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## **2014 Behavioral Health and Performance Standing Review Panel**

*Research Plan Review for:*

*The Risk of Performance Errors Due to Fatigue Resulting from Sleep Loss, Circadian Desynchronization, Extended Wakefulness, and Work Overload*

*Status Reviews for:*

*The Risk of Adverse Behavioral Conditions and Psychiatric Disorders and  
The Risk of Performance Decrements Due to Inadequate Cooperation, Coordination,  
Communication, and Psychosocial Adaptation within a Team*

### **Final Report**

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#### **I. Executive Summary and Overall Evaluation**

The 2014 Behavioral Health and Performance (BHP) Standing Review Panel (from here on referred to as the SRP) met for a site visit in Houston, TX on December 17 - 18, 2014. The SRP reviewed the updated research plan for the Risk of Performance Errors Due to Fatigue Resulting from Sleep Loss, Circadian Desynchronization, Extended Wakefulness, and Work Overload (Sleep Risk) and also received a status update on the Risk of Adverse Behavioral Conditions and Psychiatric Disorders (BMed Risk) and the Risk of Performance Decrements Due to Inadequate Cooperation, Coordination, Communication, and Psychosocial Adaptation within a Team (Team Risk).

The consensus of the SRP is that under the direction of BHP Element Scientist Dr. Lauren Leveton, there is positive movement in addressing the designated risks and associated gaps in the BHP area. A considerable number of tasks have been completed, particularly those in the Sleep Risk domain, other tasks are making good progress, and new tasks have been initiated. The transition of lighting studies and the cognition battery to flight evaluation are positive developments. Criteria have been established for when a study is ready to transition from ground-based to flight status. The significant number of BHP projects that will take place in the Human Exploration Research Analog (HERA) facility and in other analog environments also are strengths of the Element and in aggregate have the potential to reduce gaps in all three BHP Risks. Continued interest in conducting evidence reviews and data mining is a further strength, as is the hire of two additional discipline scientists.

With regard to the Sleep Risk, there is clearly a good grasp of the current state of the science. Sleep disturbance has long-term health consequences, and this is reflected in the BHP research portfolio. The SRP thinks that the appropriate gaps have been identified to address the risk, and adequately encompass the gaps related to this risk. The closure of Sleep Gap 3 tasked to document sleep loss, circadian desynchronization, extended wakefulness, and work overload over long-duration missions is a significant advance. However, the SRP suggests replacing the term “work overload” with “activity over-scheduling” in the relevant gap statements.

A major weakness in the BHP area in general is the lack of operational performance outcomes. Criteria are needed for evaluating how informative various tests and measures are that correlate with fatigue. These criteria would allow assessment of their relevance for predicting operational performance.

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The SRP recommends that research approaches should include a greater focus on the manner in which individual differences affect predictive measures, especially since the results from studies planned or already conducted will be applied to a small and select group of personnel. This perspective will better inform the relationship between data obtained via specific monitoring devices and operational performance. Greater knowledge of individual differences in sleep loss and circadian rhythm disruption also would yield targeted and thus more effective countermeasures; as such, Sleep Gap 2 should be prioritized. Robust statistical approaches including machine learning should be applied to tasks being pursued to ensure maximum applicability of outcomes, involving the efforts of statisticians specializing in small “n” studies to produce predictive tools for specific individuals. It also would be advantageous to collect and correlate biological specimens for single nucleotide polymorphisms (SNPs) to guide further risk determination.

The SRP is concerned about studies that have been ongoing for an extended period of time without addressing adequately the gaps, making significant progress towards risk mitigation, and that lack clear criteria upon which the decision to stop or continue will be made. The Optical Computer Recognition (OCR) task has been funded for approximately 15 years, and concerns have been raised about the feasibility and ultimate utility of this work by the SRP since its first meeting in 2009. While progress has been made, the Technology Readiness Level (TRL) of this project does not lead the SRP to believe that OCR will reach a level of fidelity that would warrant its deployment in space as a valid measure of stress, affect, and fatigue. A methodology should be implemented to assess success and failure of a project and whether it should be continued. Continued support of projects showing minimal progress precludes funding and application of resources to new projects with greater potential. The “sunk cost bias” of continuing a study because of the amount of funds already expended on it needs to be avoided. Moreover, it also is highly important that research task funding decisions avoid even the appearance of a conflict of interest.

The SRP emphasizes the need in the Sleep and BMed areas to further diversify the portfolio of tasks and investigators to promote new ideas and innovative approaches. A number of tasks in both of these areas are being performed by the same group of investigators and institutions that have long conducted this and related research. Proactive measures such as actively pursuing investigators from the community who have not been funded by the Human Research Program (HRP) previously and encouraging these new investigators to submit proposals would be helpful.

The SRP notes that the Sleep and BMed portfolios are not taking advantage of research that has already been conducted, particularly by/for the military. Outreach to other institutions, such as the military and homeland security, which have similar interests in sleep, fatigue, and performance as well as facial recognition strategies, could better leverage already existing resources, techniques, and findings. In addition, the SRP strongly encourages the use of more targeted literature reviews in all three BHP portfolios that include research conducted by the military and other government sources, as well as findings in the peer reviewed literature. These targeted reviews can also serve as an outreach to new investigators with expertise in subjects of interest and importance to existing gaps.

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In general, the Team portfolio is highly diverse and the tasks supported are innovative and progressing nicely. A number of tasks are synergistically addressing multiple gaps, which also is a positive feature that reflects the competent BHP Element management. The SRP recommends that an additional gap be listed for the Team risk area, focused on the evolution of teams over a long-duration period.

The Sleep area presents an excellent opportunity for HRP integration, especially postural controls and assessment of the effects of sleep and circadian disruptions on muscle and sensorimotor function. Sleep/alertness medication stability has a clear overlap with pharmacology. Further, integration can occur within the BHP area, for example, the effects of sleep and individual factors on team performance.

The SRP would like to request that the 2015 BHP SRP meeting be conducted as a site visit since both the BMed and Team areas will be under full review. A face-to-face meeting for two full research plan reviews would be much more beneficial than a WebEx/teleconference for discussions and interactions with the Element personnel and the SRP.

## **II. Critique of Gaps and Tasks for the Risk of Performance Errors Due to Fatigue Resulting from Sleep Loss, Circadian Desynchronization, Extended Wakefulness, and Work Overload**

1. *Have the proper Gaps been identified to address the Risk?*
  - A. *Are all the Gaps relevant?*
  - B. *Are any Gaps missing?*
2. *Have the appropriate targets for closure for the Gaps been identified?*
  - A. *Is the research strategy appropriate to close the Gaps?*
3. *Have the proper Tasks been identified to fill the Gaps?*
  - A. *Are the Tasks relevant?*
  - B. *Are there any additional research areas or approaches that should be considered?*
  - C. *If a Task is completed, please comment on whether the findings contribute to addressing or closing the Gap*
4. *If a Gap has been closed, does the Rationale for Gap closure provide the appropriate evidence to support the closure?*

### **Gaps and Tasks:**

**Sleep3: Does sleep loss continue on long duration spaceflight or is there adaptation? What is the nature of circadian desynchronization, extended wakefulness and work overload over long duration missions? (Closed)**

- The SRP finds this gap closure appropriate. The rationale for gap closure provides the appropriate evidence to support the closure.

Tasks:

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- Sleep-Wake Actigraphy and Light Exposure During Spaceflight – Completed Task
  - Techwatch for Sleep Monitoring Technologies for Long Duration Spaceflight – Completed Task
  - Transition Actiwatch Protocol to Medical Operations – Completed Task

**Sleep Gap 1: We need to identify a set of validated and minimally obtrusive tools to monitor and measure sleep-wake activity and associated performance changes for spaceflight.**

- The SRP thinks this gap should currently be coded as Yellow, on the edge of Red.
- The SRP thinks this gap should be reworded to include the end point of operationally meaningful performance.
- Actigraphy does measure sleep/wake activity and is a good outcome. However, a minimally obtrusive method of monitoring deep sleep in astronauts is still unavailable. As deep (stage 3) sleep is thought to have the greatest minute-by-minute recuperative value, a method for easily obtaining EEG measures would provide added benefit in terms of assessment/monitoring the adequacy of astronaut sleep. Accordingly, methods of obtaining EEG which permit more feasible application in terms of time and effort could be explored on the ground or in collaboration with technical partners.
- Psychomotor Vigilance Test (PVT) is a good outcome measure shown to reflect sleepiness, but requires correlation with operationally meaningful performance in order to function as a predictor of performance. Such studies should be conducted.
- The International Space Station (ISS) testing of the Cognition measure is a strength; additional neurocognitive test batteries are considered of lower priority.
- Clear decision points/end points for particular projects that are designed to address this gap need to be established. The OCR task has been ongoing for approximately 15 years; however, at present, data on specificity and sensitivity indicate that this task is still far from completion. This raises questions about the utility of continuing to expend efforts on this task. Other measures currently in development may prove more fruitful.
- To accelerate progress in addressing this gap, the SRP recommends seeking out scientists from the public and private sectors doing similar work on developing tools, for example, military, homeland security, and others working in related areas.

Tasks:

- Integrated Cognitive Assessment: Combining Measurement, System, and Mission – Completed Task
- Psychomotor Vigilance Test (PVT) on ISS – PI: David Dinges, Ph.D. – University of Pennsylvania
- Psychomotor Vigilance Test (PVT) Transition to Operations on the Ground – Unfunded Task/Not within Current Budget
- Development of a User Interface for the PVT SelfTest (PST) – Completed Task
- Android App Incorporating the PVT to deliver individualized Fatigue Risk Management in Commercial Trucking – Completed Task
- Individualized Real-Time Neurocognitive Assessment Toolkit for Spaceflight Fatigue – PI: Mathias Basner, Ph.D. – University of Pennsylvania

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- Validation of Assessment Tests and Countermeasures for Detecting and Mitigating Changes in Cognitive Function During Robotics Operations – PI: Charles Oman, Ph.D. – Massachusetts Institute of Technology
  - Objective Sleep Measures for Spaceflight Operations (SBIR) – Planned Task
  - BHP Performance Measures – Planned Task
  - Optical Computer Recognition of Stress, Affect and Fatigue in Spaceflight – PI: David Dinges, Ph.D. – University of Pennsylvania
  - Integrated Tools and Technologies Testing, Verification, and Validation (Flight) – Planned Task
  - Multi-Modal Neurodiagnostic Tool for Stress Monitoring – PI: Jin Lee, Ph.D. – Linea Research Corporation
  - Integrated Ground Testing of Monitoring Technologies – Planned Task
  - Integrate Workload Measures Questionnaire – Planned Task
  - Tech Watch for Improving HCI in Next-Generation Missions-2 – Planned Task
  - In-situ, unobtrusive methods for measuring workload – Planned Task
  - Validation of unobtrusive Crew Resource Management (CRM), Situation Awareness (SA), and Workload – Unfunded Task/Not within Current Budget

**Sleep Gap 2: We need to understand the contribution of sleep loss, circadian desynchronization, extended wakefulness and work overload, on individual and team behavioral health and performance (including operational performance), for spaceflight.**

- The phrase “work overload” in the gap statement is poorly defined. The SRP suggests “sleep loss, circadian desynchronization, and activity scheduling factors...” to better define the gap.
- The gap wording “team behavioral health” is unclear. The SRP suggests rewording it to “individual health and team performance.”
- Downstream effects of sleep loss on health may merit altering the gap to include sleep loss effects on physical health in addition to behavioral health.
- Greater effort needs to be made to obtain meaningful operational performance data. A major shortcoming in closing this gap is the lack of operational performance outcomes. The panel recognizes that this is an administrative challenge; however, access to such data is critical and efforts should be continued in this direction.
- Criteria are needed for evaluating the efficiency and validity of tests and measures that predict operational performance. The PVT, while sensitive to sleep loss and circadian desynchrony, is non-specific and its utility for predicting relevant operational performance has not yet been determined.
- The team aspect of this gap is not being addressed and should be given higher priority; individual differences in sleep and response to lack of sleep may affect team and interpersonal social dynamics. Because of this, individual differences merit more study. The SRP recommends an evidence report for this area. Military and other agencies likely have technical reports addressing these issues.
- Planned BHP data mining is a strength.
- There is a need to proactively pursue established investigators from the wider scientific community. The professional field is not being adequately sampled.

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Task:

- The role of sleep and circadian phase on crew safety, performance and psychological health during long-term analog space missions – PI: Steven Lockley, Ph.D. – Harvard Medical School
- Cognitive Performance and Stress in a Simulated Space Environment – Completed Task
- Psychomotor Vigilance Test (PVT) on ISS – PI: David Dinges, Ph.D. – University of Pennsylvania
- Reaction Self-Test (PVT) for ISS-12 – PI: David Dinges, Ph.D. – University of Pennsylvania
- Assess Sleep Recovery Research Findings from Other Agencies – Unfunded Task/Not within Current Budget
- Workload and Scheduling Tools for Long Duration Missions – Planned Task
- Workload and Scheduling Tools for Long Duration Missions (Research Requirements) – Planned Task
- Sleep Glymphatic Changes – Planned Task
- Sleep Glymphatic Changes (Research Requirements) – Unfunded Task/Not within Current Budget
- BHP Data Mining – Planned Task
- Tech Watch for Improving HCI in Next-Generation Missions-2 – Planned Task
- In-situ, unobtrusive methods for measuring workload – Planned Task
- Validation of unobtrusive Crew Resource Management (CRM), Situation Awareness (SA), and Workload – Unfunded Task/Not within Current Budget
- Individualized Stress Detection System – PI: Daniel Mollicone, Ph.D. – Pulsar Informatics, Inc.

**Sleep Gap 4: We need to identify indicators of individual vulnerabilities and resiliencies to sleep loss and circadian rhythm disruption, to aid with individualized countermeasure regimens, for autonomous, long duration and/or distance exploration missions.**

- The SRP thinks this gap should be prioritized. Greater knowledge of individual differences in sleep loss and circadian rhythm disruption, as well as effects on operational performance, would yield more effective and potentially individualized countermeasures.
- Robust statistical approaches, including machine learning, should be applied to the various tasks currently conducted to ensure maximum applicability of outcomes.
- The SRP thinks it would be advantageous to collect and correlate biological specimens for SNPs to guide further risk determination by linking biological data with later operational performance outcomes.
- The field is not adequately being sampled. Therefore, the SRP thinks the BHP Element should proactively pursue investigators from the wider community.

Tasks:

- Sleep and Circadian Biomarkers - Assess Relevant Investigations Across Other Agencies – Unfunded Task/Not within Current Budget

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- Evidence Review on Biomarkers of Individual Vulnerabilities to Sleep Loss and Circadian Desynchronization – Completed Task
  - Development and testing of biomarkers to determine individual astronauts' vulnerabilities to behavioral health disruptions (NRA) – PI: Steven Lockley, Ph.D. – Harvard Medical School
  - Mathematical Modeling of Circadian/Performance Countermeasures – Completed Task
  - Markers of Susceptibility to Neurobehavioral Decrements in Spaceflight – PI: David Dinges, Ph.D. – University of Pennsylvania
  - Designing Individual Countermeasures to Reduce Sleep Disruption and Improve Performance and Alertness in Space – Completed Task
  - Countermeasures for Performance Deficits from Sleep Loss and Workload in Spaceflight – Completed Task
  - Individualized Fatigue Meter for Space Exploration (SBIR Phase II) – Completed Task
  - Baseline Astronaut Sleep Data Mining – Unfunded Task/Not within Current Budget
  - Individual differences and adaptation to Isolated, Confined, and Extreme (ICE) environments – Unfunded Task/Not within Current Budget
  - EEG Prediction of Psychological States – Planned Task
  - Biomarkers as Predictors of Resiliency and Susceptibility to Stress in Spaceflight (NRA) – PI: Namni Goel, Ph.D. – University of Pennsylvania
  - Assessing the Impact of Chronic Sleep Restriction on Sleep and Performance-Associated Regional Brain Activation Using Near-Infrared Spectroscopy (Postdoctoral Fellowship) – PI: Michael Lee, Ph.D. – Brigham and Women's Hospital/Harvard Medical Center

**Sleep Gap 5: We need to identify environmental specifications and operational regimens for using light to prevent and mitigate health and performance decrements due to sleep, circadian, and neurobehavioral disruption, for flight, surface and ground crews, during all phases of spaceflight operations.**

- This gap appears to be addressed adequately and the SRP is pleased with the list of tasks presented, as well as completed, and the movement of the lighting tasks to flight evaluation.

Tasks:

- Validation of ISS Solid State Light Assembly (SSLA) Countermeasure Protocols – Planned Task
- Ultra-Short Light Pulses as Efficient Countermeasures for Circadian Misalignment and Objective Performance and Subjective Alertness Decrements – PI: Elizabeth Klerman, M.D., Ph.D. – Brigham and Women's Hospital/Harvard Medical Center
- The ISS Dynamic Lighting Schedule: An in-flight lighting countermeasure to facilitate circadian adaptation, improve sleep and enhance alertness and performance on the International Space Station – PI: Steven Lockley, Ph.D. – Harvard Medical School
- Sleep Workshop – Planned Task
- Feasibility Pilot Study on Acute Biological and Behavioral Responses to the Solid State Lighting Modules for the International Space Station – Completed Task

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- Blue Light for Enhancing Alertness in Space Missions – Completed Task
  - Characteristics of Light Exposure Necessary for Development of Optimal Countermeasures to Facilitate Circadian Adaptation and Enhance Alertness and Cognitive Performance in Space – Completed Task
  - Evaluation of Photic Countermeasures for Circadian Entrainment of Neurobehavioral Performance and Sleep-Wake Regulation Before and During Spaceflight – Completed Task
  - Optimizing Light for Long Duration Space Exploration – Completed Task
  - Replacement Lighting for Research and Training – Completed Task
  - Operational Evaluation of Photic Countermeasure to Improve Alertness, Performance, and Mood during Nightshift Work on a 105-Day Study (105-day Russian Chamber Study) – Completed Task
  - A Model of Circadian Disruption in the Space Environment – Completed Task
  - Evidence Review: long term safety effects of low spectrum light exposure – Completed Task
  - Lighting Protocols for Exploration – Planned Task
  - A Comprehensive Fatigue Management Program and an Evaluation of a Photic Countermeasure for Mission Controllers – PI: Charles Czeisler, M.D., Ph.D. – Brigham and Women's Hospital/Harvard Medical Center
  - Workload, Lighting, Scheduling, and CO<sub>2</sub> in Long Duration Mission Analogs – Planned Task
  - Radiation Effects on Melanopsin – Planned Task
  - Exploration Lighting Protocols Transition to Operations – Planned Task
  - Evaluate Fatigue Countermeasure Effectiveness for Flight Controllers – Planned Task
  - ISS Solid State Light Assembly (SSLA) Lighting Protocols Transition to Operations – Planned Task
  - Radiation Effects on Melanopsin (Research Requirements) – Unfunded Task/Not within Current Budget
  - Microgravity Effects on Melanopsin Data Mining – Unfunded Task/Not within Current Budget

**Sleep Gap 6: We need to identify how individual crew members can most effectively and safely use medications to promote sleep, alertness, and circadian entrainment, as needed during all phases of spaceflight operations.**

- The task, Operational Ground Testing Protocols to Individualize Astronaut Sleep Medication Efficacy and Individual Effects has a great deal of potential for collaboration with military investigators who previously have carried out research in this area.
- The current task provides little new information. While operationally important, the task does not qualify as new research.
- Alertness medications are available and are being used in the operational context in addition to sleep medications, but this class of pharmacological agents is not being studied. Military laboratories have carried out a significant number of studies in this area; therefore, a literature review or evidence report should be a priority. Also, prior to conducting any additional work on sleep medications, military laboratories should be

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consulted to ensure no duplication of effort.

- The SRP recommends that these medication countermeasures should be included in future modeling studies.

Tasks:

- Develop and Implement Operational Ground Testing Protocols to Individualize Astronaut Sleep Medication Efficacy and Individual Effects (pilot study) – Completed Task
- Operational Ground Testing Protocols to Individualize Astronaut Sleep Medication Efficacy and Individual Effects – PI: Smith Johnston, M.D. – NASA Johnson Space Center
- Pharmacology Database – PI: Virginia Wotring, Ph.D. – NASA Johnson Space Center
- BHP Spaceflight Medications – Planned Task
- Dose Tracker Application for Monitoring Crew Medication Usage, Symptoms and Adverse Effects During Missions – PI: Virginia Wotring, Ph.D. – NASA Johnson Space Center
- Inflight pharmacokinetic and pharmacodynamic responses to medications commonly used in spaceflight – Planned Task

**Sleep Gap 8: We need to develop individualized scheduling tools that predict the effects of sleep-wake cycles, light and other countermeasures on performance, and can be used to identify optimal (and vulnerable) performance periods during spaceflight.**

- The SRP thinks good progress had been made in completing a number of tasks addressing this gap. But it is important to proactively pursue investigators from the wider scientific community and to encourage them to submit proposals targeting the planned tasks listed.
- It is important not to “reinvent the wheel” when developing new tools. The SRP suggests building upon work in the existing literature and utilizing existing models; for example, the Sleep, Activity, Fatigue, and Task Effectiveness (SAFTE) model that is currently being widely used in military and industrial settings.

Tasks:

- Spaceprint: Development and Validation of a Tool to Predict, Evaluate, and Mitigate Excessive Workload Effects – PI: Angelia Sebok – Alion Science and Technology
- Mathematical Modeling of Circadian/Performance Countermeasures – Completed Task
- Physiologically-Based Modeling of Sleep-Wake Scheduling and the Effects of Pharmaceuticals (NSBRI Postdoctoral Fellowship) – Completed Task
- Individualized Fatigue Meter for Space Exploration (SBIR Phase II) – Completed Task
- Designing Individual Countermeasures to Reduce Sleep Disruption and Improve Performance and Alertness in Space – Completed Task
- Countermeasures for Performance Deficits from Sleep Loss and Workload in Spaceflight – Completed Task
- Field Validation of Sleep-Wake Models – Planned Task
- Scheduling Tools for Exploration – Planned Task

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- Integration of Circadian Neurobehavioral Performance and Alertness (CNPA) Model into Behavioral Health and Performance (BHP) Dashboard – PI: Daniel Mollicone, Ph.D. – Pulsar Informatics, Inc.
  - Workload, Lighting, Scheduling, and CO2 in Long Duration Mission Analogs – Planned Task
  - Workload and Scheduling Tools for Long Duration Missions (Research Requirements) – Planned Task
  - Workload and Scheduling Tools for Long Duration Missions – Planned Task
  - Tech Watch for Improving HCI in Next-Generation Missions-2 – Planned Task
  - In-situ, unobtrusive methods for measuring workload – Planned Task
  - Validation of unobtrusive Crew Resource Management (CRM), Situation Awareness (SA), and Workload – Unfunded Task/Not within Current Budget

**Sleep Gap 9: We need to identify an integrated, individualized suite of countermeasures and protocols for implementing these countermeasures to prevent and/or treat chronic partial sleep loss, work overload, and/or circadian shifting, in spaceflight.**

- According to the literature, lighting is a much stronger zeitgeber than diet, or any other environmental factor. Accordingly, the SRP thinks examination of diet as a sleep/circadian countermeasure should be of lower priority relative to lighting.
- Mindfulness training and Cognitive Behavior Therapy for insomnia (CBTi) are other possible countermeasures to pursue.

Tasks:

- Countermeasures to Neurobehavioral Deficits from Cumulative Sleep Deprivation During Spaceflight: Dose-Response Effects of Recovery Sleep Opportunities– Completed Task
- Diet as a sleep/circadian countermeasure (Research Requirements) – PI: Patrick Fuller, Ph.D. – Harvard Medical School
- Individualized Countermeasure Protocols – Unfunded Task/Not within Current Budget
- Integrated Ground Testing of Countermeasures – Planned Task
- Evaluate Fatigue Clinical Practice Guidelines/Countermeasure Effectiveness – Planned Task
- Diet as a Sleep/Circadian Countermeasure – Planned Task

**Sleep Gap 10: We need to identify the spaceflight environmental and mission factors that contribute to sleep decrements and circadian misalignment, and their acceptable levels of risk.**

- The SRP recommends that the tasks “Characterize Workload on ISS” and “BHP Data Mining” should be prioritized for future funding.

Tasks:

- Phoenix Scout Lander: Countermeasures Testbed for Spaceflight Ground Controllers – Completed Task

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- Survey of On-Orbit Sleep Quality (Sleep Quality Questionnaire) – Completed Task
  - Characterize Workload on ISS – Unfunded Task/Not within Current Budget
  - Future Vehicle Environment (Research Requirements) – Unfunded Task/Not within Current Budget
  - Sleep-Wake for ISS-12 – PI: Laura Barger, Ph.D. – Harvard Medical School
  - Subject Matter Expert CO2 Review – Planned Task
  - Investigate Effects of Acute CO2 Exposure with Existing Measures – Planned Task
  - Investigate the Effects of Acute CO2 Exposure with Other Measures (NRA) – Unfunded Task/Not within Current Budget
  - Investigate the Effects of Chronic CO2 Exposure (NRA) – Unfunded Task/Not within Current Budget
  - Investigate the Effects of Chronic CO2 Exposure with Spikes (NRA) – Unfunded Task/Not within Current Budget
  - Workload, Lighting, Scheduling, and CO2 in Long Duration Mission Analogs – Planned Task
  - BHP Data Mining – Planned Task
  - Future Vehicle Environment Questionnaire – Planned Task

### **III. Discussion on the strengths and weaknesses of the IRP and identify remedies for the weaknesses, including answering these questions:**

#### **A. Is the Risk addressed in a comprehensive manner?**

Sleep has long-term health and performance consequences. The SRP thinks that the appropriate gaps have been identified to address the risk, and adequately encompass the gaps related to this risk. The Sleep research plan shows considerable strengths. Substantial progress has been made in addressing the Sleep risk, and the array of ongoing and completed studies is impressive. The closure of Sleep Gap 3 tasked to document sleep loss, circadian desynchronization, extended wakefulness and work overload over long-duration missions is unique and a strength of the Element. In general, appropriate targets for closure of the various gaps have been identified.

A major weakness, which the SRP recognizes is not entirely within the control of the BHP Element, is the lack of operational performance outcomes with which to establish the predictive value of various tests (e.g., the PVT) and measures (e.g., actigraphically-determined sleep parameters). The SRP notes that if efficacy of a task depends on operational performance data and such data are not forthcoming, then that task should be abandoned and new tasks of that nature should not be initiated.

The SRP recommends a greater focus on individual differences and the development of individual profiles to better inform the relationship between data obtained via specific monitoring devices and operational performance. Robust statistical approaches should be applied to ensure maximum applicability of outcomes, with statisticians specializing in small “n” studies consulted to produce predictive tools for specific individuals. These individual predictive measures are key data to developing effective countermeasures. It

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would also be advantageous to collect and correlate biological specimens for SNPs to guide further risk determination.

The SRP is concerned that certain studies have been ongoing for an extended period of time despite outcomes that do not exhibit sufficient progress in closing the gap and risk targeted. Clear criteria based on TRL and other factors should be established for assessing success and failure of a project and whether it should be continued. In addition, leveraging resources and information from the military and other government and private agencies related to medication effects on performance would avoid repeating research in areas with established or similar findings that could be applied to spaceflight. Furthermore, proactively encouraging investigators from the wider community to submit proposals would broaden the array of approaches to closing gaps in the Sleep risk area.

B. Are there areas of integration across HRP disciplines that are not addressed that would better address the Sleep Risk?

The Sleep and BMed tasks tend to focus on single gaps, while a number of the studies in the Team area are synergistic in addressing multiple gaps. The Sleep area presents an excellent opportunity for integration, especially postural controls, and assessment of the effects of sleep and circadian disruptions on muscle and sensorimotor areas. Sleep/alertness medication stability has a clear overlap with pharmacology. Serotonin-specific reuptake inhibitor (SSRI) use and bone density is a significant issue and could be integrated with BHP factors. Further, integration can occur within the BHP discipline, for example, the effects of sleep and individual factors on team performance.

#### **IV. Evaluation of the progress on the Sleep Risk Research Plan since the 2013 SRP meeting**

The SRP thinks the closure of Gap 3 is a positive step forward. Movement of the lighting countermeasures to flight evaluation is also a highlight. A significant amount of research has been carried out addressing the Sleep risk, particularly impressive in light of budgetary limitations. The development of criteria for determining when a study is ready to move from ground to flight is a strength of the BHP Element.

#### **V. Additional Comments regarding the Risk of Adverse Behavioral Conditions and Psychiatric Disorders (BMED)**

- The SRP identified the following strengths in this area:
  - The hire of a BMed scientist;
  - Transition of the Cognition battery to flight evaluation;
  - Tasks addressing neurostructural changes, neurocognitive performance and biomarkers are making progress and have the potential to add to knowledge addressing this risk;
  - The use of several analog sites for conducting several of the tasks in the portfolio;

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- The planned family support workshop.
  - The addition of the term “cognitive” to the risk statement more precisely defines a pathway for addressing this risk.
  - The SRP has concerns that parts of the portfolio tend to be narrowly focused on specific labs and areas of study within the BMed domain. This situation likely deters new investigators from submitting proposals to address the various gaps, thus potentially stifling innovation.
  - Current/modern behavior monitoring technologies are not being utilized in some of the tasks funded such as, for example, computer adaptive testing, which might be more “consumer friendly” for astronauts than standard checklist measures.
  - Clear outcomes/expectations need to be specified when extending a project.
  - Concerns about progress on the OCR task in monitoring affect and stress have been repeatedly raised.

## **VI. Additional Comments regarding the Risk of Performance Decrements Due to Inadequate Cooperation, Coordination, Communication, and Psychosocial Adaptation within a Team (Team)**

- Research, including literature reviews, on the evolution of long-duration teams in terms of work performance, structure, and interpersonal processes should be encouraged. The SRP recommends that this area be included as an additional Team gap because of the lack of empirical evidence. In addition, there is a need for the development of a theoretical model of the evolution of team leadership, structure, and interpersonal processes for long duration teams.
- The portfolio tasks addressing the Team risk are highly innovative; clear efforts are evident to address all of the gaps.
- The SRP identified the following strengths:
  - The hire of an additional scientist;
  - The job analysis project assessing behavioral competencies for exploration that is a joint effort between BHP Research and Operations;
  - The number of potentially informative new as well as continuing projects in the Team portfolio, and the use of a number of analog sites to conduct these studies;
  - The high fidelity of the Hawaii Space Exploration Analog and Simulation (HI-SEAS) project and the ability of the site to support a number of projects;
  - The multiple gaps addressed in many of the projects is a significant advance;
  - The extensive focus on team performance work processes. The SRP encourages the continuation of this work;
  - The development of team measurements and other technologies.
- Other promising tasks involve team knowledge-based work processes for sharing ideas, and the focus on leadership, a major driver of team effectiveness. However, it is also important to consider the informal leadership situation.
- Tasks dealing with multi-team work activity tasks are highly necessary to ensure that these teams work well together. Moreover, the communication delay research is critical for between team dynamics and should be encouraged.
- The number of evidence reviews is a strength indicating dedication to remaining

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- current in the field.
- With regard to team composition, the SRP urges careful thought as to how research will be conducted and implemented. Because it is unlikely that teams will be selected based on personality characteristics, emphasis should be placed on training focused on dealing with individual team member personality strengths and vulnerabilities, rather than prediction.
  - Overall, an operational focus is key. What are the actionable outcomes to the Team research? These outcomes need to be clearly defined.

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## VII. 2014 BHP SRP Research Plan Reviews: Statement of Task for the Risk of Performance Errors Due to Fatigue Resulting from Sleep Loss, Circadian Desynchronization, Extended Wakefulness, and Work Overload

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The 2014 Behavioral Health and Performance (BHP) Standing Review Panel (SRP) is chartered by the Human Research Program (HRP) Chief Scientist. The purpose of the SRP is to review the Risk of Performance Errors Due to Fatigue Resulting from Sleep Loss, Circadian Desynchronization, Extended Wakefulness, and Work Overload section of the current version of the HRP's Integrated Research Plan (IRP) which is located on the Human Research Roadmap (HRR) website (<http://humanresearchroadmap.nasa.gov/>). Your report, addressing each of the questions in the charge below and any addendum questions, will be provided to the HRP Chief Scientist and will also be made available on the HRR website.

### **The 2014 BHP SRP is charged (to the fullest extent practicable) to:**

1. Based on the information provided in the current version of the HRP's IRP, evaluate the ability of the IRP to satisfactorily address the Risk by answering the following questions:
  - A. Have the proper Gaps been identified to address the Risk?
    - i) Are all the Gaps relevant?
    - ii) Are any Gaps missing?
  - B. Have the appropriate targets for closure for the Gaps been identified?
    - i) Is the research strategy appropriate to close the Gaps?
  - C. Have the proper Tasks been identified to fill the Gaps?
    - i) Are the Tasks relevant?
    - ii) Are there any additional research areas or approaches that should be considered?
    - iii) If a Task is completed, please comment on whether the findings contribute to addressing or closing the Gap.
  - D. If a Gap has been closed, does the rationale for Gap closure provide the appropriate evidence to support the closure?
2. Identify the strengths and weaknesses of the IRP, *and* identify remedies for the weaknesses, including, but not limited to, answering these questions:
  - A. Is the Risk addressed in a comprehensive manner?
  - B. Are there areas of integration across HRP disciplines that are not addressed that would better address the Risk?
  - C. Other
3. Based on the updates provided by the Element, please evaluate the progress in the research plan since the last SRP meeting.

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4. Please comment on any important issues that are not covered in #1, #2, or #3 above, that the SRP would like to bring to the attention of the HRP Chief Scientist and/or the Element.

**Additional Information Regarding This Review:**

1. Expect to receive review materials at least four weeks prior to the meeting.
2. Attend the 2014 BHP SRP meeting in Houston, TX on December 17 - 18, 2014.
  - A. Attend Element or Project presentations, question and answer session, and briefing.
  - B. Prepare a draft report that addresses each of the evaluation criteria listed in the panel charge. Debrief the HRP Chief Scientist and a representative from the BHP Element on the salient points that will be included in the report and specifically the items in the panel charge.
3. Prepare a draft final report (approximately one month after the meeting) that contains a detailed evaluation of the current IRP specifically addressing items #1, #2, #3, and #4 of the SRP charge. The draft final report will be sent to the HRP Chief Scientist and he will forward it to the appropriate Element for their review. The BHP Element and the HRP Chief Scientist will review the draft final report and identify any misunderstandings or errors of fact and then provide official feedback to the SRP within two weeks of receipt of the draft report. If any misunderstandings or errors of fact are identified, the SRP will be requested to address them and finalize the 2014 SRP Final Report as quickly as possible. The 2014 SRP Final Report will be submitted to the HRP Chief Scientist and copies will be provided to the BHP Element and also made available to the other HRP Elements. The 2014 SRP Final Report will be made available on the HRR website (<http://humanresearchroadmap.nasa.gov/>).

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## **VIII. 2014 BHP SRP Status Review: Statement of Task for the Risk of Adverse Behavioral Conditions and Psychiatric Disorders and the Risk of Performance Decrements Due to Inadequate Cooperation, Coordination, Communication, and Psychosocial Adaptation within a Team**

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The 2014 Behavioral Health and Performance (BHP) Standing Review Panel (SRP) will participate in a Status Review that will occur via a site visit with the Human Research Program (HRP) Chief Scientist, Deputy Chief Scientist and members of the BHP Element. The purpose of this review is for the SRP to:

1. Receive an update by the HRP Chief Scientist or Deputy Chief Scientist on the status of NASA's current and future exploration plans and the impact these will have on the HRP.
2. Receive an update on any changes within the HRP since the 2013 SRP meeting.
3. Receive an update by the Element or Project Scientist(s) on progress since the 2013 SRP meeting.
4. Participate in a discussion with the HRP Chief Scientist, Deputy Chief Scientist, and the Element regarding possible topics to be addressed at the next SRP meeting

The 2014 BHP SRP will produce a report/comments from this status review within 30 days of the 2014 update. These comments will be submitted to the HRP Chief Scientist and copies will be provided to the BHP Element and also made available to the other HRP Elements. The 2014 SRP Final Report will be made available on the Human Research Roadmap public website (<http://humanresearchroadmap.nasa.gov/>).

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## IX. 2014 BHP SRP Roster

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