Fiscal Year:	FY 2023	**Task Last Updated:**	FY 11/03/2022
PI Name:	Santa Maria, Sergio Ph.D.		
Project Title:	ORGANA: Oxidation-Reduction potential and Genetic Assessments for New mission Applications		
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		
Space Biology Cross-Element Discipline:	None		
Space Biology Special Category:	None		
PI Email:	sergio.r.santamaria@nasa.gov	**Fax:**	FY
PI Organization Type:	NASA CENTER	**Phone:**	650-604-1411
Organization Name:	NASA Ames Research Center		
PI Address 1:	Space Biosciences Research Branch		
PI Address 2:	MS 288-2		
PI Web Page:			
City:	Moffett Field	**State:**	CA
Zip Code:	94035	**Congressional District:**	18
Comments:			
Project Type:	Ground	**Solicitation / Funding Source:**	2021 Space Biology NNH21ZDA001N-LEIA E.10. Lunar Explorer Instrument for Space Biology Applications
Start Date:	01/01/2022	**End Date:**	12/31/2023
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:**	
No. of Bachelor's Candidates:	5	**Monitoring Center:**	NASA ARC
Contact Monitor:	Griko, Yuri	**Contact Phone:**	650-604-0519
Contact Email:	Yuri.V.Griko@nasa.gov		
Flight Program:			
Flight Assignment:			
Key Personnel Changes/Previous PI:	No changes.		
COI Name (Institution):	Broddrick, Jared Ph.D. (NASA Ames Research Center) Gentry, Diana Ph.D. (NASA Ames Research Center) Liddell, Lauren Ph.D. (NASA Ames Research Center)		
Grant/Contract No.:	Internal Project		
Performance Goal No.:			
Performance Goal Text:			

Task Description:	Space ionizing radiation (IR) and reduced gravity pose risks to long-duration space travel and eventual non-Earth habitation. Given the difficulties in recreating these effects on Earth, developing an in-depth understanding of these risks before sending crewed missions necessitates fully autonomous biological experiments. As an example, BioSentinel is a small satellite with an integrated BioSensor that will measure metabolic and growth changes induced by deep space radiation in the model organism S. cerevisiae (budding yeast). The Lunar Explorer Instrument for Space Biology Applications (LEIA) project is leveraging the same platform to answer biological questions related to lunar exploration. We hypothesize that both metabolic (redox) and genetic (knockout) assays can distinguish specific changes due to the unique combinations of direct IR damage, indirect oxidative damage, and reduced gravity incurred by exposure to the lunar environment, low Earth orbit (LEO), interplanetary space, and ground-based simulations even before differential survival becomes apparent. These environmental perturbations are known to result in subtle changes in cell growth and activity, but the resulting data is lacking pathway and molecular specificity. By leveraging a metabolic modeling framework and a series of engineered strains, our primary goal is to perform the ground testing necessary to validate strains that yield distinct responses to specific stressors, both laying the groundwork for a potential (and successful) lunar mission to characterize the relative importance of these changes within the capabilities of the BioSensor instrument and improving the usefulness of the alamarBlue assay for past and future missions. To test our hypothesis, we will pursue the following Specific Aims: Aim 1: Derive metabolic pathways usage via modeling of a colorimetric assay. The BioSentinel platform uses a redox dye to detect changes in viability and metabolic activity. AlamarBlue changes color in the presence of cell activity and creates intricate time course data that varies as a function of environmental stress, genetic background, and metabolic activity. To date, the rich information in this data has not been connected explicitly to underlying cellular processes. We will combine the data with metabolic modeling to develop a computational tool that extracts detailed metabolic information. This predictive model will not only enable analysis of our experimental design but can be applied to detect changes caused by lunar-like conditions or any autonomous mission that utilizes this reporter dye. Aim 2: Explore biological effects of a lunar-like environment using DNA repair and stress response defective mutants. Both IR and reduced gravity induce the production of reactive oxygen species (ROS), which play a key role in the generation of cellular and DNA damage, in addition to direct IR damage (e.g., DNA breaks, membrane damage). We will generate yeast mutants defective in DNA repair and stress response pathways, including oxidative damage repair, homologous recombination, and excision repair. Given the short mission duration and the expected low cumulative IR dose, we will also generate mutants containing multiple gene knockouts to increase sensitivity. We will then perform alamarBlue assays after IR exposure in both dry form and in liquid suspension, to study their response. Aim 3: Engineer endogenous ROS scavenging capabilities in yeast. An indirect effect of IR and cellular stress is the buildup of ROS. While S. cerevisiae has several strategies for ROS removal, we will engineer ROS scavenging mechanisms and evaluate if they can mitigate the unique damage caused by spaceflight stress and IR. We will over-express a native ROS scavenging enzyme and engineer a mannitol biosynthetic pathway, which specifically targets an ROS produced by IR. This aim demonstrates a potential mitigation for future spaceflight missions, enabling insight into how engineered scavenging mechanisms could improve crew safety.
Rationale for HRP Directed Research:	
Research Impact/Earth Benefits:	The ORGANA project (and the investigator team) was the basis for a new mission to the lunar surface, LEIA, which was recently awarded a ~$20M grant as part of NASA's PRISM program. Both projects are trying to understand the effects of the lunar surface environment on biological organisms, both to provide valuable information for future human missions to the Moon and to improve bio production of chemicals of interest like medicine or food. Thus, our project aims to provide lessons on how to improve instrumentation for future missions beyond low Earth orbit (LEO) as well as valuable data for future missions including biology.
Task Progress:	The team has initiated experiments to test the desiccation tolerance of a series of yeast strains defective in different DNA repair pathways. So far, we have completed five months of long-term desiccation. We are currently testing their sensitivity to ionizing radiation. This information (desiccation tolerance and radiation sensitivity) will be used to down-select strains for a potential future mission to the lunar surface. We have initiated metabolic modeling experiments by testing cell growth and metabolic activity in yeast cells using minimal media. We have also started measuring parameters important for metabolism, like glucose uptake and oxygen consumption over time. New instrumentation to measure a series of metabolic parameters (oxygen consumption, pH, conductivity, optical absorbance) is being developed by the team. The goal is to use these devices to measure the response to ionizing radiation in a series of yeast strains.
Bibliography Type:	Description: (Last Updated: 04/23/2025)
Articles in Peer-reviewed Journals	Ng S, Williamson C, van Zee M, Di Carlo D, Santa Maria SR. "Enabling clonal analyses of yeast in outer space by encapsulation and desiccation in hollow microparticles." Life. 2022 July 31;12(8):1168. https://doi.org/10.3390/life12081168 ; PMID: 36013347; PMCID: PMC9410522 , Jul-2022
Articles in Peer-reviewed Journals	Harandi B, Ng S, Liddell LC, Gentry DM, Santa Maria SR. "Fluidic-based instruments for space biology research in CubeSats." Front. Space Technol. 2022 Mar 29;3:853980. https://doi.org/10.3389/frspt.2022.853980 , Mar-2022
Papers from Meeting Proceedings	Santa Maria SR. "Evolution of biological satellites: from low Earth orbit to NASA's BioSentinel deep space mission." IAC 2022: 73rd International Astronautical Congress, Paris, France, September 18-22, 2022. Abstracts. IAC 2022: 73rd International Astronautical Congress, Paris, France, September 18-22, 2022. https://dl.iafastro.directory/event/IAC-2022/paper/69599/ , Sep-2022