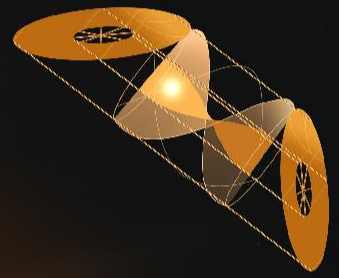
SPACE SOLAR

Powering a sustainable future



Presentation for Asian Development Bank

Net Zero is currently an illusion

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- Huge supply and demand mismatch
- High cost of whole energy system
- Mining & mineral resources & scale
- Environmental and societal challenge

Major difficulties relying on low density and weather dependent renewables

+ Net Zero by 2050 is an illusion without more capable clean energy technologies
+ Energy demand set to double by 2050 but growth in renewables > 10 times too slow

… we need innovation in new clean energy technologies…

4%

Amount of global energy generated today by wind and solar

42 x

Required increase in lithium production by 2040 to meet Net Zero demands

£173 Bn

Cost of storage capacity in H2 , CAES, Li-ion storage to deliver Net Zero for UK *

* Energies 2021 - Nottingham University, Dec 2021

Space-based solar power – a global energy revolution

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+ 24/7 baseload and dispatchable

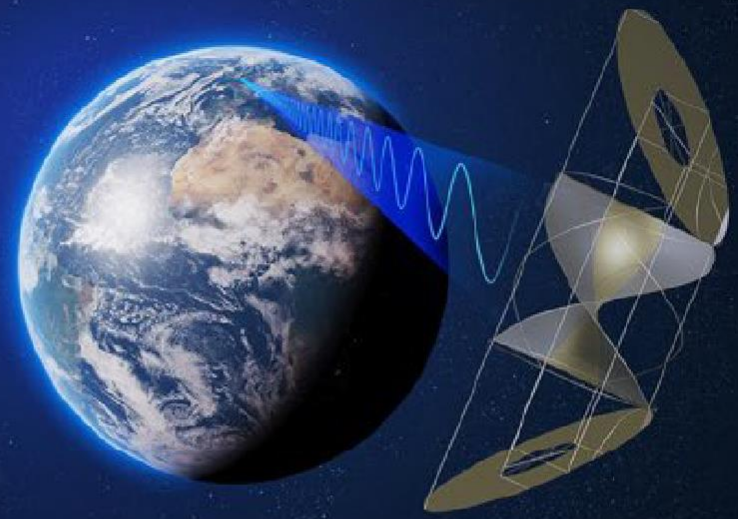
+ Lowest cost of energy ($29 / MWh)

+ Scalable for global impact by 2035

+ Sustainable, low carbon footprint

+ Flexible, exportable, high value

+ Physics understood, 5-year development



Compelling Space Solar power plant unit economics:

LCoE: As good as $29 / MWh – competitive with intermittent renewables

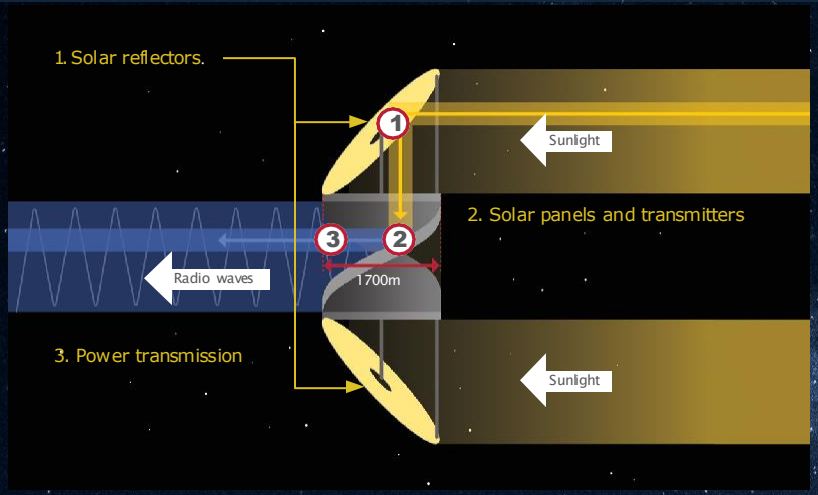
CAPEX: As good as $2.25 Bn / GW in 2024 real terms – ¼ cost of nuclear

In a narrow ring around geostationary orbit there is 100 times more solar energy than the needs of humanity in 2050.

Capable, competitive and commercially viable

Today's technology delivering tomorrow's clean energy

+ Large solar panels, beaming energy to earth wirelessly
+ Ground receiver – low impact structure with ability to dual use land underneath

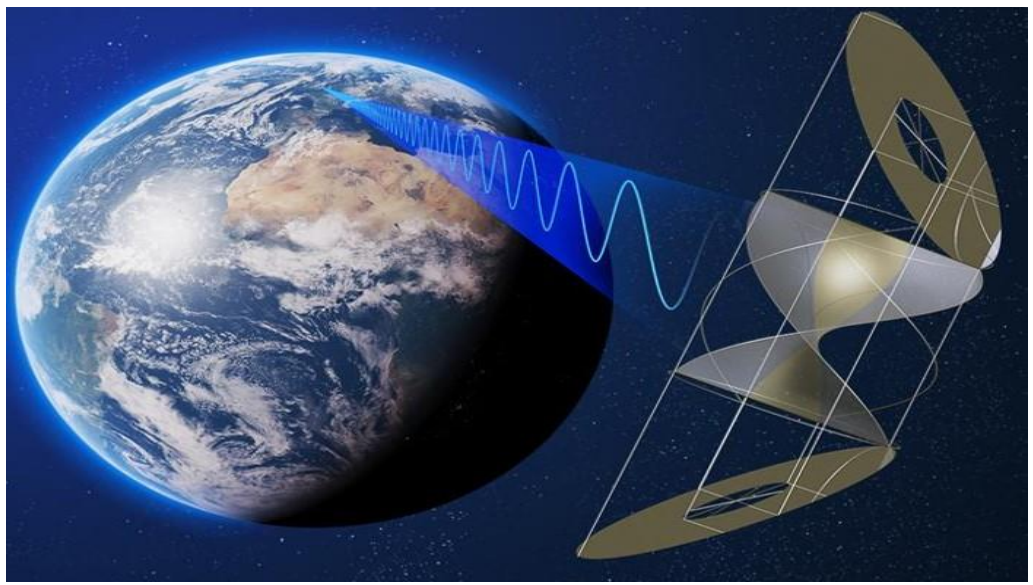


Breakthrough economic drivers

+ Space launch with reusable rockets 10% of previous cost and downward trend continuing
+ Solar panel in space generates 8 - 13 x energy vs solar panel on earth
+ Modular design - mass produced with low unit production costs and robotically assembled in space

+ **24/7** – all weather system transparent to atmosphere
+ **Exportable** – beam steering acts as transmission system as well as generation
+ **Safe** – low power density (1/4 intensity of midday sun)
+ **Scalable** – hyper modular, comprised of hundreds of thousands of similar modules
+ **Sustainable** – Land / Area Usage 40% of terrestrial solar and 8% of offshore wind for equivalent energy output. Carbon Footprint 26 gCO_2/kWh – half terrestrial solar
+ **Secure** and **Resilient** – encrypted uplink, modularity gives tolerance to failures

CASSIOPEIA key differentiating features



Lowest mass and highest power/unit mass
Lower mass amongst all existing SBSP concepts, reducing launch cost and Levelised Cost of Electricity

Modular structure
The modularity of systems makes them more resilient and easier to launch with various vehicles, given their Lego-like structure

No moving parts
Using 360-degree phased array beaming to achieve better resilience and reliability than other concepts

Intermediate products possible
Can use orbits closer to earth enabling smaller, lower cost products, hence more investable roadmap

Rectenna – a low impact structure (onshore or offshore)

Safe

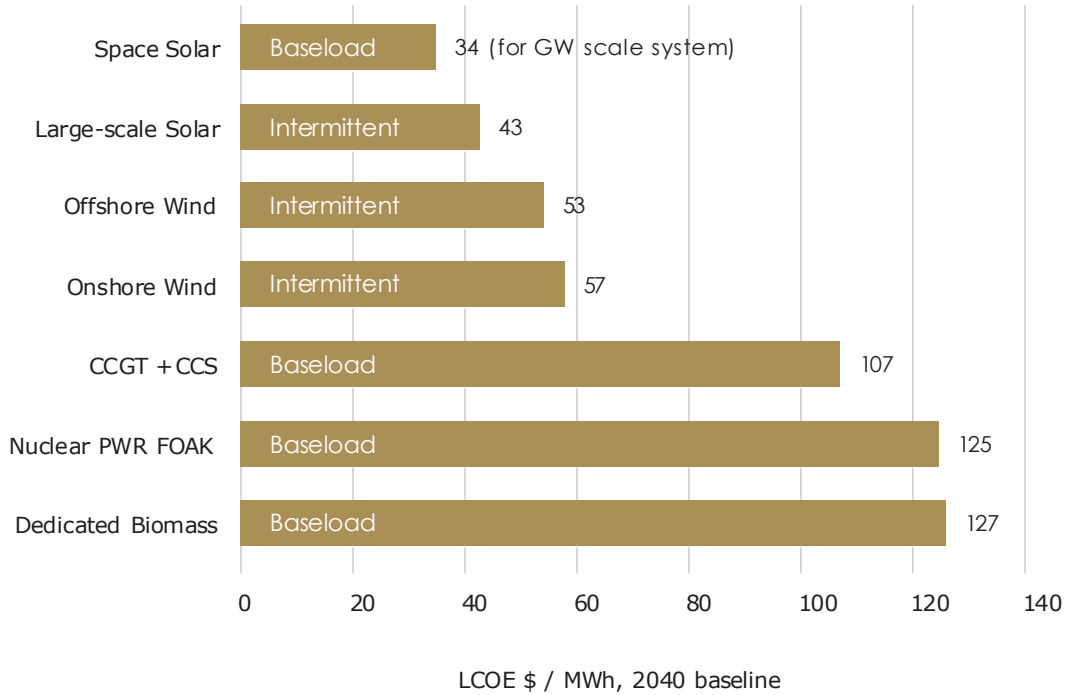
+ Retrodirective pilot beam ensures safety
+ Low power density beam with peak intensity ¼ of midday sun
+ Below long-term microwave background exposure limits at edges of rectenna

Environmental Benefits

+ Low impact 'net on poles'
+ 1km – 6km diameter*
+ 8% of area vs offshore wind farm
+ 40% of area vs solar farm
+ Onshore rectenna - dual use of land
+ Reversible

*Depending on power, frequency, latitude and other factors. Circular at equator and grows into an ellipse at higher latitudes. Can be made smaller but cost of energy is higher due to losses.

Space Solar – game changing economics



High Value of Energy

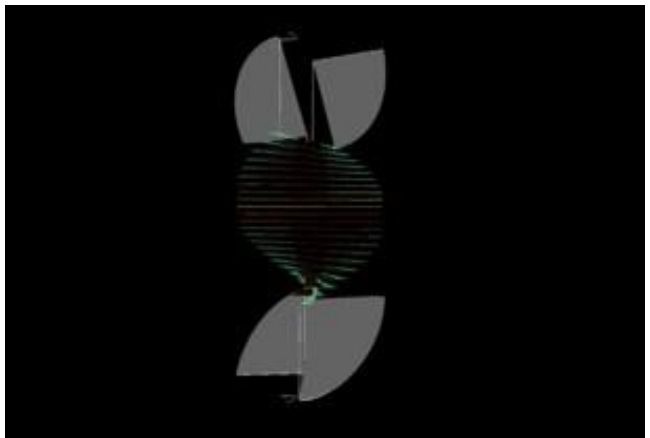
baseload, dispatchable energy essential to make the grid work with intermittent sources

Low Cost of Electricity

<< other clean baseload technologies and comparable with intermittent technologies

Source: DESNZ (UK Dept for Energy) Electricity Generation Costs 2020, showing projected costs in 2040 timescale

Product Overview – Powering Asia and the Pacific from 2030

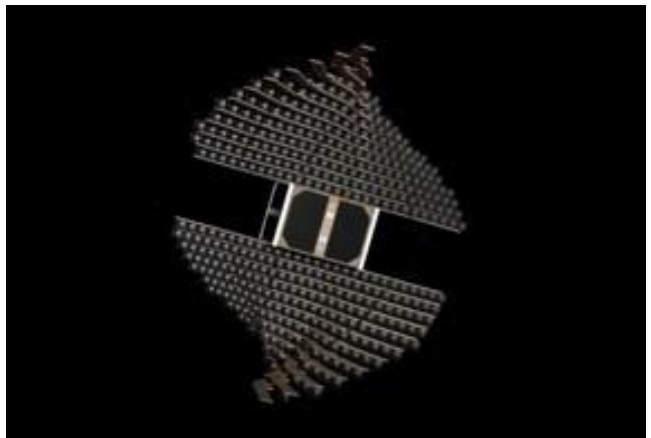


MERLIN: Highly Elliptical Orbit MW scale power

Key Characteristics:

+ Power: 30 MW
+ Size: 64 tonnes

Operational - 2030

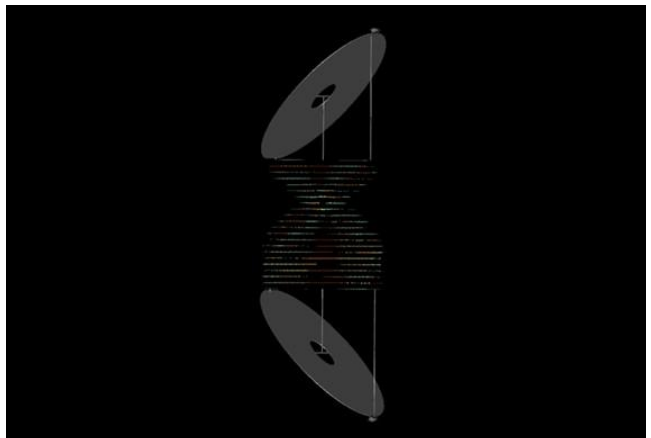


KITE: Highly Elliptical Orbit Sub-GW power

Key Characteristics:

+ Power: 180 MW
+ Size: 275 tonnes

Operational - 2033



EAGLE: GW Scale GEO continuous baseload power

Key Characteristics:

+ Power: GW scale
+ Size: 1800 tonnes

Operational - 2036

Validated technology

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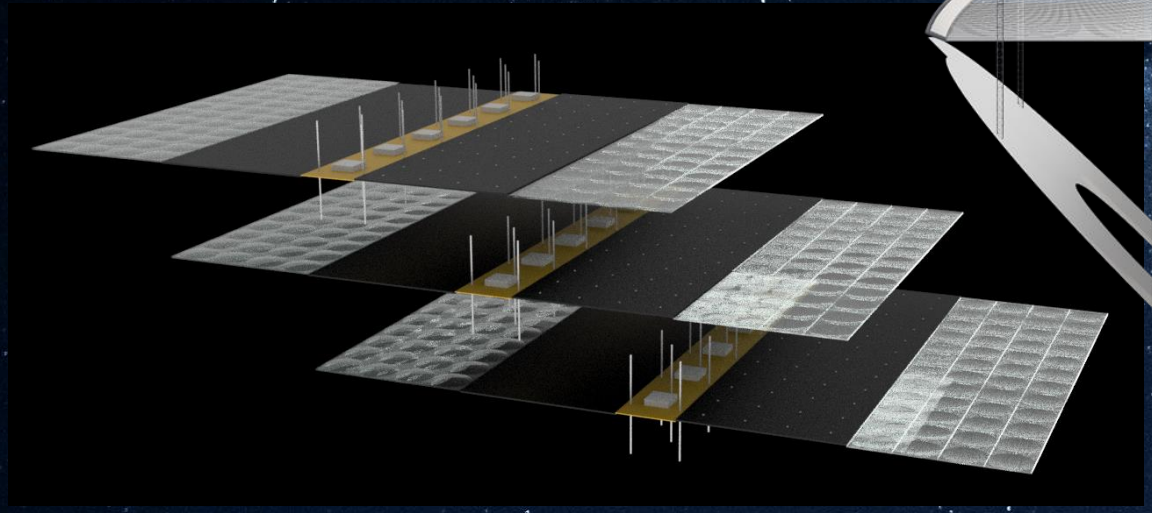
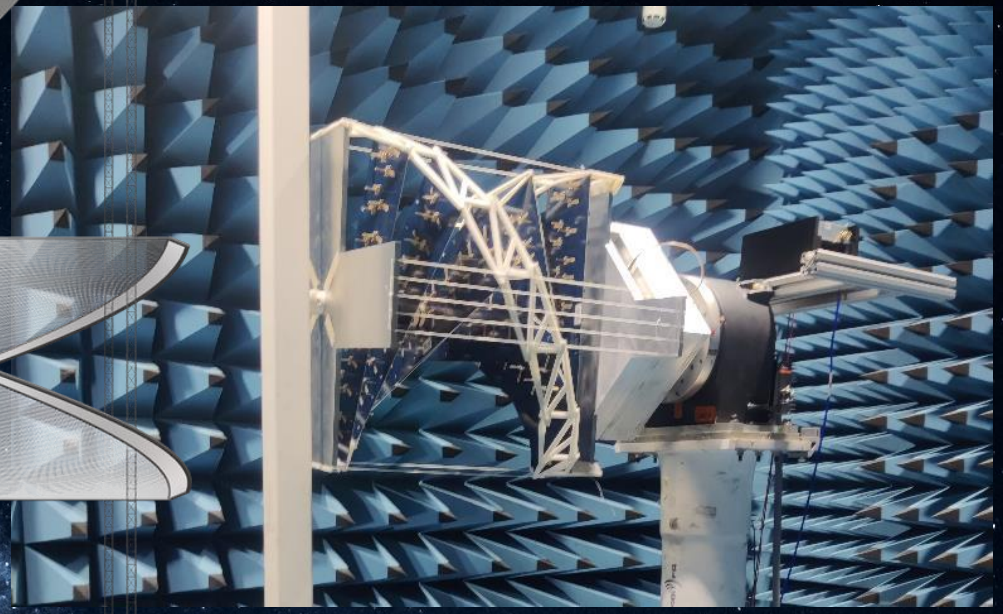
Engineering design validating performance and cost estimates





HARRIER wireless power beaming demonstrator

Powering Small Island States

Space Solar can deliver up to 33 MW to small islands from 2030 and we can scale systems as requirements grow. A constellation of Space Solar's CASSIOPeiA solar power satellites can provide reliable, affordable energy worldwide, at all latitudes.

- Each system can provide of near continuous power to a single site.
- Consistent power, including at night, is a key differentiator versus many renewable technologies such as wind and solar.
- A major advantage for land constrained nations is the dual use of land versus terrestrial solar (being able to grow crops underneath) or siting offshore. Compared with off-shore wind, there is 8% of the footprint and easier installation and maintenance.
- Less need for skilled workers and operators as nuclear or geothermal.

HMG and ESA study findings and recommendations

SPACE SOLAR

Study findings conclude that SBSP…

- ✔ is technically viable
- ✔ offers new options to deliver Net Zero
- ✔ development is well aligned to Government priorities
- ✔ leading concepts offer a competitive LCOE
- ✔ gives broader economic benefits for the UK

Recommendations made to…
Embed SBSP in Government policies
Embark on structured development programme
Seek international collaboration

GREAT BRITAIN & NORTHERN IRELAND

Space Energy Initiative – championing Space Based Solar Power

90 organisations bringing together the energy and space sectors

SPACE SOLAR

accenture
AIRBUS
ALDEN
ALPINE
Amphenol MILITARY & AEROSPACE
ARCHANGEL LIGHTWORKS
AXIOM SPACE
Department for Energy Security & Net Zero
Capgemini
CST
cfms
CGI
deimos
Deloitte.
D-ORBIT NEW SPACE SOLUTIONS
exotopic
FootAnstey Powering your ambition
fieldfisher
HEMPSELL ASTRONAUTICS
ECL
inmarsat
IQ CAPITAL
ispace
KBR
UK SPACE AGENCY
FRAZER-NASH CONSULTANCY A KBR COMPANY
gmv
METASAT UK
MAGDRIVE
MANSAC
MDA
Jacobs
Department for Business & Trade
LOCKHEED MARTIN
UKLSL
Lumi
nano avionics
nationalgrid partners
NMIS National Manufacturing Institute Scotland
OXFORD SPACE SYSTEMS
Linklaters
Reaction Engines
SPACE SOLAR
SURREY SPACE CENTRE
SPACE POWER
SOLAR SYSTEM RESOURCES CORPORATION
NORSS
SIRIN Orbital Systems AG
UK Atomic Energy Authority
ThalesAlenia Space
SURREY
The Technology Partnership
TWI
TELEDYNE e2v Everywhereyoulook
VIRTUS SOLIS
UKRI Innovate UK
Queen Mary University of London
QUEEN'S UNIVERSITY BELFAST
University of Strathclyde Glasgow
CATAPULT Compound Semiconductor Applications
CATAPULT Satellite Applications
CATAPULT Offshore Renewable Energy
CATAPULT Energy Systems
mtc
UNIVERSITY OF CAMBRIDGE
CITY UNIVERSITY OF LONDON EST 1894
Durham University
Imperial College London
UNIVERSITY OF Southampton
University of Suffolk
UNIVERSITY OF SURREY
Swansea University Prifysgol Abertawe

United Nations support

"We need to ensure that no-one and no place is left behind in our urbanising world. The Space Energy Initiative allows us to consume and generate energy equitably, distribute it with equity and ensure the opportunities that arise from its use contribute to human dignity"

Ms Maimunah Mohd Sharif
United Nations Under-Secretary General and Executive Director UN Habitat
March 2022

UN HABITAT
FOR A BETTER URBAN FUTURE

A better quality of life for all in an urbanizing world

PRESS RELEASE

UN-Habitat supports the Space Energy Initiative to help develop sustainable cities

London 10 March 2022 – UN-Habitat Executive Director Maimunah Mohd Sharif today expressed her support for technological initiatives that use space-based solar power to produce clean, renewable, and affordable power that cities can use to build green and more sustainable communities.

Launched in London, the Space Energy Initiative comes at a time when much of the world relies on fossil-based fuels that are both expensive and heavily polluting.

"Advances in science and technology have made it possible for us to make this giant leap forward towards harnessing and transmitting the power of the sun to provide our planet with clean energy. More importantly, we can do this adequately, affordably, and equitably," the UN-Habitat Executive Director told the London event.

British Member of Parliament Mark Garnier, who announced the launch of the Space Energy Initiative, said, "We all recognise the urgent need to think big and act now to reduce our reliance on carbon fuels to better protect the environment and our precious climate, while also increasing high-tech jobs and growth. I am delighted as Chair of the Advisory Board to witness for myself the commitment from every member of the Space Energy Initiative."

More than half the world's population currently lives in cities, and this is expected to rise to 70 per cent by 2030. Cities need to learn to keep up with the necessary growth whilst reducing the high-energy-consuming construction materials they use as well as the energy people use for daily consumption.

Reminding the audience that the energy consumed is not evenly distributed, the Executive Director pointed out that it is the most vulnerable who live in cramped informal settlements shrouded in darkness and suffer the most.

"We need to ensure that no one and no place is left behind in our urbanizing world. The Space Energy Initiative allows us to consume and generate energy equitably, distribute it with equity and ensure the opportunities that arise from its use contribute to human dignity," she said.

Solar-based energy has very low environmental footprint and needs only modest infrastructure on Earth, either on land or coastal areas, while generating large scale electricity at very low cost.

Current international programmes

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US NRL
Demonstration of power beaming 1.6 kW over 1 km at 10 GHz – Apr 2022
In-space test on X37B (2020 – 2022)

SBSP in Japan space policy
WPT research – in space 2025
Deployable antenna in-space demo

Solaris
3 year system study
Technology research

US AFRL / Northrop Grumman SSPIDR
sandwich tiles, thermal management;
deployable structures;
beam forming;
In-space demo 2025

MMR-SPS Concept
WPT Demo in-space 2026
GEO High power demo 2030

BEIS & UKSA SBSP Innovation
System studies, WPT demo, PV research







Space Solar – Leading development of space-based solar power and with strong government backing and partners

Technology & Programme

- Terrestrial wireless power transmission demo
- Validated design, $6M engineering work completed
- Exclusive IP in the best-in-class CASSIOPeiA design

Funding & Finance

- Agreement with Reykjavik Energy for pilot project
- Financing & product structure to minimize capital

Partners & Suppliers

- UK government support for international partnerships
- Major partners across Space, Wireless Power, Digital
- International regulatory forums established

Reykjavík Energy

Space Solar office

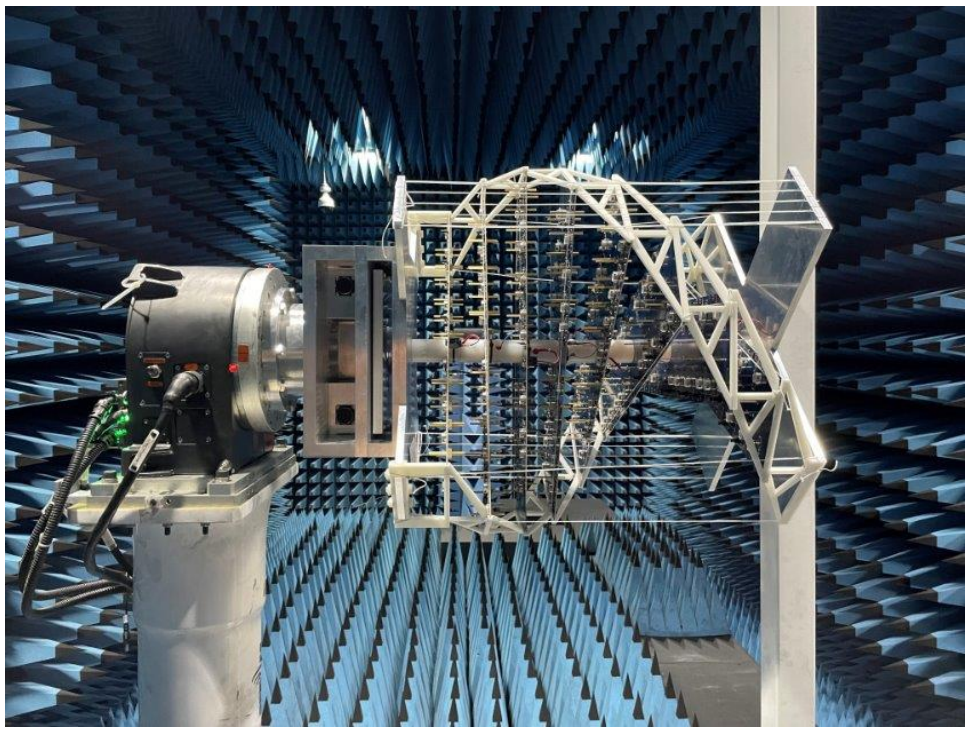
360 degree wireless power demonstration

Space Solar team

ThalesAlenia Space · Jacobs · D-ORBIT · Frazer-Nash Consultancy · CATAPULT Satellite Applications · MDA · accenture · nationalgrid · Queen's University Belfast

HARRIER: 360° retrodirective power beaming

From concept to demonstration in 6 months



World first UK prototype could pave the way for constant energy all the time - from space

Building the solar power farm in space would take more than 60 rocket flights and a team of robot builders - but it's one step closer to being a reality.

Thomas Moore
Science correspondent @SkyNewsThomas

Friday 5 April 2024 10:00, UK

www.spacesolar.co.uk

Powering a sustainable future

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Concept of operation (GW scale system)

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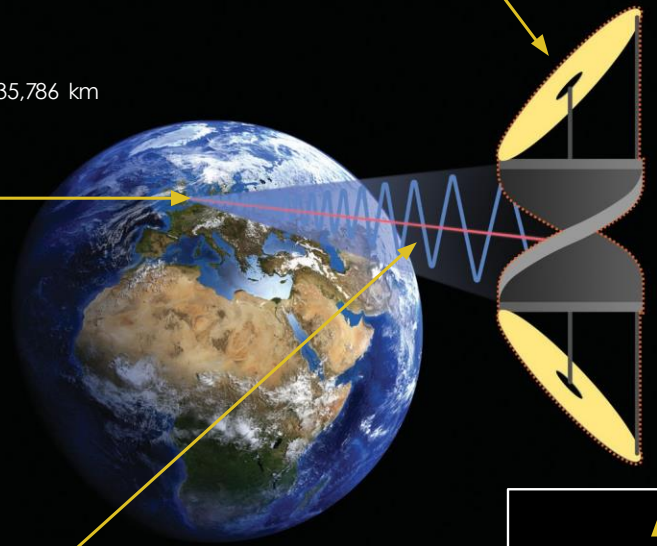
Solar Power Satellite

+ Collecting solar power and transmitting down on Earth
  - CASSIOPeiA Solar Power Satellite
  - 2,000 tonnes
  - 1,700 m diameter
  - Geosynchronous Orbit - 35,786 km

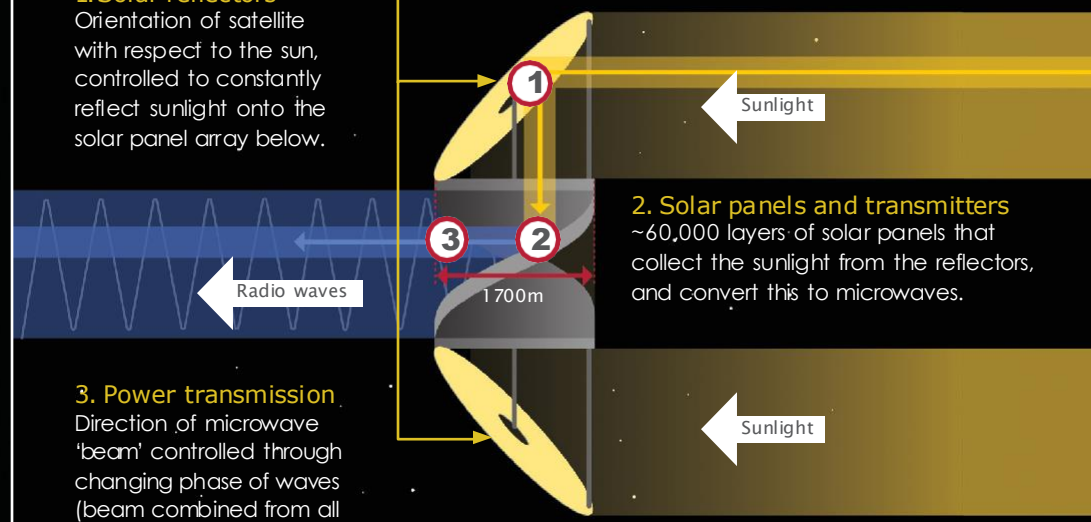
Ground Station (Rectenna)

+ 6 km (diameter) rectenna
+ Receiving 230W/m² microwave power
+ Generating 1.4 GW continuous power into grid



Wireless Power Transmission

+ Microwave beam transmission from satellite to receiver on ground (ground station)
  - Specific frequency (e.g. 2.45 GHz)
  - Locked onto pilot beam from ground station



1. Solar reflectors

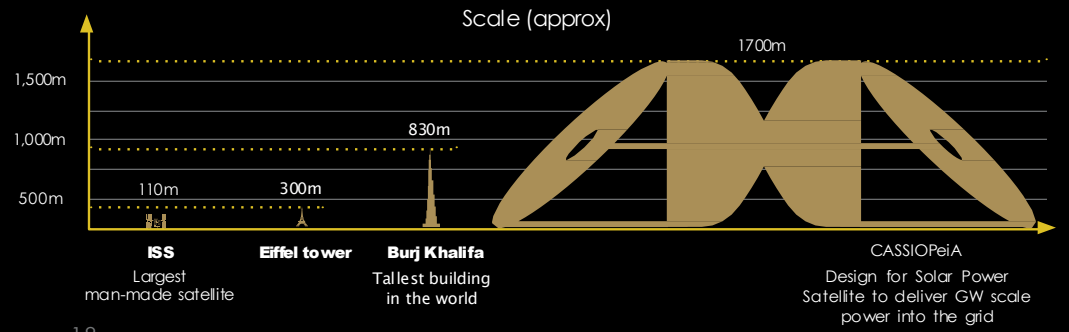
Orientation of satellite with respect to the sun, controlled to constantly reflect sunlight onto the solar panel array below.

2. Solar panels and transmitters

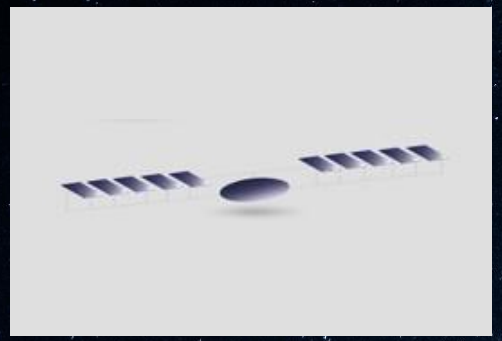
~60,000 layers of solar panels that collect the sunlight from the reflectors, and convert this to microwaves.

3. Power transmission

Direction of microwave 'beam' controlled through changing phase of waves (beam combined from all layers).



Space Solar leads the industry

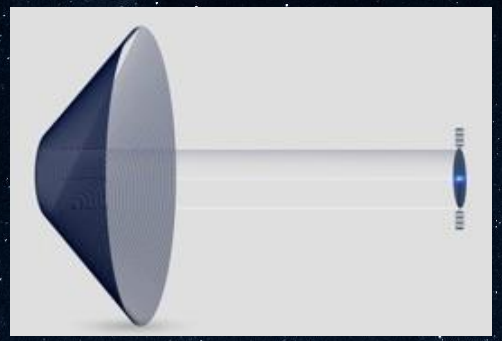


MR-SPS, China

10,000 tonnes, 12 km x 0.6 km

1 GW rated power

0.1 MW / tonne



SPS Alpha, USA

7,500 tonnes, 13 km x 6 km

2 GW rated power

0.3 MW / tonne

CASSIOPeiA, Space Solar

1,800 tonnes, 4 km x 2 km

1.44 GW rated power

0.8 MW / tonne

Space Solar's CASSIOPeiA is smallest and lightest, with class leading power per unit mass (MW per tonne), the Key Performance Indicator (KPI).

CASSIOPeiA features and differentiators

+ 360° power beaming, solid state, 100% utilisation
+ Hyper-modular design, no moving parts
+ Can use highly elliptical as well as GSO orbits
+ Use of High Concentration PhotoVoltaics
+ Ability to scale down products

CASSIOPeiA benefits

+ Lowest Levelised Cost of Electricity
+ Excellent resilience and reliability
+ Good operational utility for different markets
+ Huge reduction in use of rare earths vs terrestrial solar
+ More investable roadmap

Designs shown to scale