2002

NASA FACULTY FELLOWSHIP PROGRAM

MARSHALL SPACE FLIGHT CENTER
THE UNIVERSITY OF ALABAMA

MAGNATIZED TARGET FUSION IN ADVANCED PROPULSION RESEARCH

Prepared By:	Rashad Cylar
Academic Rank:	Undergraduate Student
Institution and Department:	Alabama A and M University Department of Engineering and Technology
NASA/MSFC Directorate:	Transportation
MSFC Colleague:	Steve Griffin Ph.D.

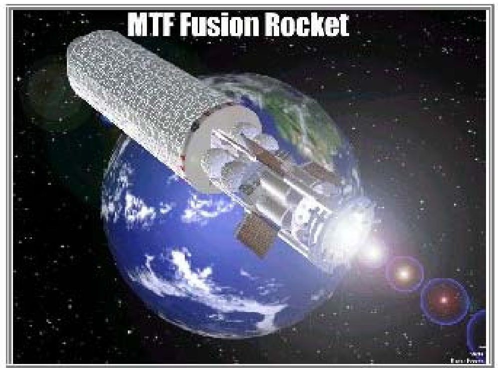

Figure 1: Proposed design for MTF Fusion Rocket

Introduction

The Magnetized Target Fusion (MTF) Propulsion lab at NASA Marshall Space Flight Center in Huntsville, Alabama has a program in place that has adopted to attempt to create a faster, lower cost and more reliable deep space transportation system. In this deep space travel the physics and development of high velocity plasma jets must be understood. The MTF Propulsion lab is also in attempt to open up the solar system for human exploration and commercial use.

Fusion, as compared to fission, is just the opposite. Fusion involves the light atomic nuclei combination to produce denser nuclei. In the process, the energy is created by destroying the mass according to the distinguished equation: $E = mc^2$. Fusion energy development is being pursued worldwide as a very sustainable form of energy that is environmentally friendly. For the purposes of space exploration fusion reactions considered include the isotopes of hydrogen-deuterium (D^2) and tritium (T^3).

Nuclei have an electrostatic repulsion between them and in order for the nuclei to fuse this repulsion must be overcome. One technique to bypass repulsion is to heat the nuclei to very high temperatures. The temperatures vary according to the type of reactions. For D-D reactions, one billion degrees Celsius is required, and for D-T reactions, one hundred million degrees is sufficient. There has to be energy input for useful output to be obtained form the fusion

To make fusion propulsion practical, the mass, the volume, and the cost of the equipment to produce the reactions (generally called the reactor) need to be reduced by an order of magnitude or two from the state-of-the-art fusion machines. Innovations in fusion schemes are therefore required, especially for obtaining thrust for propulsive applications. Magnetized target fusion (MTF) is one of the innovative fusion concepts that have emerged over the last several years. MSFC is working with Los Alamos National Laboratory and other research groups in studying the underlying principles involved in MTF.

Magnetized Target Fusion is an attempt to combine MCF (magnetic confinement fusion) for energy confinement and ICF (inertial confinement fusion) for efficient compression heating and wall free containment of the fusing plasma. It also seeks to combine the best features to these two main commonplace approaches to fusion. When plasma is magnetized a material wall implodes it to the required density and temperature. The use of gaseous linear as the imploding wall and the use of compact toroids as the target plasma. In the toroids there is a magnetic field that slows down the thermal loses from the target plasma to the imploding material wall. This allows a relatively low implosion velocity, which is required while achieving near adiabatic compression. The correct imploding velocity can be reached by highly efficient electromagnetic acceleration techniques as compared to lasers, leading to low cost and low weight compact reactors.

The plasma jets will implode target plasma, which is created from merging compact toroids generated through theta pinch coils. Two conical theta pinches are used to generate and launch to compact toroids in the form of spheromaks into a rector chamber. The spheromaks contain fissionable materials. Magnetic fields are embedded in the spheromaks in force-free Woltjer-Wells-Taylors State of minimum energy, which has been proving to be stable in experimental cases. Depending on the relative orientation to their helicity, an FRC is formed or a larger spheromaks. An FRC is formed when the helicity is counter-aligned, in any other case a spheromak is formed. Since a spheromak is in a state of minimum energy, it is expected to be more stable theoretically. Both cases continue to be investigated.

Fusion Propulsion Unit

This MTF concept has very attractive features:

- The dense, hydrogenous liner is capable of converting greater than 97% of the neutron energy into charged particle energy.
- An attractively low-level fusion yield per pulse can be maintained (< 1 GJ), with a gain in excess of 70.
- The magnetic nozzle can operate as a magnetic flux compression generator to provide the necessary circulating power for continued operation, yet still maintain a high nozzle efficiency.
- The electrical energy from flux compression can recharge a capacitor bank or other energy storage without using a high voltage power supply.
- The electrical circuit is comprised mainly of inductors, capacitors and plasma guns, without any intermediate equipment, which allows a high rep-rate.
- All fusion related components are within the current state of the art for pulsed power technology.
- The scheme does not require any prefabricated target or liner hardware. All necessary fuel and liner material are introduced into the engine in a gaseous form and delivered to the fusion reaction region in a completely standoff manner.

–There are no classification issues.

The Plasma Feed Charge/Dump Box

One of the main project that I worked on this summer was the Plasma Feed Charge/Dump Box. The Marshall Gun is the name of the gun that is used to fire the plasma into one central location, which produces propulsive reaction. Within the makeup of the plasma gun and all of its components there consist a system which initiates the Marshall Guns known as the Charge/Dump box. The Charge/Dump box acts as the charge circuit as well as the power supply for the plasma gun. The charge initiates the gun and the dump performs as a safeing system for the end of each test firing. Any unused energy is dumped through a common centralized ground.

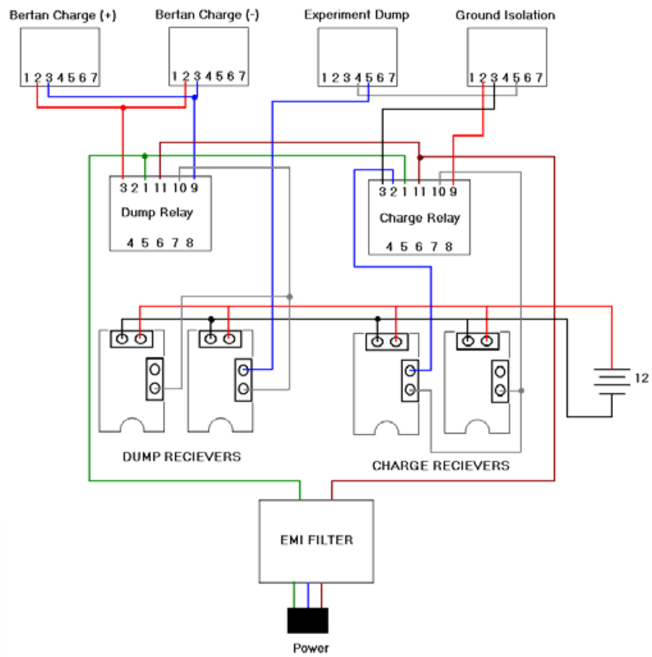

Figure 2: Relay Section of Box

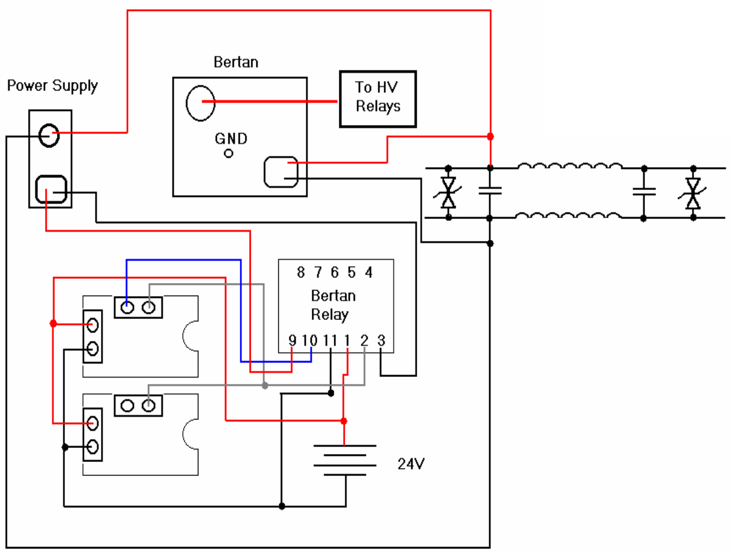

Figure 3: Bertan Section of Box

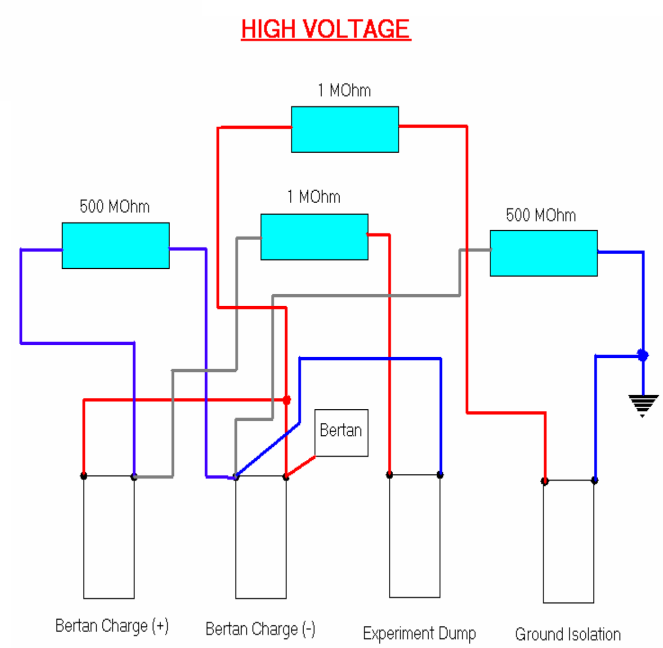

Figure 4: High Voltage Section of box

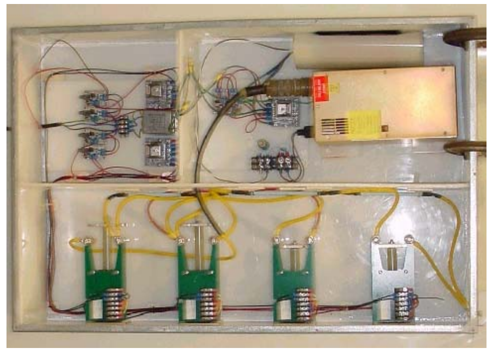

Figure 5: Actual Photo of Chare/Dump Box
Actual Size 3x4 Feet

Results

The construction of the Marshall Gun is still in the making and there has not been a firing of the Marshall Gun this summer. Previous tests were fired in the past three years, which has generated some interesting data. The Charge/Dump box has been armed and verified that it is in full working condition.

Future Applications for Magnetized Target Fusion

In the future, if a space vehicle is ever launched using Magnetized Target Fusion the charge dump box will play a major role in the vehicle's propulsion. The present construction of the Guns and Charge/Dump box is rather large and are strictly used for test purposes only. A more efficient and reliable construction will have to be made in order for the rocket to perform at the levels that MTF will produce.

Resources

The Plasma Feed Charge Dump box required the use of several materials found in the Electronics Lab located in Lab B. Some supplies not on hand had to be ordered. Jeff Richeson and Steve Griffin supervised the wiring of the dump box.

Conclusion

The NASA Summer Faculty Fellowship Program has been time well spent this summer. With this being my first summer with NASA, as well as my first internship as an undergraduate student, I have learned a lot and have grown to respect the work that is done at NASA's Marshall Space Flight Center.

Acknowledgements

I would like to thank all of Marshall Space flight Center's employees and contractors that I have worked with this summer. Special thanks to Propulsion Research Lab B and C for making this experience a good one.

References

[1] Clayton, P. R. (1992), *Introduction to Electromagnetic Compatibility*, John Wiley, pp. 242-279.