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ENABLING INTERSTELLAR TRAVEL: THE NEED FOR A DIVERSE MIX OF ADVANCED ENERGY CONCEPTS: SAFE TRACKING LASER POWER TRANSMISSION, HARVESTING PROBES & FUTURE PROPULSION SYSTEMS

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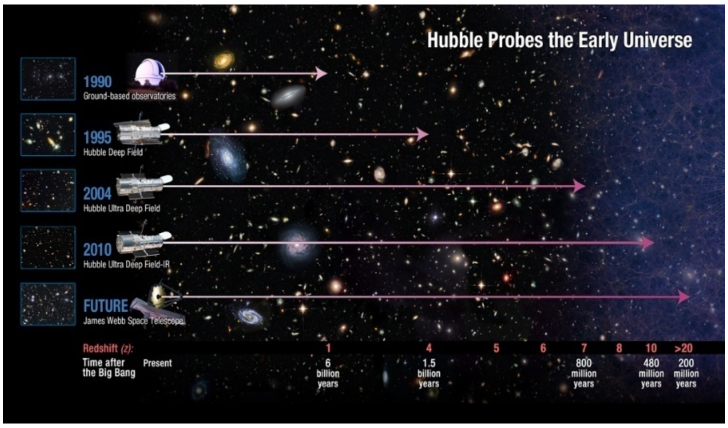
Abstract- *This paper represents a joint effort of various scholars, independent scientists and a student operating through the Interstellar Travel MeetUp group, based in Washington, D.C. in the United States of America. The project was presented during the 68th International Astronautical Federation Congress, which took place in Guadalajara, Mexico in 2016. Our paper provides a systematic evaluation of power systems in terms of their power generation capacity, size, risks and availability led to the finding that no current one single power system can be relied upon for interstellar travel. Our contribution offers considerations on topics such as space resupply stations, wireless power transmission to spaceships (while at high velocity, using tracking/tethering with lasers), as well as harvesting drones. Futuristic propulsion technologies like the ionic levitation, laser, warp and solar concentrator are considered as alternatives for current propulsion systems. In addition to placing an emphasis on fundamental physics and propulsion research, the authors propose two novel initiatives that will advance interstellar technology while producing already-valuable technologies for terrestrial and orbital use: 1) An educational development initiative – The 'Nicola Energy City Kit'is based on existing wireless power transmission technology and existing CanSat technology – to advance wireless power and data transmission for terrestrial and interstellar use. These technologies can affordably be tested on Earth first, and then in space. We propose a broad-based open education program that also motivates students to engage in STEM-related jobs. 2) A mobile save testing bed ('sandbox') for radical energy concepts – The UMPH lab is an unmanned outpost that accumulates large quantities of matter in save distance from Earth and conducts autonomous experiments, while harvesting energy or matter for the science and in-orbit resupplies.*

Keywords: *high technology*; *common technologies to space systems*; *space power*; *space propulsion*; *the International Astronautical Federation Congress*.



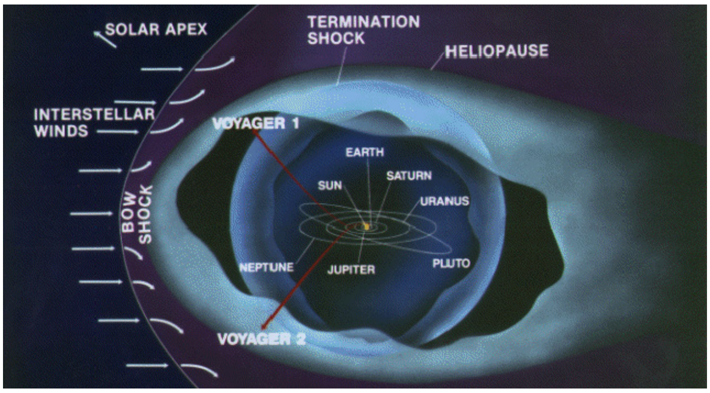
Source: Wikipedia Commons

I. INTRODUCTION

New telescopes have, and are likely to continue showing humanity what's out there. We are living is an age wherein anything seems possible. And, the space age is maturing. For example, the *Kepler* space observatory has located planets similar to Earth. As of May 10, 2017, NASA's Kepler mission has discovered 4,496 candidate exoplanets; 2,335 confirmed exoplanets; and 21 confirmed exoplanets "less than twice Earth-size in the habitable zone".[1]

[1] Information recorded and quote taken from NASA's official website at nasa.gov: Accessed 6 June 2017 at: https://www.nasa.gov/kepler/discoveries.

By way of further example, NASA's *Voyager Interstellar Mission* (VIM) accomplished objectives which seems unrealistic when the spacecraft were laughed several decades ago. NASA, for example, reports that as of February 2017, "Voyager 1 was at a distance of 20.6 Billion Kilometers (138 AU) from the sun and Voyager 2 at a distance of 17 Billion kilometers (114 AU)." Voyager mission reports support our claim that it is possible for human designed spacecraft to travel interstellar.[2]



Source: NASA.gov

This paper involved ten co-authors combined knowledge and focuses on existing technologies for advanced space travel as part of an Interstellar Travel MeetUp online consortium based in Washington, D.C.[3]This is a group for people interested in learning more about newly emerging trends related to plans for interstellar travel, asteroid mining, space policy and space law and outer space development. The ideas contained in this paper were accepted for presentation and archival delivery before the International Astronautical Federation - International Academy of Astronautics Congress, which took place in Jalisco, Guadalajara Mexico from 26-30 September, 2016.[4]This paper was accepted as part of Session C: "Technology", which invited papers on "common technologies to space systems", including astrodynamics (C1), materials and structures (C2), space power (C3) and space propulsion (C4). Specifically, Session C3 brought together scholars with ideas that focused on space power. The Session

Overview states:

Reliable energy systems continue to be key for all space missions. The future exploration and development of space depends on new, more affordable and more reliable energy sources of diverse types ranging from the very small to the extraordinarily large. Moreover, the continuing support for space activities by the public requires that these activities are increasingly inserted into the global challenge to transition current terrestrial energy systems into more environmentally friendly, sustainable ones. The space sector has traditionally served as cutting edge precursor for the development of some renewable power systems. These activities are now put into a much larger space & energy perspective. Topics range from joint technology development up to visionary concepts such as space solar power plants. The Space Power Symposium addresses all these aspects, covering the whole range from power generation, energy conversion & storage, power management, power transmission & distribution at system and sub-system levels including commercial considerations. It will include, but not be restricted, to topics such as advanced solar and nuclear systems for spacecraft power and propulsion, novel power generation and energy harvesting, and examine the prospects for using space-based power plants to provide energy remotely to the Earth or other planets.

II. THE SIGNIFICANCE OF PRESENTING AT THE IAC CONGRESS

On Tuesday morning 27, September 2016 (9:30-11:45) three of the co-authors, Edythe Weeks, Cameron Ashkarkhizani, and Nancy C. Wolfson, presented an overview and summary of the ideas contained herein, as part of IAC2016 technical session -*C3.2 Wireless Power Transmission Technologies, Experiments and Demonstrations*. Innovative research and advanced engineering concepts are presented each year by the international community during the International Astronautical Federation with its partner organizations, the International Academy of Astronautics (IAA) and the International Institute of Space Law (IISL), as they hold the International Astronautical Congress (IAC).

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[2]*Voyager: The Interstellar Mission*, NASA Jet Propulsion Laboratory, California Institute of Technology at: https://voyager.jpl.nasa.gov/mission/interstellar.html.
[3] See the *Interstellar Travel Meetup* at: http://www.meetup.com/Interstellar-Travel-100-Year-Starship/.
[4]For a list past cities and nations hosting the International Astronautical Congresses, see: http://www.iafastro.org/events/iac/past-iacs/.

The IAC has been happening since 1950; it is considered by the international space development community as "the most important annual interdisciplinary space meeting worldwide". Just a few years after Mexico formed its own space agency, the 67th Annual International Astronautical Federation Congress entitled "Making Space Accessible and Affordable to All Countries" was held in Guadalajara from September 26-30, 2016. The ideas contained in this paper were accepted for presentation and archival delivery before the International Astronautical Federation - International Academy of Astronautics Congress. During the IAC2016 in Mexico, "more than 2,000 abstracts were to be presented, 146 involved plenary sessions and about 30 symposia. This dynamic involving interaction of ideas between approximately 3,000 participants, academics, representatives and delegates "of the highest prestige in the world of aeronautics and astronautics, linked to over 100 countries". Being in attendance at the IAC allows a person to understand discussions on future plans and activities for outer space. It is consider being at the "The Olympic Games of Space" (named this because of its "academic and industry-oriented events that bring together the most important minds of the globe in the field").[5] In spite of all of this, a major obstacle continues to be a general lack of awareness from the global general public. This project and our efforts support the conviction that it is possible for authors from broad range of backgrounds to make a valued contribution to extend the global reach of innovative research in advanced engineering ideas and concepts. In so doing, we are advancing belief systems to influence the emergence of space travel.

III. LIKELY CHALLENGES

Two main challenges to interstellar travel stem from the human body's unsuitability for space and the current level of technological advancement. This paper investigates, examines and discusses this fundamental part of the technological challenge through the concept of power systems. Propulsion, navigation and control, life support systems, communications, as well as mission equipment depend on reliable energy supply and distribution. Systematic longevity and risk evaluation of current power system and sub-systems (such as nuclear reactors, fuel cells, photo-voltaic cells, bio-energy, laser and x-ray power transmission) can lead to reconsideration of futuristic concepts such as hull ionization, photon harvesting, solar sails and a strategy based on unmanned vehicles for energy harvesting and supplies. Methods for reliable and sustainable power may be achieved by sending probes ahead of missions, to build a network of re-powering and resupplying stations, with advanced, gravitic field propulsion. We suggest to give students development kits based on CanSats and nano satellites, to foster the development of underlying technologies.

A. Statement of the Problem: Prior Art

The prevailing opinion among scientists is that power systems, in terms of their power generation capacity, size, risks and availability, cannot be relied upon for interstellar travel. Neither single, hybrid nor backed-up concepts of nuclear reactors, fuel cells, photo-voltaic cells, or current anti-matter concepts appear feasible.

B. Why Our Concept is Significantly Relevant

Recent news regarding the discovery a planet orbiting the star nearest to our own sun, Proxima Centauri, possibly, being able to support life. The planet orbits the sun, is close to earth and has been deemed to be inhabitable. How will we get there? And if we can get there, what will we bring and what should we leave behind? As earthlings begin our journey into the stars, my hope is that we bring the best qualities of humanity. Our planet has not seen the best of us, and we are currently struggling with the reality of that fact. Our hope is for a collective new phase in human consciousness as we look to the stars for answers to our problems.

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[5]Press release accessed 12 December 2016: http://www.iafastro.org/wp-content/uploads/2014/04/IAC-2016-Live-Webcast-of-all-Plenaries-Available.pdf.

Let us bring the best of humanity to our endeavors to share in a new adventure of discovery of the universe. The survival theof human race could be at stake. Our planet may one day change conditions that may not be suitable for human habitation. Patterns of human evolvement keep us searching for what is beyond. It is our human nature to discover what is out there. Another planet that could sustain life should be explored further. The idea of finding of a planet within the habitable zone in the Proxima Centauri system shows a great deal of promise in terms of what can be expected in the years to come. Another possible Earthlike home planet only 4.25 light years away, could spark new discovering and further research considering the likelihood that there can be resources made available to benefit Earth and those that inhabit our planets. This latest news will benefit all of us. These finds are an exciting and important prospect for the development of propulsion systems that can get us to the next level of interstellar space travel within this generation. In addition, such data stimulates investors, for example report of Steven Hawking's involvement with the *Starshot* project for interstellar space exploration.[6] It is important that we take note of the reasons that stimulate and motivate involvement in these technical ventures. This paper makes strategic considerations on topics such as space resupply stations, wireless power transmission to spaceships (while at high velocity, using tracking/tethering with lasers), as well as harvesting probes. Futuristic propulsion technologies like the solar sails, hull ionization and radioisotope thermoelectric generators are considered. Although by many accounts, none of them may be considered feasible at this time, because of the restrictions posed by elements of time, distances, fuel, velocities and storage space. The most significant systems are listed below.

IV. FUTURISTIC PROPULSION TECHNOLOGIES

A. Ionic Levitation

In order to leave the surface of the Earth, atmospheric effects can be utilized to propel a vehicle into space. While atmospheric ionization to create lift is possible in the dense atmosphere of the Earth's surface, this will not be feasible in space where there is no atmosphere.

Name	SI Value	Abbreviation	SI
Mobility Constant	200.	$mm^2 \cdot V^{-1} \cdot s^{-1}$	square millimetres per volt-second
Resistivity (Air)	20.	PΩ·m	petaohm meters
Gravitational Acceleration	9.1	$m \cdot s^{-2}$	meters per second squared
Current (set)	33.33	μA	microamperes
Mass	1.	g	grams
Power (Predicted)	1.	W	watts
Power (at given Voltage)	1.	W	watts
Gravity Force	9.1	mN	millinewton
Gap against Force	54.6	mm	millimetres
Voltage from Power	30.	kV	kilovolts
Plasma Resistance	899.96	MΩ	megaohms
Plasma Resistivity-area	16.48	$G\Omega \cdot m^{-1}$	gigaohms per meter
Estimated Plasma Area	100.	mm^2	square millimeters
Resistivity for Plama Area	1.65	MΩ·m	megaohm meters
Mass to lift	1.	Mg	megagrams
Force to lift	9.1	kN	kilonewton
Current Gap to lift	1.82	A·m	ampere meters
Voltage required	30.	GV	gigavolts
Power provided	1.	GW	gigawatts
Current at Power	33.33	mA	milliamperes
Gap at Power	54.6	m	metres

Generally, ionic levitation using electricity to ionize the atmosphere to generate lift falls within a 1 W per 1 g lifting and is based on a 5.46 cm gap and 30kV to generate a plasma between the leads. The normal resistivity of air is 20 PΩ·m, but this becomes Plasma when the 30kV voltage is applied so that the resistance per meter becomes 16.48 $G\Omega \cdot m^{-1}$ for a current of 33.33 μA. See Table for a list of values and assumptions. Note, properties in bold represent physical constants and values in italics represent assumptions. Now, if we extrapolate this to 1 Mg = 1 metric ton, and allow our gap to stretch to 54.6 m, we would be providing 30 GV at 33.33 mA for a total power draw of 1 GW, which is enough to power a whole city. Pushing an arc of electricity through a the rather large, 54.6 m gap, almost a city block, is at about the level of lightening. Extending the gap to 54.6 km would reduce the power but now the separation is too massive to manage despite the lower current (33.33 μA) and power (1 MW). See Table for detailed calculations.

[6]Tariq Malik (April 12, 2016) "Stephen Hawking Helps Launch Project 'Starshot' for Interstellar Space Exploration" *Space.com*.

Property	Value	Units (Full Name)
Mobility Constant	$200.mm^2.V^{-1}.s^{-1}$	square millimetres per volt-second
Resistivity (Air)	20.PΩ·m	petaohm meters
Gravitational Acceleration	$9.1m·s^{-2}$	meters per second squared
Current (set)	*33.33μA*	microamperes
Mass	*1.g*	grams
Power (Predicted)	*1.W*	watts
Power (at given Voltage)	1.W	watts
Gravity Force	9.1mN	millinewton
Gap against Force	54.6mm	millimetres
Voltage from Power	30.kV	kilovolts
Plasma Resistance	899.96MΩ	megaohms
Plasma Resistivity-area	$16.48GΩ·m^{-1}$	gigaohms per meter

Table 1: Ionic Levitation Constants, Assumptions, and Results

To lift a ton, one would have to ionize 54.6 meters of air (the cross-sectional area is undefined but assumed to be rather large) *and* provide 1 GW of power which would be very difficult to provide either externally or as a part of the 1 T craft. The assumption is for standard pressure and temperature in the lower atmosphere. When the atmosphere becomes thinner, as in the mesosphere and ionosphere, the amount of power required will increase overall despite the gradual decrease in the force of gravity.

Property	Value	Units (Full Name)
Mass to lift	*1.Mg*	Megagrams
Force to lift	9.1kN	Kilonewton
Current Gap to lift	1.82A·m	ampere meters
Voltage required	30.GV	Gigavolts
Power provided	*1.GW*	Gigawatts
Current at Power	33.33mA	Milliamperes
Gap at Power	54.6m	Metres

Table 2: Ionic Levitation of 1 Ton Mass

While 1GW power generation in modern terms may seem astronomical, it must be remembered that with respect to fusion or other future power technologies it should be possible for 11.13 μg (micrograms) of mass to be converted into energy per second which is the equivalent of 1.5264 mmol (millimoles) of Hydrogen converted to 381.6 μmol (micromoles) of Helium every second or 1.374 moles of Helium per hour from 5.496 moles of Hydrogen. And if pure antimatter were used, or a based on Hawking Radiation, only 11.13 μg (micrograms) of esoteric fuel is required per second. This implies the energy level of a Type 2 society (A civilization that is capable to utilize all its resources from the home planet would be Type 1; Type 2 would entail that in addition to Type capabilities, the civilization also has the technology and ability to harnessing all the energy of its star, according to the Kardashev scale). Alternatively, it is possible to building a million 5.46 cm gap regions along the bottom hull of the ship to provide the equivalent levitation. However, caution must be taken to provide enough separation between each ionic generator as not to interfere with adjacent generators, thus diminishing the overall effect. This will depend on the cross-sectional area of plasma generation. In either case the same amount of atmosphere would be ionized though in this case only 1 MW of power is required, which is still beyond modern technology but is close to the technology of a Type 1 civilization.

B. Laser Propulsion

We propose one technique is to use space-based, high-frequency laser light in the X-Ray range to propel the solar sail within the confines of the solar system. We further propose unmanned missions to the destination system to set up similar system to decelerate a manned craft as it approaches. The reason we have chosen X-Ray frequency light is because it diverges more slowly over greater distances. Ideal laser divergence is given by $\theta = \lambda / (\pi \omega)$, where λ is the wavelength of the beam, ω is the radius of the beam as it leaves the laser and θ is the angle of divergence. So for X-Rays of 10 nm wavelength and an aperture of 10 cm, we have a divergence of approximately 3.2×10^{-8} radians meaning that over a light year the beam diverges to tan(θ)*distance or about 3.0×10^{8} m, making the collection of the beam by the sail much less effective and leading to the use of stellar light sources for power rather than the laser for interstellar corrections to be supplemented with various alternate means of propulsion as described throughout this paper.

C. Practical Solar Concentrators

Provided collimated and focused beams can be deployed with sufficient source power, such mechanisms in principle can enable spacecraft to attain relativistic velocities. However, a good lower range performance estimate for the effectiveness of light sails can be arrived at using the following toy model scenario where merely ambient sun-light is used. The purpose for this digression is to affirm the possibility of realizing a worst case scenario to bound the argument for collimated beam sails. [1].

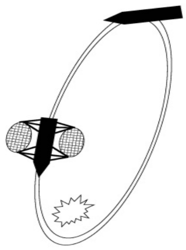


FIGURE 1 illustrates spacecraft undergoing O'berth maneuver or relativistic analogue around a star and powered by photovoltaic cells.

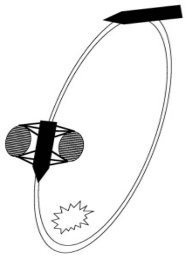


FIGURE 2 illustrates spacecraft undergoing O'berth maneuver or relativistic analogue around a star and powered by thermo-electric cells.

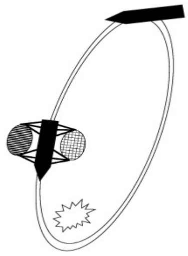


FIGURE 3 illustrates spacecraft undergoing O'berth maneuver or relativistic analogue around a star and powered by photovoltaic cells and thermos-electric cells.

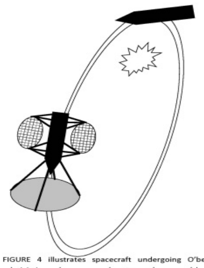


FIGURE 4 illustrates spacecraft undergoing O'berth maneuver or relativistic analogue around a star and powered by photovoltaic cells augmented by a tethered attached light-sail.

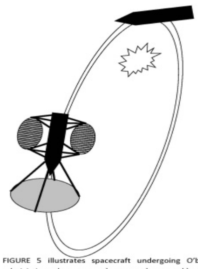


FIGURE 5 illustrates spacecraft undergoing O'berth maneuver or relativistic analogue around a star and powered by thermo-electric cells augmented by a tethered attached light-sail.

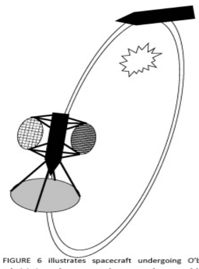


FIGURE 6 illustrates spacecraft undergoing O'berth maneuver or relativistic analogue around a star and powered by photovoltaic cells and thermo-electric cells and augmented by a tether attached light-sail.

One of the authors herein, James Essig, as part of an independent inventors partnership (Essig and Essig) co-invented, built and tested multi-function, multipurpose solar concentrators. They were able to concentrate sun-light by a factor of about of 100 times. Essig and his co-inventor brother were interested in verifying the each and lost cost manufacture of powerful concentrators having a mass-specific power output of 10 kilowatts per kilogram. This experiment involved full deployment of gas pressure deployable solar concentrators using a net internal pressure of 0.1 pounds per square inch. The pressure handling capacity of an inflated structure of a given shape and aspect ratio scales as the inverse of the size of the structure. Generally, the inflation pressure required to hold open a balloon or other membranous vessel scales as the inverse of the size of the cavity for a given shape and aspect ratio. Essig & Essig tested and affirmed the plausibility of very high mass-specific collectors for concentrating or converting sun-light in space for purposes of providing power to solar sails and beam driven light-sails. However, it a critique could be made where pressure and volume are proportional to temperature and the number of particles given by an equation involving the Ideal Gas Constant, PV=n RT.

In defence of the argument, when holding temperature, volume and pressure constant, then the only factor that can be adjusted so in such cases is the mass of the gas (it can be lowered by using a lower molar weight gas). Since the gas inside the balloon can be solar heated, the desired pressure can be realized with much lower density gas of a given molecular weight. For more detailed information refer to *The Relativistic Rocketeer* and Essig and *Call of the Cosmic*

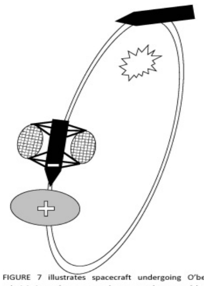


FIGURE 7 illustrates spacecraft undergoing O'berth maneuver or relativistic analogue around a star and powered by photovoltaic cells augmented by a non-tethered electrodynamically attached light-sail.

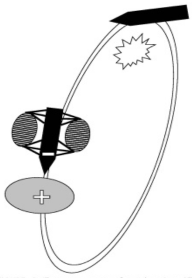


FIGURE 8 illustrates spacecraft undergoing O'berth maneuver or relativistic analogue around a star and powered by thermos-electric cells augmented by a non-tethered electrodynamically attached light-sail.

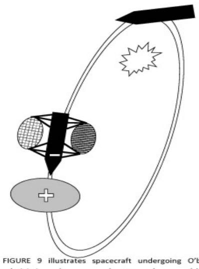


FIGURE 9 illustrates spacecraft undergoing O'berth maneuver or relativistic analogue around a star and powered by photovoltaic cells and thermos-electric cells and augmented by a non-tethered electrodynamically attached light-sail.

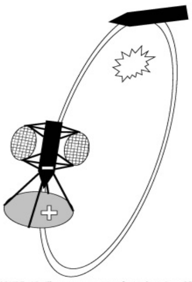


FIGURE 10 illustrates spacecraft undergoing O'berth maneuver or relativistic analogue around a star and powered by photovoltaic cells augmented by a tethered and electrodynamically attached light-sail.

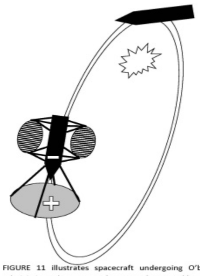


FIGURE 11 illustrates spacecraft undergoing O'berth maneuver or relativistic analogue around a star and powered by thermo-electric cells augmented by a tethered and electrodynamically attached light-sail.

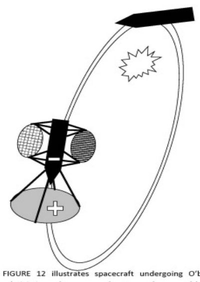


FIGURE 12 illustrates spacecraft undergoing O'berth maneuver or relativistic analogue around a star and powered by photovoltaic cells and thermo-electric cells and augmented by a tethered and electrodynamically attached light-sail.

Wild: Relativistic Rockets for the New Millennium.

This demonstrates that at sea level and 15°C, the density of air is 1.275 kg/m³. This is the value of the International Standard Atmosphere or ISA. The associated air-pressure is 101.3 kPa or 101,300 newtons per square meter. This is equal to 14.7 pounds per square inch. Since air pressure or any gas pressure scales according to the first power of density for the ideal gas law, the density of air at 0.1 PSI is equal to $[1.275 \text{ kg/m}^3](0.1\text{lb/in}^2)/(14.7\text{lb/in}^2)\} = 0.0086734 \text{ kg/m}^3$. Our solar concentrators capable of concentrating roughly 1,000 watts had an inflation volume of about 0.1 m³. The mass of the incorporated Nylon of which much was metalized and reflective was about 0.1 kg per thousand watts of reflective capacity. As a space-based system, the required internal air pressure would have been a mere 0.1 PSI with an associated air mass of 0.00086734 kg or 0.86734 grams.

So, for an array of such concentrators as designed by Essig's co-inventor, the required mass quantity of air is only about 0.0086734 times that of the Nylon composition of the devices. This is an important consideration because the required inflation gas can be minimized for solar concentrators deployed in space. Therefore, in order to produce 1 Gigawatt of power at one A.U. from the Sun, $(1{,}361)(10^6)$ watts of incident power are required assuming a systemic efficiency of 73.475 percent. Such power levels may be achieved with a 1 million square meter capture area at 1 A.U. with 73.475 percent conversion efficiency. Such conversion efficiency may plausibly factor in imperfections in conversion mechanisms and inert mass such as resulting from connecting power cables, PV cells, or thermos-electric cells and the like. However, provided a mass-specific power capture of 0.1 kg/kW, the total mass of the required collector apparatus alone need be only about 100 metric tons. The required air-mass would be equal to 867.34 kg. This further serves to establish our assumption that, once the solar concentrator material packages are delivered to cis-lunar or solar orbit, the additional mass required for inflation gas is almost a trivial concern as far as the extra payload required to transport the inflation gas. In order to obtain the power densities we use membranous Nylon having a thickness of 1 mil or one-thousandth of an inch. This works out to be about 0.00254 centimeters or 0.0000254 meters. Let's suppose that instead we used a membrane material having 100 times the tensile strength of Nylon but having a thickness which is 100 times less than the Nylon films we used. The mass of the collectors themselves may plausibly be reduced by a factor of 100. The total mass of the collector apparatus may be reduced to 1 metric ton. The membranous material of manufacture need only be 0.000000254 meters. Carbonaceous super materials such as carbon nanotubes and graphene are likely up to the challenge, here. The required air-mass would be equal to 867.34 kg. Reducing the thickness by another factor of 1,000 such as by employing membranes made of graphene or metallic hydrogen reduces the required reflective material to only one kilogram. The required air-pressure may also be reduced by a factor of 1,000. The required air-mass would be equal to 0.86734 kg.

Now, the molecular mass of dry air as an average of all molecular constituents is 28.97 atomic mass units. Again, using ordinary air composition at sea-level, once the solar concentrator material packages are delivered to cis-lunar or solar orbit, the additional mass required for inflation gas is almost a trivial concern as far as the extra payload required to transport the inflation gas. Now, the ideal gas law is expressed as follows: PV = nRT.

Here, P is absolute pressure in N/m^2, V is the gas volume in m^3, n is the number of moles of the gas, R is the universal gas constant which is equal to the product of the Boltzmann constant and the Avogadro constant, and T is the gas temperature in Kelvins. Now, the mass of the hydrogen atom is 1.007825 AMU. The use of hydrogen enables reduced payload and deployment of solar concentrators for which the ratio of the mass of the membranous composition of the collectors and the inflation gas can be increased.

Since for a given pressure, temperature, and volume, the only factor that affects the mass of a pressurized gas under the model of the ideal gas equation is the mass of the individual atoms or molecules composing the gas. For a gas of many atomic and/or molecular species, the average of the species masses is what is important. So, when using diatomic hydrogen as an inflation gas, the required mass of the inflation gases for all of the above exemplar concentrators is reduced by a factor of {(28.97 amu)/[(2)(1.007825 amu)]} = 14.372. If stabilized monatomic hydrogen is used, the required mass of the inflation gases for all of the above exemplar concentrators is reduced by a factor of [(28.97 amu)/(1.007825 amu)] = 28.745. Here we assume standard atmospheric temperature of the gas and if need be artificial gas heating. Thus, in all of the above exemplar gas inflated solar concentrators, the quantity of the required gas by mass is only a small fraction of the membranous materials used to fabricate the star light collectors. Because of the small mass contribution of inflation gas in the overall scheme of things, it is easy to conceive of scenarios where extra inflation gas can be available in compressed forms so as to replenish gas lost through punctures of the collectors by dust particles and micro-meteoroids.

Consider the Newtonian equation for force:

F = M**a,**

From which we derive the formula for acceleration;

a = F/M.

Figures 1-16, below describe Essig & Essig's concept for a mechanism for stellar energy concentration may include traditionally rigid optics or pressure deformable optics. Pressure deformable optics may include neutral gas or electrical charge mechanisms for deformation of substantially membranous elements. It follows that a diamond isotopic purity for either Carbon-12 or Carbon-13 results in maximum thermal conductivity. A 50 percent ratio blend produces a minimum in thermal conductivity. High quality chemical vapor deposition methods along with high pressure have resulting in the production of high quality diamonds with a low level of crystalline defects and impurities. Generally, chemical vapor deposition builds a diamond one layer at a time until an entire crystal is obtained. A conceivable mechanism for diamond lamination of tantalum-hafnium-carbide might include some form of chemical vapor deposition. The isotopic contents of the build-up may be uniform or varying. Varying isotopic content when abrupt may conceivably enable more efficient focus, direction, concentration, and conduction of phonons, away from hot portions of tantalum-hafnium-carbide plates. Such thermal conduits may include square, rectangular, triangular, pentagonal, hexagonal, septagonal, octagonal, or any other regular polygonal cross-sectional shape. These conduits may be expansive or tapered so as to de-focus or concentrate the phononic heat energy. Other cross-sectional conduit shapes include irregular polygons, purely curvilinear contours, a mixture of continuous curves and straight edges and the like.

All of the latter contours may vary in shape, size, number of edges, and number of curves, and the like along the length of the conduits so as to enable more efficient displacement of heat from the refractory plates. Another interesting concept includes chemical vapor deposition processes for producing tantalum-hafnium-carbide plates or light-nets. Such layer by layer composition may enable greater control over the growth process of the refractories' molecular structure as well as crystalline and granular properties. Accordingly, such optimized refractory plates may have significantly increased melting points. Analogous thermal conduits to the diamond forms may be fabricated from the refractories themselves. However the conduits are fabricated, the conduits would likely require a thermal insulating outer wall which may be relatively so and thus made of isotopic blends of diamond or appropriate tantalum-hafnium-carbides.

Essig suggests that other materials may be used as insulators such as those commonly used in the aerospace and astronautics industry for thermal insulation and heat tolerance. Essig also informs that useful proposals include the carbon-based materials used for the more temperature resistant tiles of the now retired space-shuttles and their successor crafts currently under development.

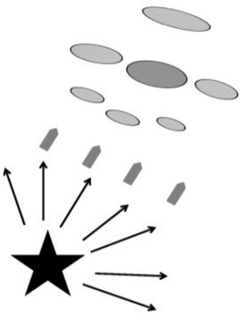


FIGURE 1 illustrates circular sails in various sizes as for various phases of opening (gridded ovals) and mass driver launched mini sail-pods (dark gray bullets) catching up with the already deployed and being deployed light sails.

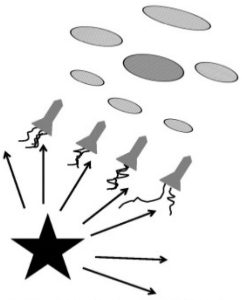


FIGURE 2 illustrates circular sails in various sizes as for various phases of opening (gridded ovals) and mass relativistic rocket launched mini sail-pods (dark gray bullets) catching up with the already deployed and being deployed light sails.

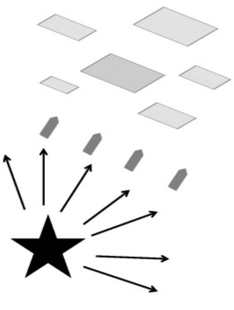


FIGURE 3 illustrates square sails in various sizes as for various phases of opening (gridded ovals) and mass driver launched mini sail-pods (dark gray bullets) catching up with the already deployed and being deployed light sails.

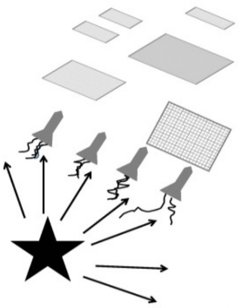


FIGURE 4 illustrates square sails in various sizes as for various phases of opening (gridded ovals) and mass relativistic rocket launched mini sail-pods (dark gray bullets) catching up with the already deployed and being deployed light sails.

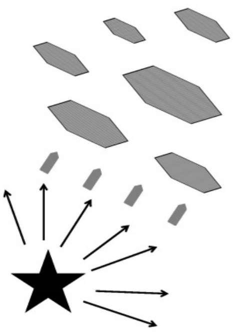


FIGURE 5 illustrates hexagonal sails in various sizes as for various phases of opening (gridded ovals) and mass driver launched mini sail-pods (dark gray bullets) catching up with the already deployed and being deployed light sails.

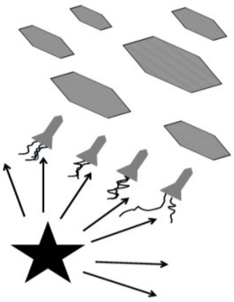


FIGURE 6 illustrates hexagonal sails in various sizes as for various phases of opening (gridded ovals) and mass relativistic rocket launched mini sail-pods (dark gray bullets) catching up with the already deployed and being deployed light sails.

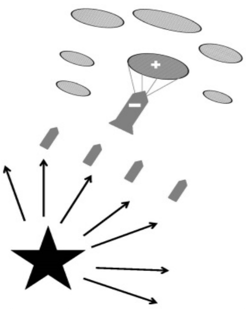


FIGURE 7 illustrates circular sails in various sizes as for various phases of opening (gridded ovals) and mass driver launched mini sail-pods (dark gray bullets) catching up with the already deployed and being deployed light sails as well as tether charge connection of primary sail to spacecraft.

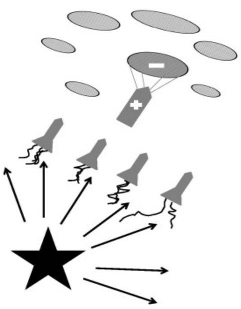


FIGURE 8 illustrates circular sails in various sizes as for various phases of opening (gridded ovals) and mass relativistic rocket launched mini sail-pods (dark gray bullets) catching up with the already deployed and being deployed light sails as well as tether charge connection of primary sail to spacecraft.

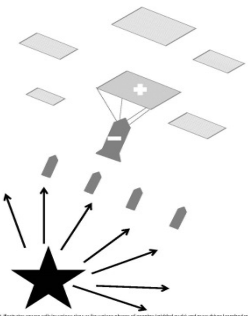


FIGURE 9 illustrates square sails in various sizes as for various phases of opening (gridded ovals) and mass driver launched mini sail-pods (dark gray bullets) catching up with the already deployed and being deployed light sails as well as tether charge connection of primary sail to spacecraft.

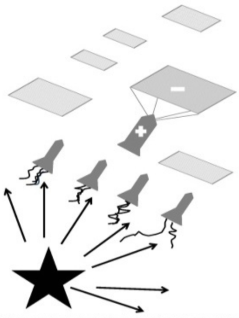


FIGURE 10 illustrates square sails in various sizes as for various phases of opening (gridded ovals) and mass relativistic rocket launched mini sail-pods (dark gray bullets) catching up with the already deployed and being deployed light sail as well as tether charge connection of primary sail to spacecraft..

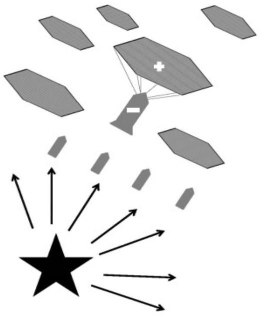


FIGURE 11 illustrates hexagonal sails in various sizes as for various phases of opening (gridded ovals) and mass driver launched mini sail-pods (dark gray bullets) catching up with the already deployed and being deployed light sails as well as tether charge connection of primary sail to spacecraft.

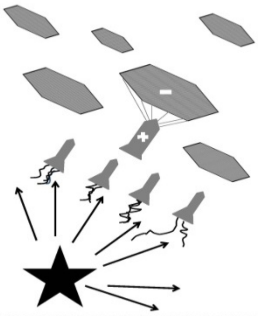


FIGURE 12 illustrates hexagonal sails in various sizes as for various phases of opening (gridded ovals) and mass relativistic rocket launched mini sail-pods (dark gray bullets) catching up with the already deployed and being deployed light sails as well as tether charge connection of primary sail to spacecraft.

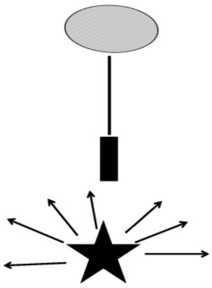


FIGURE 13 depicts stellar sail mode augmented with artificial beam mode which could be a laser, maser, phased array microwave or radio-frequency beam, or massive species beam.

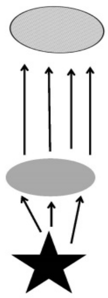


FIGURE 14 depicts stellar sail mode augmented with beam mode for which the beam is artificially collimated natural star light.

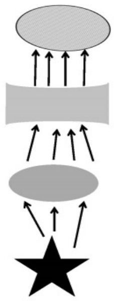


FIGURE 15 depicts stellar sail mode augmented with beam mode for which the beam is artificially collimated natural star light by a compound optic.

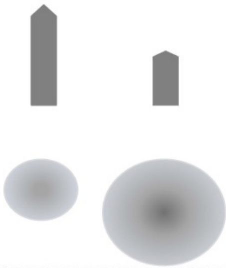


FIGURE 16 illustrates relativistic aberration of a uniform disk source with darker shades of gray denoting lower apparent temperatures. Also note apparent increases in source diameter as a result of relativistic aberration for which the right portion of the figure depicts a spacecraft gamma factor that is twice that depicted on the left side. Also note the relativistic length contraction depicted on the right-side in the background reference frame.

Assuming we start with a spacecraft having a mass of 10,000 metric tons of which 90 percent is inert reaction mass and 90 percent of the remaining mass is nuclear fusion fuel, leaving 100 metric tons for the craft and collector.We will assume a collector mass including inflation gas of 50 metric tons and the remainder of the final payload is the propulsion module and crew habitat. We will further assume an acceleration of 0.1 m/s^2.

Therefore; we obtain the required starting propulsive force as:
F = M**a =** $(0.1\ m/s^2)(10^7)$ kg = 10^6 newtons.
Now, we are going to assume an exhaust velocity of 0.119c which we assume is also the specific impulse.
Now, the formula for relativistic momentum for a mass is:
P = Mvγ.
The formula for force exerted by an exhaust stream is:
F = dP/dt = d Mvγ/ dt.

Assuming;
F = M**a =** $(0.1\ m/s^2)(10^7)$ kg = 10^6 newtons,
The, force is otherwise expressed as:
F = dP/dt = d Mvγ/ dt **=** $(0.1\ m/s^2)(10^7)$ kg = 10^6 newtons.

The required force from the mass of the inert exhaust expelled in the ship frame is:
$\Delta M v\gamma/\Delta t = \Delta M(0.119\ C)(1.007156599)/\Delta t = M(0.119c)(1.007156599^{7})/(1s) = 10^{6}$ newtons.
Thus, the quantity of fuel expelled per second in the ship frame is:

$M = (10^{6}\ N)/\ [(0.119)(300{,}000{,}000\ m/s)(1.007156599)/(1s)] = 0.027812kg$.
The kinetic energy of the exhaust per second in the ship frame will be:
$K.E._{exhaust} = \{(0.027812\ kg)[c^{2}](1.007156599)\} - \{(0.027812\ kg)[c^{2}]\} = 1.79135 \times 10^{13}$ joules.

However, power levels greater than 10 TJ are hard to ask for a system having a mass under 100 metric tons. Even a 1,000 metric ton system would be a hard sell to produce the required power. It is true that carbonaceous super-materials and refractories are open to improvement in terms of thermal conductivity. However, the computed power level would likely require what can effectively be referred to as "Unobtainium". Extrapolations into the topic of neutron dense crystal packing or so-called neutron element materials and quark-based bulk materials would suffice in principle where employed as sheets of femtometer thickness especially in the form of porous grids doped with charged leptons. These hypothetical materials are merely fiction as present. Perhaps a more realistic composition in the foreseeable future would include ultra-compressed atomic matter having densities approaching that of stellar white dwarfs. Again, the application would require manufacture of very thin sheets perhaps for use as engine chamber walls and the like. Such degenerate matter compositions may enable the rough 10 TJ scenario provided above thereby providing a lower boundary value for what is possible for light-sail craft velocities. Collimated and otherwise focused beams can and would be a better choice. So, the previously presented scenario for which a one square kilometer sub-section of an inflated collector having an invariant mass of one kilogram filled with hydrogen would theoretically work.The ratio, $\{[1.79135 \times 10^{13}\ \text{Watts}]/[10^{9}\ \text{Watts}]\} = 1.79135 \times 10^{4}$ is the required number of square kilometers of the collector as well as the number of kilograms of mass of the incorporated membranous material. The inflation gas where diatomic or monatomic hydrogen is used poses a trivial increase in collector mass. The mass of the collector would be a mere 1.79135×10^{4} kilograms or 17.9135 metric tons. Now, we assume that the quantity of fuel expended per second ship frame decreases in proportion to the remaining total invariant mass of the spacecraft. Recall that the mass ratio of the rocket at the beginning of the first stage is 10. Thus, the terminal velocity after all of the fuel has been expelled will be 0.267349984c. It should be mentioned that the relativistic rocket equations assume a constant acceleration. In this example, we assume that the spacecraft starts off at rest in the background which can be interpreted as the CMBR without Doppler shifting and relativistic aberration.

In general, the alternative relativistic rocket equations are:

$$t = (c/a)\sinh(aT/c) = [[(d/c)^{2}] + (2d/a)]^{1/2}$$
$$d = [(c^{2})/a]\,[[\cosh(aT/c)] - 1] = [(c^{2})/a]\,\{\{[1 + [(at/c)^{2}]]^{1/2}\} - 1\}$$
$$v = c\tanh(aT/c) = (at)\,/\,\{[1 + [(at/c)^{2}]]^{1/2}\}$$
$$T = (c/a)\ \text{inversesinh}\ (at/c) = (c/a)\ \text{inversecosh}\ [[ad/(c^{2})] + 1]$$
$$\gamma = \cosh(aT/c) = [1 + [(at/c)^{2}]]^{1/2} = [ad/(c^{2})] + 1$$

Now, consider the following relation for gamma:

$$\gamma = \cosh(aT/c) = [1 + [(at/c)^{2}]]^{1/2} = [ad/(c^{2})] + 1$$
$$= c\ \text{Tanh}\ [(Isp/c)\ \ln\ (M0/M1)] =$$
$$= C\ \text{Tanh}\ [(0.119c\ /c)\ \ln\ (10)] =$$
$$= 0.2673c.$$

Substituting 0.2673c into the Lorentz factor formula produces a Lorentz factor of 1.037774065. From this, one could obtain the following formulation:
$\gamma = 1.037774065 = [ad/(c^{2})] + 1$.
Thus, the distance of acceleration becomes:
$d = (\gamma - 1)[c^{2}]/(0.1\ m/s^{2}) = (1.037774065 - 1)[c^{2}]/(0.1\ m/s^{2}) = 3.39966 \times 10^{16}$ meters which is about equal to 3.5 light-years. The ship frame propulsive power reduction can be reduced by a factor of 10 at terminal velocity. However, the collection area in a Newtonian approximation of the collectors will need to increase by a factor of: $\{\{[3.39966 \times 10^{16}\ \text{meters}]/[1.5 \times 10^{11}\ \text{meters}]\}^{2}\}(0.1) = 5{,}136{,}750{,}274$; relative to the inertial size previously considered of 1.79135×10^{4}square kilometers at 1 A.U. from the source. For a one leg exiting velocity, this scenario is not viable since with current materials, such a low mass collector would be impossible to manufacture. However, future materials may yet enable the above performance scenario. Once we have developed infrastructure around stars much more luminous than the sun, then the above scenarios would be workable thus again providing a lower first order boundary consideration for the practicality of light sail craft. The above result

[7]This is the 0.119c exhaust velocity in the ship frame. The force due to acceleration is computed in the ship frame.

neglects relativistic Doppler red-shifting of the source which introduces a small modification of the computed size of the sail. Since the size of the sail as computed is already extreme, considering Doppler source red-shifting will have little impact on the viability of the concept for the computed input values assumed.

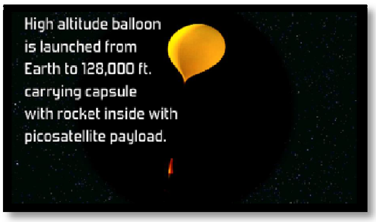
Now the formula for relativistic wavelength redshift yields the following result.
$\lambda = \lambda' \{[(1 + \beta)/(1 - \beta)]^{1/2}\}$
$\lambda_{shift} = [(1 + 0.267349984)/(1 - 0.267349984)]^{1/2} = 1.31522.$
So, $\lambda_{shif}^{4} = 2.99226.$

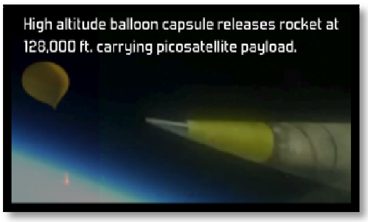
The area of the sail would need to increase by another factor of 2.99226 to yield a collection area of about 1.5 x 10^{10}. There is generally a fourth power of redshift factor in required sail area as well as a second power radial distance factor as noted previously. So the Newtonian approximation becomes less accurate as the spacecraft velocity in the stellar radial coordinate becomes closer to that of light. Relativistic aberration effects also become significant for extreme spacecraft Lorentz factors associated with velocities close to the speed of light. However, using a stellar cycler mechanism at locations roughly positioned at 1 A.U. from the Sun may work, and then so even in cases where the centripetal acceleration approaches 100 Earth g's in the spacecraft reference frame. Accordingly, the relativistic Lorentz force would keep the spacecraft in revolution about the Sun. However, it may be better to start off at a much smaller Sun-centered radial coordinate to enable the spacecraft to rapidly accelerate to a velocity of 0.267349984c. Various methods of enabling the crew to actually survive 100 g accelerations have been proposed but are beyond the scope of this paper. Such tolerance for rapid acceleration would enable solar light sail craft operating by ambient sunlight a practical consideration once industry catches up with what physics allows. Thus, there is a definite preference for utilizing collimated source beams to drive a sail craft out of the solar system instead of trying to rely on ambient sun-light. However, Essig presents plausible ambient background light scenarios that would in principle work if only O and B type stars would be used as host light sources. We assert that quasars will suffice. However, one possible caveat would be being able to locate light sail in the vicinity of a quasar [2]. After having looked into concept technologies for propulsion and the confirmation that the laws of physics and cost are hampering interstellar travel, the next section will introduce strategies that focus on increasing resource effectiveness.

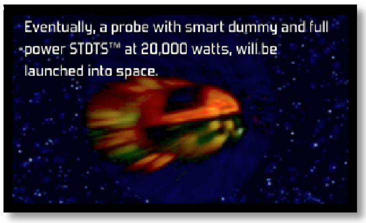
D. The STDTS™ Warp Drive

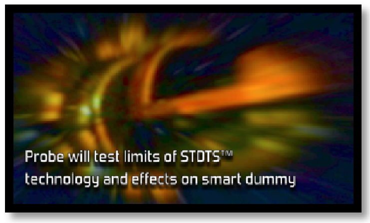
These images describe how the *Space Time Dilator Transport System*™ (STDTS™) technology, which is currently undergoing planning, development and testing by Marshall Barnes, an independent US research and development engineer. STDTS has proved successful due to the fact that it creates a specially synthesized electromagnetic field that creates a gravitic effect in the direction of motion of any metal object that it envelopes, thus providing acceleration. Various thinkers have proposed Warp Drives as solutions of the Einstein Field Equations within the framework of General Relativity. For example, the Alcubierrewarp drive (1994) and the Natario warp drive (2001). However, both inventors have indicated the "warp drive violates all the known energy conditions because the stress energy momentum tensor is negative implying in a negative energy density" [3]. The proposed idea herein is being suggested as a potential functioning alternative to general relativity based models for warp drive, as all such approaches require massive amounts of exotic matter and negative energy and in addition have engineering challenges that render them impossible. More recently, reports indicate that a team of NASA scientists, led by Dr. Harold ("Sonny") White, has been working on warp drive technology representing a "variation of the Alcubierre warp drive"[4]. For example, a recent article states that "White believes that advances he and others have made render warp speed less implausible. Among other things, he has redesigned the theoretical warp-traveling spacecraft — and in particular a ring around it that is key to its propulsion system — in a way that he believes will greatly reduce the energy requirements". Regarding this technology, the article quotes White as saying that, "We're not bolting this to a spacecraft"[5]. NASA's website indicates that "Warp Drive" or any other term for faster-than-light travel still remains at the level of speculation.

The bulk of scientific knowledge concludes that it's impossible, especially when considering Einstein's Theory of Relativity. There are certainly some credible concepts in scientific literature, however it's too soon to know if they are viable"[6]. We have included several articles which today may be viewed more as pop culture than science. Still, a wide range of published ideas could prove crucial to future visions [7]. After all, science fiction writers have given us many images, which later became real technologies. One day interstellar travel and faster than the speed of light will be perceived as real rather than imaginary. STDTS ™ system is a privately funded project, expected to be tested in the Earth's atmosphere near the edge of space in 2018. Plans include using a pico satellite to see if when the field is pulsed, constant acceleration can be tracked from the Earth's surface. Such an exhibition of acceleration would confirm conclusively that STDTS™ may be used in space to test the limits of velocity for the very first time.









Emphasis is on probes and unmanned vessels, some of which may contain 'smart dummies' equipped with seniors that would collect accurate data on any energies, forces, etc. that a human may be subjected to so that accurate data can then lead to effective development solutions for shielding etc. Also, the use of probes and robotic crews would allow for rapid development of other uses while the challenges for human involvement may be sufficiently addresses. The greater significance of the STDTS technology is the fact that it is not a replacement for other means of propulsion, but accelerator adjunct to them. This means other methods can save fuel and only be used when they are really needed as opposed to an entire journey. Because of the way inertia works in space, every time the STDTS field is pulsed (which warps space in front) the craft goes faster with no theoretical upper limit and the power requirement could be supplied by anything from the kind of radioactive isotope used by Cassini to solar panels. At this moment, STDTS powered probes are best suited, however, to build a network of re-powering and resupplying stations, simply because they are closer to physical reality and can get the job done faster.

V. STRATEGIES TO ENABLE INTERSTELLAR TRAVEL IN THE FUTURE

A. Space Resupply Stations and Harvesting Drones

The idea of sending drones with supplies into space or to planets is not new. Yet, there is limited research on what strategies will can leverage existing technologies. A space ship travelling towards another star will have been accelerated to a high speed. If it was to stop for a resupply, it had to use large amounts energy to slow to down (for docking) and to speed up again. If, however, the spaceship could take on energy from resupply stations without slowing down and speeding up again, then this would be an enabling innovation. This can be achieved by a combination of wireless power transmissions and 'tracking and tracing', where the power is transmitted to the spaceship where sending and receiving instruments are closely aligned – facing each other. Where a network of these stations is laid out, it is imaginable that every few resupply stations will be on course to dock for supplies that cannot be 3D printed, re-cycled or replicated from energy. Allowing a space ship enough supplies to securely make it from resupply station to resupply station reminds of '7-mile boots' and railroad expansion of early settlers who broke down vast distances to feasible stages.

B. Wireless Power Transmission to Spaceships

One of the most intriguing inventions proposed for development for interstellar travel is based upon the costly production of antimatter by bombarding atoms in accelerators which generate an enormous amount of heat and energy. Official reports indicate that the amount of energy required producing enough antimatter to propel a rocket similar to as described in modern science fiction such as *Star Trek*, indicate that the rate of production is orders of magnitude below what would be required for advanced space flight. What's more, the amount of power required to ramp up production is quite beyond modern technological abilities.
However, if Solar input can be more efficiently harvested, it is believed sufficient power can be achieved to produce enough antimatter fuel in a sufficient period.

VI. PROTOTYPING

A. About Fast-tracking

To fast-track the development of interstellar travel technologies and strategies, it is crucial to motivate the next generation of scientists and technologists to dare reaching for the stars. It is in our interest that as many learners as possible should see first-hand that they have all it takes to produce valuable space research. By gamifying the space sector entry, we enable them to follow a career as a scientist or engineer in the growing space sector. We want learners to proudly tell their friends and families that they worked on a satellite, a space ship or electronics.

This will also increase the general willingness to engage in Science Technology Engineering and Mathematics (STEM) subjects, and for advanced learners, increase their confidence. In the process of exploring space technology, skills in the domains, such as electronics, 3d printing, physics, software and soft skills (presentation, team building) are developed. We propose the use of satellite development kits ('CanSats' for students and nanosatellite development kits for more advanced researchers) to boost the development of promising technologies. Cansat kits consist of two units that can be launched from drones or sounding rockets, they can be programmed and customized with sensors and they come with telecommunications links. These kits can be produced for an affordable price. European Space Agency (ESA)'s Education Office and UK Government initiativesemploy them increasingly to run student competitions and to select top talent. A community with Open Source hardware and software is developing alongside. The nanosatellite development kits, who have very similar properties to space-grade nanosatellites. The dimensions, structure and power systems are compatible to those of nanosatellite platforms for space. 'New Space' companies make it possible to integrate an experiment or payload that was developed in a development kit into a nanosatellite that will be launched into space. The possible applications are countless. With such process, government institutions, companies, educational institutions and even individuals can develop space assets months, instead of years. We also propose that both the CanSat and nanosatellite platform should be made available to every educational and research institution, so that relevant experiments can be developed in the space theme that inspires especially the young developers. For the more advanced developers, using such platforms means that their inventions can be easily and affordably adapted for testing in space. The following subsection will outline how such fast-tracking approach can be applied to advance interstellar travel technologies. In favour of this argument it can be mentioned that the launch cost per kilogram decreased from US $52,000 to US $2000 over the last 10 years, making space access even more affordable.

B. Proposed Prototype I: Nicola Energy City Kit

To simulate a power system that uses wireless power transmission and tracking (as suggested in the section concerning resupply stations), we propose a miniature model of a city. Some buildings (3D printed or crafted) will have small microcontrollers and either laser or microwave transmitters/receivers installed in them. All buildings and cars will also have LEDs. Miniature cars also have electric motors and some of them will have batteries. Most units can be created from CanSat components and can thus be re-designed to work in suborbital tests or in space test platforms.

The following experiments can be conducted in an affordable manner and studied by students:

- *Wireless power transmission using laser or microwave between buildings over different distances (success visible by lit LEDs)*
- *Utilization of residual heat*
- *Negative effects of false calibration*
- *Tracking and tracing of cars with wireless power transmission (success visible by moving cars, lit LEDs)*
- *Two-way power exchange between stationary and moving units (with and without battery)*
- *Two-way and cloud transmission of data (in chunks or continuously) between units*

Advancements in these simple experiments can serve as pioneering projects. By choosing a different frequency band, the range can be increased significantly, which suggests short-term potential for commercial asteroid and terrestrial applications. Technology-readiness analysis of subsystems such as power extraction, power transmission, power storage and power usage in combination with fast data transport will be increased. Each finding can be further analyzed for risks for humans. Strategies and systemic use cases can be mapped out and tested. The following existing prototype, together with the CanSat and nanosatellite platform technology could be the base of this model build.

C. Existing Prototype I – Power Beaming Demonstration Unit

It is common knowledge that to turn on an electric light, it must be plugged into an electrical socket. Not only is the lamp plugged into an electrical outlet, but that outlet is in turn connected to power wires that go all the way back to a power plant where energy is converted into electricity.

But what if this could change? How would life be different if electricity could be generated in one place and transmitted to another, without being connected by power lines? The Space Special Interest Group (SIG) of the National Society of Black Engineers (NSBE) is investigating this possibility. If this technology can be made feasible, power plants would not even have to be located on planet Earth. They could be in Earth orbit, or perhaps even as far away as the Moon. NSBE is starting small, by studying a table top demonstration device that converts a small amount of electricity into microwaves, beams it a short distance, re-converts it back to electricity, and uses it to illuminate a set of LED lights. Microwave power beaming systems have been investigated for more, than 30 years.[8] The concept has recently become more practical for terrestrial and space applications with the development of rectifying antennas at higher frequencies (35 and 94 GHz) and power sources at high frequencies and high powers. The demonstration utilizes the latest microwave technologies and has proven a safe method of transferring power without the need for a physical media (wires, etc.). Studies of the receiving unit has shown frequencies in other areas of the EM spectrum can also be used with similar or better results. This is particular useful in deep space exploration were starlight is weak and solar cells are almost useless. The investigation will look at Gamma Rays as the source. Gamma Rays carry tremendous amount of energy and is a powerful presence throughout space. That would give deep space missions an abundant and limitless energy source for a steady and constant power flow for onboard storage.

D. Proposed Prototype II: Universal Matter Propulsion Harvester Lab (UMPH Lab)

Some propulsion technologies are either too dangerous to be tested on earth or their energy demand makes a satellite with batteries and reactor to heavy/economically non-feasible. For these scenarios, we suggest the development of a harvesting probe that can manufactured on earth, assembled in orbit and send to safe distances. In such distance, they could convert matter (from planets asteroids, fusion or one day perhaps dark matter, antimatter and others) into large amounts of concentrated energy that is required for distinct propulsion experiments. Once such UMPH labs deliver sufficient results, they can be re-purposed as resupply stations or be used to extract material and energy for terrestrial application. To kick off the development of UMPH labs, we suggest to make available grants for candidate technologies. With the current momentum around commercial space and interplanetary resources, it appears the natural next step that the private sector steps in to deliver necessary inventions and innovations.

E. Earthly Applications

Although we have focused on outer space applications, as with many space technologies, these ideas could have disruptive applications on Earth. Recent energy crises around the world often point to a shortage in energy generation capacity. This reminds of the long-held misconception of a shortage in the ability of produce food to feed the world, which turned out to be a distribution issue rather than a production capacity issue. Energy systems for generation, distribution, storage and application are advancing rapidly, but not rapid enough to keep up with demographic and socio-economic trends of the 21st century. Space energy systems, even though they don't appear feasible now (like space-based photovoltaic satellites wirelessly transmitting energy to Earth), will become increasingly relevant as natural resources on Earth are depleted. In this paper we argue the need for actively making space science technology more accessible to society as a whole. Space technology is socially and commercially attractive and inspirational. The research from CanSat experiments is valuable but the socio-economic effect (motivation, skills and confidence building) is underrated. We believe that these improvements can be further enhanced by implementing interstellar type technology. The study of these improvements here on Earth, can serve as a testing ground for their implementation in outer space. Alternative living and working spaces can be developed, using space science technology, ergonomics and knowledge about human sensory science and utilize its integrated application to provide practical and effective alternative solutions to critical phenomena affecting many work environments and enhance workforce creativity on Earth. Innovation related to space systems offer a unique lens for inspiring cutting edge ideas, strategies and the application of these concepts aimed at heightening creativity. This includes enhancing workplace health, problem solving, creativity, stress reduction and productivity issues to help us prepare to improve the quality of life for more people, globally, using space innovation.

VII. CONCLUSION

Similar to the eventual emergence of wireless and internet technologies, interstellar travel is likely to become more feasible. Our paper grappled with the possibilities and challenges of developing energy systems based on a mix of proven (e.g. nuclear) and new (WARP) technologies. This includes strategies that increase efficiency, such as resupply stations and harvesting drones.

[8] For more information see: https://en.wikipedia.org/wiki/Space-based_solar_power.

To facilitate timely readiness of such advanced systems, a framework is suggested that includes conducting broad-based open development efforts with scalable and available low-cost technologies such as CanSats and nanosatellite development kits. Our paper in intended to promote encouragement and an invitation to a wide range of people, from all nations. Especially, those who may have never been granted permission to contribute their ideas to the outer space development and interstellar travel puzzle. In addition to disruptive technology, we are calling for disrupting ideologies and discourses which tend to cause the majority of people to believe their knowledge does not matter. The life story of Srinivasa Ramanujan, the genius Indian mathematician can serve as a testament to support the claim that there may exist people out there with undiscovered useful insights to the space travel conundrum. Let this combined effort serve as an invitation to those with ideas to contribute, which are translatable for humanity's great endeavor to advance space travel.

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