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# Behavioral Health & Performance (BHP) Standing Review Panel (SRP) Final Report

January 2010

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## I. Executive Summary & Overall Evaluation

The first meeting of the Behavioral Health and Performance (BHP) Standing Review Panel (SRP) was held in Houston, TX on November 1-3, 2009. Our task was to assess the Integrated Research Plan (IRP) related to the fields covered in the SRP charge (see section VIII). Having considered and discussed the extensive materials distributed prior to the meeting, and the highly informative briefings by the NASA BHP Human Research Program (HRP) personnel during the site visit, the SRP agreed that the IRP is comprehensive and was developed carefully. Question and answer periods with the presenters were particularly productive and helpful to the SRP. The presenters' willingness to share information and positive responses to the SRP's suggestions were greatly appreciated.

Although the IRP and related documents are impressive, the SRP does have a number of recommendations regarding both the overall plan and its component parts.

### *Overall Evaluation*

Overall, the IRP is an impressive piece of work. The three major areas of risks and their gaps are clearly defined, and many of the research projects mentioned seem relevant and potentially useful (although the brevity of the descriptions makes this difficult to judge). The following suggestions are applicable to all parts of the IRP; recommendations related to the three individual areas follow.

### *General Recommendations*

1. The focus of the IRP should be broadened, from a concentration on anticipating and countering problems during space exploration to include an additional emphasis on enhancing psychological processes and performance before, during, and after spaceflight – i.e., to maximize positive aspects as well as to minimize negative ones. Maximizing the positive aspects is a critical, but often undervalued, aspect of enhancing adaptation and resilience. The term “behavioral health,” which has come to imply a medical emphasis, should be replaced by “psychological well-being” or “optimal psychological functioning.” In a number of places, we have suggested changes in wording. These are not “strategy” as such, but words shape perceptions, and perceptions shape strategy. **NOTE:** Notwithstanding the preceding, the terminology now used in the IRP will be followed in this report.
  2. The BSleep area is much more fully developed than BMed or BTeam. This disparity should be addressed in future plans. Sleep disturbances and their effects may be more apparent in even short-duration missions and may be easier to measure; however, the importance of the other two areas in optimizing well-being and performance is equally high.
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3. A number of research projects in the various areas seem to have been in progress for many years and over many renewals. Their actual contributions to application in space should be evaluated to determine what can be expected in terms of useful deliverables, and when. If NASA is serious about emphasizing research with clear space applications, it should consider such deliverables as important criteria for future funding. Reviewers should be “arm’s length”: i.e., neither grantees of, nor otherwise connected with, NASA or NSBRI, so that projects are identified and funded in keeping with best practices of peer review.
  4. There is a large scientific literature on optimizing individual and team functioning and on prevention of problems, much of which does not appear in the IRP. Small groups of subject matter experts should be consulted to identify the best and most practical articles. This should be done every three and four years; in the intervals, NASA staff should periodically bring the database up to date. All such reviews must include non-English language materials as well as materials appearing in conference reports, books, and other non-refereed journal outlets.
  5. Some of the components of the IRP document mention data collection before, during, and after missions. This is excellent, and should be extended to all projects where feasible. Furthermore, attention should be paid to whether psychological and psychosocial changes persist, increase, or adapt out as a function of flight phase and duration. This is mentioned for gap Sleep 3, but is equally relevant to many other tasks. The psychological effects and after-effects of spaceflight need to be monitored and optimized, for the astronaut as well as his or her family.

The following two general proposals are outside the area of authority of the BHP. We recommend that they be considered by other levels of NASA and NSBRI.

6. In assessing grant proposals in the BHP area, neither grant review panels nor NASA itself should assume that astronauts will be reluctant to participate in psychological research. The practice of downgrading or not implementing proposals because of a belief in such reluctance should cease. If the proposed research is deemed to be of high scientific/applied value, the astronauts should be given the opportunity to decide about taking part.
7. Consideration should be given to making existing databases concerning astronauts’ psychological states and performance assessments available, suitably “anonymized” to researchers. We realize that this is an extremely sensitive area, and one in which other levels of decision-making within NASA would have to be involved. Nevertheless, Institutional Review Boards in major universities are thoroughly experienced in safeguarding participant anonymity in sensitive areas of research and can ensure appropriate conditions that even a very careful individual researcher may have overlooked. In requesting their consent, astronauts can also be assured that none of the information, interpretation, or conclusions would be made public (or fed back to NASA) in any way that could identify the source.

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## II. Critique of Gaps and Tasks in the *RISK OF BEHAVIORAL AND PSYCHIATRIC CONDITIONS*

*The SRP recommends that BMed and BTeams organize a targeted workshop or in some other way get a more diverse outside community of leading scientific experts involved in widening the scope of their considerations and encouraging more of the outstanding researchers to submit proposals. From the list of the projects being funded, it does not appear that NASA is making full use of the wide and deep pool of the potentially available expertise.*

### **BMed1: What are the optimal methods to enhance behavioral health and prevent decrements during exploration missions?**

*The SRP recommends revising this gap to:*

*What are the optimal methods to enhance positive mood states, cognitive processes, and psychological adaptation before, during, and after exploration missions? Also, see General Recommendation 5.*

Current Task:

Survey of Medical Operations and Flight Crews (TBD)

Missing Tasks Identified by the SRP:

- *Police and other first respondent agencies, and the Department of Defense, have stress inoculation techniques administered before deployment. NASA should review this psychological inoculation literature to help maintain optimal states and improve coping and stress management during training, flight, and post-flight periods.*
- *HRP should assess and incorporate meta-analyses that have already been conducted, e.g., on subjective well-being. These studies have identified modifiable and modulating factors that could target of preventive interventions (e.g., DeNeve & Cooper, 1998; Steel & Ones, 2002).*
- *The current emphasis on sleep medications alone is a flaw in the current task, as well as in the Sleep gaps. For example:*
- *There should be a task assessing cognitive behavior therapy for sleep-related difficulty. There is considerable literature documenting the efficacy and effectiveness of this approach (Morin, Bootzin, Buysse, Edinger, Espie, & Lichstein, 2006), which has considerable benefits over medication (National Institutes of Health (2005)).*
- *There should be a program of research that specifically addresses whether relaxation training, yoga, and/or meditation methods can improve how astronauts deal with stressors encountered in long-duration spaceflight, including (but not limited to) reducing arousal and minimizing sleep disturbances. Some are very low in requirements (e.g., progressive muscle relaxation). The use of different light wavelengths to entrain the circadian rhythm should also be tested, possibly beginning with simulation/analogue studies.*
- *It is important to review international data (e.g., non-US astronauts), including those published in languages other than English.*

### **Bmed2: What are the optimal methods to predict decrements in behavioral health (which may negatively affect performance) during exploration missions?**

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*The SRP recommends combining Bmed2 and BMed3, and revising the gap as follows:  
What are the optimal methods to predict, detect, and assess adverse mood and other mental states (which may negatively affect performance) during and after exploration missions?*

- *The list of current tasks focuses exclusively on depression. There is no rationale for this limited perspective; there are many other negative states that occur in analog environments and have occurred in spaceflight (irritability, fugue states, psychosomatic symptoms, anxiety).*
- *In the SRP's judgment, it is unrealistic to expect the biomarkers for depression to be found in one research task, i.e., to be able to predict, diagnose, or measure depression using neuroimaging methods.*
- *An alternative approach would be to focus on the prediction of aversive conditions that involve affect, cognition, or behavior, based on findings in the literature on elite performers. This somewhat broader goal would refocus the effort on identifying affective, cognitive, and behavioral factors that are "early" warning signs of deterioration of performance. Moreover, these factors may not neatly fit into the categories that are described in the Diagnostic and Statistical Manual for Psychiatric Diagnoses. One of these is asthenia, which should be evaluated (possibly as a psychological or psychosomatic analogue of chronic fatigue syndrome).*
  - *See General Recommendation 4.*

#### Current Tasks:

Objective Detection, Evaluation and Countermeasures for In-flight Depression (Depression Detection, (NIN))

- *The SRP's judgment is that there is enough evidence concerning optimal methods for the detection, evaluation, and treatment for depression that this task is redundant. More importantly, why is depression the only outcome measure? The IRP should consider the prediction of all probable adverse mood states, including mood disorders, anxiety, asthenia, and related stress reactions.*

Prediction of Incidence of Depression in Astronauts (Review Predict Depression) (BHP Directed)

- *See comment for previous task.*

#### Missing Task Identified by the SRP:

- *Literature on asthenia should be evaluated (possibly as a psychological or psychosomatic/psychophysiological analogue of chronic fatigue syndrome).*

**Bmed3: What are the optimal methods to detect and assess decrements in behavioral health (which may negatively affect performance) during exploration missions?**

*As indicated above, the SRP recommends the combining of Bmed2 and Bmed3 into a single gap.*

- *The research effort aimed at recognizing affective disturbances by either voice stress analysis or facial expression analysis was an area of concern for the SRP. Both lines of research have been subject to considerable activity for a number of years with*

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*inconsistent findings. Problems such as the effects of microgravity and the subsequent result of increased facial edema would seem to complicate this issue further, and the SRP is doubtful that these lines of research will result in fruitful findings in the foreseeable future.*

- *Subjective (peer, family, self) reports are a valid way to measure adverse mental states, and such data should be collected systematically (see General Recommendation 7). Because subjective reports have their own limitations, more objective measures might be useful as sources of supplementary information. However, NASA should be careful to avoid investing heavily in high-tech gadgets or procedures that are not well validated or widely accepted by scientists working in other laboratories.*

#### Current Tasks:

Optical Computer Recognition (OCR) of Stress, Affect and Fatigue during Performance in Space Flight. (OCR Spaceflight)

- *Given the shortcomings of facial expression analysis, the value of this research is questionable.*

Objective Monitoring of Crew Neurobehavioral Functions (105-day Russian Chamber Study) (RCS-105 Neurobehavioral Function)

- *Insufficient details are given about this study, so that it is impossible to assess whether it will provide the needed information.*

Critical Review: Acoustic Analysis and Content Analysis (TBD)

- *Not enough details are given about this study, so that it is impossible to assess whether it will provide the needed information.*

Unobtrusive Technologies (TBD)

- *Not enough details are given about this study, so that it is impossible to assess whether it will provide the needed information.*

#### Missing Tasks Identified by the SRP:

- *The measurement of changes in mood and anxiety can be primarily based on self-assessments (see below). However, it would be very useful to collect or consider information regarding the potential importance of individual differences in the ability to self-monitor emotional states. The ability to accurately introspect and report one's psychological state has possible implications for astronaut training.*
- *Rather than focusing exclusively on technology, it would be important to assess traditional subjective and observational methods including self, peer, and family reports as well as interviews. These approaches are fundamental to psychological and psychiatric assessment in terrestrial settings, and there is little reason to doubt their validity in such settings. They could be used to monitor the emotional state of the astronaut and warrant further investigation in the space context.*

**Bmed4: What aspects, if any, of cognitive performance change during long duration missions? If there are changes –do they persist post mission? If so, for how long?**

- *This is the first time that post-mission changes are explicitly mentioned, an excellent idea*

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*that should be expanded to other gaps. See General Recommendation 5.*

Current Tasks:

Changes in Cognition / Neuroimaging Surveillance

CNS1: Radiation Exposure Acute Functional CNS Effects

- *Why is this task here? Radiation would have many effects on health and psychological functioning, not only on cognition.*

Detection & Prevention of Neurobehavioral Vulnerability to Space Radiation. (Neurostructural Changes Radiation)

**Bmed5: What are the optimal methods for detecting and assessing cognitive performance during exploration missions?**

- *Cognitive performance may be somewhat difficult to assess, but detecting it does not require a task. Delete “detecting and”.*
- *It is important to recognize that “cognition” is not a monolithic block of processes but is comprised of many different functions. Current efforts at cognitive assessment appear to focus on information processing tasks. The IRP needs to look at those aspects of cognition that are known to be most vulnerable to stress-related (including sleep deprivation-related) decrements: specifically, judgment, decision-making, abstract thinking, breaking cognitive set, original solutions to novel problems, and other executive functions. When sleep deprived and under stress, people are more impulsive and fixated on over-learned solutions.*
- *It is not clear whether the Current Tasks involve the measurement of the processes listed above. More measures may need to be developed.*

Current Tasks:

CogGauge: A Cognitive Assessment Tool (CogGauge)

Cognitive State Monitoring System as Predictor of Performance (TBD)

**Bmed6: What individual characteristics predict successful adaptation and performance in an isolated, confined and extreme environment?**

- *The SRP does not know why this is still listed as a gap. There have been decades of research and reviews on this topic in a wide range of isolated, confined, and extreme environments.*

*If this gap remains, the SRP recommends revising this gap to:*

*What individual characteristics predict successful adaptation and performance in an isolated, confined and extreme environment, especially during long duration missions?*

*If this gap remains, an additional task should be to obtain a better understanding of the mechanisms that underlie individual differences in adaptation.*

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Current Tasks:

Identify Trait/Malleable Characteristics of High-Performing Individuals (TBD)

Effects of Wintering-Over on Psychological Well-being (TBD)

- *This overlaps with Antarctica Personnel Experiences (below); the two tasks could be combined.*

Critical Review of Submariners, Antarctica Personnel Experiences (TBD)

- *Many such reviews are already in the literature.*

Literature Review on Resilience (especially in Military context) (TBD)

- *Why “especially in Military context”? Resilience has been studied in many stressed populations.*

Missing Task Identified by the SRP:

- *Selection data related to resilience should be evaluated.*

**Bmed7: What are the optimal methods for treating the individual or modifying the environment to remedy behavioral health problems during exploration missions?**

- *Bmed7 gap should be paired (although not necessarily combined) with Bmed1 gap.*
- *This gap mentions modifying the environment, but does not specify what aspects of the environment may be modifiable, or how they could be modified.*
- *More connection should be made with the wealth of existing literature on psychological treatments of a variety of adverse mental states. Experts in these areas should be consulted for their advice on ways to adapt existing empirically-supported methods to the special circumstances of spaceflight.*

Current Tasks:

Self-guided Depression Treatment on Long-duration Space Flights. (Self-Help Depression)

A Multimedia, Computer-Based, Self-Directed, Autonomous, Stress and Anxiety Management Countermeasure (Self-help Stress/Anxiety/Affect)

Behavioral Issues Associated with Long Duration Space Missions: Review of Astronaut Journals (Journals)

Habitability recommendations for BHP (space, ergonomics) (TBD)

- *Physical environment should be looked at beyond the variables of space and ergonomics. For example, tasks should consider light-dark cycles, privacy, environmental monotony and flexibility, etc..*

Countermeasures: Behavioral Health Adaptation to Isolated, Confined and Extreme Environments (ICE) (TBD)

Medical issues/bounded autonomy (Asynchronous telemedicine; self-treatment) (TBD)

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- *The topic of bounded autonomy is highly specialized. Although it might be important, it strikes the SRP as being out of place as a topic to be selected for special attention in a list of general issues of importance. The individual interests of specific investigators should not be listed as major goals.*

**Bmed8: What are the most appropriate and effective ways for crews to use behavioral health medications during exploration missions?**

- *The SRP thinks that the phrase “behavioral health medication” needs to be defined/explained in this gap.*
- *How is appropriateness different from effectiveness? Can an ineffective use be appropriate, or an effective use be inappropriate?*
- *The SRP thinks that this gap should either be integrated with other areas or removed.*

*If this gap remains, the SRP recommends revising this gap to:*

*What are the most effective ways for crews to use behavioral health medications during exploration missions?*

Current Tasks:

Review current practices – international space partners (TBD)

Investigate prophylactic drug use (Selective serotonin re-uptake inhibitors, etc.) (TBD)

Medical issues/bounded autonomy (Asynchronous telemedicine; self-treatment) (TBD)

Med side effects, interaction effects, storage and effectiveness of meds in radiation environment (TBD)

- *This task should read “in the space environment” and not just radiation environment; characteristics other than radiation may have an effect.*

Develop Behavioral Medications Database (TBD)

- *This study should begin as soon as possible, rather than after 2018 as indicated in the timeline. Once developed it should be updated regularly.*

**RECOMMENDED NEW GAP:**

**Little assessment has been done of how family -- as well as colleagues and friends -- can affect attitudes, motivation, emotions, psychological health, and performance throughout all phases of the astronaut’s career, including the period after active space flying. The SRP recommends that serious attention be paid to research and application (family orientation/training, long-term post-mission support) in this area.**



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### **III. Critique of Gaps and Tasks in the *RISK OF PERFORMANCE DECREMENTS DUE TO INADEQUATE COOPERATION, COORDINATION, COMMUNICATION, AND PSYCHOSOCIAL ADAPTATION WITHIN A TEAM***

*The SRP recommends that the BMed and BHP Gap Team components of BHP organize a targeted workshop or in some other way get a more diverse outside community of scientific experts involved in widening the scope of their considerations and encouraging high skilled researchers to submit proposals.*

*The gaps should deal explicitly with the training, performance, and psychosocial aspects.*

*Drop gaps BHP Gap Team6 and BHP Gap Team7. Move the tasks from BHP Gap Team6 to BHP Gap Team3 and the tasks from BHP Gap Team7 to BHP Gap Team3 and the new suggested Communication gap as indicated.*

#### **BHP Gap Team1: Given the context of long duration missions, what are the most likely and serious threats to task performance, teamwork, and psycho-social performance? (Priority 1)**

- Refer to enhancing task performance, teamwork, and psychosocial performance. Do not focus on “likely and serious threats.”*
- There is nothing here about the specialized roles of team members. What happens to the team if something happens to a person who is performing a critical role?*
- The tasks in this gap need more refinement. The tasks will not address the gap, and seem to have no practical consequence. How does a measure of team cohesion, e.g., identify ways of enhancing team cohesion?*
- Literature searches and reviews should consider military psychology and general industrial/organizational psychology literatures.*

#### Current Tasks:

Systematic Query: Crew History

Systematic Query: Measure of Team Cohesion, Team Dynamics, and Leadership in a Simulated Environment (Team Standardized Measures)

- Why is this specifically calling out simulated (presumably meaning space simulation) environments and not looking at astronaut or even analogue data?*

Risk Assessment: Task Performance, Teamwork, and Psychosocial Performance

- The SRP does not see the connection to risk assessment in this.*

#### **BHP Gap Team2: Given the context of long duration missions, what are the most optimal ways to create tools to monitor and measure task performance, teamwork, and psycho-social performance? (Priority 2)**

- Delete “most”: optimal does not take gradations, something either is or is not optimal (i.e., the best).*

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*The SRP recommends revising this gap to:*

*Given the context of long duration missions, what are the optimal ways to create tools to monitor and measure task performance, teamwork, and psycho-social performance?*

Current Tasks:

Tools to Measure Crew Cohesion/Performance

Developing, Maintaining, and Restoring Team Cohesion (Team Cohesion)

Assess Additional Measures for Monitoring Task Performance, Teamwork, and Psychosocial Performance

**BHP Gap Team3: Given the context of long duration missions, what additional approaches would enhance current in-flight interventions and countermeasures for supporting task performance, teamwork, and psycho-social performance? (Priority 2)**

Current Tasks:

Identify Optimal Countermeasures to Support Task Performance, Teamwork, and Psychosocial Performance

Inform SHFH: Psychosocial Food Requirements Food Operations (TBD)

**BHP Gap Team4: Given the context of long duration missions, what are the optimal ways to select individuals and compose crews to ensure/optimize/facilitate task performance, teamwork, and psycho-social performance? (Priority 3)**

Current Tasks

Crew Composition Studies [BHP In-House (Review); NRA (ISS Study)]

Validate Measures for Composition (TBD)

**BHP Gap Team5: Given the context of long duration missions, what are the optimal ways to train crews, leaders, and ground support to ensure/optimize/facilitate task performance, teamwork, and psycho-social performance? (Priority 3)**

*Special attention should be paid to the training, selection, and evaluation of leaders.*

- *Add training for dealing with linguistic, cultural, and gender differences to this gap.*
- *Specify training leaders and crew on their roles, rules, and how to recognize and avoid dissension, cliques, and rivalry.*
- *Use of manuals and evaluations-should be included as part of the training.*

Current Tasks:

Optimizing Crew Performance in Long Duration Space Exploration: Best Practices for Team Training and Cohesion Measurement (Opti Team) Crew Cohesion and Crew Performance

Evaluate Crew-Ground Training

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Training Evaluation: Task Performance, Teamwork, and Psychosocial Performance

**BHP Gap Team6: Given the context of long duration missions, what are the optimal ways to support and enable multiple distributed autonomous teams to support task performance, teamwork, and psycho-social performance? (Priority 1)**

Current Tasks:

Crew interactions and Autonomy during Long Duration Isolation and Confinement 105 day study. (RCS 105 Autonomy)

- *Need to consider effects of astronaut autonomy on ground crew and devise countermeasures for potential negative impact.*

Effects of High vs. Low Autonomy on Space Crew Member Performance (Autonomy). (Autonomy ISS)

- *Need to consider effects of astronaut autonomy on ground crew and devise countermeasures for potential negative impact.*

Crew Scheduling Tools. (SPIFE Scheduling)

Autonomy, Cohesion, and Performance Review (TBD)

**BHP Gap Team7: Given the context of long duration missions how does constrained communication impact task performance, teamwork, and psycho-social performance? (Priority 2)**

- *SRP recommends that this gap be replaced by the one suggested below, except for the first Current Task, which should be moved to BHP Gap Team3.*

Current Tasks:

Countermeasure for Managing Interpersonal Conflicts in Space: A Continuation Study (Self Help Conflict Management)

- *The SRP suggests moving this task to BHP Gap Team3.*

Optimal Communication Strategies: Crew-Ground Interaction (TBD)

- *This seems obvious.*

Psychosocial Performance Factors in Space Dwelling Groups (Crew Communications Lab Sim)

**RECOMMENDED NEW GAP:**

**A gap that deals with problems associated with communication (to include training as well as performance)**

**Possible tasks under this gap would be:**

- **Asynchronous, delayed, and otherwise constrained communication.**
- **Specific issues with communication during EVAs.**
- **Communication training for multicultural and multilingual crews.**
- **Move communication-related tasks from Team7.**

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#### **IV. Critique of Gaps and Tasks in the *RISK OF PERFORMANCE ERRORS DUE TO SLEEP LOSS, CIRCADIAN DESYNCHRONIZATION, FATIGUE, AND WORK OVERLOAD***

*The SRP notes that the degree of sleep loss and circadian desynchronization may be different on long duration spaceflights away from Earth's orbit than on ISS flights that involve slam shifting and multiple sunrises and sunsets per 24 hours. Much of the circadian shifting issues of current operations seem related to specifics of orbital missions and may not be as significant on long duration, exploration-class missions. See also Sleep3 gap below.*

##### **Sleep 1: What are the best tools to detect, monitor and assess performance decrements due to sleep loss, circadian desynchronization, fatigue and work overload?**

- *The SRP recommends that Sleep 1 and Sleep 2 gaps be combined into one gap to be worded: What are the optimal methods to assess changes in performance during space flight, due to sleep loss, circadian desynchronization, fatigue, and work overload?*
- *All tasks need to look at emotional and physiological domains.*
- *The kinds of cognitive task measured need to be specified.*
- *Should make wording similar to what was used in Bmed gaps.*
- *Concern was expressed that actigraphy is not a measure of quality of sleep, nor a sufficient measure by itself of total amount of sleep. For example, agitated sleep can manifest as wakefulness; a relaxed waking state such as deep relaxation or meditation can manifest as sleep). Actigraphy is most typically used only when sleep-wake logs are kept simultaneously. There may be better ways to assess sleep-wake patterns using newer technology (e.g., ambulatory EEG) whose development and availability NASA should monitor.*

##### Current Tasks:

Cognitive Performance/Stress in Simulated Space Environment

Psychomotor Vigilance Test (PVT) on ISS (Cognitive Performance/PVT)

Validation of Assessment Tests and Countermeasures for Detecting and Mitigating Changes in Cognitive Function During Robotics Operations (RobotOPs)

Integrated Cognitive Assessment: Combining Measurement, System and Mission (CAT – Cognitive Assessment Tool)

Individualized Fatigue Meter

##### **Sleep 2: How is performance in space flight affected by sleep loss, circadian desynchronization, fatigue and work overload?**

- *See the SRP's comments on BMed5 gap (page 6).*

##### Current Tasks:

Cognitive Performance/Stress in Simulated Space Environment

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Psychomotor Vigilance Test (PVT) on ISS (Cognitive Performance/PVT)

Validation of Assessment Tests and Countermeasures for Detecting and Mitigating Changes in Cognitive Function During Robotics Operations (RobotOPs)

Integrated Cognitive Assessment: Combining Measurement, System and Mission (CAT – Cognitive Assessment Tool)

Individualized Fatigue Meter

**Sleep3: Does sleep loss continue on long duration missions or is there adaptation?**

- *This is a very good gap and, as indicated in General Recommendation 5, should also be added to BMed gaps about cognition, mood states, etc., and Team gaps about cohesion, etc.*
- *Does a continuing sleep regimen that is shorter than on Earth affect well-being, crew interaction and performance? If so, how?*

Current Task:

Sleep/Wake Actigraphy and Light Exposure During Spaceflight (Actigraphy)

**Sleep4: How can individual astronauts' vulnerabilities to sleep loss and circadian rhythm disruption best be determined?**

Current Tasks:

Evidence Review on Biomarkers of Individual Vulnerabilities to Sleep Loss and Circadian Desynchronization (TBD)

Sleep/Wake Measures in a Space Analog Environment

**Sleep5: How can light be used to optimally minimize circadian problems in space?**

The SRP recommends revising this gap to:

*How can light, dark, the timing of activities, social activity, and sensory stimulation be used to optimally enhance performance and minimize circadian problems in space?*

Current Tasks:

Operational Evaluation of Photic Countermeasure to Improve Alertness, Performance, and Mood during Nightshift Work on a 105 day Simulated Human Exploration Mission to Mars. (RCS-105 Photic CM)

Blue Light for Enhancing Alertness in Space Missions. (Blue Light Alertness)

Optimizing Light for Long Duration Space Exploration (Optimizing Light)

Evaluation of Blue-enhanced Light as a Countermeasure for Circadian Entrainment, Enhancement of Neurobehavioral Performance and Sleep-Wake Regulation Before and During Spaceflight (Blue versus White Light)

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Characteristics of Light Exposure Necessary for Development of Optimal Countermeasures to Facilitate Circadian Adaptation and Enhance Alertness and Cognitive Performance in Space (Blue Light CM Timing & Intensity)

- *NOTE regarding above tasks: More research is needed to determine whether blue light is more effective and efficient than full spectrum light, and on whether there are undesirable side-effects. The concentration of Current Tasks on light seems too narrow. Methods to increase physiological arousal and/or of increasing alertness, such as sensory stimulation, behavioral and social activity, when meals are scheduled, and so forth, increase optimal performance and may supplement bright light to help maintain stable sleep-wake circadian rhythms.*
- *The advantages of carefully timed exposure to light and dark and the timing of activities (meal times and social activity) over sleeping medications are considerable (e.g., lower side effects, no known adverse impact on sleep architecture).*

Feasibility Pilot Study on Acute Biological and Behavioral Responses to the Solid State Lighting Modules for the International Space Station (SSLM)

Missing Task Identified by the SRP:

- *Avoid over-reliance on, and consider possible negative side effects of, blue light.*

**Sleep6: How can individual crew members optimally use sleep and alertness medications prior to and during spaceflight?**

- *Why are medications the only countermeasures considered? BHP should examine other possible treatments for sleep (see BMed1 gap, page 3).*
- *Assess range of the actions of the medications, not just whether they put you to sleep and wake you up. BHP should consider things such as hangover effects, possible problems if astronauts must be awakened abruptly and be fully alert to deal with an emergency, and anxiety reactions depending on short and longer half- life.*
- *Should add behavioral, psychological, and environmental treatments.*

The SRP recommends revising this gap to:

*How can individual crewmembers optimally use sleep and alertness medications and non-medication interventions prior to and during spaceflight?*

Current Tasks:

Sleep/Wake Medications- Assess Interactions (TBD)

Sleep/Wake Medications- Pharmacokinetics/Efficacy (TBD)

Develop and Implement Operational Ground Testing Protocols to Individualize Astronaut Sleep Medication Efficacy and Individual Effects. (Individualized Meds Protocols) (TBD)

**Sleep7: What are the behavioral and physiological outcomes associated with chronic sleep loss, circadian desynchronization, fatigue and work overload?**

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*REMOVE GAP: This gap seems unnecessary. There is extensive literature concerning these topics, and reviews exist as well (e.g., Akerstedt & Wright, 2009; Duffy & Czeisler, 2009; Van Dongen & Dinges, 2005).*

Current Task:

Conduct a review that assesses the evidence related to the association between chronic sleep loss, circadian desynchronization, fatigue and work overload, and behavioral and physiological outcomes (BHP).

**Sleep8: How can predictions of the effects of chronic work-rest schedules on performance be used to prevent work overload and mitigate risk?**

Current Tasks:

Designing Individual Countermeasures to Reduce Sleep Disruption and Improve Performance and Alertness in Space (Mathematical Model Harvard)

Operational Requirements-Modeling (TBD)

Develop Sleep Module of Integrated Medical Model (IMM) (ExMC)

A Scheduling and Planning Tool in NEEMO 14 – A Simulated Space Environment (Scheduling NEEMO 14) (ITA with ARC. Involves collaboration with SHFH)

**Sleep9: What are the countermeasures needed to recover from chronic partial sleep loss, work overload, and/or slam sleep shifting, and that permit recycle back into the same sleep restricted schedules?**

- *Slam-shifting seems to some extent to involve a social/political problem resulting from decisions on the ground as to when some events are scheduled, rather than a scientific issue to be investigated through research. Besides doing the research, NASA might try to ameliorate the scheduling problem (we realize that this part of the strategy is beyond the purview of the IRP-BHP group, but it needs to be addressed nevertheless).*

Current Tasks:

Countermeasures for performance deficits from sleep loss and workload in space flight

Jet-Lag/ Training/Study (TBD)

Optimal Countermeasures for Lunar (TBD)

**Sleep10: What flight rules and requirements improve sleep, circadian desynchronization, fatigue and work overload, to reduce performance errors?**

Current Tasks:

Survey of On-Orbit Sleep Quality (Sleep Quality Questionnaire) (Sleep Quality Questionnaire SQQ)

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Phoenix Scout Lander: Countermeasures Testbed For Spaceflight Ground controllers. (Mars Lander CM)

A Comprehensive Fatigue Management Program and an Evaluation of a Photic Countermeasure for Mission Controllers (FMC)

## **V. Discussion on the strengths and weaknesses of the IRP**

### **Strengths:**

- Sleep area is well developed compared to the other areas.
- The IRP provides convincing evidence that NASA is taking the behavioral sphere seriously, and the SRP strongly supports what appears to be a burst of activity and interest in the behavioral health area.
- The IRP represents a good early look at existing gaps and some of the tasks that might be useful in eliminating them.
- Approaching the problems through the systematic identification of gaps is an excellent strategy.
- The milestones are well laid out.
- Multiple levels of review and asking for outsider input are steps in the right direction
- The interactions between in-house and external research activities are promising and should be strengthened.

### **Weaknesses:**

- We were not given enough details regarding many of the specific tasks to assess them.
- In some places, the IRP is not up to date with current knowledge, research, and practice in the social sciences -- for example, but not limited to, industrial/organizational psychology, social psychology, socioeconomics, etc.. For example, recent investigations have shown that problem behaviors as well as subjective feeling states, e.g., happiness, can spread via social networks and have significant impact on individuals even when they do not directly interact with others. Moreover, focus group methodologies and qualitative research can be used to quickly identify significant group factors that may require further studies (Fowler & Schreiber, 2008; Lazer et al., 2009).
- The IRP ignores a considerable body of published research in positive psychology (see, e.g., Snyder & Lopez, 2002).
- Cultural and gender issues should be addressed more intensively.
- There is too much emphasis on medication as treatment/prophylaxis when there are other effective, cheaper, and side-effect free alternatives that are not being explored.
- The IRP should not divide the Risks of Behavioral and Psychiatric Conditions. There is no value added in this strategy, which mistakenly treats the continuum from psychological well-being to serious psychological and behavioral problems as though it were a dichotomy.
- The three risks do not clearly articulate what challenges are facing them.
- Considering results from analogue and simulation conditions can be useful, but the usefulness of the data depends on the environment's psychological similarity to spaceflight -- which needs to be evaluated. When there are adequate data collected in



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space, major reliance must be placed on those findings.

- There needs to be someone inside the HRP organization that looks at what these SRPs are evaluating, but they need to do it on a more frequent basis. The state of the art is constantly changing, and gaps are opening and closing at an unprecedented rate. Therefore, the organization should consider instituting a process that will enable the HRP to monitor changes on an ongoing nature, e.g., quarterly updates of SRPs.
- Opening research funding to non-US PIs should be considered by NASA. We realize that this is outside the purview of the HRP.
- The Team field is a growing area, and the current work of experts in the field do not seem to be incorporated in the current research. Most of the IRP research is in the psychosocial area and does not look at the higher level work. In medicine, considerable effort is currently being expended to look at task breakdown, the characteristics of high performing teams, and the nature of team-based errors. None of this involves social functioning beyond those aspects of interpersonal behavior that are necessary for high efficiency and high reliability team performance. A specific example would be in the operating room, where researchers have identified optimal and suboptimal behavioral markers of surgeons, anesthesiologists and operating room nurses (e.g., Flin & Maran, 2004). Other groups have been dissecting the communication process in operating room teams (e.g., Manser, Dieckmann, Wehner, & Rallf, 2007). This kind of research is currently absent from the NASA research world.
- Under the BMed Risk, there is too much concentration on depression. Mood disorders are understandably one important concern, but there are several other potential problems that are perhaps equally probable and equally deleterious (anxiety, irritability, fugue states, asthenia). They should also be addressed. Still others, currently classified separately as psychiatric issues -- psychotic episodes, for example -- are toward the maladaptive end of the continuum; but the SRP again reminds NASA that this *is* a continuum.
- Post-mission effects such as reintegration into the customary environment are mentioned as a concern, but no task concentrates on them.
- Family issues are not addressed. A review of research on military and other families that experience prolonged separation from a member involved in dangerous work is advisable, as is some focused research on astronaut families themselves as well as their interactions with the astronaut before, during, and after missions. Among potential issues are:
  - The toll that long separations during training, missions, and post-return job commitments (e.g., travel) takes on the family;
  - Coping with problems back home during training, during missions, and during post-mission commitments;
  - Feelings of helplessness, when a problem at home could be handled by the astronaut if he or she were there;
  - Family changes that occur while the astronaut is gone and to which he or she must adapt upon returning.

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## **VI. Discussion of element specific questions in addendum and/or any other issues or concerns the panel chooses to address.**

1. Are there obvious, unrealistic aspects in the IRP schedule (e.g., timing, sequence, interdependencies)?
  - Yes.
  - There should be periodic reviews of the schedule/timelines by NASA to make sure they remain appropriate, or to modify them as needed.
  - Some projects have been going on a very long time (such as the optical facial scanning activities) and there have been no proven applications. It is hard to justify why some of the projects have been supported for as long as 10-12 years, unless the usefulness, validity, and reliability of these measures are going to be tested on ISS.
  - Literature reviews are not handled well. It seems like a side activity that requires more thought, especially as it will affect the proposed timelines.
  - Reviews should be done by arm's length investigators (see General Recommendation 4).
    - Some of the proposed reviews already exist. NASA should look at this information before reinventing it. For example, are there not already adequate literature reviews on depression and anxiety, on shift work, etc.? A group or committee should be formed to evaluate existing reviews and decide what would be superfluous to review again.
    - There should be some planning for how the information from completed tasks will be used 3 or 4 years later. What is being learned should not be lost.
    - There is not enough basic information on brain metabolism specific to depression to use near infrared as a diagnostic tool.
2. Is the portfolio of tasks sufficiently complete to acquire an adequate description (e.g., characterization and quantification) of risks?
  - No. Our specific suggestions are detailed in the gaps/tasks above.
3. Is the portfolio of tasks developing or validating the appropriate technologies and methods to monitor, detect, and assess risk?
  - No, not completely. Too narrow a focus in some cases; see our specific recommendations.
  - Specialized subject matter experts should be consulted extensively. For example, it would be useful to convene a panel of experts on empirically-supported treatments for mood and anxiety disorders, with the goal of obtaining their recommendations regarding existing procedures that might best be adapted for use during long-duration missions. They might also recommend ways to test and evaluate the suitability and effectiveness of these adapted methods.
4. Is the portfolio of tasks developing and validating the appropriate countermeasures needed to prevent, mitigate, and/or treat risks and risk factors?
  - If this question refers to whether the portfolio is adequate, the answer is, not completely (and in some cases, not even close). Some of the on-going studies, for example in the assessment and treatment of depression, are quite idiosyncratic to the interests and

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experience of specific investigators who happen to have ongoing connections to NASA and/or NSBRI.

5. Is the portfolio well balanced among risk description, countermeasure development and technology development activities for each of the three risks?
  - Underdeveloped description of risks for BMed and Team gaps.
  - There is not much on optimization/countermeasure development in any of the three areas. To the extent that the description of both risks and tasks lacks details, it is difficult to determine whether the optimization/countermeasure techniques to be tested are adequate.
  - Technology development is not a huge issue in this area and should not be pursued for its own sake.
    - The computer interaction area in Team gap is interesting, but more work needs to be done. For example, there should be a comparison between the depression computer task that is currently being used and more traditional, empirically validated methods. Cognitive behavior therapy could be the most effective program, and has already been tested (see the comment under BMed 1 gap). Among potentially useful expert consultants are Professors Steven Hollon (Vanderbilt University), Aaron Beck, and Robert De Rubeis (both at the University of Pennsylvania).
6. What criteria can be used to assess the degree to which the gap has been sufficiently addressed to mitigate risk?
  - When do you know whether what you have done is successful?
  - There is a process in trying to validate whether something will be useful: conducting outcome studies, making systematic comparisons between the new method and established ones, best practices empirically validated. Management needs to have some criteria for judging when a gap has been filled. To do this, flight and post-flight data on psychological states, sleep, and performance would have to be used.
  - There are multiple steps to this goal:
    - It may be generally more difficult to ascertain when a psychological countermeasure (CM) can be considered effective when compared to other kinds of biomedical problems and CMs. More work may therefore be required for a CM in the psychological area and this will need to be evaluated regularly.
    - There should be a critical review of the progress of NASA and NSBRI studies. It is imperative that this review be conducted by a group outside NASA, NSBRI, and their contractors. This is for two reasons: The first is that it is important that objectivity is maintained and that any special interests or biases are minimized or removed. Second, it is not apparent that any current entity has the authority to make necessary recommendations to ensure objective and optimal research activity.
    - The judgments should be qualitative, not only quantitative - expert panels should review obtained data/findings in relation to relevant mission criteria.
    - This should be an iterative process.
  - Look at work on consensus criteria to evaluate recommendations (e.g., Chambless & Ollendick, 2001; see also the website of Division 12 of the American Psychological Association regarding empirically supported treatments, <http://www.psychology.sunysb.edu/eklonsky-/division12/>).

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- It has to be realized that the process will be different for this area (behavior) than an area like radiation, where there may be more specific answers.
  - Efficacy studies, such as: Standard psychotherapy outcome studies comparing the technology developed to other known effective treatment methods; selection criteria as predictors of later performance; standardized training manuals to enable assessment of reaching training goals; comparison of computerized conflict resolution procedures with training a crew member to be the specialist in conflict resolution.
  - NASA should adopt a balanced approach that includes optimizing well-being and performance as well as preparing to detect and mitigate serious problems if they occur. The focus on possible negative factors, while understandable from an engineering perspective, is not ideal for approaching issues of psychological support.
7. What criteria can be used to aid prioritization of gaps within and across the three BHP risks?
- Survey of operational data.
    - What were the results of the previous data? This is currently not well integrated.
    - How much knowledge do we have about how to deal with situations that arise?
    - Mitigation: More efforts to plan for space environments to enhance positive experiences of long-duration missions – environmental design, hobbies, recreational activities, etc.

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## VIII. Behavioral Health & Performance (BHP) SRP Charge

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The SRP is chartered by the Human Research Program (HRP) Program Scientist at the NASA Johnson Space Center (JSC). The purpose of the SRP is to review and provide analysis on the status and progress of HRP Elements and Projects. Your report will be provided to the HRP Program Scientist and will also be given as a courtesy to the BHP Element at JSC.

The SRP should (to the fullest extent practicable):

1. Evaluate the ability of the Integrated Research Plan (IRP) to satisfactorily address the risks by answering the following questions:
  - A. Have the proper Gaps have been identified to address the Risks?
    - i) Are all the Gaps relevant?
    - ii) Are any Gaps missing?
  - B. Have the proper Tasks have been identified to fill the Gaps?
    - i) Are the Tasks relevant?
    - ii) Are any Tasks missing?
2. Identify the strengths and weaknesses of the IRP, *and* identify remedies for the weaknesses, including answering these questions:
  - A. Are the risks addressed in a comprehensive manner?
  - B. Are there obvious areas of potential integration across disciplines that are not addressed?
3. Address (as fully as possible) the questions provided in the charge addendum and to comment on any additional information provided to the Panel that is not addressed in #1 or 2 above.
4. Expect to receive review materials at least five weeks prior to the site visit.
5. Participate in a SRP teleconference to discuss any issues, concerns, and expectations of the review process approximately three weeks prior to the face-to-face meeting
  - A. Discuss the SRP charge and address questions about the SRP process
  - B. Identify any issues the SRP would like to have answered prior to the site visit
6. Attend the SRP meeting (and possible tour) at NASA/JSC.
  - A. Attend Element presentations, question and answer session, and briefing
  - B. Prepare a draft report including recommendations from the SRP that will be briefed to the Program Scientist by the SRP chairperson or panel. The report should address #1 and 2 above, the questions in the charge addendum, and any other information considered relevant by the SRP.
7. Prepare a final report (within one month of the site visit) that contains a detailed evaluation of the risks and provides specific recommendations that will optimize the scientific return to the HRP. The final report should provide a comprehensive review of Item #1 and 2 above, address the questions in the addendum to the charge, and any additional information the SRP

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would like to provide.

8. Consider the possibility of serving on a non-advocate review panel of a directed research proposal or on a solicited research peer review panel; or otherwise advise the Program Scientist.

Addendum to charge (Element Specific Concerns):

1. Are there obvious, unrealistic aspects in the IRP schedule (e.g., timing, sequence, interdependencies)?
2. Is the portfolio of tasks sufficiently complete to acquire an adequate description (e.g., characterization and quantification) of risks?
3. Is the portfolio of tasks developing or validating the appropriate technologies and methods to monitor, detect, and assess risk?
4. Is the portfolio of tasks developing and validating the appropriate countermeasures needed to prevent, mitigate, and/or treat risks and risk factors?
5. Is the portfolio well balanced among risk description, countermeasure development and technology development activities for each of the three risks?
6. What criteria can be used to assess the degree to which the gap has been sufficiently addressed to mitigate risk?
7. What criteria can be used to aid prioritization of gaps within and across the three BHP risks?

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## IX. Behavioral Health & Performance (BHP) SRP Roster

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