Industrial Production of Positronium and Its Uses

By William Mook

Abstract
Humanity is already a Kardashev Class 2 civilization on an instantaneous power basis. This article explores how humanity will make use of artificial solar flares to produce industrial quantities of positronium. This positronium will be used to make star travel with photon rockets commonplace.

Keywords: Solar energy, Kardashev, antimatter, photon rocket, interstellar travel, relativistic rocket equation, star faring civilization.

Introduction

Prometheus was the Greek god of foresight, always thinking of the future. To that end he stole fire from the gods and brought fire to humanity on the Chariot of Helios, the Sun. This article explores a modern version of this legend, based firmly in modern day engineering and scientific understanding.

Near term alternatives to humanity's legacy power system must entail some low-cost nuclear source delivered at less than $0.01 per kWh to be competitive today. To support today's industrial economy, and more importantly, end the use of legacy fuels extracted from deep within the Earth whilst depositing their exhaust in the atmosphere, which in the end returns Earth to the Carboniferous era, requires that we produce synfuels that the market readily accepts. Synfuels made from atmospheric carbon using hydrogen extracted from water with nuclear energy to produce hydrocarbon fuels everyone is familiar with fills this bill.

This requires that 44.4 TW of primary nuclear energy be used to deliver synthetic secondary fuels at a rate of 14.8 TW all at a cost of less than $3.8 trillion per year.

Making hydrogen from water with these nuclear processes to produce synthetic fuels from atmospheric CO_2 was considered in a previous paper.[1] This approach ends the use of legacy fuels, restores balance to our atmosphere, and sets the stage for the eventual adoption of direct hydrogen use by humanity over the next 24 years.

Achieving these price points gives us access to virtually unlimited riches! The world's oil production was said to have peaked around 2008.[2] It is no surprise that the idea spawned a banking crisis at that time. The sub-prime mortgage market was a weak link in the banking system, and was a symptom of a problem, not the cause. The root cause was lack of energy in the future to power our future industrial growth. Addressing this cause will reverse the economic decline of the industrial world while reversing our reliance on confrontational politics that rely in turn on increasing militarization of our culture.

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[1] William Mook, "Report #1, PH240," Paper given at Stanford University, Stanford, CA, Fall 2015.
[2] Tom Whipple, "The Peak Oil Crisis: July 2008 – A Month to Remember," *Falls Church News-Press*, December 5, 2008, fcnp.com/2008/12/04/the-peak-oil-crisis-july-2008-a-month-to-remember.

What About the Future Beyond 2040 AD?

Developing low-cost nuclear power derived from

1. natural fusion – solar power;
2. artificial fusion – using 6LiD; and
3. artificial fission – using 235U & 238U, 233Th fuel cycles

is what it will take to secure economic dominance in energy, wresting it from the hands of those who lack the imagination to develop real alternatives. We now consider the physics of continuous growth in human energy use and what future energy trillionaires might consider as their next steps to maintain and enlarge their financial position by being of service to industrial humanity going forward.

To this end, I consider tapping directly into solar energy from the Sun in space. Namely, what is required to capture positronium in sufficient quantities from the Sun when produced by an artificially induced and maintained solar flares?[3]

What outputs are needed to support human industry on Earth today and far into the future? To this end, we also consider a future super civilization that operates throughout the solar system and beyond using captured positronium generated in an artificial solar flare.

Epistemology and the Kardashev Scale

In 1964 and later in 1985, the Russian astronomer Nikolai Kardashev felt that the growth of energy use in technical civilizations was an inevitable feature of progress.[4] Humanity, according to Kardashev, will one day become a super civilization of the type he envisioned. This fundamental tenet has changed radically in the 21st century with the adoption of sustainable development by the United Nations. This adoption stems from acceptance of the limits to growth epistemology promoted by the Club of Rome through the 1990s. Placing firm limits on growth is considered an acceptable way to deal with the effect that unlimited growth has upon the environment. This thinking considers humanity's present reliance upon the biosphere as a permanent fixture of both human biology and human industry.

Like the Club of Rome and the UN, Kardashev accepts that exponential growth over short periods has the capacity to alter nature radically. Where Kardashev differs from the UN is that he views exponential growth as a natural consequence of progress and considers changes not only at the level of the biosphere, but also at the level of the cosmos.

Kardashev thus constrains his considerations only by the observable limits of the cosmos and physics, rather than the much more greatly constrained limits of disturbance to our

[3] Space Science Board, *United States Space Science Program: Report to COSPAR* (Washington, DC: National Academy of Sciences-National Research Council, 1972); G. H. Share and R. J. Murphy, "The Physics of Positron Annihilation in the Solar Atmosphere," *Astrophysical Journal Supplement Series* 12/2008 (161) 2: 495.
[4] Nikolai Kardashev, "The Inevitability and Structure of Super Civilisations," *Proceedings of the International Astronautical Union* 1985:497.

fragile biosphere. Present thinking also enforces a dependence of industry upon the biosphere, which is ultimately dangerous to both humanity and the biosphere. This dependence of human industry on biological energy flows also requires that the vast majority of humans live at a subsistence level and that humans survive in far lesser numbers than they do today. How to bring about the implied depopulation required is an unresolved problem. Further, how desirable depopulation is as distinguished from an undesirable extinction event is not well considered. The point being, how do we stop a depopulation process from leading to our certain extinction? This seems to be an important question to answer if you support depopulation as a solution to environmental problems.

Kardashev certainly accepts that we should treat our biosphere with respect and care, but ultimately as human understanding and capability grows, we will use appropriate technology to *isolate human industry from the biosphere* regardless of industry's size. Once human industry surpasses the power level of the biosphere, which it will do at 4,000 TW in the 2150s assuming a 4% growth rate, we then create an industrial infrastructure that supports synthetic expansion of our biosphere off world. In this case, the Earth's native biosphere itself is untouched by humans except where absolutely necessary. It is important to achieve this today because we already exceed the capacity of the biosphere to support our need for oxygen as shown in Table 1.

Table 1: Oxygen Consumption Burning WTI Crude.

Component	Mass	Combustion Product Weight	Moles	Enthalpy of Formation	Joules	Oxygen
Barrel WTI Crude Oil	131.48 kg				6,140.8 MJ/barrel	461.35 kg O_2
Carbon	110.72 kg	405.99 kg CO_2	9,227.0 moles	393.5 kJ/mole	3,630.8 MJ/barrel	295.26 kg O_2
Hydrogen	20.76 kg	186.85 kg H_2O	10,380.4 moles	241.8 kJ/mole	2,510.0 MJ/barrel	166.09 kg O_2

Today, humanity masses 400 billion kg and consumes 0.54 TW in food energy. Thus, the food energy needed by humanity is 3% of our industrial energy consumption and 0.003% of all biospheric energy flows. Linking human industry to the biosphere enforces a burden on the biosphere that need not exist and magnifies humanity's impact on the biosphere. Again, supplying the oxygen for humanity and its livestock is already a burden, and the only way forward is a zero-impact philosophy.

It is interesting to note that millions of varieties of Algae contain all types of nutrients produced at an 11% photosynthetic efficiency of sunlight to biomass. With luminescent salts, solar spectrum may be modified so that colors unusable to chlorophyll may be made usable, doubling photosynthetic efficiencies to 22%. At 220 Watts/m^2, 0.54 TW of food energy requires only 2,455 square kilometers of growth area to create all the nutrients to feed cell cultures that supply 3D food printers in sufficient quantity to feed everyone a large variety of high-quality foods at reasonable prices.

Gerard O'Neill also adopted Kardashev's view in his Space Colony Studies of the 1970s.[5] This *zero impact approach* frees humanity of the constraints of Earth whilst freeing the natural biosphere of any impact at all from human activity. In the end the natural biosphere of Earth is depopulated without any decrease in human numbers as humanity becomes increasingly independent of the natural biosphere.

With this understanding in mind, Kardashev perceived that super civilizations come in three varieties:

1. civilizations that control all the power on their planet;
2. civilizations that control all the power in their star system;
3. civilizations that control all the power in their galaxy.

On this scale, Kardashev rated humanity as K = 0. Our present adherence to sustainable development will keep us at K = 0 for the foreseeable future. While appreciation of the fragility of the biosphere is commendable, and no one argues with humanity's present dependence on the biosphere and our adverse impact on it, present approaches keep humanity at K = 0. A more beneficial approach may be a *zero-impact, least-restrictive* philosophy that incorporates all the benefits of sustainability, whilst freeing us of the artificially low constraint thresholds of sustainability and enforced reliance.

Astronomer Carl Sagan noted the following relations when considering Kardashev's scale;

1. civilizations that control all the power on their planet. For the Earth this is 17.38×10^{16} Watts which Sagan rounded to 10^{16} Watts;
2. civilizations that control all the power in their star system. For the Sun this amounts to 3.83×10^{26} Watts. Sagan rounded this figure to 10^{26} Watts;
3. civilizations that control all the power in their galaxy. For the Milky Way this totals 5.00×10^{36} Watts rounded to 10^{36} Watts.

from which he derived the following equation;

$$\text{Kardashev Number (K)} = (\text{LOG}_{10}(\text{Power in Watts}) - 6)/10$$

[5] G. K. O'Neill, "Space Resources and Space Settlements," 1977 Summer Study at NASA Ames Research Center.

Figure 1: An H-bomb explosion an example of K = +2 energy use. From *Operation Ivy*, produced by the US Department of Defense and the US Atomic Energy Commission, released in 1952, and available via standard creative common license. Narration by Reed Hadley. An 11-megaton explosion produces 4.6 x 10^{16} Joules released in picosecond reaction times, which exceeds the power output of the sun.

Expansion of the Kardashev Scale across Human Experience

It is interesting to note that the basal metabolic rate in humans averages 72.7 Watts and that a modified Kardashev Number of 0 is an energy rate of the minimum viable population of humans (around 14,000 persons). Also, the metabolic rate of a single mammalian cell is 3 x 10^{-10} Watts, and a Kardashev Number of -1 equals the power of 1 million cells the size of the smallest multi-celled organisms. A Kardashev Number of -2 equals the power of a Kinesin protein walking along a cytoskeleton filament.

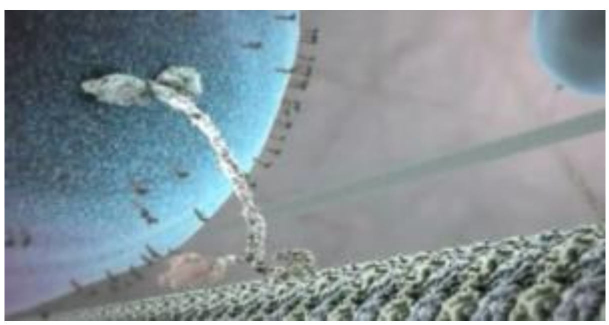

Figure 2: Kinesin an example of K = -2 energy use. From *Inner Life of the Cell: Mitochondria Animation Conception and Scientific Content*, by Alain Viel and Robert A. Lue (Cambridge, MA: Harvard University Press, 2006). © 2006, the Presidents and Fellows of Harvard College, available via standard creative common license Animation by John Liebler/XVIVO.

Humanity's Kardashev Rating

Humanity's current Kardashev Number, based on average industrial energy flows, is K = 0.7236, whilst the proposed rate of use for synfuel previously outlined has a Kardashev Number of K = 0.7647. Other numbers of interest include the metabolic rate of humanity, which is 0.54 TW. This translates to K = 0.5732 and makes hardly any difference in our total at present. At a 4% per year growth rate in industry (far higher than the natural 1.15% growth rate in human numbers), it will take humanity until 2178 AD to reach a Kardashev

Number of K = 1 on a continuous basis and until 2765 AD to reach a Kardashev Number of K = 2 on a continuous basis.

The biosphere's 4 quadrillion watts of power represents K = 0.96, which is 5.7% of the amount of sunlight intercepted by Earth in space. At 4% annual growth in continuous industrial energy production, humanity will achieve this level of energy use by 2154 AD. Yet if we ignore the present rate of continuous power production on Earth and look at instantaneous power production, *we have already exceeded the power output of the Sun* for very brief periods. By this measure, we are a Kardashev 2.5+ civilization, using Kardashev 0 political and economic systems to manage our affairs. This is a problem for humanity generally, and leads predictably to a common mode failure that could lead to our extinction.

One aspect of legacy fuel use is the amount of biospheric energy needed to support oxygen production on Earth so that we can burn our legacy carbon fuels. Even if fuels were unlimited in supply, the atmosphere is not. Consider that a barrel of West Texas Intermediate crude oil masses 131.48 kg. When a barrel is burned, this produces 405.99 kg of CO_2 and 461.35 kg of oxygen in the process (see Table 1). The energy released by burning the crude oil products totals 6.1 GJ per barrel. The amount of sunlight needed to make this much oxygen requires 194.1 GJ of biosphere energy, which in turn requires nearly 4 TJ of sunlight. Today's rate of energy consumption using legacy fuels exceeds the current capacity of the biosphere to add oxygen, which explains both of Keeling's curves: the famous CO_2 and the less well known O_2 curve.[6]

The Power of the Sun

As noted above, the power output of the Sun is 3.83×10^{26} Watts. When converted at high efficiencies to positronium, this power level will not exceed 4 million tons of positronium each second at present levels of solar luminosity. Less than half a gram per second is required to meet our present energy needs. Synthetic increases in luminosity combined with increasingly efficient collection could maintain solar conditions on the planets whilst exceeding the limits described here.

Now, Gerard O'Neill and Stanford, with NASA support, have estimated that it takes 10 metric tons of material and 10,000 Watts to support a person in deep space indefinitely using total recycling in a synthetic biosphere.[7] Mark Roth, MD, has developed procedures to place mammals in reversible suspended animation using small quantities of H_2S.[8] These methods might be extended to indefinite terms. Rindler has solved the Tsiolkovky

[6] R. Keeling and H. Graven, "Two Decades of Atmospheric O_2 Measurements and Their Implications," Scripps Institution of Oceanography. Paper presented at the NOAA Global Monitoring Annual Conference 2012, San Diego, CA.
[7] Richard D. Johnson and Charles Holbrow, *Space Settlements: A Design Study*, NASA, SP-413 (Washington, DC; NASA, 1977).
[8] Charlie Schmidt, "Mark Roth: Profile," *Nature Biotechnology* 27 (2009): 13.

rocket equation for relativistic motion, allowing us to estimate the amount of positronium needed to supply a photon rocket.[9]

$$dV/c=\mathrm{TANH}\ (\mathrm{LN}_e(M_0/M_1))$$

With two boosts of a positronium-fueled rocket that first fires and accelerates a 10-ton payload per person to 90% light speed and then slows to rest relative to a target star some distance away, we can see that a single stage, assuming a 7% structure fraction, has 915.4 tonnes take-off weight for every person on board and that each person requires the vehicle carry a total of 853.4 tonnes of positronium. This allows a ship travelling at 90% light speed to travel 2.3 light years per year of ship time following a boost at each end that lasts 2.85 years ship time, which equals 4.00 years star time, whilst traversing 1.26 light years distance, a distance of 2.52 light years overall traversed in boost, with the remainder coasting. Once at the terminus, a flare similar to a solar flare is formed, and is used to recharge the rocket's positronium propellant if desired, or to support an extrasolar human civilization. A trip to Alpha Centauri entails a 10-month ship time coasting phase and takes 3.72 years ship time each way. A 49-light-year trip takes 28 years ship time at this speed.

Figure 3: Solar Eruption. From Goddard Spaceflight Center 2014. Published by Goddard Media Studios. Publicly available via creative common license from NASA's Goddard Space Flight Center/SDO

The point of this calculation is that a Kardashev 2 civilization should have the capacity to remove 87,941 persons per second from the solar system by tapping all of the Sun's output. That is 27.7 trillion persons per year. With a natural rate of growth of 1.15% per year, this represents the population limit of the Sun, for a Kardashev Type 2 civilization of 2.4 quadrillion persons. This is the K = 2 limit to growth within our solar system. We will

[9] Charles W. Misner, Kip S. Thorne, and John A. Wheeler, *Gravitation* (San Francisco: Freeman 1973), Section 6.2.

not reach this population level before 3125 AD, well after we reach Kardashev Type 2 status (which we have already achieved with our technology on an instantaneous basis). Thus it is likely that human numbers will stabilize and fall in the future as large numbers of people decide to seek their fortunes off-world.[10]

A more important calculation for us today is the rate of positronium production needed to maintain stable numbers of people within the solar system today.

$$\text{Rate of positronium use} = 7.4 \times 10^9 \times 0.0115 \times 853.4 / (8766 \times 3600) = 2301 \text{ metric tons/second}$$

This is the rate of positronium needed to remove people from the solar system at a rate that maintains human population on Earth today. This rate of power use totals 0.05% of the Sun's output. It is also about a million times the energy intercepted by Earth from the Sun. Removing people into interstellar spacecraft at double the peak rate of population growth reverses population growth on Earth and allows us to reduce numbers on Earth to any level desired within thirty years or less, without reducing absolute human numbers. Those in transit are time dilated and in suspended animation. So, they are not reproducing. They do, however, face the risks of interstellar travel.

Fermi Paradox

Enrico Fermi, considering these facts following the first atom bomb test, asked, "Where are they? The Extra Terrestrial Intelligences (ETIs)[11] The physics of evolution presumably operates everywhere. Science is the same everywhere. We have the capacity to travel to the stars with atomic energy. Where are they? There are several answers possible. The thinking today is that there are those ETIs that refuse to constrain growth and become extinct through environmental collapse or thermonuclear war. In that case, we will not see them. There are also those that do constrain growth along the lines of sustainable growth promoted today by the UN. In this case, the thinking goes there are no ETIs because they're permanently in balance with the natures of their home worlds, and there are no super civilizations, none, as Kardashev imagined.

Yet there is always a Gaussian distribution around any mean in living systems. So, there must be other answers to Fermi's question! Some super civilizations must exist even if the majority do not become super civilizations. Given the nature of exponential growth, we still must answer Fermi's question! Where are they?

Another answer that makes sense is that the operation of the speed of light limit, in combination with time dilation and advanced suspended animation, limits the rate of growth of mobile populations! Since there is an inexorable increase of probability of vehicle loss with distance for mobile populations, an exponential drop off in the density of any super civilization as it moves away from its home world is expected. This means that the human affected zone around Sol, once humans create a super civilization in the

[10] Natalie Angier, "A One-Way Trip to Mars? Many Would Sign Up," *New York Times*, December 8, 2014.
[11] Charles Krauthammer, "Are We Alone in the Universe?" *Washington Post*, December 29, 2011.

future, is limited in all practical senses to about a 1,000 light year radius of Sol. The rate of drop off depends on the dangers of high speed interstellar flight.

Freeman Dyson in 1960 outlined what a super civilization might look like to astronomers.[12] The Kepler Space Telescope may have found evidence of such a super civilization nearby.[13]

Positronium Production in the Sun

Positron annihilation radiation from solar flares was first observed by Chupp in 1973.[14] In 2004, Share[15] showed that positrons are produced naturally in the Sun from the interaction of particles within solar flares. Could long-lived solar flares be induced and maintained in the solar photosphere to produce a stream of positronium which is then used by humanity?

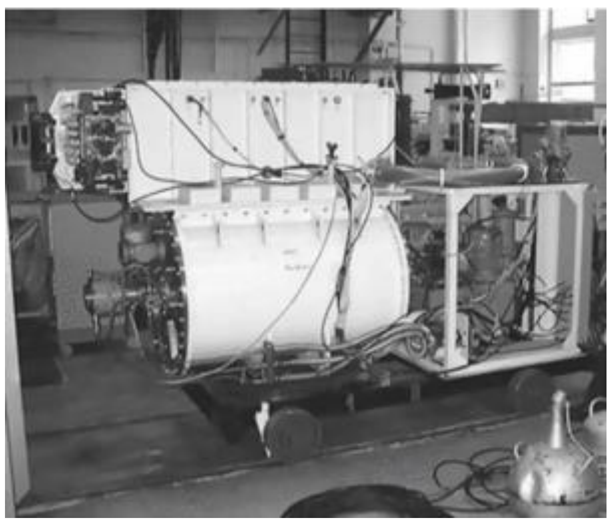

Figure 4: LM-4 Nuclear Pumped Laser Module. Eksperimentalnyy kompleks LM/IGR Ustroystvo i printsip raboty. Proceedings of the 2nd International Conference "Physics of Nuclear-Excited Plasma and Problems of Nuclear- Pumped Lasers," Arzamas-16, 1995 vol. 2, 172-78. Photo produced by Russian Federal Nuclear Center and excluded from copyright by the Supreme Court of the Russian Federation, plenum decision no. 15/2006, point 22, as a public work.

The photosphere is a natural basis for controlled excitonic matter. Nonlinear optical effects in the plasma can be exploited to create self-sustaining structures that exhibit Boolean interactions and may undergo controlled replication. Once made to occur in the

[12] Freeman J. Dyson, "Search for Artificial Stellar Sources of Infra-Red Radiation," *Science* 131 (3414): 1667-68.
[13] Ross Anderson, "The Most Mysterious Star in our Galaxy," *The Atlantic*, October 13, 2015; T. S. Boyajian et al., "Planet Hunters X. KIC 8462852: Where's the flux?" *Solar and Stellar Astrophysics*, September 14, 2015.
[14] Space Science Board, *Report to COSPAR*.
[15] Share and Murphy, "The Physics of Positron Annihilation."

solar atmosphere, the process is then controlled by radio waves. According to Stephen Wolfram, it does not take a lot of technology or a lot of evolution to do computations as complex as anything. Wolfram also points out that computing is a new kind of science as important as calculus, and its broad application will change the way we view the world.[16]

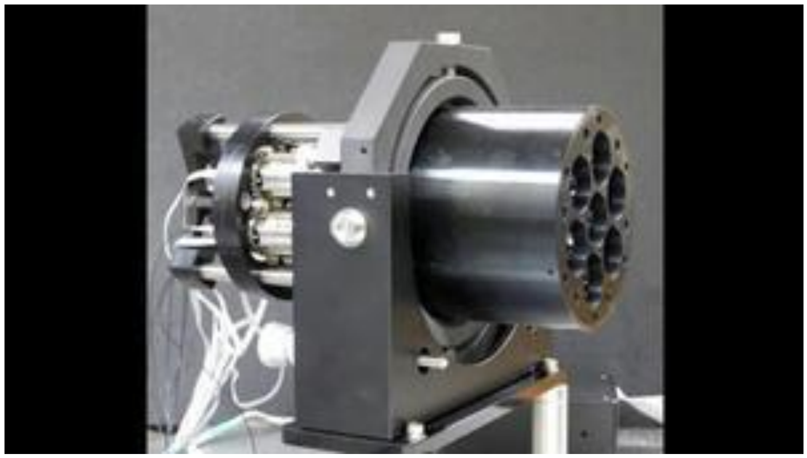

Figure 5: EXCALIBUR Space-based nuclear pumped X-ray laser. © DARPA. Images, photographs, audio, and video files and other works created by DARPA or its systems engineering and technical assistance contractors (© DARPA) and posted on the DARPA website may be used for educational or informational purposes, including, for example, photo collections, textbooks, public exhibits, web pages.

Projecting patterns of gamma rays to induce a pattern of excited plasma in the solar atmosphere from a series of powerful laser blasts produces a synthetic solar flare. Nuclear pumped lasers[17] delivered to the solar surface provides this. This engineered pattern interacts in a nonlinear way to implement a computing platform in the solar surface itself. This pattern self-replicates and evolves in a manner similar to those described by John Conway in his computer based “Game of Life” to produce steady streams of positronium like Bill Gosper’s Glider Gun. Just as interacting patterns on a surface that follow a few simple rules may carry out a computation to maintain a structure as complex as anything, humanity, as described here, produces a pattern on the solar surface to maintain a permanent solar flare that efficiently generates a controlled stream of positronium that is received by a receiving station at Earth Sol Lagrange Point 1, converting our instantaneous K = 2 status to a permanent one.

At 90 TJ/gram, a flow of 192 milligrams of positronium per second is required to produce 17.3 TW. To produce 44.4 TW requires 493 milligrams per second. These streams may then be sent to GEO and LEO satellites to generate powerful laser pulses that are received on Earth. Alternatively, positronium may be compressed and stored as a Bose-Einstein condensate at high density, and maintained in a stable form by active quantum-

[16] Stephen Wolfram, *A New Kind of Science* (Champaign, IL: Wolfram Research, 2002).
[17] S. P. Melnikov, *Lasers with Nuclear Pumping* (New York: Springer Science + Business Media, 2015); T. E. Repetti, “Application of Reactor-Pumped Lasers to Power Beaming” Report Number: EGG-PHY-9978 (Idaho Falls: EG and G Idaho, 1991).

level controls. If this seems overly optimistic, one should consider that Cooper Pairs that are responsible for superconductivity are Bose Einstein condensates as well. Confining 4.4 x 10^{27} positronium pairs per cc creates a bulk material that has the same density as iron. At this density, separation between pairs is 4.8 Ångstroms. This is almost ten times the Bohr radius of 0.53 Ångstroms of Ps at 13.6 eV.[18]

The Program

Candle flames persist even though the fuel and oxidizer that flow through them changes constantly. The Great Red Spot of Jupiter has been present on that planet since 1655 AD. This shows that nature can maintain vortices and other immaterial objects persistently over long periods. So, even while the solar environment precludes solid and even liquid materials, the nature of the solar photosphere is such that it can be manipulated with intense light sources in useful ways. By creating light sources with fusion reactions in the photosphere, a feedback loop is possible in the nonlinear optical materials created, and a self-replicating machine made of structured interacting plasma becomes possible. The plasma patterns would then be controlled by more gentle microwave beams from an orbiting radio telescope.

How Humanity May Structure Plasma in the Solar Photosphere.

The project involves two satellites at a minimum. One is the receiver, operating at Earth Sol Lagrange Point 1, and it also provides microwave and laser control signals. This satellite operates at 1.5 million km from Earth. Two is the transmitter flare forming device, which flies past Jupiter and is gravity boosted into an orbit that falls into the Sun at a point near the solar surface where the line between the Earth's center of gravity and the Sun's center of gravity intersects the surface.

Satellite 2 is a flare-forming device that becomes the positronium transmitter. It consists of a number of self-contained X-ray lasers, each pumped by a small nuclear charge shining through a tantalum synthetic hologram carefully oriented above the photosphere. When fired, each satellite projects structured patterns of light into the photosphere. Interacting plasma is formed there whilst other satellites set the pattern's initial program.

Satellite 1 is the positronium receiver, which consists of a Ioffe-Penning trap of an appropriate size operating at L1. Initial designs call for the creation of high-intensity positronium beams that beam positrons and electrons to reforming satellites in geosynchronous orbit. These geosynchronous satellites then beam laser energy to receivers on Earth that replace the nuclear system described in my first paper. Ultimately, just as hydrogen replaces hydrocarbons once vastly lower cost hydrocarbons are made with very low-cost hydrogen, so too will hydrogen be replaced by laser beams and later positronium once positronium comes in at a vastly lower cost than nuclear energy made more conventionally.

Transitioning from our present hydrocarbon legacy fuels we will proceed as follows;

1 Synthetic Alkanes – $10.00/MWh – 20 TW – Terrestrial

[18] Nouredine Zettili, *Quantum Mechanics: Concepts and Applications* (New York: John Wiley, 2009), 35-36.

2 Hydrogen (protons) – $1.00/MWh – 400 TW – Advanced Terrestrial
3 Lasers (photons) – $0.10/MWh – 80 PW – Interplanetary
4 Anti-matter (positronium) – $0.01/MWh – 160 ZW – Interstellar

Satellite 1, at Lagrange Point 1, also operates as a research lab that develops positronium storage technologies and other techniques that make more efficient use of positronium. The entire program is completed in ten years at a cost of less than $100 billion, radically reducing energy costs and transforming human industry in the process.

Collecting $3.8 trillion for primary fuel replacement each year, over a 50-year period, discounted at 5% per year, and supporting a 4% growth in energy demand, this project has a present value of $148.95 trillion the day the process switches on. Using Toshiba 4S reactors to produce hydrogen that is then used to convert atmospheric CO_2 to hydrocarbon fuels costs less than $15 trillion. Using even more advanced technologies described here involves the construction of two satellites, creating nearly free energy in the process. The revenue, when valued as an annuity, when used to support bank debt in a stable central bank, allows the annuity to be leveraged 50 to 1 in a banking system (the Federal Reserve carries loans with a 53 to 1 leverage as of 2008). This supports up to $7,447.5 trillion in loan activity. This is an amount sufficient to end the financial crisis within our banking system at present and support 4% industrial growth throughout the world indefinitely. Further efficiencies are gained by collecting the $6.0 trillion from end users of energy. This allows these amounts to be increased proportionately to support the industries that develop appliances vehicles and industrial equipment to make use of positronium directly.

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About William Mook, PE: Bill Mook was **t**rained in aerospace engineering, and worked for 16 years in alternative energy and space commerce technology. For a full bio, see www.vimeo.com/user1527401.

Editors' Notes: We thank William Mook for applying his high level of Space Engineering knowledge to fundamental aspects of humanity's future expansion not just to the Solar system but into the cosmos. The Space Community needs the long range scientific thinking of William Mook. Drawing on Russian Astronomer Nikolai Kardashev's work in the 20th Century, Mook hypothesizes the future capture of solar power and create artificial fission to meet humanity's needs and to facilitate interstellar travel. ***Bob Krone and Gordon Arthur.***