August 25, 2021

Ms. Kamala Harris
Vice President
The White House
Office of the Vice President
1600 Pennsylvania Avenue, N.W.
Washington, DC 20500

Re: Proposal for a National Strategy on Space Solar Power

Dear Vice President Harris:

In your role as Chair of the National Space Council, we know your primary concern will be identifying ways that space assets can directly improve the lives of Americans. One path to accomplishing that goal is to leverage decades of American creativity to move the world permanently beyond the fossil fuel age. The Beyond Earth Institute proposes that a *National Strategy on Space Solar Power* can help achieve that goal quickly.

Space Solar Power (SSP), the concept of harvesting solar energy in space and safely delivering it to Earth, was invented in the US in the 1960s by an immigrant World War II veteran, Dr. Peter Glaser. A National Research Council assessment published 20 years ago, "Laying the Foundation for Space Solar Power," outlined the technical feasibility of the concept (the full report is available at this link: https://beyondearth.org/wp-content/uploads/2021/08/Full-NRC-SSP-2001-report.pdf). America can achieve sustainable, net-carbon zero, 24-7 energy through a mix of existing renewable, but intermittent, sources and SSP, when and where it is needed. However, while the physics of space solar power has been demonstrated repeatedly over decades, the cost of implementing the system has been impractical – *Until now!*

An American revolution in space technology is now creating low-cost reusable launch systems, advances in robotics, and the mass production of spacecraft hardware. With these advances, it is possible to develop SSP that is competitive with fossil fuel and other conventional electric power generation options.

The need for new, net-zero carbon energy options is urgent. The US and the world desperately need to stem greenhouse gas-driven climate change. America must pursue multiple options, implementing existing technologies as well as integrating new energy solutions to achieve net-zero carbon emission by 2050, and help the world to do the same during this century. Space Solar Power – which is now economically viable – will help us reach that goal.

Other nations are aggressively pursuing SSP. The United States in many ways is already behind both friends and competitors in this new field (e.g., China and Japan among others). The US Congress funded an SSP initiative in the Department of Defense during the last Administration. While this is a positive development, this program is narrowly focused on military missions and needs, and will <u>not</u> result in a commercial solution that can meet America's energy needs or address climate change. Recent initiatives funded by private donors are directed toward long-term research and not practical and timely action.

Attached is a Beyond Earth Institute Report title "**Catching the Sun: A National Strategy for Space Solar Power**," which provides a detailed description of SSP and the rationale for it. The Beyond Earth Institute has also taken the liberty of preparing the attached draft Space Policy Directive calling for a National Strategy for Space Solar Power.

In this period of climate crisis, we need to take bold steps to pursue all technically feasible and economically viable technology options. This is especially true if our national space efforts can directly benefit so many people on the ground. Dispatchable, scalable 24-7 space solar power has the potential to make a key difference in turning the tide on climate change. A failure to pursue SSP would undermine our efforts to mitigate climate change and once again diminish US leadership in energy, in space, and in protecting the environment. Therefore, we urge you to make Space Solar Power a priority issue for the National Space Council.

The Beyond Earth Institute (**www.beyondearth.org**) is a non-profit think tank which conducts research, provides analysis, makes recommendations, and develops vital insights regarding space policy proposals with near-term and far-ranging implications. We believe the ultimate goal of space exploration and development is to help move humanity beyond Earth, and that the legal and policy framework should be established now to enable that future. We also believe that government space activities can and should help people on Earth in their everyday lives, even as we work to build a future with economically vibrant communities of people living and working beyond planet Earth.

We are available to you and your staff at any time to provide a more comprehensive briefing on this proposal. To arrange a meeting, contact Tony DeTora at Tony@beyondearth.org or 703.203.8597.

Best regard,

Steve Wolfe
President

Tony DeTora
VP, Policy Coherence

John C. Mankins
Advisor

Attachments: BEI Report: "Catching the Sun: A National Strategy for Space Solar Power"
BEI Draft Space Policy Directive: A National Strategy for Space Solar Power

CC: Chirag Parikh, Executive Secretary, National Space Council
Antony Blinken, The Secretary of State
Bill Nelson, The Administrator of the National Aeronautics and Space Administration
Jennifer Granholm, The Secretary of Energy
Lloyd Austin, The Secretary of Defense
Gina Raimondo, The Secretary of Commerce
Pete Buttigieg, The Secretary of Transportation
Shalanda Young, The Director of the Office of Management and Budget
Jake Sullivan, The Assistant to the President for National Security Affairs
Dr. Eric Lander, The Director of the Office of Science and Technology Policy

The August 2021 BE Report

The Beyond Earth Institute

Catching the Sun:

A National Strategy for Space Solar Power

BEYOND EARTH INSTITUTE

Issued by
Beyond Earth Institute

Executive Summary

Space Solar Power can fulfill the promise of clean, safe, renewable, affordable energy reliably delivered where and when it is needed. Space Solar Power can power the world, and power worlds beyond, while moving our civilization beyond the fossil fuel age. Having developed all the underlying technologies, America can and should take the lead in creating this better tomorrow.

Space Solar Power is a broad term for power generation and distribution systems that collects the Sun's energy in space and delivers it to nearly any point on Earth where the energy is required. Space Solar Power systems are designed to be safe and will not harm birds or aircraft in the sky, nor will they harm humans, animals, vehicles or structures on the ground. By continuously harvesting sunlight in space, outside of the day/night cycle and above the obscuring atmosphere and weather, Space Solar Power yields up to 40 times greater sunlight access than traditional ground solar systems.

Space Solar Power has been theoretically possible for years, but economically grounded. New American technology is driving two Space Solar Power-enabling trends: significantly lower space launch costs and lower space hardware costs due to advanced manufacturing. Our geopolitical competitors see the possibilities and are eagerly pursuing dominance of this promising technology.

America needs a strong national commitment to Space Solar Power and a directed Space Solar Power research and development program. We must leverage the full array of governmental and private resources to produce a full-scale demonstration of Space Solar Power. Such a demonstration should provide a pathway for an economically sustainable approach, including involvement of international and private sector partners.

Space Solar Power is a critical enabler for space exploration and development, leading to communities of people living and working beyond Earth. It is an important step in securing the future of human civilization and our achievements as a nation.

What is SSP?

Space Solar Power (SSP) is a broad term for a power generation and distribution system that collects the sun's energy in space, converts sunlight into transmissible wavelengths, and uses wireless power transmission technologies to safely and efficiently convey the energy to remotely-located receiving antennas, which can be placed almost anywhere on Earth where the energy is needed.

In the 1960s and 1970s, an era known for people first rocketing their way into orbit, solar photovoltaic (PV) arrays were first being applied in space, and wireless power was demonstrated. With a spark of inspiration, Dr. Peter Glaser of Arthur D. Little invented the solar power satellite. Dr. Gerard K. O'Neill, physicist of Princeton University, subsequently popularized the concept of SSP as part of his idea for human settlements in space.

Space is an ideal location to harvest sunlight for multiple reasons. The Earth's atmosphere absorbs radiation. Outside of the atmosphere, sunlight has a greater energy concentration. According to NASA, "roughly 340 watts per square meter of energy from the Sun reach Earth. About one-third of that energy is reflected back into space." [1] In space, orbits can be selected to avoid the Earth's shadow and the resulting day-night cycle we all experience, guaranteeing nearly full-time sunlight. "Atmospheric conditions can reduce direct beam radiation by 10% on clear, dry days and by 100% during thick, cloudy days." [2] Finally, weather can block the sun for days or weeks at a time (i.e., clouds, fog, rain, snow, etc.) meaning the available sunlight in space can be 10-40 times greater than that available on Earth.

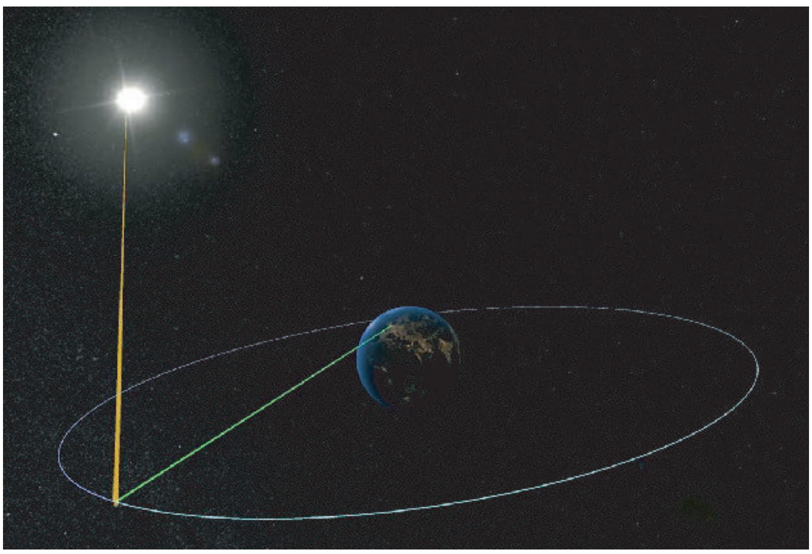


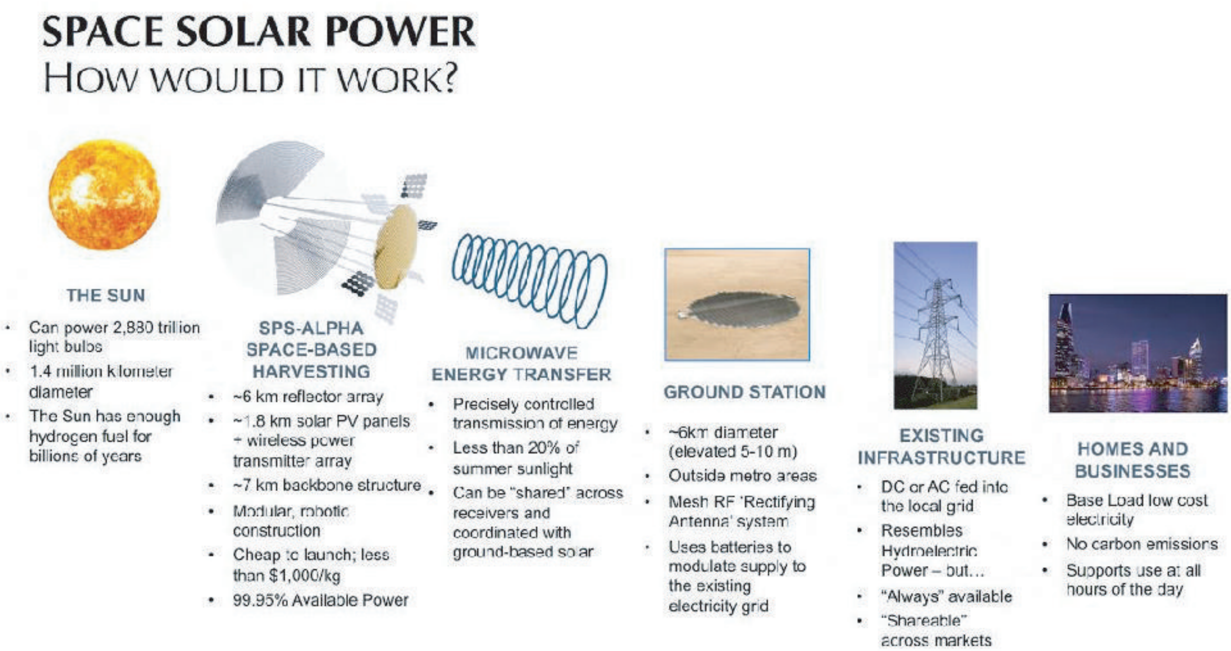
image source: Frazer-Nash

How does it work?

SSP includes systems to collect, convert, transmit, receive, and distribute energy from the Sun. Solar Power Satellites are designed to collect the Sun's energy with large solar arrays. The amount of energy that can be collected is determined by the size of the solar panels, their location in Earth orbit, and the efficiency of the solar cells. The satellites also contain the equipment necessary to convert the sunlight into electricity and transmit it wirelessly to receiving antennas on Earth.

The electricity needs to be delivered from the satellite in space to the ground with out using wires. Wireless Power Transmission (WPT) enables the transfer of energy from one location to another by means of electromagnetic (EM) waves – and hence, without wires or cables.

This is the perfect solution for transmitting the energy from space or in circumstances where power lines won't work, such as over very rough terrain or to moving vehicles or systems. The effectiveness of the end-to-end energy transmission depends on many factors: the equipment used, the power transmitted, the distance between the Transmitting Antenna in space and the Receiving Antenna on the ground, the size of each antenna, and the wavelength of the EM waves used between them. The Receiving Antenna captures the arriving EM waves and converts them into electricity. That electricity is then processed and delivered to the local power grid.



Why is Now the Time for SSP?

The physics for SSP is well understood, and the required technologies have long been available. So, why hasn't Space Solar Power been adopted yet? Why is now different?

A great many paper studies have been written since the 1970s, and periodic technology development efforts undertaken. However, affordable systems did not emerge as quickly as many hoped. The central hurdles to SSP demonstration and use in the past have been economic. The costs of launch and of the infrastructure required for assembly, the costs of the system hardware itself and the poor efficiencies of key devices (such as wireless power transmission) overwhelmed any prospect for delivering cost-competitive electricity to Earth. However, important advances since the turn of the 21st Century have greatly improved the potential economics for SSP. Specifically, low-cost launch, mass-production of modular space systems, advanced artificial intelligence, robotics for assembly, as well as other areas.

The United States enacted a series of laws that opened up space for commercial ventures and users. As a result, there have been tremendous advances in launch capabilities initially led by SpaceX, but industry-wide in the years since, by commercial firms. Commercial innovation driving down launch costs include reusable first stage rocket boosters, dramatically improved manufacturing efficiency, and improved operational efficiencies. The cost of launch has seen a 90% reduction in only the past 10 years as the SpaceX Falcon Heavy can now deliver a payload to Low Earth Orbit for $1,500 /kg. [3] As these new systems mature and new launch systems, such as SpaceX Starship, come on line, the cost of launch will continue to significantly decline.

While this revolution in launch cost has been happening, computing power continues to follow Moore's Law enabling increased efficiency and new capabilities while reducing the cost. We now have systems that fit into a shoebox that have all the capabilities it used to take a satellite the size of SUV to perform. Moreover, constellations of such modular satellites are now being manufactured in the thousands of units, and hundreds of tons. The Aerospace Corporation stated that "traditional cost models—based on larger civil and military space systems—tended to drastically overestimate the development costs of modern, smaller satellites" [4] and as hardware continues to get smaller, those cost gaps increase. As a result of technology advances and modular architectures, the cost of the hardware used in these small satellite constellations is roughly 99% cheaper than the cost per kilogram of conventional spacecraft – while also being up to 90% smaller in size for the equivalent functionality. [5]

These two factors – lower launch cost and lower hardware cost – enable SSP. For example, companies like SpaceX have been putting up mega-constellations – constellations of up to tens of thousands of individual satellites. SpaceX has launched 1,740 satellites to date in their StarLink constellation, [6] each with a mass of about 250 kg and deploying PV panels that generate roughly 5 kW of solar power.

That's a total of more than 8,700 kW of solar power – some 40-times the average power on the soon to be fully upgraded International Space Station (ISS). [7] The overall cost-effectiveness for solar power in space has improved by a factor of more than 100-to-one. More improvements are needed, as in-space cost estimates of space solar are still higher than terrestrial solar. Directed research and development, plus further reductions in launch costs and hardware costs, drive expectations that in-space solar costs will continue to fall.

Why is SSP the right goal for America today?

SSP is the right goal for America today because it can enable America to become the global leader in clean, safe, renewable, reliable, affordable, distributable, anywhere, anytime energy. SSP can power the world, and power worlds beyond, while moving the world off fossil fuels forever. By taking a leadership role on SSP today, we can create a better tomorrow.

Climate

The global understanding of climate change and concerns about its impacts have swelled, creating intense demand for new energy solutions for Earth. SSP is carbon-neutral and eliminates criterion pollutants in energy generation. SSP is clean, renewable, capable, and the only energy source that provides baseload power in a safe, reliable, and wasteless system.

Reliance on other renewables can sometimes create new environmental concerns. Some estimates show that terrestrial solar power may occupy up to 5% of total land area if it is to become a primary energy source, [8] while SSP has significantly reduced land-use requirements for clean energy generation.

The receiving antennas on Earth do not require dedicated land, so the land can still be used safely for agriculture, commercial, office, residential, and industrial uses while collecting the power from space.

Baseload Energy

SSP not only holds the promise of energy independence for America, but at scale it can also provide baseload power to all the people of the world. Baseload power is the minimum amount of electrical power needed on the grid at any time. While Earth-based solar power has become an important part of our energy mix, sunlight availability is 10 to 40 times greater in space with more energy available per square meter outside of Earth's atmosphere. Solar power satellites are not impacted by weather. With the recent advancements and continuing progress, a focused effort could achieve a full-scale demonstration within a decade.

Remote Energy

SSP enables energy distribution to remote locations. Many energy-intensive operations need to take place away from the existing grid. SSP enables them without batteries, generators, and massive amounts of fuel. SSP enables energy to offshore desalination plants, to offshore carbon capture plants, and to other locations where off-grid energy is needed.

SSP is currently under development by the U.S. Department of Defense to address their remote energy needs. There are two separate R&D projects, one at the Naval Research Laboratory and one at the Air Force Research Laboratory. These projects may well lead to deployable SSP to meet the needs of the military, but those needs do not translate into economically viable commercial-scale SSP. There are many reasons why these programs, even with significant funding increases, would not be sufficient to provide the leadership under discussion. The scale, the economics, and the technical requirements would all be significantly different when meeting these different needs.

Redundant Energy Source

SSP enables instantaneous backup power generation for locations who choose other energy sources as their primary systems. Currently, when relying on wind, solar, or other naturally variable sources, backup power generation must be available. In practice, this means that coal or oil systems are kept operating with the ability to take over generation needs. With terrestrial systems, this change can happen quite spontaneously, so the backup system needs to be available all the time, and the operators need to remain in a constant state of readiness. SSP can provide backup power, removing coal and oil backup systems from the loop.

Disaster Response

SSP could provide power availability for areas whose power generating capacity was impacted by a natural disaster. Disasters destroy infrastructure and it takes time to rebuild, reconnect, and return to the pre-disaster state. Time between the system being destroyed and being reconnected can be counted in lives lost, and property irreparably damaged. Receiving antennas are easily deployable, so SSP could fill in for a power station that has been taken offline, enabling power to be restored to hospitals, homes, and businesses more quickly, saving lives and property.

Space

International efforts to develop the resources of the Moon have also grown and would require large-scale affordable energy. SSP can provide energy in space – at the Moon, at asteroids, in Earth orbit – supporting our science missions, and enabling more ambitious projects.

Energy is a constant need and SSP can provide for the power needs of missions. It enables certain mission types, mission lengths, mission safety, and mission reliability. The more energy that is available, the more life support, the more redundant systems, the more habitable volume, the more science, the more mining, the more commerce, the more agriculture, and the more human activity can take place. SSP holds the promise of providing continuously renewable energy to any place in the inner solar system, on a planet or off one.

International Activities

Other countries are engaging on space solar power as well. China is pursuing any new technology that holds significant promise, and SSP is no exception. Russia has used in-space solar panels for years. India, Japan, UAE, the U.K., and the European Union, are all interested in making this technology work for their needs.

China in particular, has made significant progress toward space solar power during the past decade, developing a dedicated facility for the R&D and establishing in Spring 2021 a national committee to coordinate SSP research. China has announced plans to conduct a major SSP demonstration by the mid- 2030s. [9]

In Japan, Mitsubishi conducted major demonstrations of wireless power transmission in 2015.

Continuing Japanese R&D on key SSP technologies includes deployable structures, high-efficiency solid state devices and other topics.

The United Kingdom (UK) during 2020-2021 conducted the first-ever assessment of space solar power for the UK under the joint-auspices of the Ministry of Business, Energy and Industrial Strategy (BEIS) and the UK Space Agency. [10] An announcement is expected by the Fall of 2021 of a significant commitment to SSP at the national level.

South Korea, India and Australia have seen interest and studies undertaken by universities, for-profit firms and government Agencies. Other countries are also taking some of these steps and showing interest.

It is important to note that even if the U.S. were to adopt an aggressive program immediately to develop SSP capability, such international efforts are unlikely to wane. Our work will run parallel to other efforts already underway. Only through the strongest statement and commitment at the national level, and a directed research, development, and demonstration effort can America seek to claim leadership in SSP. While that may be challenging, for the U.S. to allow other nations, particularly adversarial nations, to move ahead on SSP while we limit our investment will put the future of U.S. energy security at a great disadvantage.

How Safe and Secure is SSP?

Wireless power transmission brings to mind a host of safety and security questions. How will wireless transmission impact people? Will this be a danger to airplanes or birds? Are buildings, bridges, or other structures at risk of harm from these transmissions? The answer to all of these questions is that SSP systems are designed to be safe, and no harm will come to people, birds, aircraft, structures, or anything else from these transmissions. In fact, these transmissions are not much different than those surrounding us every day.

Power transmission from the solar power satellite is generally through microwave transmission at a low power level. Although the wavelengths are the same as used in our kitchen appliances to cook food, the signal strength is much, much lower. The Federal Communications Commission (FCC), which is responsible for regulating wireless transmissions, notes that microwave ovens “should not be confused with the lower-energy, non-ionizing radiation” produced by low power transmissions. [11]

The U.S. Food and Drug Administration, one of the agencies tasked with protecting the public health, says “Microwaves are used to detect speeding cars and to send telephone and television communications.” [12] Microwaves are also used for doppler radar systems.

Extensive research has shown that there is no damage to people, animals, structures, or anything else from these low power transmissions. This ensures that birds, airplanes, and anything else flying through the air will remain safe, as will people, animals, and structures on the ground.

Questions about cyber security of the satellites themselves, or of technical glitches, that might allow the power levels to increase are also important. The satellites will be designed in a failsafe way, to ensure that they are not capable of transmitting at an unsafe power level.

Additionally, there are concerns about cyber attacks disabling a transmitter or taking control and turning it off, cutting the flow of energy to a part of the world. We recently saw the cascading impacts when part of the Colonial Pipeline was shut down via a ransomware attack, the rising cost of fuel, the immediate shortage and panic-buying which increased demand for gasoline by 40% over the previous week. [13] As with cybersecurity at all levels, SSP systems will have to employ the most rigorous protective protocols available and build specialized protocols to update such safety measures on a regular basis.

Are There Open Legal and Regulatory Questions with SSP?

The current U.S. legal and policy landscape for SSP is ill-defined. Such lack of clarity could expose inventors and entrepreneurs to potential civil liability and to criminal prosecution. More likely, those individuals will continue working on other projects which don't bear the same potential personal and professional risks.

A key regulatory area is wireless transmission of power, which would fall in the jurisdiction of the FCC in America, and require coordinating globally through the International Telecommunications Union (ITU). The ITU serves as an international diplomatic unit where the nations of the world work together to identify which uses are preferred for various radio frequency bands. The ITU table of frequencies serves as a treaty for the nations of the world in transmissions that cross international borders. Wireless transmissions are mostly regulated with respect to the interference they can cause to devices or to other transmissions. Each nation remains responsible for regulating wireless transmissions within its own borders.

It will be important that the nations of the world recognize that wireless power transmission fits well within the standard, accepted framework and are fundamentally no different from signals from radio, television, cell phone, satellites, and other systems we use every day. Negotiations on the use of specific frequencies will need to take place, tests will need to be conducted to ensure no harmful interference or identify devices or transmissions that might be impacted. The ITU and the national regulators around the world conduct these studies regularly, and are well versed in this analysis. Moving existing users from desired frequencies may be challenging, but there is significant experience with that as well. The FCC has been clearing existing users from the C-Band (3.7-4.2 GHz) for future use in 5G communications. [14]

As we have become more aware of the environmental impact of individual activity multiplied across billions of people living their everyday lives, we are now investigating more than ever the potential harm that systems can create in unexpected places. As such, there are additional questions about environmental impact of power transmissions. Although we do not expect to identify negative impacts, we need to better understand if these power transmissions might alter the chemistry of the atmosphere, including the ozone layer, or otherwise increase climate stress.

Greater attention is also being paid to space sustainability. The environmental considerations for satellites are being expanded to consider orbital debris, light pollution, impacts of satellites re-entering our atmosphere, and other space sustainability goals. Solar power satellites will need to conform to all laws and regulations in place, and be designed to account for these emerging areas of interest.

Additionally, regulations and protocols will be needed on how SSP electric power will tie into the electrical grid. This might also be a challenge, as there are many stresses and disparate viewpoints about grid management. But the terrestrial solar tie-ins have eased the way, and the benefits of the system should encourage significant buy-in across America and the world.

How will SSP Enable our Future in Space?

Building large enough systems to serve global energy needs will require a significant amount of mass. When launching into space, the more mass, the larger the rocket, and the more costly. As discussed previously, developments in the launch industry have brought launch prices down dramatically. Eventually, however, it may make economic sense to use resources that already exist in space.

The geology of the Moon and asteroids are well-known, and the base materials needed to construct most of the satellites are available there. Mining on the Moon or asteroids could provide these base materials needed for most of the satellites, with electronics and other delicate or specialized components being launched from the ground. Plans for mining these materials, as well as the development of new techniques, are already underway. [15]

Enabling capabilities such as advanced in-space mining, in-space manufacturing, on-orbit autonomous assembly, assessment, and maintenance, would require advanced robotic systems – both autonomous and telerobotically controlled, and a capability to maintain, upgrade, and repair the robots.

Modularization of SSP components will mean that those components will also be available to use for other in-space infrastructure. It will also allow the scale of production, and cost savings inherent in that, to be benefit these other in-space infrastructure projects/needs.

These in turn would enable additional people in space. People who would live and work there – at first for a short time, then for longer and longer stretches. Eventually, individuals will go to one or more of these locations to stay – to make a home.

As we move from stations and bases into communities – it is self-evident that energy needs will be significant. Throughout human history energy, water, and the freedom to act and own are the base requirements for advancement, achievement, and growing societies. Human ingenuity is a boundless resource. At billions of years of clean power, the Sun comes in a close second. We need to tap into it for the long run, to continue and expand on our success as a species. The COVID pandemic is a dramatic warning sign that we are at risk to a single event, and these changes can ensure that such an event doesn't eliminate our species, our history, our technology, our capabilities, and our future.

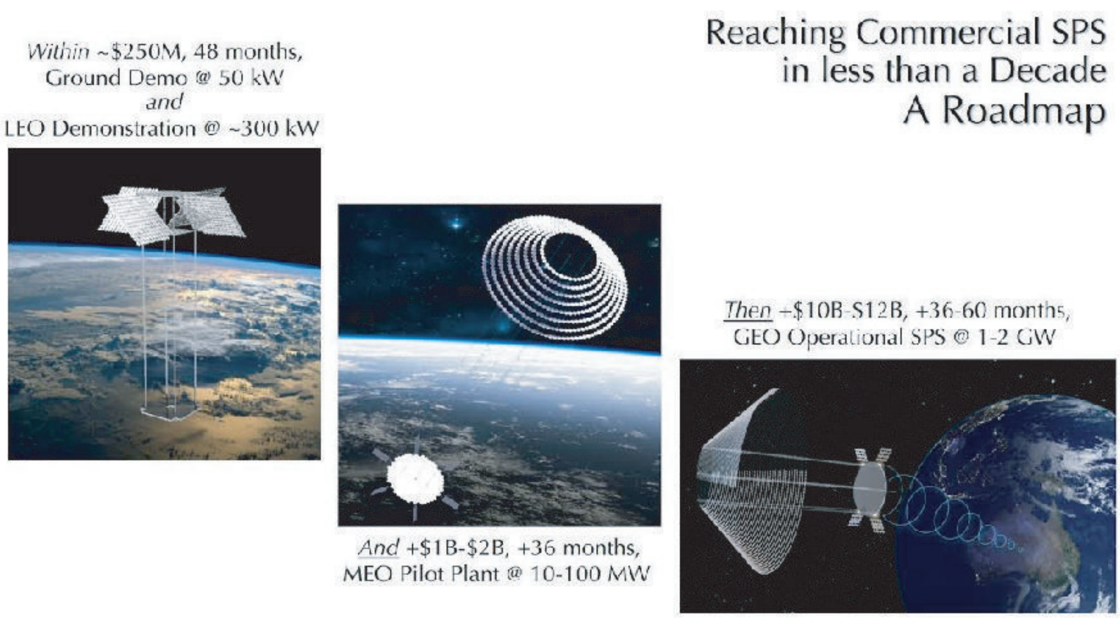
Policy Recommendations

Creating a Space Solar Power commitment at the national level, and implementing a directed research, development, and demonstration effort will be be costly and challenging, but America and all of humanity, will reap benefits vastly outweighing any expense.

Therefore, the United States should embark on a program, leveraging the full array of agencies and resources, to demonstrate SSP. Such demonstration should provide a pathway for a commercially sound approach and include international and private sector partners.

The following policy recommendations provide an outline for a strong approach that could successfully implement SSP as a major component of the national and global energy mix in the nearest term. The American government should:

1. Declare that the development and use of SSP technology is a key national goal and an integral component to meet our energy needs in the future.
2. Take a "whole of government" approach to SSP technology assessment, development, demonstration, and use.
3. Develop the necessary SSP technology and systems.
4. Deploy and use SSP and wireless power transmission systems.
5. Design SSP systems to meet the existing and potential future terrestrial commercial needs, as well as the NASA, DoD and commercial space mission requirements for government and commercial use.
6. Resolve spectrum management, space sustainability, and other regulatory issues.
7. Resolve operational security, cybersecurity, and other security issues.
8. Demonstrate SSP and WPT systems within space and from space to Earth.



Conclusion

While the authors of this paper are wary of grand policy declarations, a strong national commitment is needed for America to lead the world in Space Solar Power. Without such a commitment, other adversarial nations may have a clear path to control the energy production of the future. Or, without such a commitment, the world will continue to rely on fossil fuels for the next century or longer, maximizing the climate impacts until new reserves can no longer be found.

We do not think SSP is simple or easy, but it is clear to us that research, development, and demonstration of SSP in the near term is critical to the future of humanity. SSP is also enabling for space exploration and development, leading to communities of people living and working beyond Earth. We are closer than ever before in making SSP a physical reality and an economic reality. The reduction in costs for space launch and capable satellites brings us closer, and continuing reductions will get us to break-even faster than most suspect. The potential use of in-space resources to build large systems will reduce costs further and drive prices down while creating economic incentives to build more capacity quickly.

There are clear policies that must be engaged if America is to become a global leader in SSP. The authors believe the recommendations are clear, concise, and achievable. We hope policy makers embrace the opportunity and make the commitment to SSP for the people of America and of the world.

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Presidential Policy Directive
National Strategy for Space Solar Power

Memorandum for:

The Vice President
The Secretary of State
The Administrator of the National Aeronautics and Space Administration
The Secretary of Energy
The Secretary of Defense
The Secretary of Commerce
The Secretary of Transportation
The Director of the Office of Management and Budget
The Assistant to the President for National Security Affairs
The Director of the Office of Science and Technology Policy

Section 1. Policy. The ability to develop, deploy and use government and commercial space solar power (SSP) and wireless power transmission (WPT) systems safely, securely, and sustainably is vital to combating the global threats posed by climate change, to maintaining and advancing United States strategic leadership in developing new, scalable net zero carbon dispatchable baseload energy sources for US and global electricity markets, and to US leadership in space. SSP systems may include solar power generation (SPG) systems (including optics such as concentrators, photovoltaics (PV) and power management and distribution (PMAD)); wireless power transmission (WPT) systems (including microwave and laser power transmission); large in-space low-mass structural systems (assembled and deployable); critical robotic and mechanical systems supporting assembly, deployment and repair; solar electric propulsion; and, other systems (e.g., for transportation, attitude control and station-keeping, etc.). SSP systems have the flexibility to deliver power for commercial or government purposes on Earth, as well as for spacecraft, lunar and other surface systems, and other applications in which large, scalable power is required, thereby enabling adaptable and affordable power and operations. Cooperation with commercial and international partners is critical to achieving America's strategic objectives for space solar power.

This memorandum establishes a national strategy to ensure the development and use of SSP systems to enable and achieve the climate, national security, commercial, space exploration and space science objectives of the United States. In the context of this strategy, the term ‘‘development’’ includes the full process from supporting research and development to design, testing and production, and the term ‘‘use’’ includes launch, operation, and disposition.

This memorandum outlines high-level policy goals and a supporting roadmap that will advance the ability of the United States to use government, commercial and international SSP systems safely, securely, and sustainably. The execution of this strategy will be subject to relevant budgetary and regulatory processes and to the availability of appropriations.

Section 2. Goals. The United States will pursue goals for SSP development and use that are ambitious in their substance and their timeline, and which enable SSP to become a viable mid-term net zero carbon terrestrial energy option in the campaign to counter climate change by the late 2020s, with nearly continuous dispatchable power at scales of gigawatts and greater. These goals will also enable a range of future space missions and applications, with the aim of accelerating achievement of key milestones such as the in-space demonstration and use of new SSP capabilities. This memorandum establishes the following such goals for the Nation:

(a) Develop capabilities that enable production of SSP systems to deliver almost continuously dispatchable, baseload-scale net-zero carbon power to markets on Earth. To maximize international adoption, private-sector adoption and low-cost, these capabilities should be developed through public-private partnerships and with international partners to the greatest degree possible;

(b) Develop capabilities that enable production of SSP systems suitable to lunar and planetary surface and in-space power, as needed. To maximize private-sector engagement and cost savings, these capabilities should be developed to enable a range of terrestrial as well as space applications, including future commercial applications;

(c) Establish the technical foundations and capabilities—including through identification and resolution of the key technical challenges—that will enable options for SSP to meet future terrestrial commercial needs, as well as commercial space, National Aeronautics and Space Administration (NASA) and Department of Defense (DoD) mission requirements;

(d) Demonstrate a space solar power system (including wireless power transmission) on the surface of the Moon that is scalable to a power range of 1 megawatt-electric (MWe) and higher to support a sustained lunar presence and in situ resource utilization (ISRU) in the permanently shadowed regions (PSRs). To the extent feasible, this power system should align with mission needs for, and potential future government and commercial applications of, in-space SSP and space solar power for terrestrial power;

(e) Demonstrate a space solar power pilot plant system in Earth orbit that can deliver power of not less that 100 megawatt-electric (MWe) to one or more terrestrial markets, scalable to a power range of 1 gigawatt-electric (GWe) and higher. To the extent feasible, this SSP system should align with needs of potential future government and commercial mission applications; and,

(f) Develop advanced SSP capabilities that provide for future improvements in various efficiencies (PV arrays, WPT, etc.), higher specific energy, improvements in operations (e.g., repair and maintenance) and longer operational lifetime than existing SSP capabilities, thus enabling commercially-competitive space solar power to be delivered broadly and at large scale into terrestrial markets.

Section. 3. Principles. The United States will adhere to principles of safety, security, and sustainability in its development and use of SSP systems (including WPT), in accordance with all applicable Federal laws and consistent with international obligations and commitments.

(a) Safety. All executive departments and agencies (agencies) involved in the development and use of SSP systems shall take appropriate measures to ensure, within their respective roles and responsibilities, the safe development, testing, launch, operation, and disposition of SSP systems. For United States Government SSP programs, the sponsoring agency holds primary responsibility for safety. For programs involving multiple agencies, the terms of cooperation shall designate a lead agency with primary responsibility for safety in each stage of development and use.

(i) Ground development. Activities associated with ground development, including ground testing, of SSP systems shall be conducted in accordance with applicable Federal, State, and local laws and existing authorities of regulatory agencies.

(ii) Launch. Established safety guidelines and safety analysis and review processes for Federal Government launches of spacecraft, including SSP systems, and for launches for which the Department of Transportation has statutory authority to license as commercial space launch activities (commercial launches). These guidelines and processes address launch and any subsequent stages during which accidents may result in any effects on the public or the environment. Launch activities shall be conducted in accordance with these guidelines and processes.

(iii) Wireless Power Transmission. The safety, security and non-interference due to wireless power transmission (WPT) from an SSP system in space to a ground receiver shall be conducted in accordance with applicable Federal, State, and local laws and existing authorities of regulatory agencies. Key issues associated with spectrum allocation and management will be resolved by the Federal Communications Commission of the DOC and through the International Telecommunications Union (ITU).

(iv) Operations and disposition. The operation and disposition of SSP systems shall be planned and conducted in a manner that protect human and environmental safety and national security assets. SSP systems may be operated on interplanetary missions, in sufficiently high orbits, and in low-Earth orbits. These systems should be stored in sufficiently high orbits or safely reenter Earth’s atmosphere for destruction after the operational part of their mission.

(b) Sustainability. All agencies involved in the development and use of SSP systems shall take appropriate measures to conduct these activities in a manner that is suitable for the long- term sustainment of United States space capabilities and leadership in SSP.

(i) Coordination and Collaboration. To maximize efficiency and return on taxpayer investment, the heads of relevant agencies shall seek and pursue opportunities to coordinate among existing and future SSP development and use programs. Connecting current efforts with likely future applications will help ensure that such programs can contribute to long-term United States SSP capabilities and leadership. Agencies also shall seek opportunities to partner with international agencies, the private sector, including academic institutions, in order to facilitate contributions to United States SSP capabilities and leadership. To help identify opportunities for collaboration, the heads of relevant agencies should conduct regular technical exchanges among SSP programs, to the extent that such exchanges are consistent with the principle of security and comply with applicable Federal, State, and local laws. Agencies shall coordinate with the Department of State when seeking opportunities for international partnerships.

(ii) Commonality. The heads of relevant agencies shall seek to identify and use opportunities for commonality among SSP systems, and between SSP and terrestrial power systems, whenever doing so could advance program and policy objectives without unduly inhibiting innovation or market development, or hampering system suitability to specific mission applications. For example, opportunities for commonality may exist in goals (e.g., demonstration timeline), design, development, supplementary systems, methods, and infrastructure (e.g., testing facilities, launch facilities, and workforce).

(iii) Cost-effectiveness. The heads of relevant agencies should pursue SSP development and use solutions that are cost-effective while also consistent with the principles of safety and security. For any program or system, the head of the sponsoring agency(ies) should seek to identify the combination of ground-based and in-space testing and certification that will best qualify the system for a given mission.

(iv) Operational Security. The heads of relevant agencies shall pursue operational security for SSP deployment, operations and disposition, working with international and commercial partners. For any systems, these considerations will include cyber-security.

(v) Protection of the Space Environment. The heads of relevant agencies should pursue SSP development and use solutions that, to the extent practicable, minimize impacts from SSP systems on orbital debris, light pollution and other factors as may arise.

(c) Technology Transfer. All agencies involved in the development and use of SSP systems shall take appropriate measures to protect sensitive information, consistent with sound technology transfer principles. To facilitate timely cooperation and collaboration, where it is in the interest of the US Government, Agencies shall establish appropriate technology transfer and sharing agreements with international partners vis-à-vis SSP technologies and systems, and facilitate such agreements among private sector organizations and international counterparts. For United States Government SSP programs, the sponsoring agency holds primary responsibility for security.

Section. 4. Roles and Responsibilities.

(a) The Vice President, on behalf of the President and acting through the National Space Council, shall coordinate United States policy related to the development, demonstration, and use of SSP systems.

(b) The Secretary of State shall, under the direction of the President, coordinate United States activities related to international obligations and commitments and international cooperation involving SSP.

(c) The Administrator of NASA shall conduct and support activities associated with development and use of SSP systems to enable and achieve United States climate, energy, exploration and space science objectives. The Administrator of NASA shall establish the performance requirements for SSP capabilities necessary to achieve those objectives. When appropriate, the Administrator of NASA shall facilitate private-sector engagement in NASA SSP activities, and shall coordinate with the Secretary of State to facilitate international activities, with the Secretary of Commerce to help facilitate private-sector SSP activities, with the Secretary of Energy on relevant technology developments, and with the Secretary of Defense concerning relevant applications of SSP technology and systems.

(d) The Secretary of Energy shall, in coordination with sponsoring agencies and other agencies, as appropriate, support development and use of SSP systems to enable and achieve United States climate, energy exploration, scientific, and national security objectives. When appropriate, the Secretary of Energy shall work with sponsoring agencies and DOC to facilitate United States private-sector engagement in Department of Energy (DOE) SSP activities.

(e) The Secretary of Defense, working with other Agencies shall conduct and support activities associated with development and use of SSP systems to enable and achieve United States national security objectives. When appropriate, the Secretary of Defense shall facilitate private-sector engagement in DoD SSP activities.

(f) The Secretary of Commerce shall promote responsible United States commercial SSP investment, innovation, and use, and shall, when consistent with the authorities of the Secretary, ensure the publication of clear, flexible, performance-based rules that are applicable to use of SSP and are easily navigated. Under the direction of the Secretary of Commerce, the Department of Commerce (DOC) shall ascertain and communicate the views of private-sector partners and potential private-sector partners to relevant agency partners in order to facilitate public-private collaboration in SSP development and use. These considerations shall include the resolution of spectrum allocation and management under the auspices of FCC responsibilities.

(g) The Secretary of Transportation shall, when appropriate, facilitate private-sector engagement in the launch or reentry aspects of SSP development and use activities, in support of United States science, exploration, national security, and commercial objectives. To help ensure the launch safety of an SSP payload, a payload review may be conducted as part of a license application review or may be requested by a payload owner or operator in advance of or apart from a license application.

(h) The Director of the Office and Science and Technology Policy shall coordinate United States policy related to research and development of SSP systems.

Section. 5. Roadmap. The United States will pursue a coordinated roadmap for federally-supported SSP activities to achieve the goals and uphold the principles established in this memorandum. This roadmap comprises the following elements, which the relevant agencies should pursue consistent with the following objective timeline, subject to relevant budgetary and regulatory processes and to the availability of appropriations:

(a) By the mid-2020s, establish the technical foundations and capabilities – including through identification and resolution of the key technical challenges – that will enable SSP options to meet sustainable terrestrial commercial needs, as well as commercial space, NASA and DoD mission needs.

  (i) Conduct requirements assessment. NASA and DOE, in cooperation with DoD, and with other agencies and private-sector partners and international partners, as appropriate, should assess the ability of SSP capabilities to enable and advance existing and potential future terrestrial commercial needs, as well as NASA, DoD and commercial space mission requirements.

(ii) Conduct technology assessment. NASA, in cooperation with DOE and DoD, and with other agencies, private-sector partners and international partners, as appropriate, should evaluate technology options and associated key technical challenges for an SSP system. NASA, DOE and DoD should work with their partners – including the private sector, other agencies and international partners – to evaluate and use opportunities for commonality with other SSP needs, terrestrial power needs, and demonstrations planned by agencies and the private sector.

(iii) Conduct technology development. NASA, DOE and DoD should work with their partners – including the private sector, other agencies and international partners – to develop SSP system technologies that will resolve the key technical challenges.

(b) By the mid-2020s, develop capabilities that enable production of SSP systems that are suitable for sustainable delivery of net zero carbon energy to markets on Earth at commercially competitive prices, using technologies that are consistent with safe, commercially-competitive lunar and planetary surface and in-space power applications as needed. Begin development of advanced SSP capabilities that provide for future improvements in various efficiencies (PV arrays, WPT, etc.), higher specific energy, improvements in operations (e.g., repair and maintenance) and longer operational lifetime than then-current SSP capabilities.

(c) By the mid- to late- 2020s, resolve spectrum management and other regulatory issues, working through appropriate US and international organizations that will enable SSP options to meet future terrestrial commercial needs, as well as commercial space, NASA and DoD mission needs.

(i) Spectrum Management. NASA, in coordination with the Department of Commerce, DOE, DOD, other Agencies, the private sector and international collaborators, as appropriate should develop recommendations for, and approval of spectrum allocation choices for SSP wireless power transmission, focusing on the requirements of an SSP pilot plant (see below).

(d) By the mid-to late-2020s, demonstrate a space solar power system delivering power from low Earth orbit (LEO) to the surface of the Earth, delivering not less than 1 kW of power to the receiver on Earth.

(i) Initiate a LEO SSP demonstration project. NASA should initiate development of an SSP system producing not less than 100s of kilowatts (kW) power in LEO by means that are scalable to a large-scale, all-weather dispatchable SSP system and delivering not less than 1 kW to Earth for demonstration by 2026. NASA should consult with other agencies, and with the private sector, as appropriate, when developing project requirements.

(ii) System development. NASA should work with DOE, and with other agencies and private-sector partners to develop the LEO SSP power demonstration project.

(iii) Conduct demonstration mission. NASA, in coordination with other agencies and with private-sector partners, as appropriate, should launch and conduct the LEO SSP demonstration project.

(e) By the late-2020s, demonstrate a space solar power system delivering power to the surface of the Moon that is scalable to a higher power to support sustained lunar presence and resource development and utilization at the lunar polar regions and elsewhere.

(i) Initiate a surface power project. NASA should initiate development of an SSP system delivering not less than 100 kilowatt-electric (kWe) power for lunar surface demonstration by c. 2028, with scalability to power levels at or above 1 megawatt-electric (MWe). NASA should consult with other agencies, and with the private sector, as appropriate, when developing project requirements.

(ii) Engage the private sector. NASA, working with DOE and other Agencies should determine mechanisms for engaging with the private sector to meet NASA's lunar surface power needs in an effective manner consistent with the guiding principles set forth in this memorandum. In evaluating mechanisms, NASA, DOE and others should consider the possibility of NASA issuing a request for proposal for the development and construction of the surface power system or demonstration.

(iii) System development. NASA should work with DOE, and with other agencies and private-sector partners, as appropriate, to develop the lunar surface power demonstration project.

(iv) Conduct demonstration mission. NASA, in coordination with other agencies and with private-sector partners, as appropriate, should launch and conduct the lunar surface power demonstration project.

(f) By the late-2020s, develop, deploy and operate a space solar power pilot plant system delivering net zero carbon power to one or more markets on Earth at 100 MW or greater, and scalable to 1 gigawatt (GW) and higher to support competitive commercial operations in a wide range of terrestrial markets.

(i) Initiate an SSP pilot plant project. NASA, working with DOE and the Department of State should initiate an SSP pilot plant project for terrestrial markets by c. 2028, with initial delivered power of at least 100 MWe with a system scalable to 1 GWe or above. NASA should consult with other agencies, and with the private sector, as appropriate, when developing project requirements.

(ii) Engage the private sector. NASA, working with DOE and other Agencies should engage with the private sector through public-private partnerships to meet this milestone in a timely and cost-effective manner consistent with the guiding principles set forth in this memorandum.

(iii) System development. NASA should work with DOE, other agencies and private-sector partners, and with international partners as appropriate, to develop the SSP pilot plant project.

(iv) Conduct pilot plant deployment and operations. NASA, in coordination with other agencies, private-sector partners, and international partners, as appropriate, should launch and operate the SSP pilot plant, with operations to last for a period of not less than five (5) years before transitioning to private sector ownership and operations.

(v) During pilot plant operations, NASA, in coordination with other agencies, private-sector partners, and international partners, as appropriate, should use the SSP pilot plant for purposes of testing new SSP technologies and systems elements.

Section. 6. Implementation. The Vice President, through the National Space Council, shall coordinate implementation of this memorandum.

Section. 7. General Provisions.

(a) Nothing in this memorandum shall be construed to impair or otherwise affect:

(i) the authority granted by law to an executive department or agency, or the head thereof; or

(ii) the functions of the Director of the Office of Management and Budget relating to budgetary, administrative, or legislative proposals.

(b) This memorandum shall be implemented consistent with applicable law and subject to the availability of appropriations.

(c) This memorandum is not intended to, and does not, create any right or benefit, substantive or procedural, enforceable at law or in equity by any party against the United States, its departments, agencies, or entities, its officers, employees, or agents, or any other person.

(d) The Administrator of NASA is authorized and directed to publish this memorandum in the Federal Register.

Dated: TBD.

Signing Authority