Centauri Dreams
Imagining and Planning Interstellar Exploration

Wind Rider: A High Performance Magsail

by PAUL GILSTER *on* NOVEMBER 19, 2021

Can you imagine the science we could do if we had the capability of sending a probe to Jupiter with travel time of less than a month? How about Neptune in 18 weeks? Alex Tolley has been running the numbers on a concept called Wind Rider, which derives from the plasma magnet sail he has analyzed in these pages before (see, for example, The Plasma Magnet Drive: A Simple, Cheap Drive for the Solar System and Beyond). The numbers are dramatic, but only testing in space will tell us whether they are achievable, and whether the highly variable solar wind can be stably harnessed to drive the craft. A long-time contributor to Centauri Dreams, Alex is co-author (with Brian McConnell) of A Design for a Reusable Water-Based Spacecraft Known as the Spacecoach (Springer, 2016), focusing on a new technology for Solar System expansion.

by Alex Tolley



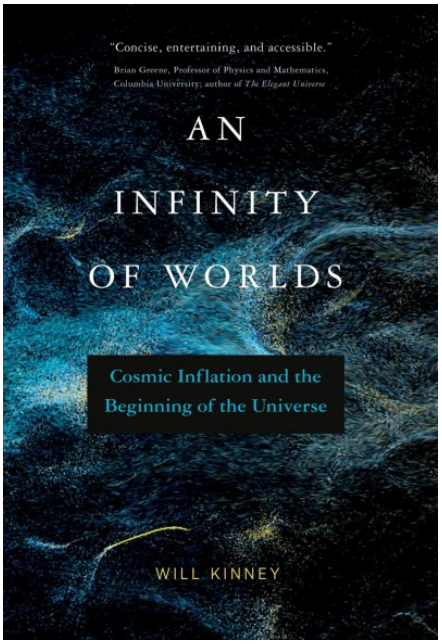
In 2017 I outlined a proposed magnetic sail propulsion system called the Plasma Magnet that was presented by Jeff Greason at an interstellar conference [6]. It caught my attention because of its simplicity and potential high performance compared to other propulsion approaches. For example, the Breakthrough Starshot beamed sail required hugely powerful and expensive phased-array lasers to propel a sail into interstellar space. By contrast, the Plasma Magnet [PM] required relatively little energy and yet was capable of propelling a much larger mass at a velocity

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Charter

In *Centauri Dreams*, Paul Gilster looks at peer-reviewed research on deep space exploration, with an eye toward interstellar possibilities. For many years this site coordinated its efforts with the Tau Zero Foundation. It now serves as an independent forum for deep space news and ideas. In the logo above, the leftmost star is Alpha Centauri, a triple system closer than any other star, and a primary target for early interstellar probes. To its right is Beta Centauri (not a part of the Alpha Centauri system), with Beta, Gamma, Delta and Epsilon Crucis, stars in the Southern Cross, visible at the far right (image courtesy of Marco Lorenzi).

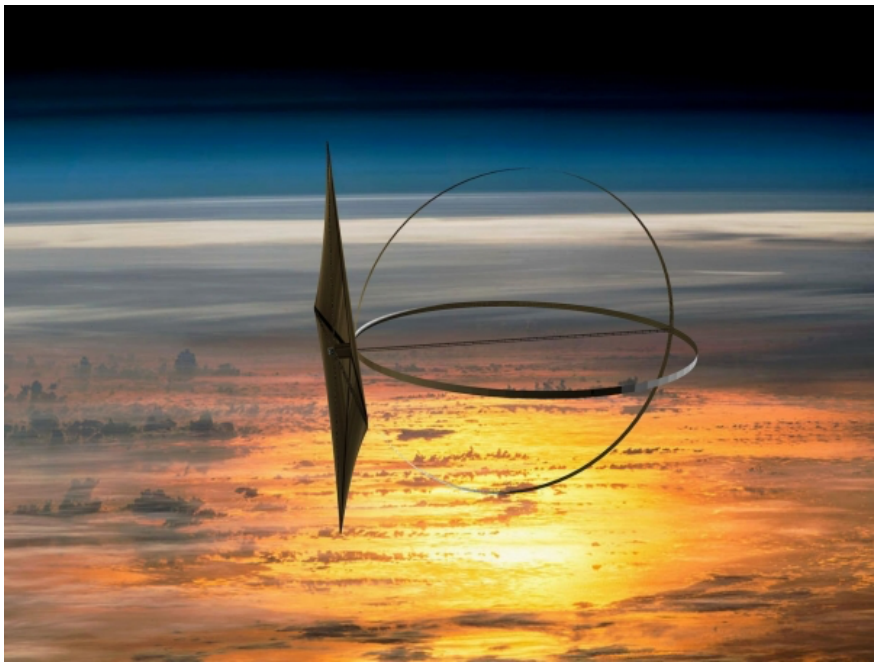
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exceeding any current propulsion system, including advanced solar sails.

The Plasma Magnet was proposed by Slough [5] and involved an arrangement of coils to co-opt the solar wind ions to induce a very large magnetosphere that is propelled by the solar wind. Unlike earlier proposals for magnetic sails that required a large electric coil kilometers in diameter to create the magnetic field, the induction of the solar wind ions to create the field meant that the structure was both low mass and that the size of the resulting magnetic field increased as the surrounding particle density declined. This allowed for a constant acceleration as the PM was propelled away from the sun, very different from solar sails and even magsails with fixed collecting areas.

The PM concept has been developed further with a much sexier name: the Wind Rider, and missions to use this updated magsail vehicle are being defined.



Wind Rider was presented at the 2021 Division of Planetary Sciences (DPS) meeting by the team led by Brent Freeze, showing their concept of the design for a Jupiter mission they called JOVE. The December meeting of the American Geophysical Union was the venue for a different Wind Rider concept mission to the SGL, called Pathfinder.

The main upgrade from the earlier PM to the Wind Rider is the substitution of superconducting coils. This allows the craft to maintain the magnetic field without requiring constant power to maintain the electric current, reducing the required power source. Because the superconducting coils would quickly heat up in the inner system and lose their superconductivity, a gold foil reflective sun shield is deployed to shield the coils from the sun's radiation. This is shown in the image above with the shield facing the sun to

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On Comments

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keep the coils in shadow. The shield is also expected to do double duty as a radio antenna, reducing the net parasitic mass on the vehicle.

The performance of the Wind Rider is very impressive. Calculations show that it will accelerate very rapidly and reach the velocity of the solar wind, about 400 km/s. This has implications for the flight trajectory of the vehicle and the mission time.

The first mission proposal is a flyby of Jupiter – Jupiter Observing Velocity Experiment (JOVE) – much like the New Horizons mission did at Pluto.

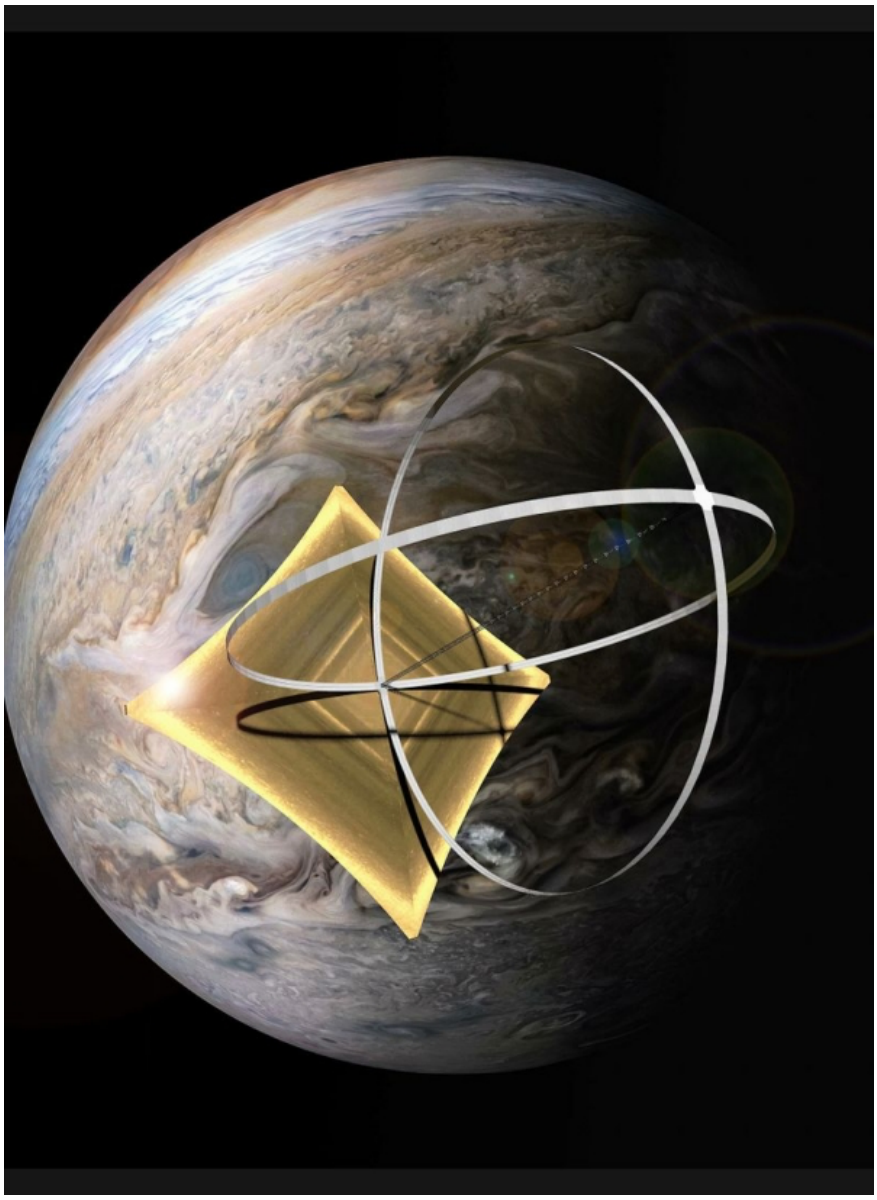


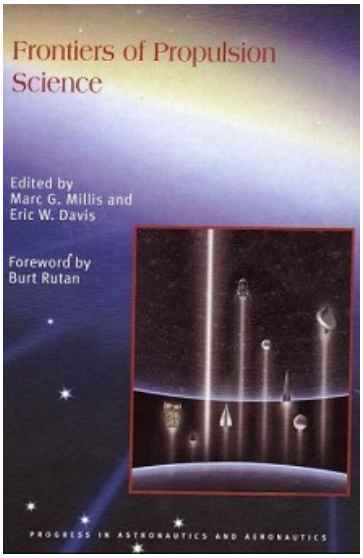
Figure 1. The Wind Rider on a flyby of Jupiter. The solar panels are hidden behind the sun shield facing the sun. The 16U CubeSat chassis is at the intersection of the 2 coils and sun shield.

The JOVE mission proposal is for an instrumented flyby of Jupiter [2]. The chassis is a 16U CubeSat. The scientific instrument payload is primarily to

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Exoplanet Projects (Earth)

AFOE

Amateur Exoplanet Archive

Anglo-Australian Planet Search

APACHE Project

ASTEP: Antarctic Search for Transiting Extrasolar Planets

ASTRA

Astro Gregas

Atacama Large Millimetre Array

Automated Planet Finder

Berlin Exoplanet Search Telescope

California & Carnegie Planet Search

Carl Sagan Institute (Cornell)

CARMENES

Carnegie Astrometric Planet Search

CBA Belgium Observatory

CHIRON

CLEVER Planets

measure data on the magnetic field and ion density around Jupiter. The sail is powered by 4 solar panels that also double as struts to support the sun shield and generate about 1300 W at 1 AU and fall to about 50W at Jupiter.

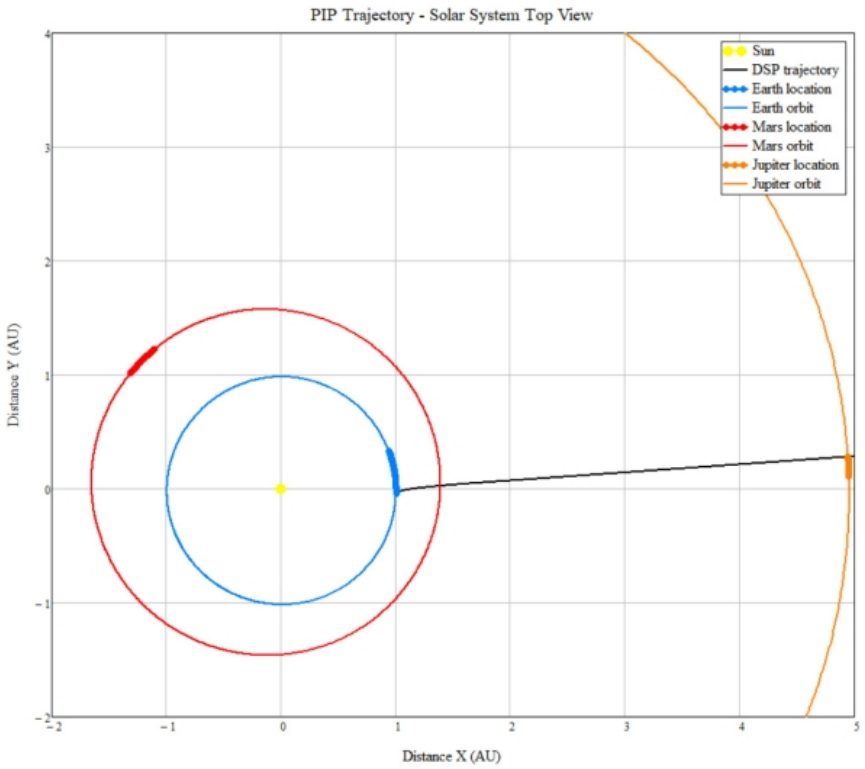


Figure 2. Trajectory of the Wind Rider from Earth to Jupiter

The flight trajectory is effectively a beeline directly to Jupiter, starting the flight almost at opposition. No gravity assists from Earth or Venus are required, nor a long arcing trajectory to intercept Jupiter. Figure 2 shows the trajectory, which is almost a straight-line course with the average velocity close to that of the solar wind.

Although the mission is planned as a flyby, a future mission could allow for orbital insertion if the craft approaches Jupiter's rotating magnetosphere to maximize the impinging field velocity. Although not mentioned by the authors, it should be noted that Slough has also proposed using a PM as an aerobraking shield that decelerates the craft as it creates a plasma in the upper atmosphere of planets.

How does the performance of the Wind Rider compare to other comparable missions?

The JUNO space probe to Jupiter had a maximum velocity of about 73 km/s as Jupiter's gravity accelerated the craft towards the planet. The required gravity assists and long flight path, about 63 AU or over 9 billion km, mean that its average velocity was about 60 km/s. This is not the fairest comparison as the JUNO probe had to attain orbital insertion at Jupiter.

CODEX

Colossus

Coralie

DayNight

DEMONEX (DEdicated MONitor of EXotransits)

Dispersed Matter Planet Project

East Asian Planet Search Network

Elodie

ESO Coude Echelle Spectrometer

ESPRESSO (Echelle SPectrograph for Rocky Exoplanet and Stable Spectroscopic Observations)

European Extremely Large Telescope

Evryscope

Exoplanet Tracker

Externally Dispersed Interferometry

Fabra-ROA

GAPS (Global Architecture of Planetary Systems)

Gemini Planet Imager

GEMSS: Global Exoplanet M-dwarf Search-Survey

Geneva Extrasolar Planet Search

Habitable Zone Planet Finder

HARPS North

HARPS-N

HATNet Exoplanet Survey

High Accuracy Radial velocity Planetary Search

Hobby-Eberly Telescope

Italian Search for Extraterrestrial Life

ITASEL

Keck Interferometer

Keck Planet Finder

KELT North

KELT South

KMTNet (Korea Microlensing Telescope Network)

KOBE: K-dwarfs Orbited By habitable Exoplanets

Large Binocular Telescope

Las Cumbres Global Telescope Network

A fairer comparison is the fastest probe we have flown – the New Horizons mission to Pluto — which reached 45 km/s as it left Earth but slowed to 14 km/s as it flew by Pluto. New Horizons took 1 year to reach Jupiter to get a gravity assist for its 9 year mission to Pluto, and therefore a maximum average velocity of 19 km/s between Earth and Jupiter.

Wind Rider can reach Jupiter in less than a month. Figure 2 shows the almost straight-line trajectory to Jupiter. Launched just before opposition, Wind Rider reaches Jupiter in just over 3 weeks. Because opposition happens annually, a new mission could be launched every year.

As the Wind Rider quickly reaches its terminal velocity at the same velocity as the solar wind, it can reach the outer planets with comparably short times with the same trajectory and annual launch windows.

The Wind Rider can fly by Saturn in just 6 weeks, and Neptune in 18 weeks. Compare that to the Voyager 2 probe launched in 1977 that took 4 years and 12 years to fly by the same planets respectively. Pluto could be reached by Wind Rider in just 6 months.

Because of its high terminal velocity that does not reduce during its mission, the Wind Rider is also ideally suited for precursor interstellar missions.

The second proposed mission is called Pathfinder [1], proposed to ultimately reach the solar gravity focal line around 550 AU from the sun. Flight time is less than 7 years, making this a viable project for a science and engineering team and not a multi-generation one based on existing rocket propulsion technology. As the flight trajectory is a straight line, this makes the craft well suited to follow the focal line while imaging a target star or exoplanet using the sun's diameter as a large aperture telescope to increase the resolving power.

As the Wind Rider reaches the solar wind velocity, it may even be able to ride the gusts of higher solar wind velocities, perhaps reaching closer to 550 km/s.

While solar sails have been considered the more likely means to reach high velocities, especially when making sun-diver maneuvers, even advanced sails with proposed areal densities well below anything available today would reach solar system escape velocities in the range of 80-120 km/s [3]. If the Wind Rider can indeed reach the velocity of the solar wind, it would prove a far faster vehicle than any solar sail being planned, and would not need a boost from large laser arrays, nor risky sun-diver maneuvers.

I would inject some caution at this point regarding the performance. The

Low Frequency Array

LYOT Project

MACHO

Magdalena Ridge Optical Interferometer

Magellan Telescope

MARVELS

MARVELS (Multi-object APO Radial Velocity Exoplanet Large-area Survey)

MASCARA

Maunakea Spectroscopic Explorer

McDonald Observatory

MEarth

METIS (Mid-Infrared E-ELT Imager and Spectrograph)

MicroFUN Microlensing Follow-Up Network

Microlensing Planet Search Project

MINERVA (MINiature Exoplanet Radial Velocity Array)

MOA

MONET

N2K

Nancay Decametric Search

NEAR

NEID Spectrograph

New Mexico Exoplanet Spectroscopic Survey Instrument

NGTS (Next-Generation Transit Survey)

NIRPS (Near Infrared Planet Searcher)

Okayama Planet Search Program

Optical Gravitational Lensing Experiment

OWL

PARAS (PRL Advanced Radial-velocity Allsky Search)

Permanent All Sky Survey

PHASES

PIRATE (Physics Innovations Robotic Astronomical Telescope Explorer)

PISCES (Planets in Stellar Clusters Extensive Search)

PLANET

PLANETS

Precision Radial Velocity Spectrometer

PRIMA-DDL

performance is based entirely on theoretical work and a small scale laboratory experiment. What is needed is a prototype launched into cis-lunar space to test the performace on actual hardware and confirm the capability of the technology to operate as theorized.

It should also be noted that despite its theoretical high performance, there is a potential issue with propelling a probe with a magnetic sail. Compared to a solar sail or a vehicle with reaction thrusters, the Wind Rider as described so far has no crosswind capability. It just runs in front of the solar wind like a dandelion seed in the wind. This means that it would have to be aimed very accurately at its target, and subject to the vagaries of the strength of the solar wind that is far less stable than the sun's photon emissions. Like the dandelion, if the Wind Rider was very inexpensive, many could be launched in the expectation that at least one would successfully reach its target.

However, there is a possibility that some crosswind capability is possible. This is based on modelling by Nishida [4]. This paper was recommended by Dr. Freeze [7].

The study modeled the effect of the angle of attack of the magnetic field of a coil against the solar wind. The coil in this case would represent the induced circular movement of the solar wind induced by the primary Wind Rider/PM coils.

Theoretically, the angle of attack has an impact on the total force pushing past the magnetic field.

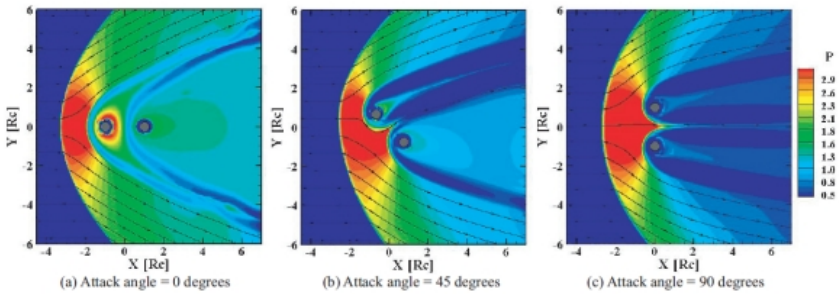


Figure 3 shows the pressure and on the field as the coil is rotated from 0 through 45 and 90 degrees to the solar wind.

The force experienced is maximal at 90 degrees. This is shown visually in figure 3 and graphically in figure 4.

Project 1640

Pulsar Planet Detection

QES (Qatar Exoplanet Survey)

Radio Interferometric Planet Search

RoboNet (Microlensing)

SAINT-EX

Search for Trojan Extrasolar Planets

SEEDS (Subaru Strategic Exploration of Exoplanets and Disks)

SHINE

Solaris

Sophie

Spectrashift

SPECULOOS

SPHERE

SPOTS: (Search for Planets Orbiting Two Stars

Square Kilometer Array

STARE

STELLA

SuperWASP

Systemic

Tennessee Automatic Photoelectric Telescope

TEP

Thirty Meter Telescope

TransitSearch

Transitsearch

TRAPPIST (TRAnsiting Planets and PlanetesImals Small Telescope)

TrES: The Transatlantic Exoplanet Survey

TRESCA Project

United Kingdom Infrared Telescope

University of St. Andrews Planet Search

UNSWEPS Project

UVES

Very Large Telescope Interferometer

VIDA

WASP (Wide Angle Search for Planets)

WHAT

XO Project

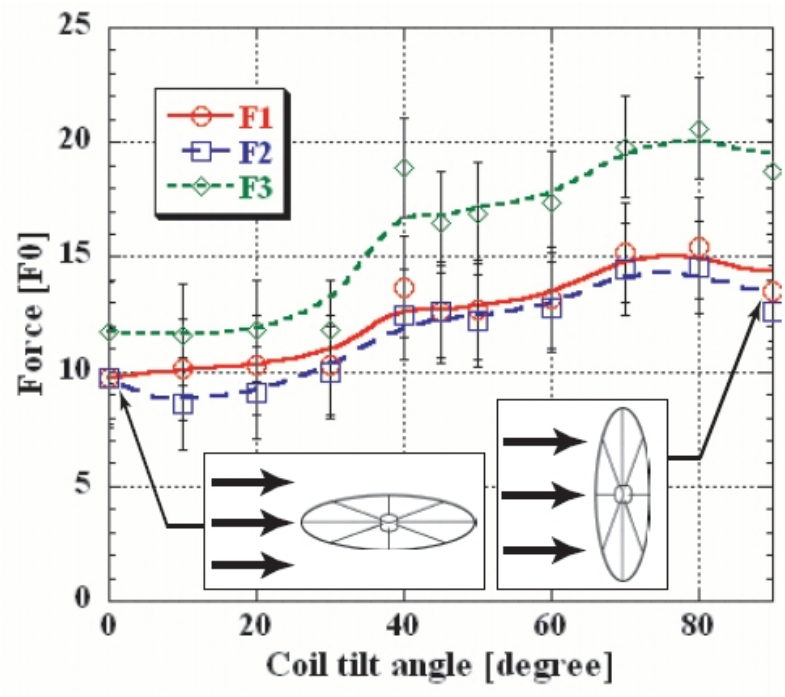


Figure 4. Force on the coil effected by angle of attack. A near 90 degrees angle of attack increases the force about 50%.

The angle of attack also induces a change in the thrust vector experienced by the coil, which would act as a crosswind maneuvering capability, allowing for trajectory adjustments as well as a longer launch window for the Wind Rider.

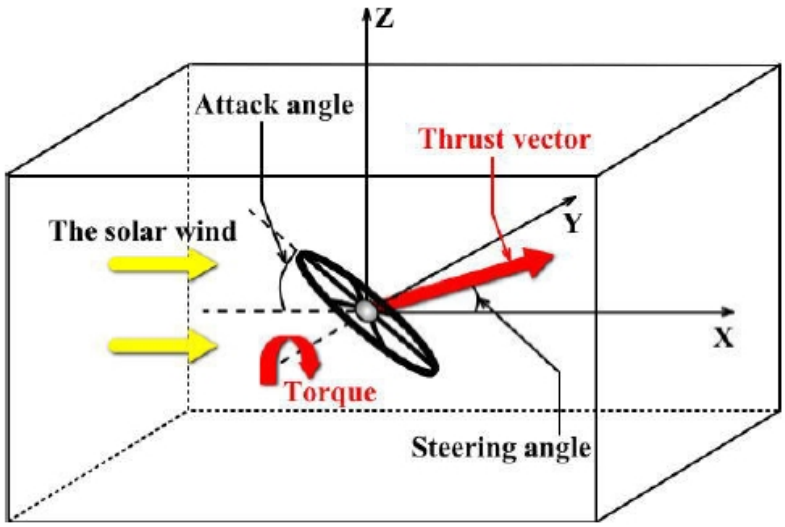


Figure 5. The angle of attack affects the thrust vector. But note the countervailing torque on the coil.

If the coil can maintain an angle of attack with respect to teh solar wind, then the Wind Rider can steer across the solar wind to some extent.

Exoplanet Projects (Space)

ACEsat

Aragoscope

ARIEL: (Atmospheric Remote-Sensing Infrared Exoplanet Large-survey)

ASTERIA

Astro-1

ATLAST (Advanced Technology Large-Aperture Space Telescope)

CHEOPS – CHaracterising ExOPlanet Satellite

CoRoT

CubeSat

Darwin

Dual Use Exoplanet Telescope

ECHO (Exoplanet Characterization Observatory)

Eddington

EPOXI (Extrasolar Planet Observation and Deep Impact Extended Investigation)

Euclid

EXCEDE

ExoplanetSat CubeSat

FINESSE

Gaia

GEST

HabEx

HEK (Hunt for Exomoons with Kepler)

High Étendue Multiple Object Spectrographic Telescope (THE MOST)

High-Definition Space Telescope

HST Astrometry

James Webb Space Telescope

Kepler

Kilometer Space Telescope

Laser Interferometer Space Antenna

LISE Hypertelescope

LUVOIR

MOST (Microvariability and Oscillations of STars)

NEAT

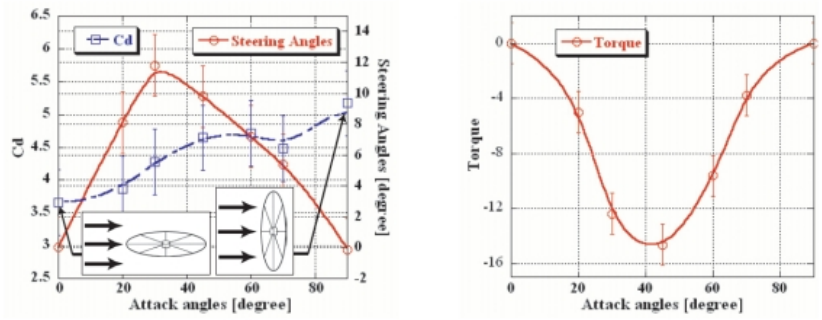


Figure 6. (left) Angle of attack, and steering angle. (right) angle of attack and the torque on the coil.

Figure 6 shows that the craft could steer up to 12 degrees away from the solar wind direction. However, maintaining that angle of attack requires a constant force to oppose the torque restoring the angle of attack to zero or 90 degrees. The coil therefore acts like a weather vane, always trying to align itself with the solar wind. To maintain the angle of attack would be difficult. Reaction wheels like those on the Kepler telescope could only act in a transient manner. Another possibility suggested is to move the center of gravity of the craft in some way. Adding booms with coils might be another solution, albeit by adding mass and complexity, undesirable for this first generation probe. Jeff Greason has an upcoming paper to be published in 2022 on theoretical navigation with possible ranges of steering capability.

In summary, the Wind Rider is an upgraded version of the Plasma Magnet propulsion concept, now applied to a reference design for 2 missions, a fast flyby of Jupiter, and an interstellar precursor mission that could reach the solar gravity lens focus. The performance of the design is primarily based on modelling and as yet there is no experimental evidence to support a finite lift/drag ratio for the craft.

Having said that, the propulsion principle and hardware necessary are not expensive, and there seems to be much interest by the AIAA. Maybe this propulsion method can finally be built, flown and evaluated. If it works as advertised, it would open up the solar system to exploration by fast, cheap robotic probes and eventually crewed ships.

References

1. Freeze, B et al Wind Rider Pathfinder Mission to Trappist-1 Solar Gravitational Lens Focal Region in 8 Years (poster at AGU – Dec 13th, 2021). https://agu.confex.com/agu/fm21/meetingapp.cgi/Paper/796237

2. Freeze, B et al Jupiter Observing Velocity Experiment (JOVE), Introduction to Wind Rider Solar Electric Propulsion Demonstrator and Science Objective.

New Worlds Imager

Origins Billion Star Survey

Origins Space Telescope

Pegase

Planet Imaging Concept Testbed

Plato

PlaVi (PlanetVision)

Project Blue

SISTINE

Space Interferometry Mission

SPICES (Spectro-Polarimetric Imaging and Characterization of Exo-planetary Systems)

Spitzer Space Telescope

SUPER-SHARP

SWEEPS

Terrestrial Planet Finder

TESS (Transiting Exoplanet Survey Satellite)

TOLIMAN

Twinkle

UMBRAS

WFIRST (Wide-Field Infrared Survey Telescope)

Further Astronomical and Astronautical Resources

100 Year Starship

Acta Astronautica

ADS Abstract Service

Alternative Earths Astrobiology Center

American Astronomical Society

American Geophysical Union

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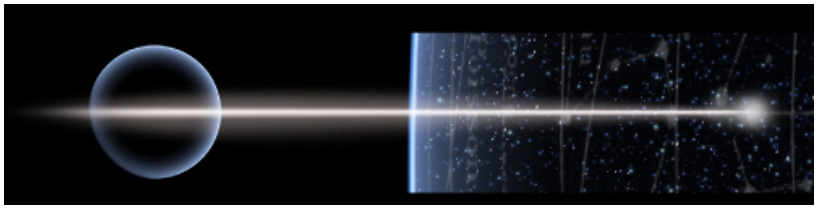
3. Vulpetti, Giovanni, et al. (2008) *Solar Sails: A Novel Approach to Interplanetary Travel*. New York: Springer, 2008.

4. Nishida, Hiroyuki, et al. "Verification of Momentum Transfer Process on Magnetic Sail Using MHD Model." 41st AIAA/ASME/SAE/ASEE Joint Propulsion Conference & Exhibit, 2005. https://doi.org/10.2514/6.2005-4463

5. Slough, J. "Plasma Magnet NASA Institute for Advanced Concepts Phase I Final Report." 2004. http://www.niac.usra.edu/files/studies/final_report/860Slough.pdf. See Figure 2.

6. Tolley, A "The Plasma Magnet Drive: A Simple, Cheap Drive for the Solar System and Beyond" (2017). https://www.centauri-dreams.org/2017/12/29/the-plasma-magnet-drive-a-simple-cheap-drive-for-the-solar-system-and-beyond/

7. Generous email communications with Dr. Brent Freeze in preparation of this article.



Comments on this entry are closed.

Mike Serfas November 19, 2021, 14:02

What a beautiful thing to see moving toward fruition! This sounds like a Golden Age of Sail waiting to come to life, when a navigator's skill and intuition (in concert with a large army of forward solar probes) make the difference between success and ruin of great enterprises.

Tacking is the key issue. This article describes a different method than the last, which stacked magnetospheres into engineered arrays. Though I'm rather unclear about how multiple rotating magnetospheres would interact with one another, I can't help but wonder: could that be used to *concentrate* solar wind? If you build a triangle of these drives in a tethered or statite position in space, can you use it to generate a small, dense beam of particles in the middle for industrial uses or redirection as a

Astronomy & Astrophysics
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RocketSTEM
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Scitizen
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propellant?

LINK

> **Alex Tolley** November 19, 2021, 16:07
>
> > Tacking is the key issue. This article describes a different method than the last, which stacked magnetospheres into engineered arrays. Though I'm rather unclear about how multiple rotating magnetospheres would interact with one another, I can't help but wonder: could that be used to *concentrate* solar wind? If you build a triangle of these drives in a tethered or statite position in space, can you use it to generate a small, dense beam of particles in the middle for industrial uses or redirection as a propellant?
>
> That is an interesting idea. The spacing is going to be important. Too wide and you just get separate magnetospheres or ones with "bent" edges. Too close and the fields act more like a single coil and the that tends to act as a sail.
>
> My sense is that it probably doesn't buy you anything, as the coils' magnetic field causes divergence and even if several coils spaced near each other could create a beam, would there be any net thrust against the sail repulsion? Even if static and the beam was used to propel another vehicle, there is still divergence between the protons and electrons that will effectively disperse the beam to equilibrate with the surrounding solar wind.
>
> Tacking such a sail is not trivial. It is like trying to force a weather vane to point at an angle to the wind. This needs a constant force if steady. It is possible a smaller force can be employed if the weather vane "bounces" back and force with an intermittent force. If the weathervane is given other vanes on struts, changing the angle of those sub vanes may keep the main vane at some angle of attack. Think of the classic kite design solar sails with small sails at the ends of the struts to steer the orientation of the sails. The same effect was achieved by IKAROS with differential reflecting material on the sail, an elegant solution IMO. Whether such an approach would work with a magsail, IDK. It needs some simulation. It is particularly difficult with the PM approach of the Wind Rider as the magnetosphere generated is many kilometers in radius and changes with the density of the solar wind. This means the structs would have to be very long and stiff, and their mass alone would not be trivial, perhaps many times that of the rest of the craft. Having said that, tailoring the shape of the magnetosphere or even redirecting the solar wind downstream (like an aircraft tail stabilizer's elevator, or a front canard wing) might be an option. Another option might be to disrupt the induced ring current of the solar wind so that the

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Space Agenda
Space Sailing
Space Telescope Science Institute
Space Transport and Engineering Methods
spaceweather.com
The neighborhood
Trans-Neptunian Automated Occultation Survey
Troy Project

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astroPT
Astroquizzical
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Atlas of the Universe
B612 Foundation
Bad Astronomy
Beyond Earthly Skies
Beyond Impossible
Billion Year Plan
Buran Space Shuttle
Captain Interstellar (Paul Titze)
Celestial Matters

magnetosphere is not symmetric across the diameter of the magnetic sail. That should induce a trim torque against the torque forcing the sail back to its stable orientation.

Worst case is that the Wind Rider is not steerable. Just as with a toy sailboat that has no control over the sail or rudder, you point it in the direction you want it to go and hope it gets close to where you want it to be. One can always add other steering mechanisms, e.g. conventional monopropellant maneuvering thrusters for small course corrections.

I think of these early designs as prototypes to test the concept. If they work, then it is worth looking at how to add components to enable more control. If it works, it could be a classic disruptive propulsion technology that is either "cheap and good enough" and/or has a huge performance boost. With market success it can be improved to incorporate the features of mature technologies to eventually dominate.

LINK

Mike Serfas November 20, 2021, 13:57

I realize it's too soon to test any of it with Wind Rider, but ultralight space megastructures need a lot of work. In theory you could make a carbon filament suitable for a space elevator, which ought to be worth testing for keeping magnetospheres together at vast distances. In theory you should be able to sight a pair of very good corner reflectors along the filament, and use a small laser bounced many thousands of times to supply the complementary compressive strength needed to mimic a solid strut. Could you use this to balance the torques of your magnetospheres against each other?

More strangely … I don't understand nearly well enough to know this, but I'm thinking some of the publications on optics lately, with notions like light bending 180 degrees in free space (https://phys.org/news/2019-10-free-space-data-carrying-bendable.html), might even allow for an "optical tweezer" that stations the satellites with no physical contact. (Apparently the bent light is an optical illusion, but it's the kind of optical illusion you can use to expand optical tweezer capability and … burn a curved hole through an object with a laser? https://www.science.org/content/article/light-bends-itself)

Of course, using light to precisely change and measure the distance between satellites should have more useful applications in VLBI astronomy. And if possible, it would be interesting to see if concentrated and fractionated solar wind can be used in industrial

Cheap Astronomy
Cocktail Party Physics
collectSPACE
Colony Worlds
Comets & Asteroids: Small Bodies of the Solar System
Cosmic Diary
Cosmic Mirror
Cosmic Tusk
Cosmic Variance
Cosmic Visions
CosmoCoffee
Cumbrian Sky
Dad2059
Deep Sky Blog
Dialogos of Eide
Dick's Rocket Dungeon
Dragon's Gaze
Dream of the Open Channel
Dreams of Space – Books and Ephemera
Dreams of Space: Books and Ephemera
Drew Ex Machina (Andrew LePage)
DSFP's Spaceflight History Blog
Dynamics of Cats
Eternos Aprendizes
Eureka
Eureka (Daniel Marín)
Ex Space
ExoClimes.com
Exoplanetology
Exoplanets Channel
Extrasolar Visions II
Final Frontier
Finding Pluto
Flank Speed
Fly Me to the Moon
Fraknoi's Universe
Future & Cosmos
Future Incredible
Future Planetary Exploration
Futurismic

processes, maybe even controlled transmutation (would https://ui.adsabs.harvard.edu/abs/2015LPICo1878.2027W/abstract be applicable?)

LINK

Alex Tolley November 21, 2021, 10:36

carbon nanotube is great under tension, but would need a some sort of truss structure to ensure stiffness over 10s of kilometers. “Outrigger” steering mechanisms won’t need perfectly rigid supports, but enough to ensure that they operate as intended. Would it be sufficient to allow for the laser pointing accuracy, and don’t forget the needed laser power supply that will decline as the craft travels away from the sun?

LINK

Mike Serfas November 21, 2021, 15:38

I’ve read mirrors can be more than 99.9999% reflective (https://www.rp-photonics.com/supermirrors.html). Breakthrough Starshot’s program depends on this to keep their probes from vaporizing. If a light beam could be bounced between two corner reflectors (perhaps with some adaptive optics) about 100,000 times before attenuating, I’m guessing you could take a 1-watt laser, 1 J/s divided by 3E+8 m/s, times 1E5 bounces, times 2 (reaction), and get I think 0.6 millinewtons of force from the light beam to keep the nanotube moderately taut. With sufficient leverage between the beam and the tether, this might instead transfer quite a bit of torque between probes (for example, if they are fired as a “chain shot” or “bolas” at a distant target). Even if both probes need to steer the same way, transferring the torque should be able to direct the angular momentum into moving one probe forward relative to the other; if they are a hundred km apart the moment of inertia for the combined system should be something ridiculous.

Also… what happens when the probes fully catch up with the solar wind moving outward? Do they become painted ships on a painted ocean, unable to use any trick discussed to change course, or does solar weather and turbulence give them continued opportunities to change course (or resist the offer)?

LINK

Galactic Journey
Gregory Benford
Habitable Worlds
Habitable Zone
Hop's Blog
Il Tredicesimo Cavaliere
In the Dark (Peter Coles)
Innovation Watch
Innumerable Worlds
Invitation to ETI
Isaac Arthur (videos)
James Essig
James Randi Educational Foundation Forum
Jatan's Space
John Cleary Creations
Jon Lomberg
Kentucky Space
Know the Cosmos
Last Word on Nothing
Laurel's Pluto Blog
Leonard David's Inside Outer Space
Letters to Nature
Lifeboat Foundation
Lone Mind
Long Bets Foundation
Long Now Foundation
Lost in Transits
Magellan AO
Many Worlds (Marc Kaufman)
Martian Chronicles
Meridiani Journal
Music of the Spheres
Nano Age
NASA Watch
NASA-UC Eta-Earth Survey
New Papyrus
Next Big Future
NGTS (Next-Generation Transit Survey)
On the Path to Space
One-Minute Astronomer

Patient Observer November 21, 2021, 18:30

Bouncing lasers light hundreds of times between mirrors is in itself an interesting way to vastly improve momentum transfer from the light to the spacecraft. Near perfect reflectivity and and collimation would be required. Even 10 or 15 round-trip reflections would reduced laser power by a huge factor.

LINK

Alex Tolley November 22, 2021, 13:40

This has been done in a lab with carefully aligned mirrors quite close together. It is a very different proposition applying this to mirrors in space, many kilometers apart and aligned by a semi-rigid strut/tether. Maybe it can be done by paying out the tether after the light is applying force and using some actuators to maintain alignment. IDK.

LINK

Mike Serfas November 22, 2021, 20:35

I'll admit there's a fair amount of daydream here, but to me it looks like in the past 25 years optics has gone from a standard-issue physics field that was all about what was impossible, to being one where any crazy thing – beat the diffraction limit, form photons into something like a molecule, bend light, form skyrmions, or (in some contexts) self-collimate a laser beam – seems to be doable. Making a probe center itself on a light beam seems easier for me to believe than most things (https://www.space.com/laser-sail-centering-breakthrough-starshot.html), and I'm thinking some clever optics ought to be able to do the converse. Alternatively the light might be bounced back and forth inside some tensile structural element to keep it confined.

LINK

Antonio November 19, 2021, 14:19

Very impressive performance. Apart from the NIAC, has this or the previous plasma magnet concept been proposed to Breakthrough Starshot for funding?

OrbitalHub
Orion's Arm
Our Universe in 202 Notations
Out of the Cradle
Overcoming Bias (Robin Hanson)
Patrick McCray
peregrinus interstellar
PHASES (Palomar High-precision Astrometric Search for Exoplanet Systems)
Physics arXiv Blog
PI Club
Planet/Planet
PLANETPLANET (Sean Raymond)
Polymath (Robert Clark)
Posthuman Blues
Potentia Tenebras Repellendi
Profiles of Our Future in Space
Project Icarus Weblog
Project Rho (Winchell Chung)
Quasar9
Real Science
Remote Central
Rick Costello Space Art
Riding with Robots
Robot Explorers
Robot Guy
Rymden i Dag
Science Meets Fiction
Science News
SciTech Journal
Scitizen
Simostronomy
Singularity Institute
Slacker Astronomy
SolStation
Sorting Out Science
Space Archaeology
Space Elevator Blog
Space FTW
Space Law Probe
Space Pragmatism

LINK

> **Paul Gilster** November 19, 2021, 14:37
> I don't know, Antonio. But I doubt it. I haven't heard any plasma magsail discussion coming via Breakthrough, but of course that doesn't mean it won't popup at the next Breakthrough Discuss in a session.
>
> LINK
>
> > **Michel Lamontagne** December 14, 2021, 15:26
> > Probably not fast enough. Will not go faster than the solar wind. Great for "close by" exploration though.
> >
> > LINK

Michael Fidler November 19, 2021, 17:13

One big question; What is this beautiful ship capable of at solar maximum? With what would be the equivalent of a typhoons winds from flux tube opening up from the sun and magnetic reconnections blasting the craft, speeds could be much faster to the Solar Lens. Launch time could be coordinated with solar flare blasts to give the maximum boost…

LINK

> **Alex Tolley** November 20, 2021, 13:48
> Bear in mind that the size of the induced magnetosphere and the thrust remains constant as it adapts to the particle density. While transient effects may increase thrust, a CME that creates a higher density of particles should simply reduce the size of the magnetosphere and maintain a constant thrust.
>
> Having said that, the authors note (and I included this in the posts) that "gusts" with higher velocity could increase the terminal velocity of the craft.
>
> Also note that the higher velocity solar wind emanates more consistently from the sun's poles. This should mean that a craft flying out of the ecliptic plane should reach a higher velocity. I understand that Jeff Greason has been looking into this regime for missions.
>
> LINK
>
> > **Michael Fidler** November 21, 2021, 2:49

Space Review
Space Transport News
Space Travel Blog UT Tartu Observatory
Spaceflight History
Spacewriter's Ramblings
Stan Erickson's Alien Civilization Blog
Star Bright?
Star Stryder
Starts with a Bang
Strange Paths
Sufficiently Advanced
Supernova Condensate
This Is Rocket Science
This Week's Finds in Mathematical Physics
Tiny Mantras
Titan Exploration
Tom Barclay/Planet Hunter
Tomorrow Is Here
Trevor Paglen
Ultratech Memes
Universe Today
Unmanned Spaceflight
Velcro City Tourist Board
Visions 2200
Visual Astronomy
Visualizing Science
Wanderingspace
Watered Down Physics
Where's The Flux (Tabby's Star)
Will Gater
Woodward Effect
Worlds of David Darling
Wow! Signal Podcast
Written Worlds

Archives

December 2022
November 2022
October 2022
September 2022

Yes, I was thinking about that after commenting but it would seem better to increase power to the wind rider while close to the sun with possible solar arrays. The solar array could be ejected after getting further from the sun but could help boost the ship to a much higher speed. The enlarged magnetic field from the coil would be able to take advantage of the solar flares and also protect the equipment from damage. Maybe the bottom sun shield could be made of some new solar power film that would not add much to the total weight of the wind rider. Lightweight Flexible Holographic Lens could be stowed and when reaching the suns gravitational lens, stretched out a crossed the round coils to help generate a usable image...

LINK

> **Alex Tolley** November 21, 2021, 10:45
> A flat sheet with a holographic lens might best be deployed and stiffened by rotation. The Pathfinder mission assumes a small nuclear (RTG) power source rather than solar PV. The sun shield is intended to become an antenna and needs to be away from the sensor/lens to avoid interfering with the image acquisition.
>
> I expect to be receiving the 2 mission studies after publication to get any more details on the craft design and mission parameters.
>
> LINK

John Davies November 19, 2021, 18:56

Paul & Alex
A striking concept. A couple of references seem to be missing. There does not seem to be a [1] or a [2] in the body of the text? [3] and later seem to be there but the first two are absent, I believe?
John

LINK

> **Paul Gilster** November 21, 2021, 7:07
> John, it's now fixed. Sorry about that.
>
> LINK

Patient Observer November 19, 2021, 19:16

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How scalable? Multi-ton payloads would be cool.

LINK

> **Alex Tolley** November 20, 2021, 11:45
> Theoretically very scalable. The principle way to scale upwards is to use more power to generate a stronger primary magnetic field which in turn increases the size and strength of the induced field in the rotating captured solar wind particles. An increase in the size and x-section of the coils is probably also required which increases mass. In principle I don't see why it shouldn't scale up to allow large robot probes and even crewed vehicles (the magnetosphere protecting the crew from solar flares).
>
> Bear in mind that the rotating captured solar wind particles is not a rigid structure like a coil, so there may be issues with this stream of rotating ions being deformed and with it the magnetosphere. That may be a problem, or possibly a benefit for some steering solutions.
>
> LINK
>
> > **Jeff Wright** November 22, 2021, 6:02
> > There was a recent NAIC paper on how a kilometer wide structure could fit in Falcon Heavy. Might that be adapted? Folks want lasers for starshot. Might masers and particle beams be useful here…making this a physical "cursor" of sorts?
> >
> > LINK

William Alschuler November 19, 2021, 21:26

The sail field is dipole shaped, like the earth's. What about the following scheme for functional plasma sail rudders: four smaller field generators that are spaced around the main ring, spaced out from it by about 10km (main induced field diameter) plus the diameter of the smaller induced fields. Two of them in the plane of the ecliptic, opposite each other, two in the plane perpendicular to the ecliptic, also opposite each other. They could be on all the time to add to the general thrust, turned off or turned down asymmetrically to give a turning thrust, or only turned on asymmetrically when needed if power/energy is an issue, when steering is desired. The sticking point I see is their mechanical connection to the main sail equipment and each other, but perhaps someone else will point to another problem. A modification of this idea might be to have just an annular ring of smaller field sails, all in parallel, aperture adding up to the desired total for thrust, selectively throttled for steering. Again their

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mechanical connection is perhaps a problem. If either idea worked it would presumably allow a return trip in-system, and not just on a spiral path, as mentioned in Tolley's prior 12/29/17 article.

LINK

Michael November 20, 2021, 10:51

I thought about a mag sail idea a while back, the coil was wound onto two bobbins. The contra rotation of the two bobbins on the same shaft opened the coil at the same time a current was set up, a sun shield of solar cells was used to allow superconductivity earlier and power the coil. The issue with mag sails is the low momentum of the solar wind, other than that a wonderful idea.

LINK

> **Alex Tolley** November 20, 2021, 14:39
> That issue of momentum is solved by the plasma magnet approach. (See my first 2017 article on the technology). Relatively small coils "capture" and induce the solar wind particles to rotate around the craft, in turn generating the main magnetic field. As this field is much greater in size than that generated by the primary coils, the thrust from the pressure of the solar wind is that much greater. Moreover, the size of the trapped solar particles is determined inversely by the density of the solar wind particles,. As the craft travels away from the sun, the solar wind density falls, but the magnetosphere increases in size to compensate, maintaining a constant thrust. In practice, the trapped particles are both being added to by the solar wind and being lost, a dynamic situation that maintains a residency of particles. The idea is very elegant, harnessing the medium by coopting it.
>
> Whether this works as advertised needs to be tested with relatively inexpensive hardware. I suspect the main costs are the launch to a position outside the Earth's magnetosphere (not a common satellite destination) and the overhead of the ground facilities and personnel to monitor the craft, similar to the that of the Planetary Society's LightSail project. (Several technical staff with computers. LightSail got a free piggyback to LEO, but the Wind Rider prototype needs a lift to much further out. Piggybacked with a free flight on the way to L2 with the JWST would have been nice).
>
> LINK
>
> > **Michael** November 21, 2021, 13:46

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> I suppose then having two sets of bobbins in a cross formation with the two coil joined at the top would be an effective means of deployment.
>
> LINK

Andrei November 20, 2021, 12:47

Thank you Mr Tolley for a very good presentation.
I think it's known on at least this site that I am a strong advocate for magnetic sail propulsion. While there's been interesting ideas presented, it was Pekka Janhunen proposal that was the game changer in my perspective.
If the method described here turn out to be feasible, the change is comparable to from doing exploration by foot – to taking a high speed train. Not Tau zero, but at least TAU. =)

LINK

Alex Tolley November 20, 2021, 14:22

Putting the thrust into perspective.

From reference 4, a 100km radius coil (equivalent to the radius of the trapped rotating solar ions) generates a thrust of 225 N. This is several orders of magnitude lower compared to a main engine of any launcher, but similarly the same orders of magnitude larger than ion engines. It is roughly comparable to the thrust of the Gemini spacecraft reaction control system thrusters.

So imagine those thrusters firing continuously for days or months.

As with any electric system, there is an energy cost. The modeled values for the coil in reference 4 is 40 kA (no kW given). (Resistance heating would be very high and the x-section of the coil large and hence massive to cope with the amperage). Although the power is much lower for the plasma magnet approach as only the primary coils are needed to be powered, there is an obvious advantage in using superconducting materials for the coils of the Wind Rider, an engineering solution suggested by a number of traditional magsail designs.

LINK

> **Andrei** November 21, 2021, 15:35
> Thank you for the clarification, I did suspect that nano- and

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picosatellite designs was the idea that gave this such a huge advantage over any other means – by low mass. And indeed, the proposal for a Jupiter mission was a Cubesat.

If high temperature super conductors could be utilized, then Nitrogen, alternatively Argon cooling also need to be incorporated into the design. While a super conductor could mean smaller power use, the cooling system it could affect the need of power as well. Yes there's one room temperature superconductor candidate, and one just under freezing point – but both need extreme pressure to conduct.

LINK

> **Alex Tolley** November 22, 2021, 13:52
> Remember that the background temperature of space is 4K. Sufficient shielding from energy sources, primarily the sun, allows an object to cool towards this temperature. This is why the cold traps on the Moon occur – permanently shadowed areas where only conduction through the ground occurs. On the Moon, surface temperatures during the night drop to -173C (100K) 23C higher than LN2. Using higher temperature superconductors one could operate even during the lunar night. At Saturn, the lowest temperatures are 82K. Well-shielded objects should be able to fall to even lower temperatures.
>
> LINK

torque_xtr November 21, 2021, 7:48

I always say that bringing innovative propulsion concepts to higher TRL does much more good than trying to squeeze everything out of chemical propulsion and plan multi-decadal outer Solar system missions. If a single flagship-class investment goes the right way, then everything with arrival time later than 2040 will be outrun.

The highest wind speeds I've seen while monitoring space weather and hunting for auroras are something around 800 km/s. Riding these gales would bring spacecraft almost into direct exhaust nuclear propulsion territory!

Are there any differences with earlier M2P2 inflated magnetosail concept, aside of superconducting coils?

I think there would be many options for lateral thrust, starting from using solar wind inhomogenities (allowing maybe an one-degree cone of

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trajectories). Interactions with pockets of interplanetary magnetic field embedded in solar wind, rotating tethered configurations, controlled bounces off Jovian magnetosphere, and likely many more ways.

But of course, all of this brings us back (or forward?) from precisely-calculated trajectories and maneuvers to the art akin to sailing the globe and getting from point A to point B through all winds and storms.

I imagine space regatta on wind riders. Traditional Earth-based sailing contests are something to watch, but solar wind racing is infinitely more rich than that. The first who makes it from Earth's L2 to Jupiter gets the main prize, but the first does not always mean the most spectacular and epic, because all kinds of solar winds, shock waves and disturbances, with different velocities, densities and interplanetary magnetic field polarities, are in the way.

LINK

> **Alex Tolley** November 21, 2021, 14:31
>
> > Are there any differences with earlier M2P2 inflated magnetosail concept, aside of superconducting coils?
>
> Winglee's M2P2 used onboard material to form the ion particles needed. The principle improvement of the PM was to dispense with the need for this by using the solar wind particles themselves.
>
> Re: steering sailing ships. As you are aware, even square-rigged sail allow a ship to change direction against the wind, primarily by use of the keel to prevent side-slip, and the rudder to push against the water. There is no equivalent in space, although planetary magnetic fields and even gravity can be harnessed in some way to change direction. Even on Earth, large merchant sailing ships did not sail up to the dock, but rather were towed in by various means, as steering under wind is too crude to allow a gentle docking with the facilities. Steering the Wind Rider is going to be an issue, although there are options. In the far future, there may even be tugs to steer them safely and gently into space docks!
>
> LINK
>
> > **torque_xtr** November 24, 2021, 6:44
> >
> > So, if I get this correct, the basic concept is just magnetobraking in reverse. Solar wind plasma runs up against magnetic field, and the secondary current is induced almost like when a neodymium magnet is dropped through a thick copper tube. The difference is, the more dilute is the plasma, the wider is the

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secondary current, just because of conductive properties of completely ionized plasma.

The removed center-of-gravity certainly looks like a solution for crosswind capability. Maybe if a payload is suspended at some distance in front of ring coil from Fig.6, like on a chute or even a paraglider, then crosswind is achieved by tugging suspension lines. The coil needs not to be rigid, it could be inflated by magnetic field pressure, and not much is needed with these gentle accelerations. It could be spread out or contracted by winding the wire onto compact coils with magnetic-field-canceling configuration, distributed along it's length. Then, the spacecraft could fly into magnetotail of a gas giant, decelerate there using trapped particles, and achieve orbital insertion by using conventional electric propulsion or even inward-moving streams of plasma. There is multitude of possible ideas, largely unexplored. The braking still requires much harder loads than acceleration, but for orbital insertion missions, reduced cruise speeds could be used to make the braking load manageable. Even 50 km/s from Earth to Neptune is something.

I cannot hold myself from imagining wind-riding races of the future again and again. "That year winds were calm and a dull race could result if not for a contestant from Space-Omega who steered aside to catch a fast-moving posket of solar wind and darted outwards at 600 km/s but missed the target by tenth of degree, unable to get exactly back on track…"

LINK

Patient Observer November 21, 2021, 18:31

Are those gusty winds associated with the 11/22 year sunspot cycle? If so, it suggests certain favorable launch windows.

LINK

charlie November 21, 2021, 14:18

This was probably one of the most difficult articles that I have ever had to look at within the Centauri Dreams long list of articles that have ever been posted. I found myself with a lot of questions and very little understanding of the explanations offered here. Additionally I do have a few comments based on what I believe I understand. To start with, this method of propulsion is totally inexplicable to me.

Are you saying to the reader that the principal concept is to induce a

continuously flowing current with in a set of superconducting coils which must be continuously shielded from principally the heat energy of the sun? I assume, that what you are attempting to do with the superconducting coils is to continuously generate a standing magnetic field which will interact with the solar when and somehow or another create propulsion. So my first question to you is if you have a flowing current in a superconducting coil which is generating a magnetic field wouldn't you eventually lose energy in the coil?

The reason for me saying this is that is not a principle of physics that a moving current will radiate electromagnetic radiation from itself due to the motion of charges? Isn't that the principal for example behind radio and TV? If so, then how do you expect this coil to maintain its energy for a long period of time such that it can serve to generate a magnetic field? Or do I have my conception of physics incorrect?

Additionally, doesn't seem really practical to be able to shield your superconductoring coil from all radiation from the sun? Especially over the many months you expected to be in operation. Especially if you are talking about tracking which I understand has to do with tilting the entire craft to permit it to turn-dozen that in turn result in having the coils being exposed to heat? And finally how do you expect (if you wish to) to insert yourself into an orbit about a planetary body that you wish to observe?

Finally, who is the author of this article and whose picture is that at the beginning of the article? It's common practice for Paul to usually introduce when he writes an article both who is the author and to identify with the caption the picture of individuals included with the article.

LINK

> **Paul Gilster** November 21, 2021, 20:32
> Actually, when I do a guest post, I always cite the author's name at the top, with his or her picture directly below, unless the author prefers no photo. So the author here is Alex Tolley, and the image is Alex.
>
> LINK

Dan Flanagan November 21, 2021, 16:29

So the WIND RIDER can reach speeds as that of the solar wind, which is 400,000 km/s?
I thought the speed of light was just under 300,000 km/s.

LINK

> **Paul Gilster** November 21, 2021, 20:31
> 400 km/s is the figure Alex cited, not 400,000 km/s.
>
> LINK

charlie November 21, 2021, 17:43

So anyway, I did look at your 2017 entry on this same plasma engine that you are talking about here currently as well as the YouTube video which got into a little bit more detail on what this whole thing is about and now I have somewhat more of a (relative) clear picture of what is going on with regards to this. I don't quite follow why a rotating conductor is required to create a rotating magnetic field which then in some fashion interacts with the solar wind and creates thrust. I can see how in a regular motor you have a counter rotation due to the push on the permanent magnets on the (stator?) which induces rotary motion, but I'm not sure exactly how that translates into an interaction with solar plasma that creates thrust.

It would seem that a rotating conductor would have a counter torque on whatever it was attached to and you would have to in some fashion provide a relatively "stationary" platform against which the rotating conductor would rotate against, but again the devil is in the details.

All that being said this is seemingly almost too good to be true in terms of its potentiality but if it is in fact true it would represent a revolutionary new development which would be capable of getting where you wanted to go (at least within the solar system) in a very, very quick fashion. Obviously there be a lot of details that would need to be addressed to make it viable but I feel assured that someone is looked into it. The question here is as was pointed out in the comments section of the video is: why hasn't this been touted from the mountain tops and stressed as a priority project ?? Quite strange, if you asked me. As for interstellar travel the man in the video made a very intriguing comment near the end of the video in which he suggested that lithium-deuterium pallets could be fired at the magnetic field which would induce thermonuclear fusion creating a temporary plasma which in effect would drive the craft to at least one half velocity of light speed. Again, quite imaginative and if realizable would certainly be a game changer.

LINK

> **Alex Tolley** November 22, 2021, 12:50

> The question here is as was pointed out in the comments section of the video is: why hasn't this been touted from the mountain tops and stressed as a priority project ?

30 years ago the same was being said of solar sails. The idea had been around for a long time. Eric Drexler was pounding the table on this back in the 1980s. Arthur C Clarke edited a book with a mix of fact and fiction called Project Solar Sail. What happened? Nada. But the Planetary Society started work on a real sail – Cosmos-1, which after 2 failures succeeded with a much smaller CubeSat version. The delays allowed JAXA to be first with a real sail (IKAROS) that was navigated into deep space. Sometimes things take a long time to gain traction against established ideas. Launchers that could be reused and land on their tails was ignored by the industry until SpaceX proved the concept. (The Space Shuttle was reusable, but hugely expensive and complicated by comparison). Now all the launch providers are designing their own versions to reduce costs and stay in business. Similarly, even though electric cars were better than ICE vehicles around the beginning of the 20th century, they fell into disfavor due to poor batter performance. Even GM could not successfully revive the concept. Tesla almost singlehandedly made electric cars "sexy" and conquered much of the range anxiety with LiOn batteries. Now every major car manufacturer is committed to making the electric vehicle the main product to be powered by renewable energy in the global Net Zero by 2050 strategy.

We know why some good ideas get stalled – vested interests satisfied with the status quo and the barriers to entry of competing technologies. Sometimes they remain stalled. Sometimes they can gain traction if resources are provided and the technology nurtured. The barrier in this case is the cost to reach a testing ground.

LINK

charlie November 22, 2021, 13:45

"I don't quite follow why a rotating conductor is required to create a rotating magnetic field which then in some fashion interacts with the solar wind and creates thrust. I can see how in a regular motor you have a counter rotation due to the push on the permanent magnets on the (stator?) which induces rotary motion, but I'm not sure exactly how that translates into an interaction with solar plasma that creates thrust.

It would seem that a rotating conductor would have a counter torque on whatever it was attached to and you would have to in some fashion provide a relatively "stationary" platform against which the rotating conductor would rotate against, but again the devil is in the details.

AND

As for interstellar travel the man in the video made a very intriguing comment near the end of the video in which he suggested that lithium-deuterium pallets could be fired at the magnetic field which would induce thermonuclear fusion creating a temporary plasma which in effect would drive the craft to at least one half velocity of light speed. ”

Alex, could you possibly throw some light or possible further explanation upon some of the points that I have raised here above from my understanding of what you have written and/or the points brought out in the video at the conference on these plasma magnetic sales ??

LINK

Patient Observer November 21, 2021, 18:38

Speculation ahead. A rotating sphere or cylinder in a fluid stream can generate a force perpendicular to the direction of fluid flow (think of a curve ball thrown by a pitcher). Could the magnet field rotate using multiple magnets as done in 3-phase motors? The rotating field could possibly accelerate the wind on one side and retard the wind on the other side resulting in a net force analogous to a rotating ball or cylinder in a fluid flow field.

LINK

AlexTru November 22, 2021, 6:18

All fine dreams described here are sound very nice, but have one huge problem – “Plasma Magnet” idea will not work as it is described in this (and reference) article.
The some parody on current loop is possible only for charged particles that has relative (to vehicle) speed vector close to zero all particles that have speed higher and lower that vehicle will be deflected only – will not form any huge (relatively to coil diameter) “current loop” , probably the charged particles that moves with vehicle’s speed to same direction will be form a small sized current loop located close to the electromagnet, no more, so finally expected thrust is defined by electromagnets physical dimensions and magnetic field strength only.
So idea that looks fine for wishful thinker has no theoretic ground under it.

LINK

Alex Tolley November 22, 2021, 12:29

I have 2 answers to your point that at the solar wind speed, the large field might “collapse” due to a lack of trapped ions.

1. The solar wind is a distribution of ion speeds, not a homogenous bulk object. The craft speed theoretically maxes out at the average wind speed, i.e. there are ions that it is traveling faster than, and ions that are still impinging on the craft’s magnetic field, as well as replacing any ions that are lost. It is therefore at some equilibrium.

2. Suppose you are correct and that this is indeed a flaw in the theory. So the craft’s maximum velocity is perhaps some fraction of the average solar wind speed. How low a fraction of the solar wind velocity can the craft reach is tolerable before you say it is unacceptable? 50%, 25%, 10%?

Having said that, the theory paper (reference 4) on the dynamics of a fixed size electric coil in the solar wind assumes that the wind is flowing past the coil’s magnetic field. The drag (i.e. thrust) is dependent on that velocity, as one would expect. However, when the coil is replaced by a stream of ions, it is possible that this model breaks down. That is the purpose of building a prototype to test reality. How does a physical craft’s performance match theory and where does it break down? Given the potential theoretical high performance and the relatively low cost of the craft, it seems well worth testing the concept.

Last thought. Best to test actual vehicles versus theory. It can be counterintuitive. Earlier in the 20th century it was thought than no aircraft could fly faster than the speed of sound. The best more recent example I can give is that a wind powered vehicle on land that can move downwind faster than the wind. This seems impossible, and many thought so, but it is not: Blackbird.

LINK

Alex Tru November 23, 2021, 4:06

There are any theoretical problem with interaction
between magnetic coil and solar wind, but this interaction will be limited by coil dimensions and close distance from it.
Due to huge relative speed difference between magnetic coil and solar wind – there will be no any “plasma current loop”, this “loop” will be blown out by solar wind there will be nothing to extend…
Whole idea of “plasma magnet” is based on this loop – that is not theoretically possible in open and very dynamic environment.
I believe that in physical laboratory the plasma media in CLOSED and very limited VOLUME can form something similar to described plasma current loop.

The “plasma magnet / current loop” idea described in this concept is directly related to “Perpetuum mobile” concept – i.e. violating thermodynamic laws

LINK

Alex Tolley November 23, 2021, 10:25

What you are saying is that the lab experiment was not truly a demonstration of the PM effect at scale and that Winglee and Slough were mistaken about the mechanism, and that this error has propagated to fool others into believing in this propulsion scheme.

But would you not also agree that the best way to test this is to build a scaled up model to test in space where the effect can be measured and the performance assessed? If you are correct about the theory, then the model will fail to demonstrate the acceleration predicted and barely move. If the model works, then your belief about the theory is wrong and progress has been made to move forward and build the JOVE CubeSat model and fly the mission.

LINK

AlexTru November 23, 2021, 18:04

> ...What you are saying is that the lab experiment was not truly a demonstration of the PM effect...this error has propagated to fool others...

Yes, it is what I mean.
By the way the data provided in reference document #5 is more similar to Volt-Ampere characteristic of vacuum (or gas discharge) tube. There are results of behavior of closed system, where particle free fly distance is hardly limited by chamber volume. It is very ridiculous to met there some reference to 30km open space loop radius , based on closed space tests :-)
Summary no physical theory supporting Slough’s proclamations, so there is nothing to test in the space – this is the main problem of discussed attractive idea.

LINK

charlie November 23, 2021, 11:41

@Alex Tru
“The “plasma magnet / current loop” idea described in this

concept is directly related to “Perpetuum mobile” concept – i.e. violating thermodynamic laws.”

With regards to your comment directly above, is there any reference here to the idea (that a moving current will radiate electromagnetic radiation from itself due to the motion of charges?):

“Are you saying to the reader that the principal concept is to induce a continuously flowing current with in a set of superconducting coils which must be continuously shielded from principally the heat energy of the sun? I assume, that what you are attempting to do with the superconducting coils is to continuously generate a standing magnetic field which will interact with the solar when and somehow or another create propulsion. So my first question to you is if you have a flowing current in a superconducting coil which is generating a magnetic field wouldn’t you eventually lose energy in the coil?

The reason for me saying this is that is not a principle of physics that a moving current will radiate electromagnetic radiation from itself due to the motion of charges? Isn’t that the principal for example behind radio and TV? If so, then how do you expect this coil to maintain its energy for a long period of time such that it can serve to generate a magnetic field? Or do I have my conception of physics incorrect?” ???

LINK

> **Alex Tolley** November 23, 2021, 15:31
> Superconducting magnets only need a tiny additional power feed to compensate for resistive losses on non-superconducting parts, as well as any requirement to maintain refrigeration.
>
> source: Superconducting Coil
> What I am not clear about is whether the induced flow of solar wind ions to create the inflated magnetosphere creates a counter force against the moving coils and this needs to be offset with more power to keep the coils rotating.
>
> The design of the JOVE mission craft that has just 1300 W to start and a mere 50 W at 5AU near Jupiter suggests that any counter force must be very small assuming all the forces have been calculated. 50W must also power the science instruments and any data communication to Earth. The

required power for keeping the induced magnetosphere operating is given in the Slough paper equations (for non-superconducting coils).

Assuming the sun shield can keep the coils in shadow, there seems no reason to expect that any power is required to maintain refrigeration of the high temperature superconducting coils, even at 1 AU.

Hopefully, access to the full paper will resolve this and related questions.

LINK

Ron S. November 23, 2021, 17:06
"a moving current will radiate electromagnetic radiation"

EM radiation require charge acceleration. Motion isn't good enough. Place a resistor and a battery in series and the only EM radiation is during the brief instants when you connect and disconnect the circuit (on and off).

LINK

AlexTru November 23, 2021, 18:43
Ron S.
Electrons that are running in "your" (battery resistor) circuit are changing direction during their trajectory from one pole to another, so they have acceleration, but create only constant magnetic field.
As well as charged particle that moves around cyclic trajectory (so it has acceleration) in perpendicular to constant magnetic field – does not radiate EM waves…
(there is only constant magnetic field)…
So your definition is not full.

LINK

AlexTru November 23, 2021, 18:51
By the way the current running in resistor –
will create heat – that is EM waves , so even in this case your example is not correct :-)
So only ideal conditions can satisfy "no energy loss" state.

LINK

Ron S. November 23, 2021, 22:07
Yes, you are correct. I was attempting a simple example to illustrate the concept, but of course in the real world these “ideal” situations do not exist.

LINK

AlexTru November 23, 2021, 18:12
charlie – I suppose you are asking your questions in wrong place – I am not author of Plasma Magnet idea. My point – that this idea does not have any theoretical support at least in modern physic.
J. Slough created plasma current inside huge magnetron-like gas discharge tube and decided that it is engine – so you should ask idea’s author about his theory.

LINK

charlie November 24, 2021, 12:54
@AlexTru

I certainly understood that you were not the author of the paper presented here. Rather I was addressing the idea that you mention a perpetual motion machine. Your comment got me to wondering whether or not the superconducting coil for the magnetic field would eventually dissipate its current energy by the omission of electromagnetic radiation. That’s what I was wondering if you had a idea about.

Superconducting conductors have perpetual current running in them and that got me to thinking that the perpetual current would radiate EM radiation and eventually exhaust its energy. I thought you (or someone else) might have a answer to that

LINK

Alex Tolley November 24, 2021, 13:47
> perpetual current would radiate EM radiation and eventually exhaust its energy.

There is no EM radiation from an electric current.

The magnetic field is not like the emission of photons that requires energy. If there was, rapidly moving a superconducting conducting wire with another superconducting coil with a flowing current would result in some heating as the em radiation from the magnet was absorbed by the wire. If it was non-superconducting, the wire would only heat up due to ohmic resistance from the induced current. As there is no resistance in a superconducting wire, there would be no heating, nor would the coil generating the magnetic field heat up or cool.

As you probably know, the changing magnetic fields in a tokamak reactor heat the plasma. The only heating effect on the magnetic coils (assuming superconducting) is due to the em radiation of the plasma heating the reactor components. There is no concomitant em emission from the superconducting magnets AFAIK.

In the case of the Wind Rider's PM approach, the solar wind ions impinging on the magnetosphere and those circulating to create that magnetosphere, could theoretically experience "heating" although this means something rather different in this situation as the temperature of the ions is measured by their velocity. [Similar to the thermosphere in the upper atmosphere, and the medium at the boundary of the heliosphere and the ISM.] The trapped ions circulating in the PM might actually be cooler than the solar wind if their velocity is reduced at all. Although the Nishida paper does not show it, the solar wind impinging on the magnetosphere is likely slowing, and therefore "cooling" as their momentum is transferred to the craft.

LINK

AlexTru November 24, 2021, 16:51

@charlie – please find tin this comments two messages above Ron S. comment and my notes to his comment – you will find there answer.

LINK

AlexTru November 23, 2021, 9:32

To test the idea in real space – someone need to design the new engine using some theory , but when we are talking about this specific “Plasma magnet” engine – there is no any theory standing after this concept, it is not supported by modern physic.
Most bothering fact that this concept can be seriously discussed…

LINK

Alex Tolley November 23, 2021, 14:16

You may disagree with the theory, but the theory has been explained and it has been validated experimentally in the lab by both Winglee (M2P2) and Slough (PM). There seems little doubt to me that the idea works in principle, it just needs testing the performance in space.

I have read various critiques of various propulsion approaches by Alexander Bolonkin who seems to reflect your thinking about false theories. For example:

> There are also many articles about magnetic sails using solar wind drag into a magnetic field of a gigantic superconductive ring (diameter 60–150 km). Unfortunately, no theory currently exists to allow computation of magsail drag. It is beyond the capability of current technology. The reader can find information about the space magsail in Reference [52].

Source: Non-Rocket Space Launch and Flight (2005)

[There are no exact mathematical solutions to the Navier–Stokes equations for all fluid flow and turbulence conditions either, but fluid dynamics can be simulated, and the simulations around airframes do seem to closely match actual wind tunnel test results. Simulations work well for wind turbine designs, and racing yacht hulls and sail designs as just 3 further examples.]

LINK

AlexTru November 23, 2021, 18:35

Fun – all name there are Alex :-)
Dear Alex Tolley, in you quote Alexander Bolonkin is talking about more reasonable variant – problem to calculate drag caused by interaction between real coil and solar wind.
When Slough’s idea even more problematic – to create drag it uses virtual huge sized “Plasma Magnet” growing up from small sized physical coil – it is much more nonsense.
Everything in “Plasma Magnet” is funny, it is hard to decide

from which fail in this idea to start…

LINK

AlexTru November 25, 2021, 4:26

> … Simulations work well for wind turbine designs, and racing yacht hulls and sail designs as just 3 further examples….

Yes it will work for real electromagnet , but will not work for virtual “plasma magnet” – that is difference.
Slough experiments for NASA are not about engine, it is about measuring volt-ampere characteristics of gas-discharge (or vacuum) tube.
Whole Slough’s idea tells as: “we do not need to build huge electromagnet – we will grow it up from plasma, so this “plasma magnet “ will create huge drag from solar wind”.
P.S. Every schoolboy can build simplest model of EMD engine using two electrodes, battery and strong permanent magnet. I am sure same principles can be scaled to space.

LINK

Drew December 1, 2021, 14:51

I’ve vaguely followed the progress of the plasma magnet idea for the last few years. I can’t say I’ve been super convinced that it will definitely work in a real space environment, but neither have i been convinced that it definitely won’t work. My understanding of what literature I’ve read is that the concept is theoretically sound, limited simulations and small scale lab tests suggest it works, but no authoritative and thorough full simulations work (ie full magnetic+electrostatic plasma simulations that allow the plasma loop to build up naturally rather than inserted on an ad hoc basis). But you sound very confident that it won’t work, AlexTru. Is there some literature you can point to that shows clearly it won’t work? (And it’s worth explicitly noting that we’re talking about the “plasma magnet” concept here, not the mini mag sphere inflatable bubble concept)

LINK

AlexTru December 4, 2021, 7:38

Drew,
I do not have any special literature that is dedicated

to this special case, be such such devices are not exists in reality.
Author gave you some reference materials to study, if you will look at the reference about laboratory tests and will analyze the content, you will find that laboratory tested device is in reality not engine, but huge gas discharge tube and authors succeed to measure it's Volt-Ampere characteristics.
So reference to laboratory results as prof of "plasma magnet" engine – is pointing nowhere, none tested any engine here.

LINK

Alex Tolley November 22, 2021, 14:15

My question on the ability to steer based on the work of the Nishida paper (ref 4) concerns the different between a rigid coil and the stream of circulating ions of the PM drive.

A symmetric force seems OK, but is an asymmetric one that torques on the ion stream going to work the same way or distort the stream? The effect may work for or against the desired vectoring effect. One way to model this might be to assume different shapes for the rigid coil or make the coil non-rigid in the simulations. (Or just test a real vehicle!)

One can understand the need for rigidity in wind and solar sails. A wind sail of any design is stretched with masts and lines under tension. Release those forces on the sail and it flaps about in the wind. All contemporary kite designs for solar sails are the same.

NASA once proposed the heliogyro solar sail for the Comet Halley rendezvous in 1986, a large design that used rotation of the sail to provide the forces to put it under tension. Theoretically one could spin up a wind sail to do the same, although I don't think it has even been attempted and would probably fail in a strong wind even it it was a desirable design.

The circulating ions in the PM are entrained by various magnetic forces, but will also be subjected to forces that impinge on the magnetic field they generate. Are they held more like the masts and tension lines of wind and solar sail craft designs, or those of the heliogyro? How resistant are they to distortion (like a storm breaking a wind sail mast)?

We can probably model this to some extent, but testing a real craft will give us the best answers at this point, just as any aircraft design that has passed all the modeling and wind tunnel tests still needs to be run through test

flights to confirm its performance.

LINK

Jeff Wright November 23, 2021, 4:07

Unlike solar sails, I see more end of life uses of these. Mine metal rich asteroid mass to cables and loop around Jupiter back to Earth as Dyson Harrops. Coils lined up at Jupiter, etc.

LINK

Nathaniel Gritzman November 27, 2021, 2:54

Would there be any utility in this craft as an asteroid redirect candidate?
Either high velocity impactor, or alternatively, send craft via traditional means to rendevouz with candidate asteroid, anchor and deploy to alter trajectory over time etc.

Asking as there's a potential source of funding NASA may have available if there's a viable possibility here.

LINK

> **Alex Tolley** November 27, 2021, 11:53
> Interesting idea. Especially the anchor and push scenario. I have passed this on to the authors.
>
> LINK

> **Alex Tolley** November 27, 2021, 12:31
> I heard back from the authors that they thought it was a very interesting idea and that their group has already been looking at it. There was a paper submitted to the conference by one of their members but it was rejected. So you are definitely on the right ideas track. No mention of possible Nasa funding though.
>
> LINK

> **Michel Lamontagne** December 14, 2021, 15:38
> There should have been a paper on that but i believe they missed the conference window. so, yes.
>
> LINK

Mark November 27, 2021, 10:22

How long would a Wind Rider take to reach the various trans-Neptunian dwarf planets? Eris? Haumea? Makemake? and so on.

LINK

> **Alex Tolley** November 27, 2021, 11:51
> Assume that the Wind Rider travels at 400 km/s, in a straight line. Divide the chosen body's distance by this velocity and you get your answer. You can do this for any celestial body in orbit outside of Earth's.
>
> LINK

dpd December 3, 2021, 6:59

I do have one question concerning mag sails.

While they can ride the solar wind to high (velocities taking only weeks or months to reach the outer planets with zero fuel costs) and they can use plasma breaking in the atmosphere or magnetic field of their destination planet upon arrival – how the heck do they return home to Earth going against the solar wind stream?

How do you configure a magnetic jib that will allow them to tack into the solar wind and return home?

LINK

Mohan Ahad December 6, 2021, 6:26

Can this device be used as the ram scoop for an intersteller ramjet?
If this is possible, then collecting the ions and accelerating them to oppose the solar wind could provide a braking system. This would overcome one of the original problems with this concept

LINK

Michael Fidler December 14, 2021, 10:57

Something that has always fascinated me is some type of large magnetic field being used for atmospheric reentry.

https://www.universetoday.com/46474/the-next-generation-of-heat-shield-magnetic/

https://www.newscientist.com/article/mg22329763-100-magnetic-bubble-may-give-space-probes-a-soft-landing/

LINK

Maui Dave June 2, 2022, 15:42

Reference [5] has the wrong date (1970) which should be 2004 and is also Phase I to the study. Figure 12 from the URL has the following caption: “A schematic and photograph of the SWS device used as the solar wind simulator. The orange segment is the copper cathode with the molybdenum disk secured. The black region is the stainless steel anode. The gray tungsten disk is placed at the end of the copper cathode to reduce sputtering. ” Was this the intended reference?

Phase II of the study (2006) can be accessed at the following URL. It contains updates to theoretical results as well as the experimental results:

http://www.niac.usra.edu/files/studies/final_report/917Slough.pdf

The 2005 presentation http://www.niac.usra.edu/files/library/meetings/annual/oct05/917Slough.pdf is also good and clarifies citations from references and has good graphics and concise explanations.

LINK

Paul Gilster June 3, 2022, 5:59

Thanks for this, Dave, and the URLs. Will check on the reference, which may need to be changed.

LINK

Maui Dave June 4, 2022, 16:47

Aloha, Paul. Wasn’t sure if this thread was still active. I can post some responses to AlexTru referencing specific equations and pages of the phase II report if that would be helpful.

LINK

Paul Gilster June 4, 2022, 20:11

Aloha, Dave. Sure, I’d welcome your responses to get

them into the record. Many thanks!

LINK

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