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"Our Research Program Endeavors to Develop the Technologies Required for Fusion Propulsion Enabling Rapid, Human Piloted Trips to Mars"

Jason Cassibry
University of Alabama in Huntsville

1. Faculty or Research Mentor

Jason Cassibry
Associate Professor
Mechanical and Aerospace Engineering
Jason.Cassibry@uah.edu
(256) 824-5107
OKT S231
Propulsion Research Center
University of Alabama in Huntsville

I have not participated in the RCEU before, except as a reviewer a few years ago.

2. Project Summary

Our research program endeavors to develop the technologies required for fusion propulsion, enabling rapid, human piloted trips to Mars. Journeys to Mars will be possible with existing chemical propulsion technologies, but the journey takes 2 years to complete. The long duration in deep space exposes astronauts to debilitating microgravity effects on skeletal and muscle tissue and increases the risk of cancer from prolonged radiation exposure naturally occurring in space. Fusion can enable this trip with a roundtrip time of 4 months, making the trip to Mars both safe and routine.

A fusion propulsion laboratory is currently being developed at UAH within the Propulsion Research Center (PRC) and the Aerophysics Research Center (ARC), and will make use of Charger 1, a 560 kiloJoule (kJ), 3 Terawatt (TW) pulsed power machine. Charger 1 is a 'pulsed power' machine, in which electric energy is slowly charged in a set of capacitors and then discharged rapidly through an electrical load, much like the flash circuit in cell phone but at much larger energies and currents. The temperatures reached in properly designed 'targets' (i.e. the electrical load connected in series with the Charger 1 circuit) can reach 10^8 K, hotter than the temperature in the interior of the sun.

Among the critical parts of our research program are the theoretical tools which assist in experimental design, diagnostic analysis, and scaling. We have developed a 3D plasma code to be used for pulsed fusion experiments called Smooth Particle Hydrodynamics with Maxwell Equation solver (SPFMax) to be used for this purpose. The code has a self-consistent circuit and electromagnetic field solver implemented and is being debugged. We have also developed an independent circuit model of Charger 1, but this has not been coupled to SPFMax.

The student supported by this RCEU program will work closely with the PI to implement and test the Charger 1 circuit model using SPFMax. Once the circuit (modeled as a sequence of capacitors, inductors, and resistors in a transmission line network) has been implemented in SPFMax, the student will study the effects of three target geometries to support experimental planning to see the effects of material properties and geometry on the current pulse (maximum current, current rise time, and pulse width in nanoseconds). The three target geometries are 1) a dummy load consisting of a large resistor which we will use to shake out basic operation of Charger 1, 2) coaxial target consisting of a single wire of 100 micrometers in diameter and 2 cm long made of lithium with a return current in an annular cylindrical shell of inner radius of 2 cm, and 3) a coaxial target with a 2 cm radius of uranium, surrounded by a dielectric shell of lithium deuteride, and a return path of 3 cm with lithium, which will support work in fission/fusion hybrid targets being explored at NASA MSFC and supported by UAH. This student will be in the critical research path, and we will work closely with him/her to ensure success.

3. Student Prerequisites

Applicants need to be a junior by Summer 2017. The applicant is expected to have a 3.5 GPA, with a 3.75 being preferable. Programming experience in MATLAB is required, and experience in the C/C++ languages is preferable. It is preferable if the student holds a RSIC account for literature survey. Access to Redstone Arsenal is not required, but preferable. Required coursework includes Physics II, Numerical Methods, Electrical Circuit Analysis, and Differential Equations.

4. Student Duties

The student will first build a circuit model of Charger 1 in SPFMax, a matlab-based code. This will consist of setting up arrays of initial charging voltage, capacitance, inductance, and resistance in each of the major sections in a matlab input file. Results (current and voltage vs time across a trivial target load) will be compared with an existing circuit model to verify success. The student will then use an existing GUI to build the geometries of the three targets discussed in section 2. Input files will then be generated by the student, which includes providing material properties for the 3 targets. SPFMax will be run with these input files, and current, voltage, and magnetic field will be plotted vs time to study how the circuit model of Charger 1 couples to various materials and geometries.

We are going to use other funds to take the student with us to the AIAA Propulsion and Energy Forum in Atlanta, GA next summer towards the end of the RCEU program, where he/she will present his findings in a nuclear and future flight session at this conference, and write a corresponding AIAA conference paper on the results. The PI will be in attendance and be a coauthor on this paper. The student will be required to lead on the paper and will create and give the presentation, with assistance from the PI.

The student will be learning to use a unique and state of the art plasma tool, while applying the modeling to existing hardware supported by UAH, NASA MSFC, and the Boeing Company. SPFMax is a multiphysics code which includes shock capturing in plasma and solid density materials, ionization, tabular equation of state, radiation transport, and nonlocal deposition of charged particle and neutrons from fusion and fission reactions, and soon will include a self consistent circuit model. There are very few codes like it in existence, and the student will be work on cutting edge research enabling fusion propulsion for interplanetary spaceflight.

5. Mentor Supervision and Interaction

The student will be working independently with at least twice per week meetings with the PI (Dr. Cassibry) and with PhD student, Mr. Ross Cortez. The student will also meet weekly as part of the group which includes a team of graduate students using SPFMax and other models. Other meeting times will be scheduled as needed. These meetings will review the students work and progress, as well as offering feedback. He will be placed in an office with other graduate students in the PRC, and have routine access to the Charger 1 fusion propulsion lab at the ARC.