Energy and Power Requirements for Heavy Lift Space Elevators

Up or Down We Must Get Used to Large Numbers

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2025 International Space Elevator Consortium

Viable Space Settlement & Space Economy

- Initial Outbound Target Goal of 1 million KG per day
  - Support Five Basic Missions
    - Moon
    - Mars
    - Solar
    - O'Neill Colonies
    - Sunshade
  - Launch to other places in the solar system
  - Large-scale GEO space manufacturing

- Initial Earth-bound Target Goal of 1 million KG per day
  - Large-scale GEO space manufacturing
  - Bring back wealth from space (asteroid mining, etc.) to pay for settlements
  - Space Tourism

Requirement Generation Considerations

Goal: 1 Mkg up and down every day for Space Settlement and Economy

- Rocket-based and reentry vehicle transportation from and to Earth is inadequate for settling space and supporting a beyond LEO Space Economy
- Trillions in Rocket/Reentry vehicle Transportation Costs Require tether-based solutions with low variable cost
- Electric-based solutions appear to be the most promising for Space Elevator concepts
- How much electric power is required for single space elevator
- Does the Electric Energy and Power requirements define the solution space for number of space elevator launches and recoveries per day
- What Architecture fulfills this goal?

Energy and Power are Required to Overcome Vertical Forces

- Vertical Forces:

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

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

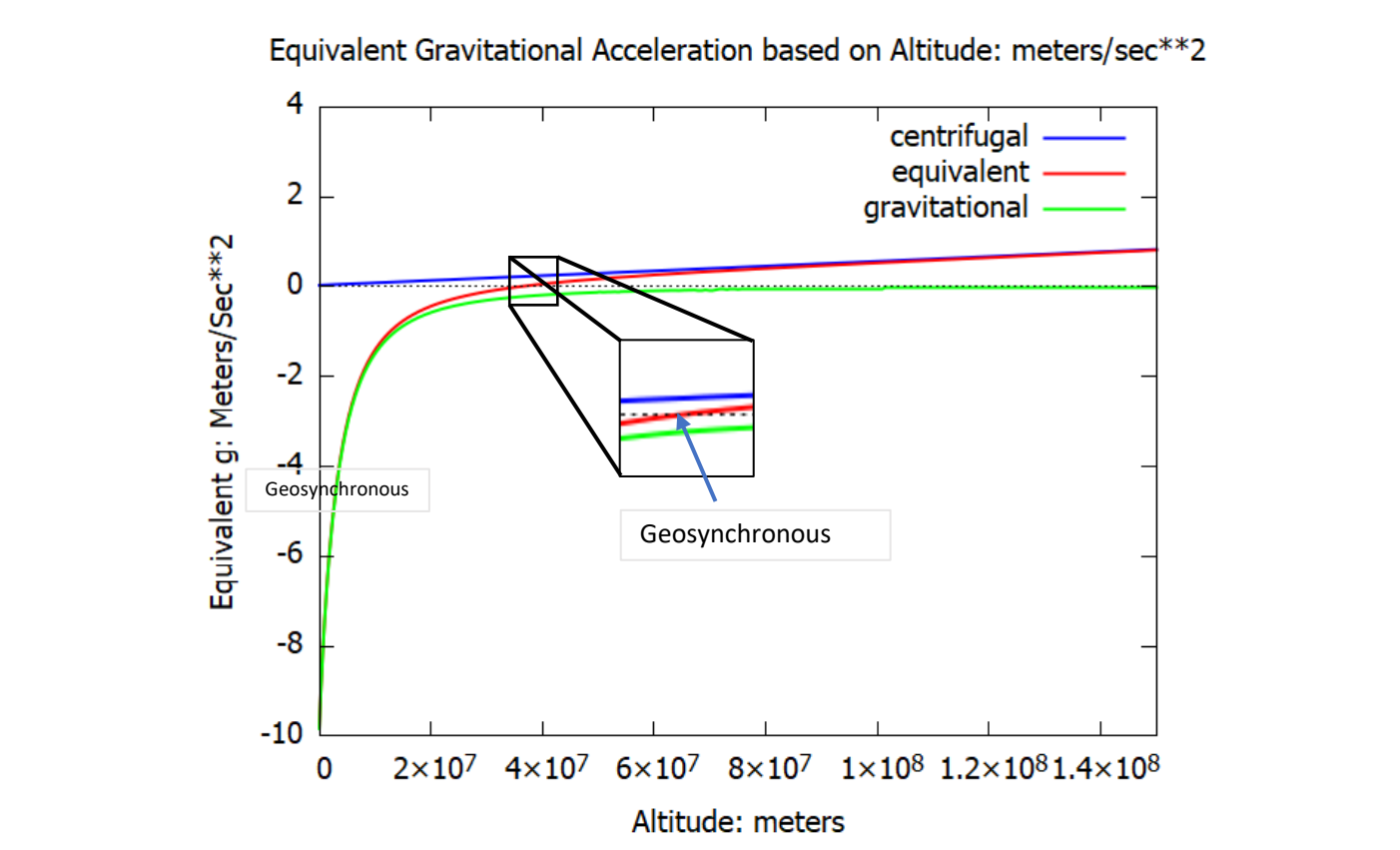
$$Force\ Equivalent = m_{SE}[(2\pi/t_{revolution})^2(r_E + h) - m_E g/(r_E + h)^2]$$

$$Gravitational\ Equivalent\ Acceleration = [(2\pi/t)^2(r_E + h) - m_E g/(r_E + h)^2]$$

Forces are Linear with Mass of Space Elevator

Vertical Forces Acting on Space Elevators

- Equivalent Gravitational Acceleration (EGA)



Energy and Power Require for Vertical Ascent

- Energy & Power Equations:

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

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

$$Accumulated\ Energy = \int_{h=0}^{h=max} \left(m_{SE}\left[(2\pi/t_{revolution})^2(r_E + h) - m_E g/(r_E + h)^2\right]\right)\ dh$$

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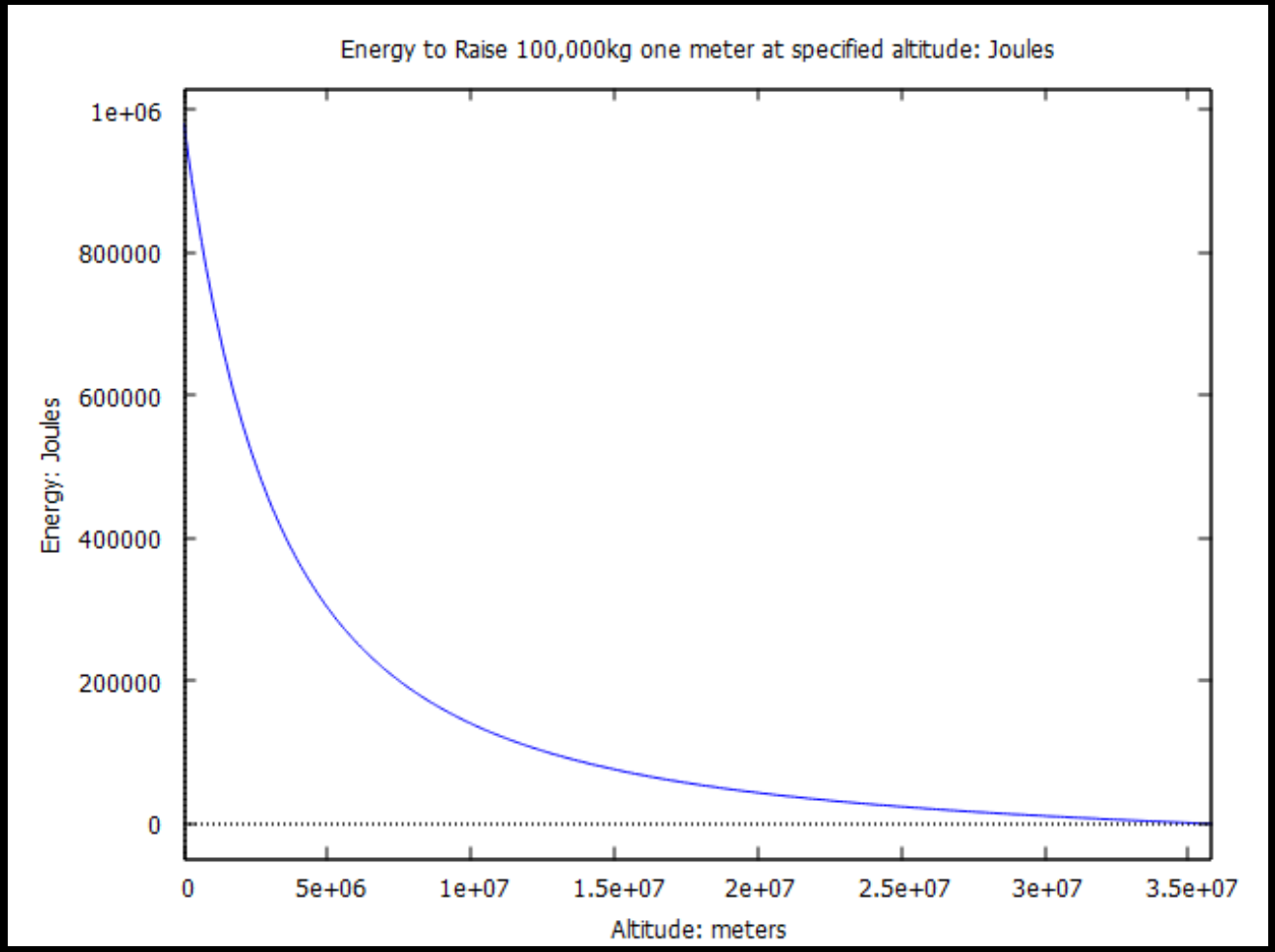
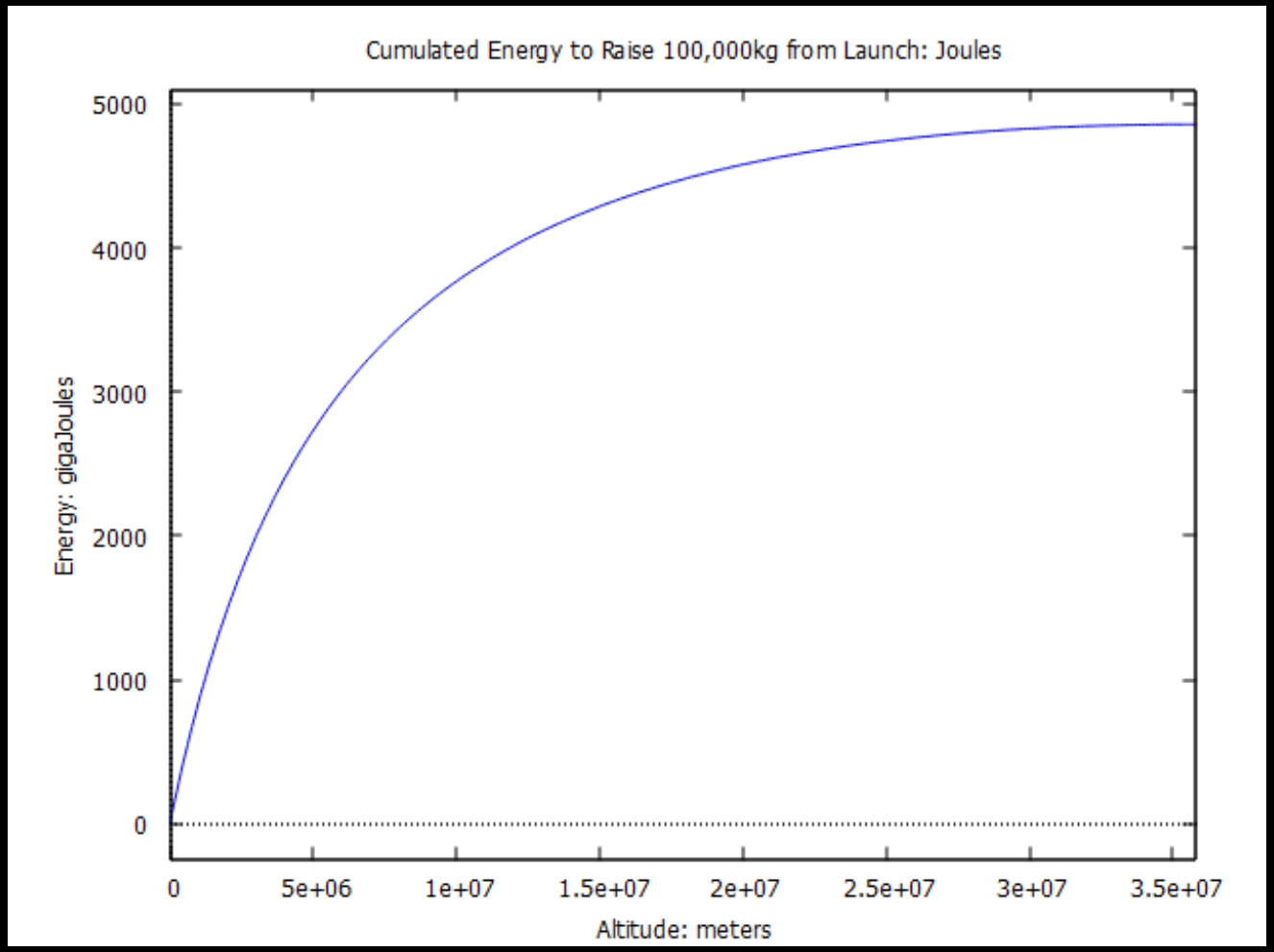
Energy & Power are Linear with Mass of Space Elevator

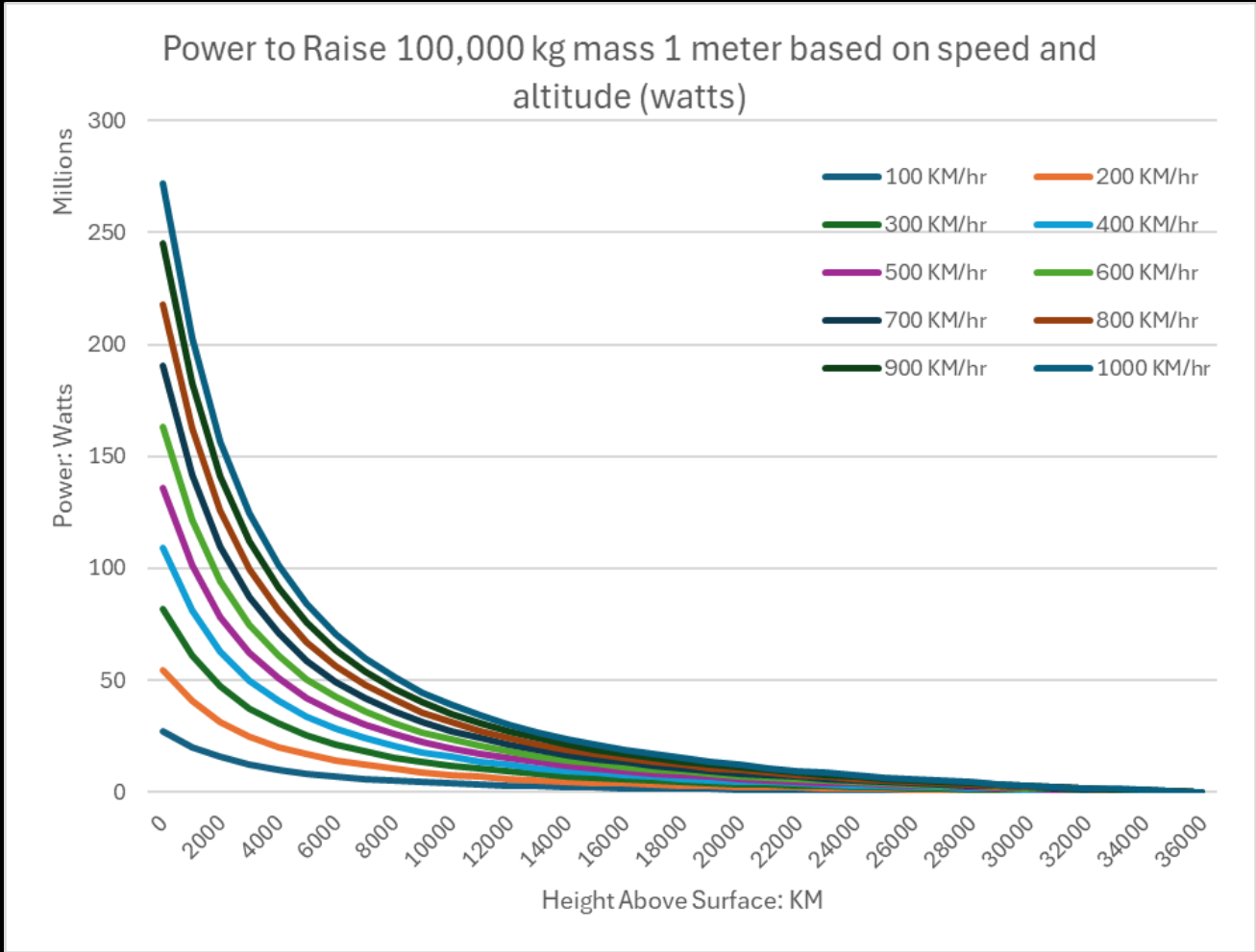
Energy Required to Raise Mass is Altitude Dependent



Accumulated Energy to Raise Mass Drastically Reduces as Its Approaches GEO



Power To Raise Mass is a Dependent on Altitude and Velocity



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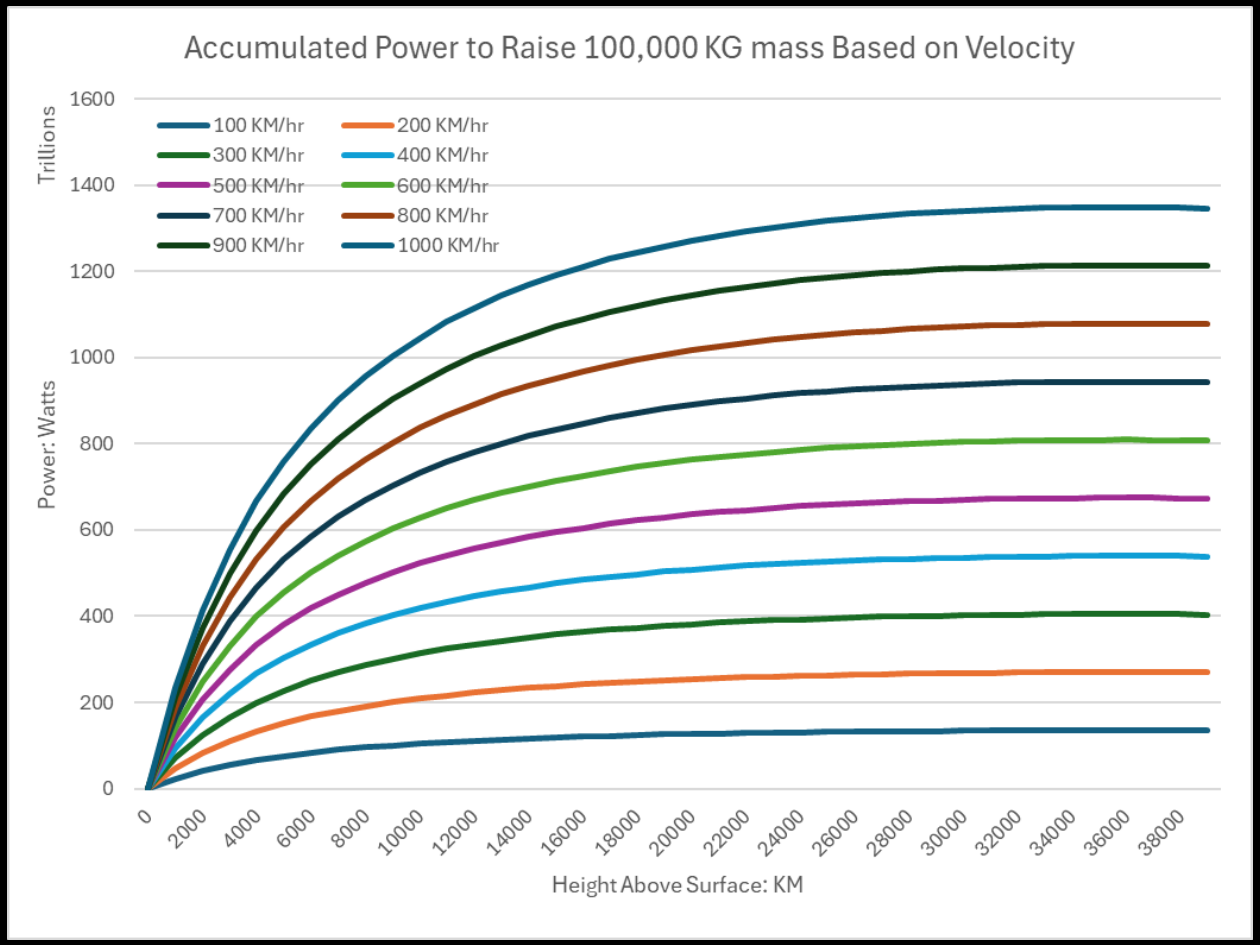
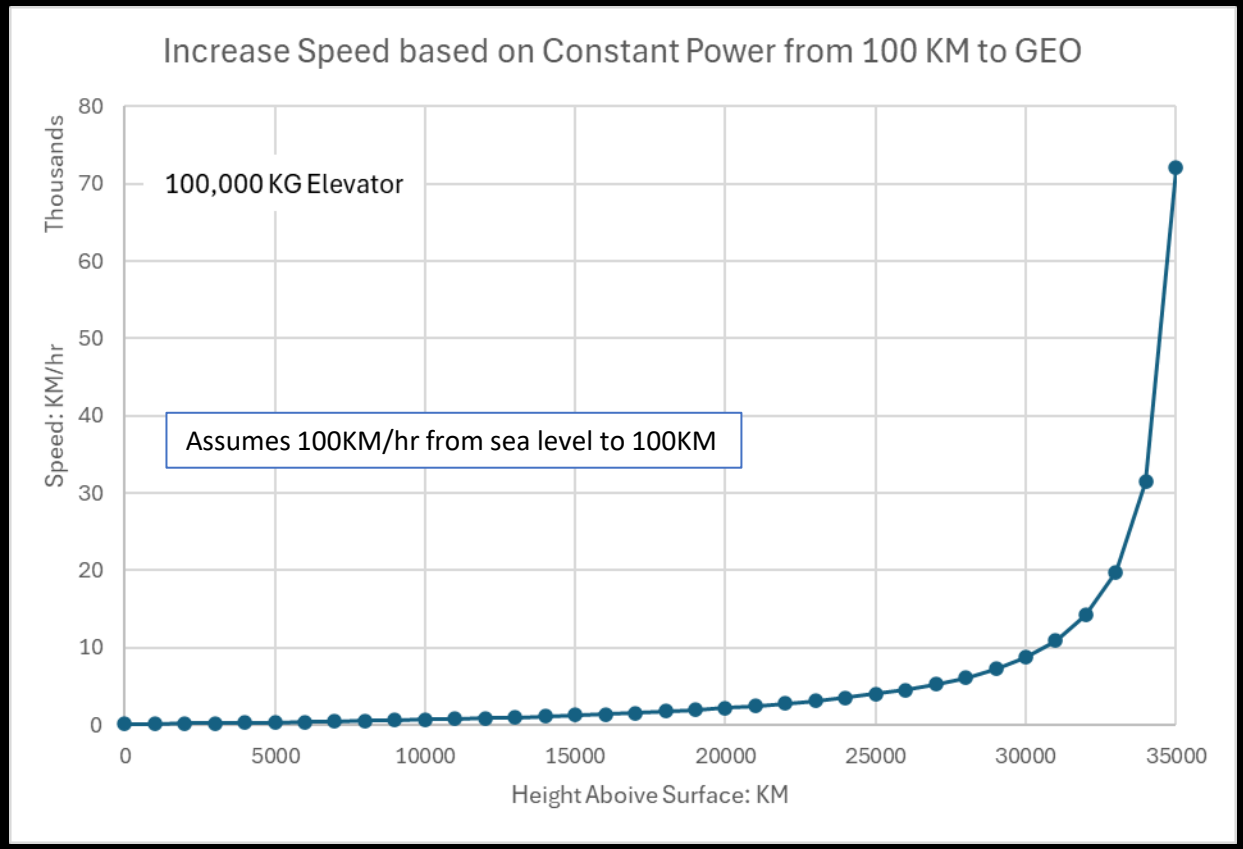


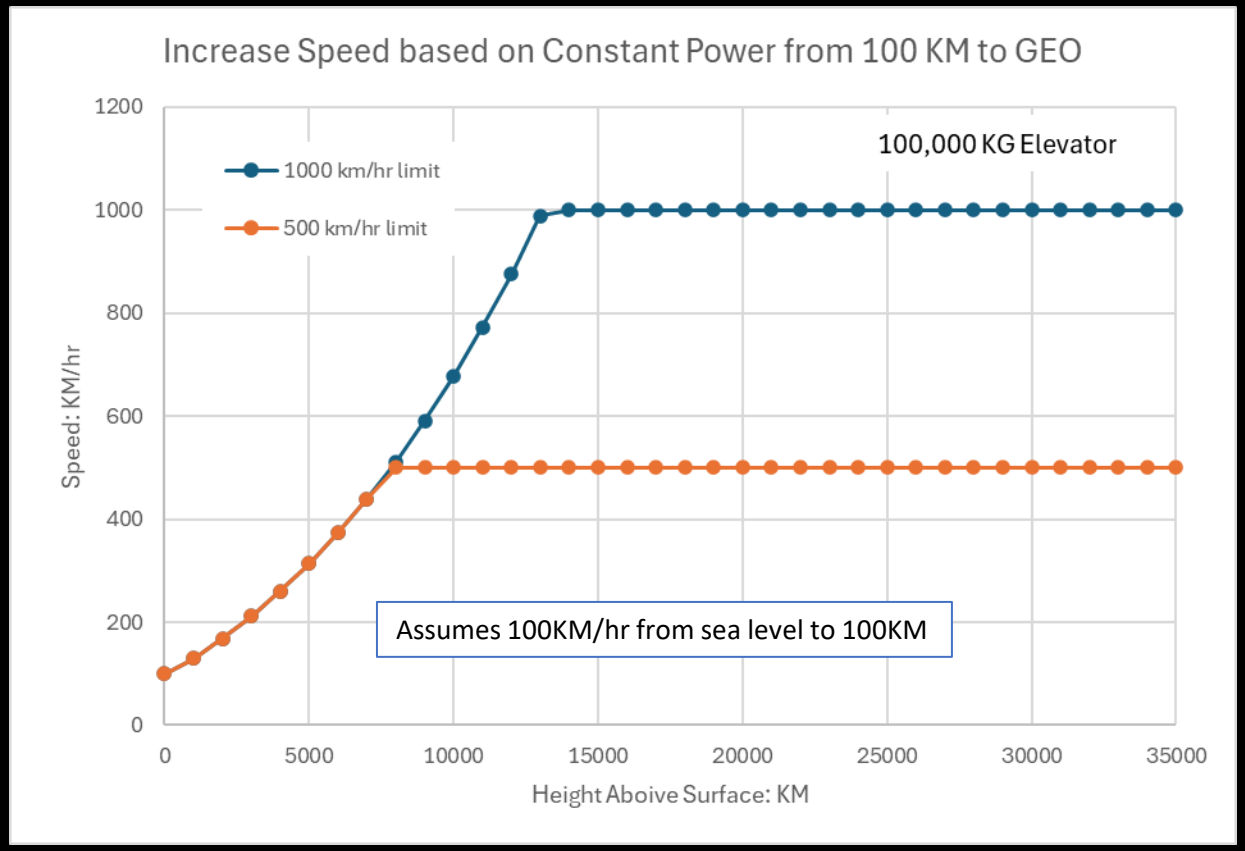
Mission Considerations

- Time to Reach GEO
- Cargo/Personnel mass required to ascend
- Energy and power for various total vehicle masses and maximum velocities
- 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

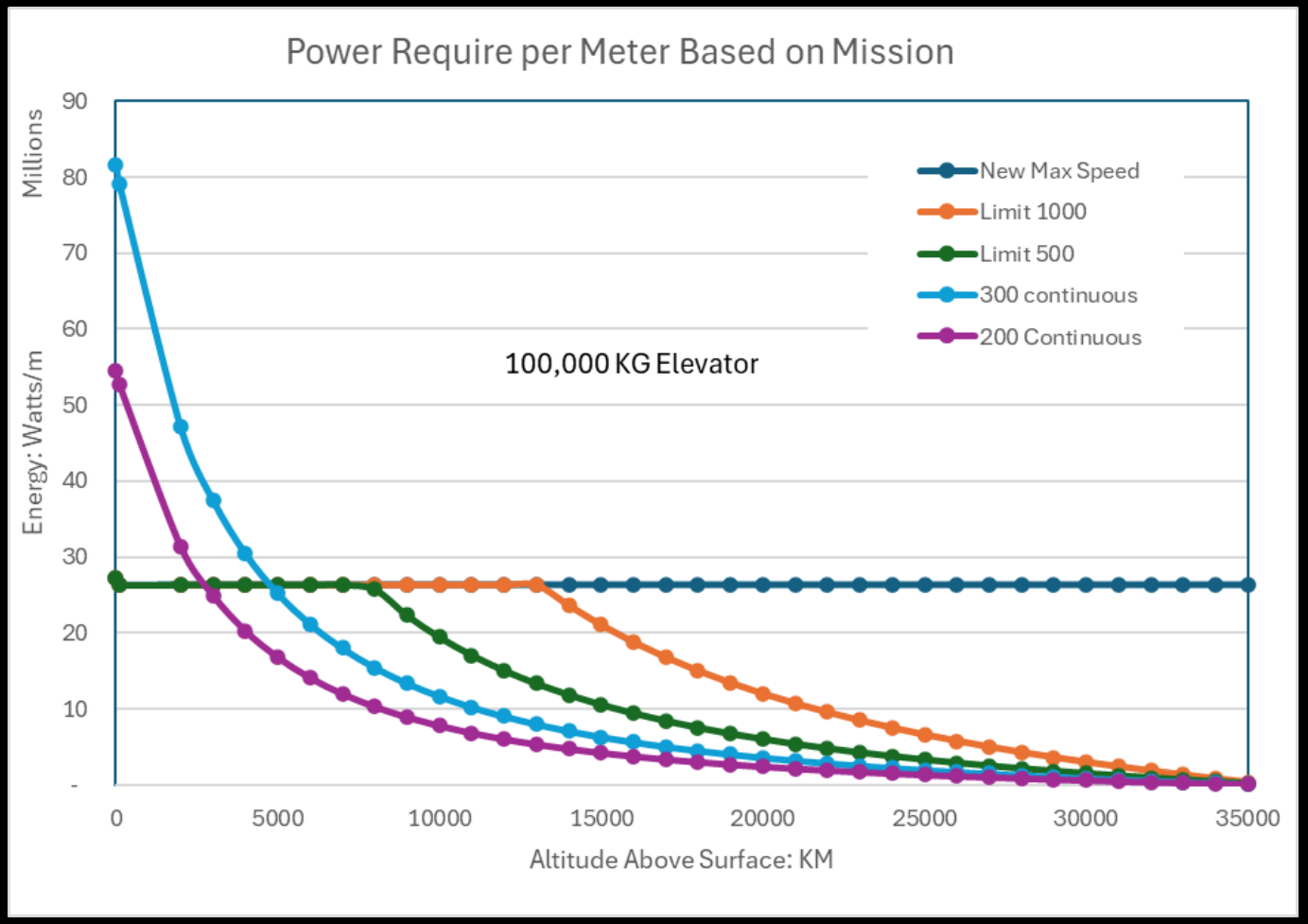
Constant Power Consumption Allows for Increased Speed



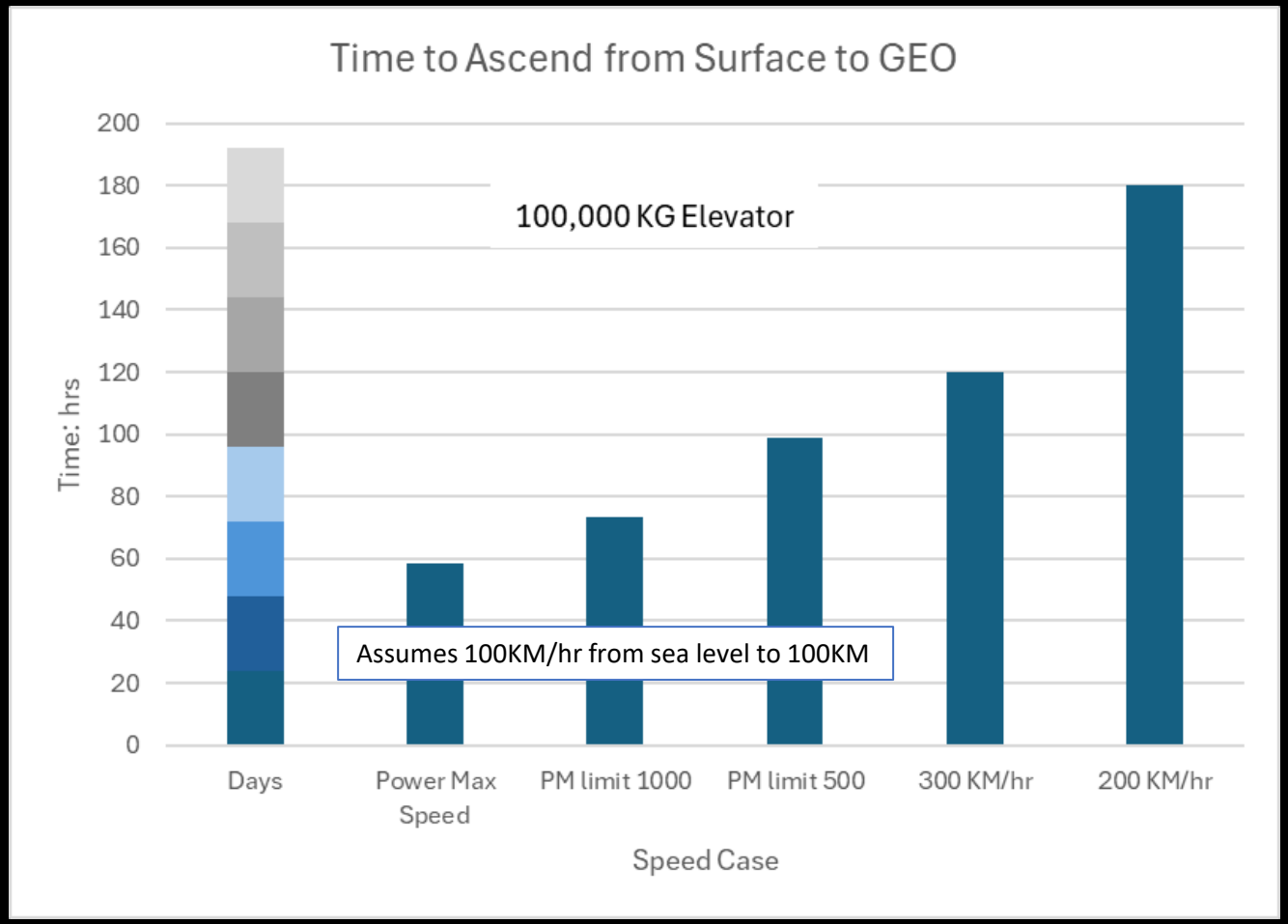
Constant Power / Maximum Velocity Limitation Profile



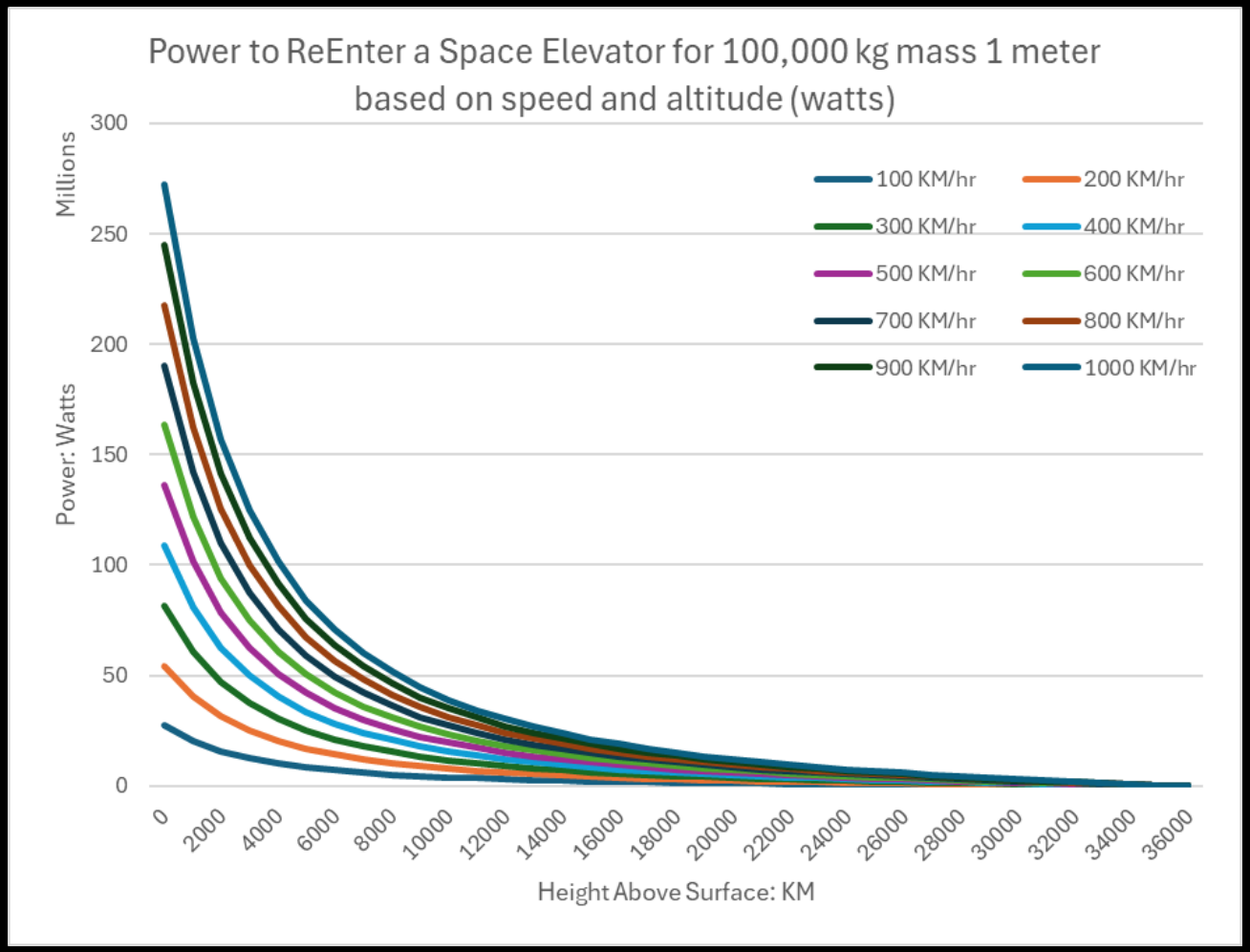
Power Required for Various Mission Profiles



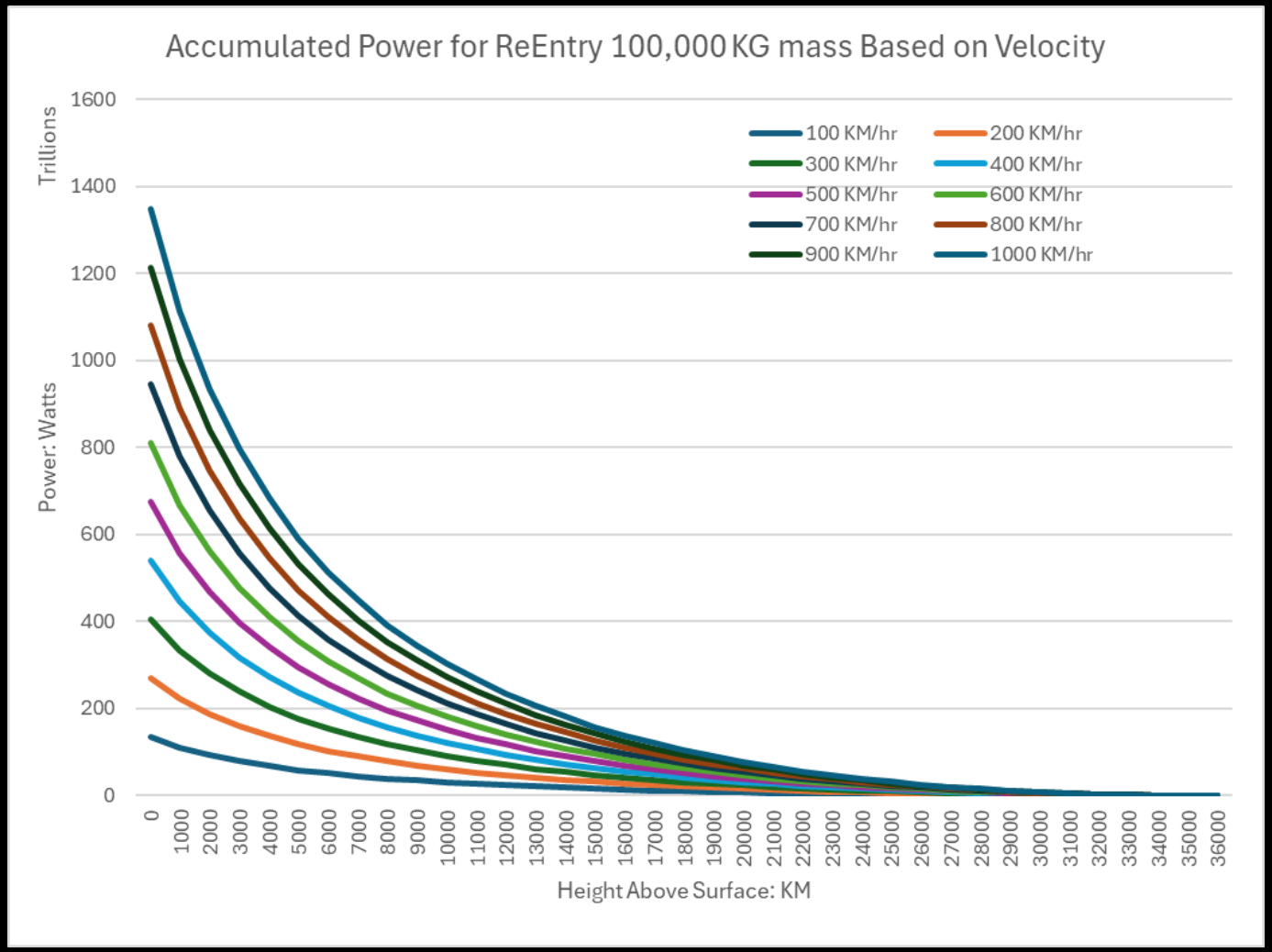
Maximum Velocity Limitation Profile Ascent Timelines



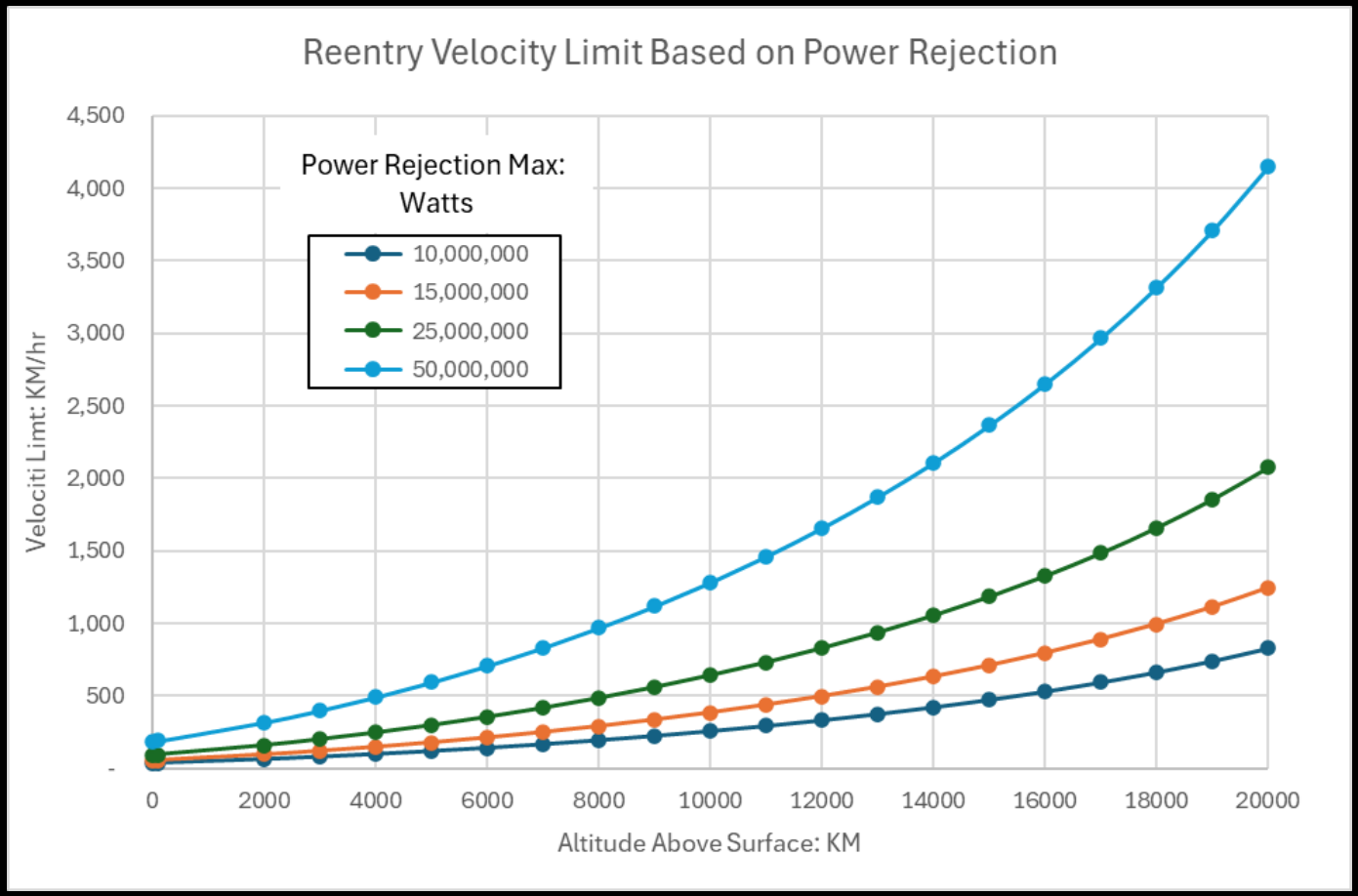
Power To Absorb Upon Reentry of a Space Elevator is Dependent on Altitude and Velocity



Reentry Mission Reentry Power Absorption / Transmission Concern



Reentry Velocity Limits Based on Max Power Rejection



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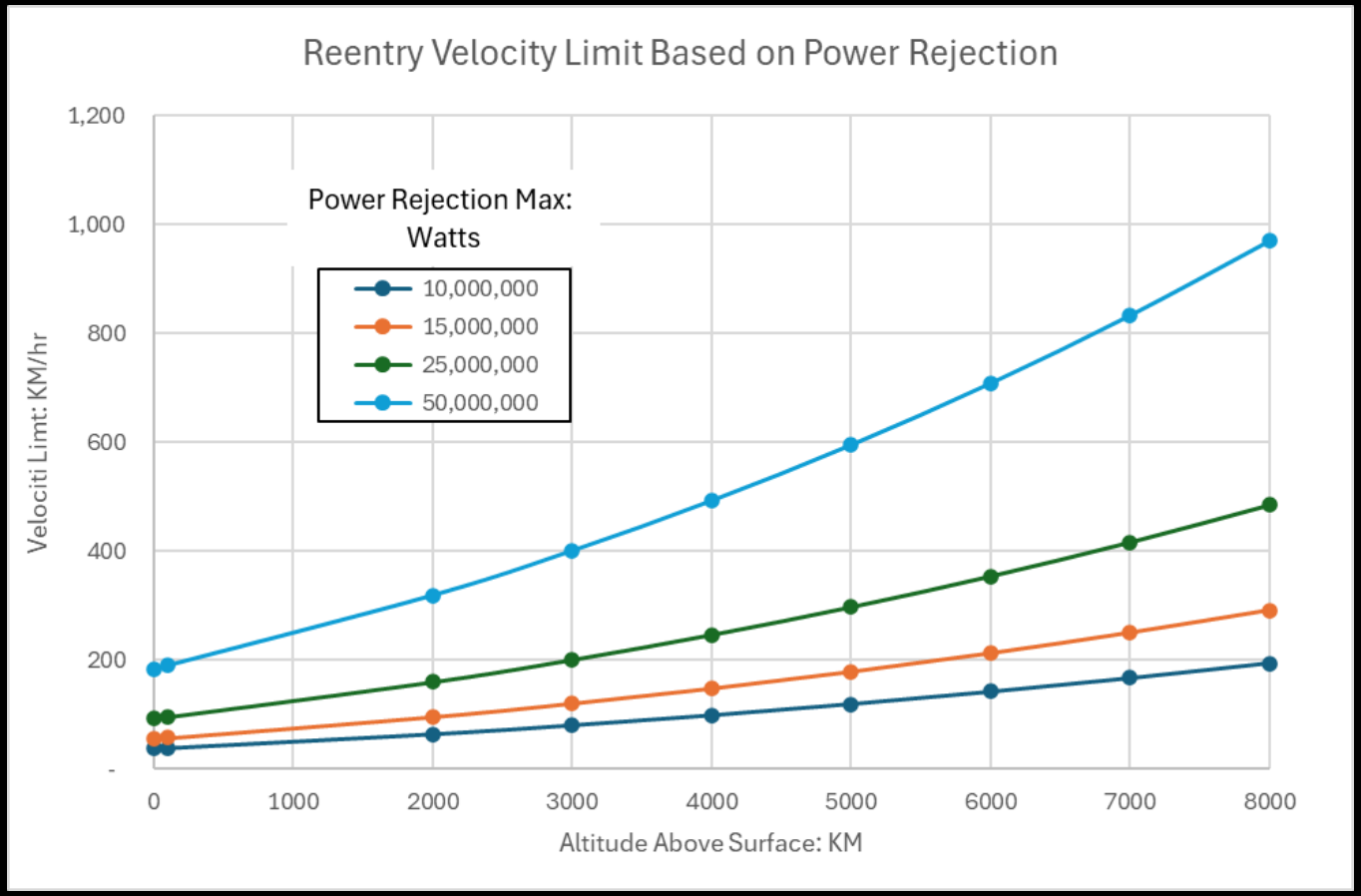

Initial Assessment of Energy & Power

- 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
- 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

Technical Challenge to Space Elevator Community

- Down-Earth gravitational forces generate considerable regenerative electric power
  - How to manage the electric power generated (use, store, or transmit)
- Inefficiencies in electric power system can create considerable waste heat that must be managed
- Safety issues with down-Earth failure modes
- What is the best vehicle design for transporting tons of precious metals
- What new technologies are needed

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