Fiscal Year:	FY 2010	**Task Last Updated:**	FY 09/14/2010
PI Name:	Brainard, George C. Ph.D.		
Project Title:	Blue Light for Enhancing Alertness in Space Missions		
Division Name:	Human Research		
Program/Discipline:	NSBRI		
Program/Discipline--Element/Subdiscipline:	NSBRI--Human Factors and Performance Team		
Joint Agency Name:		**TechPort:**	Yes
Human Research Program Elements:	(1) **BHP**:Behavioral Health & Performance (archival in 2017)		
Human Research Program Risks:	(1) **BMed**:Risk of Adverse Cognitive or Behavioral Conditions and Psychiatric Disorders		
Space Biology Element:	None		
Space Biology Cross-Element Discipline:	None		
Space Biology Special Category:	None		
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City:	Philadelphia	**State:**	PA
Zip Code:	19107-5083	**Congressional District:**	1
Comments:			
Project Type:	Ground	**Solicitation / Funding Source:**	Directed Research
Start Date:	09/01/2006	**End Date:**	08/31/2012
No. of Post Docs:	0	**No. of PhD Degrees:**	1
No. of PhD Candidates:	2	**No. of Master' Degrees:**	0
No. of Master's Candidates:	2	**No. of Bachelor's Degrees:**	0
No. of Bachelor's Candidates:	0	**Monitoring Center:**	NSBRI
Contact Monitor:		**Contact Phone:**	
Contact Email:			
Flight Program:			
Flight Assignment:			
Key Personnel Changes/Previous PI:			
COI Name (Institution):			
Grant/Contract No.:	NCC 9-58-HPF00001		
Performance Goal No.:			
Performance Goal Text:			

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 fourth year of a directed research project. This past year, we have worked on the following seven aims:
1) Submit a peer-review manuscript on the blue solid-state light melatonin suppression bench-marking study.

2) Continue enrolling subjects for the first study on alertness and cognitive performance.

3) Assay samples from the ongoing alertness study for melatonin.

4) Do preliminary analysis of polysomnography, subjective and objective alertness, and neurobehavioral test data from

Task Description:	the ongoing alertness study. 5) Develop a study design on the consequences of reducing the size of the light emitting surface to a more flight-worthy size. 6) Submit a protocol on the new study design for Jefferson IRB review. 7) Related to aims 5 and 6, a) design and acquire new prototype solid-state light sources, or b) modify the current study light sources. During the first three years of this project, we made significant progress in 1) creating two prototype 122 sq cm solid-state blue light (peak wavelength 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. The melatonin study confirmed that narrowband, polychromatic blue solid-state light suppresses melatonin in healthy subjects in a dose-response manner and enabled the calculation of a target intensity for the initial alertness study. In terms of the first aim for the past year, we completed data analysis of the bench-marking blue solid-state light melatonin suppression study and submitted a peer-review manuscript on the results. Subsequently we have received reviews that are generally positive. The co-authors are currently working on a manuscript revision. The second, 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. To date, over 300 individuals inquired about participating and went through initial elements of screening for the first 3-day alertness study. From that pool of interested volunteers, 26 subjects completed all medical, psychological, and ophthalmological examinations as well as screens for stability of sleep-wake cycles and drugs of abuse. Of the 24 subjects that entered study, 22 completed the three-day inpatient alertness protocol. Preliminary analysis of plasma melatonin, subjective alertness, objective alertness, polysomnography, and neurobehavioral data are now in process and will continue well into the next year. Until this data analysis is completed, no further volunteers will be screened or entered into the protocol. Two presentations have been made at international meetings describing the protocol and a partial analysis of the melatonin data set (Hanifin et al., 2010a, 2010b). It is important to note that the experimental 122 sq cm LED light panels we have used in the first two studies, are too large to be flight-worthy. The fifth, sixth, and seventh aims are concerned with needing to test the consequences of reducing the size of the light-emitting surface to a more flight-worthy size. This study will use the acute melatonin suppression response as its dependent variable for quantifying how different size light-emitting surfaces influence this neuroendocrine response. A set of six different study designs were initially developed to test the relative efficacy of smaller light-emitting surfaces. The LRP staff met to review those study designs with the intent of selecting a single design to best accomplish this objective. Progress has been delayed, however, in finalizing this protocol due to unexpected, emergent work on the Solid-State Light Assembly (SSLA) that is being proposed for retrofitting the current fluorescent General Light Assembly (GLA) onboard the International Space Station. Given that the light-emitting surface dimensions of SSLA are now relatively certain, we are re-formulating our approach to include the SSLA light-emitting surface dimension in our overall study design. Instead of developing a new IRB application, we have been guided to amend an existing IRB protocol for supporting this study. This month we submitted that designated IRB for renewal and plan to develop the necessary amendments once the renewal application has been accepted. We have also determined that we will not need to acquire new solid-state light sources for this project. One or more of our current solid-state panels can be modified for the purpose of this study. The ultimate goal is to develop a lighting countermeasure that enhances alertness and cognitive performance in ground crew members and astronauts. This year's results will impact the NASA Human Integration Design Handbook and the Space Flight Human Systems Standard, NASA-STD-3001, that provide guidance for supporting crew health, habitability, environment, and human factors in human space flight. Our progress addresses NASA Human Research Program Integrated Risk Plan (2009) risk areas 13, 33, and 76, and risk areas 26, 27, and 44 in the Bioastronautics Roadmap (2005).
Rationale for HRP Directed Research:	
Research Impact/Earth Benefits:	The knowledge gained from this research, though focused on spaceflight, 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; NASA HRP Integrated Risk Plan, 2009). 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 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). 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:	This is the fourth 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. For this study, we have two identical 122 sq 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 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 co-authored with our team an abstract showing the safety evaluation results (West et al., 2008). An initial melatonin suppression study was conducted to characterize the biological potency of the prototype light units and to guide the selection of the light intensity for 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 alertness study was calculated. The data showed that the blue LED light evokes a dose-response melatonin suppression in healthy subjects. The data also indicate that blue LED light may be stronger than 4,000 K white fluorescent light for suppressing melatonin. We completed a manuscript on these results and submitted it for peer review. Subsequently we have received reviews that are generally positive. The co-authors are currently working on a manuscript revision. To date, over 300 individuals contacted our program and went through initial elements of screening for the first 3-day alertness study. From that pool of interested volunteers, 26 subjects completed all medical, psychological, and ophthalmological examinations as well as screens for stability of sleep-wake cycles and drugs of abuse. Of the 24 subjects that entered study, 22 completed the three-day inpatient alertness protocol. Preliminary analysis of plasma melatonin, subjective alertness, objective alertness, polysomnography, and neurobehavioral data are now in process and will continue well into the next year. Until this data analysis is completed, no further volunteers will be screened or entered into the protocol. Two presentations have been made at international meetings describing the protocol and a partial analysis of the melatonin data set (Hanifin et al., 2010a, 2010b).
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