

# A Proposal for the Integration of Behavioural Research into International Space Station Operations

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**Abstract:** This paper proposes specific approaches for the conduct of psychological research on the International Space Station (ISS), and in the training programs supporting ISS. Justification for such research is presented, including improved safety and efficiency, the furthering of scientific knowledge, and the establishment of firm recommendations for the selection, training and support of future long duration crews on a mission to Mars. Data collection techniques and research methodologies are reviewed, including behavioural observations, surveys and interviews, and incident reporting systems. The specific uses of these data are discussed, including training refinement, validation of crew selection criteria, and design of future missions. The essential requirement that astronauts be partners in such research is also discussed, along with an exploration of the need for absolute confidentiality of psychological data and the requirement that information collected must not be used to impair astronaut careers or flight assignments.

## INTRODUCTION

This paper details the needs, methodologies and opportunities for psychological research on the International Space Station (ISS). The extended duration of the proposed missions aboard ISS, along with the multinational composition of the crews and the highly technological environment in which they will function make a thorough understanding of human operations on ISS imperative. Careful scientific study of human behaviour in spaceflight, with the support of astronauts, mission controllers and mission designers, will provide knowledge that can be used to improve training, crew selection, performance and safety for future ISS operations and extended deep space missions. Traditionally, psychological research has not been prominent in space operations, and mission planners find themselves in the position of having little hard data to guide them in human requirements for long duration mission design. This scarcity of recommendations is even more extreme given the diverse composition of future crews for ISS and Mars. This paper will discuss the necessity of conducting such research on ISS. It will then describe which aspects of ISS operations are appropriate for psychological study, detail the methods that may be employed to conduct this research, and provide suggestions for feedback of the collected information into mission training and design. This paper will then conclude with a discussion of the realistic requirements for such research, and credibility of the research with the astronauts – the eventual users, observers, and beneficiaries of this information.

## THE NEED FOR PSYCHOLOGICAL RESEARCH ON ISS

The conduct of psychological research on ISS represents an opportunity to improve safety and operational effectiveness, particularly in light of the complex multinational composition of the crews that are planned for the Station. In addition to this operationally based justification for conducting such research, the study of human behaviour and performance in this environment will increase our understanding of the physiologic and psychological limitations for humans under conditions of isolation, confinement and risk as well as under the unique conditions of outer space. Furthermore, a complete understanding of human performance in this environment will

be essential in preparation for future piloted missions to Mars and beyond. Each of these justifications for conducting a program of psychological research is explored in detail below.

### **Safety and Improved Operational Effectiveness**

Traditionally, psychological research in space has assumed a low profile in comparison to research in other scientific disciplines. This fact is due to a number of reasons, including a lack of operational requirements. Until recently, the short durations of space missions and the homogeneous composition of astronaut crews have meant that studies of crew behaviour were not seen as crucial to mission safety or success. This perception may be changing. In a recent speech, NASA administrator Dan Golden described “the human factor” as currently the most important factor that stands in the way of future space exploration (Birenbaum, 1997). The International Space Station represents a significantly different operation from previous space missions. The technological sophistication, the operational complexity, along with the diverse composition of crews and the prolonged mission durations presents an environment of unparalleled complexity in terms of human factors. The recent experiences of American astronauts who flew extended duration missions aboard the Russian Mir space station have confirmed the role that human factors play on such missions (DeCotis, 1997; Burrough, 1998).

Of primary concern in crew operations aboard ISS is that of the human interface with the advanced technology inherent in Space Station design. In commercial aviation, for example, the fallibility of humans has been determined to be a factor in the majority of serious accidents (Boeing Commercial Airplane Group, 1997). The advent of technology in the form of computerized flight management systems has increased the sophistication of modern avionics and eliminated many of the traditional sources of operator error in these aircraft. However, the increasing levels of automation have brought along with them their own sources of error and threats to safety. There is no reason to expect that space operations will be immune to these difficulties. Indeed, given the operational complexity of the environment, the singular nature of ISS operations, and the magnitude of potential accidents, an aggressive effort to maximize safety is mandatory. In aviation, research has been intensive over the last decade in an attempt to understand the nature of individual and crew performance in advanced-technology aircraft, including both the optimizing of operational safety and the minimizing of human error. It has been argued that such an approach must be based on accurate observation and on quantifiable data (Helmreich, 1997). Recognizing the importance of such human factors interventions, the FAA mandates “Crew Resource Management” training for all U. S. carriers. Such programs educate aircrew to improve leadership and teamwork, along with specific techniques for cross monitoring, error trapping, and other safety enhancing behaviours. It would be reasonable to assume that such an approach would be ideal for station operations. As in aviation, such training would require objective data from simulation and operational observations to design, modify and refine such a program.

Aside from the paramount justification of improved safety, a structured group dynamics assessment and training program would be a means of improving the efficiency and productivity of routine operations. Although crews have traditionally trained technical skills in repetitive fashion, team skills have often been neglected. Based on observations and simulations, training can be refined to improve team co-ordination through rehearsed prioritization and delegation of tasks. Again, commercial aviation aircrews train such practices in simulation and in recurrent training programs until such leadership and crewmember behaviours are second nature. Improved routine operation and increased situational flexibility are the results of such training. To reiterate, these training approaches must be based on accurate research of group and individual behaviours in the operational settings. Furthermore, once the training has been designed, further observational data will guide the improvement and modification of these training programs.

### **Multinational Crews**

A further area of potential difficulty in ISS operations will be the multinational and multicultural composition of the crews. On board the station, this is likely to produce a number of foreseeable difficulties. The most obvious of these will be language, as astronauts from the United States, Canada, Japan, Russia, and the various constituent countries of the European Space Agency will be required to communicate vital information to one another and to mission control. There are, however, more subtle difficulties that may arise. Studies have identified various dimensions of human behaviour that vary from culture to culture. Preferences in individual versus team functioning that differ from country to country, for example, have significant implications for crew functioning and harmony (Helmreich and Merritt, 1998). Styles of leadership may suit astronauts from one country far more than from

astronauts from another, and crewmembers and mission control will need to have some awareness of this potential source of problems. Simple gestures or practices that may be seen as benign to one crewmember may be offensive and a constant source of irritation to another crewmember simply because of cultural differences in accepted norms of behaviour. Another source of variation between cultures is the preference or disdain of proceduralization and automation. Certain cultures tend to be overly adherent to regulations, while others tend to be too cavalier in their disregard for rules and standardized procedures. These factors have been implicated in a number of airline catastrophes around the world (Helmreich and Merritt, 1998). Aside from the foreseeable difficulties of multinational operations, there will undoubtedly be many that have yet to be identified. It will be essential for safe multinational space operations that the complexities of multicultural crew dynamics are thoroughly studied, and that safeguards be designed into training and operations to minimize the inevitable difficulties that will arise.

## **Medical and Psychological Science**

Aside from operational justification, studies of human behaviour on ISS will contribute significantly to the expansion of both medical and psychological knowledge. From a biomedical perspective, carefully designed observational studies of human behaviour will provide insights into the effects of spaceflight on the highest levels of neurological function. Few, if any studies have investigated the effects of weightlessness and the space environment on affect, anxiety, and other more abstract functions of the brain. A thorough understanding of these effects is obviously essential as crews mount longer duration and more ambitious missions in space. The inclusion of a psychological assessment in other studies of neurologic function, or in the investigation of the effects of pharmaceutical agents in space will expand the scope of those investigations by providing valuable additional information on central nervous system function.

From the perspective of academic psychology, the study of human behaviour on ISS will allow researchers to study human performance under conditions of extreme stress, isolation and confinement. As a psychological laboratory, it provides an opportunity to study multicultural and interpersonal interactions under stress, hopefully shedding some light on what makes us function in the current complexities of the global village. Understanding of such issues will be of paramount importance as high-risk and high-performance environments such as aviation and medicine become more diverse in their team compositions in the years to come. Space provides a unique combination of confinement, remoteness, danger, technological sophistication and multiculturalism in which to study human psychology.

## **Going to Mars**

Perhaps the most important reason to study the behaviour of crews on ISS is to prepare for what comes next in the exploration of space. A piloted mission to Mars will entail degrees of isolation and technical complexity beyond anything so far encountered in the human experience. A complete understanding of the performance of multinational crews in this environment, along with a thorough understanding of the effects of space on the human mind will be absolutely essential to the success of such a mission. The optimal styles of leadership, the countermeasures to prevent the development of crew dysfunction and mood disorders, the techniques for selection of compatible crewmembers, the methods of maintaining optimal crew efficiency and safety need to be studied and developed before such a mission can be mounted (Pierce et al., 1997). ISS provides us the opportunity to conduct such research.

## **PROPOSALS FOR RESEARCH AND METHODOLOGY**

Research of human behaviour in environmental settings, also termed naturalistic research, has traditionally been viewed as difficult to conduct. The environmental constraints placed upon researchers requires compromises to be made and observational techniques to be developed that allow the collection of data in a manner that does not interfere with the complex operations of that environment (Radloff and Helmreich, 1968). This is both desirable and necessary. It is desirable in the sense that minimally intrusive observational techniques that do not disrupt operational behaviour provide the opportunity to study environmentally specific behaviours in their truest form, unencumbered by experimental manipulation. It is also necessary that operations not be interfered with, since significant disruption of Station operations would be deemed unacceptable, thus jeopardising the likelihood of being

able to conduct the research at all. Non intrusive techniques of data collection that may be employed with ISS operations include discrete observation, surveys and incident reporting. Each of these methodologies can provide valuable information, and techniques can be adapted from other environments where these forms of data collection have been developed and implemented.

## **Observation in Space Operations and Simulations**

Direct observation of behaviour is perhaps the most informative means by which to study it. The Aerospace Crew Research Project at the University of Texas at Austin has used the method of in-flight observation to assess aircrew behaviour for many years. Trained observers fly with commercial aircraft crews, using continually refined observational techniques to study various aspects of crew performance, including communication, leadership, and human interface with automation. These observations have allowed the development of a clear picture of cockpit dynamics and safety practices. Such direct methods will not be possible with ISS, and more remote observational techniques will need to be devised. These may include remote video observation, as has been employed in studying undersea habitat aquanauts (Radloff and Helmreich, 1968) and intensive care unit personnel (Symon and Cunningham, 1995). Recent studies on board the Russian space station *Mir* have used the analysis of recorded audio transmissions to attempt to study stress in astronauts and cosmonauts (Gushin et al., 1997). Such monitoring would, of course, require the complete understanding and acceptance of astronaut crews.

Simulation represents an opportunity for studying human behaviour and for developing observational techniques that may be used in orbit. Many if not all station activities will be practiced and developed with the aid of sophisticated simulation. This simulation will range from flight-simulator-like simulation of Shuttle flights and docking manoeuvres, to ISS assembly and underwater EVA rehearsals. Each of these simulations provides an opportunity to observe human behaviour more directly than is possible in orbit, as well as the opportunity to develop observational techniques for remote operations. Observing astronaut behaviour in simulation and comparing it to observed performance in space would provide feedback to training personnel about the effectiveness of the simulation, as well as feedback to psychologists about the validity of on-orbit observational techniques.

## **Interviews and Surveys**

Another common method used to assess crewmembers would be the use of surveys and interviews. Surveys may be implemented before, during and after missions. Relevant information would include attitudes and perceptions on crewmember interactions, safety concerns, and self-assessments of personal performance and difficulties. Although it would be unwise to rely on self-report data alone, due to the inherent bias of such methodology, such information may provide valuable insights when considered in tandem with more objective observational data. Surveys and interviews are likely the only means by which to uncover more complex psychological processes, including moods, perceptions, and attitudes. Such information will be essential in understanding and minimizing the complex interpersonal and cross-cultural dynamics of the multinational Station crews. As is the case for observational techniques, the understanding and cooperation of the astronaut crews is essential for this methodology to produce reliable data. In order to justify such cooperation, the ability of researchers to guarantee the confidentiality of such information is an absolute requirement. Any inability to make such guarantees, or a perception that such guarantees are insincere, will be unacceptable and will negate any possibility of reliable data being collected.

## **Incident Reporting**

A third technique, which has proved extremely useful in identifying pitfalls in automation, procedures, and training, is that of confidential incident reporting. Such a system has proved invaluable in aviation as a means to provide feedback to aircraft designers and airline training departments over the last two decades in the United States. The blame-oriented culture of aviation mandated that the first of these incident-reporting systems was completely anonymous. When the National Aeronautics and Space Administration (NASA) and the Federal Aviation Administration (FAA) created the Aviation Safety Reporting System (ASRS) in 1975, there was tremendous reluctance on the part of pilots to volunteer personal experience of an incident or undesirable occurrence in commercial aviation. The guarantee of anonymity and the inability of authorities to use the ASRS reports for

punitive purposes led to the acceptance by the aviation community of this form of information gathering. In the most recent report from the ASRS, over 3000 incidents were reported to the system in the preceding month, the majority being made by commercial pilots (Aviation Safety Reporting System, September 1999). The airline industry has found this information to be so useful for safety purposes that a cultural shift has taken place within the professional world of commercial aviation. Such error reporting systems are now seen as crucial to flight safety, and incidents in aviation are viewed very much as indicators of system or training deficiencies. Many airlines have begun instituting their own incident reporting systems, less confidential but giving more company specific information that is available for immediate use. Many carriers have become far less concerned with individual blame and far more concerned with correcting systemic deficiencies (Jones and Tesmer, in press).

The training and operational environment for ISS will be too small to allow truly anonymous reporting of errors and incidents – both during training and in actual operations. However, the establishment of a non-punitive and safety-focussed means of identifying problems will likely aid mission planners, trainers, and operational staff in improving usability and safety in Station operations. The establishment of such a system requires that the professional cultures of ISS be thoroughly understood. Should the current environment be one of fear of reprisal in the face of human error, then such systems will not work. It is essential that astronauts, controllers, and other personnel not fear reprimands or restricted flight assignments should they step forth with concerns or admissions of error. An evaluation of the current astronaut and mission control culture will assist in the development of such a system.

## **UTILIZATION OF RESEARCH DATA**

As discussed in the above sections, psychological and behavioural data will be difficult to collect. Data collection will undoubtedly require the cooperation of the astronauts that will live aboard ISS, and considerable effort will be required to collect such information. It is reasonable to ask in what manner this information will be used in order to justify the effort and expense required collecting it.

The observational data can be used to directly feed back into training. Procedures and protocols are developed to accomplish complex tasks, and observed performance of these tasks in both simulation and operations gives explicit feedback to training departments on whether the devised procedures are optimal in achieving their desired outcomes. Such practices have been employed in aviation for many years with great success. Similarly, observational feedback will help designers in producing more user-friendly hardware and software, as specific design deficiencies can be brought to light by studying the people that use such systems. Survey data would also give feedback to training programs by providing a forum to collect opinions and attitudes about various aspects of training and operations. Observational data can also be used in individual astronaut and crew selection by providing objective criteria with which to validate accepted or experimental selection criteria (Rose, Fogg, Helmreich, and McFadden, 1994). It is important, as will be discussed below, that observational data not be used to determine career progression of current astronauts in order that data validity be preserved.

Perhaps most importantly, carefully collected psychological, behaviour, and performance data will be invaluable to designers and planners of future missions. In particular, this means a piloted mission to Mars. There currently exist no reliable guidelines by which to select, train, and support multinational crews for extended duration missions. Such recommendations will need to address not only cultural concerns, but also specific crew composition, gender, training needs, and psychological support and countermeasure requirements. Such recommendations must be based on valid data to be credible, and ISS represents the most natural and obvious environment in which to collect such information.

## **INVESTIGATOR CREDIBILITY AND ASTRONAUT SUPPORT**

A point that deserves separate consideration is the credibility of the investigators in the eyes of the users and operators of ISS. Astronauts and ground personnel must have complete confidence in the ability and intent of investigators to guard data with the utmost confidentiality. The potential damage to both reputation and career should such information be made public requires that researchers take extraordinary measures to safeguard psychological research data. Furthermore, it is only with such reassurances that truly accurate and reliable

information can be collected, as individuals are unlikely to divulge personal or career threatening information without certainty that it will not be damaging to their careers, reputation, and family.

Traditionally, the space community, particularly in the United States, has been reluctant to embrace psychological research (Santy, 1994). This reluctance has undoubtedly been due in part to a perceived lack of relevancy of the research to space operations, or due to fears that the intrusive nature of psychological research posed a threat to both career and reputation. Given the likely understanding of the need for accurate psychological research in the planning and execution of future missions, it is reasonable to expect that the astronaut community will be more accepting of such research than has been the case in the past.

## SUMMARY

Psychological research on board ISS is valuable primarily for three reasons. First, it allows the assessment of human functioning in a unique and extreme environment. Such study will expand our understanding of the limits of individual performance, and of the functioning of groups under conditions of stress, isolation, and confinement. Second, and of more immediate concern, the study of human behaviour during the operation of ISS provides a means by which to gauge the effectiveness of training, provide data to improve crew selection, and allow optimizing of station operations. This has direct implications for improved safety and increased likelihood of mission success. Third, detailed study of all aspects of human performance and behaviour on ISS will provide the foundation on which mission designers, training personnel and astronauts will develop firm guidelines for the selection, training and support of a crew to Mars.

This research will optimally be composed of multiple methodologies, including observations, surveys and interviews, and incident reporting systems. Such research will at times be technically difficult, and will require the support of administration and astronauts. The support of astronauts will likely occur if and only if the relevancy of the research can be demonstrated, and if confidentiality can be assured. The opportunity exists for ISS to take a leadership role in psychological research, much as the space program has lead the world in so many other academic arenas.

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