Fiscal Year:	FY 2019	**Task Last Updated:**	FY 02/01/2019
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:**	10/30/2019
No. of Post Docs:	0	**No. of PhD Degrees:**	0
No. of PhD Candidates:	3	**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:**	
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Flight Program:	ISS		
Flight Assignment:	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:	We are pleased to report significant progress on the project, for both ground-based and flight-based efforts. In the flight effort, the CAL system launched in spring 2018 and PI operations commenced in November 2018. We have run about 500 successful sequences on the apparatus, pursuant to our effort to implement adiabatic cooling to very low temperatures, on the order of 100 pK or lower. This will be achieved by gradually relaxing the magnetic trap in which the atoms are confined. Initially, the atoms are held about 150 um from the atom chip that produces the trap magnetic fields, with an atom oscillation frequency of about 1200 Hz. Our goal is to move the atoms to about 1 mm from the chip, and reduce the trap frequency to 1 Hz or lower, while minimizing any motional excitation or sloshing of the atoms. We have successfully implemented a protocol for the first stage of this process, displacing the atom to the desired final location and reducing the trap frequency to 100 Hz, with no measureable motion excitation. We are presently working on reducing the trap frequency to about 2 Hz. We have observed atoms in a trap with this frequency, but accompanied by an unexpected source of heating or atom loss. We are investigating this loss process. If this can be resolved, it should be possible to attain temperatures below 1 nK in this trap. We expect to resolve this issue within the next few weeks. The final stage of expansion will require careful adjustment of the trapping fields to produce a stable but very weak trap. The effort required is not yet easy to predict, but there is a good chance this project will be completed by the end of the current period. Follow-up projects include testing the use of supercooled atoms as an inertial reference mass, and support of the CAL upgrade to permit atom interferometry. In our ground efforts, we have successfully implemented an atom interferometer gyroscope with Earth-rate sensitivity. A Bose-Einstein condensate is produced in our specially-designed magnetic trap. Off-resonant lasers are used to coherently split the condensate into wave packets, which are then driven into circular trajectories orbiting the trap with a diameter of about 0.5 mm. When the packets are subsequently recombined they exhibit interference, and the phase of the interference is related to the rotation rate of the experimental platform. We observe interference signals with a visibility of about 60%. We have verified the rotation sensitivity by slightly rotating the optical table holding the apparatus, and the measured interference shift agrees with expectations. We are presently preparing a manuscript on these results for publication, which will certainly be completed by the end of the reporting period. Future efforts include increasing the size of the atom orbit, and allowing the atoms to make multiple orbits before measurement. Both of these techniques will enable further improvements to the rotation sensitivity.
Bibliography Type:	Description: (Last Updated: 02/15/2024)
Abstracts for Journals and Proceedings	Moan E, Sackett C, Luo Z. "A trapped-atom Sagnac interferometer using reciprocal circular trajectories." 49th Annual Meeting of the APS Division of Atomic, Molecular and Optical Physics (DAMOP) Meeting, Ft. Lauderdale, Florida, May 28–June 1 2018. Bulletin of the American Physical Society. 2018 May;62(8):Abstract ID: Q06.00010. http://meetings.aps.org/Meeting/DAMOP18/Session/Q06.10 , May-2018
Papers from Meeting Proceedings	Moan E, Luo Z, Sackett CA. "A large-area Sagnac interferometer using atoms in a time-orbiting potential." Presented at SPIE Photonics West (OPTO), Conference on Optical, Opto-Atomic and Entanglement-Enhanced Precision Metrology XII: OE120, San Francisco, CA, February 2-7 2019. Proceedings of SPIE Optical, Opto-Atomic and Entanglement-Enhanced Precision Metrology; 109341X, 2019. https://doi.org/10.1117/12.2515457 , Feb-2019