Fiscal Year:	FY 2011	**Task Last Updated:**	FY 10/12/2011
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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Zip Code:	19107-5083	**Congressional District:**	1
Comments:			
Project Type:	GROUND	**Solicitation / Funding Source:**	Directed Research
Start Date:	09/01/2006	**End Date:**	09/30/2012
No. of Post Docs:	0	**No. of PhD Degrees:**	0
No. of PhD Candidates:	2	**No. of Master' Degrees:**	1
No. of Master's Candidates:	1	**No. of Bachelor's Degrees:**	0
No. of Bachelor's Candidates:	1	**Monitoring Center:**	NSBRI
Contact Monitor:		**Contact Phone:**	
Contact Email:			
Flight Program:			
Flight Assignment:	NOTE: End date changed to 9/30/2012 per NSBRI (Ed., 1/27/2012)		
Key Personnel Changes/Previous PI:			
COI Name (Institution):			
Grant/Contract No.:	NCC 9-58-HPF00001		
Performance Goal No.:			
Performance Goal Text:			

Task Description:

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 and NASA ground crew.
This is the fifth year of a directed research project. This past year, we have worked on the following seven aims:

1) Publish a peer-review manuscript on the blue solid-state light melatonin suppression bench-marking study.

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

3) Complete assay of alertness study samples for melatonin.

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

5) Develop a pilot study design on the consequences of reducing the size of the light-emitting surface to a more flight-worthy size and submit a study protocol for Jefferson IRB review.

6) Related to aim 5, design the necessary solid-state light source exposure systems for the pilot study.

7) Related to aim 5, screen, recruit and enter subjects into the pilot study.

During the first four years of this project, we made significant progress in 1) creating two prototype 122 sq cm solid-state blue light (peak wavelength 469 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 published a peer reviewed manuscript on the blue solid-state light melatonin suppression bench-marking study in the Journal of Applied Physiology (West, 2011).

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. Over 300 individuals volunteered to be screened for the first 3-day alertness study with the blue LED light units. From that pool of 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. Analysis of plasma melatonin, subjective alertness, objective alertness, and neurobehavioral data will be finalized this year. Analysis of polysomnography data is in process. Two presentations have been made at international meetings describing the protocol the preliminary data (Hanifin et al., 2010a, 2010b; Ed. note: see FY2010 Task Book Bibliography). Preliminary testing of visual performance and color discrimination has been done with selected intensities of the narrow bandwidth blue LEDs with 8 healthy subjects.

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 testing the consequences of reducing the size of the light-emitting surface to a more flight-worthy size. The initial pilot study uses the acute melatonin suppression response as its dependent variable for quantifying how different size light-emitting surfaces influence this neuroendocrine response. A pilot study protocol has been designed and approved by the Jefferson IRB. Two new exposure systems have been designed, constructed, and equipped with blue-enriched broad-bandwidth LEDS (6,500 K) for this study. Importantly, this blue-enriched LED light source is similar to one of the LED sources being specified for the Solid-State Light Assembly (SSLA) that is being proposed for retrofitting the current fluorescent General Light Assembly (GLA) onboard the International Space Station. Subject recruitment, screening and enrollment has been initiated. To date, subjects have completed more than 10 study nights for this ongoing 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 (2010) risk area 22 (Sleep 5, 9, and 10) Critical Risk areas. These areas concern countermeasures that will optimally mitigate performance problems associated with sleep loss and circadian disturbances and the "mismatch between crew physical capabilities and task demands."

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, 2010). 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 fifth year of a directed research project 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 and NASA ground crew. For this project, we have four 122 sq cm solid-state light sources: two with narrow-bandwidth (peak 469 nm) LEDs and two with broad-bandwidth blue-enriched LEDS that emit white-appearing light with a CCT of 6,500 K. These units provide a large, uniform light-emitting surface with intensity modulation. An independent safety analysis of both LED light sources based on national (ACGIH) and international (ICNIRP) criteria has been completed. James Maida of JSC and Charles Bowen, Ph.D., of Lockheed Martin (retired) have confirmed that the blue LED units meet NASA's safety standards (West et al., 2008). An initial melatonin suppression study was conducted with the narrow bandwidth blue LED units to characterize their biological potency and to guide the selection of the light intensity for the first alertness study. Healthy subjects (N>=8) completed a total of 84 nighttime melatonin suppression experiments. Data analysis was completed permitting the calculation of a target intensity for the alertness study. The data showed that the blue LED light evokes a dose-response melatonin suppression. The data also indicate that blue LED light is stronger than 4,000 K white fluorescent light for suppressing melatonin. A peer-reviewed manuscript has been published on these results (West, 2011). Over 300 individuals volunteered to be screened for the first 3-day alertness study with the blue LED light units. From that pool of 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. Analysis of plasma melatonin, subjective alertness, objective alertness, and neurobehavioral data will be finalized this year. Analysis of polysomnography data is in process. 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; Ed. note: see FY2010 Task Book Bibliography). Preliminary testing of visual performance and color discrimination has been done with selected intensities of the narrow bandwidth blue LEDs with 8 healthy subjects. A pilot study protocol on the consequences of reducing the size of the light-emitting surface to a more flight-worthy size has been designed and approved by the Jefferson IRB. Two exposure systems with broad-bandwidth blue-enriched LEDS (6,500 K) are being used for this study. Subject recruitment, screening and enrollment has been initiated. To date, subjects have completed more than 10 study nights for this ongoing study.
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