Fiscal Year:	FY 2017	**Task Last Updated:**	FY 06/14/2017
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:**	2
No. of PhD Candidates:	4	**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: Extended to 10/30/2019 per U. Israelsson/JPL (Ed., 12/14/17)		
Key Personnel Changes/Previous PI:			
COI Name (Institution):	Burke, John Ph.D. (Air Force Research Laboratory)		
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. 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:	In regards to our proposed flight experiments, we report the following progress: We have performed extensive modelling and analysis for the adiabatic cooling experiments. Using the original CAL1 chip trap, we developed a set of parameters that produces a very weak trap as an endpoint for expansion. We maintain a relatively large bias magnetic field in the trap to help reduce sensitivity to stray background fields. We expect that stray backgrounds will likely be the limiting factor in the expansion, but we have also modeled techniques to compensate for backgrounds using available current elements in the apparatus. The trap configuration we found will allow adiabatic cooling to a temperature of about 100 pK. We also investigated the dynamics of adiabatic expansion. We find that an expansion time of 10 s should be sufficient to maintain non-adiabatic heating effects below the 100 pK level. The dominant limitation here will again probably be background field gradients, since these cause the trap to shift in an uncontrolled way. This generally leads to motional excitation. We have documented these efforts in a paper recently submitted to Microgravity Science and Technology. We have also performed analysis relevant to our proposed inertial sensing flight experiments. The removal of the Bragg beam from the apparatus has required some changes to this project. We find that an accelerometer measurement should still be possible, with a measurement sensitivity of about 0.1 micro-g. We are exploring methods to recover a rotation measurement, at the 1 micro-rad/s level of accuracy. For our ground experiments, we continue development of an atom-interferometer gyroscope. It is essential to have a well-characterized trapping potential for the atoms to move in. We have developed a powerful and rapid method to measure the potential energy function, and we are exploring a new method to impose small adjustments to the potential in order to correct for any observed imperfections.
Bibliography Type:	Description: (Last Updated: 02/15/2024)
Abstracts for Journals and Proceedings	Fallon A, Leonard R, Sackett C. "High-precision measurements of the 87Rb D-line tune-out wavelength." 47th Annual Meeting of the APS Division of Atomic, Molecular and Optical Physics, Providence, Rhode Island, May 23-27, 2016. Bulletin of the American Physical Society. 2016 May;61(8):BAPS.2016.DAMOP.N5.9. http://meetings.aps.org/link/BAPS.2016.DAMOP.N5.9 , May-2016
Abstracts for Journals and Proceedings	Fallon AJ, Berl S, Sackett CA. "High-precision measurements of the 87-Rb vector polarizability." 83rd Annual Meeting of the APS Southeastern Section, Charlottesville, VA, November 10-12, 2016. Bulletin of the American Physical Society. 2016 Nov;61(19):BAPS.2016.SES.G4.7. http://meetings.aps.org/link/BAPS.2016.SES.G4.7 , Nov-2016
Abstracts for Journals and Proceedings	Moan E, Arpornthip T, Sackett CA. "Tomographic characterization of an atom trapping potential." 83rd Annual Meeting of the APS Southeastern Section, Charlottesville, VA, November 10-12, 2016. Bulletin of the American Physical Society. 2016 Nov;61(19):BAPS.2016.SES.G4.8. http://meetings.aps.org/link/BAPS.2016.SES.G4.8 , Nov-2016

Articles in Peer-reviewed Journals	Horne RA, Sackett CA. "A cylindrically symmetric magnetic trap for compact Bose-Einstein condensate atom interferometer gyroscopes." Rev Sci Instrum. 2017 Jan;88(1):013102. https://doi.org/10.1063/1.4973123 ; PubMed PMID: 28147663 , Jan-2017
Articles in Peer-reviewed Journals	Oh E, Horne RA, Sackett CA. "Fast phase stabilization of a low frequency beat note for atom interferometry." Rev Sci Instrum. 2016 Jun;87(6):063105. https://doi.org/10.1063/1.4953338 ; PubMed PMID: 27370424 , Jun-2016
Articles in Peer-reviewed Journals	Fallon AJ, Sackett CA. "Obtaining atomic matrix elements from vector tune-out wavelengths using atom interferometry." Atoms. 2016;4(2):12. Published online: 30 March 2016. https://doi.org/10.3390/atoms4020012 , Mar-2016