Fiscal Year:	FY 2022	**Task Last Updated:**	FY 06/13/2022
PI Name:	Sackett, Charles 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		
PI Email:	sackett@virginia.edu	**Fax:**	FY
PI Organization Type:	UNIVERSITY	**Phone:**	434-924-6795
Organization Name:	University of Virginia		
PI Address 1:	Physics		
PI Address 2:	382 McCormick Rd		
PI Web Page:			
City:	Charlottesville	**State:**	VA
Zip Code:	22904-1000	**Congressional District:**	5
Comments:	Other names: CA Sackett; Cass Sackett.		
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:	1	**Monitoring Center:**	NASA JPL
Contact Monitor:	Callas, John	**Contact Phone:**	
Contact Email:	john.l.callas@jpl.nasa.gov		
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 Co-Principal Investigator (Co-PI) John Burke has left Air Force Research Laboratory (AFRL) to take a program management job at DARPA (Defense Advanced Research Projects Agency). Our points of contact at AFRL are now Brian Kasch and Gordon Lott.		
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 developing and demonstrating atom interferometer capability. In the first part of the year, we completed a set of CAL runs that provided a measurement of the recoil frequency of the rubidium atoms used. The recoil frequency characterizes the energy delivered to an atom when it absorbs a single photon, and high-precision measurements of the recoil frequency are important for determining the fine-structure constant accurately. The demonstrations on CAL were not of high precision, but they showed that the atom interferometry capabilities could be used for a physically interesting measurement. These measurements will be documented in a joint paper with the CAL team on atom interferometry, which is currently under development. CAL suffered technical issues later in the year, and after these were repaired, the facility was focused on implementing cooling of potassium atoms. This limited time available for other experiments. However, the adiabatic expansion techniques that we previously developed proved highly useful in bringing the CAL system back online with a new trapping configuration, and for working with potassium after cooling was successful. In our ground-based work, we made substantial progress in our gyroscope progress, where we rebuilt the apparatus to improve reliability and stability. In the new apparatus, we demonstrated a Sagnac interferometer with an enclose area about ten times larger than our previous results, and we were able to maintain the interference signal after the atoms completed two orbits through the Sagnac path. Furthermore, with the improved stability we demonstrated continuous operation for approximately 36 hours, which was a sufficient time to obtain quantitative data on the stability of the Sagnac signal. Although the signal exhibited more noise than expected, it did not exhibit long term drifts. We believe that the anomalous noise is due to instability of our trap magnetic fields and we have developed a remediation plan. Our other ground experiment uses atom interferometry to characterize tune-out wavelengths in rubidium, optical wavelengths where the dynamic polarizability of the atom is zero. Last year a new student started on this apparatus, and was able to complete an analysis of earlier data. Those results were written up and published in January 2022.
Bibliography Type:	Description: (Last Updated: 07/01/2025)
Abstracts for Journals and Proceedings	Sackett CA, Sen B. "An atom interferometric measurement of the photon recoil frequency aboard the International Space Station." 52nd Annual Meeting of the APS Division of Atomic, Molecular and Optical Physics, Virtual, May 31- June 4, 2021. Bulletin of the American Physical Society. 2021;66(6):Abstract: C05.00001. https://meetings.aps.org/Meeting/DAMOP21/Session/C05.1 , May-2021
Abstracts for Journals and Proceedings	Beydler M, Sackett CA, Moan ER. "A compact atom-chip apparatus for Sagnac interferometry." 52nd Annual Meeting of the APS Division of Atomic, Molecular and Optical Physics, Virtual, May 31- June 4, 2021. Bulletin of the American Physical Society. 2021 May;66(6):Abstract: H09.00010. https://meetings.aps.org/Meeting/DAMOP21/Session/H09.10 , May-2021
Articles in Other Journals or Periodicals	Williams J, Aveline D, Bigelow N, Chiow S, Elliott E, Engels P, Gaaloul N, Kohel J, Krutzik M, Lundblad N, Meister M, Rasel E, Roura A, Sackett C, Sbroscia M, Schleich W, Thompson R, Worner L, Yu N. "Quantum test of the universality of free fall in Earth’s orbit." White Paper for the Decadal Survey on Life and Physical Sciences Research in Space 2023-3032, National Academies of Sciences, Engineering, and Medicine. Cleveland, Ohio : NASA Glenn Research Center, 2021. , Nov-2021

Articles in Peer-reviewed Journals	Luo Z, Moan ER, Sackett CA. "Semiclassical phase analysis for a trapped-atom Sagnac interferometer." Atoms. 2021 Mar 27;9(2):21. https://doi.org/10.3390/atoms9020021 , Mar-2021
NASA Technical Documents	Urban DL, Kim J, Paul AL, Sackett CA, Suman SR, Weislogel M, . "High Throughput Ground-based Reduced Gravity Testing." White Paper for the Decadal Survey on Biological and Physical Sciences Research in Space 2023-2032, National Academies of Sciences, Engineering, and Medicine. Cleveland, Ohio : NASA Glenn Research Center, 2021. NASA/Document ID# 20210023623. https://www.nationalacademies.org/our-work/decadal-survey-on-life-and-physical-sciences-research-in-space-2023-2032 , Nov-2021