

Fiscal Year:	FY 2024	Task Last Updated:	FY 08/23/2023
PI Name:	Goel, Namni Ph.D.		
Project Title:	Biomarkers as Predictors of Resiliency and Susceptibility to Stress in Space Flight		
Division Name:	Human Research		
Program/Discipline:			
Program/Discipline-- Element/Subdiscipline:			
Joint Agency Name:	TechPort:	No	
Human Research Program Elements:	(1) HFBP: Human Factors & Behavioral Performance (IRP Rev H)		
Human Research Program Risks:	None		
Space Biology Element:	None		
Space Biology Cross-Element Discipline:	None		
Space Biology Special Category:	None		
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Comments:	NOTE: Formerly at the University of Pennsylvania until July 2019.		
Project Type:	GROUND	Solicitation / Funding Source:	2013 HERO NNJ13ZSA002N-Crew Health (FLAGSHIP & NSBRI)
Start Date:	10/23/2019	End Date:	09/30/2024
No. of Post Docs:	No. of PhD Degrees:		
No. of PhD Candidates:	No. of Master' Degrees:		
No. of Master's Candidates:	No. of Bachelor's Degrees: 1		
No. of Bachelor's Candidates:	Monitoring Center: NASA JSC		
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Flight Program:			
Flight Assignment:	NOTE: End date changed to 9/30/2024 per NASA-JSC (Ed., 5/2/24) NOTE: End date changed to 9/20/2024 per NSSC information (Ed., 9/3/20)		
Key Personnel Changes/Previous PI:			
COI Name (Institution):			
Grant/Contract No.:	80NSSC20K0243		
Performance Goal No.:			
Performance Goal Text:			

<p>Task Description:</p>	<p>NOTE: Continuation of "Biomarkers as Predictors of Resiliency and Susceptibility to Stress in Space Flight," grant NNX14AN49G, due to Principal Investigator (PI) move to Rush University from University of Pennsylvania in summer 2019, requiring issue of new grant.</p> <p>This proposal is responsive to the NASA Behavioral Health and Performance gap (BMed5) to find individual characteristics that predict successful adaptation and performance in an isolated, confined, and extreme environment, especially for long duration missions. The project also relates to Human Research Program (HRP) Sleep Gap 4 to identify indicators of individual susceptibilities and resiliencies to sleep loss and circadian rhythm disruption, to aid with individualized countermeasure regimens, for autonomous, long duration, and/or distance exploration missions. The proposal is also responsive to BMed 1 and BMed 2, and Sleep Gap 2 and Sleep Gap 9 [Ed. note: Gap names have changed since this 2014 proposal. See https://]. To address these gaps, this proposal will assess biomarkers as predictors of resiliency and susceptibility (individual differences) to performance stress and sleep loss using the HRP Human Exploration Research Analog (HERA) and the Hawaii Space Exploration Analog and Simulation (HI-SEAS) high fidelity space analog facilities. We will conduct a ground-based experiment—strongly anchored in our previous laboratory-based research—on N=32 healthy men and women (ages 26-55) in the HERA facility (short-duration analog) and on N=6 healthy men and women (ages 21-65) in the HI-SEAS facility (long-duration analog) to determine the predictive validity of a set of relevant, valid, and reliable biomarkers for distinguishing those who are more resilient versus those who are more susceptible to the adverse neurobehavioral effects of the combination of high performance demands and total sleep deprivation (TSD) stressors—two conditions commonly experienced in space flight. These biomarkers include the following: cardiovascular measures (blood pressure, heart rate and heart rate variability, stroke volume, and cardiac output), salivary cortisol, catecholamines (dopamine, noradrenaline, and adrenaline), an inflammatory marker (C-reactive protein; CRP), metabolomic markers (via unbiased metabolomics), and microRNAs (epigenetic markers). The project deliverable will be a countermeasure (set of diverse biomarkers) for distinguishing those who are more resilient versus those who are more susceptible to the adverse neurobehavioral effects of high-performance demands and sleep loss stressors. If valid markers of such susceptibility can be found, it will be possible to optimize and individualize crew resources and mitigate stress and other behavioral health and performance risks autonomously during long-duration space flight.</p> <p>The SIRIUS (Scientific International Research In a Unique terrestrial Station) missions are the first time NASA's Human Research Program (HRP) partners with Russia's IBMP (Institute for Biomedical Problems) Ground-based Experimental Complex, NEK (Nezemnyy Eksperimental'nyy Kompleks) to conduct a series of analog missions. Dr. Goel's project will be part of the 2019 mission as well as the 2021 mission.</p>
<p>Rationale for HRP Directed Research:</p>	<p>The project's research will deliver a countermeasure (set of diverse biomarkers) for distinguishing those who are more resilient versus those who are more susceptible to the adverse neurobehavioral effects of high performance demands and sleep loss stressors. If valid markers of such susceptibility can be found, it will be possible to optimize and individualize crew resources, and mitigate stress and other behavioral health and performance risks autonomously during long-duration space flight. This information would also be of use on Earth in applied occupations that demand similar risks and stressors.</p>
<p>Research Impact/Earth Benefits:</p>	<p>We integrated the complex, multifaceted five-day stress and sleep loss experiment into NASA Human Exploration Research Analog (HERA) and successfully collected data in all four 14-day 2015 and all four 30-day 2016 missions (N=32 crewmembers). These data include the following biomarkers: blood markers from 6 time points in 32 crewmembers (190 blood markers; n=2 crewmembers did not participate in one biomarker assessment); 2 saliva markers each from 6 time points in 32 crewmembers (382 saliva markers; n=1 crewmember did not participate in one biomarker assessment); blood pressure markers from 6 time points in 32 crewmembers (191 blood pressure markers; n=1 crewmember did not participate in one biomarker assessment); stroke volume and cardiac output from 6 time points in 32 crewmembers (191 stroke volume and cardiac output markers; n=1 crewmember did not participate in one biomarker assessment); and heart rate from 6 time points in 32 crewmembers (189 heart rate markers: 3 heart rate monitor data points were not collected due to n=2 crewmembers mistakenly not turning on the heart rate device and n=1 crewmember not participating in one biomarker assessment; however, heart rate data collected from the echocardiography and/or blood pressure devices can be used as needed). We also have data from 11 neurobehavioral tests for 32 crewmembers (348 neurobehavioral tests; one crewmember did not participate in 4 neurobehavioral assessments). Almost all the missing data can be attributed to one crewmember who experienced a medical emergency. Finally, we have continuous actigraphy data on n=16 crewmembers for 14-days each (a total of 224 days of actigraphy) and on n=16 crewmembers for 30 days each (a total of 480 days of actigraphy).</p> <p>Analyses of the wrist actigraphy data from the four 14-day HERA missions of 2015 (n=16) and the four 30-day HERA missions of 2016 (n=16) indicate crewmembers were compliant with the dictated sleep-wake times at baseline and recovery and were not sleeping during the total sleep deprivation (TSD) night. As expected for these 32 crewmembers, on average, the performance variables show significant impairment with TSD (with individual differences in neurobehavioral responses). Thus, the sleep loss manipulation in HERA was highly effective.</p> <p>We successfully completed the 17-day initial "shakedown" mission in November 2017 on N=6 subjects. Two miRNA samples were not collected due to blood flow issues with the blood draws, and one NTB test bout was not collected; all other pilot data were successfully collected. We successfully completed the 4-month, long-duration mission in Nezemnyy Eksperimental'nyy Kompleks (NEK) in July 2019 on N=6 subjects, with all data collected. We successfully completed the 8-month, long-duration mission in NEK in July 2022 on N=5 subjects, with all data collected (one subject withdrew during the mission). Unfortunately, we will not be participating in the 12-month, long-duration mission in NEK as originally planned.</p>
<p>Task Progress:</p>	<p>Bibliography Type: Description: (Last Updated: 09/28/2023)</p> <p>Abstracts for Journals and Proceedings Chen L, Xiong E, Goel N, Allison KC. "The psychological effects of meal timing among individuals with obesity." 2022 Penn Undergraduate Research Mentoring Program Conference, Philadelphia, Pennsylvania, September 19, 2022. Abstracts. 2022 Penn Undergraduate Research Mentoring Program Conference, Philadelphia, Pennsylvania, September 19, 2022. , Sep-2022</p>

Abstracts for Journals and Proceedings	Goel N, Pasetes LN. "Biomarkers as predictors of resiliency and susceptibility to stress in space flight." 2023 NASA Human Research Program Investigators' Workshop, Galveston, Texas, February 7-9, 2023. Abstracts. 2023 NASA Human Research Program Investigators' Workshop, Galveston, Texas, February 7-9, 2023. , Feb-2023
Abstracts for Journals and Proceedings	Pasetes LN, Rosendahl-Garcia KM, Goel N. "Robust phenotypic stability of cardiovascular measures across long-duration missions." 2023 NASA Human Research Program Investigators' Workshop, Galveston, Texas, February 7-9, 2023. Abstracts. 2023 NASA Human Research Program Investigators' Workshop, Galveston, Texas, February 7-9, 2023. , Feb-2023
Abstracts for Journals and Proceedings	Hoopes EK, Goel N, Keiser T, Taplin M, Witman MA, Patterson F. "Circadian timing of sleep and eating relative to biological timing using dim light melatonin onset (DLMO) methodology." 2023 University of Delaware College of Health Sciences Research Day, Newark, Delaware, March 8, 2023. Abstracts. 2023 University of Delaware College of Health Sciences Research Day, Newark, Delaware, March 8, 2023. , Mar-2023
Abstracts for Journals and Proceedings	Goel N, Rosendahl-Garcia KM, Pasetes LN. "Acute total sleep deprivation adversely impacts cardiovascular measures across long-duration intervals." 2023 Associated Professional Sleep Societies Meeting, Indianapolis, Indiana, June 3-7, 2023. Abstracts. 2023 Associated Professional Sleep Societies Meeting, Indianapolis, Indiana, June 3-7, 2023. , May-2023
Abstracts for Journals and Proceedings	Pasetes LN, Rosendahl-Garcia KM, Goel N. "Trait-like stability of cardiovascular measures across long-duration intervals after baseline and recovery sleep phases." 2023 Associated Professional Sleep Societies Meeting, Indianapolis, Indiana, June 3-7, 2023. Abstracts. 2023 Associated Professional Sleep Societies Meeting, Indianapolis, Indiana, June 3-7, 2023. , May-2023
Abstracts for Journals and Proceedings	Pasetes LN, Rosendahl-Garcia KM, Goel N. "Cardiovascular measures display robust phenotypic stability to total sleep deprivation across long-duration intervals." 2023 Associated Professional Sleep Societies Meeting, Indianapolis, Indiana, June 3-7, 2023. Abstracts. 2023 Associated Professional Sleep Societies Meeting, Indianapolis, Indiana, June 3-7, 2023. , May-2023
Articles in Peer-reviewed Journals	Walsh RFL, Smith LT, Titone MK, Ng TH, Goel N, Alloy LB. "The relationship between physical activity states and depressive symptoms: Using ambulatory assessment to characterize day-to-day associations among individuals with and without bipolar spectrum disorder." <i>Depress Anxiety</i> . 2022 Dec;39(12):835-844. https://doi.org/10.1002/da.23290 ; PubMed PMID: 36254832 ; PubMed Central PMC9729395 , Dec-2022
Articles in Peer-reviewed Journals	Klerman EB, Brager A, Carskadon MA, Depner CM, Foster R, Goel N, Harrington M, Holloway PM, Knauert MP, LeBourgeois MK, Lipton J, Mellow M, Montagnese S, Ning M, Ray D, Scheer FAJL, Shea SA, Skene DJ, Spies C, Staels B, St-Onge MP, Tiedt S, Zee PC, Burgess HJ. "Keeping an eye on circadian time in clinical research and medicine." <i>Clin Transl Med</i> . 2022 Dec;12(12):e1131. https://doi.org/10.1002/ctm2.1131 ; PubMed PMID: 36567263 ; PubMed Central PMC9790849 , Dec-2022
Articles in Peer-reviewed Journals	Walsh RFL, Smith LT, Klugman J, Titone MK, Ng TH, Goel N, Alloy LB. "An examination of bidirectional associations between physical activity and mood symptoms among individuals diagnosed and at risk for bipolar spectrum disorders." <i>Behav Res Ther</i> . 2023 Feb;161:104255. https://doi.org/10.1016/j.brat.2023.104255 ; PubMed PMID: 36682182 ; PubMed Central PMC9909602 , Feb-2023
Articles in Peer-reviewed Journals	Flatt AJ, Peleckis AJ, Dalton-Bakes C, Nguyen HL, Ilany S, Matus A, Malone SK, Goel N, Jang S, Weimer J, Lee I, Rickels MR. "Automated insulin delivery for hypoglycemia avoidance and glucose counterregulation in long-standing type 1 diabetes with hypoglycemia unawareness." <i>Diabetes Technol Ther</i> . 2023 May;25(5):302-314. https://doi.org/10.1089/dia.2022.0506 ; PubMed PMID: 36763336 ; PubMed Central PMC10171955 , May-2023
Articles in Peer-reviewed Journals	Chai Y, Gehrman P, Yu M, Mao T, Deng Y, Rao J, Shi H, Quan P, Xu J, Zhang X, Lei H, Fang Z, Xu S, Boland E, Goldschmied JR, Barilla H, Goel N, Basner M, Thase ME, Sheline YI, Dinges DF, Detre JA, Zhang X, Rao H. "Enhanced amygdala-cingulate connectivity associates with better mood in both healthy and depressive individuals after sleep deprivation." <i>Proc Natl Acad Sci USA</i> . 2023 Jun 27;120(26):e2214505120. https://doi.org/10.1073/pnas.2214505120 ; PubMed PMID: 37339227 ; PubMed Central PMC10293819 , Jun-2023
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Articles in Peer-reviewed Journals	Malone SK, Matus AM, Flatt AJ, Peleckis AJ, Grunin L, Yu G, Jang S, Weimer J, Lee I, Rickels MR, Goel N. "Prolonged use of an automated insulin delivery system improves sleep in long-standing type 1 diabetes complicated by impaired awareness of hypoglycemia." <i>J Diabetes Sci Technol</i> . 2023 Jul 14:19322968231182406. https://doi.org/10.1177/19322968231182406 ; PubMed PMID: 37449426 , Jul-2023
Articles in Peer-reviewed Journals	Ballard R, Parkhurst J, Julian K, Pasetes LN, Fawcett A, Li A, Goel N, Sit DK. "Light therapy for adolescent depression: A scoping review." <i>Curr Psychiatry Rep</i> . 2023 Sep;25(9):373-386. https://doi.org/10.1007/s11920-023-01437-5 ; PubMed PMID: 37490215 , Sep-2023
Awards	Goel N. "Member and Chair, Executive Committee, Sleep Research Society, 2020-Present." Jun-2023
Awards	Goel N. "Member, Sleep Research Society Foundation Board of Directors 2018-Present." Jun-2023
Awards	Goel N. "Member, Sleep Research Society Board of Directors 2018-Present." Jun-2023
Awards	Goel N. "Member, Board of Directors, Associated Professional Sleep Societies, 2020-Present." Jun-2023

Awards	Goel N. "Member, COV-IRT (The Coronavirus International Research Team), 2021-Present." Jun-2023
Awards	Goel N. "President, Sleep Research Society, 2022-Present." Jun-2023
Awards	Goel N. "Member, Obstructive Sleep Apnea Awareness Program CDC Grant, Strategic Planning Workgroup, American Academy of Sleep Medicine, 2021-Present." Jun-2023
Awards	Goel N. "Member and Chair, Nominating Committee, Sleep Research Society, 2021-Present." Jun-2023
Awards	Goel N. "External Advisory Board Member, Center for Sleep and Circadian Biology, Northwestern University, Evanston, IL, 2023." Apr-2023
Awards	Goel N. "Key Opinion Leader, Insomnia Roundtable Discussion, Sleep Research Society Foundation Industry Advisory Council (IAC), 2023." May-2023
Awards	Goel N. "Member and Chair, Committee on Committees, Sleep Research Society, 2021-Present." Apr-2023
Books/Book Chapters	Casale CE, Brieva TE, Yamazaki EM, Antler CA, Goel N. "Acute sleep deprivation in humans." in "Encyclopedia of Sleep and Circadian Rhythms (2nd edition)." Ed. C.A. Kushida. Cambridge MA: Elsevier, Academic Press, 2023. p. 217-29, https://dx.doi.org/10.1016/B978-0-12-822963-7.00005-0 , Jan-2023
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