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BASE LOAD SPACE SOLAR POWER

A FEASIBLE NEAR-TERM APPROACH TO AGGRESSIVELY MITIGATE CLIMATE CHANGE

Space Baseload Solar Power for Australia & the World

Updated May 2022

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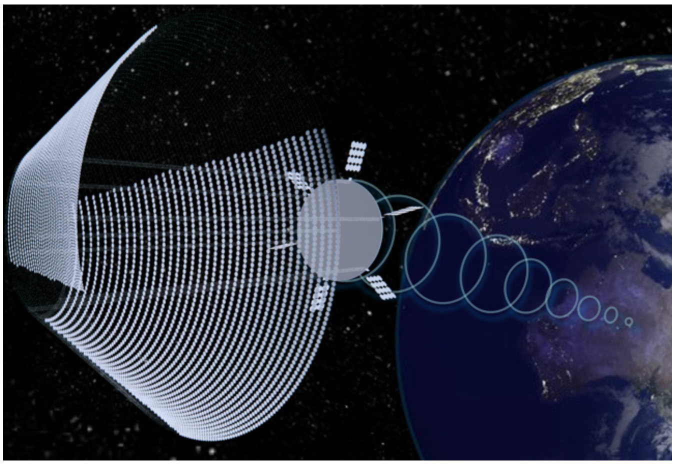
EXECUTIVE SUMMARY



Solar Space Technologies Pty Ltd (SST), a Melbourne, Australia-based firm working with Mankins Space Technologies, Inc. (MSTI), a California-based company proposes to develop and commercialise a novel systems technology – SPS-ALPHA ('solar power satellite via arbitrarily large phased array') to harvest continuously-available solar energy in space and deliver that carbon net-zero power wirelessly and on-demand to markets globally and in space. The project will result in development and deployment of the first solar power generation satellite, ground receivers and associated infrastructure in less than 7-8 years for a total cost of less than $2B, beginning with a modest initial investment, described below.

To accomplish this goal, and to do it in less than a decade, SST and MSTI propose establishing key partnerships in the US and internationally, including a primary Australia-United States of America (USA) commercial-government partnership, with additional partnerships in Japan, the United Kingdom, Europe, New Zealand and elsewhere.

SST – working with MSTI and others – plans to develop and deploy the first solar power satellite (SPS) using key technologies (existing in the laboratory, but used in a novel system application), and to develop by 2040 a total capacity of at least 18 gigawatts of electricity for the Australian and Pan-Pacific electricity market.

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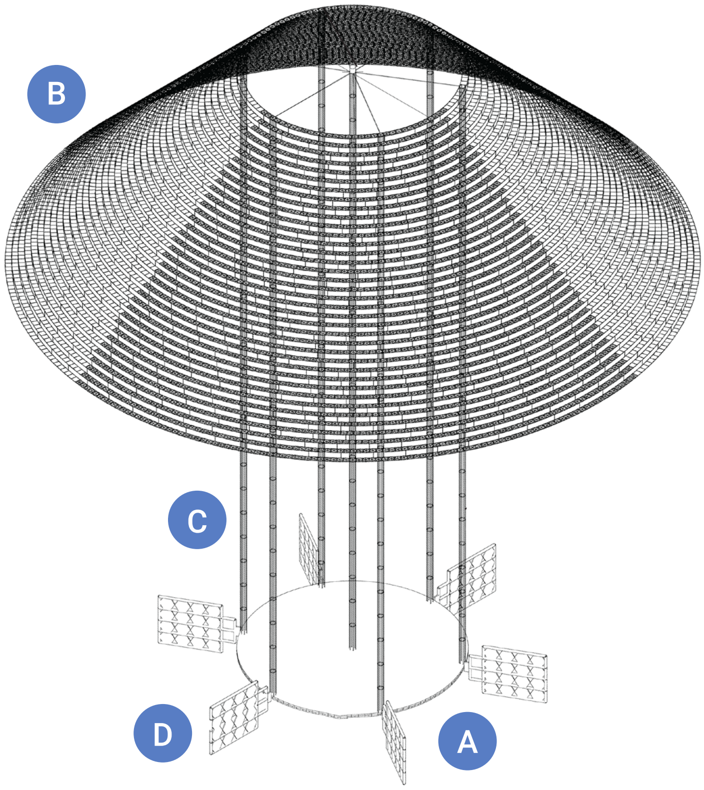
WHAT IS BEING PROPOSED

"Low cost, limitless energy with no carbon emissions for Australia & the world."

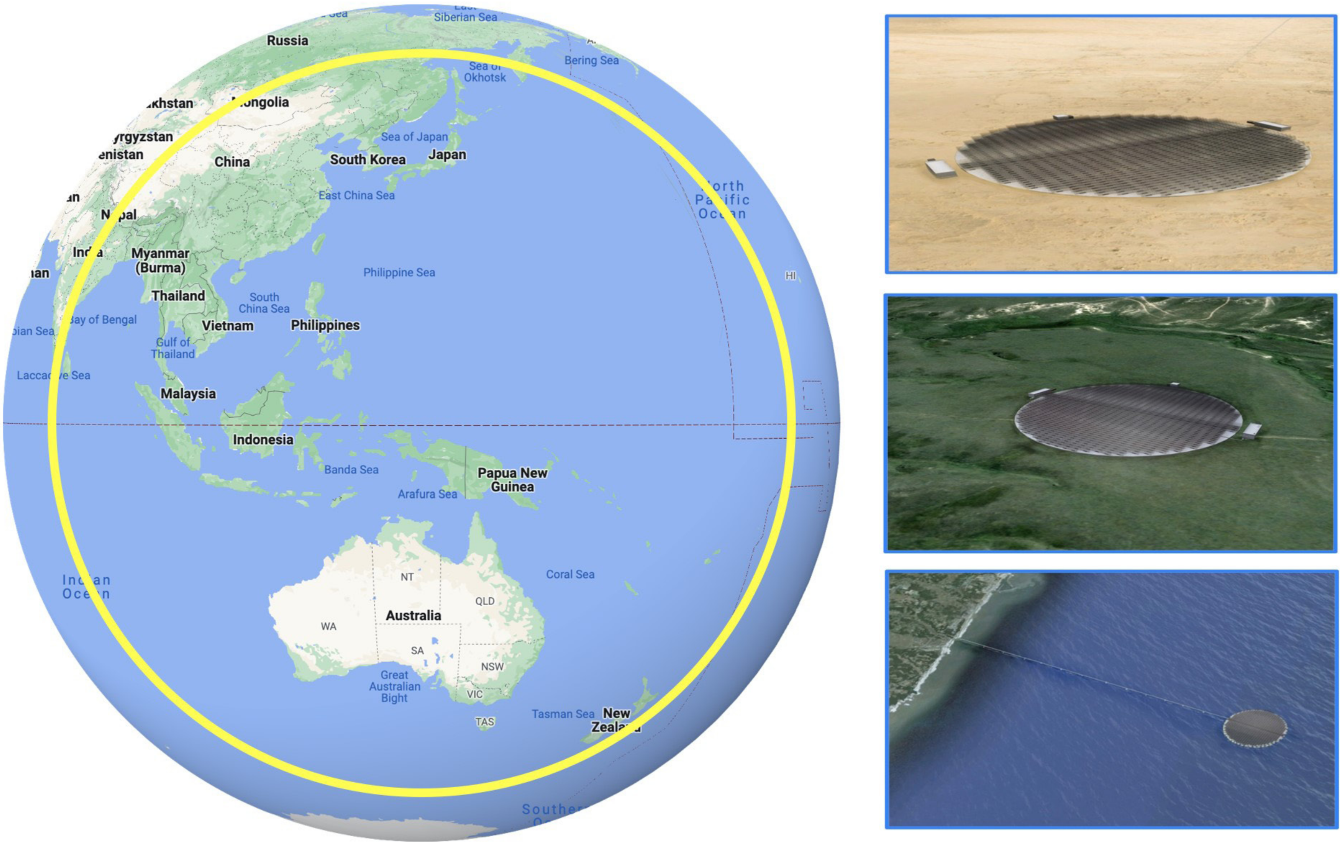
SST, working with MSTI will develop the novel modular space systems concept: "SPS-ALPHA" (solar powered satellite via arbitrarily-large phased array), first examined under a NASA Innovative Advanced Concepts (NIAC) project (2011-2012). SPS-ALPHA comprises a large number of mass-produced modular space systems (on average @ 5-10 kg), assembled into four major segments: (a) an Earth-facing energy conversion array (sunlight-to-RF), (b) an array of lightweight, sunlight redirecting heliostats (mirrors), (c) a supporting structural system (connecting (a) and (b), and (d) a number of supporting modules comprising the 'balance of systems' (such as attitude control, communications, and robotics).



- A — *Energy Conversion Array*
- B — *Reflector Array*
- C — *Connecting Boom Structures*
- D — *Example Attitude Control Modules*

The concept-of-operations involves several activities:

• First, the SPS-ALPHA platform is launched to Earth orbit,
• The platform, comprising a large number of identical, mass-produced modules is assembled in its operational orbit (e.g., geostationary Earth orbit),
• Once assembled, the platform intercepts and harvests solar energy using a large number of low-mass heliostats (i.e., reflectors) to redirect incoming sunlight and spread it across a large, but modular photovoltaic (PV) solar array,
• The PV array transforms the sunlight efficiently into radiofrequency (RF) energy (at microwave wavelengths),
• The microwave energy is transmitted on-demand safely, precisely and with high-efficiency to receivers for markets on Earth, and
• Finally, an energy storage system is operated in conjunction with the receiver to assure load-levelling and high-availability.



A single SPS-ALPHA might send power to receivers (only one at a time), across a wide area on Earth below. For example, a platform over Australia, as illustrated, might transmit power not only to anywhere in Australia, but also as far north as Japan, as far East as New Zealand, west as far as India – and to markets (e.g., Singapore, South Korea, Malaysia, etc.) anywhere in between. The wireless power receivers are wire mesh in nature, and can be elevated to assure non-interference with land use below. They may be based onshore over deserts or farmland, or offshore.

COSTS & BENEFITS

Working with international commercial-government partnerships, MSTI and SST propose to develop, manufacture, deploy and operate full-scale SPS-ALPHA platforms with a mass of about 8,000 MT, sized to each deliver approximately 2 GW of dispatchable baseload power 99.8% of the time, at a cost of approximately $10B each. Each SPS will deliver energy at a levelized cost of electricity (LCOE) of less than 5¢ per kilowatt-hour ($, US) over a 30-year nominal lifetime. The energy return on energy invested (EROEI) is estimated to be greater than 98%, with an energy invested payback time of approximately 60 days.

Based on recent market development (e.g., carbon net-zero policy-driven government incentives and investments) for investors, this project should generate net revenues of just less than $2B (US) per year from each deployed, full-scale SPS-ALPHA (generating 2.1 GW), resulting in rates of return of approximately 20% and investment payback times on the order of 6-7 years.

The project will create tens-of-thousands of new, high-quality jobs in participating countries with near zero CO2 emissions resulting from the power consumed, representing perhaps 60,000-100,000 work-years during development, and a sustained workforce of 2,000-3,000 employees per platform in perpetuity (due to operations and maintenance). The project will be scalable limited only by funding, manufacturing capacity and space launch infrastructure.

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NEAR-TERM MARKET OPPORTUNITY

The Australian market represents an exceptional opportunity for novel energy solutions, such as space solar power. [1] The total installed capacity delivers approximately 30GW, with this power generated by a combination of fossil fuels (about 80% coal, oil and natural gas) and renewables (about 20%) including hydro, solar and wind.[2] The average levelized cost of electricity (LCOE) is approximately 10¢-20¢ per kilowatt-hour ($, US), with selected options delivering electricity at less than 10¢ and others demanding more than 50¢ per kWh (LCOE).[3]

Moreover, an SPS positioned in a geostationary Earth orbit (GEO) above western Australia could deliver power (not simultaneously) to locations where a receiver had been established comprising more than 50% of humanity (about 4 Billion individuals) – with combined economies totaling more than $30T-$40T GDP annually ($, US). Many of these locations have current LCOEs equal to or greater than those in Australia. Space solar power should, however, not be viewed as a singular solution to the challenge of carbon net-zero energy, but rather as an important part of a multi-faceted energy portfolio.

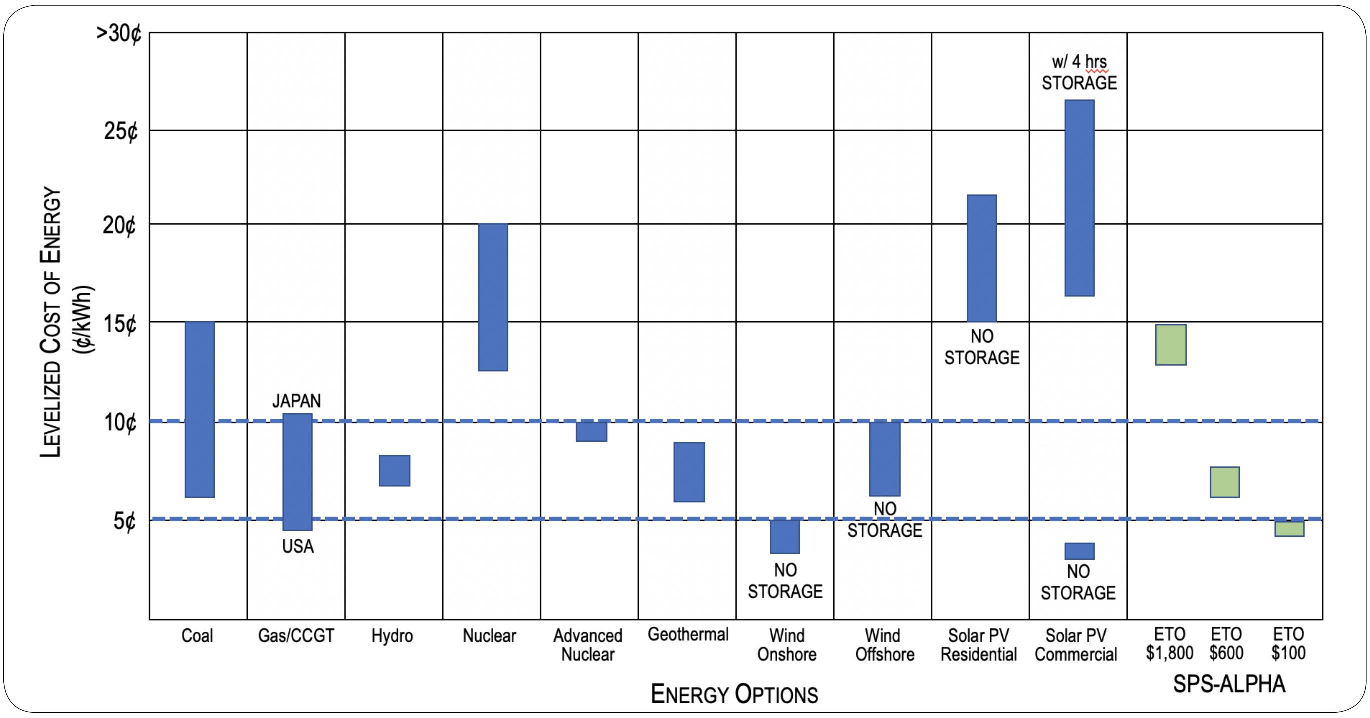

FIGURE 2: Average Levelized Cost of Electricity (LCOE; $, US) of SPS-ALPHA compared with various other sources [4]

CLIMATE IMPACT

Space solar power delivered by SPS-ALPHA is projected to be the lowest carbon-emitting source of baseload power available during the coming decades, with energy payback – i.e., the recovering of all energy involved in the manufacture and deployment of the platforms in space and receivers on Earth in approximately 60 days. Sized to deliver 2.1 GW of baseload power, a single SPS-ALPHA would generate some 552 billion kilowatt-hours over its targeted lifetime of 30 years or more, eliminating approximately 400 million tons of CO2, as compared to a typical coal-fired power plant.

In addition, by providing a solar option for dispatchable baseload power and due to the capability to reposition the delivery location as required, space solar power can be used in combination with intermittent ground solar or wind turbine energy – removing the requirement for fossil fuel-based backups.

PLAN FORWARD

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The SST plan to realise space solar power for Australia comprises several phases over less than 8 years to develop and begin delivery of SSP to markets in Australia and globally; as follows:

•Phase 0.5: Development and testing of the critical functionality in an integrated systems-level testbed, and creation of the Australia Centre for Energy and Space in Victoria; requiring an initial $12M ($, Aus). ACES and the testbed, involving largely off-the-shelf technologies will be accomplished within 12 months of receipt of funding.

•Phase 1: Development and demonstration of an SPS-ALPHA prototype, incorporating critical technologies (see below) in an integrated systems-level testbed facility. This demonstration, involving selected new technologies will to be accomplished within an additional 18 months (total duration: 30 months). Phase 1 will require additional funding of $38M ($, Aus.); total funding through end of Phase 1: $50M ($, Aus).

•Phase 2: Comprising development and launch of an operational SPS-ALPHA prototype to low Earth orbit (LEO). Here, the project will demonstrate in-space assembly of a platform capable of generating up to 300kW with precision delivery of kW-class power to locations in Australia, the USA, and elsewhere. Phase 2 will be accomplished over an additional 24-26 months (total duration: 54-56 months), comprising additional funding of about ~$200M to ~$250M ($, Aus); total funding through Phase 2: ~$250M ~$300M ($, Aus).

•Phase 3: Involving deployment of the first, full-scale, but moderate-size SPS-ALPHA “pilot plant” to deliver space solar power to a high-value remote market, potentially involving a remote mining location in Australia. Phase 3 will require approximately an additional 36-48 months (total time of 7-8 years) at an initial cost of approximately $1.5 - 2.0 B ($, Aus). The pilot plant is projected to deliver approximately 100MW with a lifetime of 15+ years.

•Phase 4: Following Phase 3, we will begin the manufacture, launch, assembly and operation of full-scale SPS-ALPHA platforms delivering affordable baseload power (up to 2.1 GW) to various locations in Australia, the US and beyond, at an estimated LCOE of ~10¢ per kWh for Earth To Orbit (ETO) launch prices at $1,200-$1,500 per kg, and for less than ~5¢/kWh with projected launch prices at $100 per kilogram ($, US).

CRITICAL TECHNOLOGIES

Like all new energy options, SPS-ALPHA will involve the successful integration of various critical technologies into new systems, and their demonstration of readiness for use.

The key capability of wireless power transmission (WPT) via microwaves was first demonstrated in the 1960s-1970s by William R. (“Bill”) Brown and Mr. Richard (“Dick”) Dickinson (of the Raytheon Corporation and NASA’s Jet Propulsion Laboratory, respectively). Moreover, the component technologies for WPT have evolved significantly during the past 20 years due to unrelated demand for high-efficiency wireless devices – such as mobile phones – enabling high-efficiency, all- electronic WPT today.[5]

There are several developments accomplished during the past decade that are key to the economic viability of SPS-ALPHA.

The factory-based mass-production of satellites for the new ‘mega-constellations’ (Starlink, Kuiper System, OneWeb, and others) is now achieving hardware costs of roughly $1,000-$2,000 per kilogram for space systems – again, a 99% reduction below the traditional cost of some $50,000-to-$200,000 per kilogram for Earth-orbiting spacecraft. The enabling feature of the SPS-ALPHA concept for space solar power is the use of a highly-modular architectural approach. This characteristic, enabled by recent advances in robotics in highly-structured environments makes possible the low-cost per kilogram mass production of the SPS-ALPHA system – reducing the expected cost of the platform hardware by a factor of 100 compared to traditional spacecraft.

Low-cost Earth-to-orbit (ETO) transportation is also crucial to the viability of space solar power; this is one of the major transformations that enable SSP to proceed today. During the past 10 years, ETO transport at costs of less than $1,500 to $3,000 per kilogram have been operationally demonstrated by Space Exploration Technologies, Inc. (SpaceX). The emergence of new, exceptionally low-cost launch vehicles (e.g., Starship+Heavy Booster from SpaceX, New Glenn from Blue Origin, or others), now promise to drop the cost of transportation to low-Earth orbit (LEO) from the traditional level of about $20,000 per kilogram to less than $200 per kilogram – a reduction of 99%.[6]

Additional important technologies include low-mass structural systems, high-efficiency and low-mass photovoltaic (PV) arrays, wireless networked systems, and others. All of these have advanced dramatically in recent years. In the case of structural systems, the capability for rapid-prototyping through additive manufacturing (aka, "3D printing") will be employed to accomplish the objectives of Phase I and Phase II (described above) as planned.

Together, these dramatic changes in space programs transform the economics of space solar power. Fortunately, all of the technologies required for SPS-ALPHA have been proven at TRL 4-5 – many by Mr. Mankins through past projects – including their use in various terrestrial applications.[7]

LEADERSHIP

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SST is led by founder Mr. Serdar Baycan of Melbourne in the state of Victoria, Australia. Mr. Baycan is a respected architect with extensive experience in formulating, obtaining funding for and implementing numerous building projects over the past 25-plus years. John C. Mankins of California, USA is the founder and president of Mankins Space Technology, Inc. He is a globally-known expert in the fields of space solar power and space technology management. In 1995, Mankins published the first detailed definitions of the "TRLs" (technology readiness levels), the global standard for assessing the maturity of a new system. In 2011, he invented the first financially-viable, hyper-modular and mass-producible SSP concept, SPS-ALPHA. Mr. Mankins wrote the book "The Case for Space Solar Power", published in 2014.

SST and MSTI are now reaching out to various leaders in industry, academia, the financial sector and Government in Australia, the USA and elsewhere to build a strong and resilient partnership to accomplish this project and bring a new and important climate-sustainable energy option forward.

For additional information regarding this exciting project, please contact us.

REFERENCES

1.See: https://www.energy.gov.au/government-priorities/energy-data/australian-energy-statistics

2.See: https://www.originenergy.com.au/blog/electricity-generation-in-australia/

3.See: https://www.csiro.au/en/News/News-releases/2018/Annual-update-finds-renewables-are-cheapest-new-build-power

4.See: https://www.iea.org/reports/projected-costs-of-generating-electricity-2020; also: https://www.lazard.com/perspective/levelized-cost-of-energy-levelized-cost-of-storage-and-levelized-cost-of-hydrogen/

5.See: https://en.wikipedia.org/wiki/Wireless_power_transfer#Microwaves_and_lasers

6.See: https://www.spacex.com/about/capabilities, https://dgit.com/space-x-falcon-heavy-vs-blue-origin-new-glenn-5690/, https://www.blueorigin.com/new-glenn/, and https://www.teslarati.com/spacex-ceo-elon-musk-says-that-bfr-could-cost-less-to-build-than-falcon-9/

7.See: https://www.newsweek.com/game-changer-fight-against-climate-change-opinion-1693929

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