G-Lab

An ISS Co-Orbital Free-Flying Gravitational Biology Laboratory

33rd Annual Meeting of the American Society for Gravitational and Space Research
October 25-28, 2017

The Space Studies Institute

Princeton Professor Gerard K. O' Neill founded SSI in 1977 with the hope of opening the limitless resources of space to humanity.

Our mission is to access the energy and material resources of space for human settlement as soon as practical.

Our approach is to complete the missing technological links to make possible the permanent human settlement of space.

SSI's Legacy

Conferences and Publications

Why G-Lab?

"Fifty years after the creation of NASA, our goal is no longer just a destination to reach. Our goal is the capacity for people to work and learn and operate and live safely beyond the Earth for extended periods of time, ultimately in ways that are more sustainable and even indefinite."

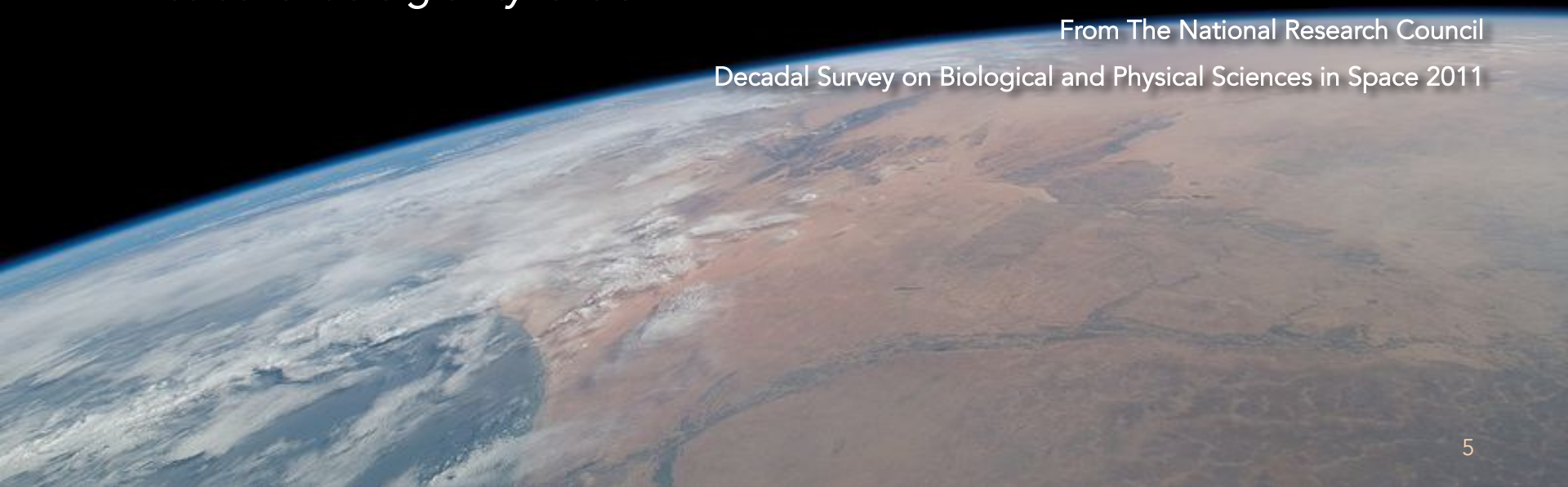
From the Introduction to US National Space Policy, June 2010

Why G-Lab?

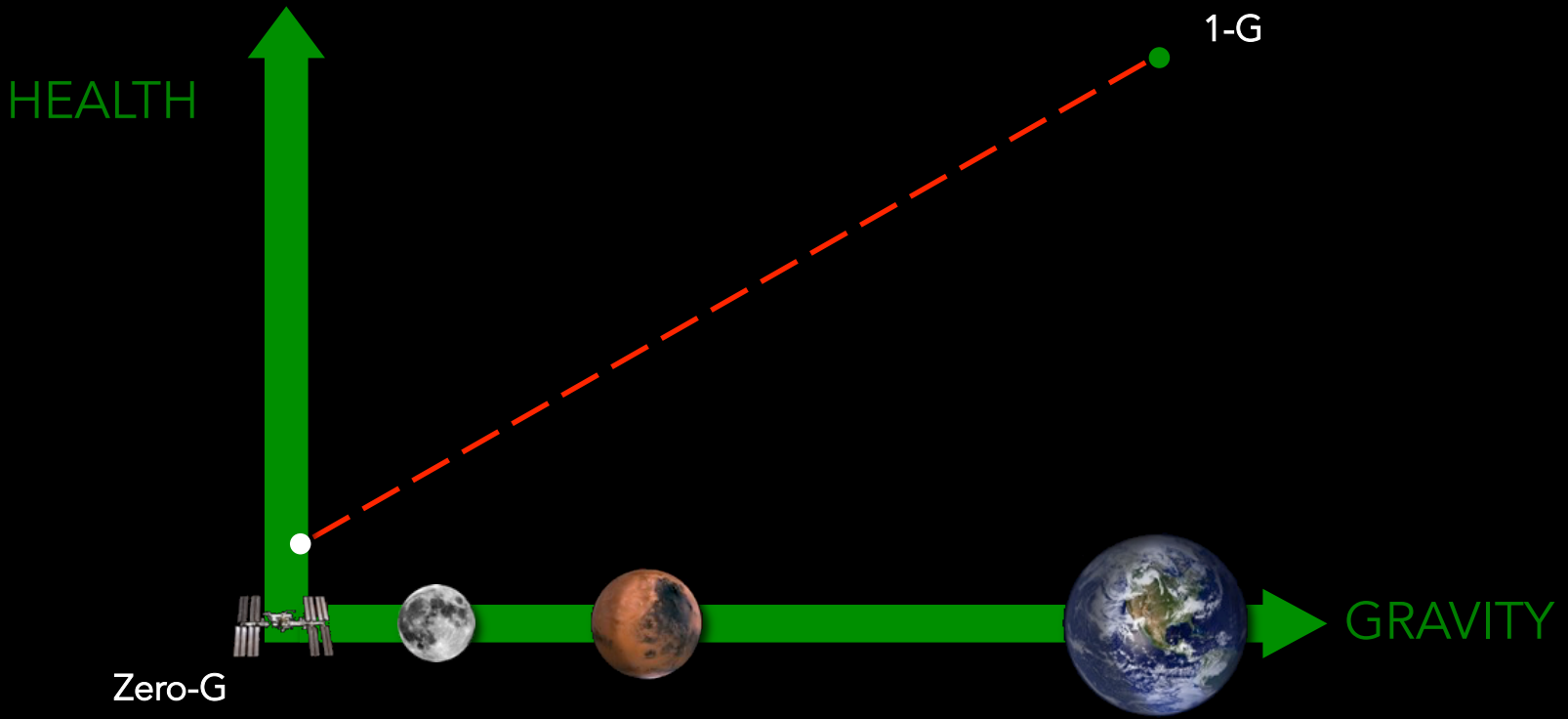
"Finally, despite its awareness that the [NASA] large centrifuge program has little likelihood of being restarted, the …Panel would be remiss if it did not strongly recommend an animal centrifuge capable of accommodating rats/mice at variable gravity levels."

From The National Research Council

Decadal Survey on Biological and Physical Sciences in Space 2011



What Is The Minimum G Required For Permanent Settlement?



After J. Carroll and J. Goff

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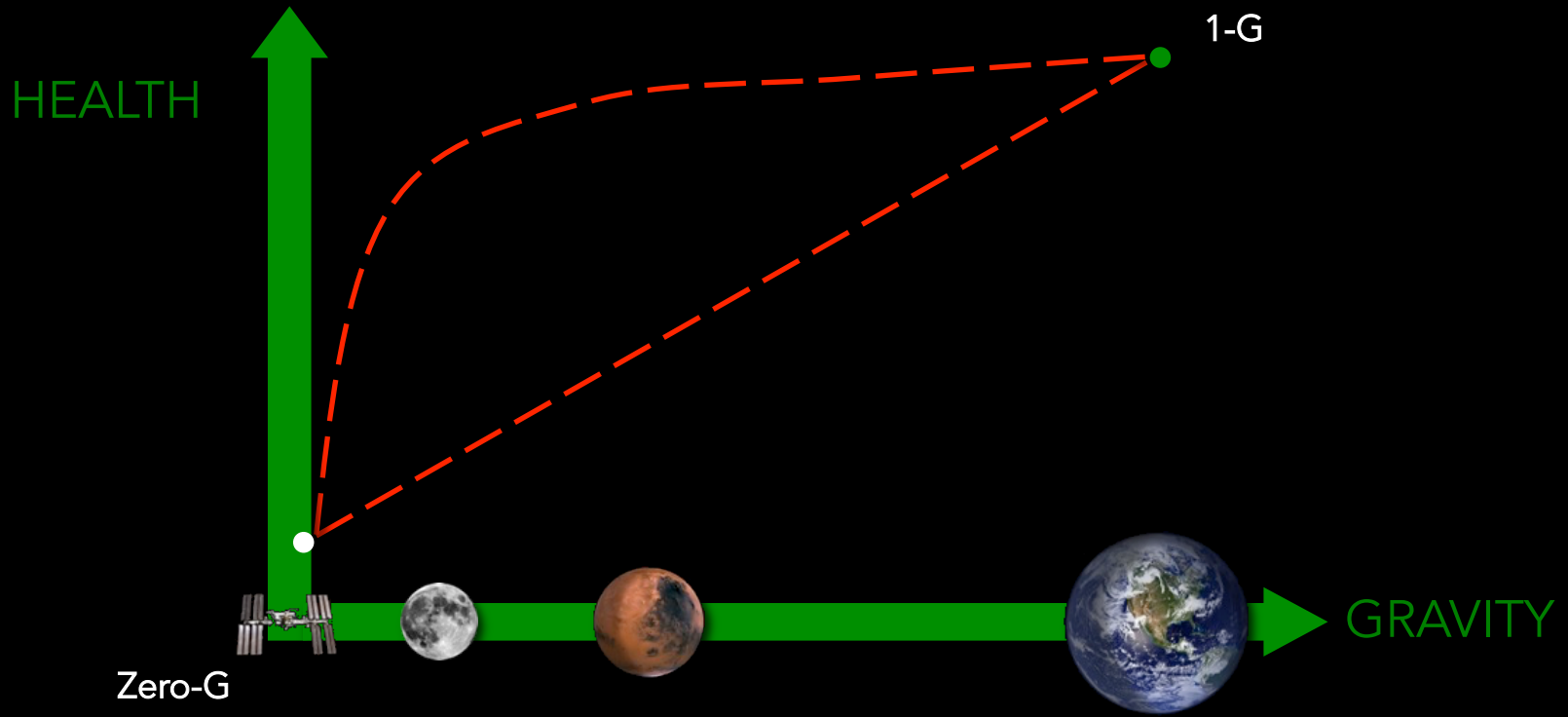

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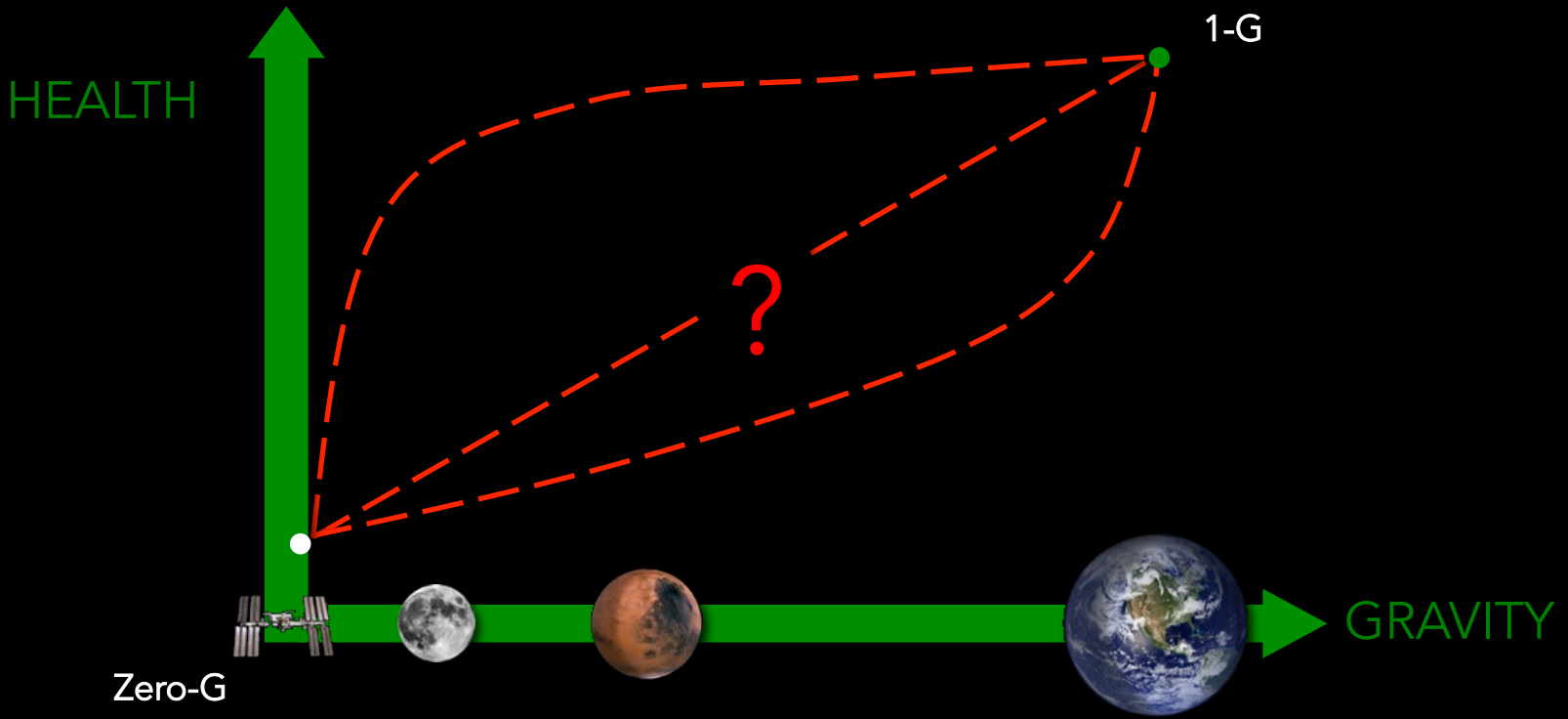

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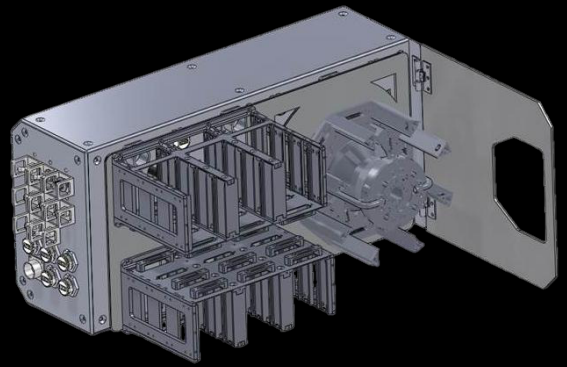
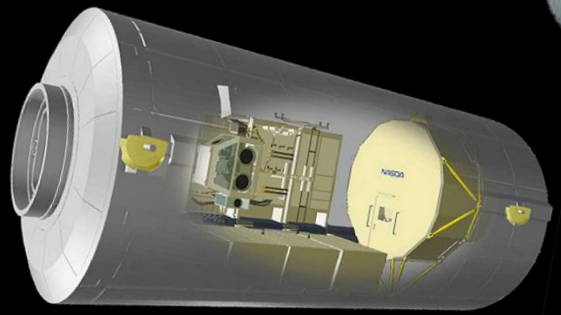
Solutions Using ISS?

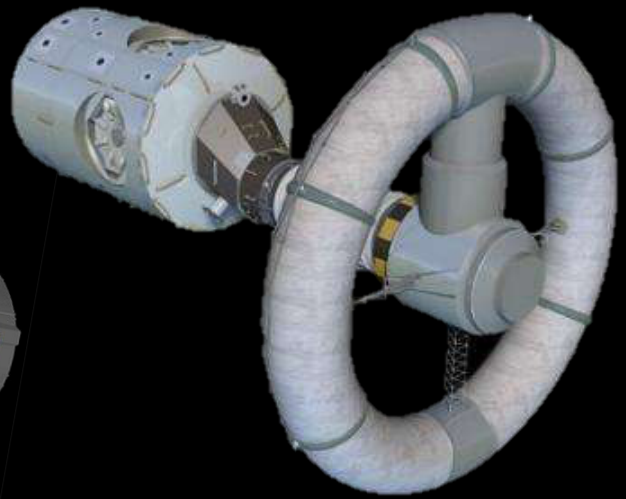


Nanoracks-Astrium
Centrifuge



NASDA-JAXA
Centrifuge Accommodations
Module

NASA Nautilus-X
Centrifuge



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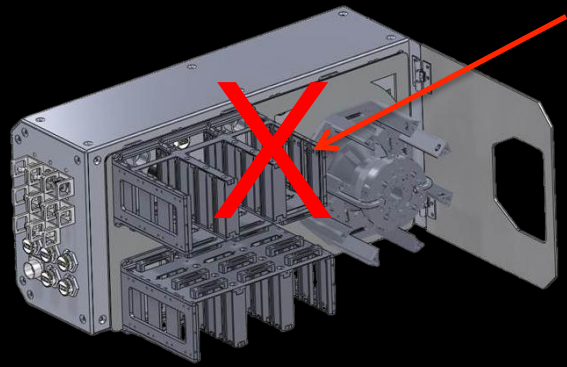
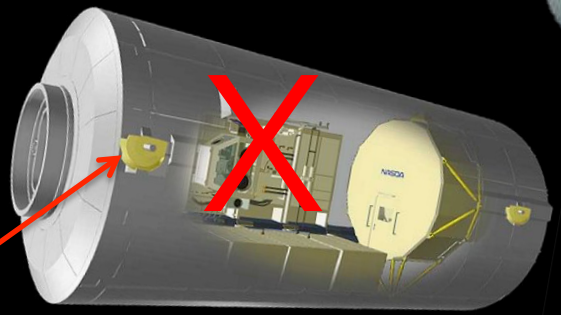
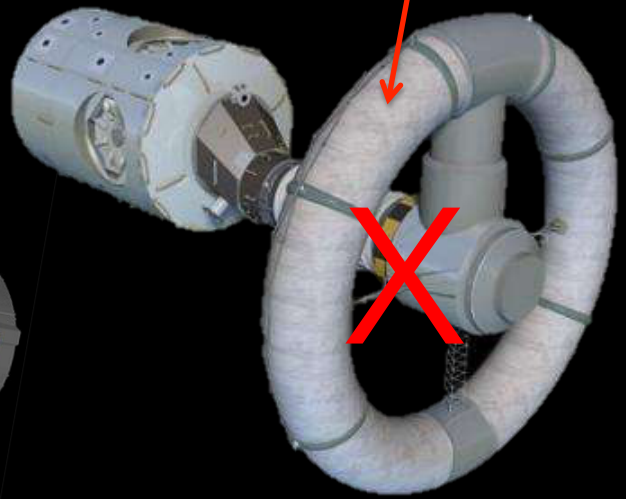


Too small for multi-generational vertebrates

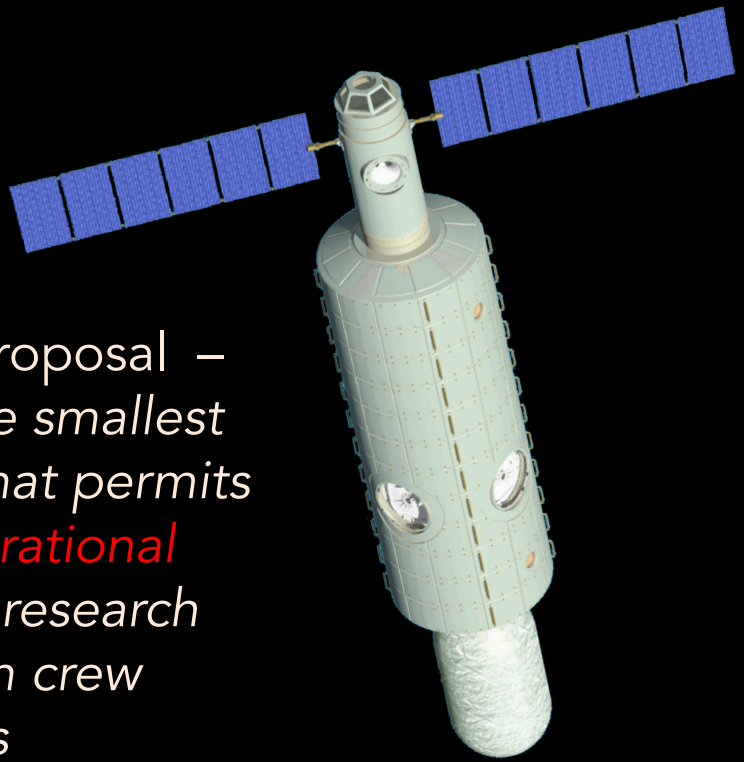


Too disruptive for ISS
(momentum & vibration issues)

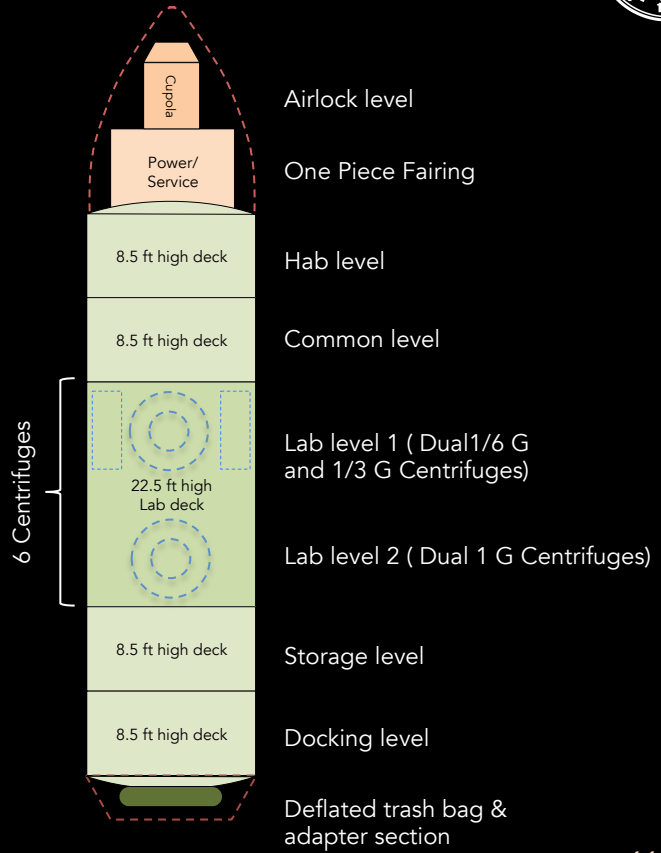
Too big for ISS



We Need A Dedicated Free-Flyer



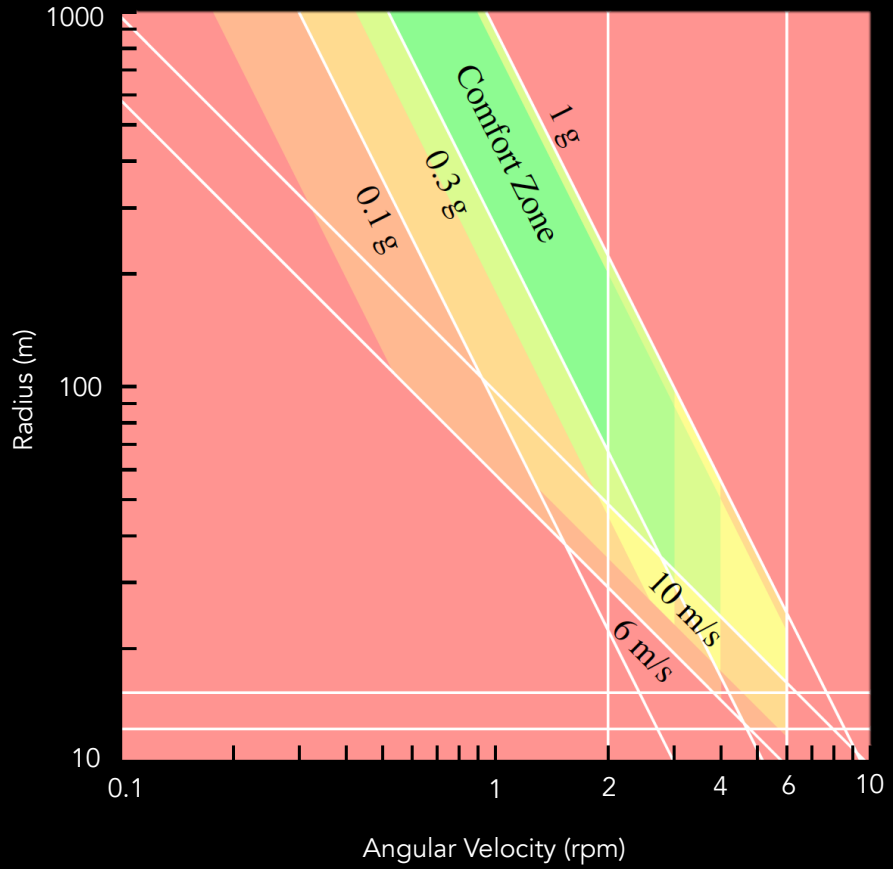
2012 SSI Proposal – *remains the smallest free flyer that permits multi-generational vertebrate research with human crew researchers*



What's Changed Since 2012?

- Applying the "SpaceX" and "NewSpace" developmental paradigm to orbital human spaceflight facilities
  - Potential Order of Magnitude cost reduction
    1. At $550/kg fabrication cost, 90 t of on-orbit mass = $50 m
    2. 4 years of development using 50 person team = $100 m
    3. Test and miscellaneous expenses estimated = $50 m
- Rotating facility permits simplification of many subsystems and allows longer tour of duty for crews
  - ECLSS becomes significantly easier – the "Home Depot" space station
  - Elimination of many custom components in favor of manual solutions and highly repetitive structures employing common components

4 RPM Chosen As Design Point



After *Space Settlement Population Rotation Tolerance*, A. Globus, 2015

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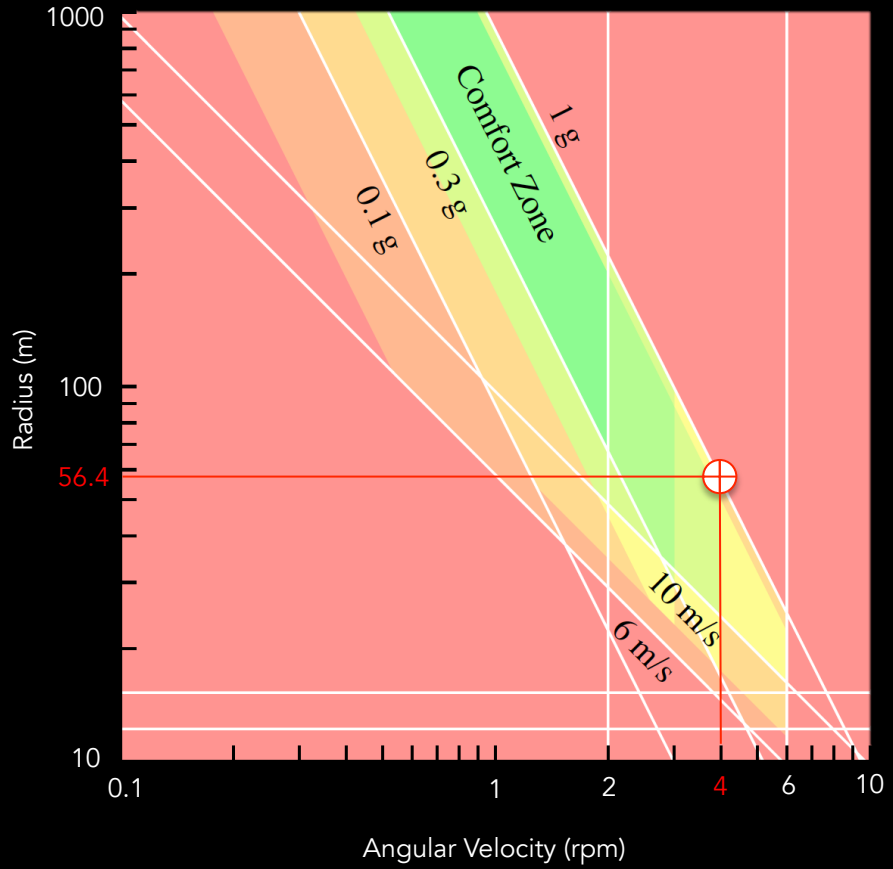

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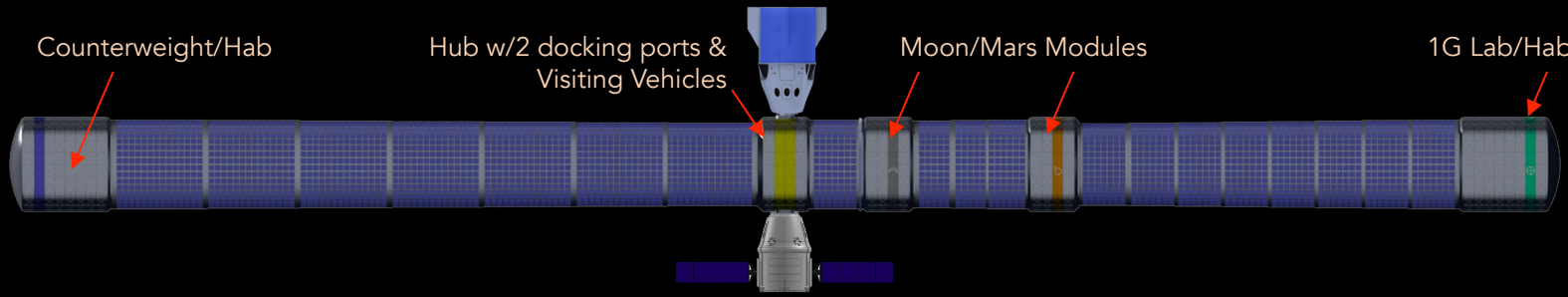
2017 G-Lab Concept



"Bolo" or "dumbbell" shape, rotating at 4 rpm, with telescoping solar arrays.

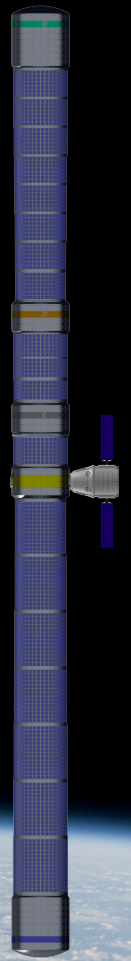
Designed to match the diameter of the baseline launch vehicle (7 m), each launch = 45 t mass. Initial facility on-orbit <100 t.

Three laboratories at Lunar, Martian and Earth G, one Hub module and one counterweight that serves as a secondary or growth Hab module.

Two international standard docking ports.

A Sense of Scale

A Sense of Scale



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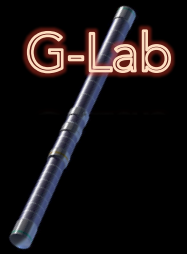
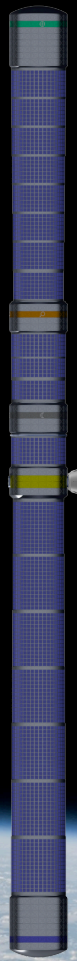
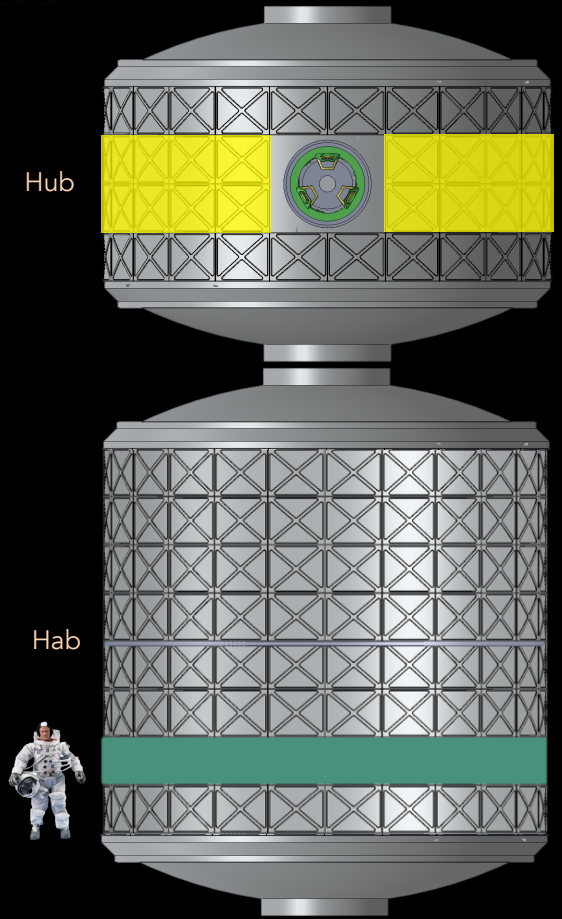


106 m



131 m

Common Modules



Common Module components:

Each individual deck is 3 M tall (barrel section)
Diameter is 7 M
Domes are spherical segments
Skylab-style launch using fairing only where required

Lab modules are both 3 M tall (barrels)
Counterweight module same as Hab module

Double hull, 112 mm MMOD gap, 2 mm outer skin, 4-5 mm inner skin, aluminum

Domes are covered w/ "launch" MLI foil for MMOD, where exposed to space

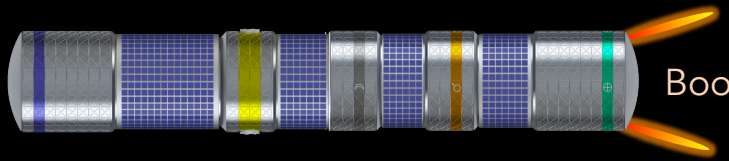
No portholes; artificial 8K "windows" electronically de-spun to show Earth at permanent nadir

Baseline Launch Vehicle & Assembly CONOPS

Blue Origin New Glenn 2 Stage LV

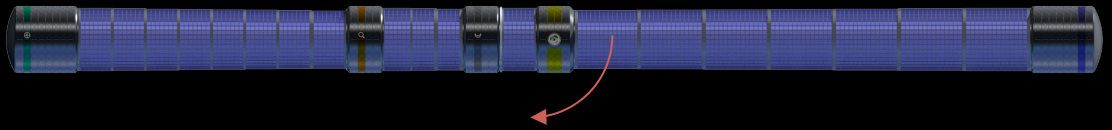
Credit: Blue Origin

AR&D of Dual 45 t Modules

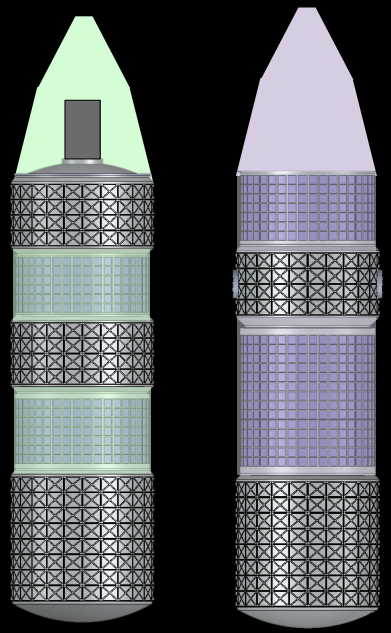


Boost to Final Orbit

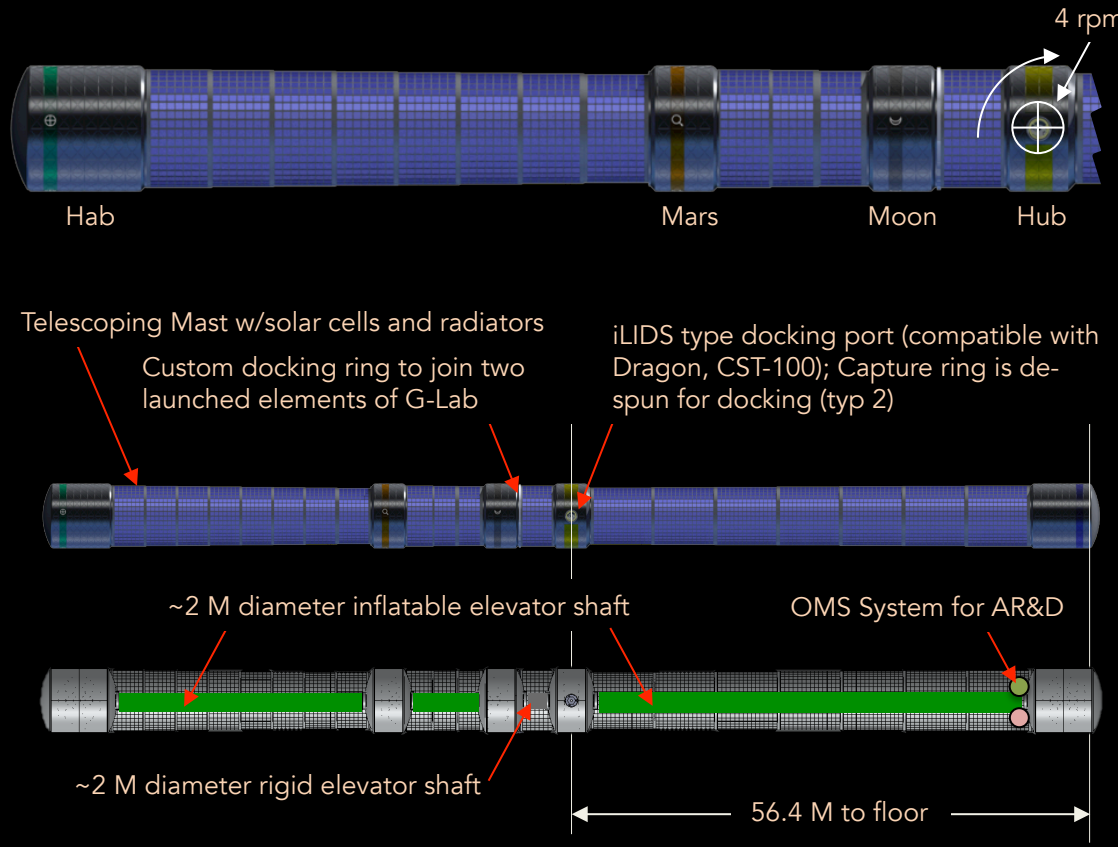
Crew Arrival, Extension & Spin Up



Launch & On-Orbit Configuration



Purple, Launch 1
Green, Launch 2



Commissioning

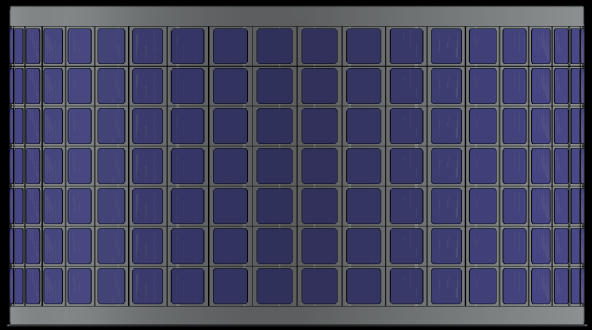
- Launch 1 – Purple Launch – remotely jettison nose fairing – active payload
- Launch 2 – Green Launch – remotely jettison nose fairing – passive target
- Purple flight and Green flight maneuver to automated rendezvous and docking, jettison barrel fairings and deploy station to full length
- Crew Launch – Dragon/CST-100 or other crew spacecraft with at least 3 seats followed by spin up
- First supply vehicle launch – Dragon or equivalent
  - Brings research animals, and acts as lifeboat for future crews
  - Future re-supply vessels can include Cygnus, HTV, etc. If retrofitted with docking vs. berthing ports

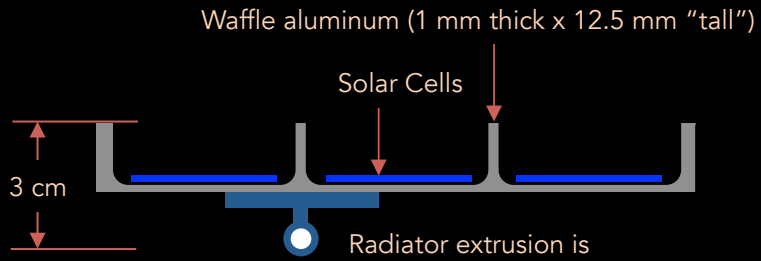
Element	Type	Launch Vehicle	Day	Crewed?	Duration
Purple Flight	Hub & Counterweight	New Glenn	1	No	30 days
Green Flight	Habs & Labs	New Glenn	30	No	30 days
Red Flight	Crew Spacecraft	F9-Dragon 2	60	Yes	14 days
Yellow Flight	Cargo Spacecraft	TBD	70	No	Unlimited

Operational Flights to follow on 90-120 day intervals with 1 or 2 crew-person exchange per flight

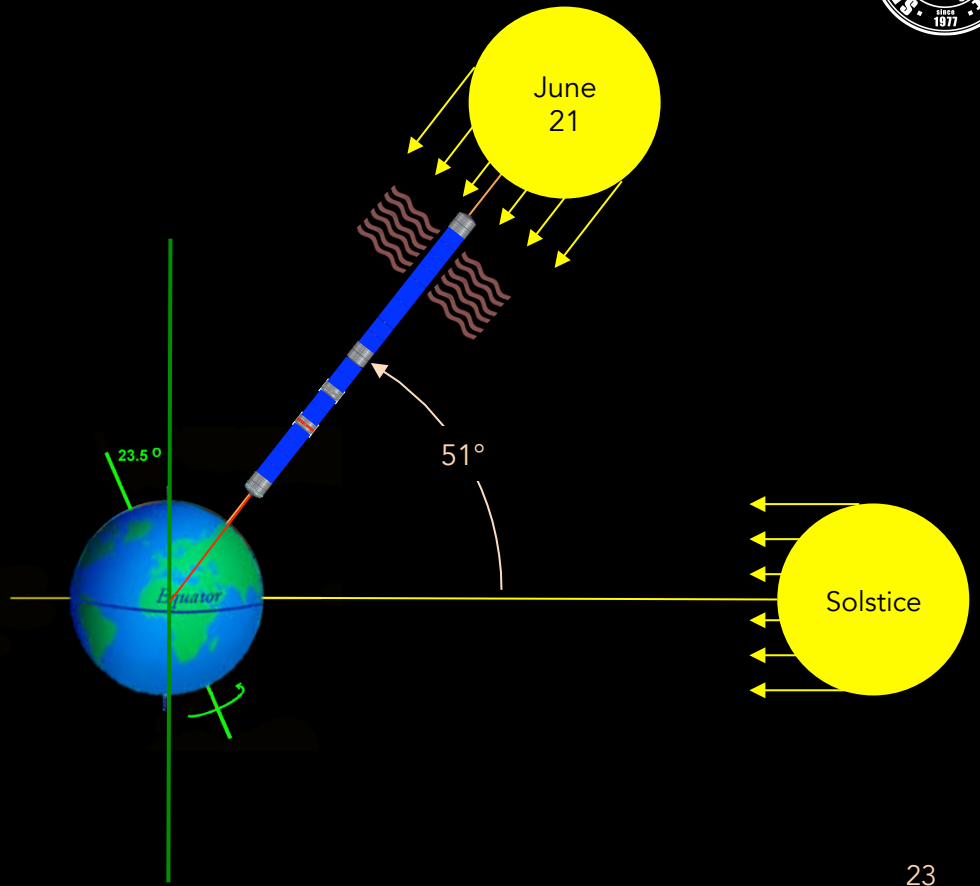
Power & Radiators

Total Instant Available Power ≃ 150 kW





Radiator extrusion is vertically banded allowing selection of radiating surface as a function of insolation/shade angles



Public-Private Partnership

- SSI funds and manages design and development of station elements
  - As an international NGO, it would operate the facility for all humankind
- Launch of first two station elements supported by tax-deductible donations and/or international contributions
  - Possible only if development and fabrication costs can be *significantly reduced* from normal practice
- Initial crew and cargo flights paid for by anchor customers (primarily international space agencies in return for access to facility) until transition to commercial operations

Growth & Self-Sufficiency

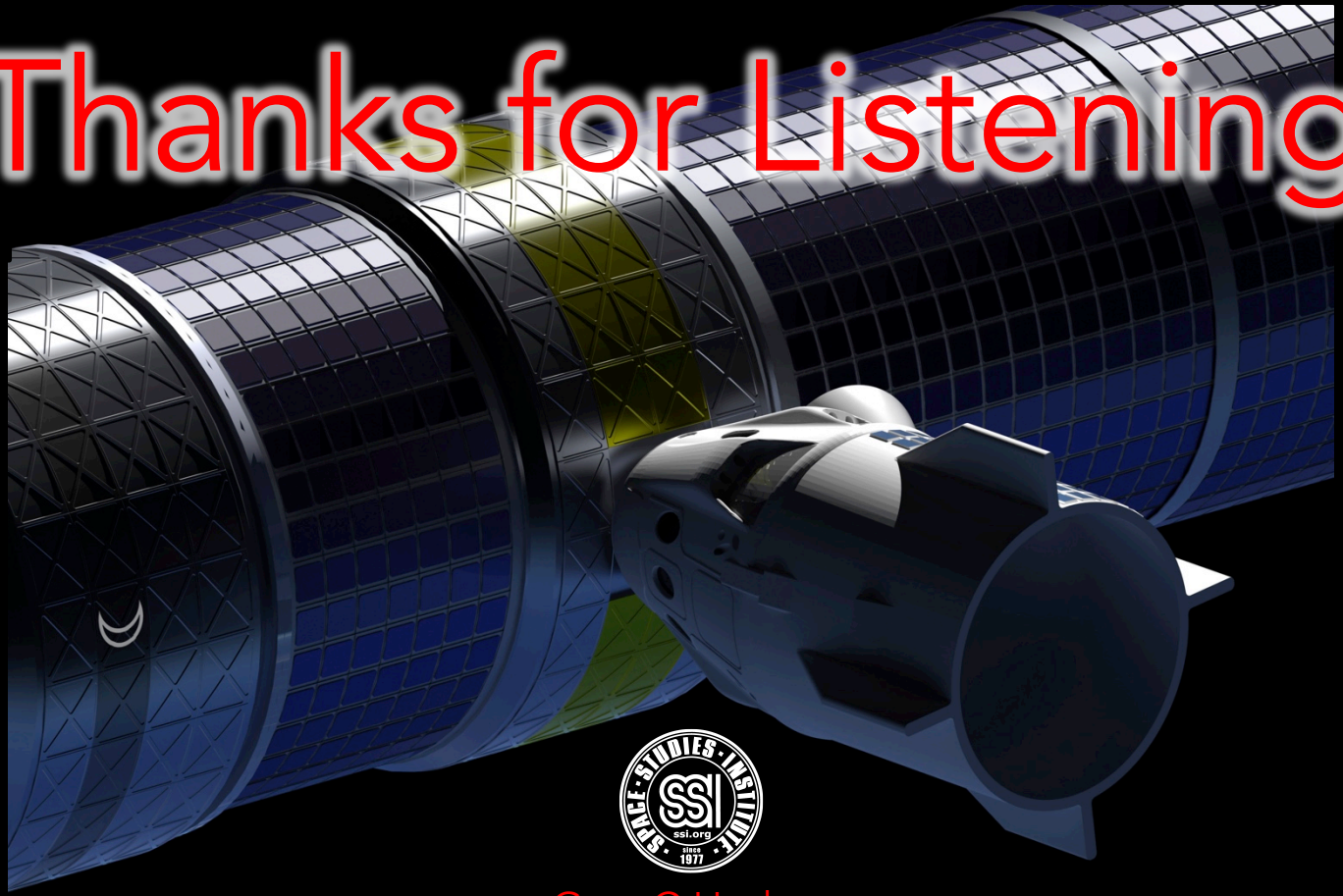
- Counterweight can be outfitted for up to four passenger cabins
- At $50M/person, two single-person cabins, each occupied once per quarter, could generate sufficient funding per annum to operate the facility and pay for crew rotation, after expenses for delivering the passengers to G-Lab
  - Creating this “destination” opportunity becomes the financial incentive for a launch company to consider donation of two establishment launches to emplace G-Lab into LEO
  - Generates >$200 m per year for continuing operations for ten year research program

ISS Co-Orbital Strategy

- ISS is the only current international spaceflight destination
- By co-locating with ISS, crew and cargo missions to ISS will have a secondary destination
  - This destination lowers the cost of servicing both orbital facilities while leaving ISS available for microgravity experimentation
  - Each facility becomes the “lifeboat” or backup for the other

The Shape of Things to Come

Thanks for Listening!



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