Fiscal Year:	FY 2007	**Task Last Updated:**	FY 06/11/2008
PI Name:	Brainard, George C. Ph.D.		
Project Title:	Blue Light for Enhancing Alertness in Space Missions		
Division Name:	Human Research		
Program/Discipline:	NSBRI Teams		
Program/Discipline--Element/Subdiscipline:	NSBRI Teams--Human Performance Factors, Sleep, and Chronobiology 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		
PI Email:	george.brainard@jefferson.edu	**Fax:**	FY 215-923-7588
PI Organization Type:	UNIVERSITY	**Phone:**	215-955-7644
Organization Name:	Thomas Jefferson University		
PI Address 1:	Light Research Program		
PI Address 2:	1025 Walnut St., Room 507		
PI Web Page:			
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:**	7
No. of PhD Candidates:	1	**No. of Master' Degrees:**	2
No. of Master's Candidates:	1	**No. of Bachelor's Degrees:**	4
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 a new, directed research project. To initiate the work, we proposed the following seven aims:

1) Assemble a team of investigators who will create a set of study designs to be run from 2006 to 2012.

2) Establish either collaborative, consultant or subcontract agreements for elements of the work which are best done outside of Thomas Jefferson University (TJU).

3) Write and secure Institutional Review Board (IRB) approval of the first study design.

Task Description:	4) Design and fabricate the initial solid-state light sources for testing. These sources will serve as the independent variables in the initial study design. 5) Have an independent safety analysis completed on the solid-state lighting prototypes. 6) Purchase and calibrate equipment for assessing alertness and cognitive performance in the study volunteers. 7) Develop a multiyear plan for the development and testing of specific lighting technologies that can be installed in the CEV and other space exploration habitats for acutely enhancing astronaut and ground crew alertness. Towards accomplishing the first two aims, written correspondence, phone calls and direct meetings were used to establish the team of investigators. Over the first year, a total of eight meetings were held: five meetings at TJU in Philadelphia, one in League City during the NASA Human Research Program Investigators Workshop, one at the External Advisory Committee meeting in Houston, and one at Johnson Space Center (JSC). As a result of these meetings, key collaborators who have formally agreed to participate on this project. These include James Maida of JSC's Habitability and Human Factors Branch; Charles Bowen, Ph.D. of Lockheed Martin's Human Factors Design team; David Dinges, Ph.D. and Namni Goel, Ph.D. from the University of Pennsylvania; Stephen Lockley, Ph.D. of Brigham and Womens Hospital and Harvard Medical School; David Sliney, Ph.D. of the U.S. Army Laser/Optical Radiation Program at Aberdeen Proving Ground; and Mark Rollag, Ph.D. of the University of Virginia. These collaborators will work with scientists and staff of TJU's Light Research Program (LRP) towards accomplishing the goals of this project. The collaborators will work on selected aspects of this project as per their expertise. Progress towards the third aim involves the development of two experiments. Subject recruitment for the first experiment will be initiated during this month (the end of the first funding year) and the study will be completed in the second funding year. The second experiment will be initiated and run during the second year. The first experiment is a bench-marking study to characterize the biological potency of the prototype solid-state light source that is described below. A within-subjects, acute light-induced melatonin suppression study will be done with eight healthy men and women. This study will have two important outcomes. First, it will help characterize the biological efficacy of the prototype solid-state light source relative to monochromatic and polychromatic light sources previously studied in our lab. In addition, it will guide the selection of the light intensity that will be tested in the second study, which will focus on alertness. The IRB for the first study has been approved by TJU. The protocol for the second experiment, a two-day study on the alerting effects of blue light, is still being refined. Once the experimental design is completed, a separate IRB covering that work will be written and submitted for review. Progress towards the fourth aim involves our collaboration with Apollo Light Systems, Inc., an industrial partner of NSBRI. Apollo has donated engineering time and materials to develop a large panel of narrowband blue LEDs. This light source will be the independent variable in the first two experiments discussed above. Working closely with an engineer from Apollo, we have modified the original prototype so it can provide a broad range of light intensities with no change to spectral output. Jefferson's LRP staff has thoroughly characterized the prototype radiometry and photometry. This light unit is now completely serviceable for experimental use. Concerning our fifth aim, David Sliney, Ph.D. of Aberdeen Proving Ground has made a series of radiometric measurements of the prototype and has provided an 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). His draft report confirms 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 will be distributed to James Maida at JSC and Charles Bowen, Ph.D. of Lockheed Martin for review. For our sixth aim, we have purchased and received polysomnography and psychomotor vigilance task equipment. Setup, testing, and calibration of this equipment has been initiated and will be completed prior to the start of our second experiment. This equipment will not be needed for the first bench-marking experiment. Finally, for the seventh aim, extensive discussions have been held between TJU's LRP and the extramural collaborators concerning a multiyear plan for the development and testing of specific lighting technologies that can be installed in the CEV and other space exploration habitats for acutely enhancing astronaut and ground crew alertness. The specific experiments, experiment sequence, and technology development will be determined once data is available from the first two studies.
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 also will be significant 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, 20 million Americans do shift work which interferes with a biologically healthy nocturnal sleep cycle (U.S. Congress OTA, 1991). This group has been shown to be more likely to suffer from a wide variety of ailments, including cardiovascular disease, gastrointestinal distress, cognitive and emotional problems. Furthermore, recent epidemiological studies of female night-shift nurses have shown that they are statistically more likely to suffer from breast cancer and colon cancer compared to day shift workers. Our laboratory is involved in testing the hypothesis that exposure to light at night is a risk factor for cancer (Blask, et al., 2005). 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. Additionally, many people experience the same effects due to air travel across several time zones. The U.S. Air Force has supported our laboratory

	in the past to study the acute alerting effects of light (French, et al., 1990; Brainard, et al., 1996). A number of 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 for treating jetlag. Side effects from exposure to bright white light for this 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 initiated Phase I testing of light therapy with blue solid-state lighting for SAD patients (Glickman, et al., 2006).
Task Progress:	During this first project year, the team of investigators was established. They include James Maida of JSC's Habitability and Human Factors Branch; Charles Bowen, Ph.D. of Lockheed Martin's Human Factors Design team; David Sliney, Ph.D. of Aberdeen Proving Ground; David Dinges, Ph.D. and Namni Goel, Ph.D. of the University of Pennsylvania; Stephen Lockley, Ph.D. of Brigham and Womens Hospital; and Mark Rollag, Ph.D. of the University of Virginia. These collaborators will work with the scientists of our laboratory to fulfill the project goals. For this project, we are collaborating with Apollo Light Systems, Inc., an NSBRI industrial partner, to develop a large panel of blue LEDs to serve as the independent variable in our first two experiments. Working closely with Apollo, we have modified the original prototype so it can be adjusted to provide a broad range of light intensities with no change in spectral output. Our laboratory has thoroughly characterized the prototype's radiometry and photometry and it is now ready for use in our first two experiments. Dr. David Sliney, a key collaborator on this project, has made a series of radiometric measurements of the prototype and has provided an 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). His draft report confirms 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 will be distributed to James Maida at JSC and Charles Bowen, Ph.D. of Lockheed Martin for review. This progress enables the initiation of the first experiment, a bench-marking study to characterize the biological potency of the prototype light. The study employs a within-subjects light-induced melatonin suppression protocol with healthy men and women. The study is approved by Jefferson's IRB, and subject recruitment has been initiated. This study will be completed during the coming year and will have two important outcomes: it will help characterize the biological efficacy of the prototype light source relative to other light sources previously studied in our lab, and it will guide light intensity selection for the second experiment on the effect of blue light on alertness. Our laboratory has acquired polysomnography and psychomotor vigilance task equipment for studying the alerting characteristics of this prototype light source. Although not needed for the first bench-marking experiment, setup, testing, and calibration of this equipment has been initiated and will be completed prior to the start of the alertness experiment. During the coming year, the alertness protocol design will be completed and a separate IRB covering that work will be submitted. Once IRB approval is granted, the study will be initiated.
Bibliography Type:	Description: (Last Updated: 10/30/2023)
Abstracts for Journals and Proceedings	Brainard GC, Hanifin JP, Rollag MD. "Photoreception for circadian, neuroendocrine and neurobehavioral regulation." 8th International Congress of Physiological Anthropology, Kamakura, Japan, October 9-14, 2006. 8th International Congress of Physiological Anthropology, October 2006. , Oct-2006
Abstracts for Journals and Proceedings	Brainard GC. "Photoreception for the neurobehavioral effects of light in humans." 2nd CIE Expert Symposium on Light and Health, Ottawa, Canada, September 7-8, 2006. 2nd CIE Expert Symposium on Light and Health, September 2006. , Sep-2006
Abstracts for Journals and Proceedings	Gooley JJ, Rajaratnam SM, Brainard GC, Kronauer RE, Czeisler CA, Lockley SW. "Spectral sensitivity of the human circadian timing system." 72nd Cold Spring Harbor Laboratory Symposium: Clocks & Rhythms; Cold Spring Harbor, NY, May 30-June 4, 2007. 72nd Cold Spring Harbor Laboratory Symposium: Clocks & Rhythms, May 2007. , May-2007
Articles in Peer-reviewed Journals	Hanifin JP, Brainard GC. "Photoreception for circadian, neuroendocrine, and neurobehavioral regulation." J Physiol Anthropol. 2007 Mar; 26(2):87-94. PMID: 17435349 , Mar-2007
Awards	Brainard GC. "Invited Keynote Speaker at the Light and Wellbeing Symposium, London, United Kingdom, September 27, 2006." Sep-2006
Awards	Brainard GC. "Invited Keynote Speaker at the 2nd International Commission on Illumination Expert Symposium on Light and Health, Ottawa, Canada September 7, 2006." Sep-2006
Awards	Brainard GC. "Invited to teach a master's class at Lightfair International, New York, New York, May 9, 2007." May-2007
Papers from Meeting Proceedings	Brainard GC, Provencio I. "Photoreception for the neurobehavioral effects of light in humans." 2nd CIE Expert Symposium for Light and Health, Ottawa, Ontario, Canada, September 6-7, 2006. Proceedings of the 2nd CIE Expert Symposium, 2006, p. 6-21. , Sep-2006
Significant Media Coverage	Kreykenbohm S, Gronbach R. "Interview regarding the influence of light on human physiology and the future of research in the area. Article specifically describes NASA and NSBRI research." Light Live! 2007 Jan;8(1):4-9., Jan-2007

Significant Media Coverage	Strong C. "Dr. Brainard provided information about NASA and NSBRI. Although the opening paragraph discusses astronaut risks, no more was included in the final print of the article." Neuropsychiatry Reviews. 2006 Sep;7(9):page 1,18-19., Sep-2006