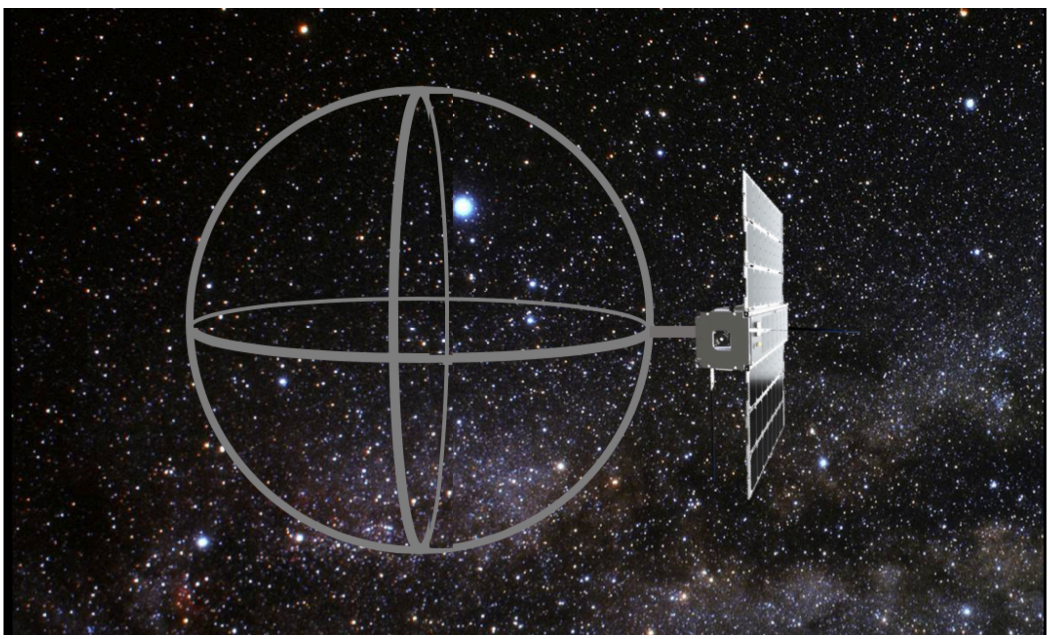
StarRider: a Technology Demonstration Mission for the Plasma Magnet Sail



By

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Abstract

The plasma magnet sail (PMS) is a lesser-known advanced propulsion concept, with the ability to generate very large drag forces in a space plasma environment. This could take the form of accelerating a spacecraft away from the sun to hundreds of kilometers per second using the solar wind, or creating drag in a planetary magnetosphere or ionosphere to brake a spacecraft into a capture orbit. Its simplicity, near-propellantless nature, and high thrust to mass ratio, make it very attractive for a number of missions including probes or even manned missions to the outer solar system. It also is potentially useful as a cost-saving secondary propulsion system for missions where a large part of the delta-V cost is in decelerating relative to the ambient space plasma.

The plasma magnet was invented by John Slough, a professor at the University of Washington, who has tested several prototypes in laboratory vacuum chambers. Its operating principle has been verified in an environment that simulated the solar wind plasma, but not one where multi-kilometer scale plasma phenomena can be observed, so its current technological readiness level (TRL) is 5. I propose a demonstration mission for this technology using a Cubesat, a satellite with a mass budget of several kilograms, made primarily out of commercial off the shelf (COTS) components. A Cubesat would not be able to mount the kind of multi-kilowatt system that a fast probe or manned mission would need, so it would bring the TRL of this technology to 7.

The primary objective of this mission is to verify the impressive performance that technology has on paper and in the lab tests. It will include several plasma diagnostics to test many of the assumptions that Slough uses to derive performance figures for the plasma magnet. If the thrust generated by the plasma magnet is close to that suggested by theory, the StarRider spacecraft should be capable of accelerating far past solar escape velocity to become the fastest object ever launched out of the solar system by humans. This is the secondary mission objective.

This mission promises to put a potentially revolutionary propulsion technology, as well as space decentral, in the public spotlight, and to pave the way for faster and lower cost interplanetary missions in the future. Once developed, the plasma magnet would be a versatile technology, enabling vastly more cost effective missions to Mars, the asteroids and the outer planets. As of now, these destinations are restricted to small probes launched by government agencies due to the high propulsion requirements of these missions, but plasma magnet technology could open up interplanetary travel to a broader range of non-government organizations.

Background

Many advanced propulsion concepts have been proposed which attempt to get around the huge propellant requirements of chemical rockets, some more feasible than others. The most proven concept is electric propulsion, where a strong electric or magnetic field accelerates a plasma up to speeds much higher than the exhaust gasses of chemical rockets. Fundamentally, all electric thrusters are limited by the amount of electrical power available, and adding more power generation capacity inevitably adds more mass to a spacecraft. Therefore, in order to maintain the advantage in delta-V over chemical rockets, mission designers are forced to use very low thrust systems, where a spacecraft fires its thrusters continuously, slowly spiraling away from Earth, and toward the destination. These trajectories usually take even longer than Hohmann transfers. Some, such as Franklin Chang-Diaz, inventor of the VASIMIR engine, have proposed using electric propulsion for fast transits to Mars, but this would require large space nuclear reactors with very high power to weight ratios, and regulations currently put the development of such a reactor out of reach of non-government organizations. Since fast space travel is fundamentally energy-intensive, the only way to avoid the nuclear option is to find an effective way to utilize solar energy. Traditional photovoltaic panels do not have a particularly good power to weight ratio, but since solar particles carry momentum as well as energy, it is possible for a spacecraft to entirely break free of the limits set by the rocket equation by utilizing solar energy.

Previous sail concepts

There are two main methods of doing this: lightsails and magnetic sails. Lightsails, more commonly known as solar sails, use an extremely thin sheet of reflective material to propel the spacecraft by exchanging momentum with photons from the sun. They are unlimited in terms of top speed, but are limited by thrust to weight ratio, since the only way to increase thrust is to make a larger sail, which increases mass. Eventually, a limit is imposed by the mass per area of the sail material, forcing the same slow spiraling trajectories that ion thrusters use. Lightsail-2, a planned Cubesat mission by the Planetary Society will have an acceleration of 58 micrometers per second squared [1].

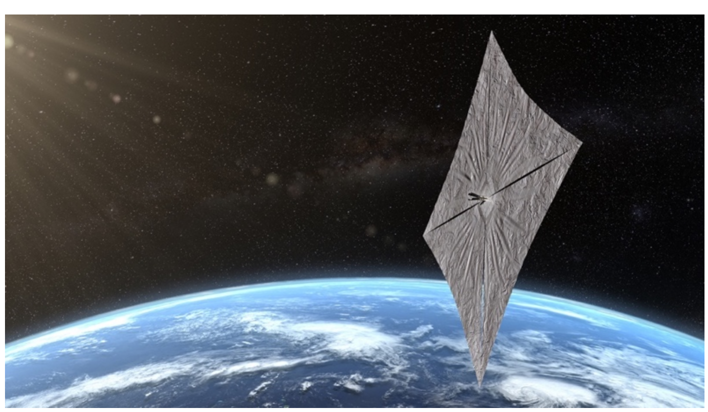

Figure 3: Artist rendition of the Lightsail-2 spacecraft [1]

The other option is a magnetic sail, where the “sail” is not a physical object, but a magnetic field generated by a spacecraft, which gains momentum by deflecting charged particles in the solar wind. The solar wind is composed of ions and electrons expelled from the super-hot solar corona at a velocity of between 350 and 800 kilometers per second. It imparts about a thousand times less force per unit area than sunlight, so a magnetic field must cover a much larger area than a lightsail to generate the same thrust. The concept was originated by Robert Zubrin and Dana Andrews in 1988, and involved an enormous (tens of kilometers) ring of superconducting wire to generate the necessary magnetic field [2]. However, it never left the drawing board due to the engineering challenges of creating a flexible, lightweight, superconducting wire and keeping it cold in space, to maintain superconductivity. In theory, high performance superconductors could allow accelerations up to a centimeter per second squared [3].

An earlier attempt to improve on this original magnetic sail concept was made by Robert Winglee, in 1999, which is usually called M2P2 (mini-magnetospheric plasma propulsion) or sometimes MPS (Magneto-plasma sail). In this design, an electrical power supply powers a dipole magnet and plasma is injected into that dipole field in order to add plasma pressure to expand it. Since it was proposed, other members of the advanced propulsion community have found some problems with it. Mainly, the plasma source on the spacecraft needs an extremely high magnetic flux to provide enough pressure for expansion, meaning that a realistic M2P2 propulsion system would need large superconducting magnets, and the cooling system to go with them. Also, the solar wind strips away the plasma quickly enough that the propulsion system has an effective specific impulse not much better than some ion thrusters [4].

The plasma magnet

A plasma magnet works in a superficially similar but fundamentally different way to M2P2. It operates more like an AC induction motor, or an induction cooktop. An alternating current, which is in this case is in the low frequency radio range is applied to a set of coils in order to generate a rotating magnetic field (RMF). This field induces an EMF in the surrounding plasma which accelerates electrons azimuthally until their acceleration is halted by the collisional drag force caused by the relatively stationary ions. Since the resistivity of space plasmas tends to be low (because of the high electron temperature), very large currents of tens of kiloamps can be produced. Magnetic hoop force will expand and spread out this plasma current ring until the magnetic pressure driving the expansion equilibrates with the pressure of the outside plasma environment. This is the sum of the magnetic field pressure, the thermal plasma pressure, and the dynamic plasma pressure. In pretty much all scenarios of interest, the dynamic pressure dominates over the others, and this directional pressure generates a propulsive force. The effective size of a plasma magnet sail depends on the outside plasma pressure, and will increase when that pressure decreases. Therefore, in the solar wind, it should produce constant thrust regardless of distance from the sun [3].

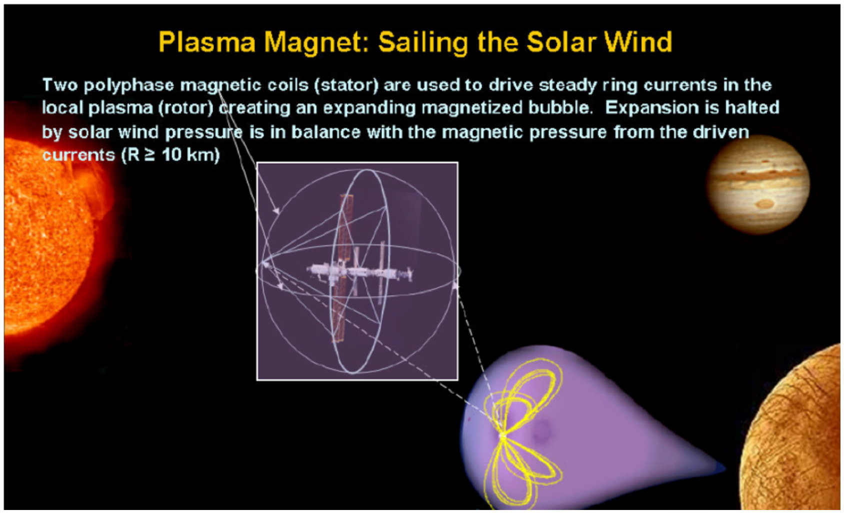

Figure 1: Illustration of a Plasma Magnet Sail. Note that the size of the spacecraft and its coils is insignificant compared to the magnetic field that it generates (bottom right) [3].

In the experimental work for the 2007 NIAC phase 2 study, Slough and colleagues tested a plasma magnet in a large dielectric vacuum chamber with a Magnetoplasmadynamic (MPD) thruster as a surrogate solar wind source. It was operated as a pulsed device for only 200 microseconds, but during that interval, dynamic equilibrium was observed with between the magnetic pressure of the plasma magnet and the dynamic plasma pressure provided by the MPD thruster. A large portion of the thrust from the MPD thruster was transferred to the plasma magnet coils, although there were several factors in the experiment which make extrapolating the thrust results to a real propulsion system difficult. The plasma also stayed expanded for a short time after the MPD thruster was turned off, demonstrating some of the enhanced stability characteristics suggested by theory [3].

By interacting with the solar wind on a large scale (tens to hundreds) of kilometers, a plasma magnet sail should be able to create thrust power several orders of magnitude greater than the electrical power it uses, and therefore can achieve far greater thrust to weight ratios than conventional electrical propulsion. An additional advantage is that it does not use a significant quantity of propellant. Slough estimates that plasma magnet creating a sail 100 kilometers in diameter would only require that 1.8 milligrams of gas be released by the spacecraft during the startup of the plasma magnet. The time constant for the dispersal of this plasma is 1.5 years, so even for a very small spacecraft, the storage for that gas would be a small portion of the spacecraft's mass budget [3].

The plasma magnet's main disadvantage as a propulsion system is that it can only generate thrust in the direction that the surrounding space plasma is flowing. In a planetary magnetosphere like Earth's, a plasma magnet would only be able to slow down an orbiting spacecraft, and a plasma magnet alone would not be able to achieve a capture orbit around planets without magnetospheres [3]. However, there is a technique called plasma aerocapture described by Kirtley et al [4]. Which would allow a plasma magnet with an additional dipole magnet coil to generate large braking forces in the upper atmospheres of planets via charge-exchange reactions, without going in deep enough to require an aeroshell [4].

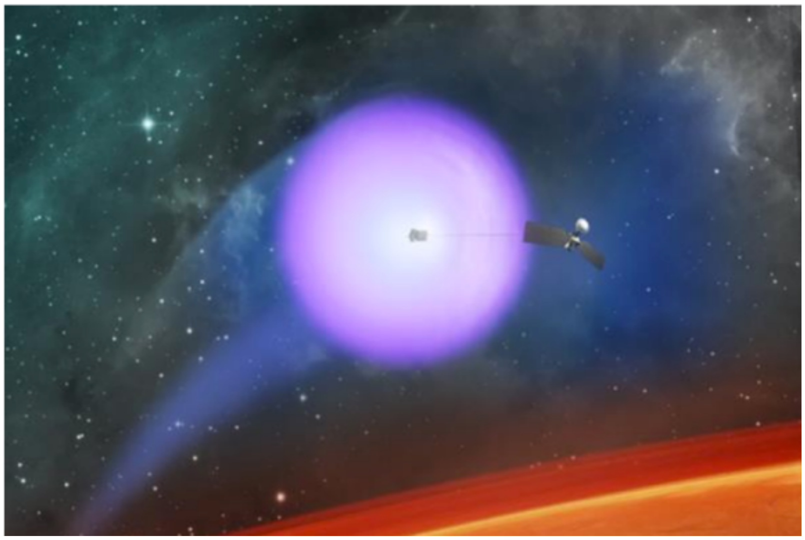

Figure 2: An illustration of a probe using plasma aerobraking at Mars (Kirtley, 2012)

A plasma magnet also can't accelerate a spacecraft beyond the velocity of the solar wind, which can vary from 300 to 900 km/s [3]. This speed is almost too fast for interplanetary travel, but is also not fast enough for interstellar travel on reasonable timescales. Even with these limitations, the following missions can be done with a plasma magnet using a kilowatt level power supply, and only minimal use of conventional propulsion.

1. Probes to the outer planets carrying multi-ton payloads
2. A tug spacecraft carrying radiation-shielded passenger modules from EML1 to low Martian orbit.
3. A flyby mission to the interstellar object 2017 U1 Oumuamua.
4. Sending telescopes to the solar gravitational lens point at 550 AU, to resolve continent-sized features on nearby exoplanets.

According to the scaling relation that Slough derives for the plasma magnet, the thrust it produces depends only on the coil radius, coil power, and plasma resistivity. For a coil radius of 7 meters (which is convenient for calculations), and a value of plasma resistivity from experimental results, thrust is given by:

$$eq1: \quad F = .0544 * P_{RMF}$$

Every 20 kilowatts of RF power adds about a kilonewton of thrust, significant for even large manned spacecraft [3]. By itself, the propulsion system would have an acceleration approaching a meter per second squared. A manned spacecraft on a long-term mission would carry a power supply of this category just for life support, and since the coils would not add much mass, it would be worthwhile to use a plasma magnet as a secondary propulsion system, which could save several kilometers per second of delta-V from missions to destinations like asteroids, where conventional propulsion is still needed for braking at the destination and returning to earth.

Technical Description

The impressive performance that this technology has on paper depends on several key consequences of the assumptions that go into the theoretical analysis. They are supported by computer simulations and laboratory tests, but need to be verified in the real space environment, which differs from the plasmas used in laboratory tests in that it has vastly lower density [3]. They are:

- That the plasma maintains high-beta equilibrium as it expands and is free of magnetohydrodynamic (MHD) instabilities.
- That the magnetic dipole field achieves 1/R scaling with radius in steady-state.
- That the resistivity of the plasma is similar to what was observed in lab tests.
- That the force on the plasma from solar wind pressure is efficiently transferred to the spacecraft.

The StarRider spacecraft will be equipped with electrical and plasma diagnostics to determine whether these effects occur as expected, and if they don't, collect data to inform future theoretical and computational analysis that may be able to address these unforeseen problems.

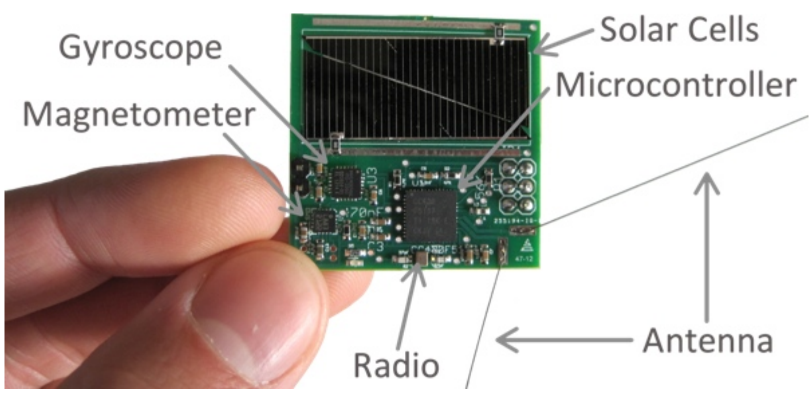

Figure 3: A "Sprite" chipsat, developed by project Kicksat

For measurements of plasma parameters away from the spacecraft, it will rely a set of deployable chipsats, spacecraft small enough to fit onto an single circuit board. It will carry several of these, the exact number determined by space and cost limitations. Each one would be ejected by a spring-loaded mechanism during a test of the plasma magnet, and would use a 3-axis magnetometer to measure the magnetic field profile as it drifts away, sending that data to the mothership to be relayed back to earth. Plasma beta during expansion can be determined from the magnetic field profile, as can the scaling of the field with radius in steady-state. If MHD instabilities, such as the ballooning and interchange instabilities should appear during startup, the data from these chipsats should allow some basic characterization of them, such as measuring their growth rates. Chipsats should also be able to roughly determine the edge of the artificial magnetosphere generated by the plasma magnet, and thus the effective area of the magnetic sail.

A chipsat could also gather more direct plasma data. Radio antennas are used by space probes to gather data on the temperature and density of the ambient space plasma environment, using thermal noise spectroscopy [6]. The density profile can be used to determine plasma confinement in the system, and thus the optimal rate for the spacecraft to release gas into the surrounding space. Electron temperature can determine plasma resistivity, a crucial parameter in Slough's estimations of plasma magnet performance [3]. However, this method would only be effective near the spacecraft, where the plasma Debye length is smaller than the length of the chipsat's antenna [6]. For reference, the Debye length of the solar wind is approximately 10 meters.

An important non-propulsion application of plasma magnet technology is as a shield against solar particle radiation. Some simulations suggest that a system as small as what is envisioned for StarRider should be able to accomplish this [10]. However, solar particle flux is difficult to measure with inexpensive equipment. The current associated with solar wind protons is on the order of nanoamps, far lower than most sources of noise in an electrostatic collector. Standard silicon charged particle detectors cannot detect particles with energy as low as most solar wind protons have, but some types of phosphorous-doped detectors may allow measurement of these particles if available within budget [7].

Propulsion System

The plasma magnet propulsion system is made up of three major subsystems: the RMF antennas, the power supply, and the gas supply. The antennas will be deployable, at 1-2 meters in diameter when fully deployed. The two loops connected directly to the spacecraft are the actual RMF antennas, with the third perpendicular to both of them being an unpowered loop used to measure magnetic flux. The most straightforward option for deploying these coils would be to have each of them attached to an inflatable fabric jacket, which would expand into the correct shape when inflated. Another option may be to use a shape-memory alloy like Nitinol. When heated by an electric current, nitinol wire will attempt to return to the shape that it was in the last time it was above its transition temperature. A wire made of a shape-memory alloy attached to each of the main coils, if shown to be a reliable deployment mechanism, would offer large mass and volume savings over an inflatable system, and would allow a larger antenna. According to Slough's scaling relations, the performance of a plasma magnet should scale linearly with antenna radius, so any significant increase in antenna size would be worthwhile [3].

The power supply needs to provide variable, low frequency (100-200 khz) RF power to the coils at high efficiency, and do so using a low-voltage DC source [3]. It consists of 3 main components: a sine wave generator, a power amplifier, and an oscilloscope for measuring the feedback signal. A class-C amplifier would be ideal because of its simplicity and high efficiency, although this would require a variable capacitor of much higher capacitance than is typically available, in order to adjust the resonant frequency of the antenna circuit. If this is impractical, then a less efficient class-B amplifier can be used. These electronics will need to be custom designed and assembled in order to miniaturize them down to the required specifications and make them space-capable.

The spacecraft will also need to discharge a small amount of gas into the surrounding space, at least during startup of the plasma magnet. Plasma density should drop off with the cube of radial distance from the spacecraft, for optimal RMF current drive. Since discharging gas at a constant rate will result in a density profile of one over R squared, the flow will need to be controlled at a non-constant but very slow rate. The total amount of plasma contained in the artificial magnetosphere at any one time will be a fraction of a milligram, and Slough estimates very high plasma confinement, so a gram of gas would be more than sufficient for the entire mission. The storage cylinder for the gas should be plenty small enough to fit into cubesat dimensions [3].

If the plasma magnet does startup successfully and generate measurable thrust, then the spacecraft will proceed with a series of tests to optimize its performance and determine empirical scaling relations. RMF power output can be varied within the bounds of a cubesat's limited power generation capacity to find the lower bound for thrust scaling. Using chipsat data from a first set of runs, RMF frequency and gas discharge rate can be adjusted in subsequent runs to find the optimal conditions for startup and steady-state operation.

Mission Profile

To begin running tests with the plasma magnet, the spacecraft needs to be far enough away from earth's magnetosheath that it can effectively interact with the solar wind. This distance corresponds to roughly 100,000 kilometers, and once the spacecraft is in an orbit with an apoapsis above this number, it can raise its orbit all the way to escape velocity (assuming the plasma magnet works as expected). A rideshare opportunity to the moon would be more than sufficient for this purpose. The spacecraft would deploy just after the trans-lunar injection burn, using most of its monopropellant to inject onto a gravity-assist trajectory resulting in a high elliptical orbit around the earth. In figure 4, an example of this kind of trajectory was modeled using "Children of a Dead Earth", a space combat game which includes a full n-body orbital mechanics model. It shows that a burn of only 20m/s is sufficient to alter the spacecraft's trajectory from a transfer to low lunar orbit to a high elliptical earth orbit with a period of about 14 days, which could be in a 2-1 orbital resonance with the moon if fine-tuned. If the launch is during waxing crescent moon, the spacecraft will be traveling away from the sun at apogee, and can begin running plasma magnet tests and raising its orbit in the process. However, if the launch time is not ideal, the spacecraft could use another lunar gravity assist to raise its perigee above 100,000 kilometers.

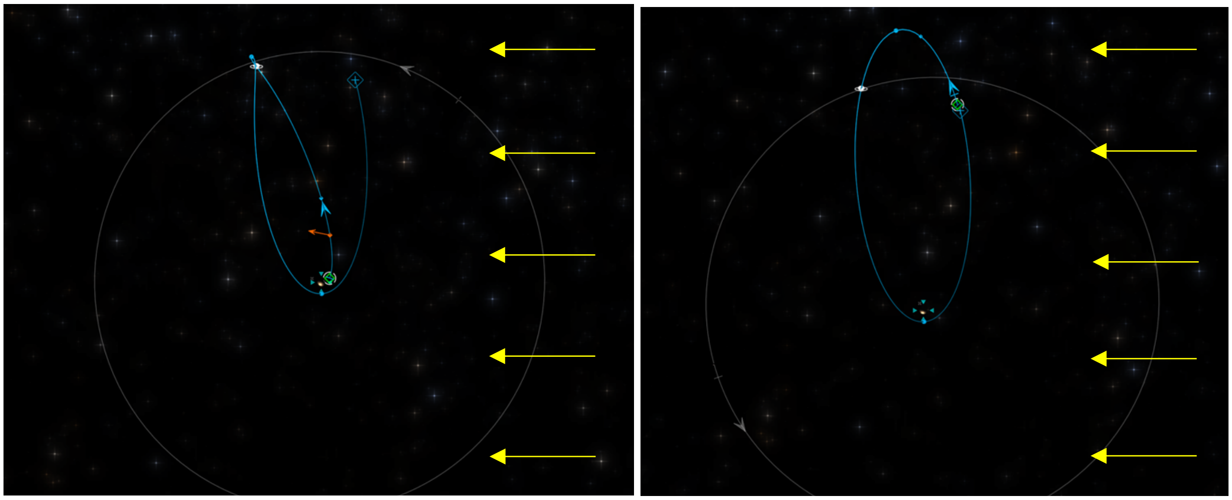

Figure 4: A gravity-assist trajectory around the moon (left) and the resulting earth orbit (right). Orange arrow indicates a course correction burn, and Yellow arrows indicate solar wind direction.

Although the primary mission objective is to test the performance of the plasma magnet as a propulsion system, the secondary objective is to attempt to break the record for the fastest interstellar object launched by humans. To determine if this objective is within the realm of possibility, an estimate must be made for the thrust generated by the plasma magnet.

The Clydespace 3U platform will serve as an example design for the following analysis, since it has a large solar array for its size and S-band communications, as well as a substantial payload capacity. With a 60% efficient power supply, it would produce about 30 watts of RMF power [8]. Substituting two of Slough's equations gives the following scaling relation for the thrust of a plasma magnet of arbitrary size:

$$eq2: \quad F = \frac{\mu_o}{8\eta} * R_o P_{RMF} C_d$$

Where R_o is the coil radius, P_{RMF} is RMF power, η is plasma resistivity and C_d is a drag coefficient relating the sail size implied by the balance between magnetic pressure to the real momentum transfer from the solar wind to the spacecraft [3]. Slough estimates a drag coefficient of 5 for a sail with an equilibrium radius of 30 kilometers, but does not comment on what it might be for a sail more fitting with Cubesat scale, only saying that a scale length of 10km is "sufficient" for "substantial" interaction with the solar wind. Given the enormous power leverage implied by equation 2 with $C_D > 1$, I'd call that a little more than substantial [3]. More recent computational studies have attempted to model smaller artificial magnetospheres, with varying results. A 2011 JAXA study estimated a drag coefficient of 1.1 for a 5.5 km sail, but another in 2014 by some of the same researchers implies a coefficient closer to .5 [9] [10]. However, both of these studies modeled a magnetic moment perpendicular to the solar wind direction, rather parallel to it, as in Slough's proposal. This difference in configuration may significantly alter the drag coefficient [3]. Therefore, simulation studies need to be done on this more specific configuration to get a thrust estimate that can be relied on.

For 30 watts of RMF power, a moderately conservative drag coefficient of .5, and a value of plasma resistivity from Slough's experimental results, equation 2 gives 57 millinewtons of thrust. With a mass of 5kg, as is a standard limit for a 3U Cubesat, acceleration is 11 millimeters per second squared. Starting from the apogee of the elliptical orbit in figure 4, it would take about a day of constant thrust to reach escape velocity. This time can be spread out over many tests and diagnostics for the plasma magnet, and it might be extended if the spacecraft can drop its orbit back down with a lunar gravity assist. High data-rate communication with Earth should be possible in this phase of the mission. For a 1 watt S-band transmitter on the spacecraft and a commercially available ground station with a 3 meter dish, The Shannon-Hartley theorem (equation 3) gives a channel capacity of 130 kilobits per second [11] [12].

$$eq3: \quad C_c = W * log_2(1 + \frac{P_{Signal}}{P_{Noise}})$$

For the top speed run, StarRider will operate its plasma magnet at maximum power for intervals, draining its batteries before powering down to recharge. The ClydeSpace 3U platform comes standard with a battery pack which could supply 30w RMF power for 48 minutes at a time [8]. The plasma magnets in lab tests reached equilibrium in less than a millisecond, so a few seconds would be plenty of time for a system in space to start up [3]. This way, it can maintain a large drag coefficient even when far enough away from the sun that its solar panels have reduced power output. However, it will reach a point where the solar arrays can't charge the batteries while providing enough power to critical systems. At this point, it drifts until it runs out of power completely and dies.

A Matlab script was written to model this trajectory using 2-body physics, starting in an orbit parallel to Earth's, and accelerating away from the sun with average thrust proportional to 1 over R squared (see figure 5). After accelerating for a little over 5 months, the spacecraft reaches a distance of 3.8 AU, where it shuts down noncritical systems and coasts into interstellar space. Once the spacecraft is far enough out of the sun's gravity well, its speed converges to 29.8 km/s, significantly faster than Voyager-1 at 17 km/s.

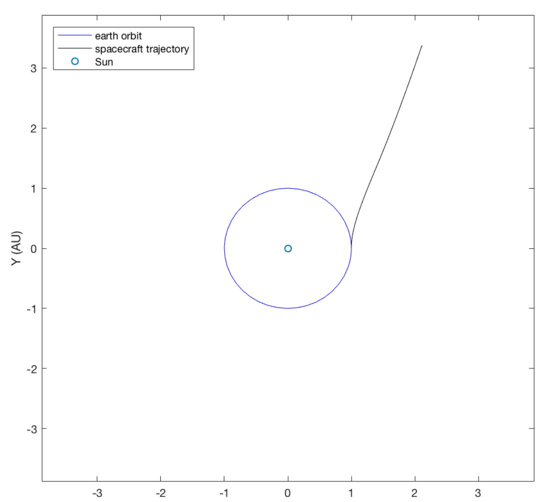

Figure 5: Plot of trajectory away from the sun

Communication should still be possible during the early part of the acceleration phase, since the Shannon-Hartley theorem gives a channel capacity of 100 bits/second out to a tenth of an AU from Earth. The spacecraft will have to fly autonomously from here on, only sending periodic radio pings to allow ground stations to track it [11]. Tracking may be possible up to as much as 1 AU from Earth using a commercially available ground station, but from then on, time would need to be bought on a deep space network to make contact [12].

Budget and timeline

Rideshare opportunities to the moon are rare right now, but will be more common in the near future as newspace companies like Moon Express begin sending missions, and as NASA's Deep Space Gateway program ramps up. Nevertheless, there is additional risk in being dependent on other projects which could be delayed or canceled. The cost of a rideshare will be highly situational, but the absolute worst case scenario for launch cost would involve buying a small launcher like Rocket Lab's Electron at around 6 million USD, and finding other groups interested in small deep space satellites to help pay for it. The launch will likely be the most expensive part of this mission, since purchasing or assembling a Cubesat platform will only cost a few hundred thousand, and the power supply and deployment mechanism for a small-scale plasma magnet does not seem like an engineering challenge that would require a lot of innovation. However, that estimate should not be relied on. the Lightsail-2 project was initially estimated to cost 1.8 million, but over time, its budget ballooned to 6.6 million [1]. Ideally, the computational studies to get an accurate thrust estimate would be done in parallel with the electrical and mechanical engineering work to develop the propulsion system and diagnostics. Adding that to the typical development time for Cubesats, an initial guess on my part for total development time is 5 years. Total mission duration would be between 6 and 7 months, comparable to the MarCO Cubesats that are part of NASA's Insight mission. However, all primary mission objectives would be achieved within several weeks of the launch.

Next Steps

Should this mission successfully bring the TRL of the plasma magnet up to 7, a follow-up to bring it up 8 or 9 could involve a larger spacecraft with more power generation capacity, closer to what would be required for a large and fast probe or a manned mission. It could attempt to demonstrate more advanced maneuvers like plasma aerobreaking at Mars or braking in the plasma environment of Jupiter's magnetosphere. In doing so, It could carry a serious science payload to one of those destinations for a fraction of the cost of a probe using conventional propulsion. A secondary objective of a mission to Jupiter could be using the rotating plasma torus around Io to inject onto a transfer orbit back to Earth. This would show that robotic sample return and even manned missions to Jupiter can be done relatively inexpensively.

Value Proposition

The value of this mission is two-fold: as a pure technology demonstration mission and as a publicity and outreach project. If any organizations are going to use a plasma magnet as major component of future space missions, it is crucial to verify its operation and scaling in the real solar wind plasma. Lab tests and computer models may verify some of its operating principles, but it's simply impossible to build a laboratory vacuum chamber big enough to demonstrate plasma behavior on multi-kilometer scales. The StarRider spacecraft will able to determine the performance of the plasma magnet as a propulsion system and possibly as a radiation shield over a limited range of values for RMF frequency and power.

By transferring kinetic energy from the solar wind to a spacecraft on a large scale, the plasma magnet aims to solve the fundamental energy problem in achieving fast interplanetary travel. Theory and computer modeling suggest that it should be able to achieve orders of magnitude greater thrust to weight ratio than previous sail concepts, and if its real-world performance is even close to that, then it would shift how interplanetary travel is planned in a major way. The ability to achieve high-energy interplanetary transfers with a relatively simple and inexpensive propulsion system would put many solar system destinations, including those in the outer solar system, within reach of non-government organizations for scientific exploration and infrastructure development, as well as enhancing the capabilities of traditional governmental space agencies by allowing larger payloads and lower mission costs. Should the plasma magnet function as an effective shield against solar particle radiation, it would be a similarly game-changing breakthrough in spaceflight. The ability to protect spacecraft, surface bases, or possibly even entire planets from solar radiation would drastically reduce one of the biggest health risks involved with the human exploration of deep space.

Since the StarRider spacecraft may be able to surpass Voyager 1 as the fastest object launched out of the solar system by humans, It will create an opportunity to generate a lot of attention from media outlets and the public. When used to their full potential by accelerating spacecraft up to solar wind velocity, plasma magnets could enable travel to Mars in as little as a week, and to the outer planets in weeks to months. Although it would be very difficult to decelerate from these speeds, these are the kind of performance figures that media outlets tend to spread prolifically. Also, in the spirit of the Voyager golden records, the spacecraft could carry a data storage device as a symbolic “message to the stars” that aliens could hypothetically find to learn about earth and humanity if we destroyed ourselves (although I personally think it is far more likely to be retrieved by future humans). Getting together a group of organizations to collaborate on putting together this message would help to build networks between many existing organizations in space and science advocacy.

At the 2017 Tennessee Valley Interstellar Workshop, Jeff Greason, the chairman of the Tau Zero Foundation, expressed interest in doing a plasma magnet demonstration mission [13]. However, I have not seen any public announcements or other media from the foundation since that would indicate that they are actively pursuing this project. In April 2017, they received a $500,000 grant from NASA to do a three year study reviewing interstellar propulsion concepts, so it seems likely that this is their current priority for the time being. Nevertheless, should StarRider be selected by the mission activation vote, it would make sense to collaborate with Tau Zero, sharing know-how and resources or possibly even combining both mission plans into one.

Ever since space exploration began to stagnate, people have been waiting for a technological breakthrough that would bring back the rapid progress of the space race era. Recently, SpaceX has been making impressive progress with their reusable rockets, uplifting the hopes of space enthusiasts, but even with full reusability and orbital refueling, chemical rockets are very limited in their interplanetary capabilities. If plasma magnet technology is successfully demonstrated in as dramatic a way as is proposed, it could be a similarly pivotal moment, reshaping how people think about interplanetary travel. In the process, it would captivate the hopes and ambitions of space enthusiasts, drawing much attention and support to the organization or group of organizations that make the mission happen.

Role of Team Member

I (Josh Perry) am the only team member currently working on this project. For the next year, I am going to be spending a lot of my time on the academics and the research project involved in finishing my bachelor's degree. At most, I will be able to spend one day each week on this or other Space Decentral projects. I think that I am not particularly well qualified to be project manager since I have barely any experience with project management and only a surface level understanding of many of the physics and engineering fields that would be involved with this project. To help rectify this, I will be taking some additional classes in electrical engineering and plasma physics the next semester. For the time being, I think I would make an adequate manager if no one more qualified is available, since I have at least a surface level understanding of pretty much all the physics and engineering involved. I also have had a lot of time to think about various possibilities for the mission before settling on the plan outlined in this proposal and I am personally very enthusiastic about this technology and its potential. What I really want is for this idea to change the way people think about interplanetary travel the way it has changed how I think about it. Of course, the technology might not work nearly as well in practice as the theory and lab experiments suggest, but someone needs to try.

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