Fiscal Year:	FY 2019	**Task Last Updated:**	FY 10/24/2019
PI Name:	Takahashi, Fumiaki D.Eng.		
Project Title:	Structure and Stabilization of Laminar Jet Diffusion Flames		
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		
PI Email:	fxt13@case.edu	**Fax:**	FY
PI Organization Type:	UNIVERSITY	**Phone:**	440-520-5939
Organization Name:	Case Western Reserve University		
PI Address 1:	Mechanical and Aerospace Engineering		
PI Address 2:	10900 Euclid Ave		
PI Web Page:			
City:	Cleveland	**State:**	OH
Zip Code:	44106-1712	**Congressional District:**	11
Comments:	NOTE: Also affiliated with NASA Glenn Research Center		
Project Type:	GROUND,Physical Sciences Informatics (PSI)	**Solicitation / Funding Source:**	2015-16 Physical Sciences NNH15ZTT001N-15PSI-C: Use of the NASA Physical Sciences Informatics System – Appendix C
Start Date:	12/13/2017	**End Date:**	12/12/2019
No. of Post Docs:		**No. of PhD Degrees:**	
No. of PhD Candidates:		**No. of Master' Degrees:**	
No. of Master's Candidates:	1	**No. of Bachelor's Degrees:**	
No. of Bachelor's Candidates:		**Monitoring Center:**	NASA GRC
Contact Monitor:	Stocker, Dennis P	**Contact Phone:**	216-433-2166
Contact Email:	dennis.p.stocker@nasa.gov		
Flight Program:			
Flight Assignment:			
Key Personnel Changes/Previous PI:			
COI Name (Institution):			
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	In early 2012, the Structure and Liftoff In Combustion Experiment (SLICE) was conducted in the Microgravity Science Glovebox (MSG) aboard the International Space Station (ISS). Methane, ethylene, or a selected nitrogen dilution of each fuel issuing from a burner tube in coflowing air was ignited to form a laminar diffusion flame. Flow conditions and the finite-rate combustion chemistry caused the flame to detach from the burner rim and lift to a new stabilizing position downstream. The structure of the flame was characterized and the liftoff velocity limits were determined as a function of the fuel and burner diameter. The flame temperature, soot, and CH* radical concentrations were measured and compared with computation. Although the lifted flame far from the burner (~10 cm) might be stabilized with a triple-flame structure, i.e., a stoichiometric diffusion flame base with fuel lean and rich premixed branches, the stabilizing and lifting mechanisms of burner-rim-attached flames were still largely left unstudied.		

Task Description:	The global objective of the proposed research is to elucidate the diffusion flame stabilizing and lifting mechanisms. The specific aims include: (1) analyze thoroughly the SLICE liftoff velocity limit data to extract general trends, (2) conduct ground-based liftoff experiments using C1 – C4 hydrocarbons to study fuel effects, (3) perform computation with full chemistry to reveal the flame structure and flame-flow interactions, leading to the liftoff conditions. The overall merit of the proposed research is fundamental contributions to combustion science and NASA's microgravity combustion research, through the effective use of underutilized SLICE data on the liftoff limits and the rigorous validation of the numerical methods, including reaction mechanisms, soot formation, and radiation models. The Principal Investigator (PI) has more than 20 years of experience and knowledge in microgravity combustion research and has served as a co-Investigator for the SLICE project. Case Western Reserve University has recently expanded the Fire and Combustion Laboratories, equipped with various fire testing instruments, and the computation will be performed using the Case High Performance Computing Cluster. If successful, the proposed research will give a significant impact on the research area of flame stabilization, which has been one of major subjects of interest since the early days of modern combustion research, started several decades ago. As a result of recent advances in flame diagnostic techniques and numerical predictive capabilities, including comprehensive chemical kinetics, it is now feasible to elucidate complex flame-flow interacting phenomena such as flame stabilization. A federal financial assistance is needed to accomplish such an important scientific goal.
Rationale for HRP Directed Research:	
Research Impact/Earth Benefits:	If successful, the proposed research will give a significant impact on the research area of flame stabilization, which has been one of major subjects of interest since the early days of modern combustion research, started several decades ago. As a result of recent advances in flame diagnostic techniques and numerical predictive capabilities, including comprehensive chemical kinetics, it is now feasible to elucidate complex flame-flow interacting phenomena such as flame stabilization.
Task Progress:	During the reporting period 12/13/2017 to 12/12/2018, we have performed the following tasks: (1) Hand-carried an engineering model of the Smoke Point in Co-flow Experiment (SPICE) experimental assembly from the NASA Glenn Research Center (GRC) to the Case Western Reserve University (CWRU) on 3/23/18. After setting up and running the experiment over the spring/summer, the apparatus was returned to the GRC on 8/31/18, in response to a request by NASA. Additional experiments are needed. (2) Measured the stability limits (lift-off and blow-off) of laminar diffusion flames in the Earth gravity (1g) in the SPICE apparatus for various fuels using various burner tube diameters. The fuels tested thus far include ethane, propane, butane, and 1-butene and the burner tube diameters used are 0.4 mm and 0.8 mm. In general, the critical fuel jet velocity at the flame lifting is larger for a larger fuel tube diameter, for alkenes than alkanes (due to the higher reactivity), and for a lower number of fuel carbon atoms (due to the lower fuel density). The critical fuel jet velocity for ethane with 0.8 mm dia. fuel tube in the present experiment is approximately 21% higher than that obtained in the SLICE's 1g test in 2012 [Takahashi et al., 2012]. The calibration of the fuel mass flow controller and the air fan need to be completed. Other fuels planned to be tested include methane, ethylene, acetylene, and propene. However, because of the SPICE apparatus's upper limits of the mass flow controller for fuel (500 sccm in N2) and the coflowing air speed (~65 cm/s), the lifting limit could barely be reached for the fuel with a high reactivity such as ethylene even using the smallest burner tube diameter (0.4 mm). For a highly reactive fuel such as acetylene and/or for a larger diameter will require an experimental apparatus capable of wider fuel and air flow rate ranges. (3) Initiated the fabrication of a new burner system for studying the structure and stabilization of laminar diffusion flames in 1g at the CWRU campus. The burner consists of a stainless-steel fuel tube (0.4 – 2.1 mm i.d.) and a coaxially installed contour nozzle (~25 mm i.d. exit) for the coflow air. Four mass flow meters (Hastings, HFM-200 and HFM-201) have been purchased for the flow ranges of 500 sccm N2 for the fuel, 200 sccm N2 for an additive to the fuel, 50 slpm for the coflow air, and 15 slpm for an additive to the air. The burner assembly will be installed on a 3D translational stage for the diagnostic measurements. (4) Made an oral presentation of the results of the stability limits, obtained using the SPICE experimental apparatus, at the 34th Annual Meeting of the American Society for Gravitational and Space Research, Bethesda, Rockville, MD, October 31-November 3, 2018. Reference: Takahashi, F., Kulakhmetov, R., Stocker, D.P., Ma, B., and Long, M.B., Microgravity Enhances the Stability of Gas-Jet Diffusion Flames, 28th Annual Meeting of the American Society for Gravitational and Space Research, New Orleans, LA, November 28-December 2, 2012.
Bibliography Type:	Description: (Last Updated: 04/14/2021)
Abstracts for Journals and Proceedings	Smith L, Souza D, Takahashi F. "Stabilization of Laminar Jet Diffusion Flames." 34th Annual Meeting of the American Society for Gravitational and Space Research, Bethesda, MD, October 31-November 3, 2018. Program & Abstracts. 34th Annual Meeting of the American Society for Gravitational and Space Research, Bethesda, MD, October 31-November 3, 2018. , Nov-2018