Fiscal Year:	FY 2023	**Task Last Updated:**	FY 02/17/2023
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:	1	**No. of Bachelor's Degrees:**	0
No. of Bachelor's Candidates:	1	**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:	March 2018 report: Our original Co-Principal Investigator (Co-PI) John Burke has left Air Force Research Laboratory (AFRL). Our point of contact at AFRL is now Brian Kasch.		
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 were centered on exploring and improving adiabatic expansion methods using the CAL 3 chip and the new dual species (Rb and K) capabilities. One of the advantages of adiabatic expansion is that it is readily adaptable to multiple species, making it a favorable method of state preparation for dual species experiments. A particular goal of our efforts is to prepare a very cold sample of Rb atoms in a non-magnetic state to use as a proof mass for acceleration and rotation sensing. For acceleration sensing, the idea is to release the atom cloud nearly at rest and use non-destructive imaging to determine their location. At time T later, the atoms would be imaged again, and finally a third time at time 2T. This would give the cloud center positions at three distinct times, from which the apparent acceleration could be obtained by direct comparison. For rotation sensing, the release atoms would be subject to a splitting pulse from CAL’s atom interferometry Bragg beam, producing two packets with opposite velocities. After time T, the Bragg beam would be applied again to bring a fraction of each packet to rest. Non-destructive imaging would be applied to measure the packet centers. The atoms would then freely evolve for time T, after which the packets would be imaged again. The rotation vector can then be obtained from the change in orientation of the two clouds. In order for this method to succeed, it is important that the atom cloud centers not drift out of imaging range during the observation time T, and that the clouds not expand so much that the absorption imaging signal becomes too weak. These can both be achieved by adiabatically expanding the clouds into a trap with confinement frequencies of a few Hz, similar to what was achieved in SM2. So far, the results in SM3 have been unfavorable, as we have run into difficulties reaching trap frequencies below about 15 Hz. We are, however, continuing to investigate this problem and hope to resolve it soon. In our ground-based work, we continued working on our atom-interferometer gyroscope project. During the previous year, we had obtained a compact atom-chip system from ColdQuanta. It is designed to allow interferometer operation similar to what we achieved in our laboratory-scale apparatus, but with a much smaller footprint, lower power consumption, and faster repetition rate. We spent most of the performance period learning how to work with the new apparatus and resolving some problems with it. Due to its compact design, any modifications are challenging and time consuming. Although we made considerable progress improving its operation, we came to the conclusion that there were still many issues that could be addressed more quickly using the larger lab-scale apparatus. So we have for now set the compact apparatus aside. We hope to return to it in the future when we can be more certain exactly what configuration is required to operate with the atom chip.
Bibliography Type:	Description: (Last Updated: 02/15/2024)
Abstracts for Journals and Proceedings	Sackett CA, Fallon A, Moan ER, Larson EA. "Measurement of the 87Rb D-line vector tune-out wavelength." 53rd Annual Meeting of the APS Division of Atomic, Molecular and Optical Physics (DAMOP), Orlando, Florida, May 30-June 3, 2022. Bulletin of the American Physical Society. 2022 Jun 1;67(7):abstract H04.00003. https://meetings.aps.org/Meeting/DAMOP22/Session/H04.3 , Jun-2022
Abstracts for Journals and Proceedings	Beydler M, Moan ER, Sackett CA. "Sagnac atom interferometer gyroscope with large enclosed area and multiple orbits." 53rd Annual Meeting of the APS Division of Atomic, Molecular and Optical Physics (DAMOP), Orlando, Florida, May 30-June 3, 2022. Bulletin of the American Physical Society. 2022 Jun 2;67(7):abstract S05.00002. https://meetings.aps.org/Meeting/DAMOP22/Session/S05.2 , Jun-2022

Abstracts for Journals and Proceedings	Sackett CA, Moan E, Beydler M. "Sagnac atom interferometer gyroscope with large enclosed area and multiple orbits." 27th International Conference on Atomic Physics, Toronto, Canada, July 17-22, 2022. Abstracts. 27th International Conference on Atomic Physics, Toronto, Canada, July 17-22, 2022. , Jul-2022
Abstracts for Journals and Proceedings	Sackett CA. "Bragg interferometer in a time-orbiting potential." Atomtronics 2022, Benasque, Spain, May 1-13, 2022. Abstracts. Atomtronics 2022, Benasque, Spain, May 1-13, 2022. , May-2022
Abstracts for Journals and Proceedings	Sackett CA. "Adiabatic expansion: Pursuing absolute zero at the Cold Atom Lab." Committee on Space Research (COSPAR) 2022, 44th Scientific Assembly, Athens, Greece, July 16-24, 2022. Abstracts. Committee on Space Research (COSPAR) 2022, 44th Scientific Assembly, Athens, Greece, July 16-24, 2022. , Jul-2022
Articles in Peer-reviewed Journals	Fallon AJ, Moan ER, Larson EA, Sackett CA. "Measurement of the 87Rb D-line vector tune-out wavelength." Phys. Rev. A. 2022 Mar 29;105(3):L030802. https://link.aps.org/doi/10.1103/PhysRevA.105.L030802 , Mar-2022
Articles in Peer-reviewed Journals	Thompson RJ, Aveline D, Chiow SW, Elliott ER, Kellogg JR, Kohel JM, Sbroscia MS, Philips L, Scheneider C, Williams JR, Bigelow N, Engles P, Lundblad N, Sackett CA, Woerner L. "Exploring the quantum world with a third generation ultra-cold atom facility." Quantum Sci. Technol. 2022 Dec 5;8(1):014007. https://dx.doi.org/10.1088/2058-9565/aca34f , Dec-2022