Fiscal Year:	FY 2021	**Task Last Updated:**	FY 04/12/2021
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.:			
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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.
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:	A laminar jet diffusion flame is formed by igniting a gaseous hydrocarbon fuel issuing from a small stainless-steel burner tube (0.4 to 2.5 mm i.d.) in coflowing air through a coaxial glass chimney (95 mm i.d.) or a converging nozzle (25 mm i.d.). As the fuel or air velocity is increased gradually, the flame base detaches and lifts off the burner rim, stabilizes at a new position downstream, and blows out eventually due to the finite rate of chemical reactions. This study investigates the stabilizing mechanism of laminar jet diffusion flames in normal Earth gravity (1g) and microgravity (ug) experimentally and computationally. During the reporting period, we have performed the following tasks. (1) Measured the stability limits of laminar coflow jet diffusion flames of propene in 1g for the fuel tubes with inner diameters of 0.8 and 1.6 mm, in addition to the fuels investigated previously (i.e., methane, ethane, ethylene, acetylene, propane, butane, butene). (2) Performed the computation using the in-house numerical code (UNICORN) with a newly incorporated chemical reaction mechanism applicable to C1 to C4 hydrocarbons. Successfully revealed the structure of a butane jet diffusion flame, for the first time, as the flame base lifted off the burner rim gradually until blowout, in response to incremental increases in the coflowing air velocity. The predicted flame stability limit was in good agreement with the measurement.
Bibliography Type:	Description: (Last Updated: 06/13/2025)
Articles in Peer-reviewed Journals	Takahashi F, Smith L, Souza DT, Katta VR. "Critical conditions at liftoff limit of a laminar n-butane-air jet diffusion flame." Proceedings of the Combustion Institute. 2023 Jan 1;39(2):1657-67. https://doi.org/10.1016/j.proci.2022.07.037 , Jan-2023
Dissertations and Theses	Souza DT. "Effects of Inert Gases and Flow Velocities on the Structure and Stability of Coflow Diffusion Flames." M.S. Thesis, Department of Mechanical Engineering, Case Western Reserve University, May 2021. , May-2021