Energy & Power Requirements for Heavy Lift Space Railway

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Abstract

A case has been made that viable space settlements or space economy is dependent on transporting millions of metric tons to Geosynchronous Orbit (GEO) and beyond or returning wealth from space to Earth. The outbound missions have been well documented, but the down-Earth has had little detailed attention. Down-Earth consideration can be from space mining operations, GEO manufacturing, personnel returning from space, or other space wealth requiring transportation to Earth's surface. It has been argued that space settlement and economy will require over 1000 metric tons per day both up and down from GEO. This challenging goal is far beyond rocket and reentry vehicle capability. Electrically-driven space elevators are promising but are currently being designed far below the 1000 metric ton capability per day.

Electrically based propulsion systems require tremendous energy and power to ascend the tether outbound. Upon descent, the electrically based propulsion system will generate regenerative power that must be used, stored, or transmitted somewhere off the Space Railway^{TM} train.

This paper will examine energy and power requirements for various-sized Space Railway^{TM} trains. The assorted sizes, speeds, and cycles per day will create the trade space for selecting an overall system architecture, transportation car design, and electric power and propulsion concepts that meet the requirements for space settlement and economy.

Introduction

Griggs (Griggs, 2025b) argued that space settlement, which will cost trillions of dollars, will have to be able to pay for itself. He recommended the mining of Near-Earth Orbit (NEO) metallic asteroids, one of which has over $70 trillion in precious metals, and brings that back to Earth for repayment of space investment, Figure 1. Large-scale Geosynchronous Orbit (GEO) manufacturing is also viable for producing various materials, pharmaceuticals, crystals, and other components in a zero-g environment that cannot be produced on Earth. Space settlement and the space economy require transportation of cargo and personnel to be viable, relevant, and vibrant.

Griggs (Griggs, 2025a) argued that large mass movement down-Earth must be addressed and viable solutions provided before a space settlement and economy can flourish. He reviewed the rocket and reentry vehicle concepts and concluded that they are inadequate to carry the mass, provided the necessary volume, and cannot launch at a frequency that can support a space settlement and space economy society.

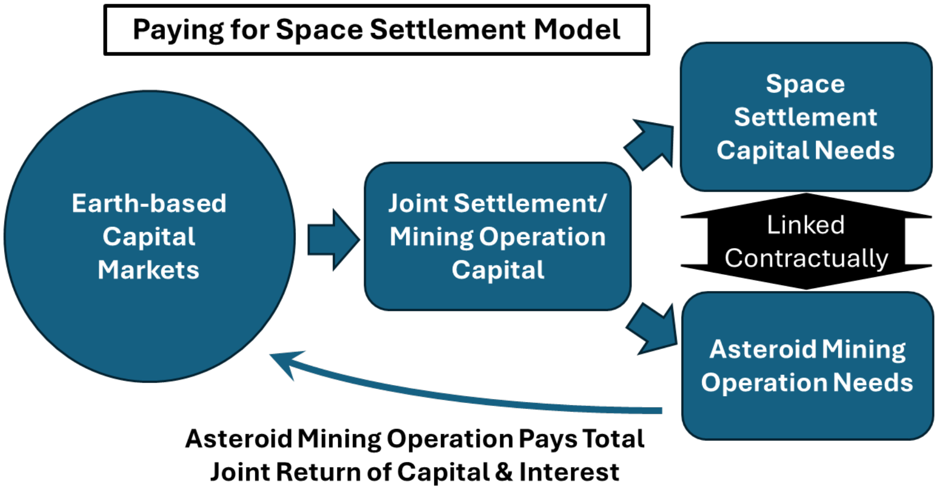

Figure 1 Paying for Space Settlement Financial Model Requires Asteroid Mining Operations.

Major Off-World and Down-Earth Transport Needs - Millions of kg (Mkg)							600 mt Elevator	
	Off-World (Mkg)	Down-Earth (Mkg)	# Falcon Heavy	Rocket Cost $ Billions	Years to Complete (1 L/wk)	Years to Complete (5 L/wk)	Years to Complete (1 L/day)	Years to Complete (5 L/day)
Moon Village	500		29,762	2,024	572	114	2.28	0.46
SpaceX Colony Mars	1,000		59,524	4,048	1144	228	4.57	0.91
Space Solar Power	5,000		187,000	11,594	3596	719	22.8	4.57
L-5 O'Neill Colony	10,500		392,700	24,304	7551	1510	47.9	9.59
Sun-Earth L-1 Sunshade	20,000		748,000	46,376	14384	2876	91.3	18.2
Space Tourism	TBD	TBD	TBD					
GEO Manufacturing	TBD	TBD	TBD					
Asteroid 3554 Amun Mined Iron - Leave in Space		30,000,000	Unknown Vehicle					
Asteroid 3554 Amun PM & PGM: $70 trillion		4,677					20	
Other Asteroids and Space Products Returning to Earth		XXX,000,000	Unknown Vehicle					
Current Total Marketspace Needs	37,000	X30,000,000	1,383,900	$85,758	26,613	5,322	188.9	31.49

Figure 2 Transport Needs from and to Earth Requires a Heavy Lift Space Railway™

His target goal for mass transportation is 1000 metric tons per day, both up and down-Earth. This was based on the various missions that have been identified, and the mass transportation needs for those missions (Figure 2).

He also concluded that the only viable near-term solutions will come from space elevators. Space Railway^{TM} is targeting a much larger space elevator than the International Space Elevator Consortium's (ISEC) open study concept. Space Railway^{TM}'s primary means of propulsion is based on electric power, as are most space elevator concepts. Short-duration propulsive force by other means has been explored, but the primary means is electrical.

Griggs identified several technical challenges for large-scale space elevators. One is the energy and power are required to be supplied to a space elevator for ascent. Another is a down-Earth space elevator will also generate a considerable amount of power, referred to as regenerative power, which must be used, stored, or transmitted. This paper will explore the energy and power requirements for various operational conditions of a large-scale space elevator. This will not include any equipment efficiencies or heat projections. That will be a topic for another paper.

Forces, Energy and Power from Earth's Surface to GEO

The Space Railway^{TM} concept of a space elevator is similar to the ISEC concept from the point that it is geosynchronous, fixed at a point on the equator, but may have the capability to move slowly to reposition on the Earth's surface, generally on the ocean.

The Forces

A space elevator under these conditions balances gravitational force with centrifugal force unless there is a change in the acceleration of the elevator. A change in acceleration can occur briefly at launch, in emergency conditions, while in transit, or upon deceleration upon reaching a destination. Gravitational force, F_g, centrifugal force, F_c, and force equivalent, F_e, are defined as follows(Bate et al., 2020).

$$F_g = m_E m_{SE} g/(r_E + h)^2$$

$$F_c = m_{SE}(2\pi/t_r)^2(r_E + h)$$

$$F_e = m_{SE}[(2\pi/t_r)^2(r_E + h) - m_E g/(r_E + h)^2]$$

Where,

m_E = mass of the Earth
m_{SE} = mass of space elevator
g = gravitational constant
r_E = radius of Earth
h = height above the surface of the Earth
t_r = time for one revolution of the Earth

Under equilibrium conditions, the net effect on a space elevator is subjected to a Gravitational Equivalent Acceleration (GEA), which is defined as

$$GEA = \left[(2\pi/t)^2(r_E + h) - m_E g/(r_E + h)^2\right]$$

A space elevator will experience diminishing gravitational forces the further it travels away from Earth. The GEA is the net result of the gravitational and centrifugal accelerations with the net of zero at GEO, approximately 35,786 km above the Earth's surface, Figure 3.

Energy

The energy required, *E*, to ascend from the Earth's surface is the force it must overcome times the height it rises. The force is dependent on the GEA and the mass of the space elevator. As noted, the energy required to ascend is dependent on height above the surface of the Earth. The distance a space elevator will travel on a tether is considerable and the energy required to raise the elevator one meter will change as a function of height. The energy required is defined as

$$E = \left(m_{SE}\left[(2\pi/t_r)^2(r_E + h) - m_E g/(r_E + h)^2\right]\right)\ dh$$

It is noted that the energy required is a linear relationship with the mass of the space elevator. This provides an opportunity for easily conducting trade studies for space elevators of different masses. Griggs (Griggs, 2025a) conducted trades for Space Railway$^{\text{TM}}$'s concepts for masses between 100 and 700 metric tons. This paper will focus on a one hundred metric tons Space Railway$^{\text{TM}}$ based space elevator. Forces, energy, and power can be assessed for larger masses by a linear relationship.

The energy required to raise a one hundred metric ton space elevator one meter is presented

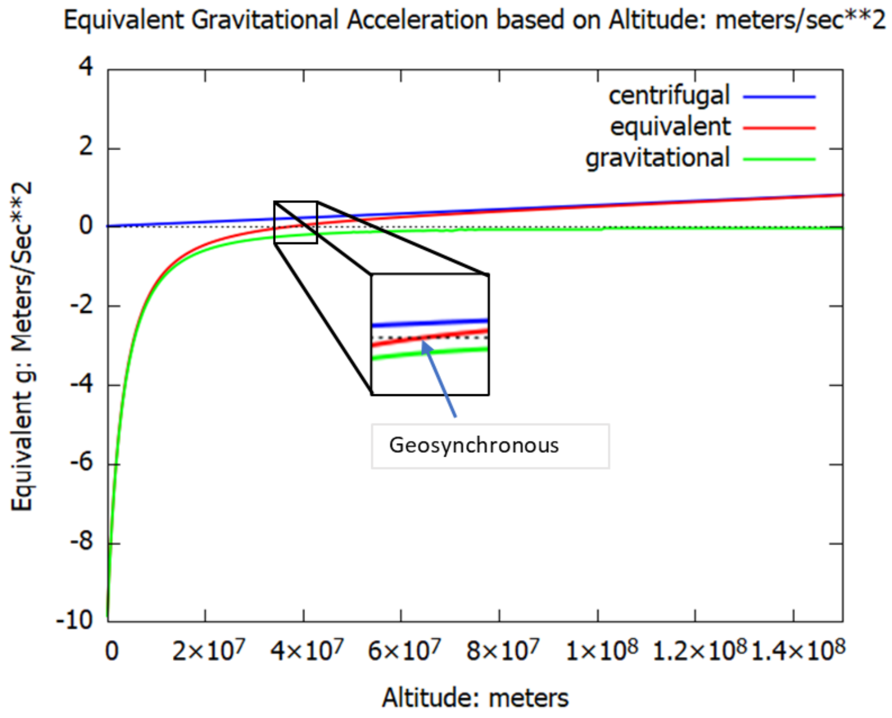

Figure 3 Gravitational Equivalent Acceleration for a Space Elevator with a Geosynchronous position

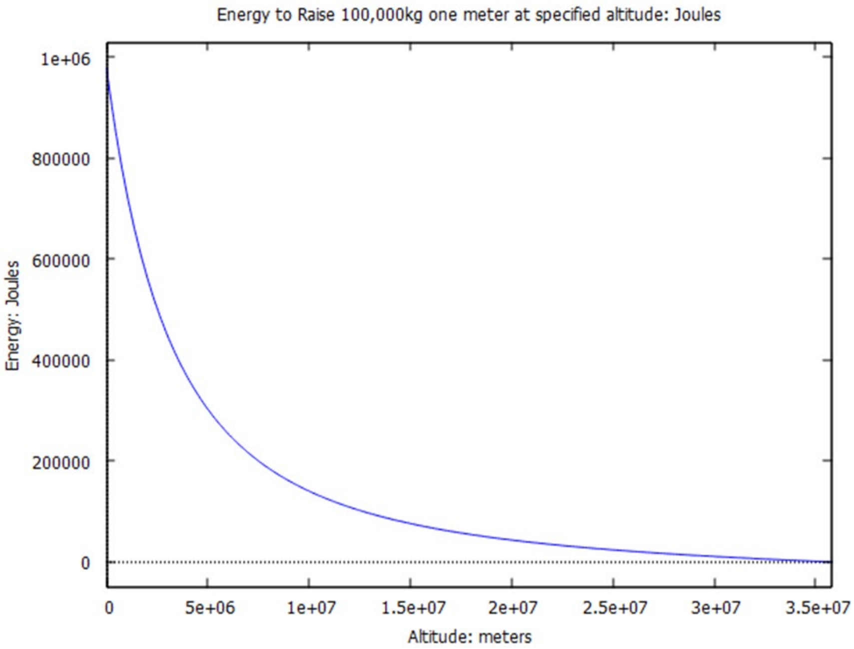

Figure 4 Energy Required to Lift a 100 Metric Ton Space Elevator One Meter is Dependent on Altitude.

in Figure 4. The amount of energy required to raise a 100 metric-ton space elevator a meter is about 1/3 of the Earth's surface energy requirement by 5000 km. The energy required is reduced even more as the elevator approaches GEO.

The accumulated required energy for a trip from the Earth's surface to GEO (Figure 5) can be staggering to those not used to large numbers in terms of power and energy. This is calculated by integrating the energy from the Earth's surface to GEO.

$$E_{Accum} = \int_{h=0}^{h=max} (m_{SE}[(2\pi/t_r)^2(r_E+h) - m_E g/(r_E+h)^2])\ dh$$

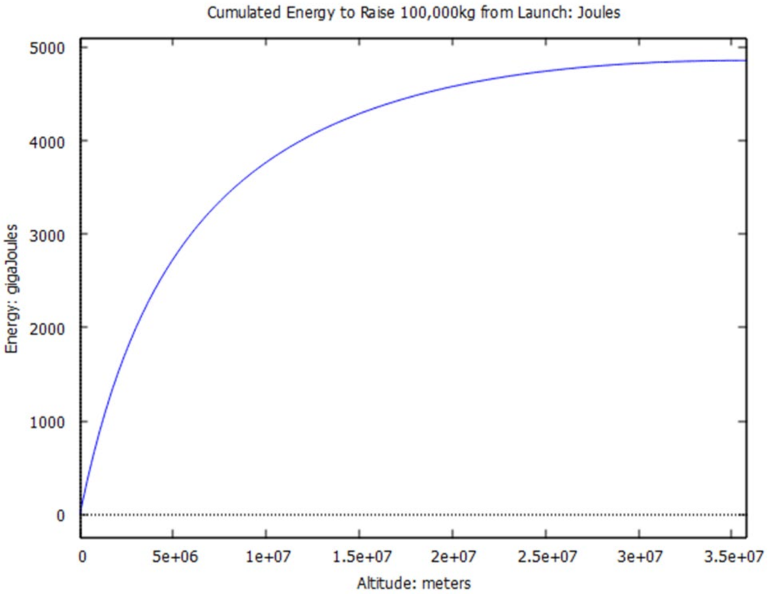

Figure 5 Accumulated Energy Required to Lift a 100 Metric Ton Space Elevator from Earth's Surface to GEO Appears to be Large but Compared to SpaceX Starship it is Minuscule.

To put this into context SpaceX Starship uses 51.2 trillion joules of energy just to obtain Low Earth Orbit (LEO). This is 533 times more than that required for a 100 metric ton space elevator to reach the same altitude with a higher payload. Starship cargo capacity is significantly reduced to obtain GEO.

Rocket's fixed fuel capacity means that mass must be reduced to reach higher altitudes than LEO. Payload mass is reduced further to provide energy for travel to the Moon, Mars, or other locations beyond various Earth orbits. A Mars trip would reduce the cargo mass to 1/3 that of a LEO destination. Space elevators do not have these limits that rockets do. 100% of the mass from the Earth's surface can obtain GEO and beyond.

Power

The energy discussion was an important one. Many discussions and analyses bypass the energy discussion and determine the power required. Power is determined by the time the energy is expended. Changes to power are as simple as changing the velocity of the elevator. Power, P, is calculated by adding in the time variable to energy equation.

$$P = \left(m_{SE}[(2\pi/t_r)^2(r_E + h) - m_E g/(r_E + h)^2]\right)\ dh/dt$$

Power is linear with respect to mass of the space elevator and increases with increased space elevator velocity as shown in Figure 6. Velocities of 100km/hr to 1000km/hr were used to represent the trade space for eventually sizing the space elevator and its design goals. Other velocity trades are presented later in the paper.

Conversely the SpaceX Starship generates an estimated 270 Gigawatts of power at launch. Compared to a higher speed space elevator traveling at 1000 km/hr the peak power is approximately 275 Megawatts. This is 982 times less power required than SpaceX Starship. The Starship liquid methane and oxygen engines produce exhaust that is detrimental to Earth's atmosphere. The rocket-based solution for transporting the Mars mission will have a

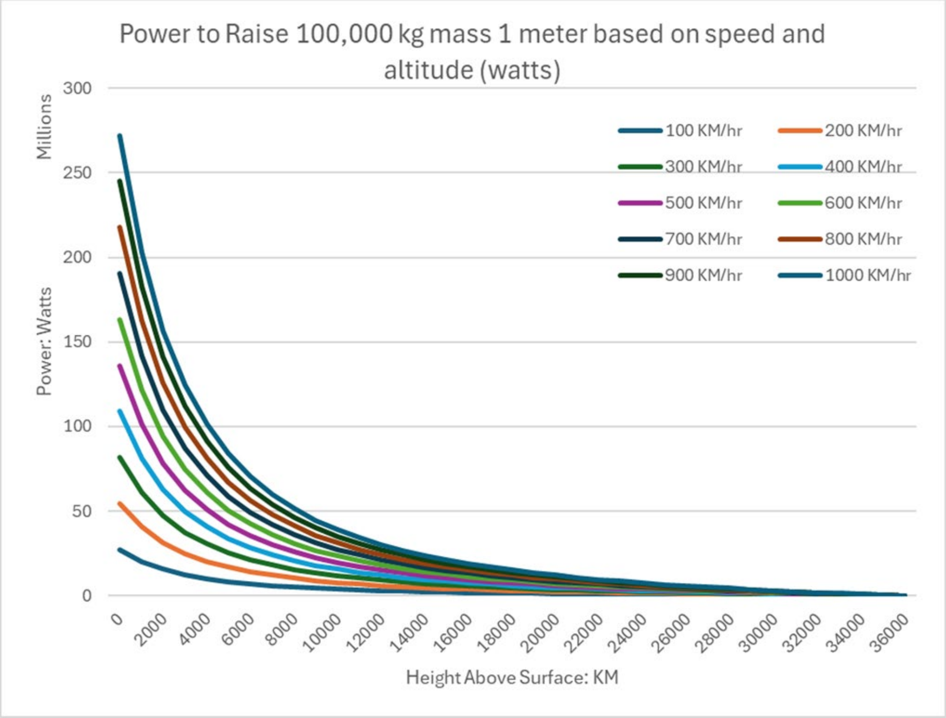

Figure 6 Power Required to Lift a 100 Metric Ton Space Elevator One Meter is Dependent on Altitude and Velocity of Space Elevator.

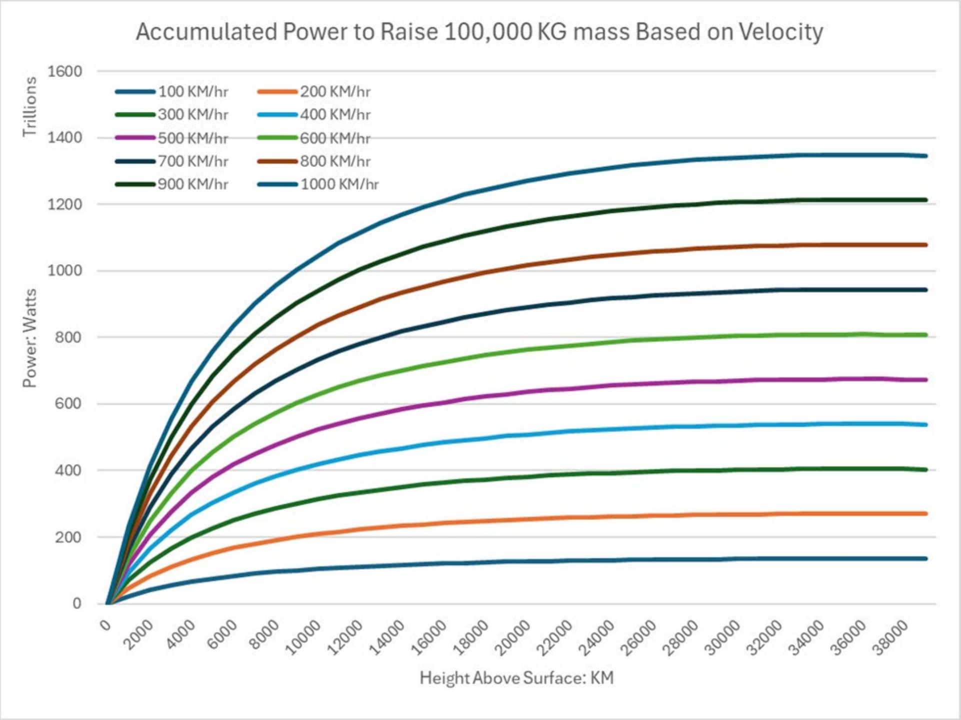

Figure 7 Accumulated Power Required to Lift a 100 Metric Ton Space Elevator One Meter is Dependent on Altitude and Velocity of Space Elevator.

tremendous impact on the Earth's atmosphere locally and perhaps globally.

The accumulated required power for a trip from the Earth's surface to GEO (Figure 7) can be staggering to those not used to large numbers in terms of power and energy. This is calculated by integrating the power from the Earth's surface to GEO.

$$P_{Accum} = \int_{h=0}^{h=max} (m_{SE}[(2\pi/t_r)^2(r_E + h) - m_E g/(r_E + h)^2]) \; dh/dt$$

These appear to be large numbers except when comparing them to a rocket solution. However, electric power is delivered to the elevator over a period of days versus minutes. The speed of ascent will determine the number of days to reach GEO. Personnel and cargo time considerations while in transit must be assessed to determine the overall elevator construction, speed, mass delivery capability, and energy and power requirements. A mission assessment will define the trade space for these considerations.

Mission Considerations that Drive Energy and Power Requirements

There are multiple goals to consider for sizing a space elevator: tether, transportation vehicle, electric power system, energy & power source, thermal management system, ground support facility, launch facility, and operational methods. All these systems together comprise the overall system architecture that once deployed will fulfill the daily mission needs for space settlement and space economy transportation to and from the Earth's surface to GEO and beyond.

Trade space is defined as a set of possible design options or system parameters for evaluating trade-offs between costs and benefits. A range of parameters is usually explored to determine if there is an optimal mix to balance the cost and benefits for meeting overall mission goals and objectives. Top-level parameters can include, but are not limited to:

- Cargo/Personnel mass required to ascend
- Volume requirements for high-density and low-density cargo/personnel
- Time to Reach GEO
- Energy and power for various total vehicle masses, maximum velocities, and number of active elevators on the tether at any point in time
- Technical and Economic considerations for a single ascent/descent
- Technical and Economic considerations for a Mission's ascent/descent
    - Moon settlement
    - Mars settlement
    - Space solar power
    - Asteroid mining supplies and returns precious metals to Earth
    - Total Space Economy support in transportation needs
    - Cargo & living creatures transportation differences.

Constant Power Supplied for Increased Velocity

Rockets can reach GEO quicker than the basic space elevator but require considerably more energy and power with less payload than a space elevator. The first study assumed that the total power delivered to the elevator would drop slightly as the elevator ascends through the Earth's atmosphere. This is due to atmospheric absorption of transmitted energy depending on the wavelengths of interest beaming from the Earth's surface. Beyond 100 km it is assumed that all energy hits the elevator's receivers.

Assuming the transmitted power remains constant at 27 MW from 100 km to GEO, the power can be used to increase the velocity of the elevator to reach GEO quicker than the current ISEC space elevator velocity of 200 km/hr. Neglecting any challenges and safety issues, the increase in velocity from the Earth's surface to GEO increases from 100 km/hr to over 70,000 km/hr, Figure 8. It is improbable that a space elevator can safely travel at these velocities on a tether. However, this analysis does provide an upper bound based on the assumptions.

Limiting Maximum Speed for Mission Safety While Reaching GEO Quicker

Considering the space elevator operating beyond Earth's atmosphere, the aerodynamic drag is negated, allowing higher velocities. Since the velocity is vertical, the forces are different from those of Earth-bound trains, and the limits can be expanded to increase velocity. A technically

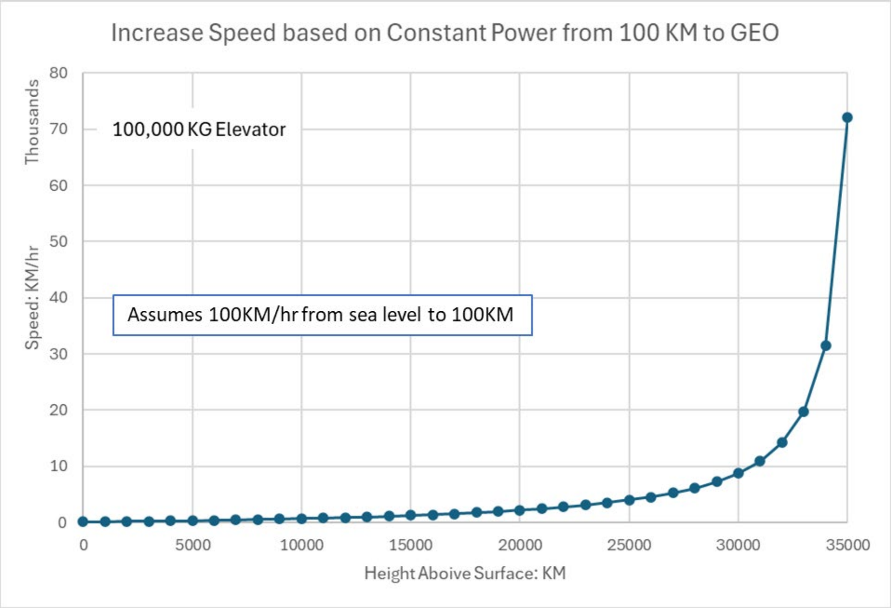

Figure 8 Constant Power Delivery to a Space Elevator Allows an Increase in Velocity to Reach GEO in Less Time

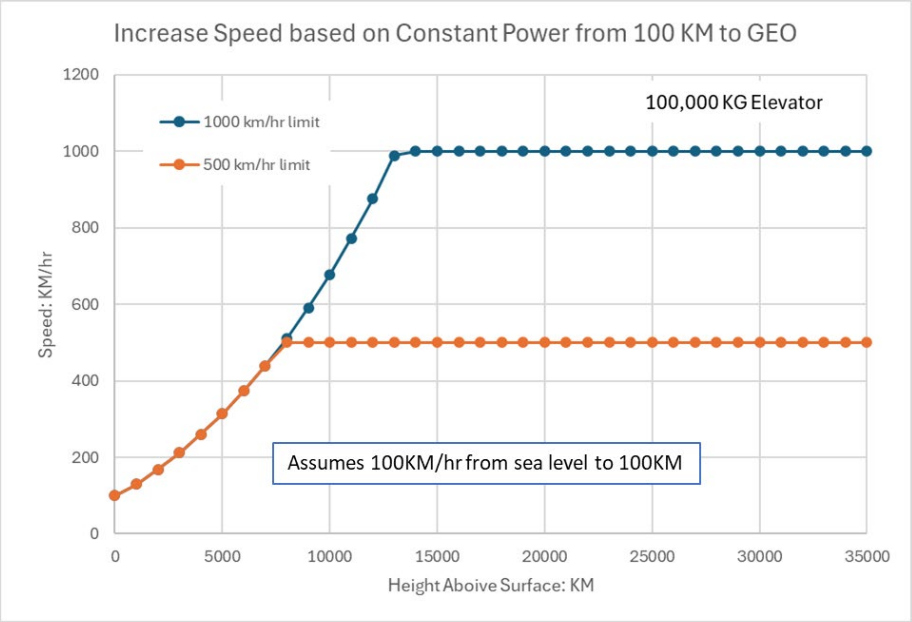

Figure 9 Velocity Limitations Must be Considered for Safety as Well as Timely Ascent to GEO

challenging, yet highly beneficial, approach would be to continue the constant power beyond 100 km until a velocity limit between 500 km/h and 1000 km/hr is achieved, Figure 9. The power would then be reduced to prevent the elevator from exceeding these velocity limits, Figure 10.

The power for various velocity profiles was calculated based on the above scenarios and the more classical constant velocities of 200 km/hr and 300 km/hr. It is noted that the constant velocity profiles require considerably more power below 5000 km above the Earth's surface than the reduced velocity with acceleration. If projected power is not an issue, then these velocity profiles can be adjusted based on

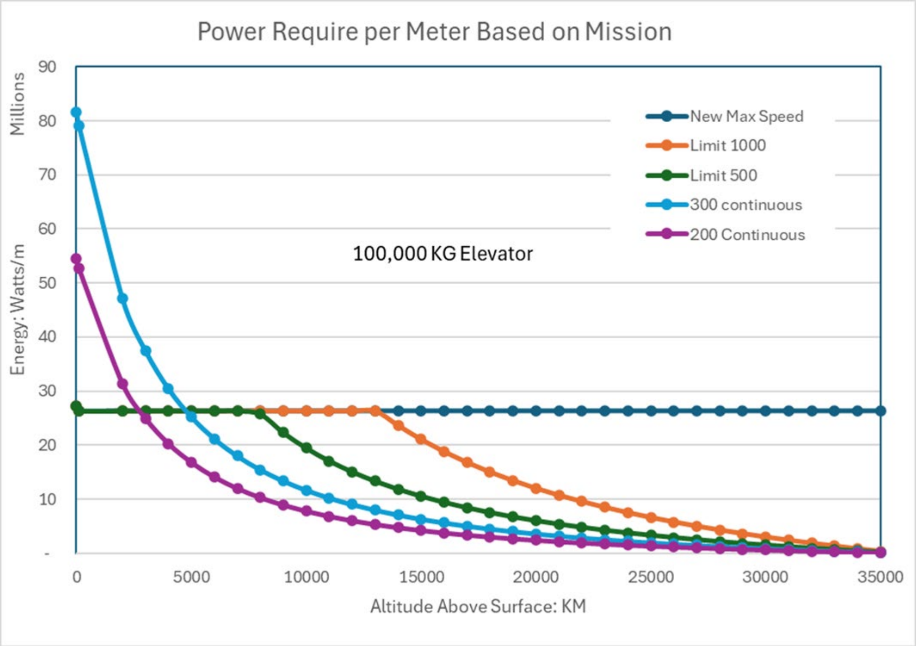

Figure 10 Velocity Limitations Reduces Power Requirements at Higher Altitudes

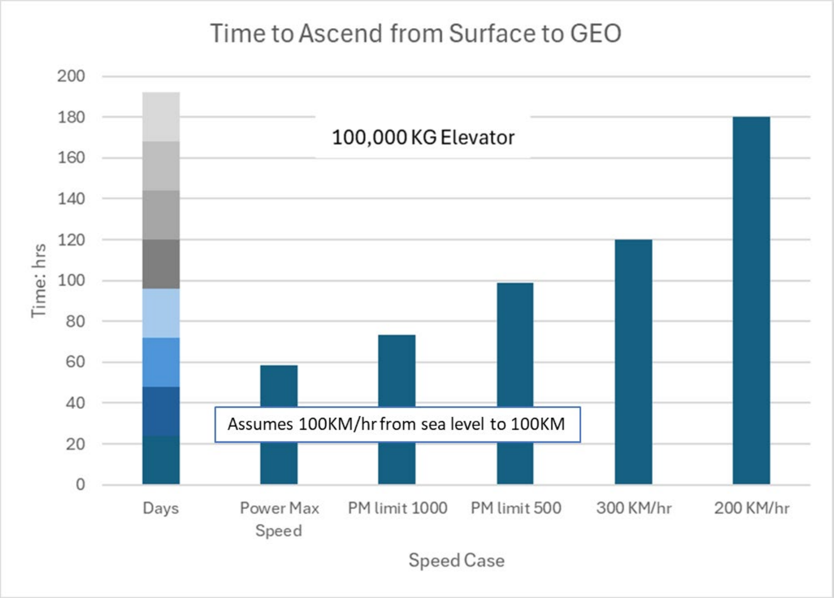

Figure 11 Velocity Based Missions Impact the Time Required to Reach GEO

available power. If, however, power projection is limited, the constant 200 and 300 km/hr constant velocity profiles may not be obtainable. The exploration of increased velocity was to reach GEO quickly for personnel and cargo considerations. It could also define the size of the elevators and the number of elevators on the tether at the same time.

Time to GEO Based on Velocity Profiles

The various velocity profiles were used to calculate the required time to reach GEO from the Earth's surface. The constant power, maximum velocity, and constant velocity profiles each take several days to reach GEO, Figure 11.

It is noted that the 1000 km/hr limit adds approximately 30% more time to the ascent than the unsafe Maximum speed scenario, which can reach over 70,000 km/hr. The 500 km/hr limit is approximately 70% more time to ascend than the unsafe maximum velocity profile. However, these are far superior to the additional days required for the 300 km/hr and 200 km/hr profiles. In addition, those profiles require additional power below 5000 km to maintain their velocity.

There is a benefit for a space elevator following a constant power profile until it reaches the maximum allowable velocity, which will be based on the technology that can be developed prior to deployment.

Rockets can, of course, obtain LEO very rapidly and eventually obtain GEO altitude, but must sacrifice payload mass by approximately 70%. Space elevators do not have this issue. If it can leave the Earth's surface with a specific mass, you can reach GEO.

The trade space for mass for the Space Railway^{TM} concepts is currently between 100 and 700 metric tons. SpaceX Starship may be able to eventually launch 250 metric tons to LEO but that would be reduce to approximately 85 metric tons to reach Mars. This is well below the goals for a Space Railway^{TM} elevator concept. A rocket may be able to get payload quicker to GEO but at a fraction of the payload of a Space Railway^{TM} train (SRT). This is like comparing a Ferrari to an eighteen-wheeler. It will get you there quicker but with limited trunk space. Space Railway^{TM} trains are the means for moving the mass required for space settlement and the space economy. This is also accomplished at 1/533 of the energy and 1/982 of the maximum power of a Starship that cannot meet the minimum payload of the smallest Space Railway^{TM} railcar.

Down-Earth Regenerative Power

The Down-Earth capability to bring back an unprecedented amount of cargo or personnel was argued by Griggs (Griggs, 2025a). One of the technical challenges he identified was the amount of regenerative power (power generated by using electric motors as brakes to control velocity, which results in the motors becoming generators). Regenerative power will now be discussed from a requirement perspective. The power generated must be used, stored, or transmitted. The efficiencies and waste heat that will be generated, depending on which approach is pursued and what system configuration is used, have too many variables to be discussed in this paper.

Regenerative power, not considering any inefficiencies, is the same as the ascending power required to ascend, except in reverse. The power generated per meter, Figure 12, is linear with respect to mass and is dependent on the velocity of the railcar.

Regenerative power at higher altitudes appears to be easily manageable. Whereas below 5000 kms it seems to be much more challenging if higher velocities are desired. This would suggest that the question of use, store, or transmit would be dependent on the quantity of regenerative power generated and the altitude that is generated. Regenerative power system and architecture solutions may be an adaptive system mode depending on circumstances.

One concept could be to just dissipate the power as heat, but that would be a tremendous amount of heat and a waste of gravitationally generated power (essentially free power). The accumulated amount of power generated can be in the quadrillions of watts, Figure 13, depending on the mass of the railcar and the velocity with which it is travelling. This is tremendous amount of power that could be put to beneficial use if stored or transmitted to systems that could use it.

Limitation may exist in the conditioning, storage, or transmission of regenerative power. It is suggested that this is an area for technological development for space elevators. The solutions for which may have other

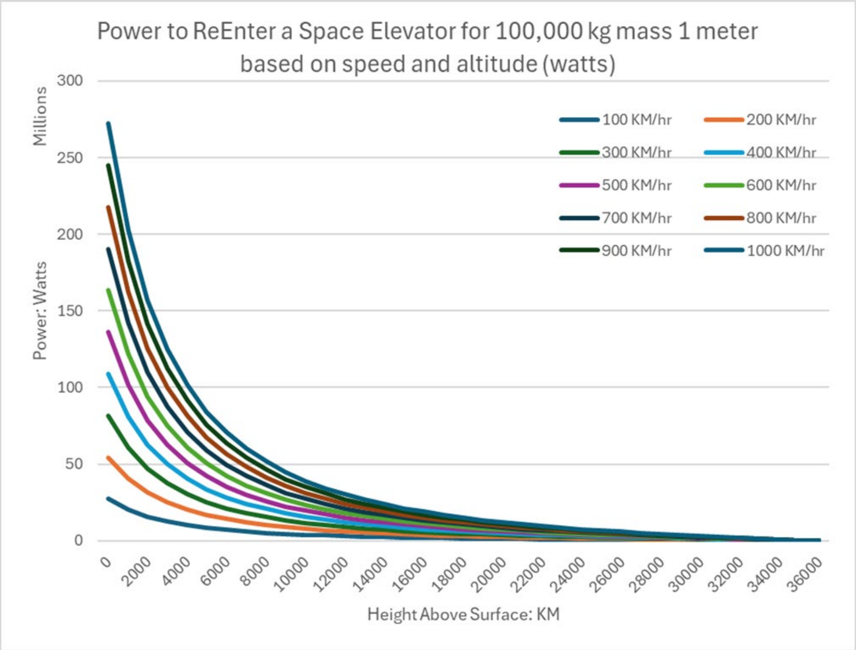

Figure 12 Power Management Must be Considered for Down-Earth Missions

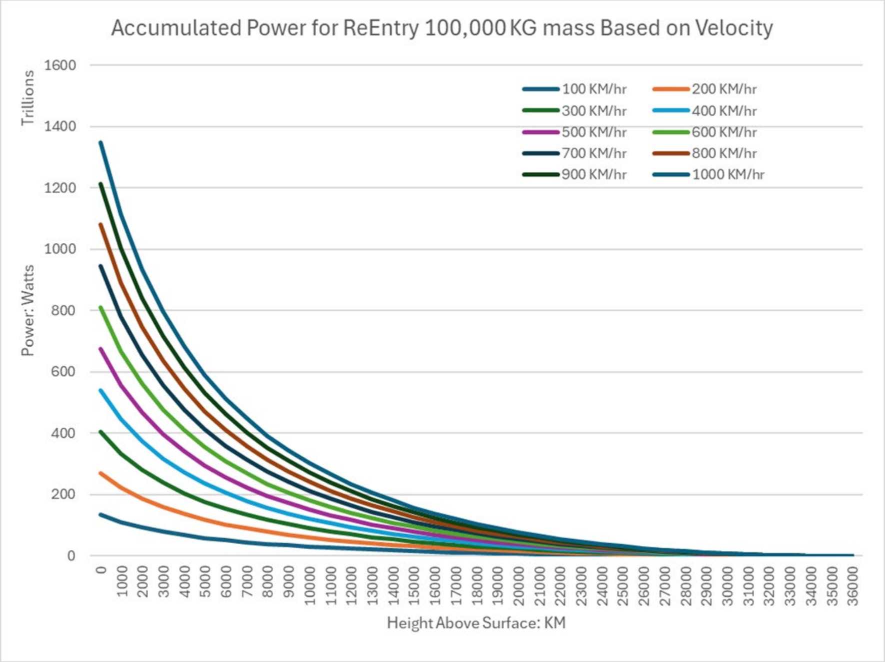

Figure 13 Total Power Available for Off-Elevator Uses is Tremendous

applications in other industries. Another solution would be to limit the velocity of descent to reduce regenerative power use, storage, or transmission limits.

Limiting Maximum Speed for Mission Safety While Reaching Earth's Surface Quicker

Use, storage, or transmission solutions may have limitations depending on available technology and operational concepts upon space elevator deployment. An operational concept for regenerative electric power system limitations would be to limit the velocity while descending.

An analysis of the power dissipation limitation of 10 to 50 megawatts per meter was conducted (Figure 14). Reduced velocity below the upper target of 1000 km/hr is created when the rejection of 10 MW/m is the limit. This occurs at over 20,000 km and will have an impact on

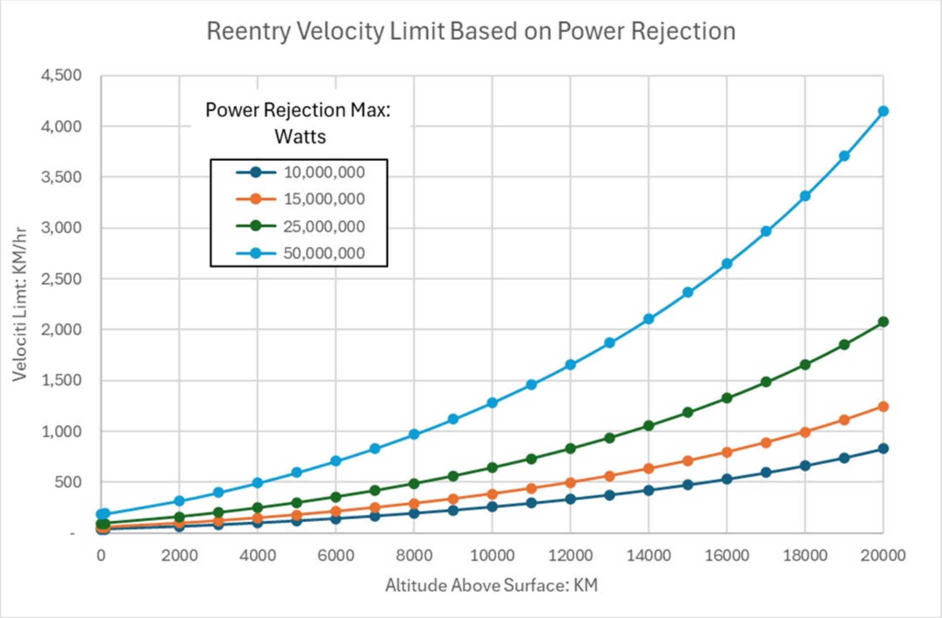

Figure 14 Power Rejection Limits May Reduce Allowable Maximum Velocity

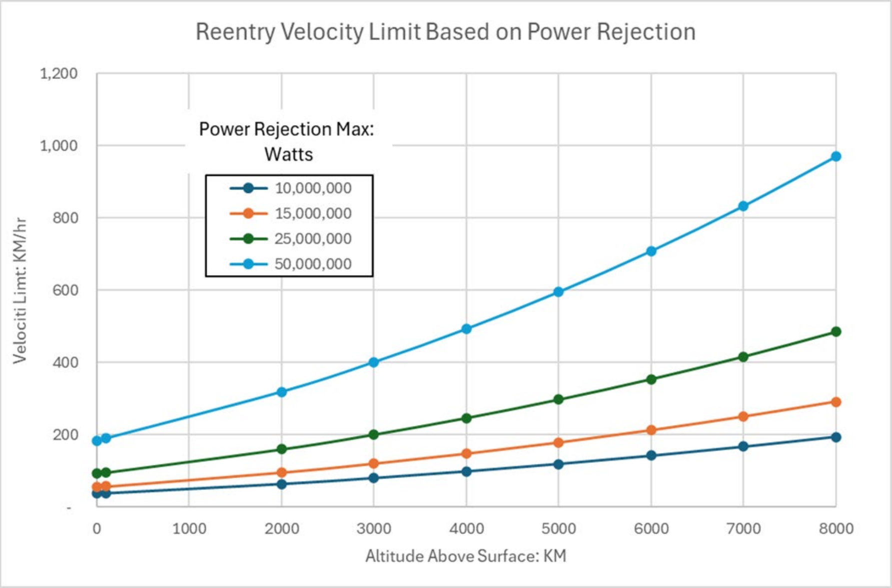

Figure 15 Power Rejection Limits May Increase Time to Descend Due to Velocity Limits

the time to descend for a space elevator. Velocity flexibility and reduced time to descend create a technology development goal of power dissipation of over 50 MW per meter. The higher the better for the margin of safety and reduced descent times. Figure 15 provides a finer detail of the velocity limitations closer to Earth's surface.

Reducing the time to descent would require more aggressive power rejection than 50 MW per meter at lower altitudes. A descent maximum velocity would be beneficial until an altitude of approximately 500 km, after which a reduction in velocity to 100-200 km/hr would be warranted for safety to prepare for landing on Earth's surface. Figure 16 provides the magnitudes of power rejection required to

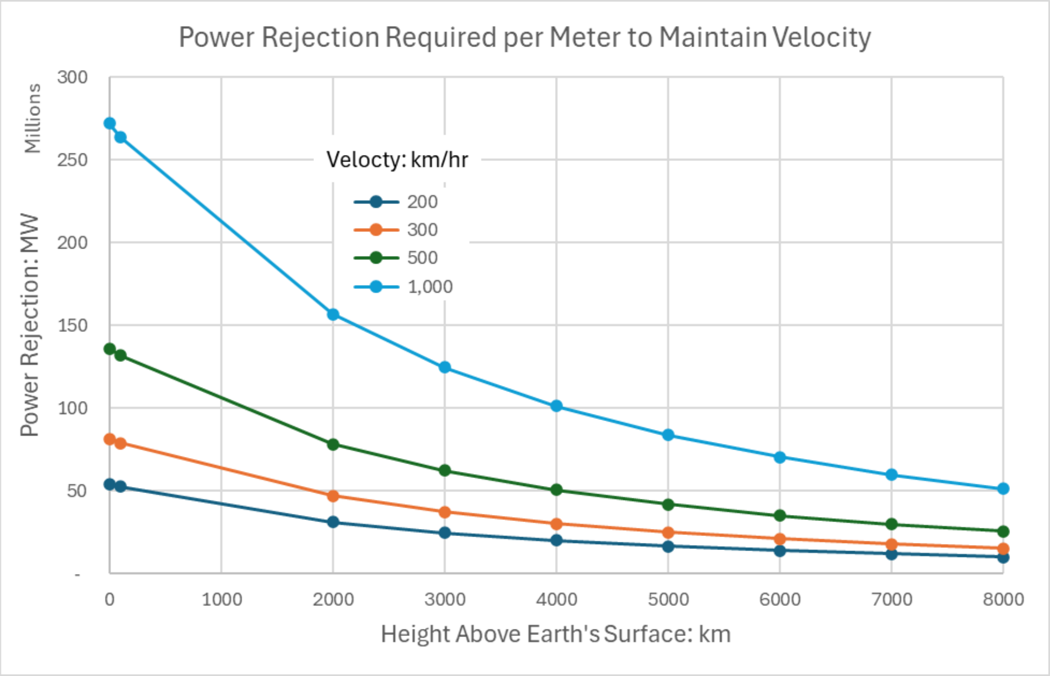

Figure 16 Power Rejection Limits May Increase Time to Descend Due to Velocity Limits

maintain the desired descent velocity, which can be up to five times greater than already discussed.

Challenges for Energy and Power Systems Development

There are several challenges with developing an energy and power system for a heavy-lift space elevator. The three considerations examined in this paper are cultural aspects of the development community, non-firm requirements, and program management for long-term development utilizing capital market funding. The latter two are uncertainty-driven based on design flexibility and funding availability. However, the culture of the engineers and scientists who would be developing the technology may be the most challenging to overcome.

Cultural Considerations that will Impede Technology Development

The aerospace industry manages power levels in terms of watts, tens of thousands of watts, several hundred thousand watts, and up to a megawatt on several more-electric large aircraft. The technical challenges for energy and power systems pertain to the magnitude of energy and power that needs to be managed. Historically, different magnitudes of power, operational duty cycles, and special operational considerations defined the process by which aerospace technology developers created new systems. The aerospace culture developed rules of thumb, intrinsic knowledge, and corporate knowledge over decades and numerous aerospace systems.

Multi-megawatt or gigawatt systems are foreign to aerospace technology developers. Culturally, their first response will be to state that it cannot be done due to the magnitude of the power needed. This reaction will be based on the energy and power requirements that will be far beyond the developed rules of thumb, intrinsic knowledge, and corporate knowledge. Other industries, such as ground-based electric power generation and the electric power grid, manage gigawatt loads in steady-state conditions with occasional excursions to higher loads. Engineers are experienced with gigawatt power, just not in the aerospace industry.

However, aircraft and space environments differ in many ways from ground-based electric power equipment. Heat rejection techniques vary significantly, and air is an excellent insulator at ground-level pressures. However, at high altitudes and in the vacuum of space, the insulation properties of air cannot be counted on. The altitude of approximately 27.5 km has the lowest breakdown voltage, of approximately 350 volts. At that voltage or above, air will turn into a plasma (corona effects), and electric power equipment will experience failures if not properly insulated.

A new cultural environment must be created that integrates experienced aerospace engineers with experienced ground-based engineers in the high-power electrical industry. This integration into a new culture is to ensure cross-pollination between the various areas of expertise that will produce solutions for space elevator energy and power technical needs. Initially, creative tension should be expected and encouraged without the team digressing into destructive behaviors.

The energy and power specialist team must also not segregate itself from other technological development activities. They must be part of the overall architecture and embedded with the other specialists in thermal management, tether design and manufacturing, railcar design, electric propulsion technologies, and operations. All disciplines are required to be a part of an integrated solution.

Requirements for a Heavy-Lift Space Elevator

The resulting requirements for energy and power must be based on a top-down approach. The daily launch and recovery (down-Earth) of space elevators based on mass, volume, and the desired timeline of ascent and descent sets the overall system and architecture requirements. Griggs (Griggs, 2025a) argued that the initial operational daily mass should be 1000 metric tons, both outbound and down-Earth.

This creates a trade space for the architecture, which includes:

- initial operational capability,
- the initial number of tethers,
- initial railcar types, capacities, volumes, and speed limits,
- a build-out plan for additional tethers, and heavier overall tether capacity for the number of railcars and overall railcar total mass on the tether,
- the energy and power management architecture,
- thermal management solutions,
- Earth surface interface infrastructure

The architecture includes long-range considerations to ensure initial solutions do not interfere with growth or future solutions.

The initial energy and power system targets solutions to meet initial and future architecture requirements. The top-down approach is used to create a trade space for various tether, railcar, energy, and power systems, and thermal management solutions. Multiple combinations of solutions will require an initial cost-benefit analysis together with project growth options to ensure an optimal solution is pursued. The energy and power system requirements are tied to the overall system and architecture solutions but require focused efforts on current and future technology development. The electric energy and power system requirements must consider, but not be limited to:

- Energy & Power per Space Elevator Dependent on:
  - Mass of cargo/personnel
  - Empty mass of space elevator
  - Velocity/velocity vs altitude profile
  - Time limit to GEO, or GEO to surface
- Architecture definition will be based on:
  - Current state of the art for energy & power
  - Expectations of future timeline energy & power capabilities
  - Total systems solutions that include all equipment and inefficiencies
- Science and Technology development needs
  - Mission needs will drive overall space elevator capability, which will drive overall architecture
  - Overall system architecture will drive science & technology development

Architecture, systems, and components need to be developed for the selected concepts that meet the requirements and provide solutions in the desired trade space. Technology development can have significant and minor challenges. The programmatic risk and risk management plan must have enough detail to manage the risk and identify performance, schedule, and funding trigger points where alternative paths must be pursued.

Programmatic Challenges for Long-Term Development

The energy and power technologies for a heavy lift space elevator will pursue solutions far beyond the current state of the art. Technology development goals should be viewed as obtained in success-oriented steps. Aerospace technologies can take decades to develop the desired attribute goals to meet a designated mission or application. This poses a challenge for using capital market funding, which requires a more rapid return on investment.

As technology matures, the desired attributes become closer to the final goal of the technology development process. Developing technologies should be assessed for applicability in other industries, and at what attribute level might that industry be willing to adopt the technology. It may not be the same level as the space elevator, but it still has value in another industry. Early spin-offs into other industries can produce considerable desired revenue for financing the further development of the technology towards the space elevator goals.

Program management techniques and documentation of technology needs, technology risks management, project and program management, an integrated master plan, and an integrated master schedule with all projected funding needs and potential funding sources are essential for managing all the development activities and funding sources. Government funding sources should also be considered but their timelines and goals may be different than those needed for a heavy-lift space elevator.

Summary: Energy and Power for a Heavy Lift Space Elevator

Energy and power requirements were generated for a heavy-lift space elevator. The current heavy-lift trade space is between 100 and 700 metric tons. Calculations were based on a one-hundred metric ton Space Railway^{TM} railcar. Equations for energy and power have linear relationships to the mass of the railcar. Thus, energy and power for vehicles with more mass can be multiplied by the mass fraction for the one-hundred metric ton values.

Electrical energy and power are assumed to be the source for propelling the space elevators from the surface of the Earth to GEO or beyond. The magnitudes of electrical energy and power are far beyond the norm of the aerospace industry. This will require new components, subsystems, systems, architectures, and operating methods that are new to the aerospace industry. However, there may be opportunities for cross-pollination with technologies from other industries that can be modified for space use. Although the electrical energy and power magnitudes are large compared to typical aerospace electric power systems, they are less than 1% of those of chemical rockets, which have lower payload capability.

Down-Earth capability of returning large masses of wealth from space will generate considerable regenerative power that must be managed. Down-Earth velocity has a linear relationship with the regenerative power generated. Operational management by reducing velocity to lessen the power generation rejection requirement is a possibility, but it increases the time required to reach the Earth's surface from GEO. Alternatively, technology development to use, store, or transmit higher energy and power levels that have not been previously explored for aerospace would allow more rapid descents and reduce the time of GEO to Earth transits.

Challenges were identified in the development of the technologies required to operate a heavy-lift space elevator. They include cultural, non-firm requirements, and long-term program management from multiple funding sources.

Follow-on studies and assessments must include more detailed requirements, operational scenarios, and potential technologies and equipment solutions that include projected inefficiencies.

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