Fiscal Year:	FY 2020	**Task Last Updated:**	FY 11/29/2019
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		
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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:**	12/12/2020
No. of Post Docs:		**No. of PhD Degrees:**	
No. of PhD Candidates:		**No. of Master' Degrees:**	1
No. of Master's Candidates:		**No. of Bachelor's Degrees:**	
No. of Bachelor's Candidates:		**Monitoring Center:**	NASA GRC
Contact Monitor:	Stocker, Dennis P	**Contact Phone:**	216-433-2166
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Flight Program:			
Flight Assignment:	NOTE: End date changed to 12/12/2020 per NSSC information (Ed., 11/29/19)		
Key Personnel Changes/Previous PI:			
COI Name (Institution):			
Grant/Contract No.:	80NSSC18M0040		
Performance Goal No.:			
Performance Goal Text:			

Task Description:	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. 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:	In early 2012, the Structure and Liftoff In Combustion Experiment (SLICE) was conducted in the Microgravity Science Glovebox (MSG) aboard the International Space Station [1]. A gaseous hydrocarbon fuel (methane, ethylene, or a selected nitrogen dilution of each fuel) issuing from a small burner tube in coflowing air was ignited to form a laminar diffusion flame. As the fuel or air velocity was increased gradually, the flame base detached and lifted off the burner rim, stabilized at a new position downstream, and blew out eventually due to the finite rate of chemical reactions. In this study, the stabilizing mechanism of laminar diffusion flames has been examined further in normal Earth gravity (1g). During the reporting period 12/13/2018 to 12/12/2019, we have performed the following tasks: (1) By using the engineering model of the Smoke Point in Co-flow Experiment (SPICE) experiment assembly, loaned from the NASA Glenn Research Center (GRC), the stability limits (lift-off and blow-off) of laminar diffusion flames have been measured in 1g [2, 3]. The fuels are methane, ethane, ethene, propane, butane, 1-butene, 70% methane in nitrogen, and 20% ethane in nitrogen. The fuel tube inner diameters are 0.4 mm and 0.8 mm. In general, the critical fuel jet velocities at the flame stability limits are larger for a larger fuel tube diameter, for alkenes than alkanes (due to the higher reactivity), and for a lower number of carbon atoms (due to the lower fuel density). (2) Furthermore, by using a newly fabricated experimental apparatus, the stability limits have been measured over much larger ranges of the fuel and air velocities as well as the fuel tube diameter than those of the SPICE rig. The apparatus consists of a stainless-steel fuel tube (0.4 – 3.2 mm i.d.) coaxially installed in a glass chimney (95 mm i.d.). In addition to the pure C1 – C4 hydrocarbons mentioned above, acetylene is also used as the fuel. (3) The computation with detailed chemistry to reveal the diffusion flame structure and flame-flow interactions leading to the flame stability-limit conditions has been initiated. A chemical reaction mechanism for butane has newly been incorporated in the in-house numerical code, especially capable of simulating unsteady flame-flow interaction phenomena such as the flame stabilizing process. REFERENCES 1. 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. 2. Smith, L., Souza, D., and Takahashi, F., Stabilization of Laminar Jet Diffusion Flames, 34th Annual Meeting of the American Society for Gravitational and Space Research, Bethesda, Rockville, MD, October 31-November 3, 2018. 3. Smith, L., Souza, D., and Takahashi, F., Stabilization of Laminar Hydrocarbon Jet Diffusion Flames in Earth Gravity and Microgravity, 27th International Colloquium on the Dynamics of Explosions and Reactive Systems, Beijing, China, July 28th - August 2nd, 2019.
Bibliography Type:	Description: (Last Updated: 06/13/2025)

Abstracts for Journals and Proceedings	Smith L, Souza D, Takahashi F. "Stabilization of Laminar Hydrocarbon Jet Diffusion Flames in Earth Gravity and Microgravity." 27th International Colloquium on the Dynamics of Explosions and Reactive Systems, Beijing, China, July 28-August 2, 2019. Abstracts. 27th International Colloquium on the Dynamics of Explosions and Reactive Systems, Beijing, China, July 28-August 2, 2019. , Jul-2019