Fiscal Year:	FY 2018	**Task Last Updated:**	FY 02/28/2018
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		
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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:**	10/30/2019
No. of Post Docs:	0	**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: 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:	I. Preparations for flight missions We have concluded our initial preparations for our proposed adiabatic cooling experiments. We had previously implemented a model of the original CAL atom chip, but we were required to revise this calculation to reflect the final chip geometry that was implemented. The new geometry is slightly less effective for these experiments, but should still permit cooling to a three-dimensional temperature below 150 pK. We re-optimized our dynamical expansion model, and also corrected a small source of heating we discovered in the way that we had originally transitioned between the various current ramps involved. This work has now been published in Microgravity Science and Technology. We have also assisted the Jet Propulsion Laboratory (JPL) staff with their own efforts to model cooling methods, in particular delta-kick cooling. It seems at this time that the adiabatic expansion technique will be favorable for reaching ultralow three-dimensional temperatures. II. Ground Investigations Our ground efforts are directed at developing a rotation-sensing atom interferometer using atoms confined in a cylindrically symmetric magnetic trap. We have made considerable progress in this regard. We can now drive atoms into a circular trajectory with a diameter of about 0.6 mm. A total of four packets of atoms undergo this trajectory, forming two independent interferometer measurements. Most technical noise sources will be common to both interferometers, but the rotation phase from the Sagnac effect will be differential. For this, it is necessary for two pairs of trajectories to close upon themselves at the same time, since the atomic wave packets must overlap with each other to exhibit interference. So far we have achieved a closed trajectory for one pair, and we expect the tools we have developed will allow us to close the second pair as well. The interferometer configuration we are using should have sufficient rotational sensitivity to detect the rotation of the Earth. We have also made several technical improvements to the apparatus that have improved the reliability of its operation. Finally, we have initiated planning for the next stage of this experiment, where we hope to transition a working interferometer to a more compact chip-based apparatus. We have designed an atom chip that will provide magnetic field comparable to our current trap, and the chip is now being microfabricated by our collaborators at AFRL.
Bibliography Type:	Description: (Last Updated: 07/01/2025)
Abstracts for Journals and Proceedings	Moan E, Arpornthip T, Sackett C. "Characterizing the potential profile of an atom trap using tomographic fluorescence imaging." Presented at 48th Annual Meeting of the APS Division of Atomic, Molecular and Optical Physics (DAMOP), Sacramento, CA, June 5–9, 2017. Bulletin of the American Physical Society. 2017 May;62(8):Abstract ID:BAPS.2017.DAMOP.K1.12. http://meetings.aps.org/link/BAPS.2017.DAMOP.K1.12 , May-2017
Articles in Peer-reviewed Journals	Sackett CA, Lam TC, Stickney JC, Burke JH. "Extreme adiabatic expansion in micro-gravity: Modeling for the Cold Atomic Laboratory." Microgravity Science and Technology. 2018 May;30(3):155-63. First Online: 15 December 2017. https://doi.org/10.1007/s12217-017-9584-3 , May-2018