Fiscal Year:	FY 2008	**Task Last Updated:**	FY 10/08/2008
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:	1	**No. of PhD Degrees:**	8
No. of PhD Candidates:	1	**No. of Master' Degrees:**	4
No. of Master's Candidates:	1	**No. of Bachelor's Degrees:**	9
No. of Bachelor's Candidates:	1	**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 second year of a new, directed research project. This past year, we have worked on the following seven aims:

1) Have independent safety analysis completed on the new solid-state lighting prototype and involve lighting engineers from Johnson Space Center (JSC) and Lockheed Martin in reviewing and approving the safety analysis and proposing any further assessments to ensure that the prototype meets NASA's standards and applications.

2) Acquire a second solid state blue light exposure system from Apollo Light Systems, Inc., an NSBRI industrial partner. Install and characterize the second system prior to its implementation in the melatonin bench-marking studies.

Task Description:	3) Complete human subject recruitment and nighttime experiments for the melatonin suppression bench-marking study with blue solid-state light. Complete assay of melatonin samples and begin data analysis for this study. 4) Complete the design of the inaugural study on the effect of blue solid-state light on alertness and cognitive performance in healthy subjects. 5) Write and secure Institutional Review Board (IRB) approval of the first alertness study design. 6) Set up and calibrate polysomnographic equipment. Train staff in use of polysomnographic equipment and performance testing batteries for assessing alertness and cognitive performance in the study volunteers. 7) Recruit and screen subjects. Begin running the first experiment on alertness and cognitive performance. As a basis for accomplishing the first aim, David Sliney, Ph.D. of Aberdeen Proving Ground provided a draft independent safety analysis based on criteria from the American College of Government and Industrial Hygiene (ACGIH) and the International Commission on Non-Ionizing Radiation Protection (ICNIRP) during the first year of the project. The report was finalized during the current year of work. It confirmed that the blue solid-state prototype operates "at all wavelengths and emission levels that are far below limits that are recognized as maximal safe exposure values." Once finalized, the report was distributed to James Maida at JSC and Charles Bowen, Ph.D. of Lockheed Martin for review. In turn, they confirmed that the prototype meets NASA's standards and applications. No further work is needed on this aim. Towards the second aim, Apollo Light Systems, Inc. fabricated and delivered a second solid state blue light exposure unit to Jefferson's Light Research Program. This light source was installed into an exposure system and characterized for spectral output and intensity control. It has been utilized in the melatonin bench-marking studies. No further work is needed on this aim. For the third aim, human subject recruitment has been completed for the melatonin suppression bench-marking study with blue solid-state light. A total of 84 nighttime experiments with these subjects have been completed. Assay of plasma melatonin samples have been completed and data analysis has begun for this study. Preliminary data assessment indicates that two subjects may have to repeat an exposure night due to technical difficulties. Although a majority of this aim is completed, work will continue into year 3. The fourth and fifth aims have now been accomplished, and the design is complete for our first study on the effect of blue solid-state light on alertness and cognitive performance in healthy subjects. Jefferson's IRB formally approved the protocol on 4/17/08. Although protocol amendments may be submitted in the coming year, we are now enabled to start subject recruitment. We are continuing work on the sixth aim. A sleep medicine physician is consulting with us on implementing polysomnography in this project, and we have hired two part time polysomnography technicians. The first polysomnography training session for the Light Research program staff was conducted on 7/9/08. Determination and purchase of the necessary polysomnography analysis software is underway. Testing of alertness and cognitive performance is being done in a separate phase-shift study, and we are currently determining if these techniques will be suitable in this project on acute alertness. We will begin work on the seventh aim when we approach completion of the sixth aim. Subject recruitment involves a lengthy interview process, followed by a tour of the live-in laboratory where volunteers will stay for three days. Once volunteers commit to participating, they must avoid prescription or non-prescription drugs, over-the-counter drugs, recreational/street drugs, and other foreign substances. Urine toxicology screens will check compliance for these criteria. Subjects will be required to maintain a scheduled sleep-wake and light-dark cycle prior to the study, complete a daily sleep-wake log and Epsworth Sleepiness Scale, and phone into a voice mailbox to record the bed time and wake up time each day. For at least one week prior to entry into the laboratory study, they will wear a wrist activity monitor to ensure compliance with the screening criteria for maintaining a consistent sleep-wake schedule. In addition, they will be screened medically by a physician and psychologically by a clinical psychologist. Both before and after the study, subjects will have eye screens by a neuro-ophthalmologist. Failure to comply with any of these requirements will result in exclusion from the study. Work on this aim may begin as soon as August of 2008.
Rationale for HRP Directed Research:	
Research Impact/Earth Benefits:	The knowledge we hope to gain from this research, though focused on spaceflight, will also benefit people here on Earth. The sleep deficits 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 sleep and circadian disruption can lead to diminished alertness, cognitive ability and psychomotor performance (Dijk et al., 2001). As a measure to counteract sleep disruptions, over 45% of all medications taken in space are sleep aids (Putcha et al., 1999). Although the studies being considered 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 occurring 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 statistically 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. The impact of these dangers affects many industries, including transportation, manufacturing, communications, and medicine. It has long been a source of concern for the military, as well. Many people also

	experience the same effects after air travel across several time zones. 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 interventions using light 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 are also 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 fewer side effects. Our group has completed Phase I testing of light therapy with blue solid-state lighting for SAD patients (Glickman et al., 2006).
Task Progress:	This is the second year of a directed research project that is intended to run until 2012. The goal is to study the efficacy of blue solid-state light for enhancing alertness 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 year we developed a second blue light exposure system that greatly enhances our ability to run studies more efficiently. Our two solid-state blue light sources are identical in construction, installed into identical exposure stations, and equivalent in performance. Each light source consists of an array of 5,776 blue LEDs (peak 475 nm). These LED prototypes provide a large, uniform light emitting surface with intensity modulation. The donation of the second light source illustrates the continuing commitment of Apollo Light Systems, Inc. to work with our laboratory as an NSBRI Industrial Partner. The safety evaluation of the prototype blue solid state light sources has been completed. David Sliney, Ph.D., provided an independent safety analysis based on national (ACGIH) and international (ICNIRP) criteria. His final report confirms that the prototype light units operate “at all wavelengths and emission levels that are far below limits that are recognized as maximal safe exposure values.” James Maida at JSC and Charles Bowen, Ph.D., of Lockheed Martin reviewed this report. They confirmed that the units meet NASA’s safety standards and were co-authors with our team on an abstract showing the safety evaluation results at NASA’s 2008 HRP Investigators Workshop. The aims of the bench-marking melatonin suppression 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. Eight healthy men and women participated in this within-subjects study, completing a total of 84 nighttime melatonin suppression experiments. Assays of plasma melatonin samples have been completed and data analysis has begun. Although further analysis is required, the preliminary data show that the blue LED light evokes a dose-response melatonin suppression in healthy subjects ($p<0.001$). Although a majority of this aim is completed, work on it will continue into year 3. This year, our collaborative team completed the design of our first study on the effect of blue solid-state light on alertness and cognitive performance. Jefferson’s IRB has formally approved the protocol. In parallel, we are establishing polysomnography and behavioral testing techniques for this project. The LRP staff had their first polysomnography training session on 7/9/08. Once the polysomnography and behavioral testing techniques are operational, we plan to begin subject recruitment for the first alertness study, possibly before the start of year 3 funding.
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