A Significant Update to the Hyper-Modular Approach to Space Solar Power
SPS-ALPHA Mark-IV

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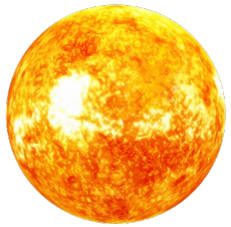
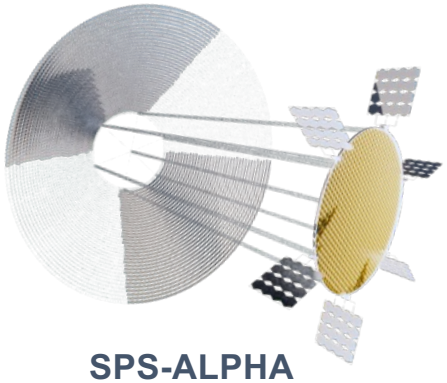
Space Solar Power : How it would work



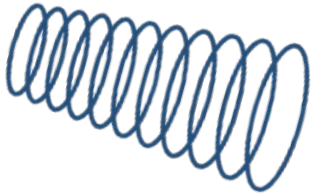
THE SUN

- Can power 2,880 trillion light bulbs
- 1.4 million kilometer diameter
- The Sun has enough hydrogen fuel for billions of years



SPS-ALPHA SPACE-BASED HARVESTING

- ~6 km reflector array
- ~1.8 km solar PV panels + wireless power transmitter array
- ~7 km backbone structure
- Modular, robotic construction
- Cheap to launch; less than $1,000/kg
- 99.95% Available Power



MICROWAVE ENERGY TRANSFER

- Precisely controlled transmission of energy
- Less than 20% of summer sunlight
- Can be “shared” across receivers and coordinated with ground-based solar

GROUND STATION

- ~6km diameter (elevated 5-10 m)
- Outside metro areas
- Mesh RF ‘Rectifying Antenna’ system
- Uses batteries to modulate supply to the existing electricity grid

EXISTING INFRASTRUCTURE

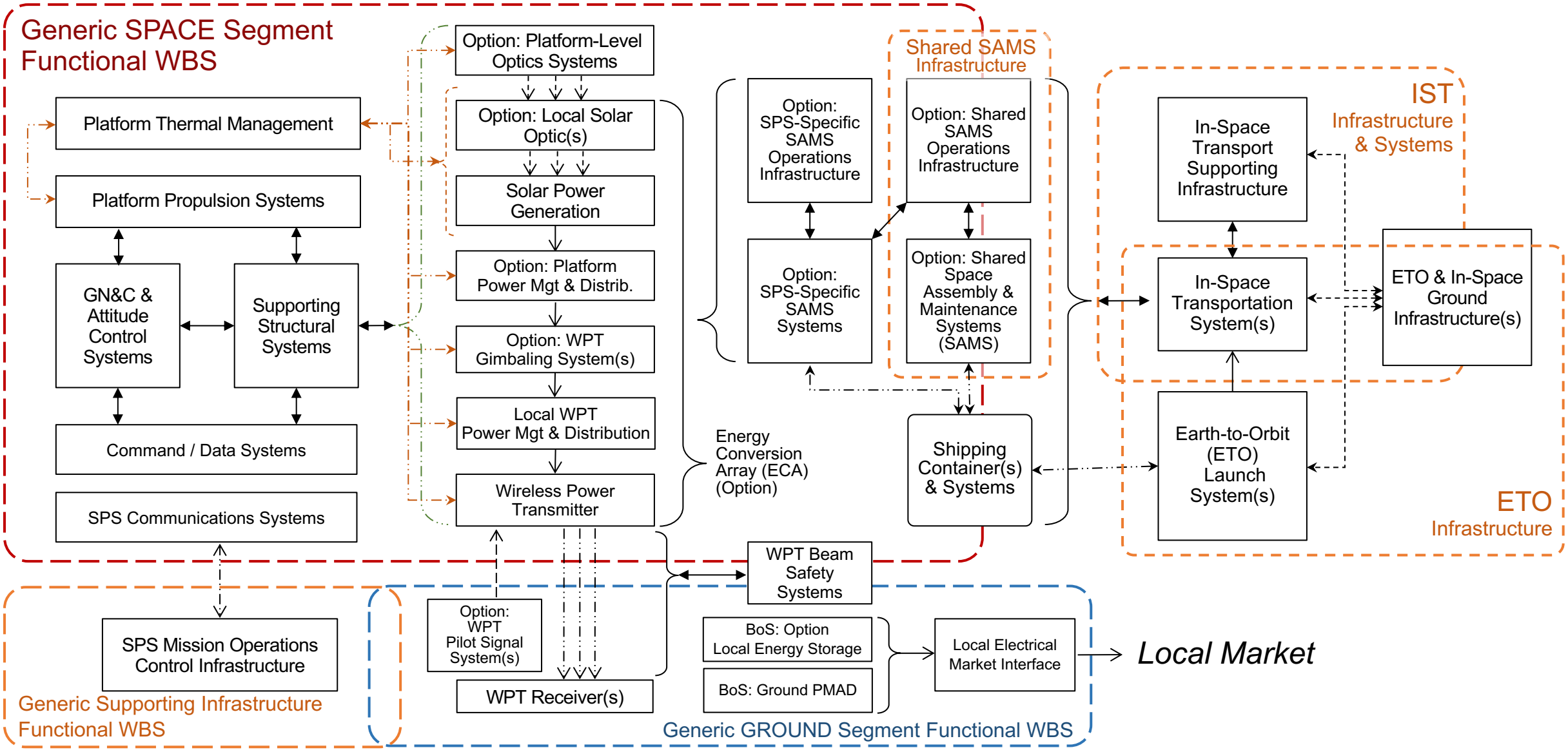
- DC or AC fed into the local grid
- Resembles Hydroelectric Power – but…
- “Always” available
- “Shareable” across markets

HOMES AND BUSINESSES

- Base Load low cost electricity
- No carbon emissions
- Supports use at all hours of the day

2024 SSP Modeling

Generic Functional Work Breakdown Structure (WBS) for SSP (Including the Space Segment)



Major Options for SPS
(Design, Technology, CONOPs...)

- Critical Characteristics for Solar Power Satellite Platforms
  - Frequency / type of power delivery from space to ground : WPT or ?
  - Voltage/Scale of the power management and distribution (PMAD) system
  - Use of rotary systems: with / without PMAD? At What Scale?
  - Active thermal or not?
  - Type of structural system: 'stick built'? large modular? thin-film?
  - Robotic assembly or kinematically deployed structural systems?
  - Type of solar power generation (SPG): PV, dynamic, solar-pumped, mirrors?
  - SPG input: solar redirection using Reflectors or not? Large single mirror or smaller heliostats?
  - One platform or more? Physically connected or not?

Evaluation of Concepts & "Programmatics"
Key Issues for Scaling from Experiments to Demonstrations to Systems

KEY SPS DESIGN ELEMENTS

- Optical Systems
- Power Generation Systems
- Power Management & Wiring
- Thermal Management
- Structures & Mechanisms
- Wireless Power Transmission Components
- Robotics
- Intelligent Systems & Security (S/W & H/W)
- Attitude Control & Propulsion
- ETO and In-Space Transport

SCALABILITY FACTORS

- Modularity
  - Size of "Modules"
  - Choices between "Bigger Modules" vs "More Modules"
  - "Connecting Tissue Issues"
- Manufacturability of Modules
- Control & Communications
- Construction, Evolution, Adaptability & Reconfigurability

METRICS

- Cost (R&D, FOAK, NOAK)
- TRRA Assessment (TRL, TNV, $R\&D^3$)
- MRL Assessment
- SW-TRL Assessment

How Might Space Solar Power be Accomplished?

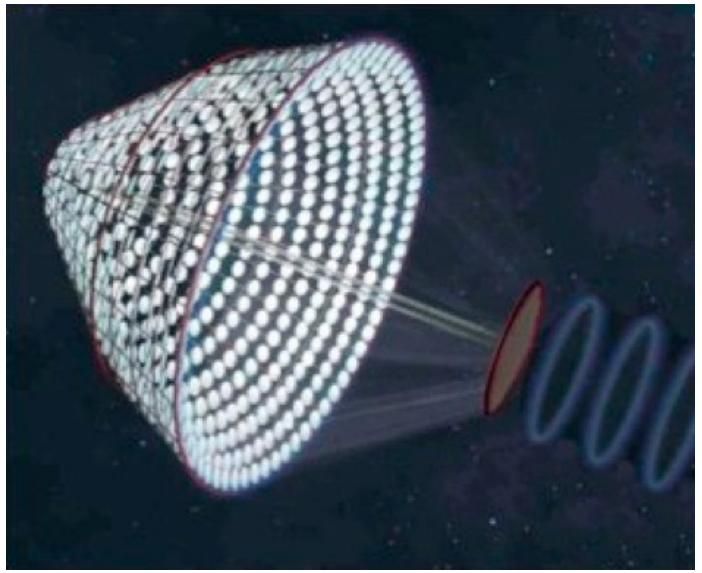
The Hyper-Modular Architectural Approach

Complex, "hyper-modular" architectures found in Nature…

Single genetic "individuals" comprising thousands to tens of thousands of "modules"

- Example: Ants – capable of forming structural systems from themselves
- Example: Bees – capable of navigation, cooperation and construction

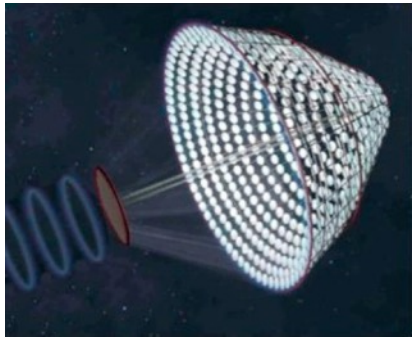
Diverse genetic "individuals" in a single community comprising 100s of species and many 1000's of individuals



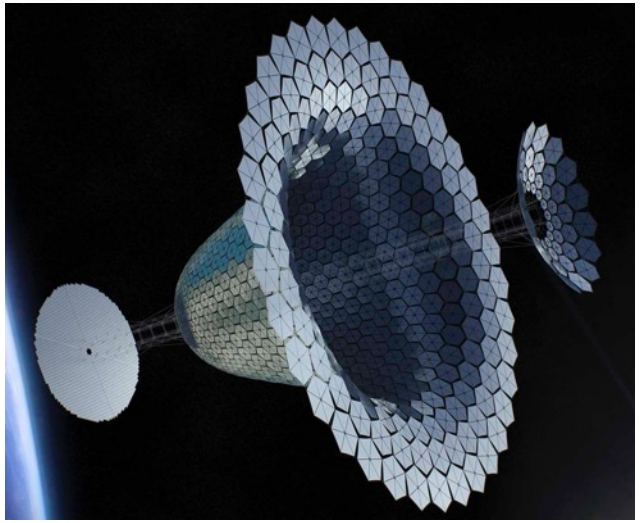
Introduced as a Space Solar Power Concept in 2012 during the NIAC SPS-ALPHA Study, Hyper-modular SPS with Robotic Assembly emerged as <u>the</u> most promising approach to SSP…

Evolution of SPS-ALPHA

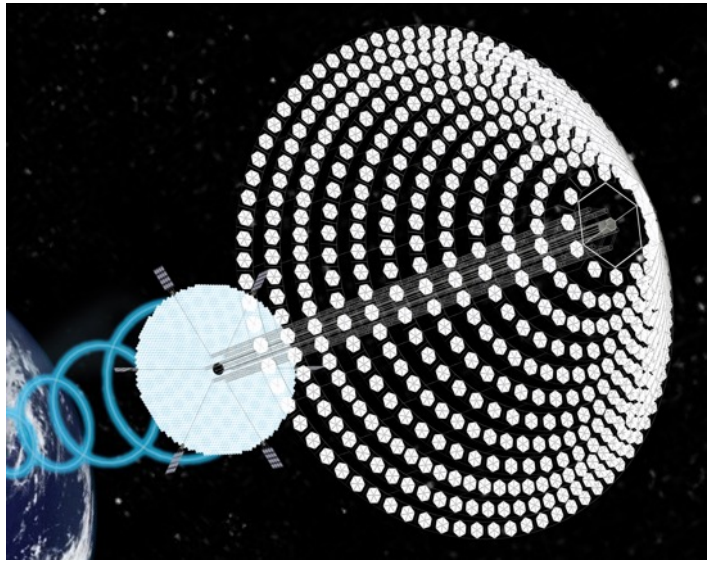
SPS-ALPHA Mk-0 (2011)



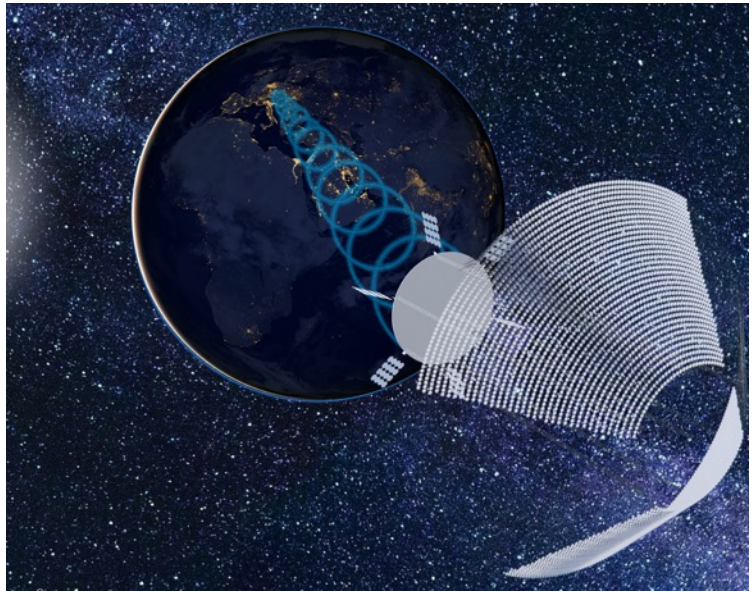
SPS-ALPHA Mk-I (2012)



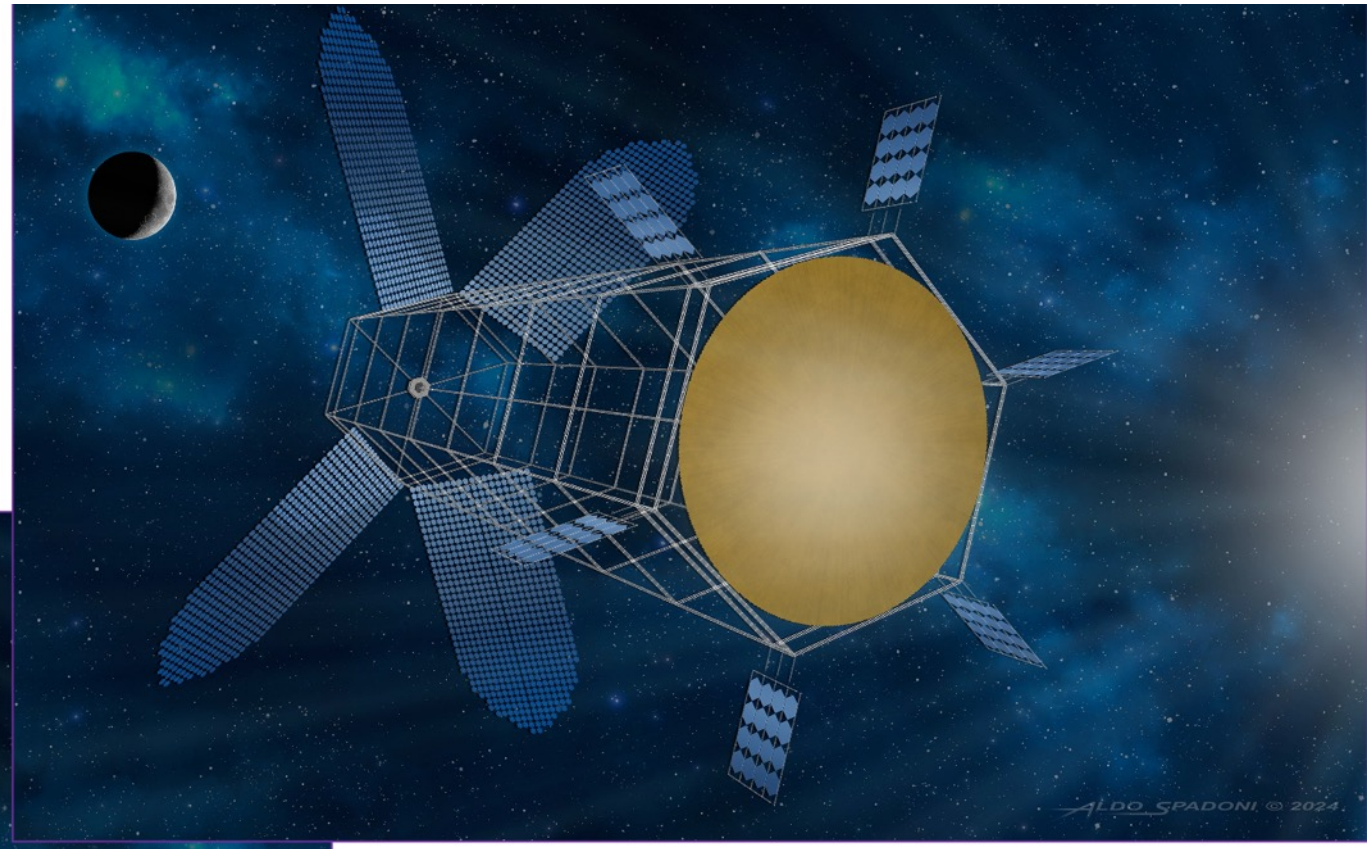
SPS-ALPHA Mk-II (2017)

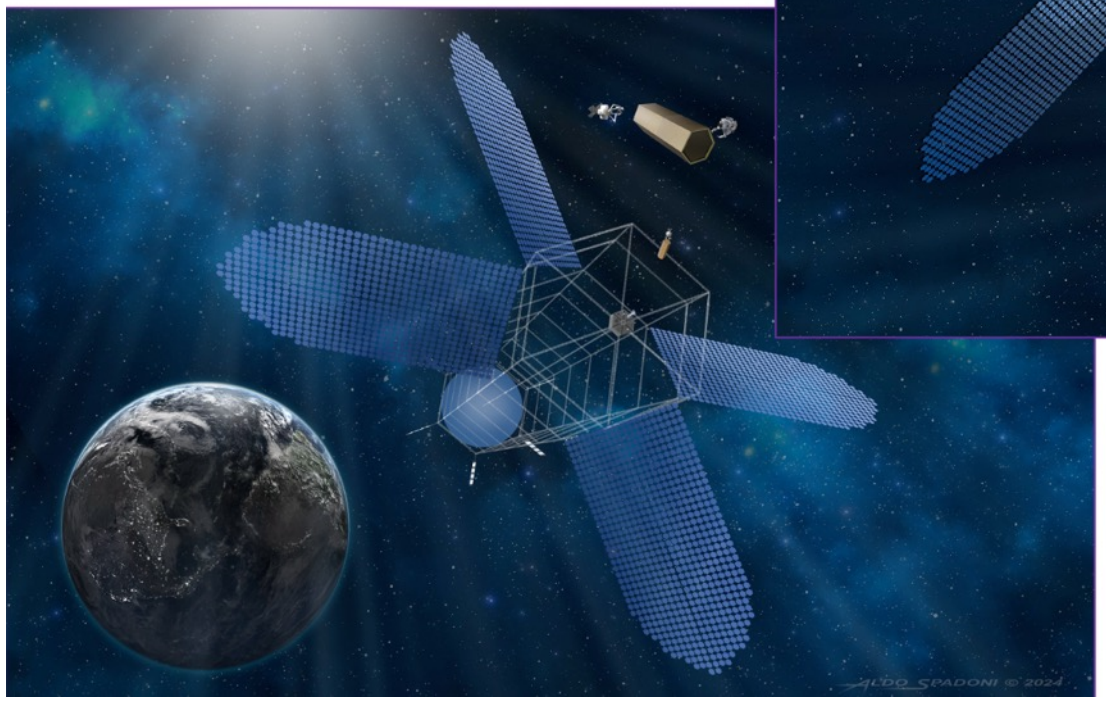


SPS-ALPHA Mk-III (2020)



SPS-ALPHA Mk-IV
(Solar Power Satellite via Arbitrarily Large Phased Array)





Comparison of SPS-ALPHA Mark-III and Mark-IV

PRELIMINARY

SPS-ALPHA Mark-III

Operational Orbit : GEO

WPT Frequency : ~2.45 GHz

Power Delivered : ~2 GW

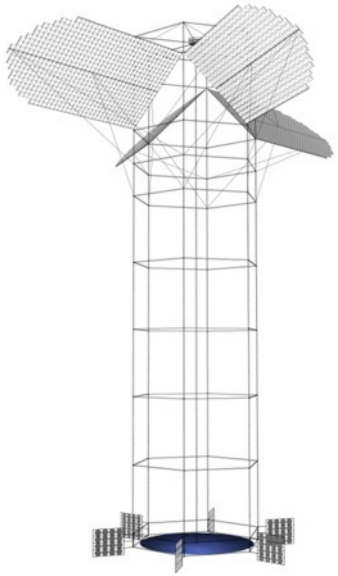
Mass : ~7,600 MT

Modules : ~1.9M

Installed Cost : ~$9.8 M

ETO Cost : ~ $200 / kg

Rcvr Diameter : 6.2 km



SPS-ALPHA Mark-IV

Operational Orbit : GEO

WPT Frequency : ~5.8 GHz

Power Delivered : ~1 GW

Mass : ~3,200 MT

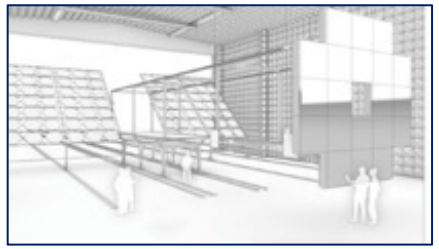
Modules : ~800K

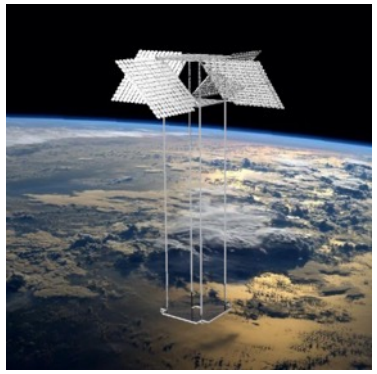
Installed Cost : ~ $4.9 B

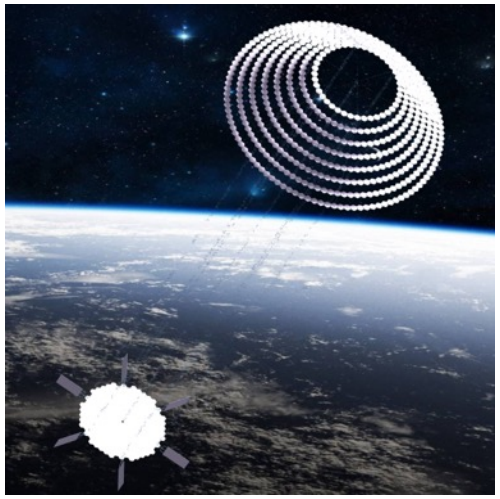
ETO Cost : ~ $200 / kg

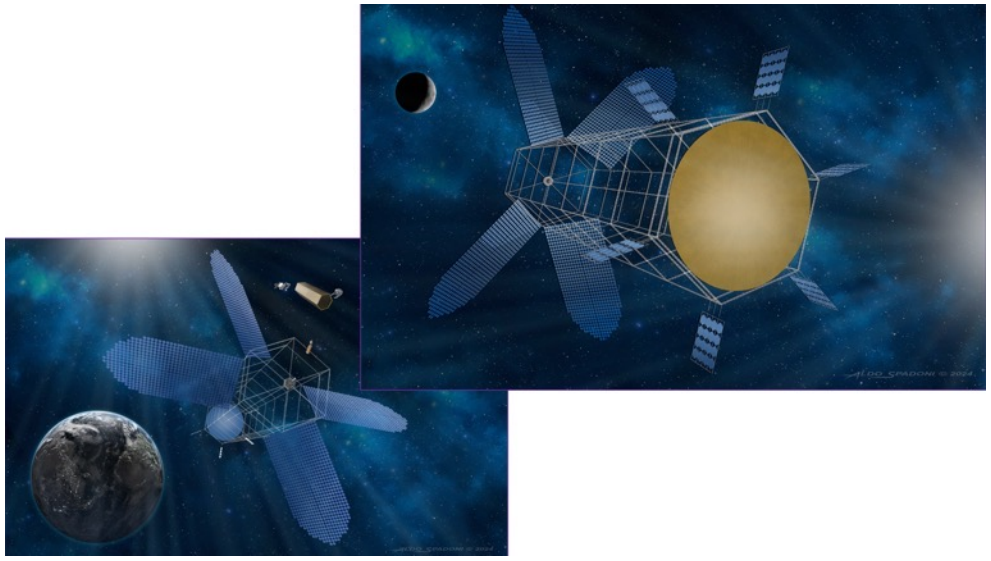
Rcvr Diameter : 3.6 km

A Roadmap to Operational / Cost-Effective SPS-ALPHA Mk-IV within a Decade









Phase 1

System-Level Lab Prototype
@ ~50kW
~$40M
12-18 months

Phase 2

System Demonstration in LEO
@ ~300kW
~$250M
+18-24 months

Phase 3

MEO Pilot Plant
@ 10-100MW
~$1B
+24-36 months
(to be updated)

Phase 4 +

Operational SPS in GEO
@ 1-2GW
+$4B-$6B
+36-60 months,