Fiscal Year:	FY 2023	**Task Last Updated:**	FY 09/17/2022
PI Name:	Carr, Christopher Sc.D.		
Project Title:	Enterococci Evolution in Space: Environmental Adaptations, Antibiotic Resistance, and Clinical Implications		
Division Name:	Space Biology		
Program/Discipline:			
Program/Discipline--Element/Subdiscipline:			
Joint Agency Name:		**TechPort:**	No
Human Research Program Elements:	None		
Human Research Program Risks:	None		
Space Biology Element:	(1) Cell & Molecular Biology (2) Microbiology		
Space Biology Cross-Element Discipline:	None		
Space Biology Special Category:	(1) Translational (Countermeasure) Potential		
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Zip Code:	30332	**Congressional District:**	5
Comments:			
Project Type:	Flight	**Solicitation / Funding Source:**	2016-17 Space Biology (ROSBio) NNH16ZTT001N-FG. App G: Flight and Ground Space Biology Research
Start Date:	11/04/2020	**End Date:**	11/03/2023
No. of Post Docs:	0	**No. of PhD Degrees:**	0
No. of PhD Candidates:	1	**No. of Master' Degrees:**	0
No. of Master's Candidates:	0	**No. of Bachelor's Degrees:**	0
No. of Bachelor's Candidates:	0	**Monitoring Center:**	NASA ARC
Contact Monitor:	Griko, Yuri	**Contact Phone:**	650-604-0519
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Flight Program:			
Flight Assignment:			
Key Personnel Changes/Previous PI:	No Co-PI/Co-I changes this year. PhD Student McKaig is transitioning to a NASA FINESST award effective 9/1/22.		
COI Name (Institution):	Burton, Aaron Ph.D. (NASA Johnson Space Center) Gilmore, Michael Ph.D. (Massachusetts Eye And Ear Infirmary) Wallace, Sarah Ph.D. (NASA Johnson Space Center)		
Grant/Contract No.:	80NSSC21K0234		
Performance Goal No.:			
Performance Goal Text:			

Task Description:	Enterococci are gram-positive bacteria that originated when our ancient animal ancestors emerged from the oceans to live on land, and brought their gut flora with them. Enterococcus faecalis (EF) and Enterococcus faecium are common human commensals and can harbor multidrug resistance. Both have been previously isolated on the International Space Station (ISS). Likely as a consequence of their evolutionary origins, enterococci show remarkable stress resistance within, but also outside, their human hosts. Their antibiotic resistance, coupled with tolerance to desiccation, starvation, and disinfection, make some EF strains potent pathogens in the built environment (e.g., hospitals), and a potential risk to crew health during space missions. The proposed study includes flight components to: 1) Characterize the frequency and genomic identity of antibiotic resistant organisms, including enterococci, on the ISS; 2) Assess the evolutionary selective pressure of the space environment (microgravity, space radiation) using EF as a model system; 3) Characterize the “natural” evolutionary history of EF on Earth and in space to reveal mechanisms of microbial adaption including natural selection. The CS-05A: Genomic Enumeration of Antibiotic Resistance in Space (GEARS) payload is designed to fulfill specific aim 1, the characterization of the frequency and genomic identity of antibiotic resistant organisms on the ISS. The Co-Principal Investigators propose to carry out longitudinal sampling of ISS surfaces in a repeated measures design. The CS-05B: Enterococcus Growth Advantage on ISS via Tn-seq (EnteroGAIT) payload is designed to fulfill specific aim 2: to assess the evolutionary selective pressure of the space environment. The flight experiment will utilize on-board long-duration microbial growth to measure the selective pressure of the space environment on a defined microbial population: Enterococcus faecalis mutants are created by transposon insertional mutagenesis; selection is measured by sequencing (Tn-Seq) and occurs on timescales far shorter than natural or experimental evolution. The third study, Adaptation & Evolution of Resilient Enterococcus in Space (AERES) will generate complete whole genomes of Enterococcus isolates from the ISS and ground, combined with follow up characterization, to seek evidence of persistence and/or evolution in the space environment.
Rationale for HRP Directed Research:	
Research Impact/Earth Benefits:	Antibiotic resistance is a growing threat to human health on Earth, resulting in infections in 2.8 million people, and causing 35,000 deaths annually (CDC data). Overuse or improper use of antibiotics is also contributing to this growing threat. Bacteria are evolving in response to the usage of antibiotics: for example, some strains of Staphylococcus aureus have acquired resistance to vancomycin from Enterococcus. Staphyloccoci and enterococci are the first and second leading causes of hospital-acquired infections, respectively. By studying the distribution of antibiotic resistant microbes on the International Space Station (ISS), a built environment similar in some ways to hospitals, we can also gain insight into how antibiotic resistant organisms survive, adapt, and evolve in response to their environment. Thus, this study will result in data that could also be relevant to human health on Earth.
Task Progress:	Genomic Enumeration of Antibiotic Resistance in Space (GEARS) progress: The Science Requirements Document (SRD) for CS05A was completed and signed in December 2021. The Principal Investigator's (PI’s) lab was completed in April-May 2022, and the lab was moved in preparation for Science Verification Test (SVT) and Experiment Verification Test (EVT) studies. Co-PI Wallace’s lab continued optimization of key aspects in the sample collection and preparation process. SVT studies were initiated, including an antibiotic stability and shelf-life assessment assay. Recently, the compliance review package for GEARS was developed in concert with the Mission Scientist (MS), and nominal flight candidates were identified. Enterococcus Growth Advantage on ISS via Tn-seq (EnteroGAIT) progress: The subaward to Massachusetts Eye and Ear (Co-PI Gilmore) was initiated (initially delayed to preserve funds), the SRD was signed/approved, and BioServe was selected as the payload developer (PD) for the EnteroGAIT/CS05B hardware. A kickoff meeting was held in late July 2022. Mass estimates for the payload were made by the PD. Total crew time was estimated. The compliance review package is currently in development in cooperation with the MS. Nominal flight candidates have been identified. Initial SVT testing is underway and will include selection of the membrane material and pore size required to retain cells during media exchange, biocompatibility and growth tests, protocol verification, media stability, and optimization of sample storage, prior to a full EVT. Adaptation and Evolution of Resilient Enterococcus in Space (AERES) progress: This sub-project was delayed until after the PI moved to his permanent lab (May 2022). Initiation is now underway and will include nanopore sequencing of isolates from multiple sources in combination with analysis of whole genomes now available via the National Center for Biotechnology Information (NCBI). Near-term evaluation of new higher-accuracy sequencing kits (ONT Kit 14) will be performed to evaluate the potential for nanopore-only genome assembly. We submitted an abstract to the American Society for Gravitational and Space Research (ASGSR) Annual Meeting, scheduled for November, 2022, to share progress on SVT work for GEARS.
Bibliography Type:	Description: (Last Updated: 09/15/2023)
Abstracts for Journals and Proceedings	McKaig JM, Burton A, Wallace S, Gilmore M, Moeller R, Grohmann E, Bryan NC, Zuber MT, Carr CE. "Enterococci in space: Adaptation, antibiotic resistance, and clinical implications. Poster presentation." 37th Annual Meeting of the American Society for Gravitational and Space Research, Baltimore, MD, November 3-6, 2021. Abstracts. 37th Annual Meeting of the American Society for Gravitational and Space Research, Baltimore, MD, November 3-6, 2021. , Nov-2021