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Project Title: Right Fidelity Experiments and Computations of Transieur Two-Phase Flow for Understanding Cryogenie Propellant Iransfer Program/Dicipline- Element/Subdicipline-			Task Last Updated:	FY 10/01/2023
Project Tank Transfer Physical Sciences Program/Discipline: Program/Discipline: Program/Discipline- FLUID PHYSICS-Fluid physics Program/Discipline- FLUID PHYSICS-Fluid physics Program/Discipline- Program/Discipline- Program/Discipline: Program/Discipline: Program/Discipline: Program/Discipline: None Program Rids: None Program Rids: None Program Rids: None Program Rids: Program Rid: Program Ri	PI Name:			
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Finant Research Program Elements None TechPort No None	Program/Discipline:			
Human Research Program Elements None Human Research Program Risks: None Space Biology Element: None Space Biology Cross-Element Disciplines None Space Biology Special Category: None P1 Email: multikov@illinois.edu Fax: FY P1 Organization Type: University of Illinois. Urbana-Champaign Frame Phone: 617-981-9247 P1 Address 1: Department of Mechanical Science and Engineering Laboratory Free Program Progra		FLUID PHYSICSFluid physics		
Human Research Program Riskis: None Space Biology Cross-Element Space Biology Special Category: None PI Email: nmilikov@illinois.edu Fax: FY PI Organization Type: UNIVERSITY Phone: 617-981-9247 Organization Type: UNIVERSITY Phone: 617-981-9247 Organization Name: University of Illinois, Urbana-Champaign PI Address 1: Department of Mechanical Science and Engineering PI Address 2: 105 S Mathews Ave, 2136 Mechanical Engineering Laboratory PI Web Page: City: Urbana State: IL Zip Code: 61801-2924 Congressional District: 13 Comments: Project Type: ELIGHT, GROUND Solicitation / Founding Southern Secure Southern Sou	Joint Agency Name:		TechPort:	No
Space Biology Element: None Space Biology Cross-Element Discipline: None PI Email: nmilkov@illinois.edu Fax: FY Pl Organization Type: UNIVERSITY Phone: 617-981-9247 Organization Name: University of Illinois, Urbuna-Champaign PI Address 1: Department of Mechanical Science and Engineering PI Address 2: Department of Mechanical Science and Engineering Laboratory PI Web Page: City: Urbana State: II. Zip Code: 61801-2924 Congressional District: 13 Comments: Project Type: FLIGHT,GROUND Solicitation / Funding NNH20/ZDA012N: Fluid Physics. Appendix A Start Date: 11/30/2021 End Date: 11/29/2026 No. of Post Does: 1 No. of Master' Degrees: 0 No. of Post Does: 1 No. of Master' Degrees: 1 No. of Master's Candidates: 2 No. of Master' Degrees: 1 No. of Master's Candidates: 2 Monitoring Center: NASA GRC Contact Monitor: Changes/Previous PI: SS Flight Assignment: 18S Flight Assignment: 18S Key Personned Changes/Previous PI: Sol23 and will continue work through 2024. COI Name (Institution): Yazdani, Mind Ph.D. (United Technologies Corporation) + September 1 Screen Science Sc	Human Research Program Elements:	None		
Space Biology Cross-Element Discipline: Space Biology Special Category: None PI Email: millikov@illinois.edu PI Email: PI Organization Type: UNIVERSITY Phone: 617-981-9247 Organization Name: University of Illinois, Urbana-Champaign PI Address 1: Department of Mechanical Science and Engineering PI Address 2: 105 S Mathews Ave, 2136 Mechanical Engineering Laboratory PI Web Page: City: Urbana State: II. Zip Code: 61801-2924 Congressional District: 13 Comments: Project Type: PILIGHT,GROUND Solicitation / Funding Name2, NNH20/ZDA012N: Fluid Physics. Appendix A Start Date: 11/30/2021 End Date: 11/29/2026 No. of PhD Candidates: 10. of PhD Candidates: 10. of PhD Candidates: 10. of Master's Candidates: 10. of Master's Candidates: 10. of Master's Candidates: 10. on G Bachelor's Candidates: 20. Monitoring Center: NASA GRC Contact Monitor: Chao, David Contact Email: david.fchao@inuss.gov Flight Assignment: 18S Key Personnel Changes/Previous PI: 2023 and will continue work through 2024. COI Name (Institution): Yazdani, Miad Ph.D. (United Technologies Corporation) Grant/Contract No.: 80NSSC22K0294	Human Research Program Risks:	None		
Discipline: None Space Biology Special Category: None PI Email: millikov@illinois.edu Fax: FY PI Organization Type: UNIVERSITY Phone: 617-981-9247 Organization Name: University of Illinois, Urbana-Champaign PI Address 1: Department of Mechanical Science and Engineering PI Address 2: 105 S Mathews Ave, 2136 Mechanical Engineering Laboratory PI Web Page: City: Urbana State: IL Zip Code: 61801-2924 Congressional District: 13 Comments: Project Type: FLIGHT,GROUND Solicitation / Funding Sources NNI120ZDA012N: Fluid Physical Sciences NNI120ZDA012N: Fluid Physical	Space Biology Element:	None		
PI Emaili: milikov@illinois.edu Fax: FY Pl Organization Type: UNIVERSITY Phone: 617-981-9247 Organization Name: University of Illinois, Urbana-Champaign PI Address 1: Department of Mechanical Science and Engineering PI Address 2: 105 S Mathews Ave, 2136 Mechanical Engineering Laboratory PI Web Page: City: Urbana State: IL Zip Code: 61801-2924 Congressional District: 13 Comments: Project Type: PLIGHT,GROUND Solicitation / Funding Sources NaPHZOZDADIZN: Fluid Physics. Appendix A. papendix A. pa		None		
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> Cryogenic chilldown governs initial stages of cryogen transport. Chilldown involves complicated hydrodynamic and thermal interactions between the liquid, vapor, and channel wall. Large initial temperature differences between the walls and the cryogen create rapid evaporation and large pressure and temperature fluctuation. Although work has attempted to identify transient flow boiling regimes, local surface temperatures, and heat fluxes, chilldown remains poorly understood due to the lack of experimental techniques capable of attaining high spatio-temporal resolution in both optical and infrared (IR) spectra. Furthermore, a lack of computational methods exists which can predict transient flow boiling and chilldown for a variety of length and time scales, and working fluid and system geometries. Here, we propose a collaborative effort between the University of Illinois, Urbana-Champaign (UIUC) and Raytheon Technologies (RTX) to develop fundamental understanding of chilldown using complementary high-fidelity experiments and computations. Internal flow pattern variations ranging from the film, transition, nucleate, to convection flow boiling using FC-72 and liquid nitrogen (LN2) in NASA relevant aluminum and stainless steel tubes, will be studied. We will use in-liquid endoscopy to study in-situ quench front propagation during FC-72 and LN2 flow boiling. The synchronous use of internal optical and external IR visualization will enable the gaining of a rigorous understanding of the thermal-fluidic behavior occurring in the near-wall region during chilldown and transient flow boiling. The obtained parameters, such as the quench front propagation rate and the temperature and heat flux distributions near the quench front, will then be used to validate high-fidelity computations. The computational framework at RTX leverages the established foundation that is capable of predicting the thermal and hydrodynamic behavior of multiphase flows in convective boiling and condensation regimes. The multiple scales associated with chilldown and two-phase flow boiling will be addressed through a combination of the previously developed Direct Numerical Simulation (DNS) approach for the nucleation near the wall, the Large Eddy Simulation (LES) formulation for the macroscopic transport in the core, and a novel coupling scheme for transporting the information across these scales. While the inherent transient phenomena such as solid condition, nucleation, and regime transition are an integral part of this framework, the model will be modified to allow transient boundary and operating conditions due to the operation of the tank during chilldown. The simulation will provide highly resolved information on the thermal and flow characteristics of two-phase cryogenic flow during the chilldown process and particularly the transient evolution of the flow regime during boiling. The model predictions will continually be validated against the high-fidelity experimental measurements over a range of test conditions. The work is broken down into tasks, which are briefly defined by: 1) Experimental analysis of transient heat transfer and pressure fluctuation during chilldown in Earth gravity with FC-72; 2) Integration of synchronous optical and IR visualization of chilldown with FC-72 and LN2 in Earth gravity for a variety of conditions including tube material, tube size, pressure difference, initial system temperature, and cryogen flow rate; 3) Simulations of transient flow boiling and chilldown in Earth gravity with FC-72 in order to provide physical insight on how the flow regime and boiling regime evolve over the course of chilldown; and 4) FC-72 flow

Task Description:

boiling tests in microgravity with simulation validation.

The outcomes of the on-Earth experiments will guide testing in microgravity on the Flow Boiling and Condensation Experiment (FBCE) on the International Space Station (ISS) to better understand the time-varying system pressure and temperatures during the cryogenic propellant transfer process.

Rationale for HRP Directed Research:

Research Impact/Earth Benefits:

Cryogenic chilldown governs initial stages of cryogen transport. Flow pattern variation and quench front propagation are crucial for analyzing and understanding the mechanism of chilldown.

Task Progress:

In the last reporting year, we completed the assembly of the loop for FC-72 but the assembled setup was just in its infancy and some issues happened when we got some preliminary results based on the verification tests. Therefore, in this early reporting year, we made several improvements to the setup to ensure the experiments and measurements operate at the desired conditions. The work on terrestrial experiments and microgravity experiments kept moving forward. We conducted terrestrial chilldown experiments with FC-72 in both copper and stainless-steel tube sections in the low Reynolds number region (<=10,000) and obtained useful heat transfer and pressure information for each test condition. The data helped us understand how the mass flow rates, subcooling, and thermal properties of the test section materials affect the transient flow boiling during the chilldown process.

In addition, as we confirmed the collaboration with Case Western Reserve University (CWRU) on the science requirement documents (SRD) in May of last year, we continuously promoted the progress of integrating our SRD and completed the integrated science requirements documents (ISRD) in September of this year after several rounds of discussion with NASA engineers and CWRU; some associated documents, e.g., the Experiment Data and Management Plan (EDMP) and Mission Requirements Documents, have also been prepared for the Science Requirements Review (SRR), which is due to occur in January of next year (2024).

Bibliography Type:

Description: (Last Updated: 09/29/2022)