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| **Fiscal Year:** | FY 2024 | **Task Last Updated:** | FY 08/10/2023 |
| **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<br>(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 | | |
| **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:** | Flight | **Solicitation / Funding Source:** | 2013-14 HERO NNJ13ZSA002N-BMED Behavioral Health & Performance |
| **Start Date:** | 12/01/2014 | **End Date:** | 06/30/2025 |
| **No. of Post Docs:** | 0 | **No. of PhD Degrees:** | |
| **No. of PhD Candidates:** | 2 | **No. of Master' Degrees:** | |
| **No. of Master's Candidates:** | 0 | **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<br>NOTE: End date changed to 06/30/2025 per NSSC information (Ed., 9/17/24)<br>NOTE: End date changed to 08/31/2024 per L. Juliette/JSC (Ed., 4/10/23)<br>NOTE: End date changed to 08/31/2023 per NSSC information (Ed., 10/13/22)<br>NOTE: End date changed to 08/31/2022 per NSSC information (Ed., 8/31/21)<br>NOTE: End date changed to 08/31/2021 per NSSC information (Ed., 2/3/21)<br>NOTE: End date changed to 12/31/2020 per D. Risin/HRP/NSSC information (Ed., 09/14/2020)<br>NOTE: End date changed to 09/30/2020 per NSSC information (Ed., 04/27/2020)<br>NOTE: End date changed to 03/31/2020 per NSSC information (Ed., 9/3/19) | | |

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| | NOTE: End date changed to 11/30/2019 per NSSC information (Ed., 10/11/18)<br><br>NOTE: End date changed to 11/30/2018 per NSSC information (Ed., 12/13/17)<br><br>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 )<br>Clark, Toni B.S. ( NASA Johnson Space Center )<br>Czeisler, Charles M.D., Ph.D. ( Brigham and Women's Hospital/Harvard Medical Center )<br>Johnston, Smith M.D. ( NASA Johnson Space Center (Retired 12/19, but still involved) )<br>Moomaw, Ronald O.D. ( NASA Johnson Space Center )<br>Lockley, Steven Ph.D. ( Co-PI: Brigham and Women's Hospital )<br>Hanifin, John Ph.D. ( Thomas Jefferson University )<br>Rahman, Shadab Ph.D. ( Brigham and Women's Hospital )<br>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."<br>Originally, the International Space Station (ISS) used General Luminaire Assemblies (GLAs) that housed fluorescent lamps for illuminating the astronauts' working and living environments. NASA 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.<br><br>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 82 SSLAs have been installed on ISS, bringing the total retrofit to 96% replacement of GLAs on the US portion of ISS. Since the onset of the SSLA retrofit, the investigators 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.<br><br>This research was designed to address 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. As of November 2021, the Human Research Program risks and gaps have since been revised per more recent IRPs; see above for the current noted Risks and Gaps and the Human Research Roadmap: https:// |
| **Rationale for HRP Directed Research:** | |

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| **Research Impact/Earth Benefits:** | 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, 2022). 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, crew members 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 npj Microgravity). 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 likely to help optimize the use of light therapy for patient populations with affective, circadian and sleep disorders.<br>References<br><br>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.<br><br>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.<br><br>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.<br><br>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:** | FINAL TASK UPDATE (Ed., 8/9/23)<br>Three ground analog studies and an International Space Station (ISS) flight study were completed successfully in this project.<br><br>In the five-day analog study, which enrolled 25 astronaut-aged participants, preliminary results found that in the evening the dynamic lighting evoked a significantly earlier onset of plasma melatonin, as hypothesized. Consistent with that finding, there was a nonsignificant trend for dynamic lighting to influence the circadian phase angle between acrophase of urinary aMT6 and scheduled wake time. There were no effects of evening lighting on subjective alertness as measured by the Karolinska sleepiness scale (KSS) or of sleep as assessed by actigraphy, as well as no effects of lighting on morning neurocognition as tested by the digit symbol substitution test (DSST).<br><br>Turning to the acute analog visual performance testing in the high-fidelity replica crew sleeping quarters, a cohort of 8 astronaut-aged participants showed significant effects of dim, presleep lighting on visual performance, as assessed by the Numerical Verification Test (NVT) and a significant decrease in color vision under nominal and dim presleep lighting as tested by the Farnsworth-Munsell 100 Hue Color Vision Test (FM100). Tests on a separate cohort of 8 astronaut-aged subjects showed a significant decrease in color vision under nominal and dim presleep lighting as scored by the FM100 in both fixed-head and freely-moving head positions.<br><br>Aboard the ISS, over 600,000 lighting measures were taken across all ISS nodes and modules. The Solid State Lighting Assemblies (SSLAs) inflight were stable in spectral emissions across all settings for nearly three years. The ISS interior lighting retrofit led to quite varied lighting conditions across the 7 astronauts studied, essentially creating 7 case studies.<br><br>There were no significant differences in aMT6s acrophases between the current and historical crewmembers during the inflight nominal schedule. When assessed by lighting condition, sleep duration was significantly longer and wakefulness after sleep onset (WASO) was significantly shorter during the current SSLA lighting as compared to the historical General Lighting Assemblies (GLA) lighting. The psychomotor vigilance task (PVT) reaction time was significantly quicker under nominal versus shifted schedules, but reaction time was not different between current SSLA and historic GLA conditions. There were no significant differences in any comparison for PVT lapses. With all data combined, there was a trend for an increase in sleep duration and a decrease in WASO as the number of SSLA installations increased. Although not statistically significant, there were indications of improvement aMT6s acrophase approaching normal timing, quicker reaction times, and fewer attentional failures as more SSLAs were installed. Visual testing preflight, inflight, and postflight on astronauts showed a significant decrease in color vision under nominal and dim presleep lighting in preflight and postflight, with a nonsignificant trend for a decrease in color vision inflight under dim presleep lighting inflight. Similar significant decreases in visual performance relative to presleep light exposures were detected. |
| **Bibliography Type:** | Description: (Last Updated: 10/30/2023) |
| **Articles in Peer-reviewed Journals** | Zielinska-Dabkowska KM, Schernhammer ES, Hanifin JP, Brainard GC. "Reducing nighttime light exposure in the urban environment to benefit human health and society." Science. 2023 Jun 15;380(6650):1130-5. Review. http://dx.doi.org/10.1126/science.adg5277 ; PMID: 37319219 , Jun-2023 |
| **Books/Book Chapters** | Johnson DA, Czeisler CA. "Components of normal human sleep." in "Foundations of Sleep Health." Ed. FJ Nieto, DJPetersen. London: Academic Press, 2022. p. 1-12. https://doi.org/10.1016/B978-0-12-815501-1.00012-0 , Jan-2022 |