Fiscal Year:	FY 2016	Task Last Updated:	FY 02/01/2016
PI Name:	Williams, Jason Ph.D.		
Project Title:	Fundamental Interactions for Atom Interferometry with Ultra	cold Quantum Gases in a l	Microgravity Environment
Division Name:	Physical Sciences		
Program/Discipline:			
Program/Discipline Element/Subdiscipline:	FUNDAMENTAL PHYSICSFundamental 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:	Pasadena	State:	CA
Zip Code:	91109-8001	Congressional District:	27
Comments:			
Project Type:	Flight	Solicitation / Funding Source:	2013 Fundamental Physics NNH13ZTT002N (Cold Atom LaboratoryCAL)
Start Date:	04/01/2014	End Date:	05/03/2019
No. of Post Docs:	0	No. of PhD Degrees:	0
No. of PhD Candidates:	0	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
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Flight Program:	ISS		
Flight Assignment:			
Key Personnel Changes/Previous PI:			
COI Name (Institution):	D'Incao, Jose Ph.D. (University of Colorado)		
Grant/Contract No.:	Internal Project		
Performance Goal No.:			
Performance Goal Text:			

Task Description:	Precision atom interferometers (AI) in space promise exciting technical capabilities with diverse applications of interest to NASA. These quantum sensors are particularly relevant for fundamental physics research, with proposals including unprecedented tests of the validity of the weak equivalence principle, precision measurements of the fine structure and gravitational constants, and detection of gravity waves and dark matter/dark energy. Our studies will utilize the capabilities of NASA's multi-user Cold Atom Laboratory (CAL), in the microgravity environment onboard the International Space Station (ISS), to study mitigation schemes for the leading-order systematics expected to limit future high-precision measurements of fundamental physics with AIs in microgravity. The flight experiments, supported by theoretical investigations and ground studies at our facilities at Jet Propulsion Laboratory (JPL), will concentrate on the physics of pairwise interactions and molecular dynamics in ultracold quantum gases as a means to overcome uncontrolled AI shifts associated with the gravity gradient and few-particle collisions. We will further utilize the dual-species AI for proof-of-principle tests of systematic mitigations and phase-readout techniques for use in the next-generation of precision metrology experiments based on AIs in microgravity. Our proposed studies require the effective position invariance, long free fall times, and extremely low temperature samples uniquely available with the CAL apparatus. It is anticipated that our studies can lead to the unprecedented level of control and accuracy necessary for AIs to explore some of the most fundamental physical concepts in nature.	
Rationale for HRP Directed Research	:	
Research Impact/Earth Benefits:	Our studies are designed to achieve technological advances in precision metrology that can only be realized in the microgravity environment of the Cold Atom Laboratory. We utilize the tools of ultracold atomic and molecular physics (namely Feshbach resonances) for exquisite control of the differential center-of-mass distributions of the dual-species quantum gases and on methods to use the fundamentals of few-body interactions to maintain coherence in atomic ensembles for enhanced precision sensor capabilities. Subsequent proof-of-principle studies with the dual-species atom interferometer on CAL will further advance the state of the art for precision interferometry with ultracold matter waves. The impact of such research to the field of metrology can be seen through its potential to increase precision for atom-interferometry and also the possibility of engineering highly efficient system-specific devices based on the fundamental nature of few-body interactions. The microgravity environment of the CAL facility will strongly favor such explorations and allow for the possibility of uncovering novel effects and quantum phases of matter, a major goal in ultracold quantum gases and other disciplines of fundamental physics. These studies can benefit life on Earth by providing both fundamental understanding of nature in previously inaccessible environments and energy regimes, and by enhancing the tools available for scientific exploration at the highest precision.	
Task Progress:	 uttracoid quantum gases and other disciplines of fundamental physics. These studies can benefit life on Earth by providing both fundamental understanding of nature in previously inaccessible environments and energy regimes, and by enhancing the tools available for scientific exploration at the highest precision. Precision atom interferometers (AI) in space promise exciting technical capabilities with diverse applications of interest to NASA. These quantum sensors are particularly relevant for fundamental physics research, with proposals including unprecedented tests of the validity of the weak equivalence principle, precision measurements of the fine structure and gravitational constants, and detection of gravity waves and dark matter/dark energy. Our studies will utilize NASA's Cold Atom Laboratory (CAL), in the microgravity environment onboard the International Space Station, to study the leading-order systematics expected to limit future high-precision measurements using the ground test bed facilities a JPL, will concentrate on the physics of principle demonstrations and low-energy s-wave Feshbach molecules in ultracold quantum gases as a means to overcome uncontrolled AI shifts associated with the differential center of mass of two atomics species influenced by gravity gradients and rotational noise on the ISS for use in the next-generation of precision metrology experiments based on AIs in microgravity. Our proposed experiments require the effective positio invariance, long free fall times, and extremely low temperature samples uniquely available with the CAL apparatus. It anticipated that these studies can lead to the unprecedented level of control and accuracy necessary for future space missions, based on precision AI-based experiments to use the cAL dual-species AI recently integration AIs, to test some of the most fundamental physics missions. For each proposed study, the approace science management and data analysis plans, generatize experimental sequences, science required a	

	innovations required in our project and the sensitivity to numerous experimental/environmental parameters, access to the GTB will be enabling to mature our studies and to optimize our utilization of CAL. This work will progress through the remaining two months of this second-year effort.
Bibliography Type:	Description: (Last Updated: 05/30/2024)
Abstracts for Journals and Proceedings	Williams J, D'Incao J, Chiow S-W, Yu N. "Atom Interferometry with Ultracold Quantum Gases in a Microgravity Environment." Presented at the 6th International Symposium on Physical Sciences in Space and the 10th International Conference on Two-Phase Systems for Space and Ground Applications, Kyoto, Japan, September 14-18, 2015. 6th International Symposium on Physical Sciences in Space and the 10th International Conference on Two-Phase Systems for Space and Ground Applications, Kyoto, Japan, September 14-18, 2015.
Abstracts for Journals and Proceedings	 Williams J, D'Incao J, Chiow S-W, Yu N. "Atom Interferometry with Ultracold Quantum Gases in a Microgravity Environment." Presented at 46th Annual Meeting of the APS Division of Atomic, Molecular and Optical Physics, Columbus, OH, June 8-12, 2015. 46th Annual Meeting of the APS Division of Atomic, Molecular and Optical Physics, Columbus, OH, June 8-12, 2015. Abstract #C2.004. <u>http://adsabs.harvard.edu/abs/2015APSDMP.C2004W</u>, Jun-2015
Abstracts for Journals and Proceedings	 Williams J, Chiow S-W, Kellogg J, Kohel J, Yu N. "Atom Interferometer Technologies in Space for Gravity Mapping and Gravity Science." Presented at the 46th Annual Meeting of the APS Division of Atomic, Molecular and Optical Physics, Columbus, OH, June 8-12, 2015. 46th Annual Meeting of the APS Division of Atomic, Molecular and Optical Physics, Columbus, OH, June 8-12, 2015. Abstract ##K1.064. <u>http://adsabs.harvard.edu/abs/2015APSDMP.K1064W</u>, Jun-2015
Abstracts for Journals and Proceedings	 D'Incao JP, Williams JR. "Fundamental Interactions for Atom Interferometry with Ultracold Quantum Gases in a Microgravity Environment." Presented at 46th Annual Meeting of the APS Division of Atomic, Molecular and Optical Physics, Columbus, OH, June 8-12, 2015. 46th Annual Meeting of the APS Division of Atomic, Molecular and Optical Physics, Columbus, OH, June 8-12, 2015. Abstract #D1.036. <u>http://adsabs.harvard.edu/abs/2015APSDMP.D1036D</u>, Jun-2015