Fiscal Year:	FY 2022	**Task Last Updated:**	FY 01/20/2022
PI Name:	Miljkovic, Nenad Ph.D.		
Project Title:	High-Fidelity Experiments and Computations of Transient Two-Phase Flow for Understanding Cryogenic Propellant Tank Transfer		
Division Name:	Physical Sciences		
Program/Discipline:			
Program/Discipline--Element/Subdiscipline:	FLUID PHYSICS--Fluid physics		
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:	nmiljkov@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 Source:**	2020 Physical Sciences NNH20ZDA012N: Fluid Physics. Appendix A
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No. of PhD Candidates:		**No. of Master' Degrees:**	
No. of Master's Candidates:		**No. of Bachelor's Degrees:**	
No. of Bachelor's Candidates:		**Monitoring Center:**	NASA GRC
Contact Monitor:	Chao, David	**Contact Phone:**	216-433-8320
Contact Email:	david.f.chao@nasa.gov		
Flight Program:	ISS		
Flight Assignment:	ISS		
Key Personnel Changes/Previous PI:			
COI Name (Institution):	Yazdani, Miad Ph.D. (United Technologies Corporation)		
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Task Description:	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 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:	New project for FY2022.
Bibliography Type:	Description: (Last Updated: 09/29/2022)