Project Title: Nexus of Neutronics-Thermal Fluid Analysis for Optimizing Centrifugal Nuclear Thermal Propulsion

Project Summary: This project is focused on conducting a preliminary optimization study of Centrifugal Nuclear Thermal Propulsion (CNTP) engines, examining both reactor physics and thermal-fluid dynamics. The next chapter of human space exploration to our solar system and beyond requires highly efficient propulsion systems. Among various designs, fission nuclear thermal propulsion (NTP) stands out for its high thrust and high specific impulse (I_{sp}). Recently, the global consent to nuclear non-proliferation and the Comprehensive Nuclear-Test-Ban Treaty (CTBT) pivoted away from using high-enrichment uranium (HEU) in nuclear reactor cores. This shift promotes the adoption of High Assay Low Enriched Uranium (HALEU) fuel across nuclear reactor designs. With HEU no longer a viable option, increasing the temperature gradient is the key to improve I_{sp}. As such, CNTP with a liquid core design has gained significant attention from NASA. CNTP uses an array of fast-spinning cylinders that confine high-temperature molten uranium. When propellant is injected into the molten fuel as bubbles, a temperature of over 5,000K can be achieved. The extremely hot propellant helps the engine to reach an impressive I_{sp} of 1,800s, tripling that of the most efficient chemical propulsion system.

Although CNTP designs have undergone investigation, there is a lack of thorough optimization and parametric studies for maximizing I_{sp}. The missing piece is associated with developing accurate multi-physics simulations of CNTP systems. Our proposed study will fill this knowledge gap by first developing computational models combining reactor physics and thermal-fluid simulations that accurately capture the system behavior of the CNTP core. Subsequently, we will use the validated models to find the optimal parameters for reactor design to achieve maximum heat transfer from the fuel to the propellant. This preliminary optimization of the current CNTP design will offer insights into future research directions by identifying areas where further detailed optimization or data collection is needed.

Dr. Yitung Chen is Professor and Chair of the Department of Mechanical Engineering at the University of Nevada-Las Vegas (UNLV). He is an ASME Fellow. He received his Ph.D. degree from the Department of Mechanical

Engineering at University of Utah in 1991. He has extensive technical backgrounds of mechanical engineering, nuclear engineering, and chemical engineering. His academic and industrial experiences in numerical and experimental fluid mechanics and thermal-fluid sciences cover multidisciplinary areas of mechanical, nuclear, biomedical, environmental, and chemical engineering. His professional and scholarly endeavors are to apply the multidisciplinary advanced experimental and computational group includes fluid dynamics, heat transfer, mass transfer, computational mathematics and physics, electrochemical, and material sciences and engineering in order to solve the multi-scale and multi-physics engineering, science, and energy problems.

He has received many awards including the Alex G. and Faye Spanos Distinguished Teaching Award, the Barrick Distinguished Scholar Award, and the "Eminent Engineer and Distinguished Professor of the Year 2012" of the Tau Beta Pi Honor Engineering Society, and the Outstanding Teacher Awards from Department of Mechanical Engineering and the Distinguished Researcher Award from College of Engineering during his tenure at UNLV. He has served as PI and Co-PI on many funded research projects. The research funding for various projects amounted to more than $17.78M from the federal government agencies, state government and private sectors. Dr. Chen is co-author of three books "Computational Partial Differential Equations using MATLAB, 1st Ed. and 2nd Ed." and "Emerging Topics in Heat Transfer Enhancement and Heat Exchangers" and contributed 6 book chapters and he is author or co-author nearly 180 technical peer-review journals and 175 conference proceedings and 120 technical presentations in different fields that include computational fluid dynamics and numerical heat and mass transfer, finite element, finite volume, and meshless numerical techniques, lattice Boltzmann method, perturbation method, compressible flow simulation, nuclides atmospheric and environmental pollution modeling, nuclides contaminant groundwater flow, thermal system design, renewable energy, energy conversion, Gen IV advance pressurized water reactor, high temperature gas reactor, lead-bismuth reactor, and molten salt reactor designs and developments, advance nuclear fuel cycle, solar cell design using metamaterials, fuel cells, high temperature heat exchanger and decomposer design, corrosion and oxide layer growth modeling, solar and nuclear hydrogen production, and biomedical engineering. Both analytical/numerical studies and experimental studies are reported. Currently, he is also the Director of Center for Energy Research (CER) at UNLV.