Fiscal Year:	FY 2024	**Task Last Updated:**	FY 02/07/2024
PI Name:	Sackett, Cass Ph.D.		
Project Title:	Development of Atom Interferometry Experiments for the International Space Station's Cold Atom Laboratory		
Division Name:	Physical Sciences		
Program/Discipline:			
Program/Discipline--Element/Subdiscipline:	FUNDAMENTAL PHYSICS--Fundamental physics		
Joint Agency Name:		**TechPort:**	No
Human Research Program Elements:	None		
Human Research Program Risks:	None		
Space Biology Element:	None		
Space Biology Cross-Element Discipline:	None		
Space Biology Special Category:	None		
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City:	Charlottesville	**State:**	VA
Zip Code:	22904-1000	**Congressional District:**	5
Comments:			
Project Type:	FLIGHT,GROUND	**Solicitation / Funding Source:**	2013 Fundamental Physics NNH13ZTT002N (Cold Atom Laboratory--CAL)
Start Date:	04/01/2014	**End Date:**	09/27/2024
No. of Post Docs:	1	**No. of PhD Degrees:**	0
No. of PhD Candidates:	2	**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 JPL
Contact Monitor:	Callas, John	**Contact Phone:**	
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Flight Program:	ISS		
Flight Assignment:	NOTE: End date changed to 9/27/2024 per U. Israelsson/JPL (Ed., 1/6/22) NOTE: Extended to 9/30/2022 per U. Israelsson/JPL (Ed., 3/9/21) NOTE: Extended to 10/28/2020 per PI (Ed., 2/28/2020) NOTE: Extended to 10/30/2019 per U. Israelsson/JPL (Ed., 12/14/17)		
Key Personnel Changes/Previous PI:			
COI Name (Institution):			
Grant/Contract No.:	JPL 1502012		
Performance Goal No.:			
Performance Goal Text:			

Task Description:	The ultimate objective of this proposal is to develop an ultra-high sensitivity atom interferometer capable of operating in and benefiting from a microgravity environment. The interferometer would be specifically suited for measurements of rotations, but it would be broadly applicable to a variety of precision measurements. Ground and flight based efforts are proceeding in three broad areas. First, we are performing ground studies and developing a flight mission for the Cold Atom Laboratory (CAL) to study atomic techniques for inertial sensing in microgravity. Ground efforts include development of new rotation-sensing techniques and implementation of an optically suspended atom source for gravimetry. Flight efforts involve implementation and characterization of atom interferometry techniques using the CAL apparatus on the International Space Station (ISS). Second, we are investigating methods to produce an ultra-low temperature atom source in free space using the CAL apparatus. The apparatus produces atoms confined in a magnetic trap, but inertial measurements require free atoms. We will investigate releasing the atoms by gradually turning off the trapping fields, allowing the atoms to adiabatically expand and cool off. This can produce a relatively dense and very low-velocity sample that is ideal for atom interferometry methods. Third, we will continue ground-based studies to develop novel precision measurement techniques for use with atom interferometry, such as tune-out spectroscopy. Techniques like this are useful for advancing scientific knowledge and would be good candidates for future flight studies.
Rationale for HRP Directed Research:	
Research Impact/Earth Benefits:	The development of precision inertial sensing techniques is useful for Earth-based as well as space-based navigation. Besides using direct sensing for inertial navigation, rotation sensing can also be useful for north-finding while gravity sensing can be used to tabulate local gravity variations and form a type of three-dimensional map for navigating. These techniques also have many applications in geophysics. Gravity sensing can be used for oil and mineral exploration, while rotation sensing can detect dynamics in the Earth's core. Gravity sensing also has defense applications such as locating underground tunnels and potential screening cargo for high-density contraband or weapons. Other precision measurement applications have less direct impact, but advance scientific knowledge. For instance, precision tune-out spectroscopy measurements of atomic matrix elements can be used to improve the interpretation of atomic parity violation experiments. These in turn impact our understanding of the standard model of particle physics and thus the nature of our universe. Direct benefits of such understanding can be hard to trace, but in general the continued advance of technological applications builds on advances in our fundamental knowledge.
Task Progress:	Efforts on the Cold Atom Laboratory (CAL) during the performance period continued our efforts to explore and improve adiabatic expansion methods for dual species gases. In the first part of the year, we achieved some promising results, but found evidence that the trap expansion was limited by large background magnetic fields. We then worked on developing better methods to measure the background field using radio frequency (rf) spectroscopy. With good knowledge of the background field, we could optimally compensate using the available electromagnetic circuits in the apparatus. Unfortunately, the apparatus began suffering a series of problems while this study was underway. Initially, the atom sourcing of the CAL 3 apparatus failed, so that cold atom samples could not be reliably produced. The team decided to suspend operations until the new CAL 3B apparatus could be installed as a replacement. However, the 3B apparatus was discovered to have a vacuum leak, rendering it unusable for science. We are grateful to NASA and the Jet Propulsion Laboratory (JPL) for expediting the launch of the SM-1 system so that there is a chance to resume science operations in 2024. The SM-1 system will permit dual species operation, so we will be able to continue our adiabatic expansion studies. We have also developed a collaboration with Mark Edwards of Georgia Southern University to further analyze data from our early CAL 2B work. In that work, we observed the trajectory of atoms released from an adiabatically released trap. The trajectory provided information about the temperature of the atoms as well as the background magnetic field. With Edwards, we have developed a new technique to also analyze the changing size of the released cloud, which provides additional information about the temperature and field. Preliminary results support our original conclusions, but provide reduced uncertainties on the quantities of interest. In our ground-based work, we continued working on our atom-interferometer gyroscope project. After spending the previous year investigating the possibility of using a compact atom-chip system for the interferometer measurements, we have this year transitioned back to our lab-scale system. We completed several characterizations of the orientation and anharmonicity of the magnetic trapping potential that are needed to understand the interferometer performance. We also implemented an improved technique to compensate for tilting of the trap with respect to gravity. Unfortunately, we also discovered that a new noise source has appeared, causing the position of the atoms in the trap to fluctuate unacceptably from run to run. We have recently been investigating the source of this noise and working to eliminate it.
Bibliography Type:	Description: (Last Updated: 02/15/2024)
Abstracts for Journals and Proceedings	Beydler MM, Chu Z, Moan ER, Sackett CA. "Compact apparatus for an atom-chip gyroscope." 54th Annual Meeting of the APS Division of Atomic, Molecular and Optical Physics, Spokane, Washington, June 5-9, 2023. Bulletin of the American Physical Society. 2023 Jun 6;68(7):F01.00139. https://meetings.aps.org/Meeting/DAMOP23/Session/F01.139 , Jun-2023
Articles in Peer-reviewed Journals	Thompson RJ, Aveline DC, Chiow Sheng-Wey, Elliott ER, Kellogg JR, Kohel JM, Sbroscia MS, Schneider C, Williams JR, Lundblad N, Sackett CA, Stamper-Kurn D, Woerner L. "Exploring the limits of ultracold atoms in space." Quantum Science and Technology. 2023 Feb 6;8(2):024004. https://doi.org/10.1088/2058-9565/acb60c , Feb-2023
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Articles in Peer-reviewed Journals	Beydler MM, Moan ER, Luo Z, Chu Z, Sackett CA. "Guided-wave Sagnac interferometer with large area and multiple orbits." AVS Quantum Science. 2024 Mar 1;6(1). https://doi.org/10.1116/5.0173769 , Mar-2024