Fiscal Year:	FY 2022	**Task Last Updated:**	FY 11/12/2021
PI Name:	Brainard, George C. Ph.D.		
Project Title:	Testing Solid State Lighting Countermeasures to Improve Circadian Adaptation, Sleep, and Performance During High Fidelity Analog and Flight Studies for the International Space Station		
Division Name:	Human Research		
Program/Discipline:			
Program/Discipline--Element/Subdiscipline:	HUMAN RESEARCH--Behavior and performance		
Joint Agency Name:		**TechPort:**	Yes
Human Research Program Elements:	(1) **HFBP**:Human Factors & Behavioral Performance (IRP Rev H)		
Human Research Program Risks:	(1) **BMed**:Risk of Adverse Cognitive or Behavioral Conditions and Psychiatric Disorders (2) **Sleep**:Risk of Performance Decrements and Adverse Health Outcomes Resulting from Sleep Loss, Circadian Desynchronization, and Work Overload		
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:	FLIGHT	**Solicitation / Funding Source:**	2013-14 HERO NNJ13ZSA002N-BMED Behavioral Health & Performance
Start Date:	12/01/2014	**End Date:**	08/31/2022
No. of Post Docs:	0	**No. of PhD Degrees:**	
No. of PhD Candidates:	3	**No. of Master' Degrees:**	
No. of Master's Candidates:	1	**No. of Bachelor's Degrees:**	
No. of Bachelor's Candidates:	0	**Monitoring Center:**	NASA JSC
Contact Monitor:	Whitmire, Alexandra	**Contact Phone:**	
Contact Email:	alexandra.m.whitmire@nasa.gov		
Flight Program:	ISS		
Flight Assignment:	Flight Definition NOTE: End date changed to 8/31/2022 per NSSC information (Ed., 8/31/21) NOTE: End date changed to 8/31/2021 per NSSC information (Ed., 2/3/21) NOTE: End date changed to 12/31/2020 per D. Risin/HRP/NSSC information (Ed., 09/14/2020) NOTE: End date changed to 09/30/2020 per NSSC information (Ed., 04/27/2020) NOTE: End date changed to 03/31/2020 per NSSC information (Ed., 9/3/19) NOTE: End date changed to 11/30/2019 per NSSC information (Ed., 10/11/18) NOTE: End date changed to 11/30/2018 per NSSC information (Ed., 12/13/17) NOTE: Element change to Human Factors & Behavioral Performance; previously Behavioral Health & Performance (Ed., 1/17/17)		

Key Personnel Changes/Previous PI:	December 2019 - Smith Johnston, MD, retired from NASA but has stayed active on this project.
COI Name (Institution):	Barger, Laura Ph.D. (Brigham and Women's Hospital/Harvard Med Ctr) Clark, Toni B.S. (NASA Johnson Space Center) Czeisler, Charles M.D., Ph.D. (Brigham and Women's Hospital/Harvard Medical Center) Johnston, Smith M.D. (NASA Johnson Space Center (Retired 12/19, but still involved)) Moomaw, Ronald O.D. (NASA Johnson Space Center) Lockley, Steven Ph.D. (Co-PI: Brigham and Women's Hospital) Hanifin, John Ph.D. (Thomas Jefferson University) Rahman, Shadab Ph.D. (Brigham and Women's Hospital) St Hilaire, Melissa Ph.D. (Brigham and Women's Hospital)
Grant/Contract No.:	NNX15AC14G
Performance Goal No.:	
Performance Goal Text:	
Task Description:	This research addresses the NASA Research Announcement (NRA) NNJ13ZSA002N-BMED: Behavioral Health and Human Performance: "Evaluation of the Neurobehavioral Effects of a Dynamic Lighting System on the ISS." This NRA solicited both "Ground Based and Flight-Definition" research with the specific instructions that the "ground study serves as a precursor to the flight study, therefore the ground study should take place in an analog with high fidelity to the ISS. The SSLAs should be studied in a high fidelity ground analog environment, then implemented on ISS to evaluate individual crewmember outcomes related to circadian physiology, sleep, behavioral health and performance using sensitive and validated measures that are feasible in the spaceflight environment." Currently, the International Space Station (ISS) uses General Luminaire Assemblies (GLAs) that house fluorescent lamps for illuminating the astronauts' working and living environments. NASA has determined that, beginning in 2016, the GLAs would be replaced with Solid-State Light Assemblies (SSLAs) containing Light Emitting Diodes (LEDs). Engineers at Kennedy Space Center developed a prototype Solid-State Lighting Assembly (SSLA) that was successfully installed onboard the ISS during ISS Expedition 18. The Principal Investigator and Co-Principal Investigator of the intended research worked with engineers, scientists, and managers from Johnson Space Center (JSC) to revise the SSLA specifications so that the new lighting units would have dual capacity to: 1) provide illumination for crew members' working and living quarters, and 2) serve as a lighting countermeasure for crewmembers' circadian and sleep disruption. NASA ordered and received for a set of SSLAs intended to have this dual capacity. This research is comprised of a multidisciplinary collaboration between Thomas Jefferson University, Brigham and Women's Hospital, and JSC to complete a ground-based study in a high fidelity analog of the crew sleeping quarters and daily living environment of the ISS. Specifically, standardized psychometric, physiological, and neurobehavioral measures are testing the efficacy of light from the SSLAs to improve vision, circadian regulation, sleep, and performance in healthy astronaut-aged subjects. In addition, the initial SSLA was installed on ISS in 2016. Since then, a total of 51 SSLAs have been installed on ISS, bringing the total retrofit to 60% replacement of GLAs on the US portion of ISS. Since the onset of the SSLA retrofit, the investigators have started the inflight ISS study to assess the acceptability, use, and impact of deployment of a dynamic lighting schedule aboard the ISS during operational flight missions on astronaut vision, sleep, alertness, circadian rhythms, and general well-being. Sleep, performance, and circadian rhythm data will be compared to those collected by their team and others during previous flight missions aboard ISS, in addition to surveillance of medical and psychological health in collaboration with mission flight surgeons. This project will generate quantitative data and knowledge for the benefit of crew health, habitability, environment, and human factors in the design of future human spaceflight vehicles and habitats. The project also will provide guidance for flight surgeons, flight psychologists, and astronauts to help optimize sleep and circadian regulation during space exploration missions. This research addresses NASA's Program Requirements Document (PRD) Risk: "Risk of Performance Errors due to Fatigue Resulting from Sleep Loss, Circadian Desynchronization, Extended Wakefulness and Work Overload" and Integrated Research Plan (IRP) Gap Sleep5: "We need to identify environmental specifications and operational regimens for using light to prevent and mitigate health and performance decrements due to sleep, circadian, and neurobehavioral disruption, for flight, surface, and ground crews, during all phases of spaceflight operations." The results of this research also specifically address other high priority risks of the Human Factors and Behavioral Performance Element, including the Risk of Adverse Cognitive or Behavioral Conditions and Psychiatric Disorders, and the Risk of an Incompatible Habitat Design. Appropriately designed lighting systems will serve as a countermeasure to mitigate such risks in future Exploration missions. Importantly, this work will lead to advances in new lighting systems for civilian applications in work places and homes. [Ed. note November 2021: Human Research Program risks and gaps have since been revised per more recent IRPs; see above noted Risks and Gaps and the Human Research Roadmap: https://]
Rationale for HRP Directed Research:	
	The sleep deficits experienced by astronauts during spaceflight along with risk of incompatible habitat design can be considered threats to the success of space missions (NASA Human Research Program Integrated Risk Plan, 2020). 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., Amer. J. Physiol., 2001; Human Health and Performance Risks of Space Exploration Missions. McPhee and Charles, eds., 2010). As a measure to counteract sleep disruptions, crewmembers report using sleep promoting drugs: 71% on space shuttle flights and 75% during ISS expeditions (Barger et al., Lancet Neurology, 2014; Flynn-Evans et al., 2016). A significant portion of the global population suffers from chronic sleep loss and/or circadian-related disorders. Evidence for disease 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). It has been shown that shift workers are more likely to suffer from a wide variety of ailments, including cardiovascular disease, metabolic disorders, gastrointestinal distress, and cognitive and emotional problems. Development of an in-flight lighting countermeasure that helps resolve circadian and sleep disruption in astronauts is

Research Impact/Earth Benefits:	likely to help optimize the use of light therapy for patient populations with affective, circadian and sleep disorders. References Dijk DJ, Neri DF, Wyatt JK, Ronda JM, Riel E, A. R-D, Hughes RJ, Elliott AR, Prisk GK, West JB and Czeisler CA (2001) Sleep, performance, circadian rhythms, and light-dark cycles during two space shuttle flights. Am J Physiol 281:R1647-R1664. McPhee J and Charles J, eds. 2010. Human Health and Performance Risks of Space Exploration Missions: Evidence Reviewed by the NASA Human Research Program. NASA SP-2009-3405 edition. Barger LK, Flynn-Evans EE, Kubey A, Walsh L, Ronda JM, Wang W, Wright KP and Czeisler CA (2014) Prevalence of sleep deficiency and use of hypnotic drugs in astronauts before, during, and after spaceflight: an observational study. Lancet Neurology 13:904-912. Flynn-Evans EE, Barger LK, Kubey AA, Sullivan JP and Czeisler CA (2016) Circadian misalignment affects sleep and medication use before and during spaceflight. npj Microgravity 2:15019; doi:15010.11038/npjmgrav.12015.15019.
Task Progress:	Circadian disruption and sleep deficiency are inherent to spaceflight including long-duration missions on the ISS. Light exposure can both reset the circadian pacemaker and provide an acute stimulant response and is therefore a powerful potential non-invasive, passive, and safe sleepiness countermeasure for use during space missions. Several decades of NASA-funded research have culminated in installation of a tuneable multi-LED (light emitting diode) Solid State Lighting Assemblies (SSLA) to replace the ageing fluorescent General Luminaire Assemblies (GLA) aboard ISS. One of the main reasons for development and installation of the SSLAs was an ability to change the spectrum and irradiance of white light to modulate the circadian phase resetting and acute stimulant effects of light, while maintaining good vision. In the current study, we have completed the initial assessments of the stability and utility of this new lighting system and begun to measure its physiological impact on circadian phase, sleep, and performance. There were no significant differences in aMT6s acrophases between the current and historical crewmembers during the in-flight nominal schedule but there was a trend for a significantly later phase in the historical versus the current group by nearly 4 hours. Consequently, as expected, sleep duration was higher and reaction time was quicker under the normal versus the shifted schedule. When correlated with the proportion of SSLA units installed, the increase in sleep duration and reduction in waketime after sleep on set (WASO) correlated with a higher number of SSLA units. The asMT6s acrophase time also approached a more normal phase and reduced in variability and reaction time, and attentional failures were less apparent. While preliminary, these results are encouraging with evidence for greater normalization of circadian phase, longer sleep, and quicker reaction times under the new lighting that appear to get better as the proportion of SSLA units installed increases. Further work remains, however, as none of the crewmembers reported here experienced the ISS environment with more than 75% of the SSLA installation complete (and most had much less exposure) and therefore the benefits of a completely retrofitted environment have not been studied. Moreover, the amount by which work schedules were shifted in the current crewmembers was modest compared to historical schedules and therefore the efficacy of the lighting to alleviate circadian misalignment and sleep loss following more challenging schedule changes is unknown.
Bibliography Type:	Description: (Last Updated: 10/30/2023)