. Career astronauts have different goals, commitments and priorities as opposed to mission specialists and visiting scientists. Kanas (1998) found that during long wintering-over periods in the Antarctic, scientists experienced fewer psychological problems than non-scientists, because they are able to use the free time productively by conducting experiments and compiling scientific reports. Finney (1991) found that conflicts between scientists and non-scientists at sea have led to open hostilities and actual destruction of data. The ability of people coming from different work backgrounds and motivation to respect each other's roles and cooperate is critical in accomplishing mission objectives. The busy work schedules that are either self-imposed or regulated via mission planners or controllers can be utilized to cope with stressors associated with long-duration missions.

Post-Flight

Re-adaptation to Earth

Debriefings at both the individual and crew level are needed for smooth readjustment to life on Earth. Some crewmembers may have had unpleasant psychosocial experiences in space that need debriefing. For example, a crewmember who was scapegoated might have unresolved feelings that would weigh on him negatively were he not debriefed.

Kanas et al. (2009) suggest that some returning space travelers have experienced psychological problems or personality changes due to being in space. Some may become more religious, spiritual or humanistic after observing the oneness of people on earth and/or the infinity of the cosmos. Other individuals may have difficulty dealing with the fame and glory, which goes along with being in space, especially during first-of- a-kind missions such as a trip to Mars.

Family reentry may also be difficult. Studies have shown that many wives of male submariners learned to adjust to the absence of their sailor husbands when on sea patrol. However, the research (Isay, 1968) reports that over half the wives experienced depression or marital strife after their husbands returned and tried to reinsert themselves into the family dynamics. Support activities must continue into the post-mission period and be tailored not only for crewmembers and for mission control personnel, but also for their family and loved ones who may have their own adjustment issues (Kanas, 2009).

Kanas (2009) recommends more attention be paid to identification and treatment of psychiatric problems that could occur in space; more psychosocial research in space; a definition for asthenia as a discrete entity in space; more investigations of cultural factors related to psychotherapy; and further studies on the influence of microgravity on taking psychoactive medications in space.

Current research (Kanas, 2009) suggests that no permanent problems are expected for basic cognitive processes and performance during re-adaptation to Earth, except for psychomotor skills that may be impaired for a limited period due to re-adaptation to gravity. Asthenia (muscle degeneration and weakness) and other negative biological processes that adapted the crew to microgravity may prove difficult to overcome when back on Earth, for example, regaining a sense of balance in relation to gravity (Kanas, Salntsky, Gushin, Weiss, Grund, Flynn, Kozerenko, Sled, and Marmar, 2001).

However, the current literature and research does not include, nor can it foresee, the myriad of stressors, environmental hazards, disruptions of cognitive and behavioral functioning, psychological factors, physiological changes, and psychosocial interactions that can interfere with mission success, crew cohesion and the ability to cope that might occur on long-duration missions.

The post-flight phase of space travel should focus on the reintegration of crews into society, family life, and professional career. Post-flight intervention should try also to insure limited decrements in performance and health over time. After space missions, both crewmembers and mission control personnel should be encouraged to follow a strategy of keeping positive attitudes towards teammates and reunification with their families. It is the role of a space psychologist to facilitate this process (Kanas et al., 2009). Placing a psychologist on-board as one of the crew may facilitate a better understanding of the effects of microgravity, as observations can originate from internal subjective experience of a crewmember and objective reports from a psychologist.

Contemporary Research

Time magazine published an article by Jeffrey Kluger in 2015 about upcoming NASA research that will place a single monozygotic twin on the International Space Station (ISS) while the other twin will serve as the terrestrial control group in order to measure the physical effects of microgravity. Scott and Mark Kelly are monozygotic twins who were both naval aviators, test pilots and eventually astronauts, yet they were never deployed into space together as NASA had a policy against sending twin brothers on the same dangerous mission to space. Mike Sufredini, Manager of NASA's

International Space Station Program, went on to say that issue to study twins did not occur during the selection for the mission but later they used this opportunity to utilize Mark as a control group based on Earth.

The ISS measures approximately 109m with 14 modules serving as living and work space, approximately the size of the interior of a 747. According to Kluger in the *Time* article, the astronauts prefer to think of it “as a four-bedroom house.” However, being confined to one place for a year, a routine will develop and when onboard the space station, it starts and ends in a phone booth-sized private enclosure that serves as a sleep chamber and personal space. The astronaut workload reported by Kluger (2015) coincides with the literature and astronaut response where the astronaut must feel the work is meaningful and useful while having enough personal time to maintain a healthy balance of work and leisure. Kluger (2015) noted that a day onboard the ISS usually follows a 30/40/30 work breakdown where 30% of the time will be devoted to science experiments, 40% to physical exercise and monitoring of station systems, and 30% fixing hardware breakdowns. Leisure time can be TV shows, books and movies while onboard the space station but the connection will become more disrupted and will prove extremely difficult on long-duration missions far from Earth. However, due to the battery of 10 medical and psychological tests on the agenda for the NASA study on Scott Kelly, leisure time may be lighter than previous missions into space (Kluger, 2015)

Scott Kelly will be partnered up for 1 year with Russian cosmonaut Mikhail Kornienko as well as a rotating crew of another 13 personnel who may be aboard anywhere from 10 days to 6 months conducting experiments or reconfiguring space station modules for the arrival of private industry crew vehicles which may arrive as early as 2017. According to Kluger (2015), NASA flight surgeons will run studies of cardiovascular efficiency, blood-oxygen levels and blood volume. Bone density, fluid shifts in the body, and cellular aging will be monitored while sonograms of the eye and optic nerve will help determine the impact on vision of fluid redistribution in microgravity. In addition, the study will assess something that has been predicted but not researched, the effect on the body's microbiome or microbes such as bacteria crucial to maintaining bodily function which will be scrutinized by comparing the analysis of bodily waste.

While the body may suffer from a myriad of problems due to long-duration exposure to microgravity, according to the literature the mind is hit even harder. A psychologist will track the cognitive functioning, mood and stress level of both astronaut Scott Kelly and cosmonaut Mikhail Kornienko during their stay onboard the ISS (Kluger (2015). The psychologist will be especially alert for the third-quarter effect which is "a slacking off of psychological performance that hits between the half and three-quarters point of any long confinement or tour of duty." NASA psychologist Al Holland reported that Scott has flown a 6-month mission and that data was gathered during his stay but the brain's changes are "not a linear thing. Running a full marathon is different from running two half-marathons" (Kluger, 2015, p.38).

The research can help us understand and counteract some of the dangers associated with space travel which are very apparent and real to the twins. In the article, Mark Kelly reported, "This is a dangerous job. The public doesn't understand how dangerous." Sadly, during Scott's last mission, it was Mark who had to lean on him since in January 2011, Mark's wife, former congresswoman Gabrielle Giffords, was shot.

NASA got the news up to Scott but it was only later that the brothers could talk. But for Mark, it was not the same since, “The one person who could have given me the most support was off the planet” (Kluger, 2015, p.38). This epitomizes the increased difficulties with long-duration space missions due to increased crew autonomy from Earth and lack of communications.

Future Research

As noted, the United States has vaguely discussed a crewed mission to Mars with a target date always a decade or two in the future. However, on December 5th, 2014, NASA demonstrated a successful uncrewed test flight of the Orion spacecraft, the next deep-space ship. There continues to be competition from private industry such as Elon Musk’s SpaceX and Mars One, as well as nations like China and India with their own space programs. Issues arise as to the applicability of space simulation studies to actual space missions because Earth-bound analogs cannot fully reproduce all stressors found in space such as microgravity, potential danger with little hope of rescue, increased doses of radiation and extreme isolation. Due to the advent of improved technology coupled with private industry funding, research in space may become more prominent and essential.

Sandal et al. (1996) found evidence among crewmembers working in different space simulation environments that different psychological reactions were occurring. Within the hyperbaric (pressurized) chamber, the crews experienced low overall anxiety, which steadily decreased over time, whereas polar expedition crews had higher anxiety during the first and third quarters of their mission. Contrary to anecdotal reports from space, in a 135-day Mir simulation study (Kanas, Weiss, & Marmar, 1996), dysphoria and tension were significantly lower in the second half when compared to the first half. These conflicting findings indicate that caution must be utilized when extrapolating phenomena found in simulation studies to actual space missions.

The crew may also be more vulnerable to pathogens then when they are on Earth since their immune systems have not been exposed to the microbes within the sterile close environment of the crew habitat. Sadly, astronauts might never be able to rejoin society if the constant radiation in space serves to mutate bacteria and viruses to a point where they are extremely deadly to the rest of the population. The astronauts may become carriers since they have been exposed for the entire duration of the trip. The psychological impact of returning to Earth to be permanently quarantined must be examined. Research into training crews to prepare mentally and emotionally for a one-way trip due to one of a myriad of unforeseeable disasters is another area for future research.

Space analog studies can still be utilized since they lead to characterization of important space-related psychological factors under controlled conditions and expose possible relationships between these factors. They also allow for manipulation of variables to elucidate cause and affect sequences. Space analog studies are practical as well in that they are cheaper and easier to perform than research in space. However, before the advent of long-duration international space missions, it would be helpful to study psychosocial factors under real-life space conditions. Analog information can never fully reproduce the variables of space travel. The International Space Station is a good arena in which to study these variables, such as the psychological, psychosocial, and cultural factors affecting crews living and working in space over long periods.

Private industry mission Mars One has continually provided press releases regarding their efforts into colonizing Mars, yet their efforts reflect little consultation with the literature and experts. A Massachusetts Institute of Technology study by Do, Ho, Schreiner, Owens, and de Weck (2014) developed a Mars settlement analysis tool that integrates a habitat simulation with an in-situ resource utilization (ISRU) sizing model and spare parts analysis. A logistics model was utilized to predict the number of launchers required to estimate the program cost as an independent assessment of the technical feasibility of the Mars One mission. Do et al. (2014) reported that growing crops as their sole source of food will produce unsafe oxygen levels within the habitat. The authors' analysis model estimated that only 8% of the mass input would yield crops over a 2-year period since the surface of Mars has little nitrogen, oxygen and water and the required technology has yet to be developed. Crews will be forced to rely upon ISRU and life support technologies that are more capable than the current state as well as the reliance upon limited resupply logistics and sparing (Do et al. (2014).

In the article, two food procurement systems were analyzed: Biomass Production System (BPS) or Stored Food (SF). For the BPS food procurement, each crew requires four Falcon-Heavy launches for a total of 17 cargo pre-deployment launches and four crew launches at a cost of $6.3 billion. The authors reported that, based on their first simulation of the baseline Mars One habitat with ISRU-derived resources, the first crew fatality would occur approximately 68 days into the mission due to suffocation from too low an oxygen partial pressure within the environment.

Do, Ho, Schreiner, Owens, and de Weck (2014) conducted a spare parts analysis which revealed that space parts quickly come to dominate resupply mass. After 130 months on the Martian surface, spare parts composed 62% of the mass brought from Earth. The article's logistical analysis revealed that establishing the first crew for a Mars settlement will require approximately 15 Falcon Heavy launchers at a cost of $4.5 billion in funding which only included the launching of life support and ISRU systems with space parts. Do et al. (2014) suggest that in order to capture a more realistic estimate of mission costs, future research should consider development and operations costs as well as the integration of other mission elements such as communications and power systems. As more crews and systems function on the Martian surface, subsequent launches will require carrying increased spare parts and consumables. The first launches include cargo pre-deployment for the first crews while the second launch campaign includes both delivery of the first crew and cargo pre-deployment for the second. While the technology aspect was the focus in this article, several issues emerged that coincide with findings in the literature and demonstrate not only a lack of research into the technical aspects and feasibility of space exploration, but the need for further research.

CHAPTER III

Method

Design of the Study

The purpose of this study was to examine the psychological and physical stressors of living and working in the extreme environment of space via interviewing an astronaut participant. The study consisted of three semi-structured interviews beginning with one focusing on altered senses and physical adjustments. The second interview emphasized social interactions. Finally, the third interview encompassed psychological, emotional and cognitive changes. Due to limited research into psychological impact, treatments and interventions, an exploratory approach was utilized.

Exploratory research is conducted for problems that are not clearly defined in order to determine the best research design, data collection, and subject selection. This approach may be appropriate for human exposure to microgravity for long duration space missions since many problems have yet to be identified and there is little corresponding research. The purpose of this research was to gain familiarity with how to sustain humans in microgravity for longer periods as well as acquire new insights or develop hypotheses for selecting, training and treating astronauts. The generalizability of exploratory research is tentative, but the information gained is a prelude to a deluge of human research into manned space missions. The number of individuals capable of participating in this research who spent significant time in space is approximately 500 depending on either the USAF or FAI definition. Therefore, an exploratory case study is a good option since it is not only difficult to find someone who has been in microgravity; many have been in space for shorter periods of time and not one human has been beyond Earth's orbit.

No agency has given exact days predicted for a manned Mars mission, but a general consensus using historical data and analyzing current technology is that a single Earth-Mars transit time will take approximately 180 days in deep space which does not include the required 2 years planet-side for the orbits of Earth and Mars to coincide as well as the return trip. Valeri Polyakov spent the longest individual time in space with 437.7 consecutive days, while over six spaceflight missions Sergei Krikalyov accrued the most days in space with 803.4 so humans are capable of being in micro-gravity for a comparable amount of time. However, the scenario and mission requirements would impose different stressors and demands as well as exposure to dangerous and yet unknown sources. Due to the limited information, an exploratory case study was used to understand human spaceflight for future research.

Participant

The astronaut participant was a 49-year-old Asian-American male. He worked at various aerospace corporations as a structural engineer, which led to becoming a mission operations manager on a space shuttle mission. At the time of the interview he had logged a total of 131 days and 18 hours in space including numerous hours of extra-vehicular activity or tasks outside of the spacecraft or station exposed to the vacuum of space.

Measures

The first interview focused on altered senses and physical adjustments to microgravity. It included questions such as, “Did you have headaches or difficulties with your eyes?” The second interview centered on social interactions asking questions such as, “How did language affect crews?” Psychological, emotional and cognitive differences experienced was the focus of the third and final interview asking questions such as, “How was your memory affected?” Complete interview questions are presented in Appendix A.

Procedures

The dissertation included a multi-phase process regarding the gathering and analysis of the data. In the first phase, questions were developed by reviewing the literature and the studies’ predicted long-duration implications. The questionnaire was then emailed to several astronaut participants. The responses of one astronaut were analyzed in order to identify themes and then transposed into an Excel spreadsheet to be analyzed via SPSS where the frequency of responses was compared with those described in the literature review.

The first phase included a literature review of research studies for deploying astronauts in order to determine the effects of long-duration space missions and generate questions. However, no humans have been sent on a long-duration space mission outside of Earth’s gravity so while researching short-term effects of space travel, the predictions of long-term effects found in those studies were used to generate questions. Studies regarding long-duration missions had been conducted by the U.S.S.R but were unavailable to the public and not in English.

The literature review revealed that selection and training within the pre-flight portion of the mission were important for determining how crews can be selected and trained to interact well. Several factors influenced how crews interacted amongst themselves as well as with the people on Earth including communication, leadership style, crew size, level of autonomy, isolation, culture, language, etc. Due to these factors, one part of the questionnaire focused on the social aspects of how astronaut crews can be selected and trained as well as how to assess and treat the symptoms depending on the level of autonomy and isolation. The literature also revealed that astronauts frequently experienced sensory and physical alterations during short-duration space missions. As these symptoms were problematic, the next set of questions focused on how they will manifest during long-duration space missions as well as how to assess and treat.

Data Analysis

The purpose of this exploratory study was to compare astronaut survey information to the literature review in order to understand:

1.) How to select individuals for long duration space travel pre-flight;
2.) How to train crews for space travel;
3.) How to treat crews while in-flight during extended deployments in space;
4.) How to reintegrate personnel post-flight on Earth or another planet; and
5.) How to cope with the underlying themes not reported or researched.

The analyses of the astronaut's interviews occurred several times in order to compare the answers to the literature review and identify underlying themes. The interviews were transcribed in their entirety and were read repeatedly, and then divided into major themes. A clinical psychologist with experience in both qualitative and quantitative data analysis reviewed the participant's responses and independently identified themes by which to categorize the participant's responses. Two post-doctoral fellows coded the participant's responses into the identified thematic categories. Both fellows had extensive experience in program development and evaluation and one had published in the area of health disparities research. The second post-doctoral fellow had extensive experience in evidence-based treatments for both child and adult mental health disorders and chronic disease management. After themes were coded, the Excel spreadsheet data was input into SPSS to determine inter-rater reliability before comparing the thematic codes to the literature review.

The interviews identified four overarching themes throughout all stages of the mission by highlighting frequently used key words and phrases along with the associated underlying themes. The four themes were: communication, un-researched problems, environmental stressors, and personal strengths. The coding themes also included an "Other" category utilized if the coders found that the four major themes did not fit the response.

CHAPTER IV

Results

Inter-rater reliability was calculated to evaluate the statistical level of agreement. Each category included quotes from the astronaut interview and when possible, how a specific factor could become problematic or how it could be counteracted. This section includes a kappa statistic analyzing the inter-rater reliability followed by the frequency of coding by each rater. The next component of the results section will examine each major category with high levels of inter-rater reliability. I will then review items that were without inter-rater agreement. Finally, this section will include several items consistently rated in the same category by the same rater but consistently different than the other rater.

Inter-Rater Reliability

The kappa statistic (Viera & Garrett, 2005) is the most commonly used method for measuring agreement between two or more observers. Kappa is standardized to lie on a -1 to 1 scale where 1 is perfect agreement, 0 is what would be expected by chance, and negative values indicate agreement less than chance. While not everyone agrees on what constitutes "good" agreement, Viera & Garrett (2005) included a table of a commonly cited scale where: < 0 indicates less than chance agreement; 0.01–0.20 indicates slight agreement; 0.21– 0.40 indicates fair agreement; 0.41–0.60 indicates moderate agreement; 0.61–0.80 indicates substantial agreement; and 0.81–0.99 indicates almost perfect agreement. The inter-rater reliability between coders in the present study was calculated by SPSS resulting in a kappa of 0.411 (p = 0.000), suggesting moderate agreement between the coders.

Coding Frequency

The two raters' responses and their frequencies are included below where Tables 2 and 3 refer to Rater 1 and 2's coding frequency respectively. Both Rater 1 and 2 coded the Environmental Stressors Category the most (Rater 1 = 31.3%, Rater 2 = 50.0%). The Communication Category was coded 28.1% and 18.8% by Rater 1 and 2 respectively. The Other Category was the third most frequently coded (Rater 1 = 28.1%, Rater 2 = 12.5%). The Personal Strengths category was not frequently coded (Rater 1 = 9.4%, Rater 2 = 12.5%) and the Unresearched category was the lowest coded (Rater 1 = 3.1%, Rater 2 = 6.3%). The categories that both raters rated while coding will be analyzed and reported both for items that were agreed upon as well as items with different coding.

Table 2 – Rater 1 Theme Coding Frequency

Themes	Frequency	Percent
Communication	9	28.1
Un-researched	1	3.1
Environmental	10	31.3
Personal Strengths	3	9.4
Other	9	28.1
Total	32	100

Table 3 – Rater 2 Theme Coding Frequency

Themes	Frequency	Percent
Communication	6	18.8
Un-researched	2	6.3
Environmental	16	50.0
Personal Strengths	4	12.5
Other	4	12.5
Total	32	100

Environmental Stressors

The Environmental Stressor category appeared to be the most frequently problematic in the literature and the astronaut interviews. For example, the literature review suggested that living within such an extreme environment would result in many difficulties and one of the questions in the interview asked what was effective in minimizing altered senses due to microgravity. The astronaut reported, “I’m not sure what you mean by 'altered senses' – but if you simply mean the adjustment to microgravity, I'd say that there is no way to prepare for it – it is something that can only be learned and adjusted once you are in microgravity. I should just say that the classic senses-smell, taste, feel, hearing and sight are unaffected by microgravity (there is some thought that sight is affected for some people but only after long-exposure to microgravity). Other 'senses' like balance, body control, sense of speed – are affected, but there is no way to prepare or pre-adapt to these changes – it is much of the fun of flying in space – being able to experience and learn to adapt to the strange new environment." A follow up question asked about how adjusted senses modify crew behaviors in microgravity and how to prepare personnel. "Again, I do not think that the sense are modified on the ISS, nor would these have any effect on the behaviors on the crew. See answer above," was the astronaut's response.

A question asked how to relieve symptoms of space sickness or Space Adaptation Syndrome and the astronaut reported, "Several medications are used to combat space sickness for the initial couple days in micro-gravity. Happily, though, virtually all astronauts have these effects disappear within 2 or 3 days of living in space. Besides medications, there are a few other 'folk' remedies that have been passed around the astronaut community, but that was much more important for shuttle missions where crews were being asked to be highly efficient from the first few minutes in orbit. Long-duration missions such as ISS stays are less of a concern, as the first 2 days are used for transit and most of the work is done well after the first few days in space." This answer will be further examined in the discussion section since the programs mentioned may have been long-duration missions on the ISS or Mir, but no research has been conducted outside of Earth's gravity with isolation from Earth.

Several questions focused on how to improve the functioning and well-being of the crews. The first asked how to lessen difficulties related to memory or motor coordination if crews realize there are impediments. The astronaut responded, "The trick is for the crew member to recognize or measure a reduction in these capabilities. There are some computer programs (e.g. WinScat) and physical tests to assist a crew member to self-evaluate. If there is a change – a conference with specialist on the ground is the best option. If ground conference is not possible, an "expert system" should be designed to assist crew members in this situation." This answer demonstrates the cross skills training required by crews and will be examined in the discussion section.

The astronaut reported that "proper scheduling and medications" will help crews receive adequate rest and sleep during long-duration missions. This answer is interesting due to the limited availability of supplies (e.g. medication) and autonomy during long-duration missions outside of Earth's gravity but will be examined in the discussion section. The follow up question focused on how workloads would be altered to reduce burn out amongst crews to which the astronaut responded with "very careful scheduling and external monitoring and oversight on the crew's workload." Another question asked was, if crews experience headaches or difficulties with their eyes on long-duration missions far away from Earth, what suggestions do you think will diminish these complications. The response was that "Astronauts headed to the ISS are given some glasses to adjust for mild changes in eyesight – based on a few shifts in eyesight seen in earlier missions. These glasses are carried as part of their personal equipment, and would be used if there is a change in eyesight. If headaches are encountered, there is a medical kit with off shelf pain killers." When asked how thinking will be affected and how spare time can be maximized, the astronaut reported that "scheduled work and scheduled free time is required, but enough flexibility needs to be built in to accommodate crew members' personality and their feelings." Once again, the results report upon the current understanding and research without factoring in the crew isolation from Earth, crew autonomy, and lack of supplies in space.

Communication

Communication was found to be a critical component in how international crews interact and function properly. Questions focused on behaviors that were encountered during space missions from several astronauts of different ethnic, cultural, and occupational backgrounds. One questions asked what interventions worked well if crewmembers displayed withdrawal or territorial behaviors. The astronaut reported, "We were trained to use as much communication as possible – address the behavior and attempt to find out what was going on. Fortunately for my crew of 3, we did not have any issues of this type of behavior." When asked how to minimize the displacement of anger, agitation and frustration that may occur amongst crews onto ground personnel or each other, the astronaut reported that, "Again, good communication is the key. Sometimes, it is better to divert the aggravation somewhere – anywhere – outside of the crew. It is not a good idea to vent to the ground team, but it is better for the flight crew to stay cohesive and use the ground as the "other guys" than to divide the crew. Once the episode is over, however, it is important to mend relationships with the ground."

Isolation from Earth and humanity has been reported as problematic in the literature as crews must function autonomously while living in almost complete isolation from the rest of humanity while also being confined with several other humans within a very small hostile environment. The astronaut reported that “The best and most important factor in fighting feelings of isolation is high quality, frequent communication with friends and family. The ISS has a telephone system that allows crew members to make phone calls most times of the day, and we have had no issues with isolation or crew dysfunction.” Once again, these results will be further examined since the ISS may be long-duration missions, but may not be able to completely replicate the feelings of isolation such as when an astronaut no longer can communicate with Earth in a timely manner as the Earth and humanity has become an indistinguishable speck amongst a sky full of stars.

The astronaut reported that in order to reduce tension and improve interactions amongst crews and ground control, “familiarity is very important – so social and other non-work activities prior to flight (with ground personnel also) helps ensure that tensions do not rise too high, and that an ‘us vs. them’ attitude does not develop.” When asked how language affects crew interactions of the crews and ground personnel, he replied, “language is a critical and dangerous aspect of international crews. Simple misunderstandings or misinterpretations can lead to serious personal issues between crew members. Again the more time spent pre-flight with each other, the better that little misunderstandings can be overcome.”

Other

Two questions and responses were coded within the Other category where both responses were "similar answer to other questions." The first question was how crews on long-duration missions deal with different fears and anxieties. In reference to this, the astronaut and literature implied selection criteria of soft skills instead of training as "those types of skills are better in-situ rather than taught after selection (you either have it or you don't)" as well as cross training crew members to monitor and intervene psychologically. The second question asked how to maintain cognitive performance during long-duration missions to which the astronaut reported that the answer was being researched by the human factors community. The astronaut and literature both suggest that effectively designing and keeping a balanced schedule regarding a crew's workload, exercise, and leisure time may help manage and mitigate some psychological and cognitive difficulties reported during analogous long-duration missions in space.

Personal Strengths

A question asked the astronaut how the psychological selection, training, and treatment might be altered to accommodate for longer-duration missions. The astronaut reported that "this is being done now for the NASA astronaut selection process. Lots of emphasis is being placed on an applicant's 'soft' skills – teamwork, self-reliance, resourcefulness, etc. With the realization that the astronauts that are chosen will be asked to live in confined spaces with a few people for long periods of time, it is felt that these types of skills are better in-situ rather than taught after selection (you either have it or you don't)." The astronaut selection criteria have been supported by the literature and different government space agencies, so the astronaut's response will be further examined in the discussion section since the private industry and particularly Mars One wants to focus on marketing instead of crew capabilities.

Unresearched Problems

Throughout the literature and interview process, there were several factors that continue to be un-researched either due to the technological infeasibility or inability to predict the myriad of hazards inherent to an extreme environment such as space. When asked how crews will deal with more autonomy due to the time delay between Earth and the spacecraft, the astronaut reported that “the issue of autonomy and time delay is a very interesting one, and one that we plan to study at NASA. There isn’t a lot of research in the literature about this.” This response will be further examined in the discussion section.

Items without Agreement

Several responses and questions were coded differently by the two raters. One question asked how crew size and composition would affect long-duration missions and extended flights. The astronaut said, “A very good question – something that psychologists are working on right now. Gender, age, relative rank and other professional relationship, personal relationships, etc. are all issues that will need to be addressed for missions that are years long.” This may have been coded in the environmental stressors by one rater, but this response included several factors including communication and un-researched problems.

The ratings of leadership styles were not in agreement as one was rated in the personal strength category while the other was in the communication group. The astronaut reported that, "leadership is critical-within the flight crew and within the flight and ground team. Most astronauts react best to an inclusive style of leadership, but each crew will be different and will have to decide what works best for them."

The reintegration of returning astronauts was rated in two separate categories, communication and other. The question asked how to prepare families with coping and reintegration. The astronaut reported that caring for the families was the biggest aspect of crew happiness and peace of mind: "NASA went to great lengths to help and assist families of ISS crew members" and he further commented that he thought that this was "one of the huge 'hidden' successes of the program." The astronaut commented on the importance of keeping families completely informed with appropriate correspondence such as photos and videos. He mentioned that families were counseled before astronauts return to prepare them for what the astronaut called "bi-lateral re-integration."

Items consistently categorized by Rater 1 as Environmental and Rater 2 as Other

The inter-rater reliability reached a significant level but five items were categorized by rater 1 as an environmental stressor while rater 2 sorted the same items into the "Other" classification. Several of these items related to the physical adaptation in space due to long-duration exposure to microgravity and the confined space habitat interior environment. The first item related to the lack of privacy within the constricted confines of a spacecraft. The astronaut reported that dealing with such conditions can be made by "selecting the right people" and that most designs for living quarters include private quarters for each crew member, something he described as very important. When asked how the interior of the spacecraft or space station affected crews during long-duration exposure to microgravity, the astronaut reported that, “the appointment of the interior of the habitat is important, but not critical, as long as good sense is used to create the living space.” The astronaut made specific mention that, “Private ‘bedrooms’ are mandatory as is a place for the crew to all gather for meals and meetings.”

Helping crews deal with physiological changes due to long-duration exposure to microgravity was placed into different categories of Environmental and Other. The question related to forthcoming research by NASA examining twins separated with one onboard the international space station. The astronaut responded that the question is a topic of research for NASA. The astronaut mentioned that, “after a long transit to Mars, the crews will be asked to adapt back to a gravity field (1/3 in the case of Mars) and begin useful work as soon as possible.” He reported that the US program prepares crews with exercise and a robust re-adaptation program in order to best adapt to a gravity environment. He specifically mentioned that astronauts returning from the ISS are subjected to 6 weeks of intensive physical training/rehabilitation. “A similar type of re-adaptation would most likely be utilized on Mars or other remote locations – but the protocol would have to be self-applied and monitored.

Another set of questions that related to physically demanding activities and preparing crews for degeneration associated with microgravity was placed in different categories. The astronaut reported that the most physically demanding activity was exercising to keep muscles and bones as conditioned as possible. He described a daily 2-hour exercise regimen with a mixture of cardiovascular exercise on a bike or running with resistance weight lifting. The astronaut specifically mentioned that, with the exercise regimen, even EVA (Extra-Vehicular Activity) or spacewalks were “no more tiring than the Earth-based training." He reported that most of the cardiovascular issues have been counteracted by the heavy exercise regimen while in microgravity.

CHAPTER V

Discussion

The literature review and interview were compared in relation to the different stages of the mission and the identified themes. This comparison examined the psychological impact of isolation, crew interaction, and experience of microgravity to increase the understanding of how to improve crew survivability and positive small group interactions as well as possible treatments for crews who transition back to Earth. The three questionnaires focused on social interactions, sensory and physical experiences, and the psychological, emotional and cognitive components of being in space. The major themes identified included communication, un-researched problems, environmental stressors, personal strengths, as well as an "other" category. The most frequently coded themes were environmental, communication, and other, which corresponds with the literature review as predicted difficulties. The astronaut did not report experiencing negative effects in space but did endorse several difficulties found in the literature review.

Astronaut and Literature Agreement

The astronaut's responses and literature coincided with regard to several difficulties in space travel as well as attempts to reduce their negative impact on the mission and crew. The astronaut specifically agreed with the importance of the following themes identified in the literature: selecting candidates with a particular set of characteristics, difficulties of living within a confined extreme environment, how to improve interactions, leadership, and several un-researched long-duration factors. While the astronaut did not experience symptoms related to space adaptation syndrome, his treatment of some of the negative side effects corresponded with the literature.

Kanas (2009) suggested that developing selection criteria is necessary to eliminate unfit or potentially unfit applicants and to identify qualified candidates who will perform and cope optimally based on their basic aptitudes, attitudes, prior experiences, and personality characteristics. The astronaut stated, "Lots of emphasis is being placed on an applicant's "soft" skills – teamwork, self-reliance, resourcefulness, etc. With the realization that the astronauts that are chosen will be asked to live in confined spaces with a few people for long periods of time, it is felt that these types of skills are better in-situ rather than taught after selection (you either have it or you don't)." He went on to comment that, "I think the most effective thing was the initial selection of crew members that are able to deal with difficult psychological issues – for themselves or their crewmates. I don't think any amount or type of pre-flight training would help this situation." Kanas et al. (2009) reported that several studies have linked superior performance to a personality profile characterized by a combination of high levels of expressivity and instrumentality as well as lower levels of interpersonal aggressiveness. These authors suggest that the greatest benefit can be expected if selection processes are combined with pre-mission training where simulations may be essential.

Kanas & Manzey (2008) proposed determining what training standards and candidate characteristics will increase resistance to the myriad of stressors, promote mission success and decrease potential casualties in space exploration. Kanas et al. (2009) recommend: (1) facilitating crew cohesion via undergoing survival training together in a variety of extreme environments; (2) crews training together pre-flight because the longer they train together, the smoother their future interactions; (3) pre-flight training involving mission control to enhance crew-ground cohesion; (4) group sensitivity training as this can reduce influences of personal, cultural, national and other peculiar behaviors during the in-flight portion of the mission; and (5) communication and conflict resolution training being tailored for the characteristics of the particular space crew involved. Similarly, the astronaut reported, “We already try to do ‘team building’ events prior to long duration missions – camping trips, survival training, etc – events where the crew members are put through rugged experiences and can then learn to trust and rely upon each other – and also learn about their weaknesses and strengths. These types of pre-flight activities will be even more important as mission durations get longer.”

The astronaut reported that, “language is a critical and dangerous aspect of international crews. Simple misunderstandings or misinterpretations can lead to serious personal issues between crew members. Again, the more time spent pre-flight with each other, the better that little misunderstandings can be overcome.” This response was verified by Santy et al. (1993) who reported that astronauts acknowledged that conversational language training is important in missions composed of international crews. These researchers surveyed nine astronauts who recorded 17 incidents of miscommunication, misunderstanding or interpersonal conflict that had a moderate or high impact on the mission. Sandal (2001) conducted a study that showed increases in interpersonal tension in the beginning, during the middle, and towards the end of confinement. This has been verified by other researchers studying personnel in isolated and confined environments (ICE) settings such as Rohrer’s (1961) polar station studies, submarine studies (Sandal, Endresen, Vaernes, & Ursin, 1999) and Russian space missions (Gushin et al., 1996). MacCallum and Poynter (1995) found that interactions between crew and mission control members were considered the largest factor affecting crew performance and safety in Biosphere 2. The astronaut reported, "We were trained to use as much communication as possible – address the behavior and attempt to find out what was going on."

The aspect of leadership was not a focus in the burgeoning stages of space travel as candidates were selected from a homologous group of pilots and engineers. When asked how leadership would affect crews and ground personnel, the astronaut reported, "leadership is critical –within the flight crew and within the flight+ground team. Most astronauts react best to an inclusive style of leadership, but each crew will be different and will have to decide what work best for them." Different leadership roles gain prominence at different times where two major leadership roles have been identified: task (instrumental) leadership which is oriented towards accomplishing work goals and operational needs, and supportive (expressive) leadership focused on morale and addressing emotional needs (Kanas, 1998). A study of a three-man crew confined in a Mir simulator for 135 days found that a measure of leader control (addressing task-oriented, instrumental characteristics) and leader support (addressing supportive, expressive qualities) correlated significantly with a measure of crew cohesion (Kanas, Weiss, & Marmar, 1996). Leon, Kanfer, Hoffman, and Dupre (1994) found that conflicts between the more experienced and conciliatory cosmonauts and the more stubborn and task-oriented astronauts was detrimental to overall cohesiveness of the group.

Long duration missions in an extreme environment will entail several un-researched factors such as disrupted communications with Earth, increased crew autonomy, fatigue, monotony, isolation, and altered senses due to microgravity. Overall, the literature and results reveal that the research does not understand the long-term effects of space travel as it is an ongoing area of study. The participant reported, "The issue of autonomy and time delay is a very interesting one, and one that we plan to study at NASA. There isn't a lot of research in the literature about this." This is supported by Shayler (2000) who notes that deep space conditions will most likely restrict communications; thus, studying different psychological stressors and coping mechanisms is essential to train the crews to treat themselves and maintain their own mental health. Kanas et al. (2007) point out that the extremes of planetary orbits encompass a 44-minute transmission time to ask a question and get a response from Earth, making it impossible to communicate in real time with family, friends, mission control, or other sources of support during a crisis.

Kanas et al. (2009) discovered impairments of perceptual-motor performance during the early phase of a mission which was likely attributed to direct effects of microgravity on the sensorimotor system, but most other effects appear to be related to non-specific stress due to physiological changes, sleep disturbance, inadequate work-rest schedules and other extreme living conditions inherent to space. Congruent with this, the astronaut reported that, "fatigue and weakness are typical symptoms experienced on the ISS – due to over-work - and time off and a temporary reduced work schedule almost always clears up these problems. Monotony is a different issue – and to my knowledge, this has not been encountered on the ISS. Monotony will be an issue for long-distance missions, and several ideas have been proposed to deal with the problem. Whichever option is taken, the crew members must feel that they are doing meaningful and useful work mixed with enough personal time to keep a healthy balance between work and personal time." The participant went on to say, "a limited amount of spare time is critical to allow crew members to spend time on personal hobbies, communication with home, just quiet time. However, the amount of free time cannot be too long – to avoid boredom. The way ISS deals with this is to have a 'task jar' of work that is always ready to be performed if there is a crew member that has free time and is looking for something useful to do."

The literature suggested several means to counteract some of the negative side effects of space travel such as with exercise, proper diet, and a stockpile of medications onboard, but according to the participant there are also some "folk remedies" passed around the astronaut community, but was not specifically listed. The astronaut agreed that "several medications are used to combat space sickness for the initial couple days in micro-gravity. Happily, though, virtually all astronauts have these effects disappear within 2 or 3 days of living in space. Beside medications, there are a few other 'folk' remedies that have been passed around the astronaut community, but that was much more important for shuttle missions where crews were being asked to be highly efficient from the first few minutes in orbit. Long duration missions such as ISS stays are less of a concern, as the first 2 days are used for transit and most of the work is done well after the first few days in space." This demonstrates the lack of research and understanding into the symptoms and treatments related to exposure to microgravity for long-durations.

Astronaut and Literature Disagreement

The only area in which the astronaut's responses in the current study did not align with the literature is that he did not report experiencing cognitive and memory deficits. In contrast, other personnel exposed to microgravity endorse a wide range of changes including vertigo, nausea, twitches, as well as the "Earth out of view" phenomenon. Current research (Kanas, 2009) suggests that no permanent problems are expected for basic cognitive processes and performance during re-adaptation to Earth, except for psychomotor skills that may be impaired for a limited period due to re-adaptation to gravity. Kornilova and Kozlovskaya (2003) define space adaptation syndrome (SAS) as autonomic reactions during microgravity, but if these reactions manifest clinically to decrease professional efficiency, the state is then defined as space motion sickness (SMS). The abnormal reactions via exposure to microgravity are due to the interaction between the gravitational factor and the vestibular system, which are interrelated. These researchers found that from Day 60 of microgravity on, abnormal oculomotor responses such as orientation illusions, vertigo, difficulties tracking moving objects and difficulties focusing were regularly observed. These symptoms were indicative of changes in the vestibular and sensory systems that went through oscillating periods of abnormal and normal.

Cosmonaut Valery Polyakov holds the record for longest stay in orbit with 438 days in 1994-1995. This provides evidence that at least one human being is capable of enduring a demanding work schedule in isolation and a long-duration confinement in outer space. Manzey, Lorenz and Poljakov (1998) repeatedly assessed Valery Polyakov during his 438-day stay in space comparing his performance pre-flight, in-flight, immediately post-flight, and during two 6-month periods after the mission. The results indicated that the first 3 weeks of long-duration space flight and the first 2 weeks back on Earth represent critical periods, as adverse effects on mood, attention, and performance are induced via the demands to adjust to the gravitational changes. When asked about these adjustment periods, the astronaut in the current study responded that helping personnel dealing with balance changes was "a great question and a topic of research for NASA. After a long transit to Mars, the crews will be asked to adapt back to a gravity field (1/3 in the case of Mars) and begin useful work as soon as possible. The US program feels that exercise and a robust re-adaptation program is the best way to adapt to a gravity environment – astronauts returning from the ISS are subjected to 6 weeks of intensive physical training rehabilitation. A similar type of re-adaptation would most likely be utilized on Mars or other remote location – but the protocol would have to be self-applied and monitored."

In addition to specific microgravity effects, the working and living conditions of space can induce stress that may lead to degradation of cognitive and psychomotor performance (Kanas et al., 2009). Astronaut Scott Kelly and others have reported experiencing long-duration effects. Scott described a stubborn eye twitch during re-entry after a 159-day stay aboard the space station stating, "It's something other long-duration astronauts have complained of too, but there is no explanation for it yet" (Kluger, 2015, p. 37). His twin, astronaut Mark Kelly, was questioned about the twitching eyes which he denied experiencing, to which his twin brother replied, "Your flights weren't long enough" (Kluger, 2015, p. 37). Some crew members experience negative side effects but most have not been in space for more than a year.

Conclusions

The astronaut's responses and literature demonstrates the motivation behind researching the long-term effects of space missions on the human mind and body. Crews will be required to spend extended durations within a confined extreme environment, or do so indefinitely. Individual crew members may or may not experience negative symptoms related to exposure to microgravity, but no research has been conducted for long periods outside of Earth orbit so generalizing maybe hazardous or unwise. Selection criteria, proper training, and interactions effects appeared to be a large deciding factor in mission success. While the private industry may be less concerned with the wellbeing or return of their crews, as scientists and researchers we must continue to identify negative factors and develop treatments for the population whether or not they are on this planet or in the depths of space. This dissertation can help guide future research concerned with the wide breadth of predictions and observed factors associated with long term space missions.

Limitations

The limitations of this study include the fact that only a single astronaut was surveyed and the difficulty with generalizing results. This is unavoidable due to the challenges of obtaining a willing participant from a pool of only approximately 500 individuals worldwide who have been deployed into space and their protected status from their respective government agencies. Another limitation was the short period of contact for the survey and the inability to compare surveys or the results of other astronauts. The lack of information available for public access has factored into the difficulty of generalizing the data for the private sector's next generation of astronauts selected from the general population. Data and research associated with space travel are rightly classified, but as private industries begin to control manned spaceflight, this study and other confidential information will need to be analyzed.

Another limitation involves using a case study methodology via interviewing rather than using assessment tools or other measurable protocols and data. This limitation could not be avoided since, as mentioned above, most astronauts are protected by their governments, and traveling in person across the world to conduct assessments would be impossible. Since there are few experts in long-duration space travel, having appropriate coders to analyze the responses of astronauts was difficult to organize. As such, post-doctorate level individuals with familiarity on psychological interactions in isolated and rural communities coded the responses.

Implications for Future Research

The largest obstacle to the current research and the future of space travel is the inability to run tests and practice missions due to costs and the associated risks for the crews. Analogous studies may contain certain aspects that may be generalized, yet some of the most pivotal dangers cannot be replicated in the lab and even more hazards lay undiscovered so the treatments will have to be developed during the mission. Kanas et al. (2007) caution against extrapolating the findings to future missions beyond Earth's orbit because the extreme distances may change the mission profile considerably. Martian mission scenarios foresee an international crew of seven members undergoing a 3-year expedition with a majority of the time spent in transit. This would include years of being subjected to the "Earth out of view phenomenon." Analog studies, with the exception of the Biosphere 2 study, have not been of such a long duration and in the Biosphere 2 study, the subjects knew that they were on Earth all the time. Psychological responses to the perils encountered during the mission will require that a crewmember or specialist trained in providing behavioral interventions function autonomously without support from Earth.

Due to the sensitive nature of the information regarding space travel and how governmental institutions are unable or unwilling to disseminate the data, the private space industry may have to rely solely upon their own studies. In the burgeoning stages of space travel, most believed it a competition amongst super powers to launch and maintain space assets. In the following stages, international crews began to integrate and were required to function as a unit as it became apparent that any venture into space would necessitate international funding and efforts. In the current stage of space exploration, the national space agencies have been giving way to the private industry. However, due to the resistance to share confidential information, the inability to fully research long-duration missions without endangering lives, the extreme engineering difficulties associated with space travel and life support, and the enormous financial demands, the private industry's progress has been difficult. Studies to assess the proper selection and training could benefit long-duration space travel as it can improve mission success and crew survivability which is a major motivation for contemporary NASA research into the effects of long duration microgravity exposure on twins (Kluger, 2015).

Private Dutch company Mars One has been gathering volunteers for a one-way mission to Mars, reasoning that a return trip may not be feasible. The literature suggests selection and training are both essential for appropriate international communications and crews have been historically chosen from leading individuals within their fields. Mars

One, however, chose their candidates from a worldwide pool of volunteers with unknown screening instruments. The crew selection criterion and selection will be presented on mass media as the candidates go through different selection and training exercises.

This presents several difficulties that were predicted by the literature but are not a focus for Mars One. For example, the general public would be unable to accurately determine which combination of skill sets are required for a long-duration space mission but Mars One continues to plan on allowing any person to volunteer and vote for their favorite candidates instead of a battery of assessments via several panels of experts. While this may be good marketing, without proper selection, training, treatment, and reintegration, the crews that Mars One select may be endangered as they overlook the literature in order to increase profits. The privatization of space may be contributing to the focus on profits instead of human advancements or crew safety, which may be inherent to the transition towards industrialization like America's railroad, automobile, oil, and steel industries.

Recently, Mars One selected their final 100 candidates and MIT research by Do, Ho, Schreiner, Owens, and de Weck (2014) suggested crews would not survive longer than a couple weeks with current technology. Mars One appeared to direct their mission with little consultation of the literature or experts while focusing on earning revenue to pay for such an endeavor. The future of space travel may be forever influenced by the outcome of Mars One as the crews that the public chose may have little chance of survival which may stifle further advancements into space since the populous has been reluctant to fund such missions. This reluctance can be evidenced with the decommissioning of the shuttle program due to losing the Challenger and Columbia as well as the magnitude of maintenance required to maintain our shuttle fleet. Another alternative result from the Mars One mission may be that it will galvanize the public to start a mass interest in space as the mission may prove humans are capable of space travel regardless of the survivability of the crews, such as with the mass exodus into the perilous 19th century American West.

Haddy (2007, p. 643) posited a situation regarding unknown stressors by asking, "Imagine a radiation-sick, sleep-deprived astronaut stepping on Mars; muscle and bone weakened and dehydrated, he or she becomes hypotensive, faints, and breaks a leg. What now, Houston?" The lack of research is evidenced by Manzey (2004, p. 781) who states, "Our current psychological knowledge derived from orbital space flight and analogue environments are not sufficient to assess the specific risks of missions into outer space" and Kanas (1998) who stated there have been no published reports from empirical studies in space addressing psychosocial issues affecting long-duration international space crews. Kanas (2009) recommends more attention be paid to identification and treatment of psychiatric problems that could occur in space; more psychosocial research in space; a definition for asthenia as a discrete entity in space; more investigations of cultural factors related to psychotherapy; and further studies on the influence of microgravity on taking psychoactive medications in space.

References

Atkinson, J. D., & Shafritz, J. M. (1985). *The real stuff: a history of NASA's astronaut recruitment program*. New York, NY: Praeger.

Bluth, B. J. (1984). The benefits and dilemmas of an international space station. *Acta Astronautica*, *11*, 149-153.

Bock, O. (1998). Problems of sensorimotor coordination in weightlessness. *Brain Research Reviews, 28*, 155-160.

Do, Ho, Schreiner, Owens, and de Weck (2014). An independent assessment of the technical feasibility of the Mars One mission plan. Paper presented at the 65th International Astronautical Congress, Toronto, Canada. Paper retrieved from http://web.mit.edu/sydneydo/Public/Mars%20One%20Feasibility%20Analysis%20IAC14.pdf. DOI: 1721.1/90819

Emurian, H. H., & Brady, J. V. (2007). Behavioral health management of space dwelling groups: safe passage beyond Earth orbit. *The Behavioral Analyst Today, 8*(2), 113-135. DOI: 10.1037/h0100607

Finney, B. (1991). *Scientists and seamen. From Antarctica to outer space.* (Edited by Harrison, A. A., Clearwater, Y. A., & McKay, C. P.), 89-101. New York, NY: Springer-Verlag.

Gunderson, E. K. E., & Nelson, P. D. (1963). Adaptation of small groups to extreme environments. *Aerospace Medicine, 34*, 1111-1115.

Gushin, V. I., Kolintchenko, V. A., Efimov, V. A., & Davies, C. (1996). Psychological evaluation and support during EXEMSI. In S. Bonting (Ed.), *Advances in space biology and medicine*, *5*, 283-296. London: JAI Press. Paper retrieved from http://www.ncbi.nlm.nih.gov/pubmed/8814804.

Haddy, F.J. (2007). NASA-Has its biological groundwork for a trip to Mars improved? *Journal of the Federation of American Societies for Experimental Biology*, *21*, 643-647. DOI: 10.1096/fj.06-7262LSF

Harrison, A. A. Behavioral health: Integrating research and application in support of exploration missions. *Aviation, Space and Environmental Medicine, 76*(6), Section II. Supplement, B3-B12. Paper retrieved from http://www.ingentaconnect.com/content/asma/asem/2005/00000076/A00106s1/art00002?crawler=true&mimetype=application/pdf.

Harrison, A.A. (2001). *Spacefaring: The human dimension.* Berkeley, CA: University of California Press

Ilhe, E. C., Ritsher, J. B., & Kanas, B. (2006). Positive psychological outcomes of spaceflight: an empirical study. *Aviation, Space and Environmental Medicine 77,* 93-101. Paper retrieved from http://www.ingentaconnect.com/content/asma/asem/2006/00000077/00000002/art00001?crawler=true.

Isay, R. A. (1968). The submariners' wives syndrome. *Psychiatric Quarterly, 42*, 647-652. DOI: 10.1007/BF01564308.

Kanas, N., (1998). Psychosocial Issues affecting crews during long-duration international space missions. *Acta Astronautica, 42*(1-8), 339-361. DOI: 10.1016/S0094-5765(98)00130-1.

Kanas, N. (1991). Psychosocial support for cosmonauts. *Aviation, Space, and Environmental Medicine, 62,* 353-355.

Kanas NA, Caldwell B. Summary of research issues in personal, interpersonal, and group dynamics. Aviation, Space, and Environmental Medicine. 2000 Sep; 71(9 Suppl): A26-A28. PMID: 10993305

Kanas, N., & Manzey, D., (2008). *Space psychology and psychiatry* (2nd ed.). El Segundo, CA, and Springer Dordrect, The Netherlands: Microcosm Press. DOI: 10.1007/978-1-4020-6770-9.

Kanas, N.A., Salnitskiy, V. P., Grund, E. M., Gushin, V. I., Weiss, D. S., Sled, A., & Marmar, C. R. (2000). Interpersonal and cultural issues involving crews and ground personnel during Shuttle/Mir space missions. *Aviation, Space, and Environmental Medicine, 71(9 Supplemental): A11-6*. Paper retrieved from http://web.mit.edu/16.459/www/Kanas.pdf. PMID: 10993303

Kanas, N. A., Salnitskiy, V. P., Boyd, J. E., Gushin, V. I., Weiss, D. S., Saylor, S. A., Kozerenko, O. P., & Marmar, C. R., (2007). Crewmember and mission control personnel interactions during international space station missions. *Aviation, Space, and Environmental Medicine, 78*(6), 601-607. PMID: 17571662.

Kanas, N., Salnitskiy, V., Grund, E. M., Weiss, D. S., Gushin, V., Bostrom A., Kozerenko, O., Sled, A., & Marmar, C. R. (2001). Psychosocial issues in space: Results from shuttle/MIR. *Gravitational and Space Biology Bulletin, 14(2) p. 35-45.* Paper retrieved from http://web.mit.edu/16.459/www/Sandal.pdf. PMID: 11865867.

Kanas, N., Sandal, G., Boyd, J. E., Gushin, V. I., Manzey, D., North, R., Leon, G. R., Suedfeld, P., Bishop, S., Fiedler, E. R., Inoue, N., Johannes, B., Kealey, D. J. Kraft, N., Matsuzaki, I., Musson, D., Palinkas, L. A., Salnitskiy, V. P., Sipes, W., Stuster, J., & Wang, J. (2009). Psychology and culture during long-duration space missions. *Acta Astronautica, 64,* 659-677. DOI: 10.1016/j.actaastro.2008.12.005.

Kanas, N., Weiss, D. S., & Marmar, C. R. (1996). Crewmember interactions during a Mir space station simulation. *Aviation, Space, and Environmental Medicine, 67,* 969-975. PMID: 9025820

Kelly, A. D., & Kanas, N. (1992). Crewmember communication in space: A survey of astronauts and cosmonauts. *Aviation, Space, and Environmental Medicine, 63,* 721-726.

Kelly, A. D., & Kanas, N. (1993). Communication between space crews and ground personnel: A survey of astronauts and cosmonauts. *Aviation, Space and Environmental Medicine, 64*, 795-800.

Kelly, A. D., & Kanas, N. (1994). Leisure time activities in space: a survey of astronauts and cosmonauts. *Acta Astronautica, 32*(6), 451-457.

Kluger, J. (2015, December 29 – January 5). Mission Twinpossible. *Time*, 184 (26-27), 32-38.

Kornilova, L. N., & Kozlovskaya, I. B. (2003). Neurosensory mechanisms of space adaptation syndrome. *Human Physiology 29*(5), 527-538. DOI: 10.1023/A:1025899413655.

Kotovskaya, A. R., & Fomina, G. A. (2009). Characteristics of adaptation and maladaptation of human cardiovascular system under space flight conditions. *Human Physiology, 36*(2), 190-197. DOI: 10.1134/S0362119710020106.

Leon, G. R., Kanfer, R., Hoffman, R. G., & Dupre, L. (1994). Group processes and task effectiveness in a Soviet-American expedition team. *Environment and Behavior, 26,* 149-165. DOI: 10.1177/001391659402600201.

Manzey, D. (2000). Monitoring of mental performance during spaceflight. *Aviation, Space & Environmental Medicine, 7*, A69-A75. PMID:10993313.

Manzey, D. (2004). Human missions to Mars: New psychological challenges and research issues. *Acta Astronautica, 55,* 781-790. PMID: 15806750.

Manzey, D., & Lorenz, B. (1998). Mental performance during short-term and long-term spaceflight. *Brain Research Reviews, 28*, 215-221. PMID: 9795225.

Manzey, D., Lorenz, B., & Poljakov, V. (1998). Mental performance in extreme environments: results from a performance monitoring study during a 438-day spaceflight. *Ergonomics, 41(4)*, 537-559. DOI: 10.1080/001401398186991.

Meehl, Paul E., (1954). Clinical vs. statistical prediction: a theoretical analysis and review of the evidence. Minneapolis, MN: University of Minnesota Press.

Myasnikov, V. I., Zamaletdinov, I. S., (1998). Psychological states and group interactions of crew members in flight (reprint). *Human Performance in Extreme Environments, 3*, 44-56.

Rivolier, J., Cazes, G., & McCormick, I. (1991). The international biomedical expedition to the Antarctic: psychological evaluations of the field party. From Antarctica to outer space (Edited by Harrison, A. A., Clearwater, Y. A., & McKay, C. P.), 283-290. New York, Springer-Verlag. DOI: 10.1007/978-1-4612-3012-0_26.

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

Rose, R. M., Fogg, L. F., Helmreich, R. L., & McFadden, T. J., (1994). Psychological predictors of astronaut effectiveness. *Aviation, Space and Environmental Medicine, 65*, 910-925.

Ruff, G. E., & Levy, E. Z. (1959). Psychiatric evaluation of candidates for space flight. *American Journal of Psychiatry, 116*, 385. Retrieved from http://dx.doi.org/10.1176/ajp.116.5.385.

Sandal, G. M. (2000). Coping in Antarctica: is it possible to generalize results across settings? *Aviation, Space and Environmental Medicine, 71,* A37-A43.

Sandal, G. M., (2001). Crew tension during a space station simulation. *Environment and Behavior, 33*(1), 134-150. DOI: 10.1177/00139160121972918.

Sandal, G. M., Endresen, I., Vaernes, R., & Ursin, H. (1999). Personality and coping strategies during submarine missions. *Military Psychology, 11*(4), 381-403. Paper retrieved from : http://dx.doi.org/10.7771/2327-2937.1025.

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

Santy, P. A., Holland, A. W., Looper, L., & Marcondes-North, R. (1993). Multicultural factors in the space environment: results of an international shuttle crew debrief. *Aviation, Space, and Environmental Medicine, 64*, 196-200.

Santy, P. A. (1994). Choosing the right stuff: the psychological selection of astronauts and cosmonauts. New York, NY: Praegar Press.

Shayler, D. A. (2000). Disasters and accidents in manned spaceflight. Chichester, UK, *Spring/Praxis*.

Suedfeld, P. (2003). Canadian psychology: the future may be almost here. *Canadian Psychology 44*(2), 85-92. DOI: 10.1037/h0086929.

Suedfeld, P. (2005). Invulnerability, coping, salutogenesis, integration: four phases of space psychology. *Aviation, Space and Environmental Medicine, 76,* B61-B66.

Viera, A. J., & Garrett, J. M. (2005). Understanding interobserver agreement: The Kappa statistic. *Family Medicine, 37*(5), 360-363. PMID: PMID: 15883903.

Walford, R. L., Bechtel, R., MacCallum, D. E., Paglia, & Weber, L. J. (1996). "Biospheric medicine" as viewed from the two-year first closure of Biosphere 2. *Aviation, Space, and Environmental Medicine, 67,* 609-617.

APPENDIX A

Interview Questions

Social Focus

For each of the questions, please consider how you would alter the selection, training and treatment to accommodate for long duration missions during pre-flight, in-flight, and post-flight.

If crewmembers appear to display withdrawal or territorial behavior, what interventions worked well?

If anger, agitation and frustration occur amongst crews, what suggestions would you have to minimize the displacement of these feelings onto ground control or each other?

When miscommunications occur amongst crews or ground control, how will a crew on a long-duration mission deal with more autonomy and the time delay between Earth and the spacecraft?

How can we diminish language and cultural differences to improve interactions during missions?

How can we help crews minimize feelings of isolation?

How will crew size and composition affect long-duration missions and extended flights?

How can crews deal with the confined conditions and lack of privacy for long-duration missions?

How can crews reduce tension and improve interactions amongst themselves and with ground control?

How can language affect the interactions of the crews and ground personnel?

How can leadership styles affect crews and ground personnel?

How can we prepare families to prepare, cope and reintegrate after long-duration missions?

Sensory and Physical Focus

For each of the questions, please consider how you would alter the selection, training and treatment to accommodate for long duration missions during pre-flight, in-flight, and post-flight.

What was effective in diminishing the effects of the altered senses due to microgravity?

On long-duration missions, how can the adjusted senses modify behaviors of the crews in microgravity and what can we do to prepare crews for these changes?

If crews experience headaches or difficulties with their eyes on long-duration missions far away from Earth, what suggestions do you think will diminish these complications?

How can we help crews deal with the balance changes due to the long duration exposure to microgravity followed by explorations and eventual return to Earth?

If crews experience fatigue, weakness, or feelings of monotony during a long-duration mission, what would minimize and help crews maintain their functioning?

When in space for extended periods, what were the most physically demanding activities and how can we prepare crews for muscle and bone degeneration before, during, and after their mission?

How can we help crews relieve symptoms of space sickness or Space Adaptation Syndrome?

How will the physical interior of the spacecraft or station affect crews during extended flights?

What can be done for crews to help deal with cardiovascular issues during long-duration missions?

What can help crews with disruptions in appetite and digestion?

Psychological, Emotional and Cognitive Focus

For each of the questions, please consider how you would alter the selection, training and treatment to accommodate for long duration missions during pre-flight, in-flight, and post-flight.

How should the psychological selection, training and treatment be altered to accommodate for longer-duration missions?

What was most effective in helping crews deal with psychological emergencies or issues?

When crews experience changes of emotions, thoughts and moods, how will the long-duration, autonomy, and vast distances affect crew interactions?

How will crews on long-duration missions deal with the different fears and anxieties?

If crews realize their memory or motor coordination is affected, what can lessen these difficulties?

How can crews maintain cognitive performance during extended missions?

How can spare-time be utilized during long missions to maximize performance of crews?

What can help crews receive adequate rest and sleep during long-duration missions?

How will workloads be altered to reduce possibility of burn out amongst crews?

How can we help crews deal with behavioral and personality changes during long-duration missions?

How will thinking be affected and how can spare time be utilized to maximize crew performance?