SUBMISSION TO

THE HOUSE OF REPRESENTATIVES STANDING COMMITTEE ON INDUSTRY, INNOVATION SCIENCE AND RESOURCES
ON
DEVELOPING AUSTRALIA'S SPACE INDUSTRY

FROM
SOLAR SPACE TECHNOLOGIES PTY LTD

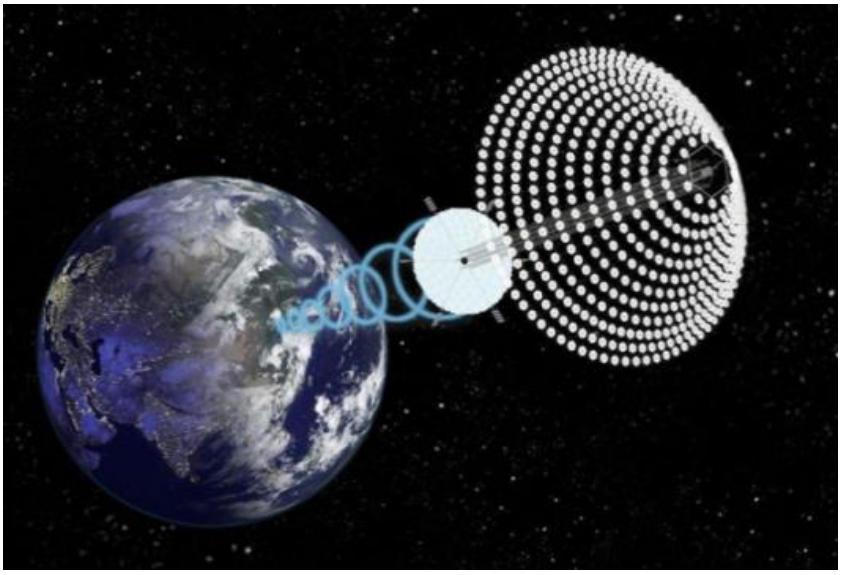
28 January 2021

Terms of Reference

The House of Representatives Standing Committee on Industry, Innovation, Science and Resources inquire into and report on, including:

- *Development of space satellites, technology and equipment;*
- *International collaboration, engagement and missions;*
- *Commercialisation of research and development, including flow on benefits to other industry sectors;*
- *Future research capacity, workforce development and job creation; and*
- *Other related matters.*

The Committee will focus on how the Australian Government can support and encourage the space industry while preserving and protecting the space environment.



Artist impression of SPS ALPHA (Mark-II) Platform Concept

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1 . Executive Summary & Recommendations

Introduction

The inquiry by the House of Representatives Standing Committee on Industry, Innovation, Science and Resources (IISR) into developing and supporting the Australia's space industry is welcomed and our detailed response for a new space industry for Australia- Space Solar Power is outlined below in accordance with the terms of reference.

Please note throughout this paper there are several similar terms and acronyms. They are briefly descibed below.

- SSP - Space Solar Power, is the general term to describe the technology required to collect and transfer solar energy from space to earth and conversion to electricity

- SPS - Solar Powered Satellite, refers to the unit (ie satellite) that collects and transfers the solar energy to earth

- SST – Solar Space Technologies, refers to the Australian company undertaking a space solar power project in Australia. For clarity in this paper the full name *Solar Space Technologies* is used to reference the commercial company.

Developing Australia's Space Industry - Space Solar Power

Space Solar Power has an important contribution to make for each of the Terms of Reference for the Standing Committee on Industry, Innovation, Science and Resources inquiry on developing Australia's space industry, yet you will not find a single word about it in any of the Australian Space Agency's literature.

The purpose of this paper is to bring to the committee's attention a transformational technology with the power to revolutionise Australia's space industry and the Australian economy.

Space Solar Power (SSP) refers to gathering solar energy in space through the design, manufacture and deployment of large satellites and transferring solar energy to earth. Space solar power systems can supply enormous amounts of low cost baseload energy without producing carbon emissions. Unlike wind power and terrestrial solar, expected SSP production levels are predictable.

Through the work of this Committee, we have an opportunity to develop a national policy for the development and investment in a new industry for Australia that will provide:

- a massive economic boost to the Australian space industry and other sectors;
- thousands of high-quality jobs;
- industry custom through payload launch to the developing Australian rocket and space launch industry;
- an energy supply to support activities in space;
- important new ties to friends and allies internationally;
- low cost base load energy for Australia and the world with no carbon emissions; and
- stability to the national electricity grid, complementing earth-based intermittent energy.

Solar Space Technologies – An Australian company delivering Space Solar Power

Solar Space Technologies Pty Ltd, (SST) is an Australian Company working with Mankins Space Technology of the USA to generate base load space solar power in Australia, and to export energy to our region and the world. John C Mankins, physicist with a 25 year career at NASA and Caltech's Jet Propulsion Laboratory and global expert on space solar power and Serdar Baycan are the forces behind the design and development of this technology and its practical application with the intention to design and manufacture in Australia as well as the USA.

The business goals and objectives of *Solar Space Technologies* are to provide Australia with a safe and low cost, affordable space solar power option for carbon emissions free electricity, and to establish the foundations of a major new industry in Australia and globally – creating many thousands of high-quality, well-paid jobs.

Solar Space Technologies has detailed project plans in place and feasibility studies to undertake the testing and development of the prototype, manufacture and provide terrestrial and low earth orbit demonstrations, pilot plants and finally in geostationary orbit (GEO), a large operational solar powered satellite. The deployment of a smaller plant in LEO is planned within 5 years, and for a large plant in GEO starting in 10 years. The feasibility studies indicate supply cost of energy by space solar power is 1/3rd of the price of conventional base load power and 1/10th of available power at remote Australian locations.

IIS&R Standing Committee's Terms of Reference

The development of SSP in Australia addresses each of the terms of reference in the following ways:

- SSP requires the development of space satellites, solar panels, ground receivers, advanced manufacturing of hundreds of thousands of modular components from specialised materials, robotics and operational technology and equipment, providing a massive boost for the Australian space industry.

- International collaboration, engagement and missions are all activities required to implement SSP and are in train including with the USA, UK, New Zealand, Japan and Canada.

- Local research partners from CSIRO, Deakin University, Swinburne University, and Australia National University (ANU) are supporting *Solar Space Technologies'* efforts with the commercialisation of research and development, including in advanced manufacturing, robotics and radiation testing with flow on benefits to many other industry sectors.

- The *Solar Space Technologies* project requires ongoing research for light weight strong durable structural materials, solar panels and collectors; development of software for intelligent robotic functions; radiation health impact studies at ground based receivers and radiation effects on degradation of space based materials, but to name a few. Workforce development and job creation will be extensive with business case studies indicating many thousands of jobs will be created through the implementation of SSP.

- For other related matters, the aim of the SSP project is to provide continuous (base-load) low cost energy to Australia and the world. This technology will result in tremendous economic benefits to the Australian economy with consumers and the manufacturing industry benefiting from low cost energy plus export opportunities including foreign aid for our Pacific neighbours.

Recommendations

As space solar power technology is new to Australia and encompasses a number of sectors including space, employment, energy, technology, manufacturing, water, agriculture/farming and economic development, I formally request that Serdar Baycan and John C Mankins, Directors of *Solar Space Technologies* and authors of this report, address the Committee for this enquiry.

Solar Space Technologies recommends the House of Representatives Standing Committee on Industry, Innovation, Science and Resources inquiry on developing Australia's space industry adopts the following recommendations;

1. **Space Solar Power development is included immediately as a space-related activity and therefore forms part of the space value chain for noting in Australian Space Agency policy and publications as part of the broader space economy.**

2. **The Australian Space Agency communicates Australia's interest in space solar power and seeks to collaborate with international space agencies and supply chain entities in the development of SSP in Australia.**

3. **Space Solar Power is identified as a new technology and priority project for inclusion in the next iteration of the Australian Government's *Australia's Technology Investment Roadmap* and *First Low Emissions Technology Statement 2020.***

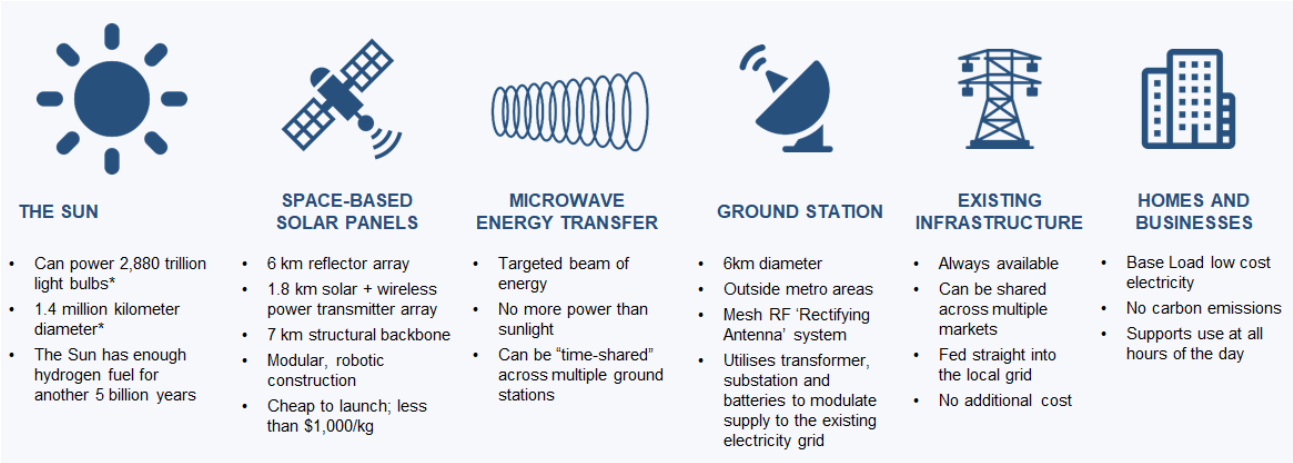
4. **The Australia government establishes a project of National importance with seed funding to review the feasibility of developing Space Solar Power technology in Australia.**

5. **The ASA communicates with other relevant Federal Government departments with related policy and service management responsibilities the potential benefits of Space Solar Power including for energy, trade, environment, innovation, water, agriculture, manufacturing industry, economic development, foreign affairs and defence.**

2. Space Solar Power – How Does It Work

Space solar power is produced through use of a solar satellite in geostationary orbit over Australia. The sun always shines in space therefore SSP produces renewable energy 99.8% of the time. The satellite collects the solar energy and transmits it as microwaves to a ground based rectenna where it is converted to electricity and transferred to the national electricity grid. Please refer to Figure 1 below.

Figure 1- Space solar power – how it works



SSP is an idea first conjured by science-fiction writer Isaac Asimov in 1941, and is now being studied by several nations because the lightweight solar panels and wireless power transmission technology required to implement SSP is advancing rapidly. This, together with lower cost commercial space launch, makes the concept of solar power satellites feasible and more economically viable than current energy systems utilised on earth.

Space Solar Power: SPS-ALPHA Overview

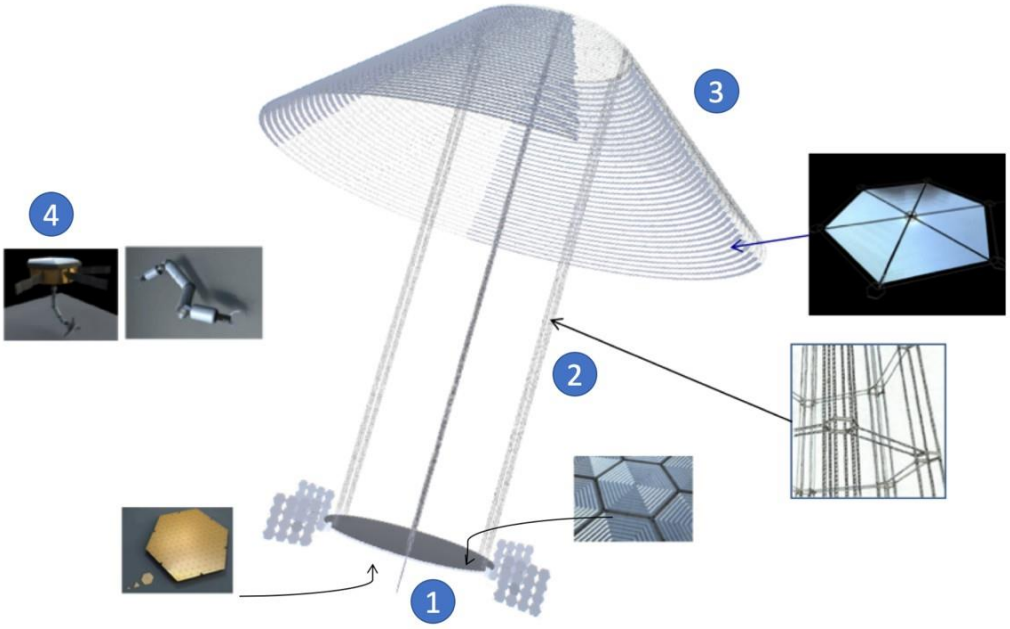
Solar Space Technologies is developing a specific system to deliver space solar power for Australia called: SPS- ALPHA, (Solar Power Satellite by means of Arbitrarily Large Phased Array) which was created in 2011 by John C Mankins and first studied with funding from NASA's Innovative Advanced Concepts (NIAC).

John C Mankins (Director SST) has subsequently developed the SPS ALPHA Mark III and associated ground based rectenna with Serdar Baycan, founding Director of *Solar Space Technologies* which is currently under design and development in Australia.

It is worth noting John C Mankins is accustomed to the development and implementation of very large technical projects during his 25 year tenure at NASA and CalTech's Jet Propulsion Laboratory. During his tenure there developed the parameters for Technical Readiness Levels (TRL's) which are used in all technical development ventures.

SPS-ALPHA Mark-III, depicted in Figure 2 is a highly-modular system that will be capable of being deployed in a variety of sizes and power delivery capacities – beginning at about 100 MW and scalable to deliver up to 2 GW to a single receiver.

Figure 2: The SPS-ALPHA (Mark-III) Platform Concept



As illustrated in Figure 2, the concept involves four primary segments in space:

(1) The energy conversion array, (1.8 kilometre diameter) which includes PV arrays, power electronics, supporting structures and wireless power transmission arrays.

(2) The connecting structural 'backbone' (7 kilometres long) connects the energy conversion array to the heliostat array.

(3) The heliostat array, which includes a large structural frame (6 kilometre diameter) on which a large number of thin-film heliostats are located – each capable of independent pointing (just as with a heliostat array on earth).

(4) And, a variety of other systems that 'scale' with the primary segments; these include the robotics that assemble and maintain the platform, propulsion systems to maintain the platform in its orbit, and others.

The fifth (5) and Earth-based element is the rectenna (rectifying antenna) which is 6 kilometres in diameter and comprises a mesh elevated structure that converts the collected microwaves into electricity for transfer to the national electricity grid.

3. Why Is Space Solar Power Feasible Now?

The science that underpins space solar power has been around since the 1960's. Feasibility studies undertaken since the 1980's have been stalled, in particular due to prohibitive launch costs. Recently, however, the technology is commercially viable and cost effective for consumers due to:

- the recent dramatic reduction in launch costs to space.
- rapid advances in advanced computing and robotics ;
- technology advances in light-weight materials of advanced manufacturing; and
- the architecture of *Solar Space Technologies* practical and modular design.

3.1 Overcoming Cost Barriers

Launch costs

Launch costs have been a primary barrier to SSP. Even using advanced technologies the satellite hardware required to gather gigawatts of power in space is heavy and, for now, must be launched from Earth. Transportation costs, however, from Earth to LEO (Low Earth Orbit) have dropped from $18,900/kg (NASA Shuttle) in 2011 to as low as $1,200/kg (SpaceX Falcon Heavy) in 2019.

Meanwhile payload capacity to LEO has increased, due to the increase in rocket size, from 25,000 kg (NASA Space Shuttle) to 63,800 kg (SpaceX Falcon Heavy).

Furthermore, a new generation of spacecraft, for example the SpaceX Starship and Super Heavy and Blue Origin's New Glenn launcher, promise to dramatically drop launch cost still further. It is foreshadowed to be $600/kilogram or less at the time *Solar Space Technologies* will be ready to launch in 2024 to 2028 as part of the *Solar Space Technologies* program, discussed in the next section.

Cost reduction due to modular design for SSP hardware

A second barrier is the cost of producing and deploying SSP space segment hardware. The production cost is addressed by recent concepts [Mankins 2017]. Specifically, by building SSP out of very large numbers of a few standard modular components, manufacturing economies of scale can be achieved for much of the system. The recent concepts for very large-scale LEO communications constellations, (e.g., Starlink, OneWeb, etc.) are accomplished on exactly the same economies of production.

Robotic workplace in Space

Additional savings can be achieved by designing the construction and operation of the space segment as a structured robotic workplace in space, similar to automated warehouses, where SSP components are designed to be automatically assembled by simple robots tele-operated as needed from Earth. Large numbers of simple robots capable of working together are well within the current state of the art on Earth.

4. Solar Space Technologies Project Plan

Solar Space Technologies proposal and project outcomes

Solar Space Technologies has detailed project plans in place to undertake the testing and development of the prototype, manufacture and provide terrestrial and low earth orbit demonstrations, pilot plants and finally in geostationary orbit, a large operational solar powered satellite. The deployment of a smaller plant in LEO is planned within 5 years, and for a large plant in GEO starting in 10 years.

The capability to deploy many gigawatts of modular, large- scale space solar power, before 2050, can readily be demonstrated by 2030 at the scale of tens (10s) of Megawatts.

The feasibility studies indicate the supply cost of energy by space solar power is one third (1/3rd) of the price of conventional base load power and one-tenth (1/10th) of the cost of available power at remote Australian locations. Refer to the table at Figure 3 below. The LCOE price at USD$ is projected to be 5 cents-7 cents per kilowatt hour (current currency exchange rate equates to AUD$ is 6.4 cents – 9 cents per kilowatt hour).

The project objective or 'mission' is to implement Phases 1 to 4 noted below and deploy an operational space solar power system with space-to-ground wireless power transmission technology by 2028. The project will build upon the novel modular space systems concept: "SPS-ALPHA" solar powered satellite by means of arbitrarily large phased array to deliver base-load solar power to Australia.

- Phase 1 Proof of concept phase Test location(s) – ground test at Avalon Airport, Corio, Geelong Australia
- Phase 2 Prototype in LEO – possible Australian or USA launch
- Phase 3 Pilot plant operational solar powered satellite in GEO or MEO for base load energy for Industry, Farming, Manufacturing, Cities and Regional Centres
- Phase 4 2GW large operational solar powered satellite in GEO for base load energy for Industry, Farming, Manufacturing, Cities and Regional Centres

Implementation Timeline and Capital Investment

The roadmap to achieve this objective comprises a handful of verifiable steps:

- Phase 0.5 (within 24 months): Initial ground testbed(s) at Avalon Airport, Corio, Geelong Australia $8M.
- Phase 1 (within 36 months): Ground Prototypes(s).
    - By the end of 2023, two or more initial 50 kW scale testbeds can be developed at an additional cost of $32M. (This is a total cost for Phase 1 of $40M, including the funding in Phase 0.5 above). These would comprise demonstrations of the key modules in the space segment and the end-to-end energy chain.
- Phase 2 (within 48 months): Low-Earth Orbit (LEO) Demonstration.
    - By 2024-2025, a US- led, international project can deploy a major demonstration in LEO at up to 1 MW scale for a cost of no more than $250M-$350M.

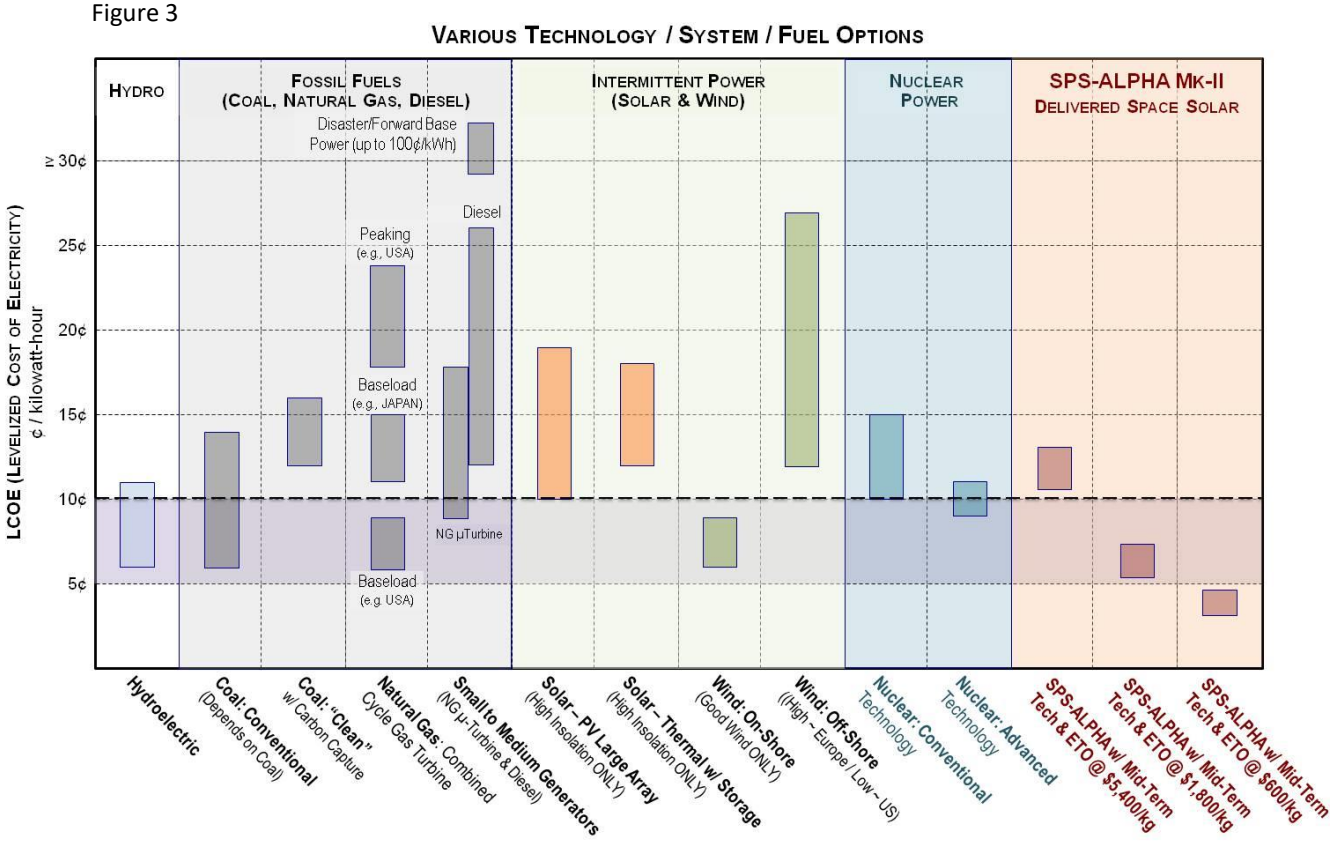
- Phase 3 (within 3-5 *additional* years): Mid-Earth Orbit (MEO) Pilot Plant.
    - Within 7-8 years, a fully- operational, but sub-scale pilot plant could be operational in a MEO orbit, delivering some 100 MW to receivers around the world at a cost of from $1B-$1.5B.

- Phase 4 (after Phase 3). Deployment of Geostationary Earth Orbit (GEO) Full-scale Systems.
    - In addition to the phase described above, deployment starting in 10 years, of 1-2 GW capacity at $6B-$12B per platform before 2050

SSP Cost Comparison with Other Energy Sources

The table below Figure 3 (reference: USA Government – Energy Information Agency Data 2018) compares the relative Levelized Cost of Electricity (LCOE) across a number of energy supply systems, including iterations of their recent development, including fossil fuels, intermittent solar and wind, nuclear power and delivered space solar power. This table illustrates the cost effectiveness of SSP.

Figure 3



5. Responding to the Terms of Reference

The following sections outline the role SSP has in response to each of the Terms of Reference.

5.1 Development of space satellites, technology and equipment

As outlined in Sections 2, 3 and 4 above, the *Solar Space Technologies* project is a large development in Australia to manufacture the hundreds of thousands of modular components made of specialised materials for the satellite and the rectenna. The energy conversion array, noted in Figure 2 is 1.8 kilometres in diameter and includes PV arrays, power electronics, supporting structures and wireless power transmission arrays. The connecting structural 'backbone' is 7 kilometres long and connects the energy conversion array to the heliostat array.

The heliostat array, which includes a large structural frame 6 kilometre in diameter has a large number of thin-film heliostats each capable of independent pointing and a variety of other systems that 'scale' with the primary segments; these include the robotics that assemble and maintain the platform, propulsion systems to maintain the platform in its orbit.

The description above highlights the number and specialisation of the components required for each satellite.

The Australian development of SSP would provide:

- a significant boost to the Australian Space industry capability for large satellite design and construction, robotics, launches, rocket designs, and consequential consumer goods;
- a significant introduction of specialised advanced manufacturing techniques and new industries;
- an enormous boost in capability to Australia's emerging space industry through research and development of advanced manufacturing materials; robotics; software; space design and
- a potential energy supply to support increasing human activity in space, including for the Moon and Mars.

5.2 International collaboration, engagement and missions

A number of countries are undertaking research and development programs for SSP. A brief outline of the current state of play is noted below.

5.2.1 Current International Space Solar Power state sponsored programs

United Kingdom

The UK Government has commissioned new research into space-based solar power (SBSP) systems that would use very large solar power satellites to collect solar energy, convert it into high-frequency radio waves, and safely beam it back to ground-based receivers connected to the electrical power grid. The research will explore whether this renewable technology could offer a resilient, safe and sustainable energy source.

A press release issued in 14 November 2020 by the UK Space Agency and the Department for Business, Energy and Industrial Strategy advised the study, led by Frazer-Nash Consultancy, will consider the engineering and economics of such a system – whether it could deliver affordable energy for consumers, and the engineering and technology that would be required to build it. One of the biggest issues to overcome is assembling the massive satellites in orbit, which has not been done before at this scale.

John C Mankins' SPS ALPHA is one of the two systems to be reviewed by the research team. The UK Science Minister Amanda Solloway said in her press release on 14 November 2020:

> *Solar space stations may sound like science fiction, but they could be a game-changing new source of energy for the UK and the rest of the world. This pioneering government-backed study will help shine a light on the possibilities for a space-based solar power system which, if successful, could play an important role in reducing our emissions and meeting the UK's ambitious climate change targets.*
>
> *As the National Space Council sets a new direction for our space policy, the UK Space Agency is committed to understanding the future opportunities space technologies open up.*

https://www.gov.uk/government/news/uk-government-commissions-space-solar-power-stations-research

United States

The United States Air Force Research Laboratory (AFRL) in New Mexico has a >$100 million contract with Northrop Grumman to develop hardware for SSP related experiments. The driving application for this military application-focused program is to deliver energy to forward operating bases in remote regions. These bases are currently supplied with energy primarily from fuel hauled by trucks which are vulnerable to attack. This results in very high energy costs at forward operating bases. This is the Space Solar Power Incremental Demonstrations and Research Project [AFRL 2019]. In addition, the Naval Research Lab (NRL) has $30M in 2020 for a project to develop power beaming. NRL conducted a small LEO flight experiment of a single SPS module during 2020.

Japan

Japan has conducted space solar power research for decades. In 2008 Japan passed its Basic Space Law and it includes SSP as a national objective. Since then Japan has had a small but important SSP R&D program. In 2015, two Japanese companies demonstrated kilowatt-scale microwave wireless power transmission as part of this ongoing effort.

China

China is also making significant investments in SSP. The China Academy for Space Technology (CAST) has an SSP program and in 2015 showcased their roadmap at the National Space Society's International Space Development Conference. The Chongqing Collaborative Innovation Research Institute for Civil-Military Integration in China is constructing a facility for SSP testing. SSP investments in China are estimated at $10M-W$30M per year, focusing on a major demonstration in space in the next 5-10 years. Combined with their dominance of ground solar panel production, China is well positioned to become the major power in all forms of solar energy, including space solar power.

China and Australia Share GEO Orbital Slots Over Australia

China is investing significantly in space solar power technology and may greatly influence the energy market in the future for the world and activities in space. The GEO orbit above Australia is shared by China and it is noted that whichever country gets to implement this technology first will have the ability to shape the rules and operations of space and provide that country with great strategic and technological reach for energy supply to Earth and space.

5.2.2 Space Solar Technologies Overseas Partnerships

Solar Space Technologies has a number of international partners in the USA which currently include Mankins Space Technologies, NASA (including the NASA Ames Research Centre), the US Naval Research Laboratory (NRL) (Dr. Paul Jaffe), and various companies, including Raytheon. *Solar Space Technologies* is discussing a Cooperative Research and Development Agreement (CRADA) to secure NRL support for R&D and testing of selected Wireless Power Transmission related equipment at the test bed site to be established at Avalon Airport, Geelong, Victoria.

Meetings are held regularly with organizations in Japan (including METI (the Ministry of Economy Trade and Industry), JAXA (the Japanese Aerospace Exploration Agency) and others to explore partnering with *Solar Space Technologies* in Australia and with the USA.

The following are the prospective additional collaborating / participating organizations and/or individuals.

- Raytheon, Inc
- Massachusetts Institute of Technology (MIT)
- Japan Space Systems (JSS)
- British Government Project where John Mankins' SPS ALPHA system is one of the two systems to be reviewed by the research team as discussed in 5.2.1 above.

Prospective new space solar power research projects are also under consideration by the European Space Agency.

5.3 Commercialisation of research and development, including flow on benefits to other industry sectors

The following are the collaborating / participating organisations.

- Solar Space Technologies Pty Ltd. Project Lead
- Commonwealth Scientific and Industrial Research Organisation (CSIRO) - Advanced Manufacturing and Robotics
- Deakin University
- Swinburne University
- Australia National University (ANU)
- Mankins Space Technology, Inc. (MSTI)

5.3.1 Solar Space Technologies' Research and Development Partners

The *Solar Space Technologies* proposal offers Australia in partnership with the USA to further develop and deploy this technology. It is expected that Canada, Britain, Japan and others in Europe will also be involved.

In Australia we have the skills and the capability to implement this game changing technology. We have partnered with CSIRO Advanced Manufacturing in Victoria and CSIRO Robotics QLD, Deakin University and Swinburne University Advanced Manufacturing and have developed detailed work plans. Recently, we have met with Australian National University's Department of Nuclear Physics to examine proposals for radiation effects on materials degradation in space.

During 2020 we have undertaken a health effects study with eminent radiation and health experts in New Zealand as to the effect of microwaves from the wireless power transmitter to the rectenna receiver. Refer to Section 6 for further details.

During 2020, a preliminary concept definition study for the LEO demonstration was conducted by Solar Space Technologies working with the International Space University (ISU); this study is available on request.

During 2020, a market application and concept definition study for the mid earth orbit - MEO 'pilot plan' was conducted by Solar Space Technologies working with the Royal Melbourne Institute of Technology (RMIT); this study is available on request.

Geelong, in Victoria is viewed as an appropriate centre to commence the testing and manufacturing for the development of the SPS Alpha Mark III. As the SPS system requires the manufacture of tens of thousands of components we believe many thousands of high technology manufacturing jobs will be created. Once work on these systems begin other resultant industries will also flourish from Geelong, Melbourne and along the East coast of Australia particularly in NSW, Queensland and South Australia as well as other states and territories.

5.3.2 Flow on benefits to other industry sectors

All these areas of inquiry have commercial applications in addition to the work on SSP. In summary the flow on benefits of investing in space solar power technology will provide;

- Base-load, despatchable, emissions free, low cost power to Australia
- Thousands of new jobs in urban and regional centres in Australia
- Energy export opportunities throughout the world
- Low cost base load energy to remote communities for
    - resources mining and smelting operations to value add product
    - agriculture
    - manufacturing
- Additional water resources for farmers, our rivers and our urban populations as space solar power requires no water to produce energy
- Energy industry – limitless, base load, emissions-free, low cost power delivered to the national electricity grid as well as to remote locations for mining and other economic activities. The power is base load and dispatchable, which can be used to provide stability to supplement the existing national electricity grid given the input of intermittent renewable energy feeds.
- Climate change – This technology will resolve issues for Governments which will provide regional and local jobs creation whilst transitioning to reduce emissions and better international targets for Australia
- Remote area delivery of low cost energy for Agriculture – food security, a more competitive industry with reduced power costs
- Minerals mining industry – remote location low cost energy source for ongoing operations and opportunities for potential new smelting operations to value add product.

5.4 Future research capacity, workforce development and job creation

5.4.1 Future Research Capacity

The SSP project requires ongoing research for light weight strong durable structural materials, solar panels and collectors; development of software for intelligent robotic functions.

Artificial Intelligence, that is, self-assembling components are required. *Solar Space Technologies* is currently working with CSIRO, Deakin University, and Swinburne University and Avalon Airport on the SPS Alpha project.

5.4.2 Health impacts study- Exposure from microwave beam in relation to health

Solar Space Technologies commissioned a report from leading NZ radiation and epidemiologists providing an initial overview of the health and safety aspects of the microwave transmission system, and the wider health issues of power generation.

New Zealand and Australia both have exposure standards based on careful review of the relevant health research, and include wide margins for safety. Standards in both countries follow international recommendations. Limits set for the public assume that exposures could be continuous.

Based on information about the proposed system provided by *Solar Space Technologies*, the report notes radiation exposures exceeding the limit recommended for the public will only be exceeded within the area of the rectenna. The exposure outside the rectenna would be 10% of the public limit and decrease to be less than 1% of the public limit at a distance of 10 km from the centre of the rectenna. Environmental factors may cause localised increases and decreases in actual levels, but exposures would still remain well below the public limits. On this basis, exposures to the microwave beam in public areas around the rectenna would not cause adverse health effects. Further studies will be undertaken to aid in the safety, design and placement of the rectenna.

5.4.3 Workforce Development and Job Creation

Tens of thousands of jobs are required to develop each solar power satellite which is proposed to be initially based in Geelong, Victoria and then expanded with manufacturing plants to be located in all Australian States and Territories and particularly in regional Australia.

To develop and implement a single SPS-ALPHA satellite, project implementation plans indicate an estimated 55,000 direct and indirect jobs will be created including in manufacturing, engineering, management and administration. The operation of each unit estimated over a 50 years life cycle would retain 11,500 ongoing direct and indirect jobs.

The advanced manufacturing requirements will enable support for education and a well-paid workforce in new technologies and mass produced components.

The technology will support regional development transition planning with employment in regional areas. Thousands of new jobs will be created and would support the transition of workers from employment sectors that are divesting.

5.5 Other related matters

SSP is a means to provide continuous low cost energy to Australia and the world. As evidenced by this submission there are a large number of industries and sectors that will be positively affected by the implementation of SSP and a selected number are outlined below.

5.5.1 Integration with Terrestrial Systems - Stability for Australia's National Electricity Grid

SSP is an ideal complement to the large and growing networks of ground-based solar and wind producers. These networks generally have a variety of intermittent sources that deliver power at different times and may include energy storage; e.g. batteries or pumping water uphill for when none of the power sources are producing. Sizing the storage is non-trivial as any stored system can run out of power given enough cloudy days without wind.

Adding dispatchable SSP can create a networked power system much easier to operate because SSP acts like a giant battery that never runs dry. Power delivery is predictable, continuous, and SSP satellites can transfer power to different networks (via ground receiving stations up to 1,000s of kilometres distant from one another) as grid requirements in various places change over the course of a day.

5.5.2 Energy Export opportunities

Australia can be an energy superpower providing limitless, base load, emissions-free, low cost space solar power to the growing world energy market, where the current USD $ 4 Trillion/annum energy market is expected to double to USD $ 8 Trillion/annum by 2050

SSP provides a solution to providing a secure source of energy without adverse consequences to human health, the environment, as well as being economically beneficial to our country and the world by ensuring a reliable continuous lower cost for electricity well into the indefinite future.

5.5.3 Foreign Aid benefits in particular to the Asia Pacific region

The introduction of low cost SSP to Australia could be used as a foreign aid initiative for the Pacific Islands and wider region.

5.5.4 The Case for Australian Government Investment in Space Solar Power

Solar Space Technologies is seeking initial funding from Government to break the 'barrier of the first mover' for this new technology and area of investment. This is especially important in either the 'new' space sector or the new energy technologies sector – and *Solar Space Technologies* is pursuing both. Following on from initial Government funding *Solar Space Technologies* has a strategy for financial sustainability based on a combination of government and private funding, development of intellectual property (IP) and project based funding as the five phase project evolves.

SST's singular focus for Australia is to have an operational SPS- ALPHA platform that supplies carbon-free baseload electricity to Australia, as well as exporting it to the world.

The recent success of commercialisation of the space program in the USA, demonstrates the benefit of government partnerships with commercial partners, such as SpaceX. The lessons learned from the program to deliver payload to the International Space Station, the Commercial Orbital Transportation Services (COTS), undertaken by successful bidder Space X, was reported by NASA to include the following:

- Government seed money was highly leveraged - commercial partners funded over 50% of the Commercial Orbital Transportation Services development costs
- Fixed price milestone payments maximized incentive to control cost and minimize schedule delays
- Government commitment to purchase operational services greatly improves the ability for companies to raise funds
- Directly contributed to the successful first attempt berthing of SpaceX Dragon to ISS

Large scale developments of national significance require considerable support from Federal Governments. This is the case for the space industry as evidenced by the USA case study discussed above, the proposed UK project and the growing number of national governments investing in space and related projects.

5.6 Conclusion

In conclusion, we have an opportunity to develop a national policy for the development and investment in a new space industry for Australia that will provide:

- a massive economic boost to the Australian space industry and other sectors;
- thousands of high-quality jobs in industry throughout Australia;
- industry custom through payload launch to the developing Australian rocket and space launch industry;
- an energy supply to support activities in space;
- important new ties to friends and allies internationally;
- low cost base load energy for Australia and the world with no carbon emissions; and
- stability to the national electricity grid, complementing earth-based intermittent energy.

6. Recommendations

Solar Space Technologies recommends the House of Representatives Standing Committee on Industry, Innovation, Science and Resources inquiry on developing Australia's space industry adopts the following recommendations;

1. **Space Solar Power development is included immediately as a space-related activity and therefore forms part of the space value chain for noting in Australian Space Agency policy and publications as part of the broader space economy.**

2. **The Australian Space Agency communicates Australia's interest in space solar power and seeks to collaborate with international space agencies and supply chain entities in the development of SSP in Australia.**

3. **Space Solar Power is identified as a new technology and priority project for inclusion in the next iteration of the Australian Government's *Australia's Technology Investment Roadmap* and *First Low Emissions Technology Statement 2020.***

4. **The Australia government establishes a project of National importance with seed funding to review the feasibility of developing Space Solar Power technology in Australia**

5. **The ASA communicates with other relevant Federal Government departments with related policy and service management responsibilities the potential benefits of Space Solar Power including for energy, trade, environment, innovation, water, agriculture, manufacturing industry, economic development, foreign affairs and defence.**

A.1 References

- A PDF copy and link to The Age article about Solar Space Technologies and Base Load Space Solar Power published 5 October 2019
  https://www.theage.com.au/world/north-america/australia-leans-into-space-race-for-solar-power-with-china-20190920-p52ta4.html

- A JPG copy and link to The Age article about Solar Space Technologies and Base Load Space Solar Power published Saturday 2 June 2019
  https://www.theage.com.au/national/victoria/energy-for-democracy-a-plan-for-out-of-this-world-solar-power-20190531-p51tao.html

- Link to John C Mankins keynote address made on 13 November 2019 at the Hudson Institute in Washington DC outlining the importance of space, space solar power and cooperation amongst democracies in the Indo-Pacific region, its strategic importance and likely future role. (John C Mankins commences speaking at about 8 minutes in.) The case for space solar power, co-operation between Australia, USA and Japan is now firmly on the table.
  https://www.hudson.org/events/1740-u-s-space-strategy-and-indo-pacific-cooperation112019

- November 2019 report to Congress of the USA-China Economic and Security Review Commission citing space solar power as a required strategic initiative for the United States.
  https://www.uscc.gov/sites/default/files/2019-11/2019%20Annual%20Report%20to%20Congress.pdf

- The UK Government has commissioned new research into space-based solar power systems. Press release from UK Minister of Science.
  https://www.gov.uk/government/news/uk-government-commissions-space-solar-power-stations-research

A.2 Selected Bibliography

The following is a selected bibliography of some of the relevant literature in the field of space solar power.

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- Internet Reference: https://www.powerengineeringint.com/renewables/solar/uk-commissions- research-into-space-solar-power-stations/
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- Mankins, John C. “Powering Space” (International Symposium on Space Technology and Science; Japan). 2019.
- Mankins, John C.; “New Concepts and Markets for Space Solar Power” (International Astronautical Congress 2020 /IAC20- C3.1.1.01). 2020.
- Mankins, John C. “The Case for Space Solar Power” (Virginia Edition Publishing, LLC, 2014) 2014.