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# International Development of Space Elevators Makes Financial Sense

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## Introduction

By the end of 2050, and very possibly sooner, there will be a direct route from earth to space in cooperation with rockets. The space elevator, once little more than a dream of science fiction, has proved increasingly possible with every new discovery made by hardworking researchers and engineers. The scientists at the forefront of this push are now saying “when,” not “if,” which means it is time to seriously examine how this monumental feat of innovative transportation technology will be created.

This paper presents the idea that the international space elevator community could benefit from focusing their efforts and supporting a major construction corporation in order to achieve a working space elevator project in the near future. For this reason, this paper chooses the Obayashi Corporation as the focus with the recognition that they are significantly ahead of others in many areas.

The Obayashi Corporation is currently the only major construction corporation that has declared their intent to build this massive project. However, their current plans deviate somewhat from the efforts of other international engineers and scientists. It would benefit all involved to pursue more collaboration, as the international plan may be more financially beneficial to the Obayashi Corporation in their unique position, and formal collaboration may similarly expedite the process for other interested parties around the world.

> Proposal: International engineers and scientists should work closely with and support the Obayashi Corporation in the development of the first space elevator.

## A Background on Obayashi

This Japanese construction company is in a unique position as the most likely candidate for a commercial company capable of developing and constructing a space elevator. Their history as a megaproject construction firm proves their qualifications for this project. Some of their notable accomplishments include their work in creating the airport island and passenger terminal for Kansai International Airport in 1994, the Akashi-Kaikyo Bridge in 1998, the Taiwan High Speed Rail in 2006, and the Waterview Connection Tunnels and Great North Road Interchange in New Zealand in 2018 (Obayashi Corporation, n.d.). They have a long history with major transportation projects, and the success of these projects proves their expertise and capability.

The Obayashi Corporation is already leading the push towards actual construction of a space elevator. They have declared that they have plans to create a space elevator capable of carrying human passengers by the year 2050 (Obayashi Corporation, 2014), and they are currently testing tether climber designs in space (Ishikawa, et al., 2019). Although other groups have shown interest, they are the only ones with a set plan and financial backing.  They have shown consistent interest in this project for several years, and their dedication to the project shows no signs of slowing down.

Their reasons for pursuing the project are their own, and they have not made any official statements regarding what sort of clients they hope to attract to this new and revolutionary transportation system. One potential client, however, happens to be very nearby. To understand the unique opportunity that Obayashi may be in a position to claim, one must first understand Space Solar Power.

**Space Solar Power**

The Space Solar Power project is one of the most promising long-term solutions for global electricity production. While solar panels on earth have varying levels of efficiency depending on season and weather, solar panels in orbit would be free from the majority of such variation in power output. However, this project will require an estimated 5 million tonnes[1] of material to be carried up into space and carefully positioned in orbit. Using rockets to do this would not only add tremendous cost to the project, but it would also offset some of the environmental benefits of clean solar energy since rockets expend a very large amount of fossil fuels. Even recent rockets at the cutting edge of current technological capabilities, such as the new Japanese rocket, HII, are only capable of carrying 4 tonnes to GEO, which is a mere 1.5% of the launch pad mass. Taking all of the equipment needed for Space Solar Power to orbit would require over one million launches. The space elevator, on the other hand, is estimated to be able to carry 79 tonnes of cargo per climber, and newer climber designs may be able to carry more. Even then, one elevator would still take many years to carry up the material necessary, so multiple elevators will be required for the eventual completion of this project on a global scale, but it will be far more efficient than rockets.

Japan faces more difficulties than many other major countries in the switch to completely carbon-neutral power generation. Their population density is very high in major cities, and traditional means of solar and wind generation are simply not efficient enough to serve their entire population. For historical reasons, most of Japan is very wary of nuclear power, and this position makes further sense when factoring in the risk of earthquakes and tsunamis potentially disrupting even the safest nuclear power plants. As a result, Japan as a whole is highly motivated to lead the way in the Space Solar Power project, and the Japan Aerospace Exploration Agency (JAXA) is currently working on the project (Japan Aerospace Exploration Agency, n.d.) in cooperation with Japan Space Systems (Japan Space Systems, n.d.). The project is being developed under the name Space Solar Power Systems, or SSPS.

[1] Mankins, John. Personal conversation with P. Swan at IAC, Washington DC Oct 2019.

Naturally, not all 5 million tonnes would be necessary to create a network for Japan. It is difficult to estimate how much they would actually need for national power generation, but one model (the METI model) involves a giant square of solar panels totaling 2km per side (Japan Aerospace Exploration Agency, n.d.). No estimates are given for its weight, but one article commenting on the plan estimates each may weigh upwards of 10,000 tonnes and that each SSPS station will be capable of an average output of 1 gigawatt, which is "about the same output as a typical nuclear power plant," (Sasaki, 2014). Japan uses about 943.7 billion kWh or 9.437 million GWh of electricity per year (World Data, n.d.). The exact breakdown of how many SSPS stations Japan will need is far beyond the scope of this paper, but it is sufficient to say that they will need many stations, which will require a lot of material—more than enough to say that it would be more efficient to transport this material, at least in part, via a space elevator.

**Obayashi's Opportunity**

Therefore, if the Obayashi Corporation can complete a space elevator around the same time as the completion and deployment of SSPS, they will be in an excellent position to secure a contract with JAXA to carry up all of the necessary material. However, their current plan stretches out to 2050 and includes building a space elevator capable of carrying passengers. While there will certainly be business for such an elevator carrying commercial satellites, astronauts from government-owned and commercial institutions, and further supplies and materials for SSPS, it seems that they will miss an opportunity for the rapid return on investment for the development and construction of the space elevator that they could receive if one is completed by the time SSPS is ready for deployment. Of course, a massive project such as the space elevator cannot be safely rushed, and if the elevator is going to carry human passengers, safety will absolutely vital.

However, the development and deployment of a space elevator designed only to carry cargo could be completed in nearly half the time necessary. A study conducted by the International Academy of Astronautics showed that a space elevator meant only for cargo could be completed as soon as 2036, while full operational capacity meant for human passengers would take longer and push the project completion date out to 2050 (Swan et al., 2013). With three very strong candidates for potential tether materials currently in testing, it is very likely that at least one of these will prove entirely capable of meeting the space elevator's needs within a mere few years (Swan et al., 2018). An aggressive development and construction plan could be initiated even before a material is fully proven, and such a plan could create a complete space elevator within 15 years, placing its completion date sometime in the range of 2036-2040. This would align well enough with JAXA's plans for SSPS.

The researchers and engineers currently focusing on this more rapid and aggressive plan for a cargo-only space elevator are the core membership of the International Space Elevator Consortium (ISEC). Although ISEC and its conference appearances attract space elevator researchers and enthusiasts from around the world, including ones from the Obayashi Corporation, its board and most active members are currently comprised mostly of American and European scientists with varying connections to different agencies and universities. The cargo-only elevator plan does not represent the view of all members and affiliates of ISEC, but it is popular among a significant portion of these most active members. Consequently, I will refer to the members who would be most interested in pursuing this plan and actively collaborating with any company willing to pursue it as the "ISEC development team" with the caveat that this is only a team *from* ISEC and not the whole consortium.

The Obayashi Corporation could stand to gain much from a collaboration with this future ISEC development team. If the cargo-only elevator can be completed in time for SSPS, it could use the steady revenue stream from that project to recoup its costs quickly and efficiently. An estimate specifically for these circumstances would be difficult to pin down, but older evaluations of a cargo-only elevator show the potential for profit within twelve years (Swan et al., 2013), and developments in climber designs since could allow for greater cargo loads and more frequent payloads, which means that if this were partnered with SSPS for guaranteed stable demand to fill up every climber, it could turn over a profit significantly sooner.

In all, this could mean that a cargo-only elevator would be well on its way to profit or perhaps even completely paid off before 2050. From the financial side, this detour from their stated mission might not slow the Obayashi Corporation down in their pursuit of a passenger-capable elevator. Projections of the eventual demand for space elevators shows that the blooming market will be able to support at *least* three and very likely more after that (Swan et al., 2013), so the Obayashi Corporation would not suffer from a lack of demand if they owned and operated two of those. There is no financial or business reason why they should refrain from pursuing a second space elevator.

From an engineering and development standpoint, working on a cargo-only elevator first should actually benefit their overall plans to create a passenger-capable elevator. The main reason why a cargo-only elevator could be completed faster is because such an elevator does not require the same types of safety measures and other technical complications. After all, if a cargo container depressurizes or ends up exposed to an excess of radiation, the worst possible loss would be some valuable equipment. Secondary systems on a cargo climber could be helpful but would not be required at the start of operations, whereas a passenger climber would need redundant systems built in. More than that, a passenger climber would need two or more tethers or some other sort of emergency backup system just in case the virtually impossible happens and the main tether is severed or detached from either end of the system. What these safety measures will look like will depend on what material the tether is ultimately made from, the setup of the galactic harbor it is attached to, and the climber design itself. In whatever form they ultimately take, these safety measures will need extensive testing before they can be trusted with human life. This is why a passenger-capable elevator will most likely take 10 to 15 years longer to develop than a cargo-only one.

Aside from the safety measures, however, a cargo-only space elevator and a passenger-capable space elevator will be very similar. The passenger-capable tether would start out very similar to a cargo-only tether until the necessary safety measures are completed, such as a multi-tether system; thus, a passenger-capable space elevator could easily be derived from a tested and proven cargo-only elevator. With a larger, collaborative team, Obayashi Corporation could design, test, and build a cargo-only elevator and apply the research and results to their ongoing project of a passenger-capable one while allowing that cargo-only elevator to produce revenue that will help offset the costs of further research. It is possible that building the additional elevator would not slow down their goal of a passenger-capable elevator at all. It would also allow for easier access to space to test passenger safety systems, which could even speed up the process.

It is also worth considering that it may be possible to adapt a cargo-only elevator into a passenger-capable one by adding the additional tethers (or other systems) and the safer climbers later on. While this may be less efficient from a market standpoint than having two elevators, since the demand will easily support two elevators, it is a potential option if something changes these market projections in the future. Either way, constructing the cargo-only elevator should not stop or even significantly slow efforts on a passenger-capable one.

For all of these reasons, it seems more than reasonable that the Obayashi Corporation would benefit from pursuing a cargo-only space elevator first with the help of a future ISEC development team. More rapid development would allow them to take advantage of the business opportunity provided by SSPS, and devoting their resources to the cargo-only elevator should not stop or even significantly slow their plans for a passenger-capable one and may even accelerate those plans.

**Other Benefits of International Cooperation**

With all of that in mind, would it benefit international researchers to join with Obayashi and enable them to construct not only one but two space elevators? Many scientists seriously pursuing the space elevator project are already considering their own plans for acquiring funding and building separate elevators. The reality of future competition in the space elevator market may tempt many to be cautious about the extent of their collaborative efforts and to keep certain development secrets for themselves.

It is true that competition is beneficial in many areas, and it has been a cornerstone of development in the space arena in the past. However, just as international efforts have moved towards cooperative projects with the ISS and the upcoming Project Artemis, commercial space agencies should similarly consider the benefits of close collaboration. This project has already been pushing the bounds of science and engineering for years, and it will continue to do so until it is complete. Collaborative research has allowed for rapid development in tether materials, climber designs, and galactic harbour infrastructure, but if the scientists collaborating today through ISEC are split into separate teams working on separate elevators, the pressure of competition could stifle collaboration and slow down the process for all involved.

Additionally, the space elevator is a massive financial risk with the potential for enormous and ongoing monetary payouts. Market projections show that there will be enough business to sustain at least three elevators and quite probably more. However, it may take some time to convince all of these potential customers to make the switch. With the Obayashi corporation already in a prime position, it will receive the potential income from SSPS and some satellite traffic, so justifying the cost of additional elevators to serious investors may prove difficult despite the market projections. Once the first elevator has proven the concept, however, and investors will not be asked for as much money up front for research and development, it will be much easier to justify the costs of construction for additional elevators.

For all these reasons, it seems not only possible but logical for the first space elevator to be developed, financed, and constructed through a truly international collaborative effort. This would pave the way for other companies to acquire the funding needed to build their own space elevators and create a larger network of earth-to-orbit transportation. A study from the International Academy of Astronautics shows that multiple elevators will become necessary very quickly (Swan et al., 2013). Thus, it would not be to anyone's detriment to share more information and allow the first space elevator to made more quickly and other elevators to follow soon after.

**Conclusion**

The first space elevator will be built sometime in the next few decades, of that we can be certain. The questions that remain are who will build it, where, and how. By formally working together in a highly collaborative environment, scientists around the world can accelerate this process and ensure that the first space elevator will be a technological and financial success. The Obayashi Corporation already leads space elevator development, and if they welcome international collaboration, they can reach their goals more efficiently and pave the way for others to follow.

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