National Space Biomedical Research Institute
Science and Technology Program
Neurobehavioral and Psychosocial Factors Team Strategic Plan
2007

Summary Description

Astronauts on long-duration missions will endure the isolation and confinement of the space environment to a greater degree than previous travelers. Methods crews use to deal with stress and the challenges of long voyages will be critical to mission success. In addition to identifying and assessing neurobehavioral and psychosocial risks to crew health, safety and productivity, the Neurobehavioral and Psychosocial Factors Team objectives include developing methods in laboratory and analog (e.g., NEEMO) environments to monitor brain functions and behavior, and countermeasures to enhance performance, motivation and quality of life. The Team is evaluating behavioral health management, crew cohesion and composition factors, the organizational environment, and communications to optimize performance effectiveness and psychosocial adaptation of crews living and working in the extreme isolated and confined environments associated with exploration missions.

Goals

The NSBRI Neurobehavioral and Psychosocial Factors Team develops countermeasures for spaceflight risks in the *Bioastronautics Roadmap* areas of Behavioral Health and Performance, and addresses gaps recently identified during the HRP Programmatic Review (NASA SAT Report, 2007). The Team also provides critical information for the development of Human Systems Integration Standards to support psychosocial adaptation and optimal performance (NASA Standard 3000), the NASA fitness for duty behavioral health and cognition standard, and operational requirements for behavioral health and radiation protection. The Team has the following primary goals supporting development of technology, countermeasures, risk mitigation strategies and operational requirements that are practical, validated and effective solutions for low Earth orbit (LEO), return to the Moon, and a mission to Mars. Critical to achieving the following three goals is the Team's continued use of analog environments, such as NEEMO and related opportunities.

Goal 1. Promotion of crew cohesion, behavioral adaptation and team performance effectiveness for missions to LEO, Moon and Mars. Countermeasure development focuses on best practices regarding prevention of social-psychological problems among crew before and during spaceflight, as well as detection and resolution of interpersonal conflicts within crew, and between crew and ground during spaceflight, before such problems affect crew performance effectiveness. Rehabilitation strategies postflight are also a focus to ensure rapid transition back to terrestrial work and family life. To achieve this goal, the Team specifically addresses Research and Technology questions in *Bioastronautics Roadmap* Risk Area 24 (Human Performance Failure Due to Poor Psychosocial Adaptation). This goal aligns well with the *Vision for Space Exploration* that designates it as priority 1 for International Space Station (ISS), priority 2 for Moon, and priority 1 for Mars. There was also consensus that this goal was High Priority in the recent NASA HRP Gap analysis, in the BHP evaluation of gaps, and in the NSBRI evaluation of gaps.

Goal 2. Maintenance of individual astronaut behavioral health and cognitive performance effectiveness in the face of spaceflight stressors during missions to LEO, Moon and Mars. Risk mitigation strategies, operational requirements and countermeasures in line with development of the CEV, and surface operations on the Moon during sorties and outpost, depend in part on the Team's development of unobtrusive technologies for early objective monitoring of astronaut neurobehavioral and cognitive functions, as well as behavioral and pharmacological interventions for problems in these areas. The monitoring technologies will be software-based, adding little to CEV upmass, and well integrated with CEV habitability requirements. For the Lunar Lander, monitoring technologies need to be integrated within the habitability requirements. To achieve this goal, the Team specifically addresses Research and Technology questions in *Bioastronautics Roadmap* Risk Area 25 (Human Performance Failure Due to Neurobehavioral Problems), that the *Vision for Space Exploration* designates as priority 1 for ISS, priority 2 for Moon, and priority 1 for Mars. This goal also encompasses *Bioastronautics Roadmap* Risk Area 26 (Mismatch between Crew Cognitive Capabilities and Task Demands), which the *Vision for Space Exploration* designates as priority 2 for ISS, priority 2 for Moon, and priority 1 for Mars. This goal was also rated as high priority in the recent NASA Gap analysis, in the BHP evaluation of gaps, and in the NSBRI evaluation of gaps.

Goal 3. Detection and prevention of space radiation hazard on astronaut and behavioral functioning during missions to LEO, Moon and Mars. The radiation hazard to astronaut brain and behavior is poorly understood, making it important to identify radiation dose-response effects on nervous system and adaptive behaviors, using simulated space radiation and animal models. The information gained will inform the most effective preventative countermeasures for astronauts on the CEV, and help establish risk mitigation strategies and operational requirements to protect astronauts. To achieve this goal, the Team specifically addresses questions in *Bioastronautics Roadmap* Risk Area 29 (Acute and Late CNS Risks), which the *Vision for Space Exploration* designates as priority 2 for ISS, priority 2 for Moon, and priority 1 for Mars. Team research is highly relevant to the development of the Crew Exploration Vehicle (CEV) via effects of CEV habitability on crew performance effectiveness, behavioral health, communication, and CNS functional integrity via CEV protection from radiation.

Objectives

Team objectives to achieve the primary goals are predicated on the following three principals that are assumed in the deliverables described below. These principals are:

- Predict and prevent preflight; monitor, evaluate and intervene inflight; and protect postflight.
- Create spaceflight countermeasures for autonomous use by astronauts.
- Minimize upmass using software countermeasures rather than hardware.

Goal 1 objectives for optimizing crew cohesion, behavioral adaptation and team performance.

A. Risk assessment and monitoring technologies include the following deliverables for maintaining crew cohesion, adaptation and performance effectiveness (SAT & BHP gaps 11, 12 & 13).
   1. Develop unobtrusive and passive methods and technologies for monitoring cooperation and conflict among crewmembers, and between crew and ground.
   2. Develop methods and technologies for monitoring integrated crew operational performance throughout missions.
   3. Identify demographic, personality and behavioral characteristics that are most likely to enhance crew cohesion, and prevent crew conflict during prolonged missions.
   4. Obtain crew cohesion and conflict data during prolonged confinement that includes as many of the conditions of spaceflight as possible.

B. Countermeasures include the following deliverables to mitigate problems in coordinated crew performance effectiveness (SAT & BHP Gaps 10 and 11).
   1. Use crew history reports (during training and missions) to identify and prevent problems that occur under certain crew configurations.
   2. Identify the crew training techniques and training environments that optimize crew performance effectiveness during prolonged periods in space.

3. Develop state-of-the-art computer-assisted techniques to use before flight and in space to enhance crew cohesion and to manage conflict resolution.
4. Establish ways to maximize the effectiveness of communications among crewmembers and between crews and ground.
5. Identify components of a "virtual entertainment center" for spaceflight and on Lunar and Mars surfaces that optimizes crew cohesion and psychosocial adaptation.
6. Review the Apollo Lessons Learned (2007) report, as well as other relevant reports to identify novel countermeasures for crew cohesion.
7. Develop countermeasures for postflight psychosocial integration of crewmembers who have been on long-duration missions.

C. Standards for crew composition and selection tools include the following deliverables for maintaining crew cohesion, coordination and performance effectiveness (SAT & BHP gaps 14 & 15).
   1. Identify valid and predictive astronaut selection tools for long-duration missions.
   2. Develop guidelines for optimizing crew selection and composition during training.

<u>Goal 2 objectives for maintaining individual astronaut behavioral health and cognitive performance</u>.

D. Risk assessment and monitoring technologies include the following deliverables for maintaining individual astronaut behavioral health and performance (SAT & BHP gaps 16 & 17).
   1. Develop valid/reliable unobtrusive real-time monitoring of astronaut facial expressions using optical computer recognition to detect stress and fatigue in space.
   2. Develop valid/reliable unobtrusive real-time monitoring of astronaut speech using acoustic analysis to detect the effects of hypoxia and fatigue in space.
   3. Develop valid/reliable brief performance self-tests to track cognitive changes in space, to aid astronauts in determining their countermeasure needs and to help resolve whether their experiences of cognitive deficits (e.g., "space fog," cognitive decline post-extravehicular activity [EVA]) can be understood and prevented.
   4. Develop state-of-the-art computer-based clinical cognitive assessment for diagnostic evaluation of the nature of clinically significant deficits.
   5. Develop valid and reliable monitoring tools to assess crew dynamics and communication problems.

E. Countermeasures include the following deliverables to mitigate problems in individual astronaut behavioral health and cognitive performance in space, and following space-flight for facilitating rehabilitation back to terrestrial life (SAT & BHP gaps 18 & 19).
   1. Develop procedures and computer-based aids that optimally meet individual astronaut behavioral health needs on long missions (e.g., knowing their families are well, managing stress, maintaining Earth holidays, private moments for sadness and joy, time off work, entertainment and leisure).
   2. Develop state-of-the-art computer-assisted techniques to assess individual astronaut emotional state and deliver cognitive-behavioral countermeasures.
   3. Develop computer-based guidelines and information for astronauts for use of medications that can affect cognitive and affective functions.

F. Standards for maintaining individual astronaut behavioral health and cognitive performance effectiveness in space include the following deliverables (SAT & BHP gaps 17, 19, and new BHP gap).
   1. Establish/inform standards for behavioral health fitness for duty by conducting behavioral health evaluations of individual astronauts serially up to flight time.
   2. Develop best practices for use of behavioral health medications in space.

3. Develop protocols for the special behavioral health management required by astronaut families as a function of longer-duration missions.
4. Develop protocols for the special behavioral health needs of astronauts following return from longer-duration missions.

Goal 3 objective for detection and prevention of space radiation effects on astronaut behavior.

G. Risk assessment and monitoring technologies include the following deliverables for detecting and preventing space radiation effects on astronaut neurobehavioral functions (SAT & BHP gap 17 and new BHP gap).
    1. Develop dose-response data on the effects of space radiation on animal learning and performance to determine the extent to which neurobehavioral functions of astronauts are likely be affected by radiation in space. Depending on the outcome of this seminal study, additional risk monitoring and mitigation may be required.

Earth Spin-offs. The primary deliverables being developed by the Team to achieve the goals for optimizing crew cohesion and performance effectiveness as well as individual astronaut behavioral health have considerable potential for Earth-based benefits. There are many Earth applications where the deliverables could enhance safety and efficiency in both public and private sectors. There are clear Earth-based benefits for performance enhancement for the Departments of Defense, Homeland Security, Energy and Transportation from the optical, voice acoustic, and performance self-test objective monitoring technologies being developed. Similarly, the development of new ways to track and enhance group cohesion and effective team performance will have benefits for high-risk, high-stress industries such as flight crews, air traffic controllers, medical personnel, offshore oil workers, military, or nuclear power operators. Benefits include greater efficiency, fewer errors, greater productivity, and less time lost due to interpersonal frictions or stress in the workplace. The computer-based conflict resolution and depression assessment/treatment support system being developed can be adapted for use in other isolated environments (e.g., polar research stations, submarines, commercial ships, underwater research bases). It also has potential for use through broadband Internet in a wide range of public settings (e.g., primary care, mental health centers, schools, social services, military bases, etc.).

Strategies for Achieving Team Goals and Objectives

During the past 18 months, the NSBRI Neurobehavioral and Psychosocial Factors Team Leads have developed a very close working relationship with the NASA Behavioral Health and Performance (BHP) Program Element to achieve Team goals and objectives relative to BHP needs, as evidenced in weekly phone calls and frequent meetings. In addition to being part of the BHP Working group, which includes the physicians and psychologists responsible for astronaut behavioral health at JSC, NBPF Team Leads and Investigators have worked closely with the BHP Program Element Manager to develop BHP briefings to the NASA Human Research Program (HRP) and to the Advanced Capabilities Division in the Exploration Systems Mission Directorate. They have also facilitated BHP work with Mission Operations Directorate (MOD) and JSC Flight Surgeons to identify data relevant to human performance in space flight, and NBPF Team Leads have worked closely with BHP Element to develop specific countermeasure needs and time lines for each deliverable to meet exploration milestones for Constellation.

Analog environments are a strategic part of achieving the Team's goals. NBPF Investigators continue to need to use NASA Extreme Environment Mission Operations (NEEMO)—in which astronauts lived in the NOAA Aquarius habitat 19 meters underwater off the coast of Florida—to assess the feasibility of brief cognitive, behavioral, physiological, and psychosocial measures for monitoring astronauts while they live and work in confinement analogous to spaceflight. NBPF Investigators have also used Everest expeditions to assess the sensitivity of voice acoustic analyses to hypoxia (an EVA-based neurobehavioral risk). Plans are underway to evaluate further a brief cognitive performance self-test in conjunction with the August 2007 launch of Phoenix Scout Lander mission, partnering with the NASA BHP Program Element and the Space Medicine Behavioral Sciences group. Plans are also well underway to use a base in the Antarctic (as a spaceflight analog of prolonged isolation) in which to test computer-assisted techniques to manage conflict resolution (developed with astronaut input) and a computer-based cognitive-behavioral intervention for mild to moderate depression. NBPF Team Leads, in conjunction with NASA BHP, are currently reviewing the planned Mars-500 project to be conducted at the Institute for Biomedical Problems (IBMP) by the Russians. This Russian project involves having six crew members live for 500 days in a ground-based isolation chamber (Mars spaceship mockup) to simulate crew life and work on a mission to Mars. The Russians have invited NBPF input to the study. If Mars-500 is deemed to be of sufficient scientific value, and feasible (logistically and fiscally), NBPF Team Leads will insert into the protocol specific monitoring technologies the Team is developing. Finally, NBPF Team members are collaborating with each other and with other NASA-funded investigators.

Finally, one overarching scientific and operational research challenge that impacts every biomedical aspect of long-duration space exploration beyond Earth orbit is the need for a behavioral management analogue of continuously isolated and confined microsocieties over periods as long as 2 to 3 years. The NBPF Team believes it is essential for such an analogue to be developed.

Examples

In the next 5-year period (2008-2013), the following outcomes will be met.

Under Goal 1 (objectives for optimizing crew cohesion, behavioral adaptation and team performance effectiveness), we expect to have made substantial progress, up to the level of spaceflight feasibility, on (A) deliverables for risk assessment and monitoring technologies for maintaining crew cohesion, adaptation and performance; (B) countermeasures to mitigate problems in coordinated crew performance; and (C) development of standards for crew composition and selection tools relative to crew cohesion, coordination and performance.

Under Goal 2 (objectives for maintaining individual astronaut behavioral health and performance), we expect to have made substantial progress, up to the level of spaceflight feasibility, on (D) development of risk assessment and monitoring technologies for maintaining individual astronaut behavioral health and performance (including computer monitoring of astronaut facial expressions, voice acoustic analyses, and brief performance self-test to track cognitive and affective changes in space); (E) completion of computer-based clinical assessment and treatment for behavioral problems; and (F) development of standards for maintaining individual astronaut behavioral health and cognitive performance in space.

Under Goal 3 (detection and prevention of space radiation effects on astronaut behavior), we expect to have resolved (G) the dose-response effects of space radiation on animal performance.

In the following 5-year period (2014-2019), the following outcomes will be met.

Completion of all Goal 1, 2, and 3 objectives, including space-ready feasibility of all technologies, countermeasures and standards being developed for behavioral health and performance. Integration into spaceflight architectures of all software-base countermeasure technologies for monitoring, testing, modeling and predicting individual and crew behavioral health and performance in space.