Space Solar Power Enabled by Dual Space Access Architecture

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ABSTRACT

This article presents the concept that Space Elevators enable space solar power (SSP) architecture. An SSP constellation will significantly impact the climate change equation by slowing the increase in greenhouse gases across the globe. This article proposes that there is a dramatic need for permanent infrastructures that can move massive amounts of tonnage to Geosynchronous Orbit (GEO) in a routine, daily, safe, and an Earth friendly manner. It lays out the concept of a Dual Space Access Architecture where rockets and Space Elevators are both compatible and complementary.

Keywords: solar power, space elevators, climate change

INTRODUCTION

This article presents the concept that Space Elevators enable space solar power (SSP) architecture. An SSP constellation is needed to significantly impact the climate change equation. Slowing the increase in greenhouse gases across the globe is a priority for the next several decades. The question is how? Dr. Mankins and several others have initiated programs to deploy SSP prototypes. This would grow into a massive effort around the globe to eliminate hundreds of coal plants by providing up to 12% of the global need for electricity by 2060.[1] This amazing and ambitious program can significantly improve the human condition.

This article quickly describes how rockets will support the initial programs by launching prototypes—and even the first production satellites to Geosynchronous Orbit (GEO)—to prove out the concept and "jump start" this incredible program. This article also proposes a dramatic need for permanent infrastructures that can move massive amounts of tonnage to GEO in a routine, daily, safe, and an Earth friendly manner. Moving 5,000,000 tonnes of satellites (estimated for SSP architecture by Dr. Mankins in October 2019[2]) is a herculean task.

The authors of this article are not experts on SSP, nor future rockets; but we are experienced in large space programs. We discuss a Dual Space Access Architecture after making the following statements to begin the discussions:

- SSP satellites are required and there are many aggressive global efforts, commercial and governmental, to prove the concept to be viable.[1]
- Future rockets will be bigger, reusable, and less expensive with the ability to launch hundreds of times.
- However, the rocket equation still dominates the amount of moveable tonnage. Future rockets cannot exceed 4% to Low Earth Orbit[3]—or 2% of launch pad mass to 42,000 km circular orbit. Therefore, launch configurations mass would have to total 250 million tonnes to achieve this SSP mission alone.

DUAL SPACE ACCESS ARCHITECTURE

We discuss the strengths and weaknesses of the components of this combined architecture with the purpose of placing mission equipment and people where they need to go and when they need to be there *Figure 1* illustrates the Dual Access approach. Expanding space access architectures to include commercial Space Elevators will enable a robust movement of SSP satellite segments. The proposed concept contains a 3-part approach to the infrastructure question:

Part A: Current and future rockets support the embryonic SSP prototypes and preliminary satellite assembly. This should continue until the first operational SSP satellite is launched to GEO with assembly of its several segments. To put this in perspective, the first practical SSP satellite (SPS-Alpha Mark II) has a mass of ~10,000 metric tonnes for 2 GW of power.[4] This early deployment capacity is because rockets have the following strengths: (1) rockets are successful today and great strides are forecast for the future, (2) they have the ability to reach any orbit, and (3) their rapid movement through radiation belts will decrease concerns.

Part B: Initiate in the near future, and then create, a commercial Space Elevator Architecture that has the characteristics of a permanent transportation infrastructure: routine, daily, inexpensive, safe, and environmentally friendly. This green road to space will enable massive movement of SSP segments to GEO for assembly.

Part C: Leverage this permanent infrastructure to raise the vast majority of the SSP satellite architecture in an Earth friendly manner.

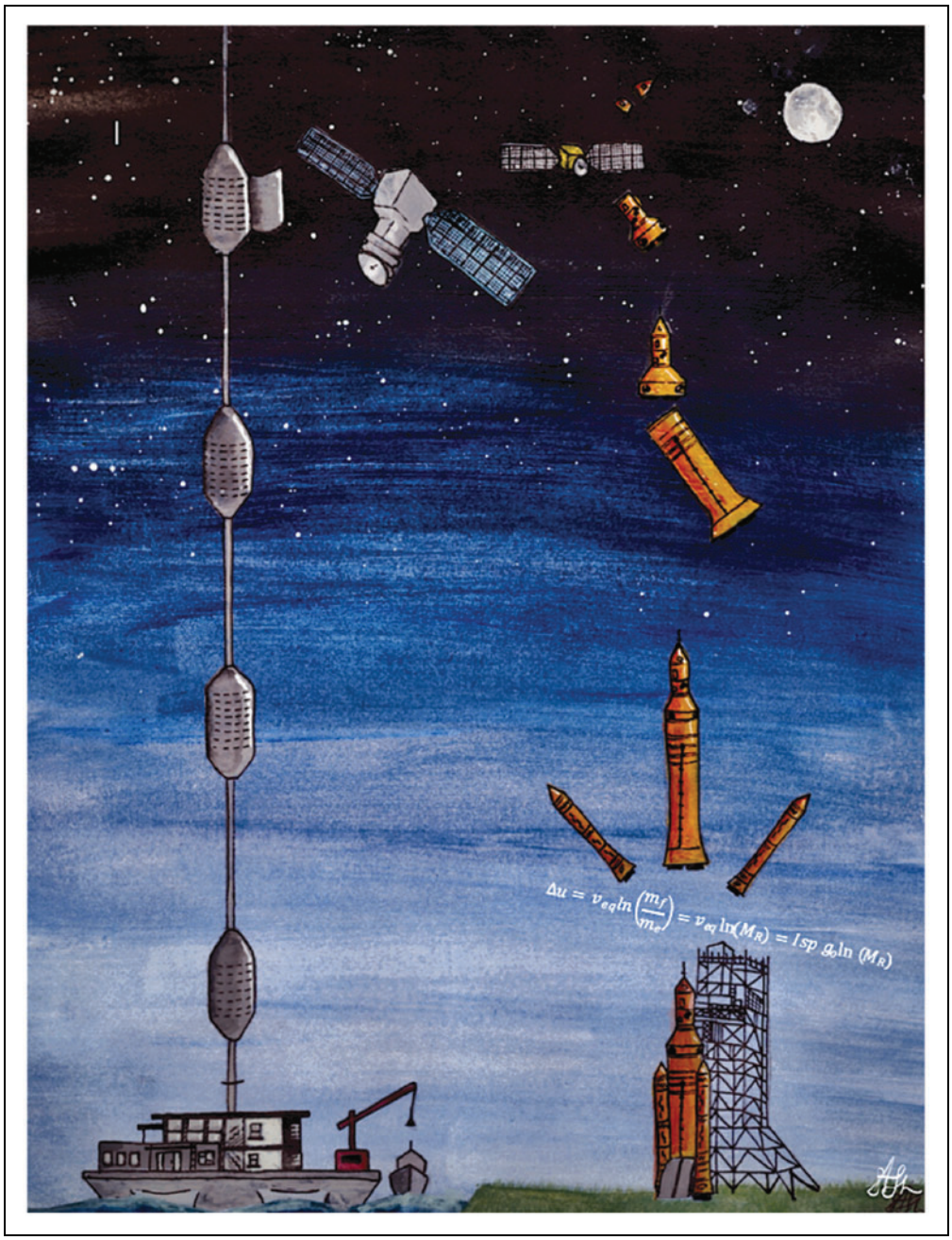


Fig. 1. Dual Space Access Architecture (Image by Amelia Stanton).

The essence of this article is that the 2 methods of achieving spaceflight are complementary and compatible rather than competitive. Each has its own strengths and weaknesses.

SPACE ELEVATOR PROPOSED PLAN

The authors of this article have a combined 104 years of experience working in the satellite development arena including several megaprojects. As each of them have been committed to Space Elevator development for decades, they have tremendous insight into the current phase of the program. Each believes that the Space Elevator Architecture described in their articles is not only achievable, but is now ready to initiate this major infrastructure mega-project. The chief architect has stated that we are ready to initiate segment level testing as we have finished the preliminary technological readiness assessment, as shown in *Figure 2*. Dr. Swan was lead author and

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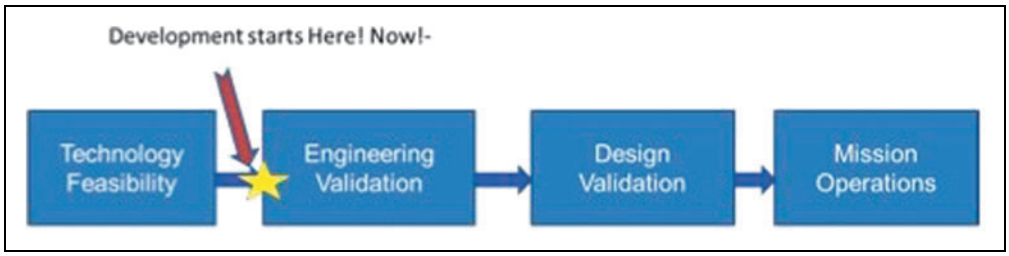


Fig. 2. Megaproject developmental process.

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editor of a 4-year study report by the International Academy of Astronautics. The study concluded that the Technology Readiness Levels for all of the segments have been evaluated and the authors agree that the program can be started.[5] The final key to the puzzle was that the material for the tether (Single Crystal Graphene) has been shown to be "strong enough" and can be "grown long enough."[6] The global Space Elevator team members are ready to start. They believe they can build a Space Elevator to match their vision.[7]

By the end of the next decade, Space Elevator infrastructures can be incrementally built with more and more capability leading to many complementary missions. Our vision toward the turn into that decade (2040s) is that there will be 6 Space Elevators located around the equator helping with the delivery of massive amounts of payload to GEO and beyond.[8] This inherent capability results from their permanent characteristics leading to a green road to space. Once a Space Elevator has been installed and upgraded to its initial capability, it will be there for a very long time, similar to roads, bridges, and train tracks. Raising payloads from the surface of the ocean to the Apex Anchor (100,000 km as a starting concept) is accomplished with external clean power—such as solar energy.

BASELINE CAPABILITY FOR THE SPACE ELEVATOR ARCHITECTURE

The 2014 publication of the International Space Elevator Consortium's (ISEC) "Architecture and Roadmap" report removes the shroud of mystery and myth from the Space Elevator's scope and complexity. The Elevator's technological basis is no longer in question. ISECs "Design Consideration" documents published between 2013 and 2017 delineated the technological needs and engineering approaches for the Tether Climber, Earth Port, GEO Region, and Apex Anchor. An architecture simulation tool has been selected. The last technological hurdle—material strong enough for the tether—has shown it will be available. This momentum of technology and engineering portrays Space Elevator mission diversity as imminent. The Galactic Harbour concept was developed to show the need to support enterprise activities throughout its permanent infrastructure. The following could be available along the GEO belt: factories and solar power generation, efficient interplanetary departures from and to the apex and arrivals at GEO, and product materials returns to the Earth Port. The Galactic Harbour, as shown in *Figure 3*, is seen as 2 Space Elevators inside a column from the Earth Port through GEO altitude and including the Apex Anchors. The expectation is that there will be robust growth of enterprise along this green road to space.

Current estimates are for the initial operational capability (IOC)—20 tonne climber capability—to occur somewhere after 2036 with full operational capability (FOC)—100 tonne climber—around 2048. Development of permanent infrastructures around the equator will not be immediate; however, its operations will enable releases toward mission destinations without consuming fuel or rocket structures. As the Space Elevator delivers 70% of its mass at the Galactic Harbour Earth Port to GEO (with 30% as Tether Climbers to be reused), the numbers associated with delivery of mass to GEO and beyond are 14 tonnes per day for IOC system [$\times 6$ SEs = 30,660 tonnes per year to GEO] and 79 tonnes per day for FOC system [$\times 6$ SE = 173,010 tonnes per year to GEO and beyond].

When looking at the gargantuan needs for SSP architecture designs,[9] the ability of a permanent infrastructure to deliver daily to GEO is important and necessary. If one were to look at customer demand (5 million tonnes to GEO)[10] and at the FOC Space Elevator, the answer is quite acceptable for a developmental program that shows incremental growth for delivery to GEO. This leads to $\sim$29 years of daily delivery to GEO by a permanent infrastructure that is the green road to space versus burning rocket fuel with tens of thousands of launches. Of course, the Space Elevator throughput could be significantly improved with growth beyond our current vision, thus decreasing the delivery dates.

Vision of the Future: Enable SSP Architecture!

The supply of SSP segments to GEO strategy has 2 components. A much stronger position results from both rocket architectures of the future and permanent Space Elevator infrastructures. Assessing the previous discussions, the logical

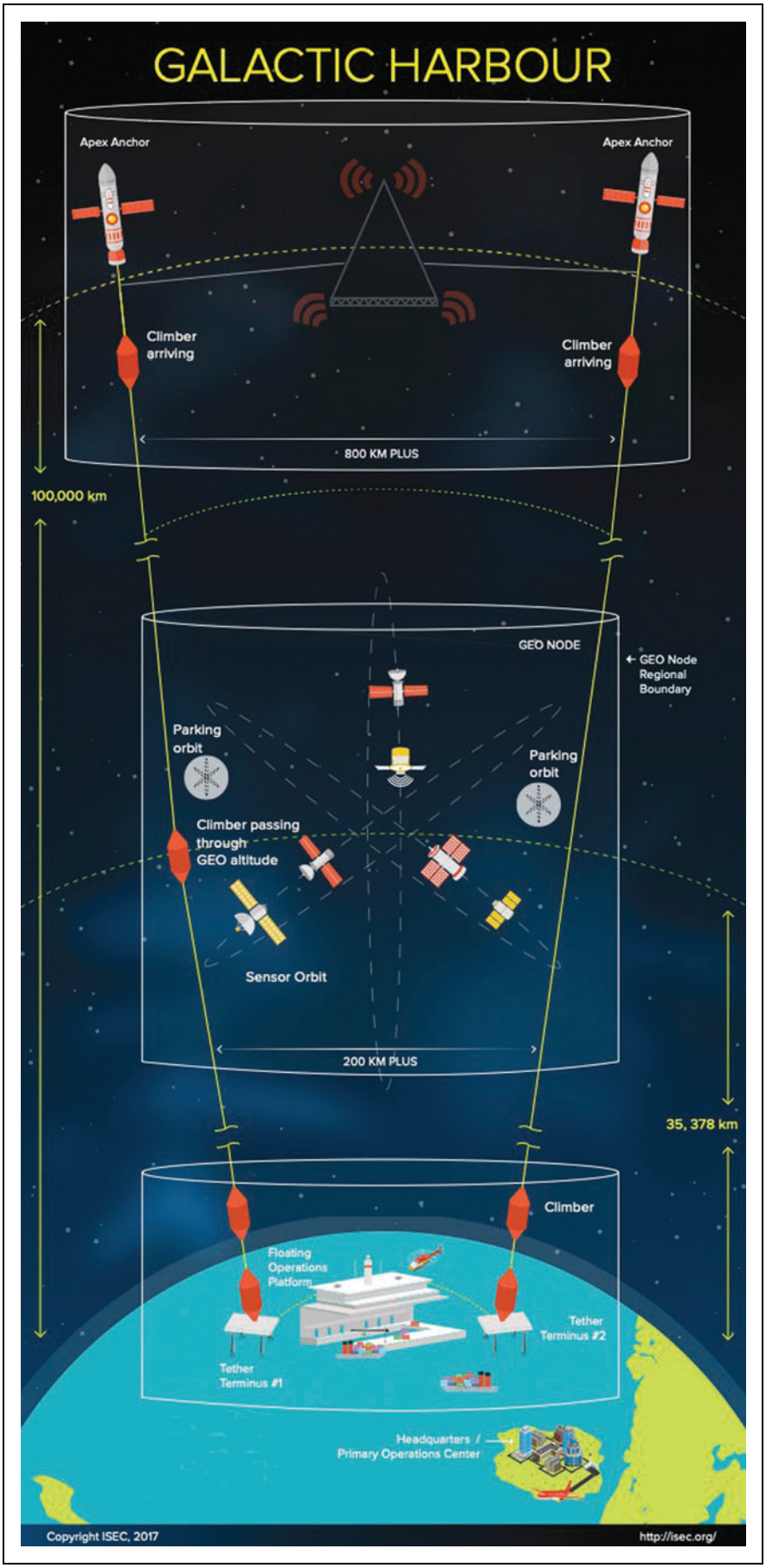


Fig. 3. Galactic Harbour.

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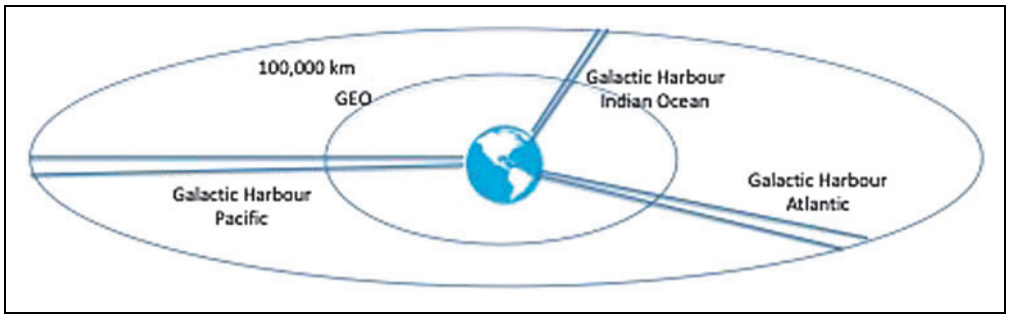


Fig. 4. Galactic Harbour Competition.

conclusion is that there should be a concerted effort to ensure development toward a Dual Space Access Architecture. Some basic realizations are that (1) Space Elevators should be leveraged for GEO and beyond and (2) Space Elevators should be optimized to deliver cargo, equipment, and supplies, as shown in *Figure 4*. These factors lead to the realization that developmental planning must be initiated in the very near future for both advanced rockets and Space Elevators. New space visions and planning scream for permanent space access infrastructures that move massive tonnage routinely, daily, inexpensively, and safely while being Earth friendly. The proposed plan is:

> Rockets to supply SSP prototypes and first operational system with Space Elevators to supply and grow the SSP GEO constellation.

THE EPILOG

This is a magnificent story. The portrait here is that the net effect of the Dual Space Access Architecture enables the deployment of SSP installations to GEO, which will improve the quality of the environment on Planet Earth—substantially and forever.

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DISCLAIMER

The conclusions of this article remain those of the authors and no statement found herein should be attributed to any individual or organization.

AUTHOR DISCLOSURE STATEMENT

No competing financial interests exist.

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REFERENCES

1. Eddy J, Swan P, Swan C, Phister P, Dotson D, Molloy B. Space Elevators are the Green Road to Space. ISEC Report. North Carolina, Lulu Publishers, 2021.
2. Mankins J. Conversation with Peter Swan at IAC-19 in Washington DC.
3. McClellan P. Getting to orbit and the rocket equation. Semiconductor Eng. 2019. https://semiengineering.com/getting-to-orbit-and-the-rocket-equation (Last accessed December 15, 2020)
4. Mankins J. SPS-ALPHA: The First Practical Solar Power Satellite via Arbitrarily Large Phased Array, a 2011-12 NASA NIAC Phase 1 Project. Sept 15, 2012.
5. Swan P, Raitt D, Knapman J, Tsuchida A, Fitzgerald M, Ishikawa Y. "Road to the Space Elevator Era," an International Academy of Astronautics Study Report. Texas, Virginia Edition Publishing Co., 2019.
6. Nixon A, Whieldon R. Graphene Progress and its Promising Future for Space Elevators. Presentation at Blue Marble Week, March 9, 2021, also YouTube.
7. Swan P, Raitt D, Swan C, Penny R, Knapman J. "Space Elevators: An Assessment of the Technological Feasibility and the Way Forward," an International Academy of Astronautics Study Report. Texas, Virginia Edition Publishing Co., 2014.
8. Swan P, Swan C, Fitzgerald M, Peet M, Torla J, Hall V. "Space Elevators are the Transportation Story of 21st Century," an International Space Elevator Consortium Study Report. North Carolina, Lulu Publishing, 2020.
9. Mankins J. Webinar entitled "NSS Space Forum—A Case for Space-Based Solar Power." National Space Society Sponsored Webinar August 20, 2020.
10. Mankins JC, Nobuyuki K, eds. The First International Assessment of Space Solar Power: Opportunities, Issues and Potential Pathways Forward. Paris, France: International Academy of Astronautics, 2011, p. 249.

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