Fiscal Year:	FY 2016	**Task Last Updated:**	FY 10/19/2016
PI Name:	Eshraghi, Mohsen Ph.D.		
Project Title:	Pore-Mushy Zone Interaction during Directional Solidification of Alloys: Three Dimensional Simulation and Comparison with Experiments		
Division Name:	Physical Sciences		
Program/Discipline:			
Program/Discipline--Element/Subdiscipline:	MATERIALS SCIENCE--Materials 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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Comments:			
Project Type:	Ground,Physical Sciences Informatics (PSI)	**Solicitation / Funding Source:**	2015 Physical Sciences NNH15ZTT001N-15PSI-B: Use of the NASA Physical Sciences Informatics System – Appendix B
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No. of PhD Candidates:		**No. of Master' Degrees:**	
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No. of Bachelor's Candidates:		**Monitoring Center:**	NASA MSFC
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Flight Program:			
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COI Name (Institution):	Tewari, Surendra Ph.D. (Cleveland State University) Felicelli, Sergio Ph.D. (University of Akron)		
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Task Description:	Formation of shrinkage porosity and bubbles during solidification disturbs the dendritic array network and seriously degrades the mechanical properties of castings, whether these are large commercial castings of aluminum or steel alloys or a small directionally solidification single crystal turbine blade. Since in-situ observation of the interaction of pores/bubbles with the primary dendrite array in the mushy zone is not feasible in opaque metal alloys, transparent organic alloys solidifying in narrow gapped rectangular cross-section glass crucibles have been extensively used for such studies. However, all these observations are essentially between bubble and a two-dimensional (2D) array of primary dendrites and are affected by the wall effects. Analytical and numerical modeling of pore formation and migration in mushy zone have also been 2D. Contrary to earlier belief, it is now recognized that the basic premise of such experiments, i.e., 2D dendrites represent morphology of a three-dimensional (3D) array, is false. Understanding pore-mushy zone interaction in real castings requires both the experimental observations and also the theoretical/numerical modeling with 3D array of dendrites. Pore Formation and Mobility Investigation (PFMI) experiments were conducted in the microgravity environment aboard the Space Station with the intent of better understanding the role entrained porosity/bubbles play on microstructure during controlled directional solidification (DS). Although, the PFMI investigators have qualitatively described some of their observed interactions between the pore and mushy zone, no attempt has been made to analytically or numerically model these observed mushy zone disturbances caused by the presence of bubbles during directional solidification. Purpose of this research is to develop a numerical 3D model which can simulate the pore-mushy zone interaction during directional solidification of Succinonitrile-Water alloys in microgravity and test the simulation results against the PFMI microstructural observations, quantitatively and qualitatively. Several sets of time-temperature-interface-bubble interaction data will be extracted and analyzed from the PFMI videos for this purpose. In order to achieve this goal, we will exploit forefront methods in microscale solidification. We propose a methodology based on cellular automaton (CA) to track the interface and Lattice Boltzmann (LB) to solve the transport equations and simulate pore formation and its motion during directional solidification. The outcome of the proposed research will be an unprecedented tool to numerically simulate the pore-mushy zone interaction during directional solidification in a 3D domain, providing critical information on microstructure response to process parameters. This will have a huge impact on the design of improved mushy zone models based on the microstructure information obtained from the direct simulation. The developed knowledge will advance the state of understanding of solidification phenomena in the microscale, will contribute to improved numerical predictions of porosity formation, and will advance the state of the art in LB methods for simulating transport phenomena. PFMI is the only 3D spatial/temporal observation of pore-mushy zone interactions available to make qualitative/quantitative comparisons with our 3D LB-CA results as a unique model for large scale simulations of pore-mushy zone interactions with a micro-scale resolution. It is expected that this research will not only provide valuable contribution to the understanding of pore-mushy zone interaction during solidification in the absence of gravity, which would be helpful for future in-space fabrication processes involving solidification, but it will be a crucial first step to quantitatively simulate such 3D interactions during terrestrial DS in realistic size sample domains.
Rationale for HRP Directed Research:	
Research Impact/Earth Benefits:	It is expected that this research will not only provide valuable contribution to the understanding of pore-mushy zone interaction during solidification in the absence of gravity, which would be helpful for future in-space fabrication processes involving solidification, but it will be a crucial first step to quantitatively simulate such 3D interactions during terrestrial DS in realistic size sample domains.
Task Progress:	New project for FY2016.
Bibliography Type:	Description: (Last Updated: 12/24/2019)