Fiscal Year:	FY 2017	**Task Last Updated:**	FY 06/16/2017
PI Name:	Olson, Sandra Ph.D.		
Project Title:	Fundamental Research on International Standard of Fire Safety in Space - Subteam 1: Study of Flammability of Fabric Materials		
Division Name:	Physical Sciences		
Program/Discipline:			
Program/Discipline--Element/Subdiscipline:	COMBUSTION SCIENCE--Combustion science		
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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PI Organization Type:	NASA CENTER	**Phone:**	216-433-2859
Organization Name:	NASA Glenn Research Center		
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City:	Cleveland	**State:**	OH
Zip Code:	44135	**Congressional District:**	9
Comments:			
Project Type:	FLIGHT,GROUND	**Solicitation / Funding Source:**	2012 Japanese Space Agency (JAXA) AO for Fundamental Research on an International Standard of Fire Safety in Space
Start Date:	07/01/2014	**End Date:**	06/30/2019
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:**	1
No. of Bachelor's Candidates:	0	**Monitoring Center:**	NASA GRC
Contact Monitor:	Urban, David	**Contact Phone:**	216-433-2835
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Flight Program:	ISS		
Flight Assignment:			
Key Personnel Changes/Previous PI:	Dr. Sandra Olson is U.S. Co-Investigator on Japan Aerospace Exploration Agency (JAXA)-sponsored project, “Flammability Limits At Reduced-g Experiment (FLARE)." JAXA Principal Investigator (PI) is Prof. Osamu Fujita, Hokkaido University.		
COI Name (Institution):			
Grant/Contract No.:	Internal Project		
Performance Goal No.:			
Performance Goal Text:			

Task Description:	The objective of the project is to develop a methodology to correlate material flammability limits in normal gravity and microgravity, which allows quantitative estimation of material flammability limit in microgravity based on the flammability data obtained on the ground. The project involves an international team including JAXA, NASA, ESA (European Space Agency), and universities in Japan, USA, and France. Dr. Olson is a U.S. Co-Investigator for the Japan Aerospace Exploration Agency (JAXA)-sponsored experiments to be conducted aboard the Japanese Experiment Module, Kibo. To establish global standards for fire safety in space, we seek to develop a fundamental understanding of how NASA's material flammability test, NASA-STD-6001.A Test 1, relates to the actual flammability of materials in micro and partial gravity. The investigation strategy is to perform extensive research via ground-based experiments, including 1g and parabolic flight tests, and via theoretical formulations. Flight experiments on orbit in International Space Station (ISS)/KIBO will be performed to verify the correlation. The flight experiments on orbit are expected in 2018 or later. By the end of the project, a new fire safety standard test method for screening spacecraft materials will be proposed that addresses the shortcomings of existing standard test method such as NASA STD 6001B.
Rationale for HRP Directed Research:	
Research Impact/Earth Benefits:	Studying materials flammability in space allows us to accurately control the flow field and thus elucidate the importance of a critical Damkohler number (flow time /reaction time) on flame extinction. The anticipated improved methodology should reduce time and cost for the spacecraft material screening. Investigation and results have Earth benefits for terrestrial fire safety.
Task Progress:	A successful TIM (technical interchange meeting) and Phase 0/1 Flammability hazard review was held at NASA White Sands Test Facility (WSTF) Dec. 6-8, 2016. Also discussed at that meeting was the FLARE project status and the ISO (International Organization for Standardization) standardization plan was updated. NASA has proposed an improved upward flame spread Test 1 of NASA STD 6001B which evaluates the upward limiting oxygen index and maximum oxygen concentration (ULOI/MOC) of a material in 1g. JAXA is pursuing a downward burning limiting oxygen index (LOI) method as a potential alternative index for flammability. For either of these methods, there is a discrepancy in the actual flammability limit in microgravity since material flammability can be higher in microgravity. An international workshop was held at European Space Research and Technology Centre (ESTEC), in Noordwick, Netherlands in January, 2017. At that meeting, the science teams presented their status to the group. In addition, plans for a parabolic aircraft campaign were discussed. A series of NASA Glenn Zero Gravity Research Facility (ZGRF) tests were continued this year with the updated Microgravity Wind Tunnel, which includes a new longer test section and two high resolution GIGE cameras. The tests were performed to determine the approximate high velocity blowoff limits for thin cotton fabrics for both opposed and some concurrent flow conditions. The materials were ignited in normal gravity and then the experiment was dropped. The ambient gas oxidizer concentration was switched to the test atmosphere to determine if the flame could survive in the reduced oxygen concentration during the 5.18 second drop. For opposed flow flame spread, the lowest section of the flammability boundary is filled in with microgravity drop data, and the wings of the boundary include normal gravity blowoff data from Fernandez-Pello, Ray, and Glassman (18th Symposium on Combustion, 1981) and Solid Surface Combustion Experiment (SSCE) quiescent microgravity data from Ramachandra et al. (Combustion and Flame 100, 1995). The minimum in the flammability boundary is at an oxygen concentration of ~13% O2 at approximately 10 cm/s, which is in the range of spacecraft ventilation flow velocities. The normal gravity buoyant only limit occurs at a limiting oxygen concentration of ~15.9% O2, significantly higher than the observed minimum in the flammability boundary. This demonstrates how a normal gravity test is not a conservative test to evaluate microgravity flammability. However, it may be possible to account for the buoyant flow and correct the data to predict a conservative microgravity limit, since the blowoff boundary is linear with flow down to very low velocities. If the blowoff boundary is determined via 1g testing, and the buoyant flow contribution is included, the minimum in the flammability boundary can be estimated by extrapolating to zero flow. Some concurrent ZGRF tests have also been conducted near the bottom of the flammability boundary, and the blowoff limits are even lower than opposed limits. Steady flames are obtained as low as 12% O2. The 12% O2 concurrent ZGRF flame spread tests were tracked to determine if they appeared to be stable. The flame length appears to grow linearly with flow, and the flame spread rate increases linearly with flow as well. This is in agreement with numerical modelling (Ferkul and T'ien, 1994). The flame length increases linearly with the flame spread rate, in agreement with the Markstein and deRis paper (1973) where they indicate a concurrent flame over a given material should have a constant burnout time (length/spread rate) for fixed oxygen and pressure. References Fernandez-Pello, A. C., Ray, S. R., and Glassman, I. (1981). "Flame spread in an opposed forced flow: the effect of ambient oxygen concentration." Symposium (International) on Combustion. Vol. 18. No. 1. Elsevier. Ramachandra, P. A., Altenkirch, R. A., Bhattacharjee, S., Tang, L., Sacksteder, K., & Wolverton, M. K. (1995). The behavior of flames spreading over thin solids in microgravity. Combustion and flame, 100(1), 71-84. Ferkul, P. V., and J. S. T'ien. (1994). "A model of low-speed concurrent flow flame spread over a thin fuel." Combustion science and technology 99.4-6 : 345-370. Markstein, G. H., & De Ris, J. (1973, January). Upward fire spread over textiles. In Symposium (International) on Combustion (Vol. 14, No. 1, pp. 1085-1097). Elsevier.

Bibliography Type:	Description: (Last Updated: 04/17/2024)
Abstracts for Journals and Proceedings	Olson SL. "Flammability limits of thin and intermediately thick fuels in normal and microgravity." Presented at FLARE International Workshop and International Topical Team Meeting, European Space Research and Technology Centre (ESTEC), Noordwjk, the Netherlands, January 23-26, 2017. FLARE International Workshop and International Topical Team Meeting, European Space Research and Technology Centre (ESTEC), Noordwjk, the Netherlands, January 23-26, 2017. , Jan-2017
Abstracts for Journals and Proceedings	Marcum JW, Olson SL, Ferkul PV. "Normoxic Low Pressure Blowoff Test Method for Exploration Atmospheres." Presented at FLARE International Workshop and International Topical Team Meeting, European Space Research and Technology Centre (ESTEC), Noordwjk, the Netherlands, January 23-26, 2017. FLARE International Workshop and International Topical Team Meeting, European Space Research and Technology Centre (ESTEC), Noordwjk, the Netherlands, January 23-26, 2017. , Jan-2017
Abstracts for Journals and Proceedings	Olson S. "Spacecraft Fire Safety Cohesive Experiment Utilization Plan: An International Topical Team Meeting Discussion Topic. " Presented at FLARE International Workshop and International Topical Team Meeting, European Space Research and Technology Centre (ESTEC), Noordwjk, the Netherlands, January 23-26, 2017. FLARE International Workshop and International Topical Team Meeting, European Space Research and Technology Centre (ESTEC), Noordwjk, the Netherlands, January 23-26, 2017. , Jan-2017