

<b>Fiscal Year:</b>	FY 2009	<b>Task Last Updated:</b> FY 09/15/2009	
<b>PI Name:</b>	Brainard, George C. Ph.D.		
<b>Project Title:</b>	Blue Light for Enhancing Alertness in Space Missions		
<b>Division Name:</b>	Human Research		
<b>Program/Discipline:</b>	NSBRI		
<b>Program/Discipline--Element/Subdiscipline:</b>	NSBRI--Human Factors and Performance Team		
<b>Joint Agency Name:</b>		<b>TechPort:</b>	Yes
<b>Human Research Program Elements:</b>	(1) <b>BHP</b> :Behavioral Health & Performance (archival in 2017)		
<b>Human Research Program Risks:</b>	(1) <b>BMed</b> :Risk of Adverse Cognitive or Behavioral Conditions and Psychiatric Disorders		
<b>Space Biology Element:</b>	None		
<b>Space Biology Cross-Element Discipline:</b>	None		
<b>Space Biology Special Category:</b>	None		
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<b>Organization Name:</b>	Thomas Jefferson University		
<b>PI Address 1:</b>	Light Research Program		
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<b>City:</b>	Philadelphia	<b>State:</b>	PA
<b>Zip Code:</b>	19107-5083	<b>Congressional District:</b>	1
<b>Comments:</b>			
<b>Project Type:</b>	GROUND	<b>Solicitation / Funding Source:</b>	Directed Research
<b>Start Date:</b>	09/01/2006	<b>End Date:</b>	08/31/2012
<b>No. of Post Docs:</b>	0	<b>No. of PhD Degrees:</b>	8
<b>No. of PhD Candidates:</b>	1	<b>No. of Master' Degrees:</b>	4
<b>No. of Master's Candidates:</b>	1	<b>No. of Bachelor's Degrees:</b>	12
<b>No. of Bachelor's Candidates:</b>	0	<b>Monitoring Center:</b>	NSBRI
<b>Contact Monitor:</b>	<b>Contact Phone:</b>		
<b>Contact Email:</b>			
<b>Flight Program:</b>			
<b>Flight Assignment:</b>			
<b>Key Personnel Changes/Previous PI:</b>			
<b>COI Name (Institution):</b>			
<b>Grant/Contract No.:</b>	NCC 9-58-HPF00001		
<b>Performance Goal No.:</b>			
<b>Performance Goal Text:</b>	<p>The overall goal of this project is to study the efficacy of blue-enriched polychromatic solid-state light for acutely enhancing alertness and cognitive performance in healthy men and women. The purpose of this work is to develop an in-flight lighting countermeasure for enhancing alertness in astronauts as well as NASA ground crew. This is the third year of a directed research project. This past year, we have worked on the following seven aims:</p> <ol style="list-style-type: none"> <li>1) Complete data analysis for the blue-enriched solid-state light melatonin suppression bench-marking study.</li> <li>2) Present the melatonin study results at the NASA Investigators Workshop and complete a manuscript for publication.</li> <li>3) Complete the setup, calibration, and staff training on polysomnographic equipment and performance testing batteries.</li> </ol>		

- 4) Secure necessary amendments to the approved IRB document for the first alertness study.
- 5) Recruit, screen, enroll, and begin running subjects for the first study on alertness and cognitive performance.
- 6) Identify follow-up studies.
- 7) As necessary, a) design and acquire new prototype solid-state light sources or b) develop modifications of current light sources for future studies.

During the first two years of this project, we made significant progress in 1) creating two prototype 122 x 122 cm solid-state blue light (475 nm) exposure systems for the studies, 2) validating the safety of these prototypes by an independent hazard analysis that met federal (ACGIH), international (ICNIRP), and NASA guidelines for safety of human ocular exposure, and 3) completing a bench-marking melatonin suppression study using the blue light prototype with eight healthy subjects.

In terms of the first aim for the past year, we completed data analysis of the bench-marking melatonin suppression study. The goals of the study were to characterize the biological potency of the prototype light units and guide the selection of the light intensity to be tested in the first alertness study. The data confirm that narrowband, polychromatic blue solid-state light suppresses melatonin in healthy subjects in a dose-response manner. Further, the data enabled the calculation of a target intensity for the first alertness study.

For the second aim, the melatonin suppression data was presented at the NASA Investigators' Workshop (West et al., 2008) and a first draft of a manuscript on the study has been completed. Revision of the manuscript by all co-authors is continuing. The intent is to submit a final manuscript to a peer-review journal during this coming year.

#### Task Description:

The third and fourth aims are concerned with our first study on the effects of narrowband, polychromatic blue solid-state light on alertness and cognitive performance in healthy male and female subjects. Although the collaborative team completed the design of this study in the prior year, further protocol modifications were necessary, and Jefferson's IRB has approved 4 separate protocol revisions since then. In parallel, we established the polysomnography (PSG) and behavioral testing techniques for this project, and LRP staff completed the necessary training for using these methods. Erin Evans, a Registered PSG Technician at Brigham and Women's Hospital, joined our team as a collaborator to assist with troubleshooting our PSG setup, data analysis, and data interpretation.

Progress on our fifth aim includes subject recruitment and participation in the alertness study. To date, over 170 individuals have applied to participate and have gone through initial steps of screening for the study. From that pool, more than 10 subjects have completed medical, psychological, and ophthalmological examinations, as well as screens for stability of sleep-wake cycles and drugs of abuse. Ten subjects have now completed the three-day inpatient alertness protocol. Preliminary analysis of plasma melatonin, subjective alertness, objective alertness, and neurobehavioral data are now in process. We plan to continue screening volunteers and entering eligible subjects into the protocol in the coming year.

In terms of our sixth and seventh aims, it is important to note that the experimental panel we currently are testing is not flight-worthy. A set of six different study designs has been developed to test the relative efficacy of smaller light emitting surfaces. The LRP staff has met to review these study designs with the intent of selecting a single design to best accomplish this objective. Although the details of the study design are not finalized, preliminary work on an IRB submission has been initiated. Preliminary discussions have addressed how to modify of the 122 x 122 cm exposure panels for the new study. Work on study design, exposure panel reconfiguration, and the associated IRB will continue into the coming year.

The ultimate goal of this project is to develop a lighting countermeasure that enhances alertness and cognitive performance. This year's progress addresses Critical Risk areas 26 and 27 in the Bioastronautics Roadmap (research questions 26f, 26h, 27b, and 27f). These areas concern countermeasures that mitigate performance problems due to sleep loss and circadian disturbances. This work ultimately impacts Critical Risk 44 concerning the "mismatch between crew physical capabilities and task demands" (question 44f).

#### Rationale for HRP Directed Research:

The knowledge we hope to gain from this research, though focused on space flight, also may benefit people on Earth. The circadian disruption experienced by astronauts during space flight can be considered a threat to the success of space missions (Longnecker and Molins, 2005). The resulting physiological and behavioral changes caused by circadian and sleep disruption can lead to diminished alertness, cognitive ability and psychomotor performance (Dijk et al., 2001). Over 45% of all medications taken in space are sleep aids taken as a measure to counteract sleep deficits (Putcha et al., 1999). Although the studies in this project are focused on developing a non-pharmacological lighting countermeasure for space exploration, it is anticipated that there will be benefits to civilians living on Earth. A significant portion of the global population suffers from chronic sleep loss and/or circadian-related disorders. Evidence for disease or illness due to a disruption of circadian homeostasis has mounted significantly in the past several years. In the United States, nearly 22 million Americans do shift work that interferes with a biologically healthy nocturnal sleep cycle (US Bureau of Labor Statistics, 2007). Shift workers have been shown to be more likely to suffer from a wide variety of ailments, including cardiovascular disease, gastrointestinal distress, and cognitive and emotional problems. Furthermore, epidemiological studies of female shift workers have shown that they are more likely to suffer from breast cancer and colon cancer compared to day shift workers. The World Health Organization has identified shift work as a probable risk for cancer (The International Agency for Research on Cancer, 2007). Our laboratory is involved in testing the hypothesis that night time exposure to light suppresses melatonin and contributes to cancer risk (Blask et al., 2005; Stevens et al., 2007). Aside from evidence of a breakdown in physical health, the effects of circadian disruption and sleep loss have long been known to have potentially dangerous behavioral effects. Mental fatigue, diminished alertness, loss of psychomotor coordination and decreased physical performance are all commonly found in individuals with sleep loss, sleep debt, or circadian misalignment. Many people also experience the same effects after air travel across several time zones. The impact of these deficits affects many industries, including transportation, manufacturing, communications, medicine, and homeland security. It has long been a source of concern for the military, as well. In the past, the U.S. Air Force has supported our laboratory to study the acute alerting effects of light (French et al., 1990; Brainard et al., 1996). Our current work for NIH has continued this effort (Lockley et al., 2006).

#### Research Impact/Earth Benefits:

	Existing therapeutic lighting interventions stand to benefit from enhancing our understanding of how different wavelengths of the spectrum affect human circadian and neurobehavioral regulation. A more efficient intervention with increased potency and/or fewer side effects could result. One such disorder currently being treated with bright white light is Seasonal Affective Disorder (SAD), also known as winter depression. It is estimated that as many as 1 in 5 Americans suffer from SAD or its milder version, subsyndromal Seasonal Affective Disorder (sSAD) (Lam and Levitt, 1999). Similar bright white light interventions also are used to treat jetlag. Side effects from exposure to bright white light for these and other therapies include: hypomania, headache, vision problems, nausea, dizziness, and anxiety. Optimizing the light spectrum for specific affective and/or circadian-related disorders could deliver the same medical impact with lower levels of light intensity and, potentially, with fewer side effects. Our group has completed Phase I testing of light therapy with blue solid-state lighting for patients with SAD (Glickman et al., 2006).
Task Progress:	<p>This is the third year of research that is intended to run until 2012. The goal is to study the efficacy of blue or blue enriched white solid-state light for enhancing alertness in men and women as a basis for developing an in-flight lighting countermeasure for enhancing alertness in astronauts as well as NASA ground crew.</p> <p>For this study, we have two identical 122 x 122 cm solid-state blue light sources, installed into identical exposure stations. Each light source consists of an array of 5,776 blue LEDs (peak 475 nm). These units provide a large, uniform light-emitting surface with intensity modulation. The light sources were designed and developed collaboratively with Apollo Health, an NSBRI Industrial Partner. David Sliney, Ph.D., has completed an independent safety analysis of the blue LED light sources based on national (ACGIH) and international (ICNIRP) criteria. After reviewing Dr. Sliney's final report, James Maida of JSC and Charles Bowen, Ph.D., of Lockheed Martin confirmed that the units meet NASA's safety standards and were co-authors with our team on an abstract showing the safety evaluation results (West et al., 2008).</p> <p>The aims of this bench-marking melatonin suppression study were to characterize the biological potency of the prototype light units and to guide the selection of the light intensity to be tested in the first alertness study. Eight healthy men and women participated in the study, completing a total of 84 nighttime melatonin suppression experiments. Data analysis has been completed and, based on the results, a target intensity for the first alertness study was calculated. The data also showed that the blue LED light evokes a dose-response melatonin suppression in healthy subjects. A first draft of a manuscript on these results has been completed. Revisions of the manuscript by all co-authors will continue into year 4 of work.</p> <p>Although the collaborative team completed the design of our first study on the effect of blue solid-state light on alertness and cognitive performance in the prior year, further protocol modifications were implemented, and Jefferson's IRB has approved 4 separate protocol revisions since then. In parallel, we established the polysomnography and behavioral testing techniques for this project and LRP staff completed the necessary training for using these methods. To date, over 170 individuals have applied to participate and have gone through initial elements of screening for the alertness study. From that pool, more than 10 subjects have completed medical, psychological, and ophthalmological examinations, as well as screens for stability of sleep-wake cycles and drugs of abuse. Ten subjects have now completed the three-day inpatient alertness protocol. Preliminary analysis of plasma melatonin, subjective alertness, objective alertness, and neurobehavioral data are now in process. We plan to continue screening volunteers and entering eligible subjects into the protocol in the coming year.</p>
Bibliography Type:	Description: (Last Updated: 10/30/2023)
Abstracts for Journals and Proceedings	Brainard GC, Hanifin JP. "Optimizing lighting for circadian, neuroendocrine, and neurobehavioral regulation during space exploration." 3rd DIN-Expert Panel, Berlin, Germany, June 24, 2009. 3rd DIN-Expert Panel, June 2009. , Jun-2009
Abstracts for Journals and Proceedings	Brainard GC. "Role of light and ocular physiology for human melatonin regulation." Circadian Disruption and Cancer, New York Academy of Sciences, New York City, New York, June 19, 2009. Circadian Disruption and Cancer, Abstract Book, June 2009. , Jun-2009
Articles in Peer-reviewed Journals	Brainard GC, Sliney D, Hanifin JP, Glickman G, Byrne B, Greenson JM, Jasser S, Gerner E, Rollag MD. "Sensitivity of the human circadian system to short-wavelength (420-nm) light." J Biol Rhythms. 2008 Oct;23(5):379-86. <a href="http://dx.doi.org/10.1177/0748730408323089">http://dx.doi.org/10.1177/0748730408323089</a> ; PMID: 18838601 , Oct-2008
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Articles in Peer-reviewed Journals	Brainard GC, Provencio I. "Photoreception for the neurobehavioral effects of light on humans." Light & Engineering. 2008;16(1):5-18. , Oct-2008
Awards	Brainard G. "PI was given the Thomas Jefferson University 2008 Research Performance Award, December 2008." Dec-2008
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Significant Media Coverage	Flam F. "Newspaper article on health risks to astronauts. Discussed sleep risks and role of short-wavelength light in circadian rhythms." Philadelphia Inquirer, Dec 1, 2008., Dec-2008
Significant Media Coverage	Landers SJ. "Discusses the Capitol Hill NSBRI demonstration." American Medical News, April 13, 2009., Apr-2009
Significant Media Coverage	Byrd D, Block J, Patterson L, Salazar J. "Podcast discussing the potential role of blue and blue-enriched light in helping regulate circadian clocks of astronauts." Earth & Sky radio series program 5651, November 2008., Nov-2008