Creating a Space Settlement Cambrian Explosion

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MacroInvent.com

Mars Society steering committee chair

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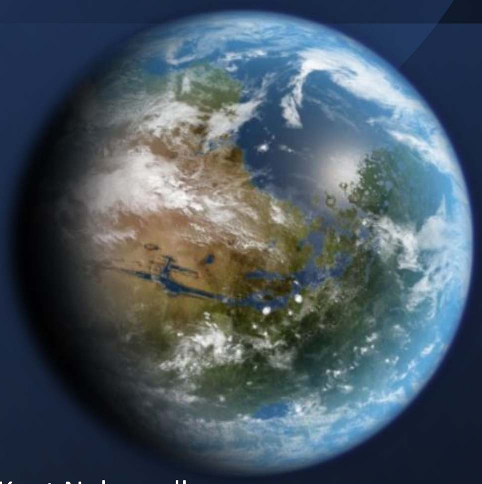
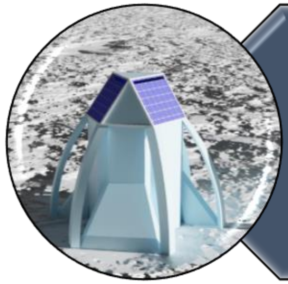
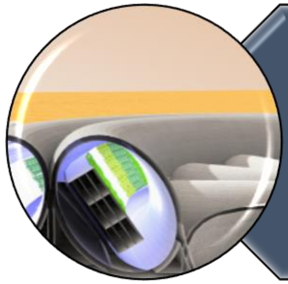
Proposals for…

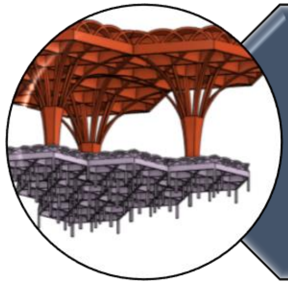




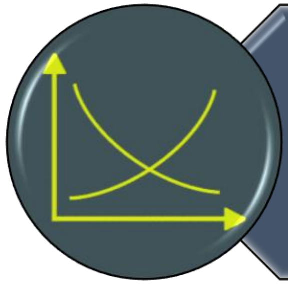
Ports and Logistics



Mars Cities



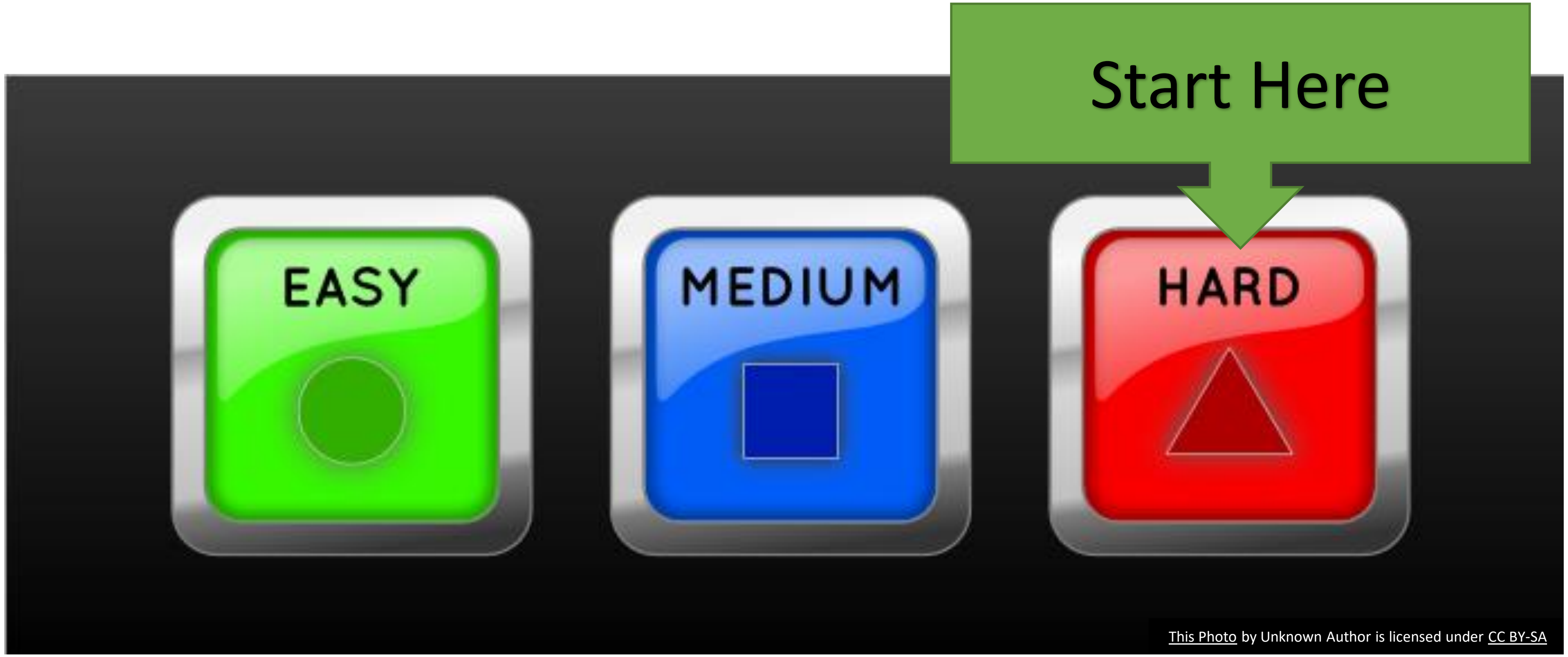
ParaTerraforming Ecologies



Economic and Technology Revolutions

Cambrian Explosion?

- Period early in the history of Earth when complex live emerged
- 538.8 million years ago
- Went from simple multicellular life to all major phyla in only 10 million years.



Steelman Argument Methodology

Grand Challenges of Space Settlement (2004)

Launch/LEO	Deep Space	Moon/Mars	Settlement
Affordable Launch	Solar Flares	Moon Landing	Air/Water
Large Vehicle Launch	GCR: Cell Damage	Mars EDL	Power and Propellant
Orbital Refueling/ Mass Fraction beyond Earth Orbit	Medication/ Food Expiration	Spacesuit Lifespan	Base Construction
Space Junk	Life Support Closed Loop	Dust Issues	Food Growth
Microgravity (health issues)	Medical Entropy	Basic Power/ Propellant Production	Surface Mining and Extraction
	Psychology	Return Flight to Earth (speed, mass, etc.)	Hybrid Manufacturing
	Mechanical Entropy	Planetary Protection	Reproduction

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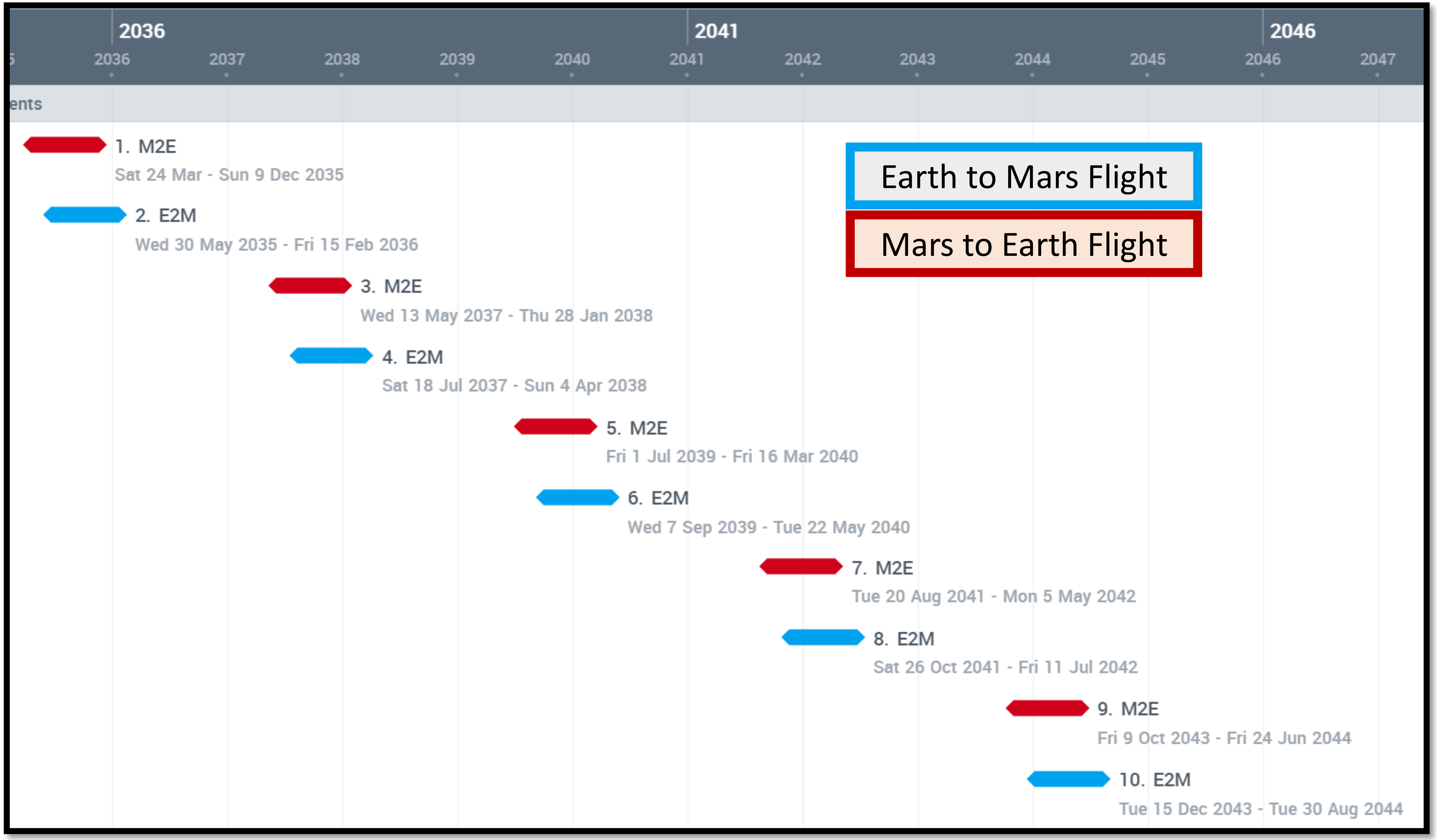
At Least Four Starship Fleets Required for Mars



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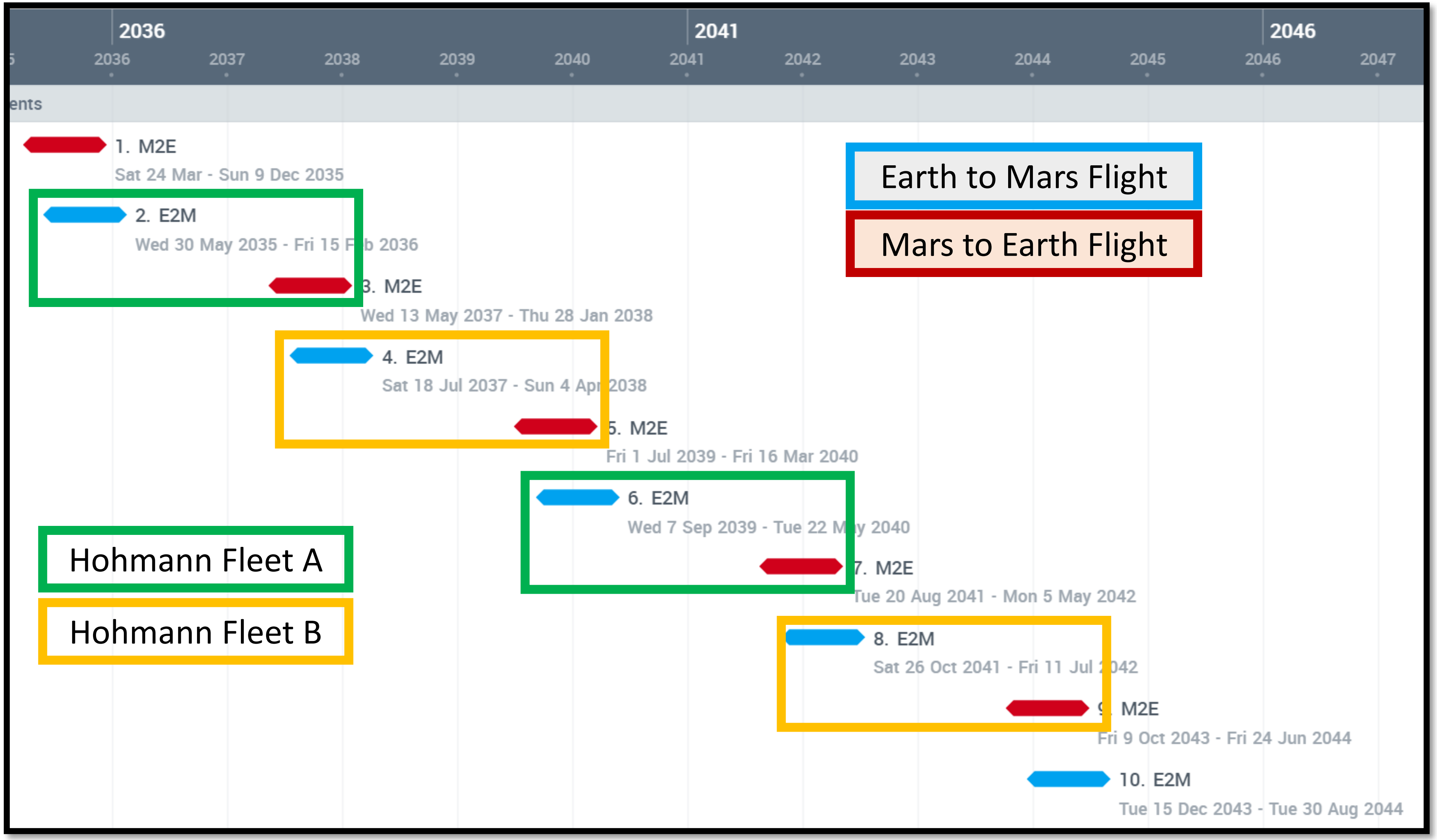
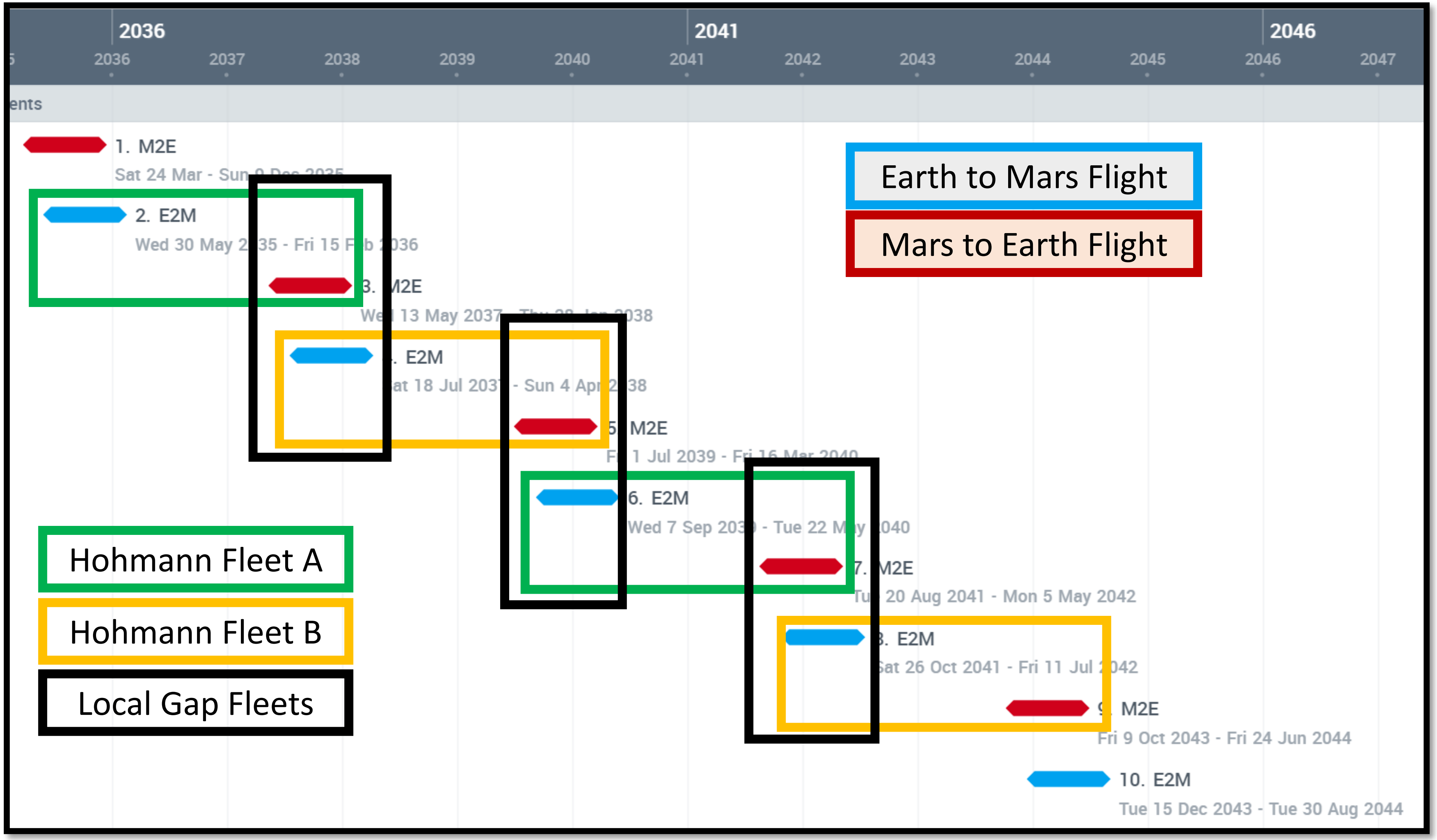


At Least Four Starship Fleets Required for Mars



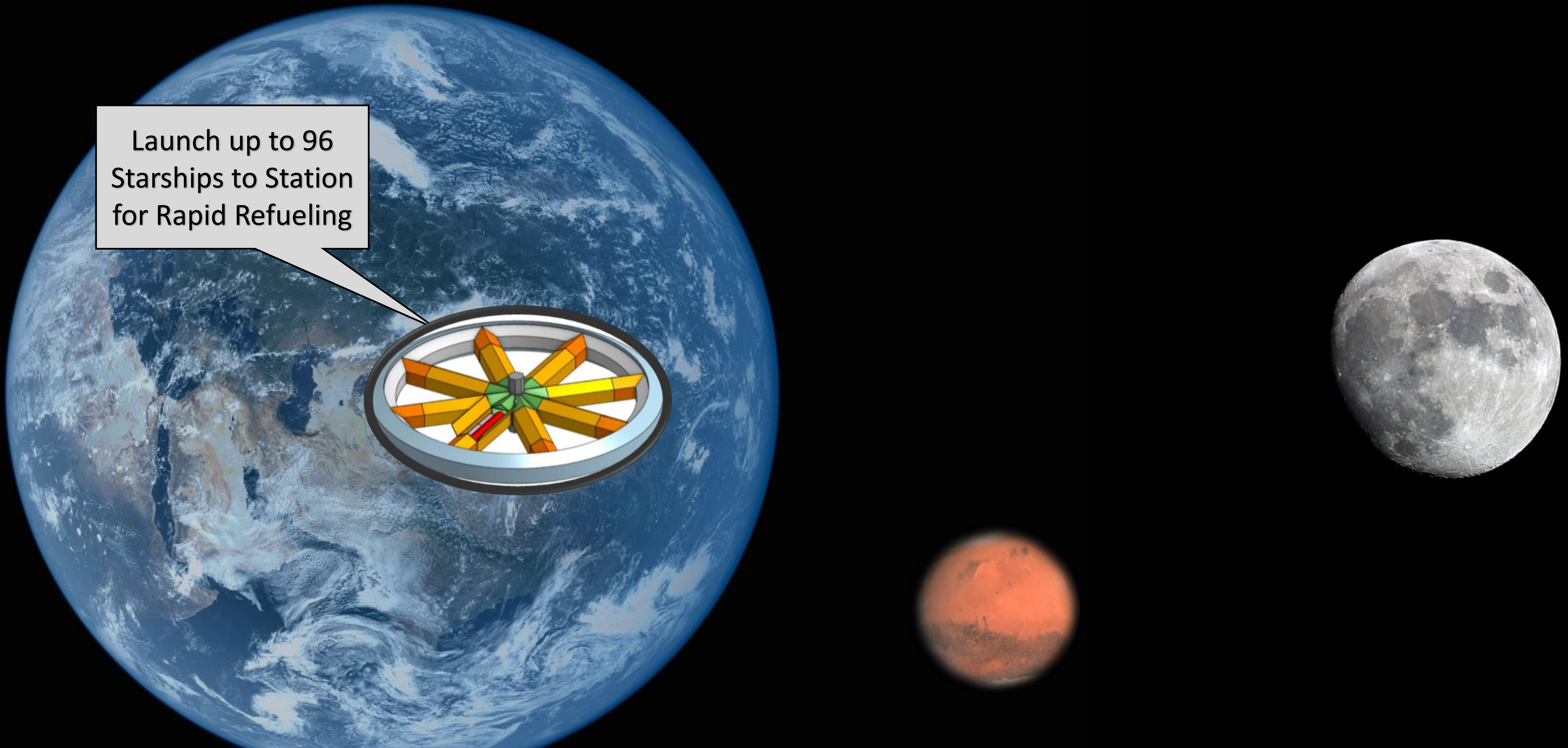
Starship Production/ Flight Rates

Earth to Mars	Return	Ships	Per ship	Per Sortie	Total Tonnes
11/15/2026	7/30/2027	3	100	300	300
1/3/2029	9/19/2029	5	100	500	800
2/22/2031	11/7/2031	12	140	1680	2,480
4/11/2033	12/26/2033	48	150	7200	9,680
5/30/2035	2/15/2036	96	150	14400	24,080
7/18/2037	4/4/2038	192	150	28800	52,880
9/7/2039	5/22/2040	288	150	43200	96,080
10/26/2041	7/11/2042	384	150	57600	153,680
12/15/2043	8/30/2044	384	150	57600	211,280
2/3/2046	10/18/2046	384	150	57600	268,880
3/22/2048	12/7/2048	384	150	57600	326,480
5/11/2050	1/26/2051	384	200	76800	403,280
6/30/2052	3/15/2053	384	200	76800	480,080
8/18/2054	5/3/2055	384	200	76800	556,880
10/7/2056	6/22/2057	384	200	76800	633,680
11/26/2058	8/11/2059	384	200	76800	710,480
1/14/2061	9/30/2061	384	200	76800	787,280
3/3/2063	11/18/2063	384	200	76800	864,080
4/22/2065	1/7/2066	384	200	76800	940,880
6/11/2067	2/26/2068	384	200	76800	1,017,680
7/29/2069	4/15/2070	384	200	76800	1,094,480
9/18/2071	6/3/2072	384	200	76800	1,171,280

Exploration requires ships.

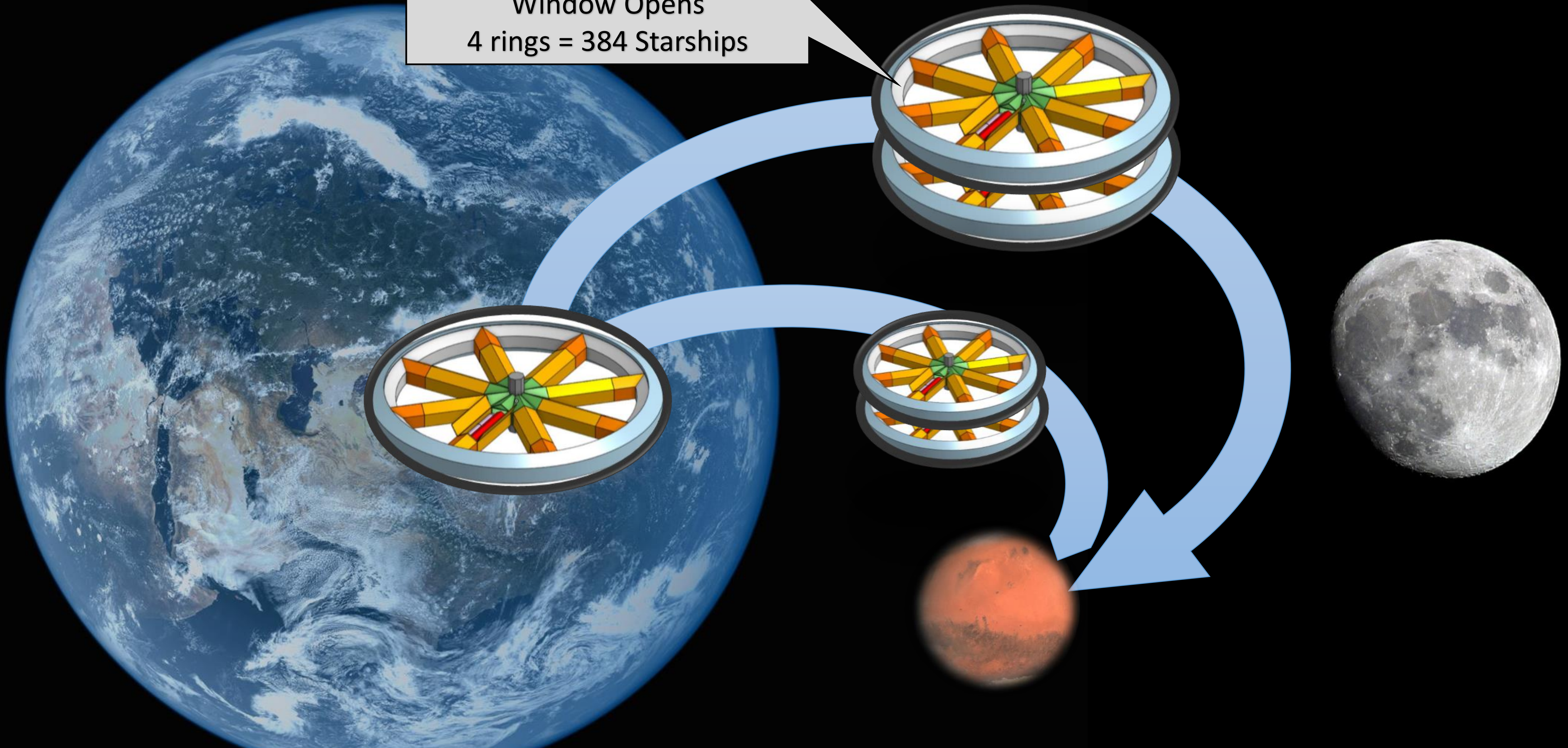
Settlement requires ports.

Logistics

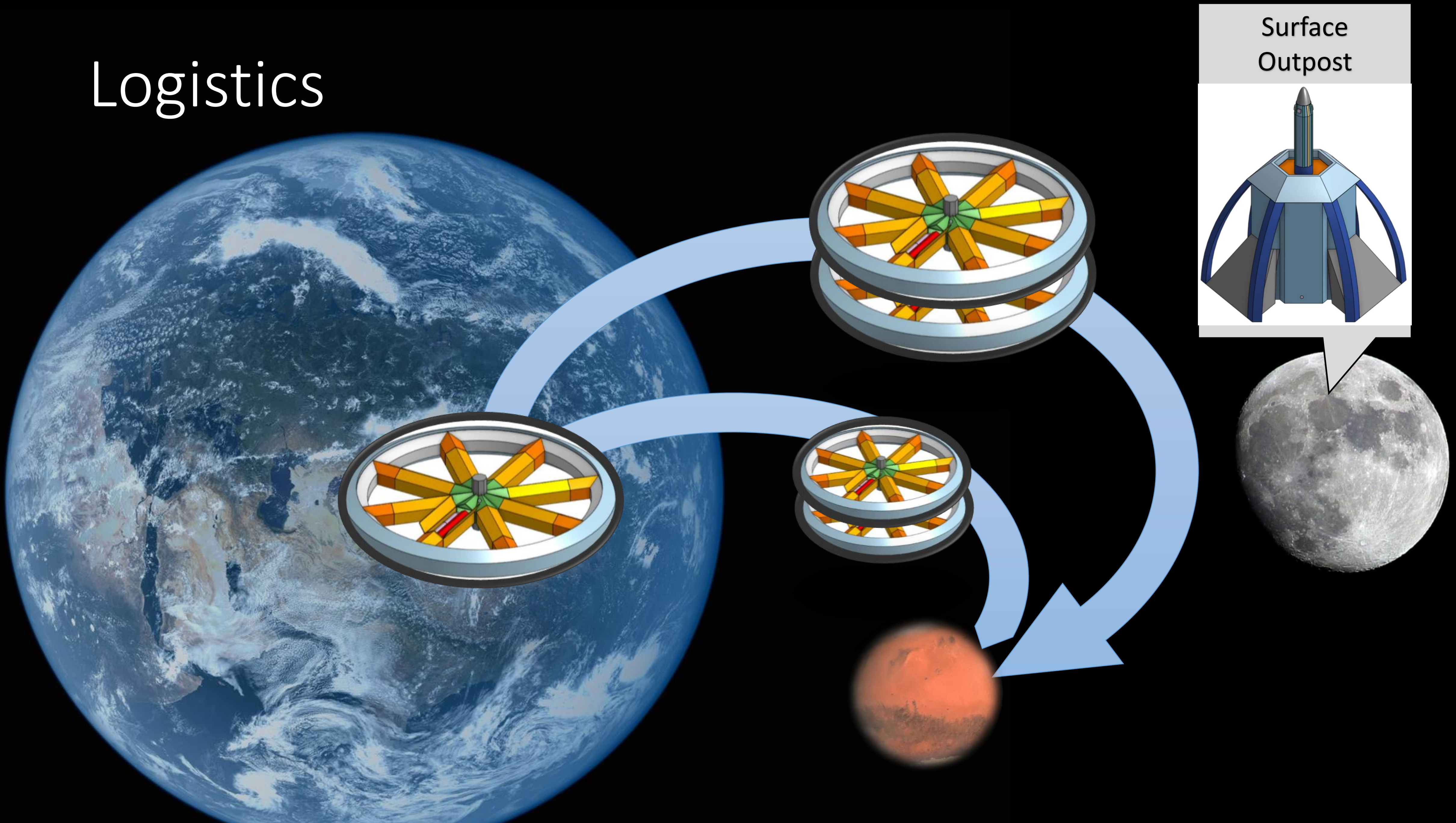


Logistics

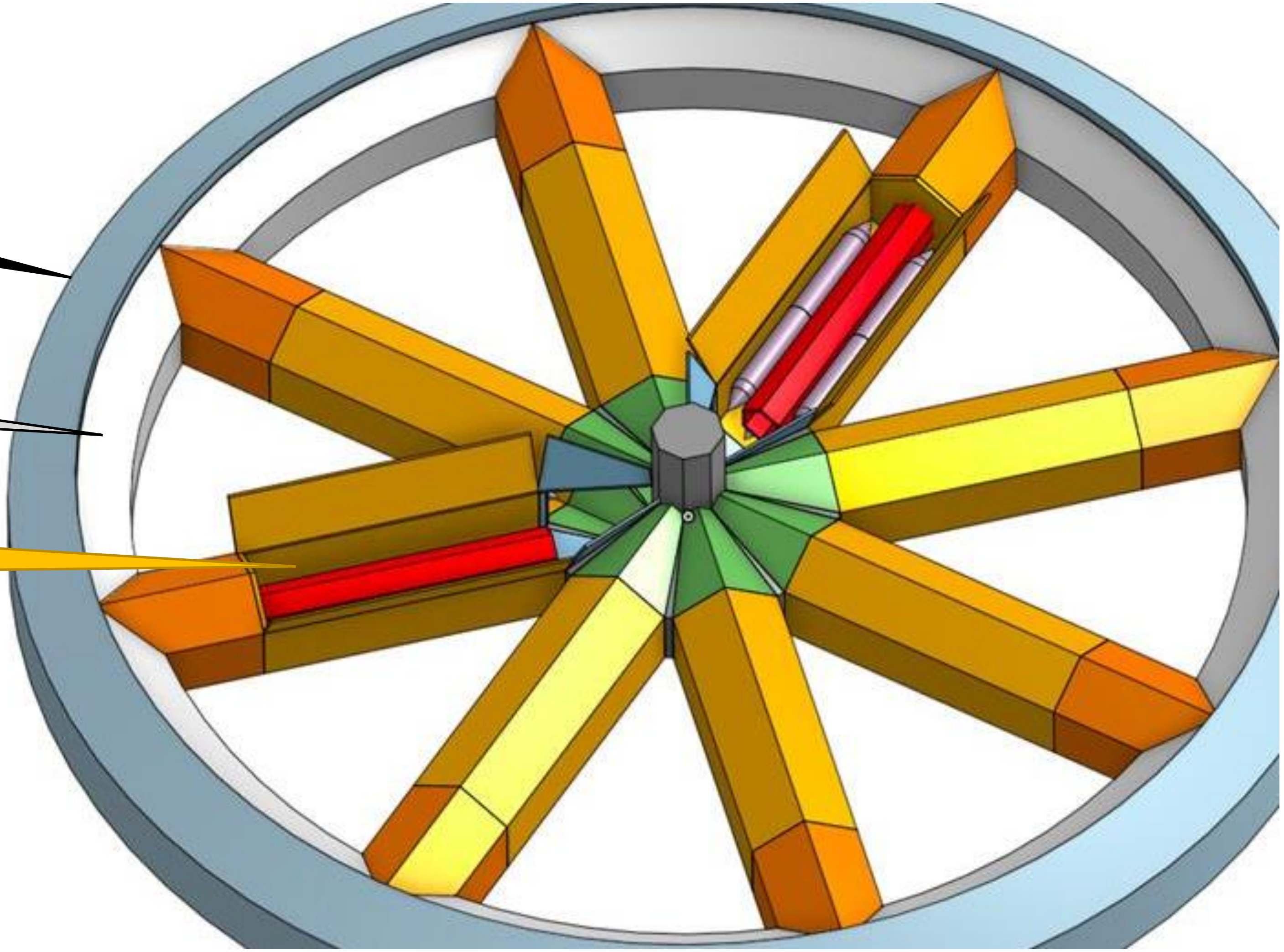
Send Mini-Fleet to Lagrange Stations Until Launch Window Opens
4 rings = 384 Starships



Logistics

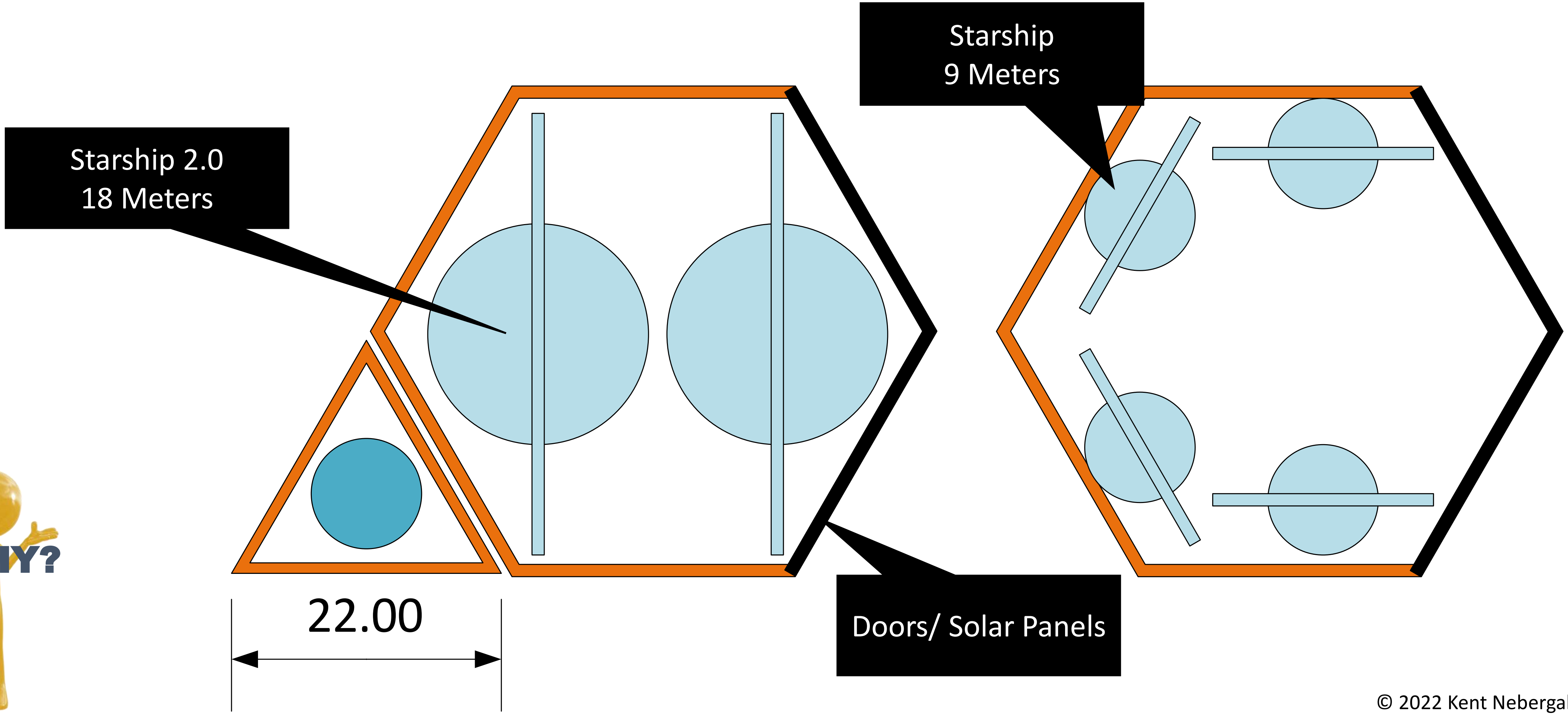


LEO Refilling/Staging Ring



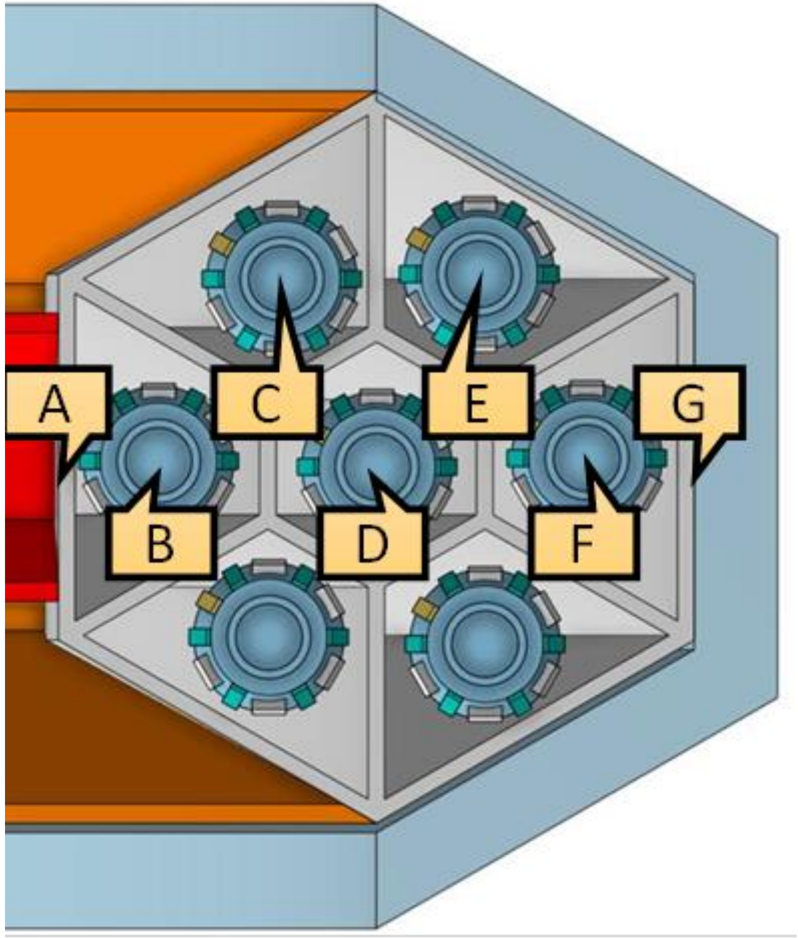
3D Illustration by Aarya Singh

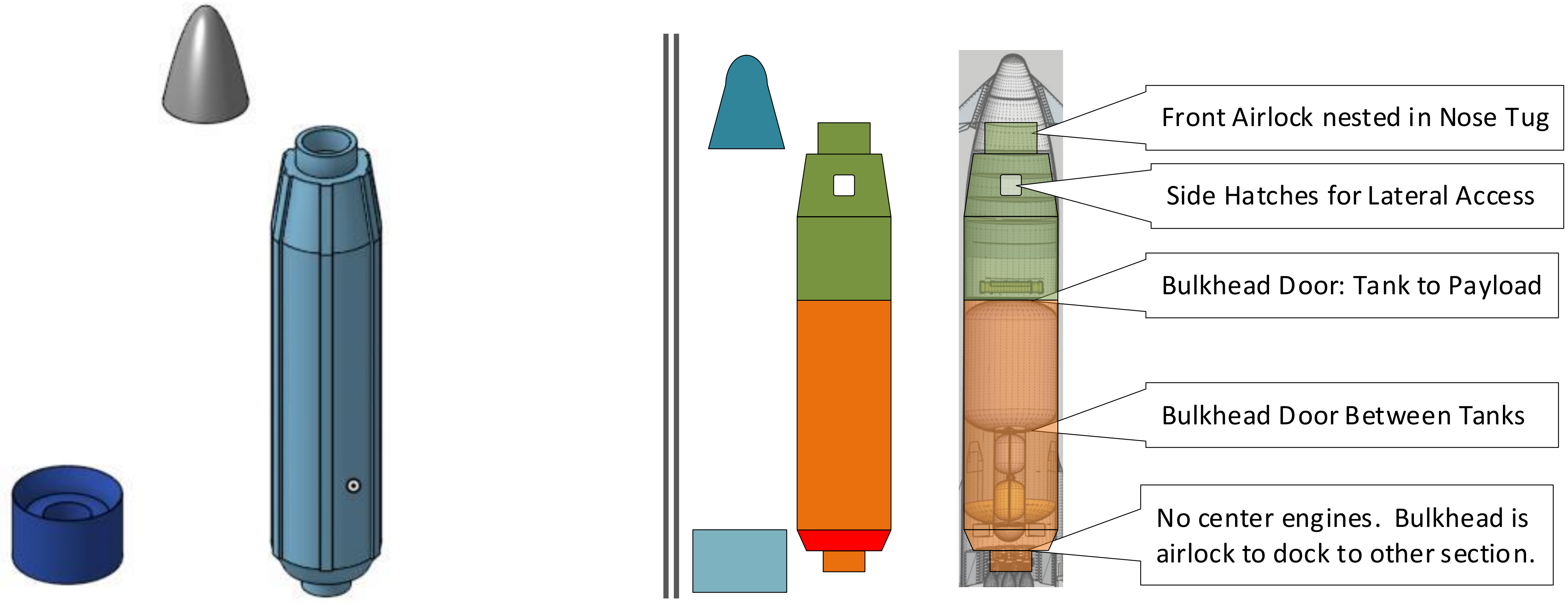
Enclosure Scaling (Why this Size?)



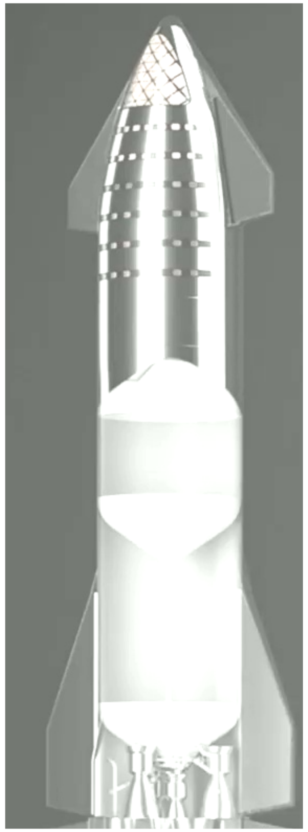
Ring Gravity (300m dia.)

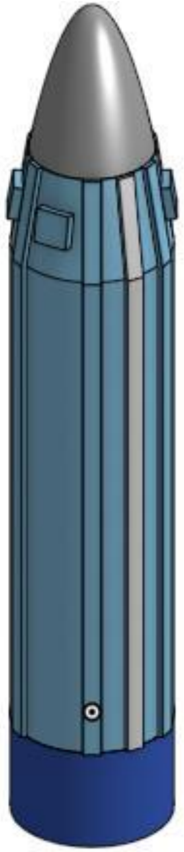
Parameter	Lunar Surface	Mars Surface
Max gravity	0.775 Earth G Boost of 3.7x	1 Earth G
Ring Speed	113 kph/ 70 mph	102 kph/ 64 mph
Bank Angle	50.28 deg	44.43 deg
Rotation Rate	2 RPM	2 RPM
Baseline	D ring center	138 Full Cars, plus 4 Half Cars

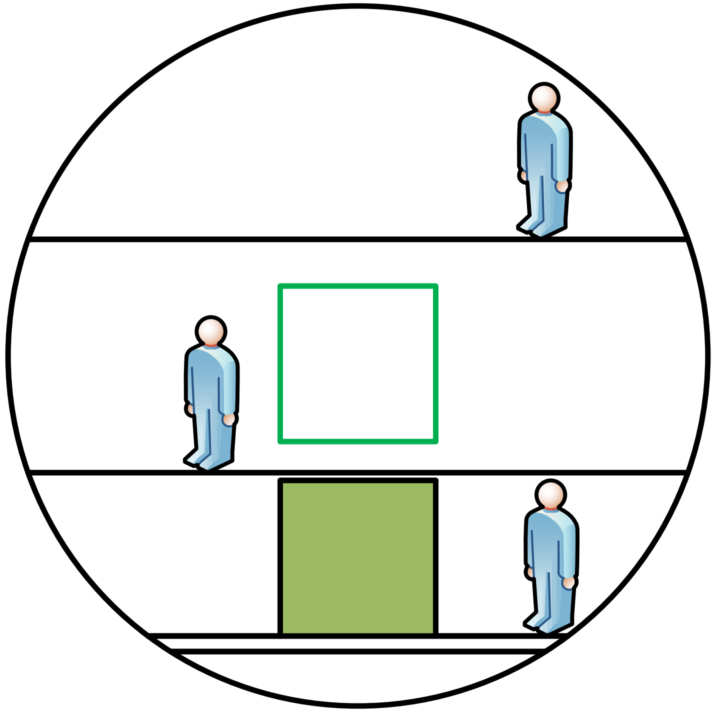


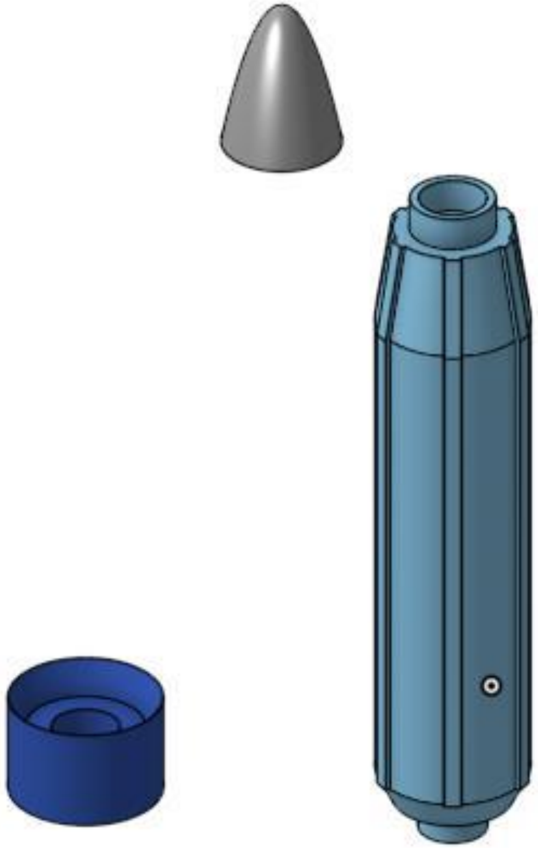


Starcar: Modular “Wet Lab” Habitat

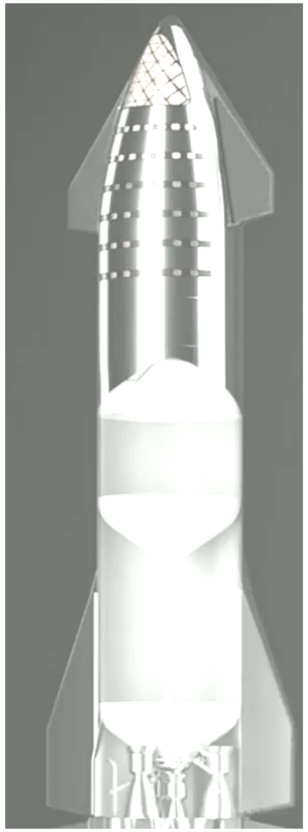


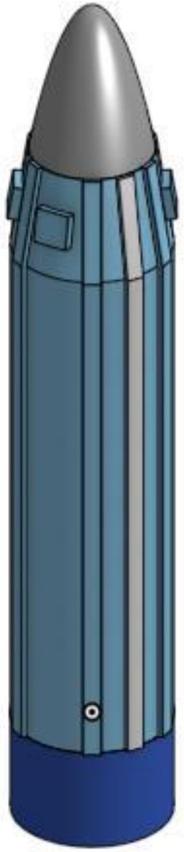






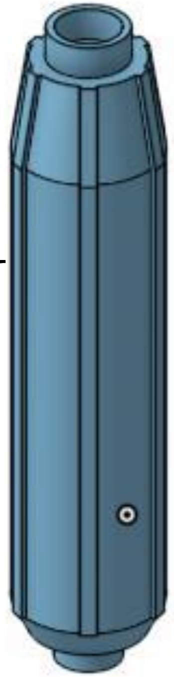
Human Scale



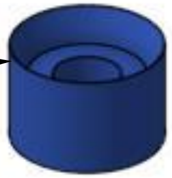


Front RCS/Tug Fairing
7.3 m base, 9 m tall
Return in Starship cargo bay.

Starcar
Length: 42.69 meters
Volume: 2000 cu. meters
Airlock Diameter: 4 meters

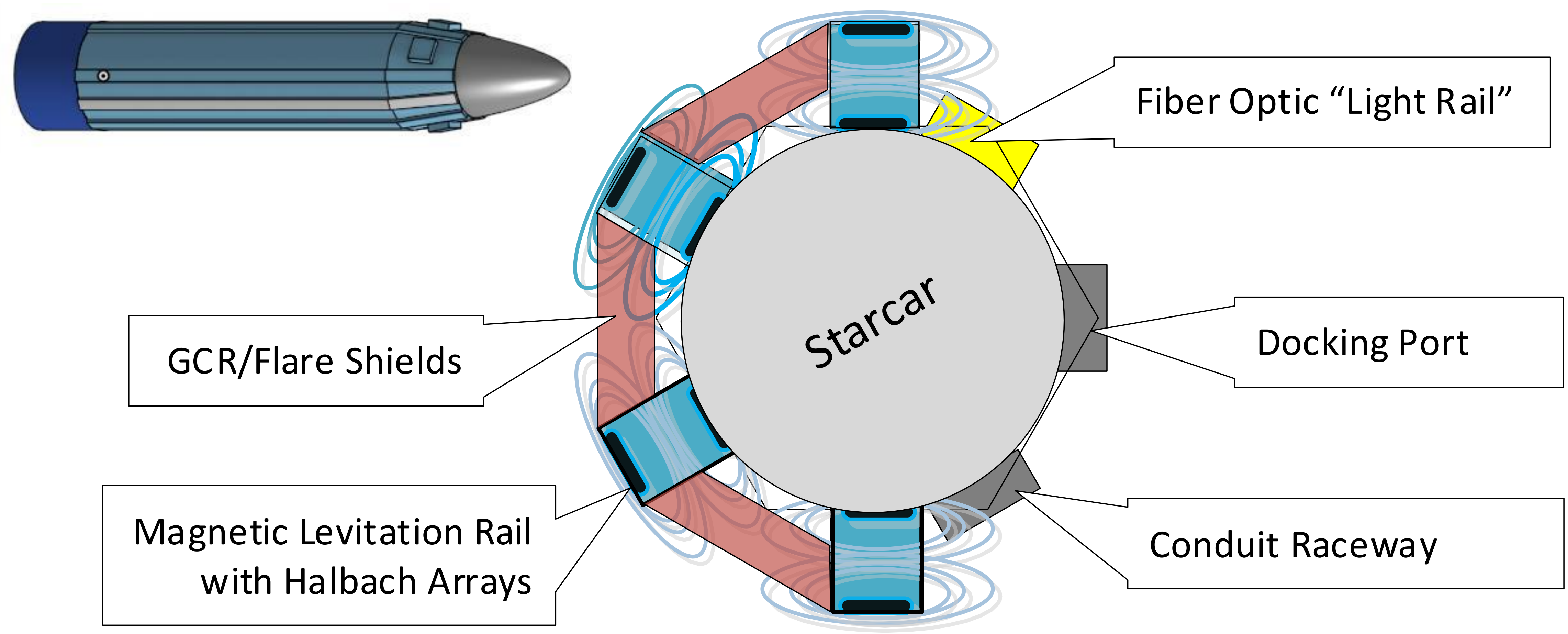


Rear Engine Block
6 m tall ring, 9 m dia.
Either dock with nose as new vehicle,
or segment in thirds and Pack



Starcar: Details

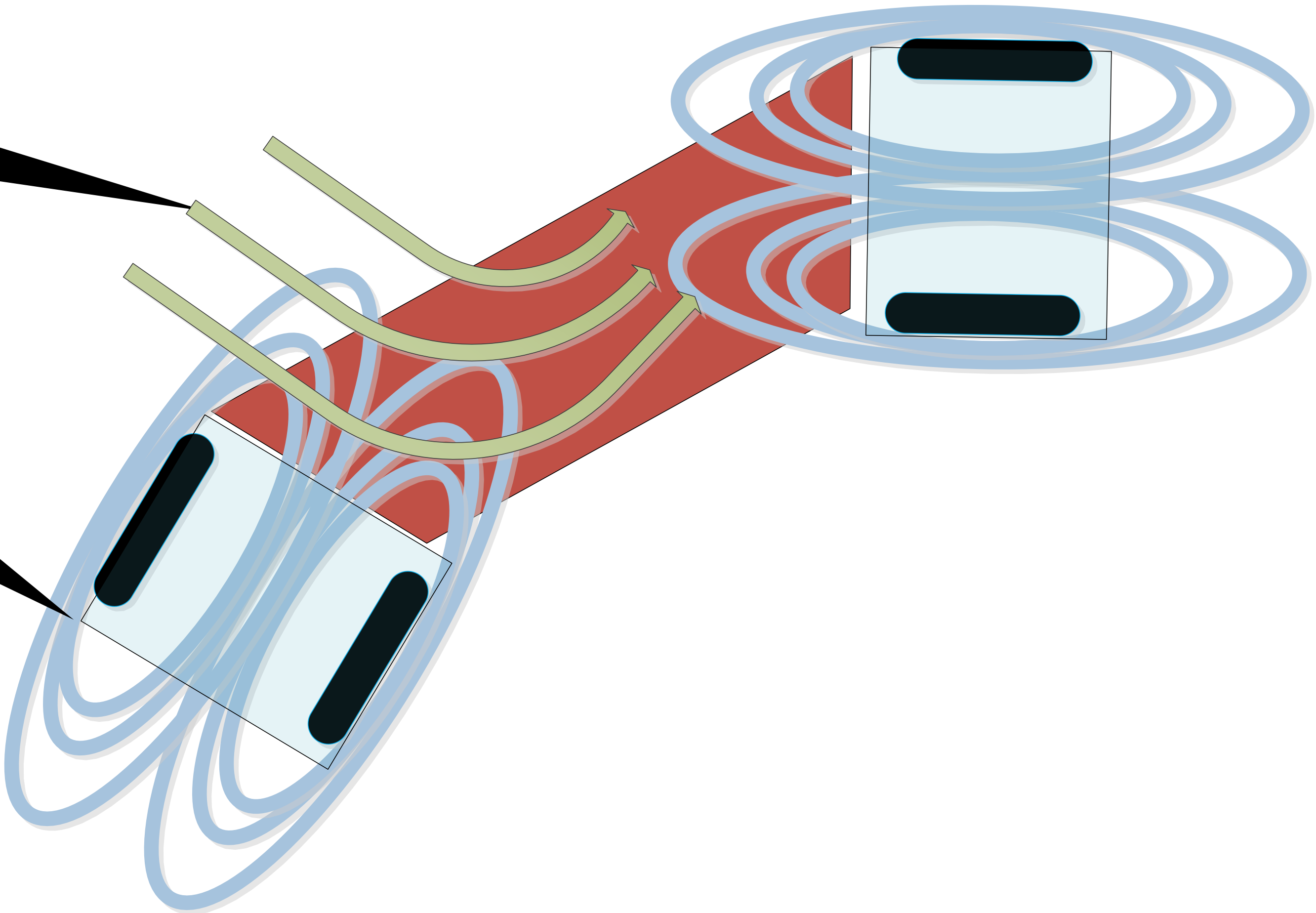
Halbach Magnets & Magnetic Levitation Rails



Halbach Magnets & Radiation Shielding

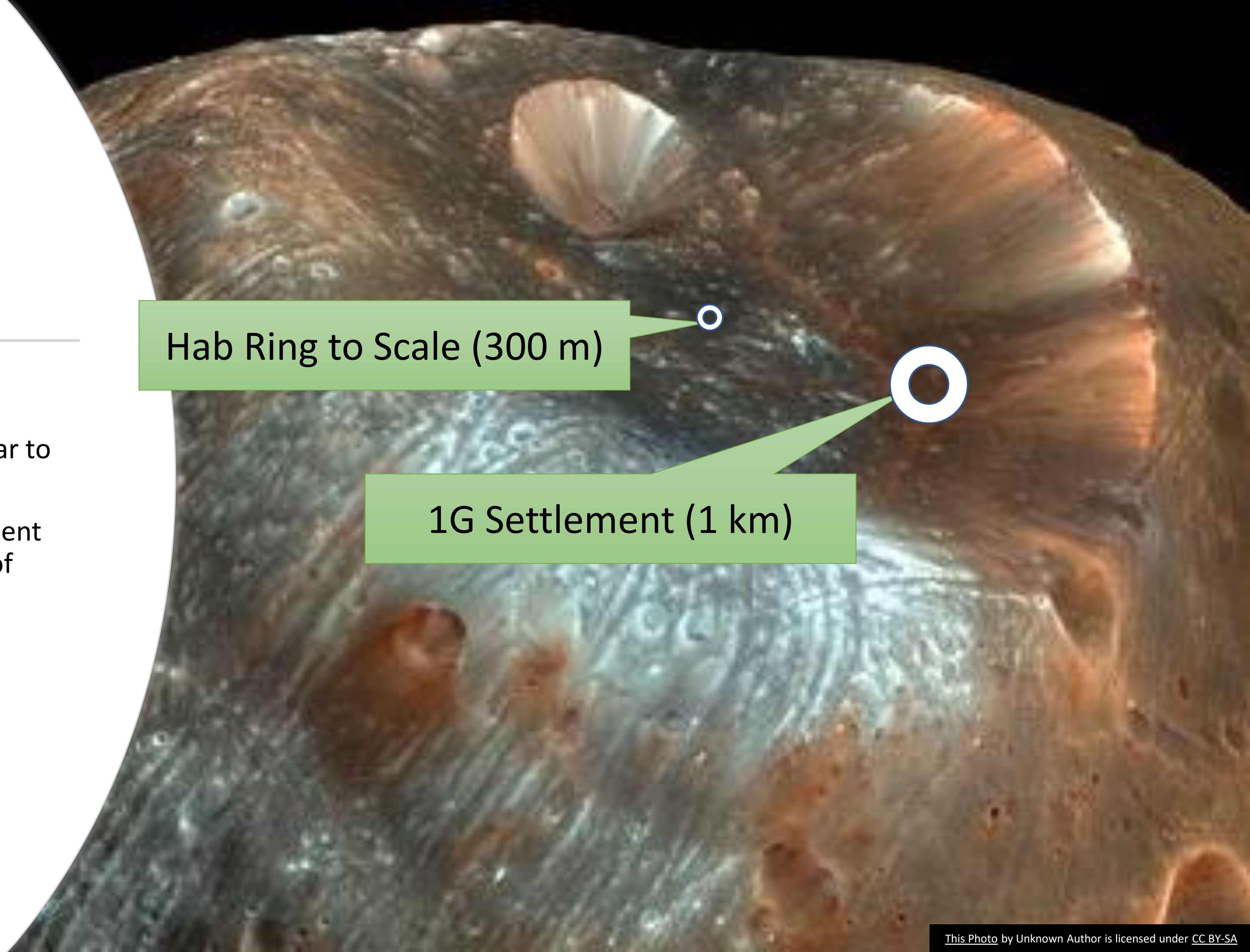
GCR between rails deflected to maximize flight time through shield material

GCR hitting magnet directly has maximum magnetic flux from both inside and outside MagLev arrays

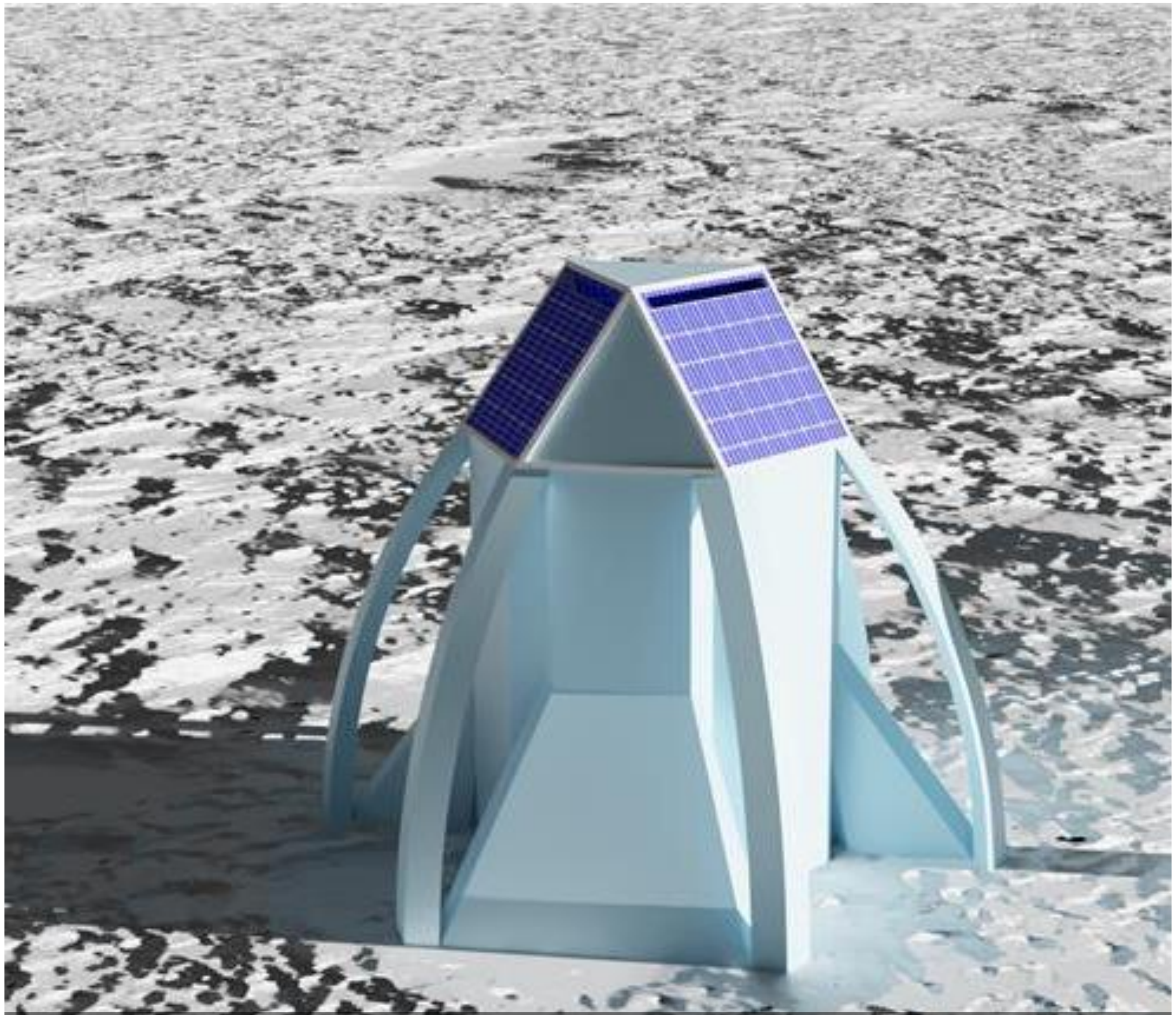


Phobos Base

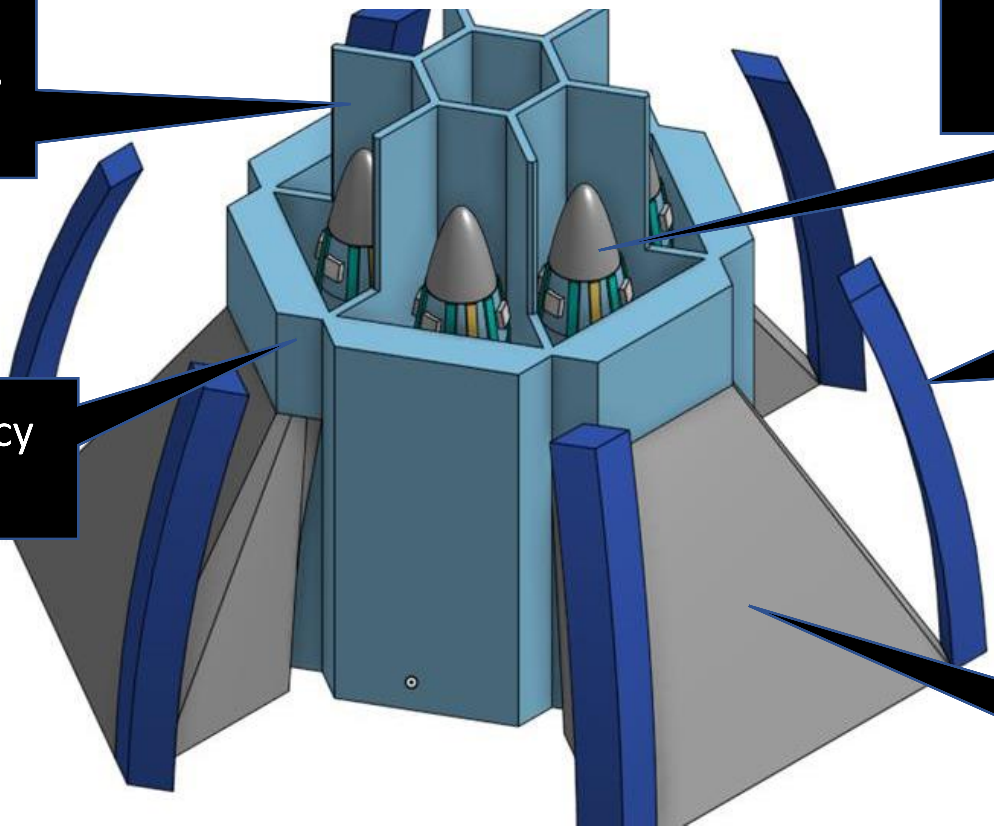
- No GCR protection required
- Could go directly from StarCar to shuttle off surface
- Vertical ring option – equivalent to being on a boat in terms of gravity gradient.
- Escape Velocity of Phobos: 41 kph/25 mph



Surface Habitats

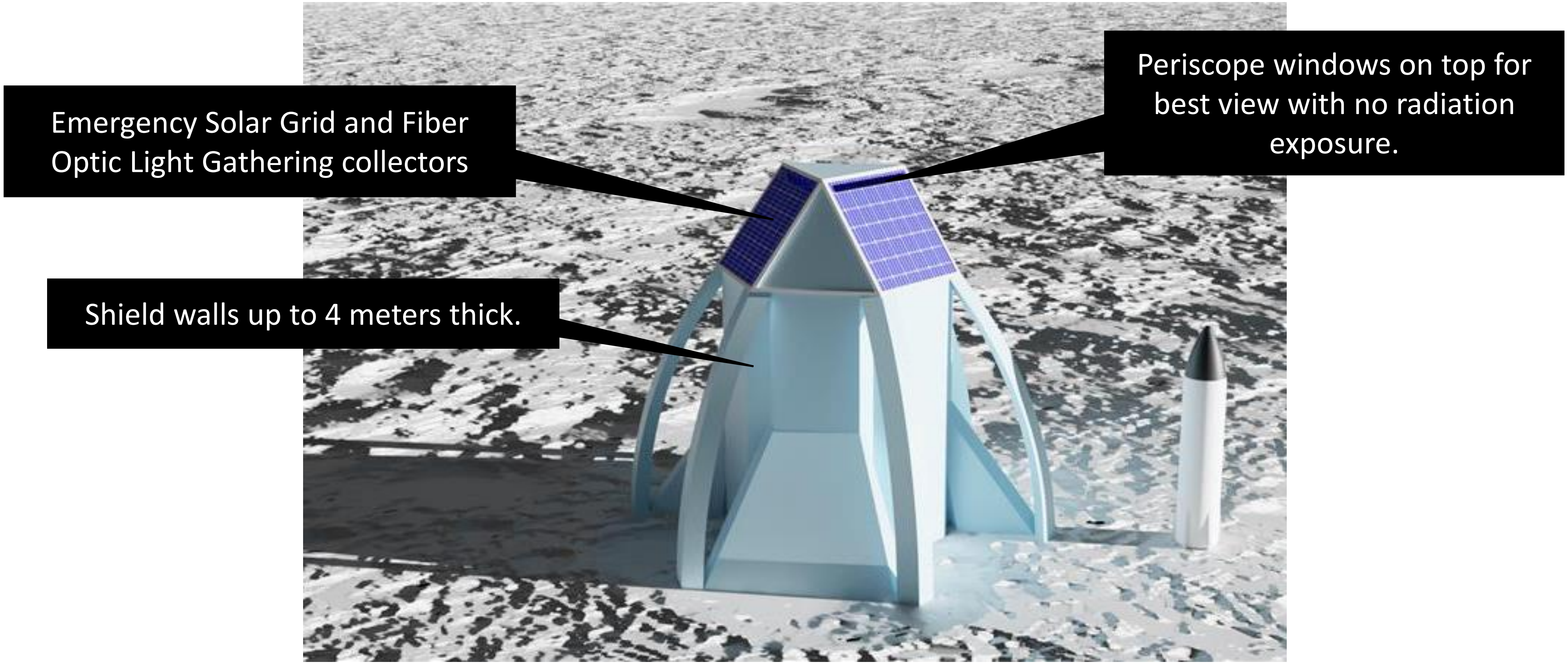

3D Illustration by Aarya Singh

Outpost Interior



3D Illustration by Aarya Singh

Outpost Exterior



3D Illustration by Aarya Singh

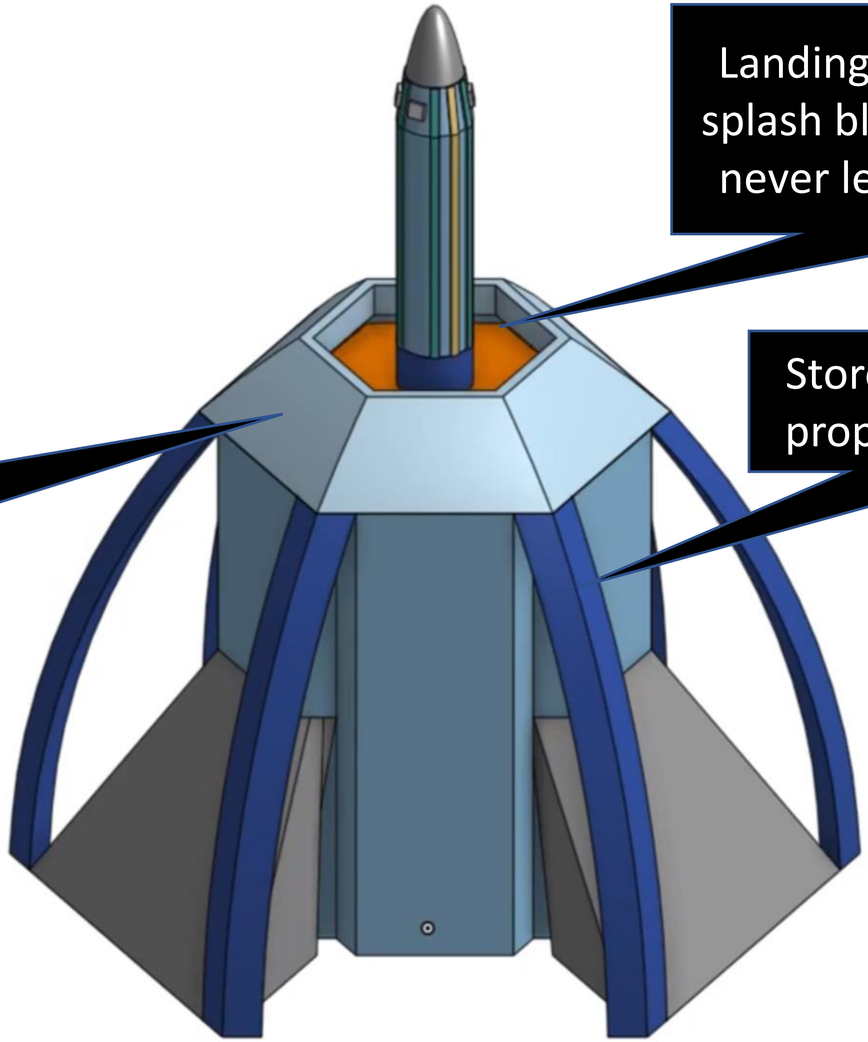
Spaceport Engineering

Landing pad is 60 meters above surface and 16 meters across.

Angled sides have open “Tesla valve” texture to redirect plume away from surface

Landing pad elevated to minimize splash blast on surface. Thrust lines never less than 100 m to regolith.

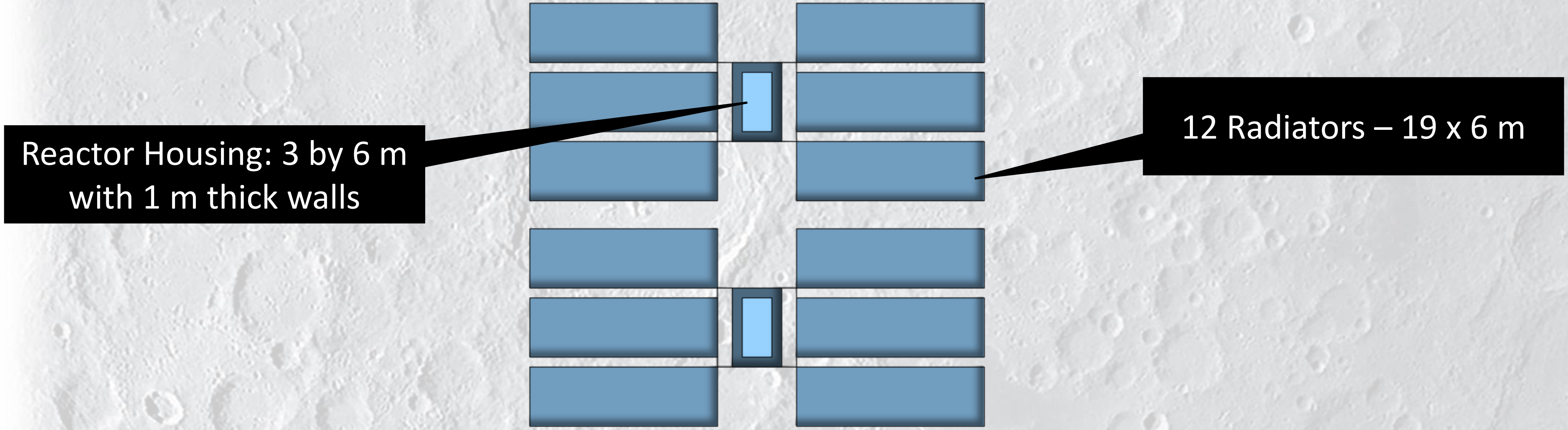
Stored Starships can cache propellant, be maintained.



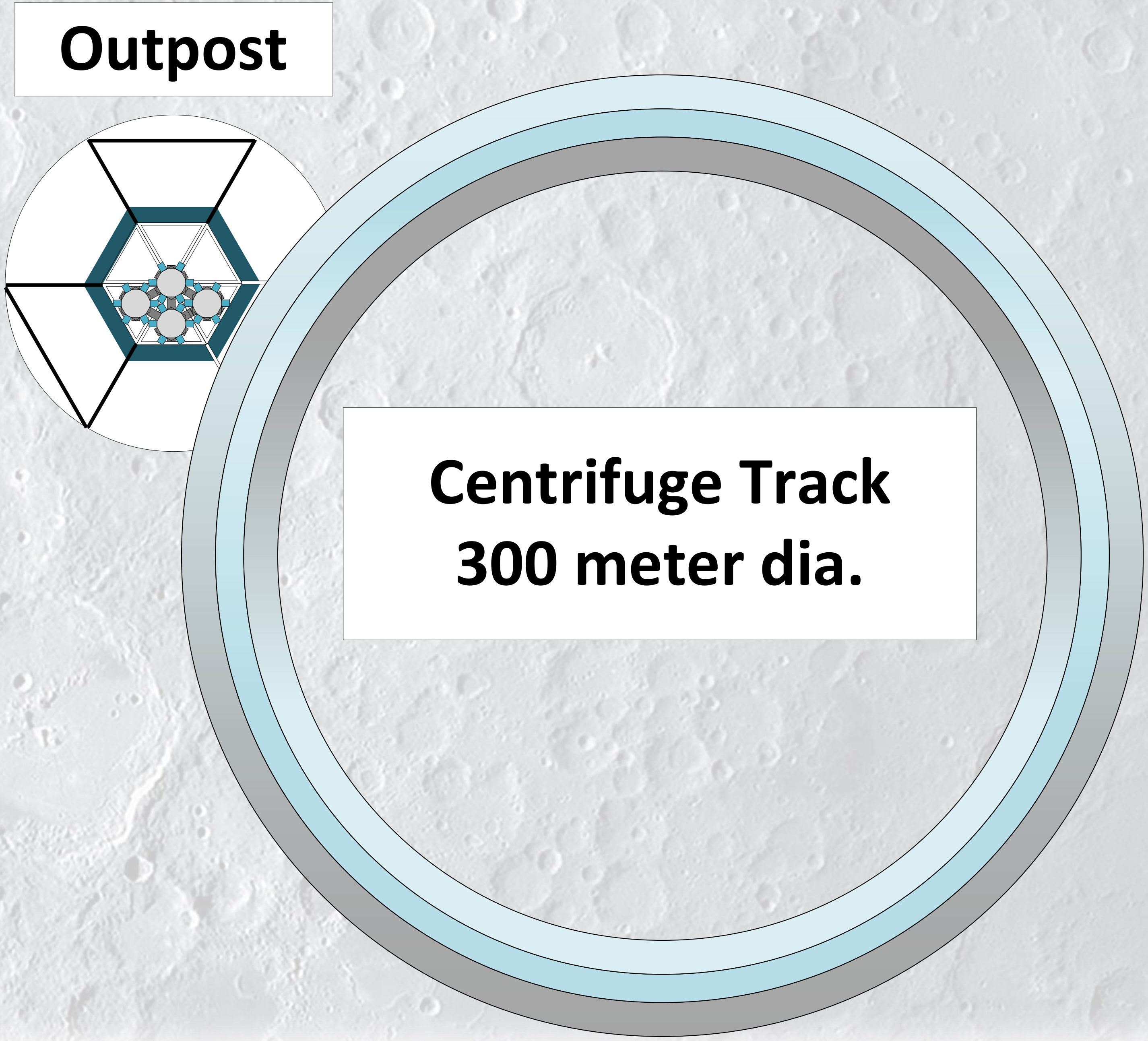
3D Illustration by Aarya Singh

Power Plant (2.4 MWe)

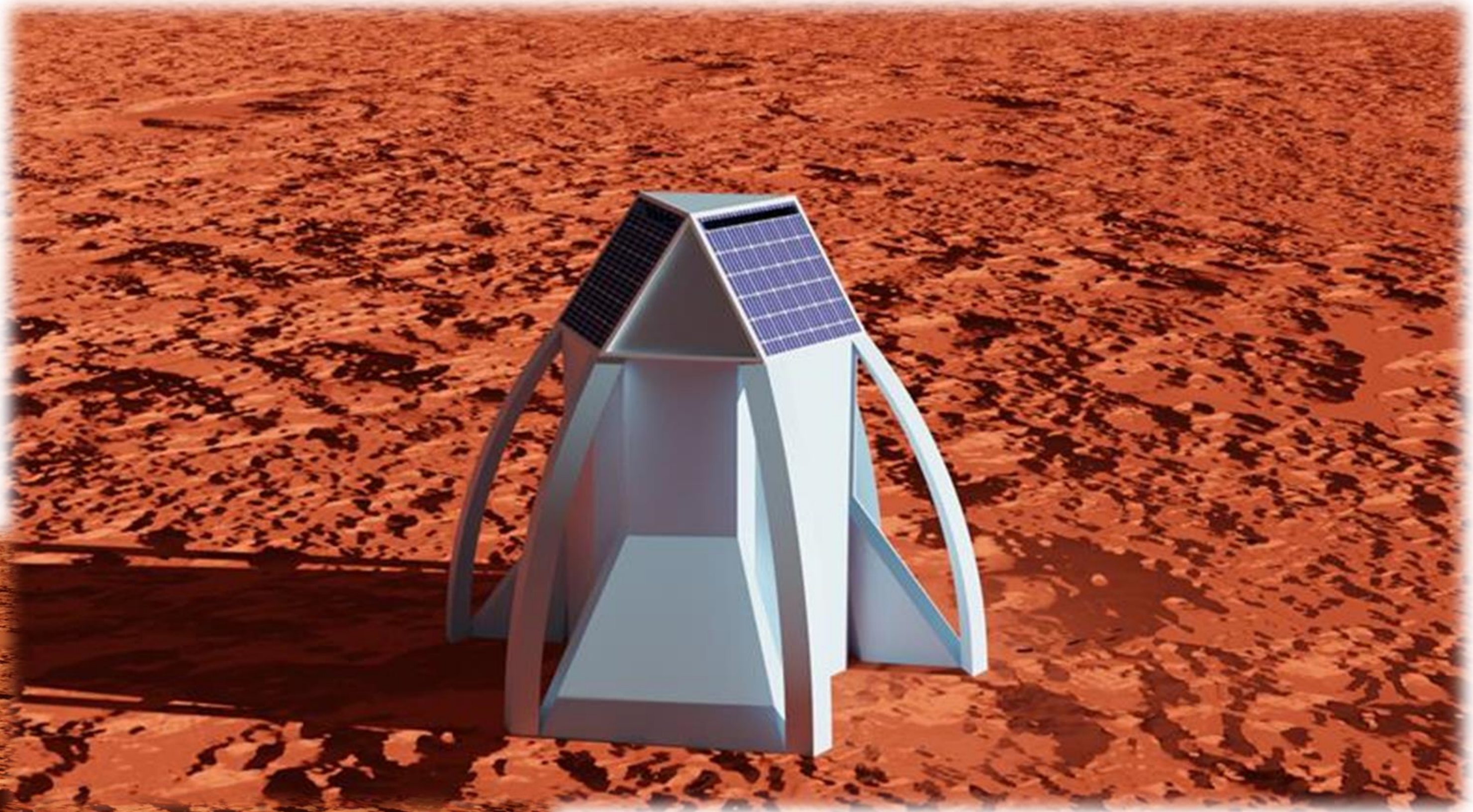
- Low-Enriched Uranium (“Megapower”) reactor – Box Truck sized
- Sunshade/solar panels over radiators to provide additional power during full sun, when radiators from reactor least efficient.

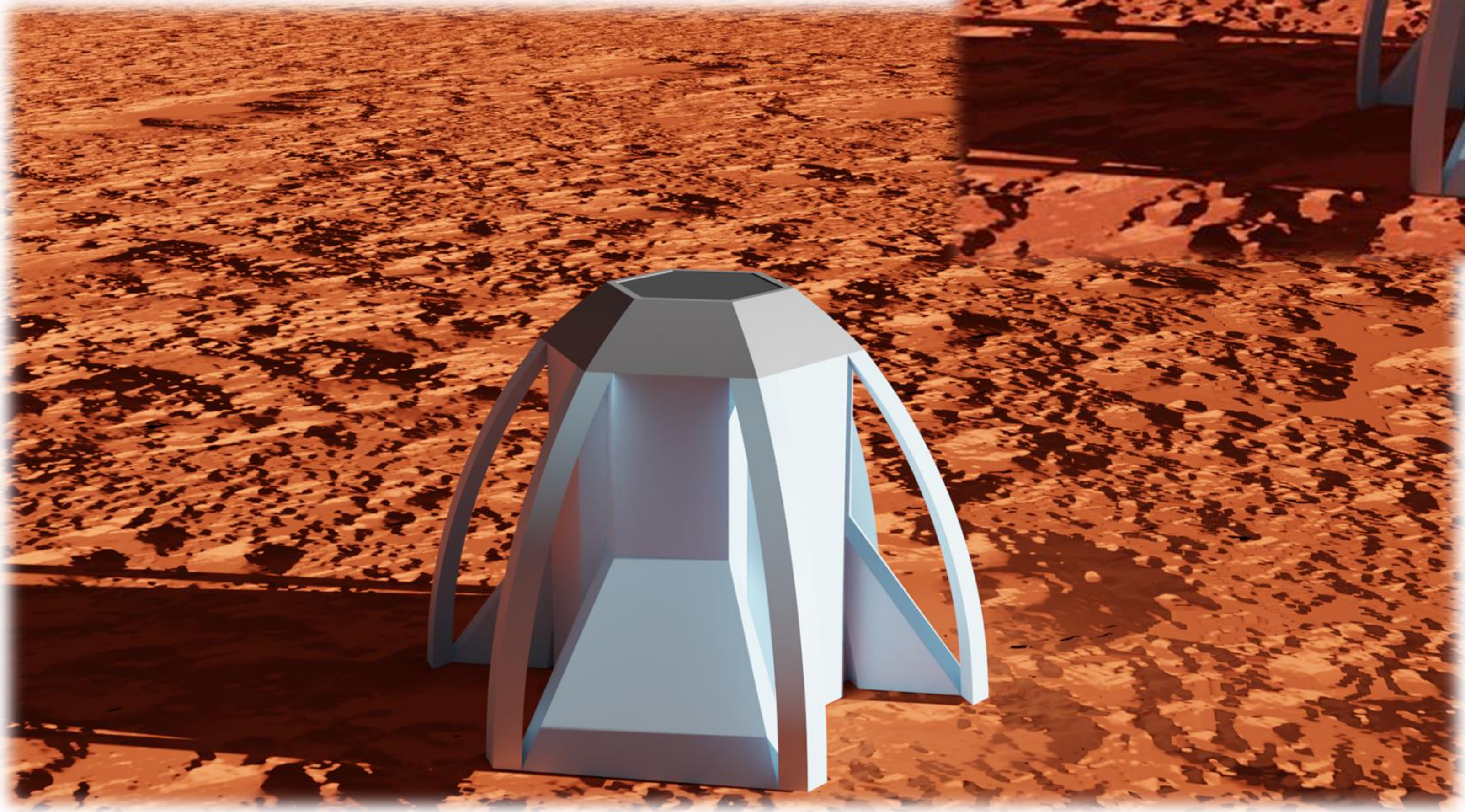


Expansion Phase: Centrifuge Habitat



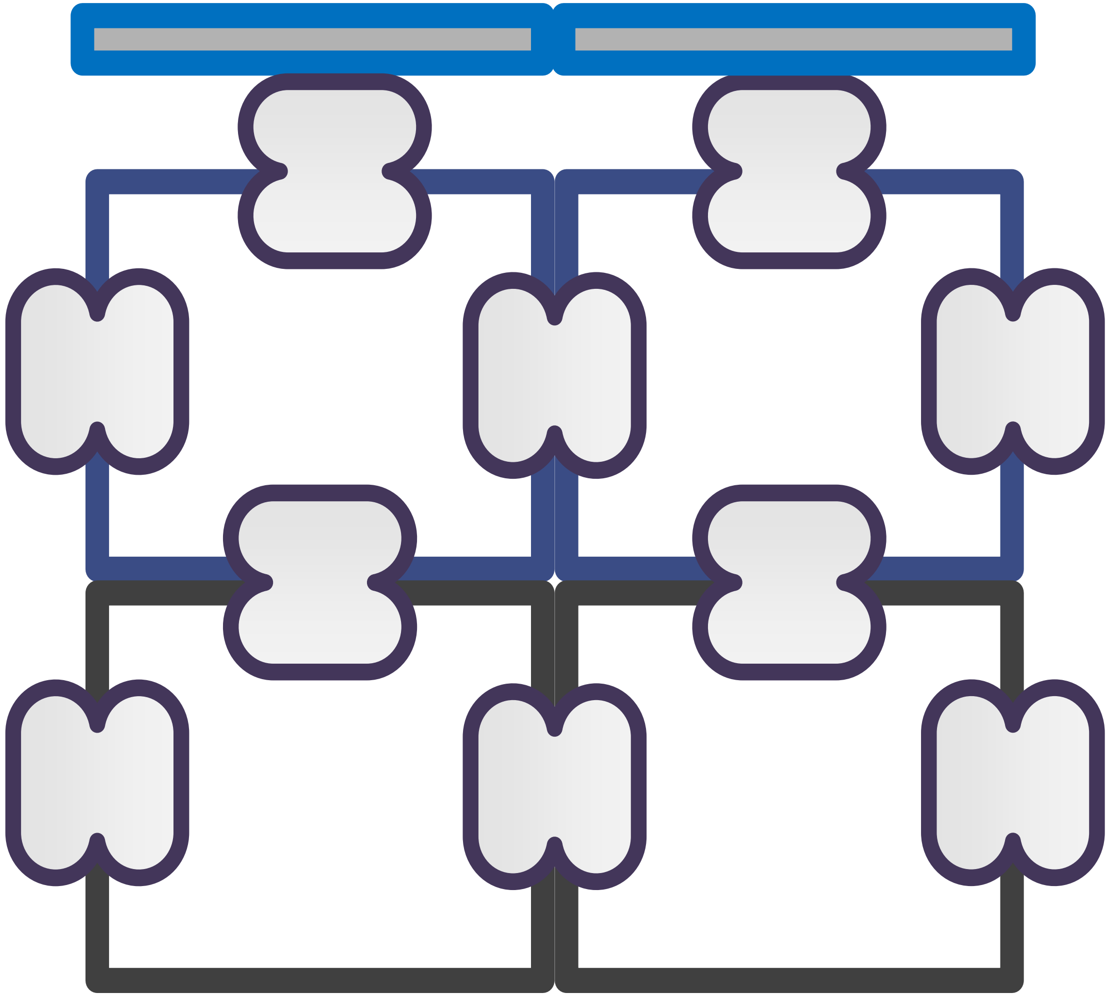
Mars Versions

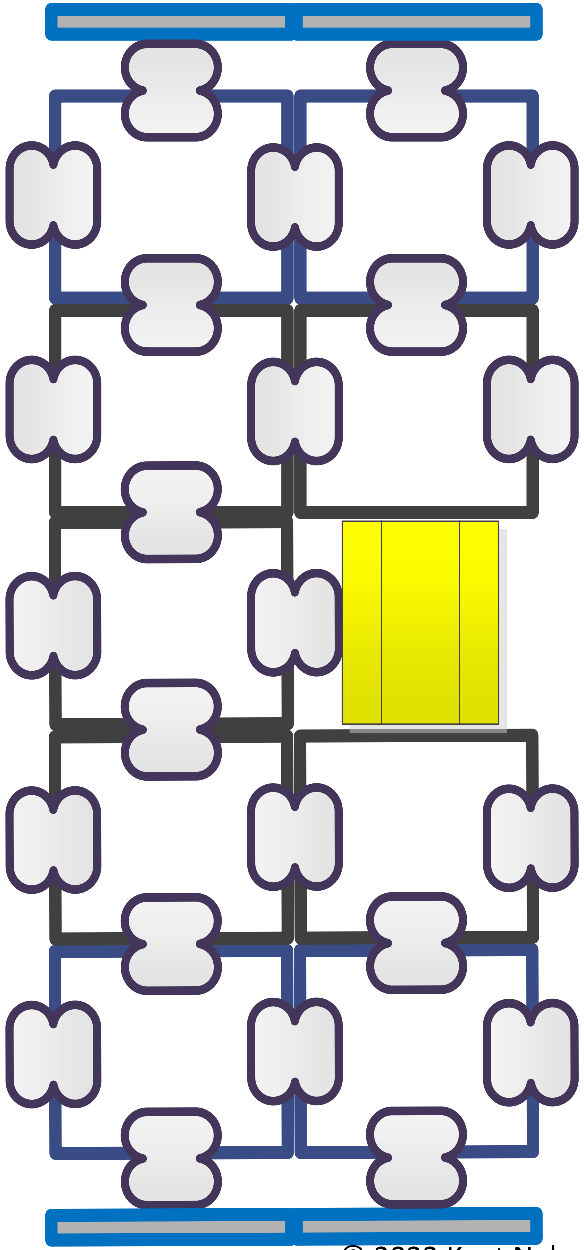




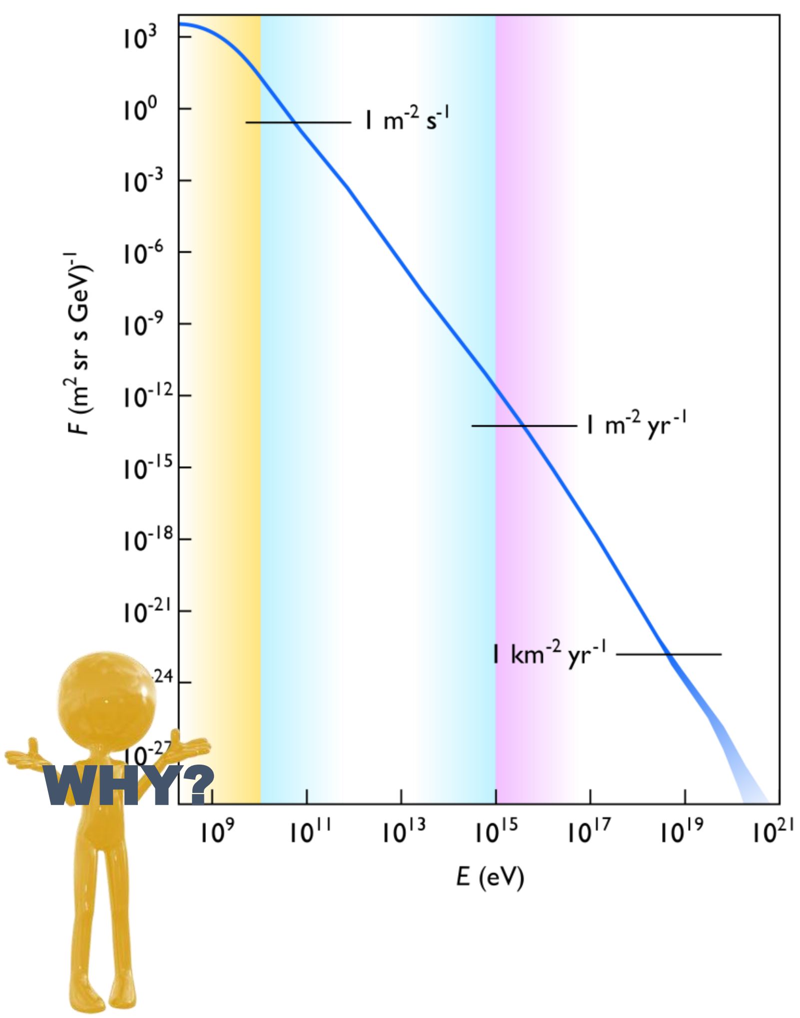
3D Illustration by Aarya Singh

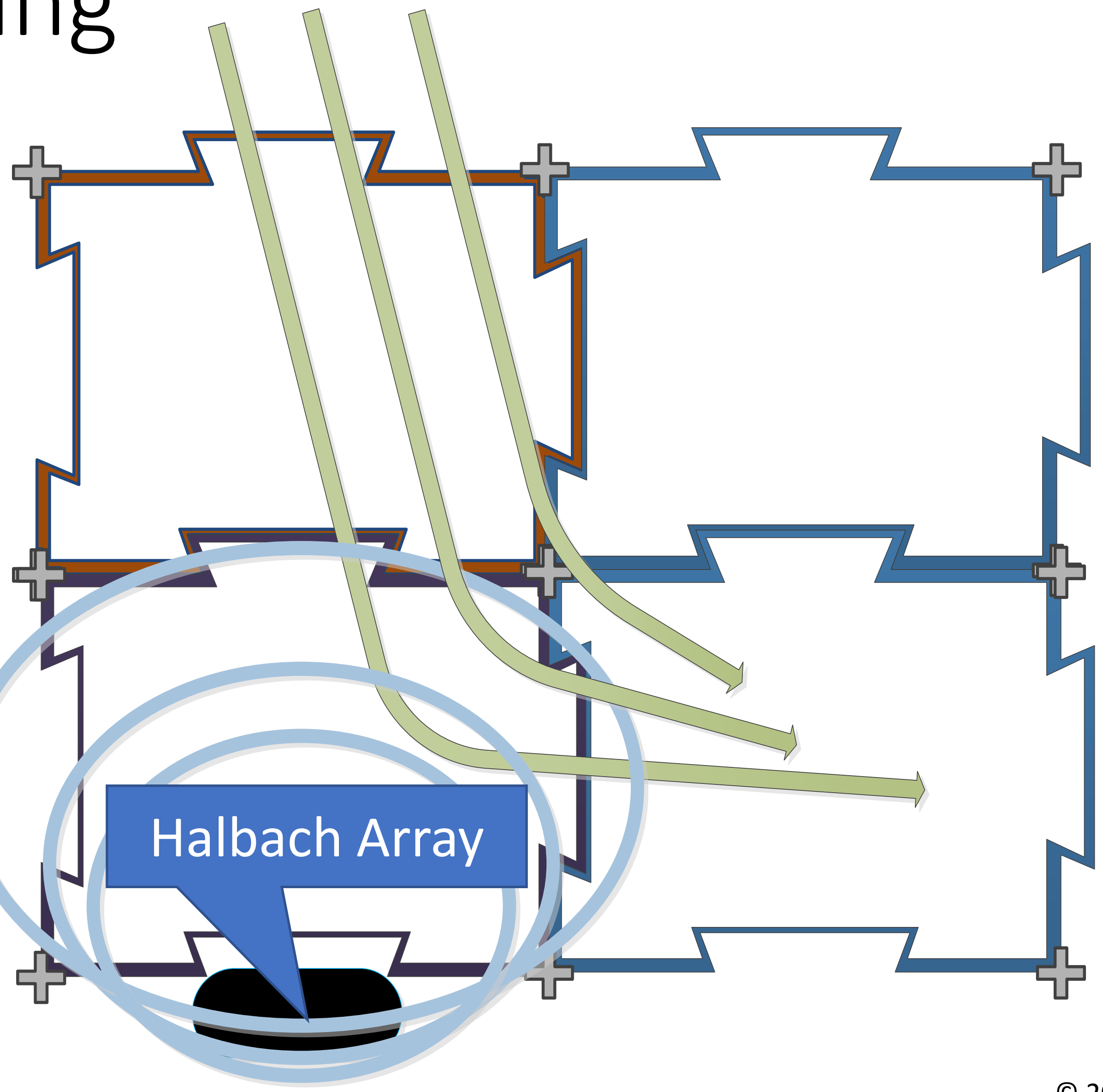
Modular Pykrete Construction





Cosmic Ray Shielding



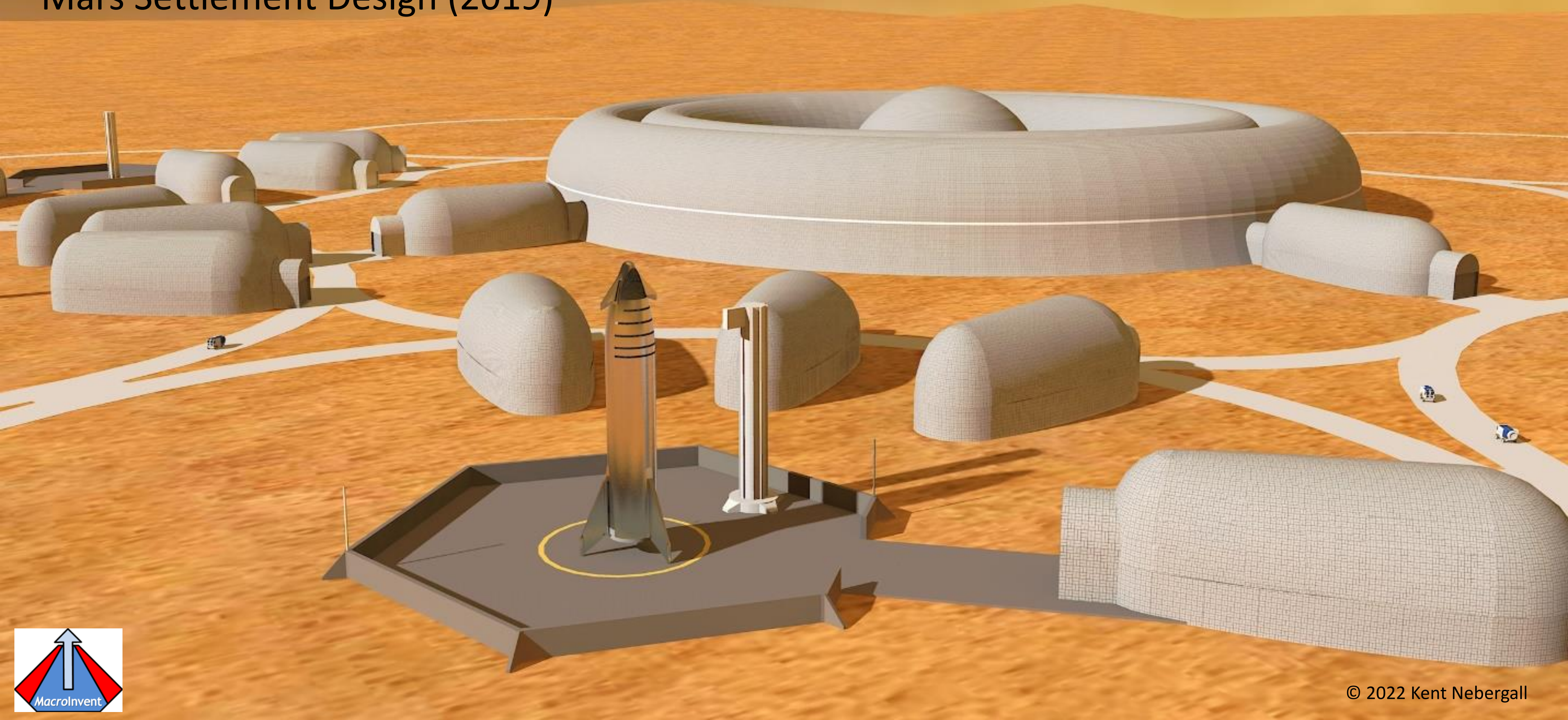


Grand Challenges (Deep Space Coves)

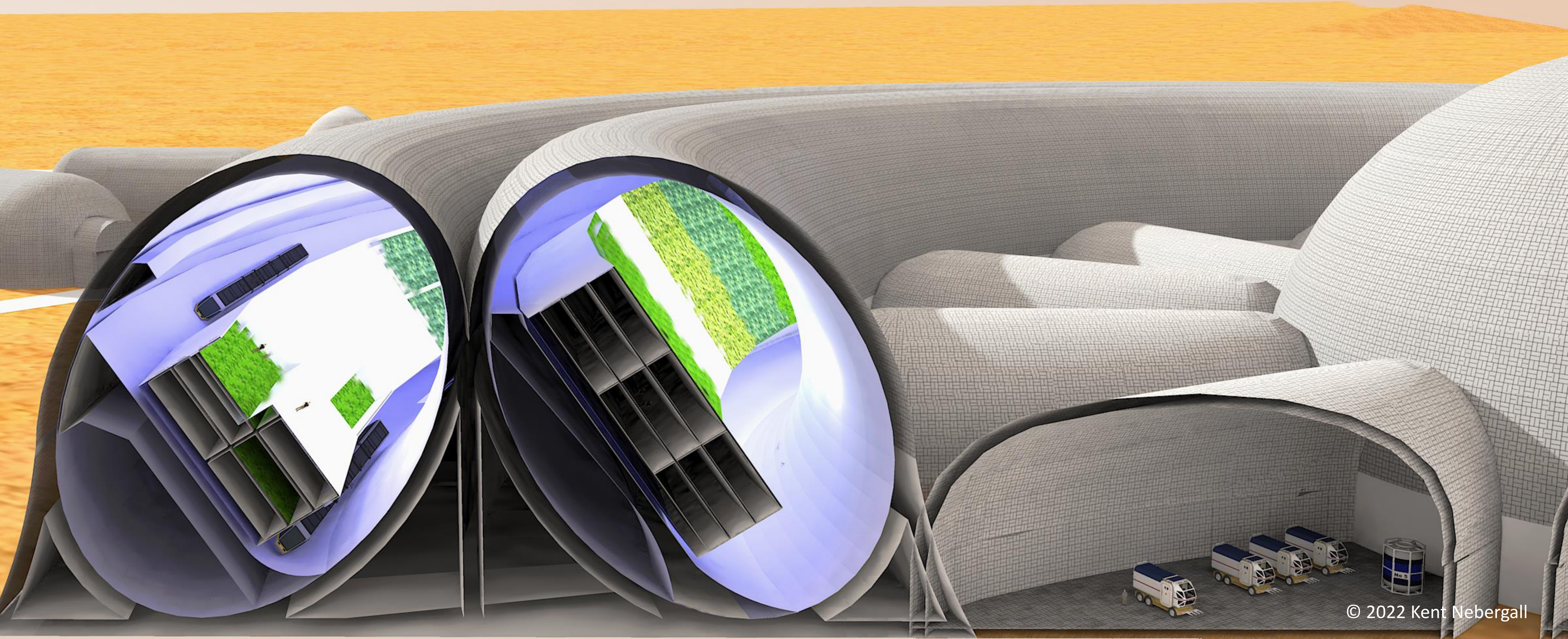
Launch/LEO	Deep Space	Moon/Mars	Settlement
Affordable Launch	Solar Flares	Moon Landing	Air/Water
Large Vehicle Launch	GCR: Cell Damage	Mars EDL	Power and Propellant
Orbital Refueling/ Mass Fraction beyond Earth Orbit	Medication/ Food Expiration	Spacesuit Lifespan	Base Construction
Space Junk	Life Support Closed Loop	Dust Issues	Food Growth
Microgravity (health issues)	Medical Entropy	Basic Power/ Propellant Production	Surface Mining and Extraction
	Psychology	Return Flight to Earth (speed, mass, etc.)	Hybrid Manufacturing
	Mechanical Entropy	Planetary Protection	Reproduction

Eureka

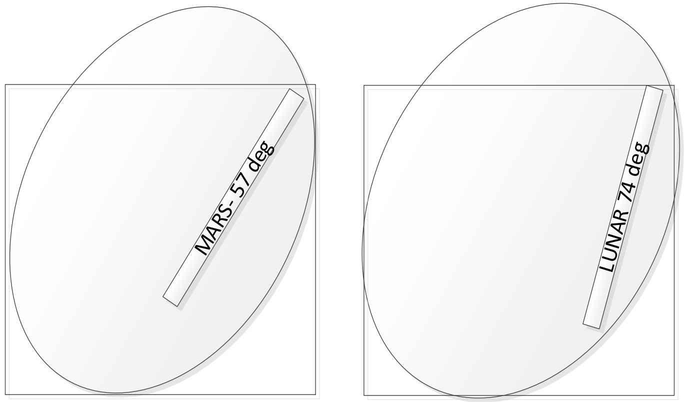
Mars Settlement Design (2019)



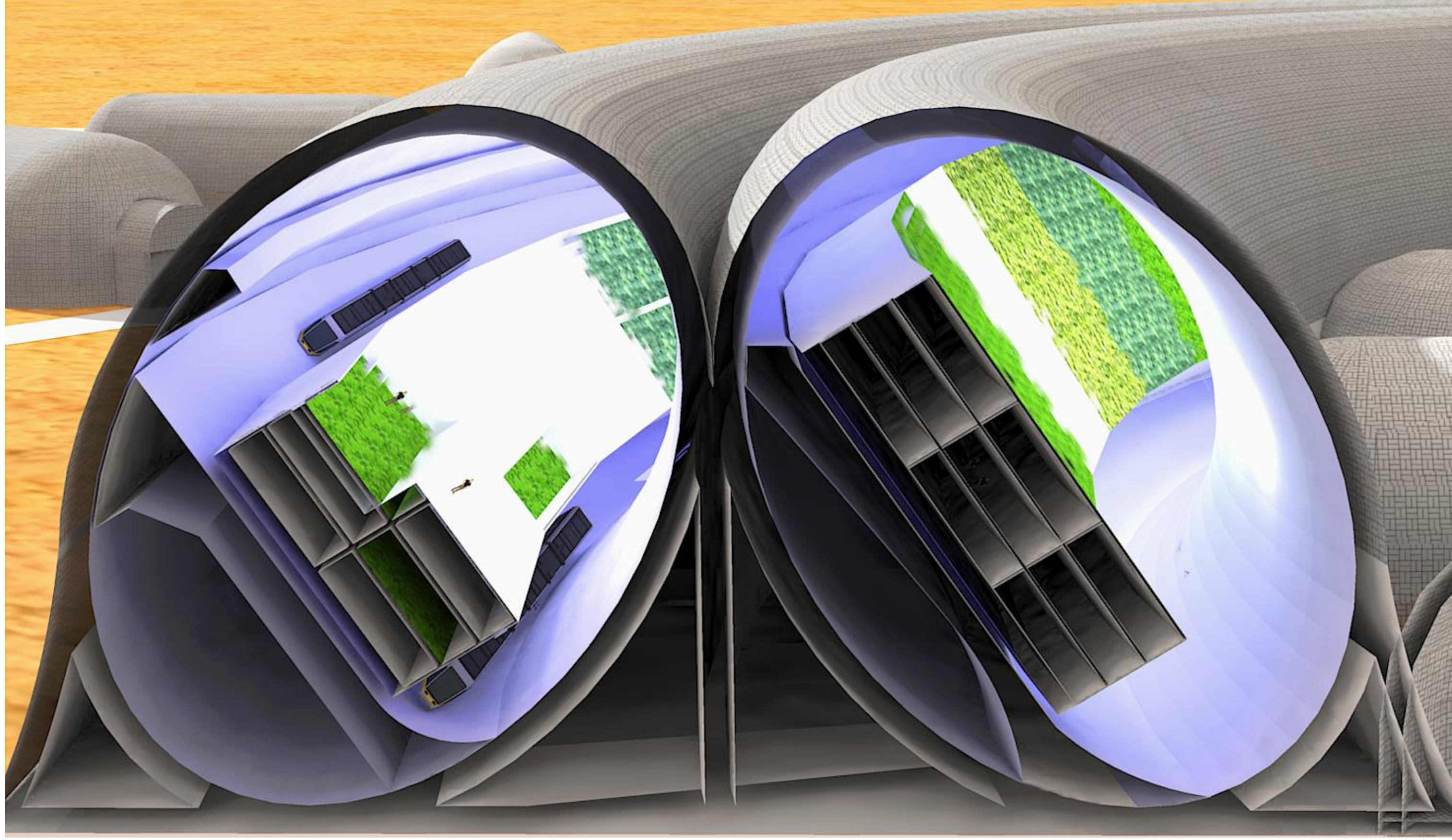
Main City Construction

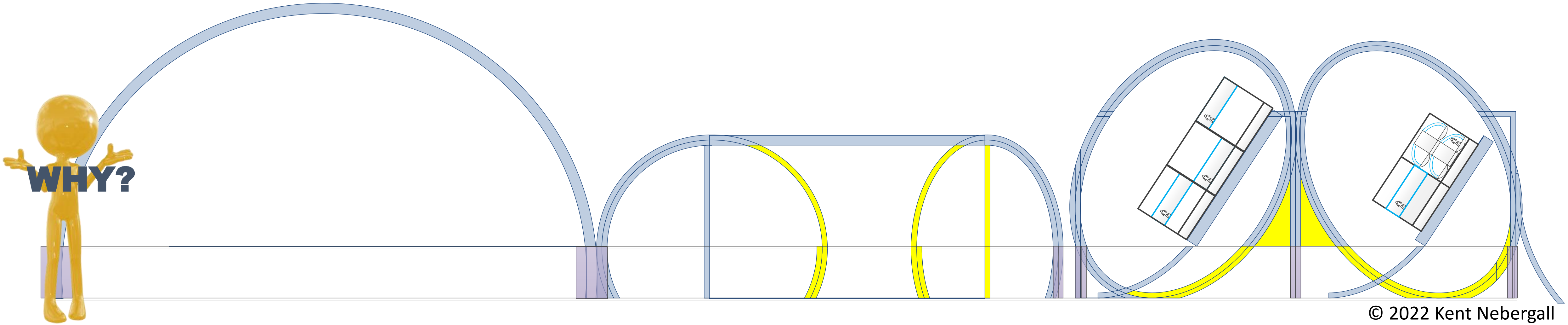


Centrifuge Rings

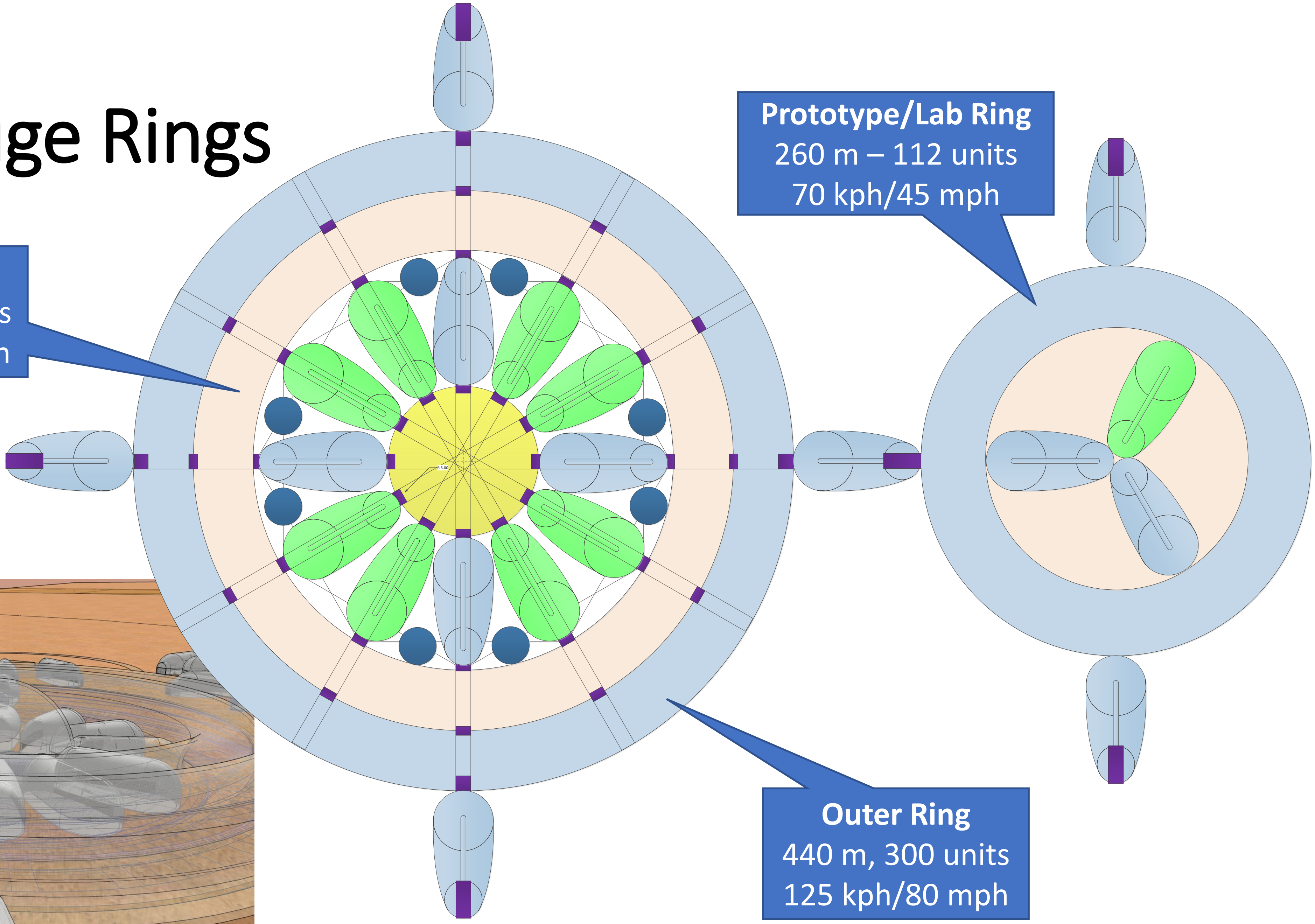


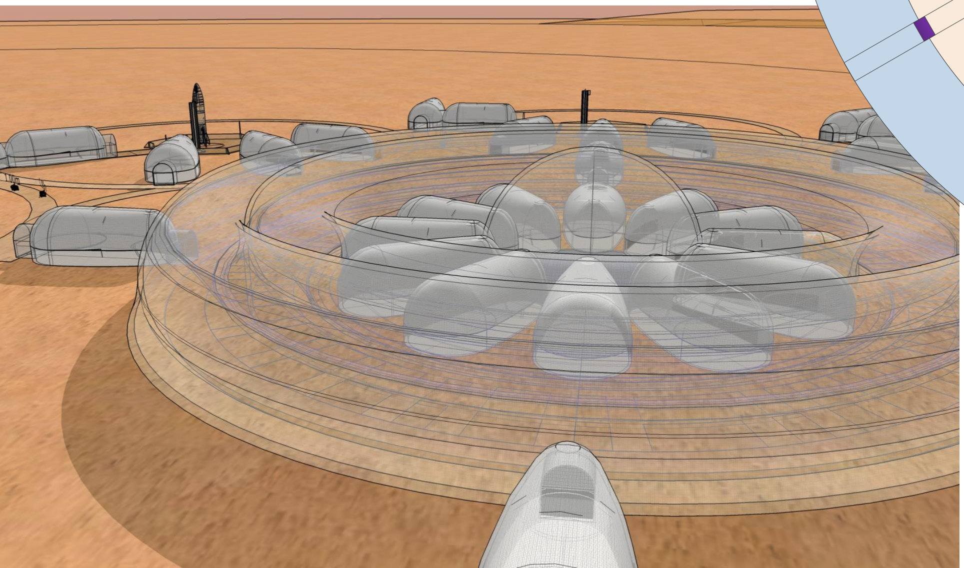
The outer ring has a track that would accommodate a spinning structure for artificial gravity. This is 57 degree slope for Mars gravity or 74 degrees for lunar gravity.



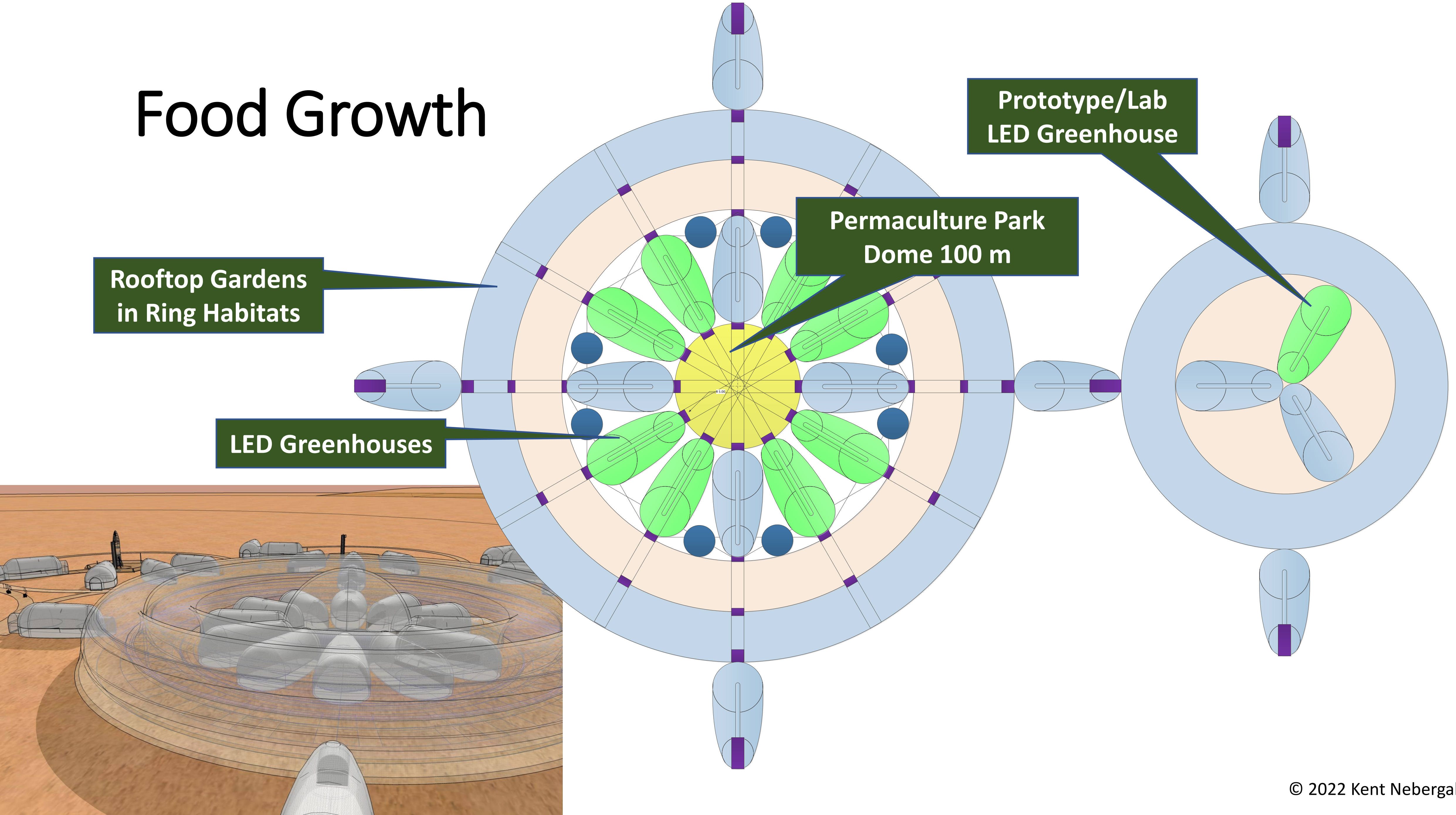


Centrifuge Rings

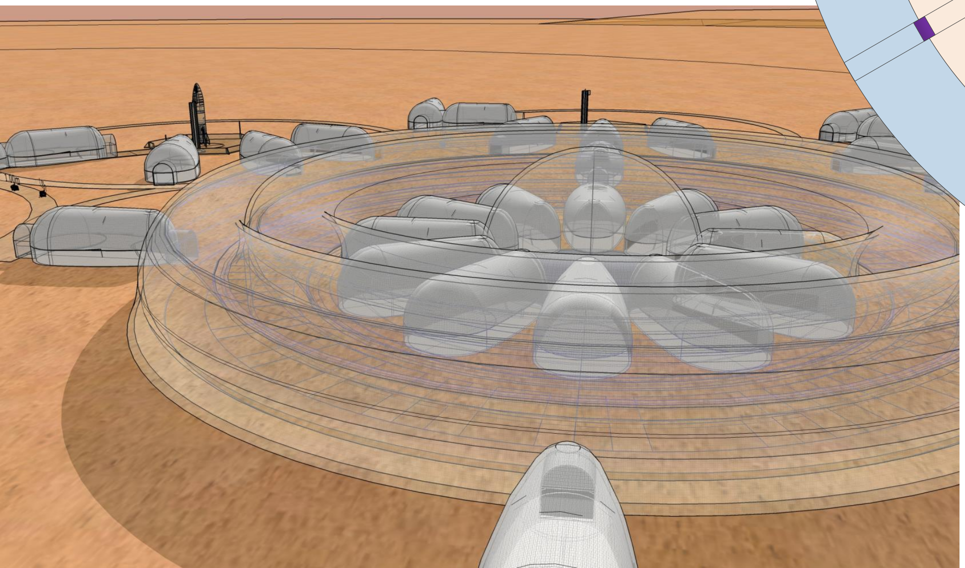


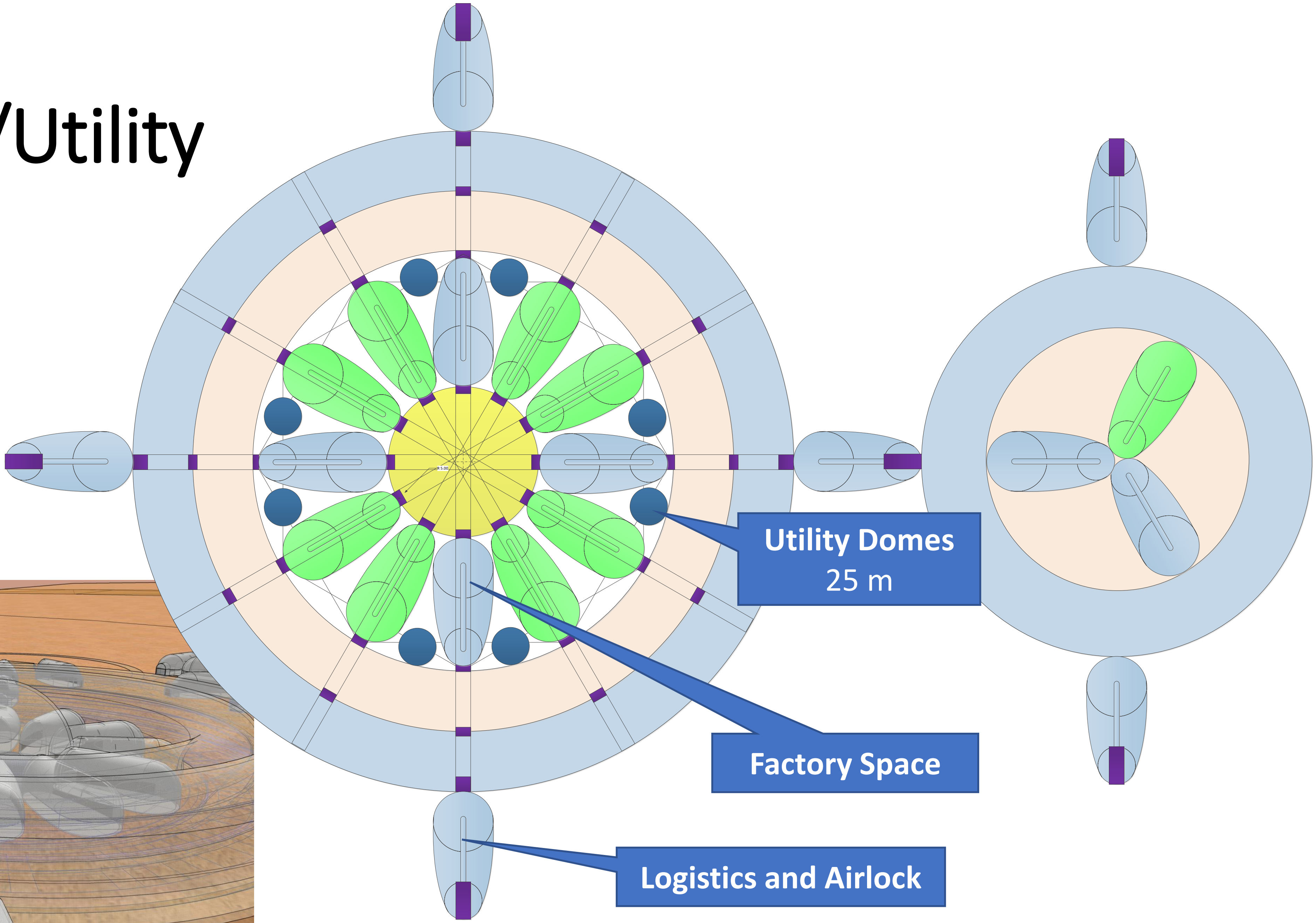


Food Growth


Rooftop Gardens
in Ring Habitats
LED Greenhouses
Permaculture Park
Dome 100 m
Prototype/Lab
LED Greenhouse

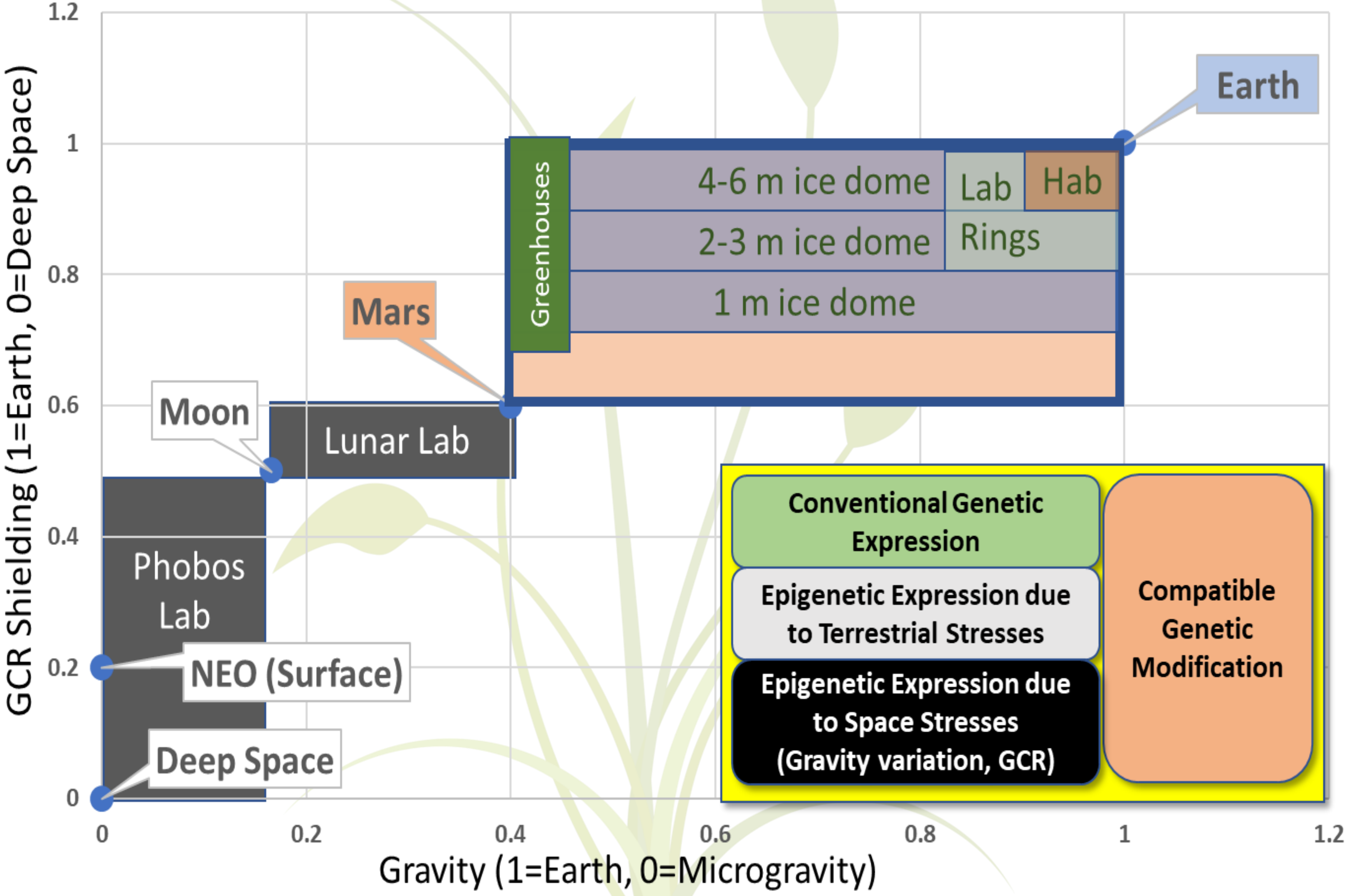
Factory/Utility





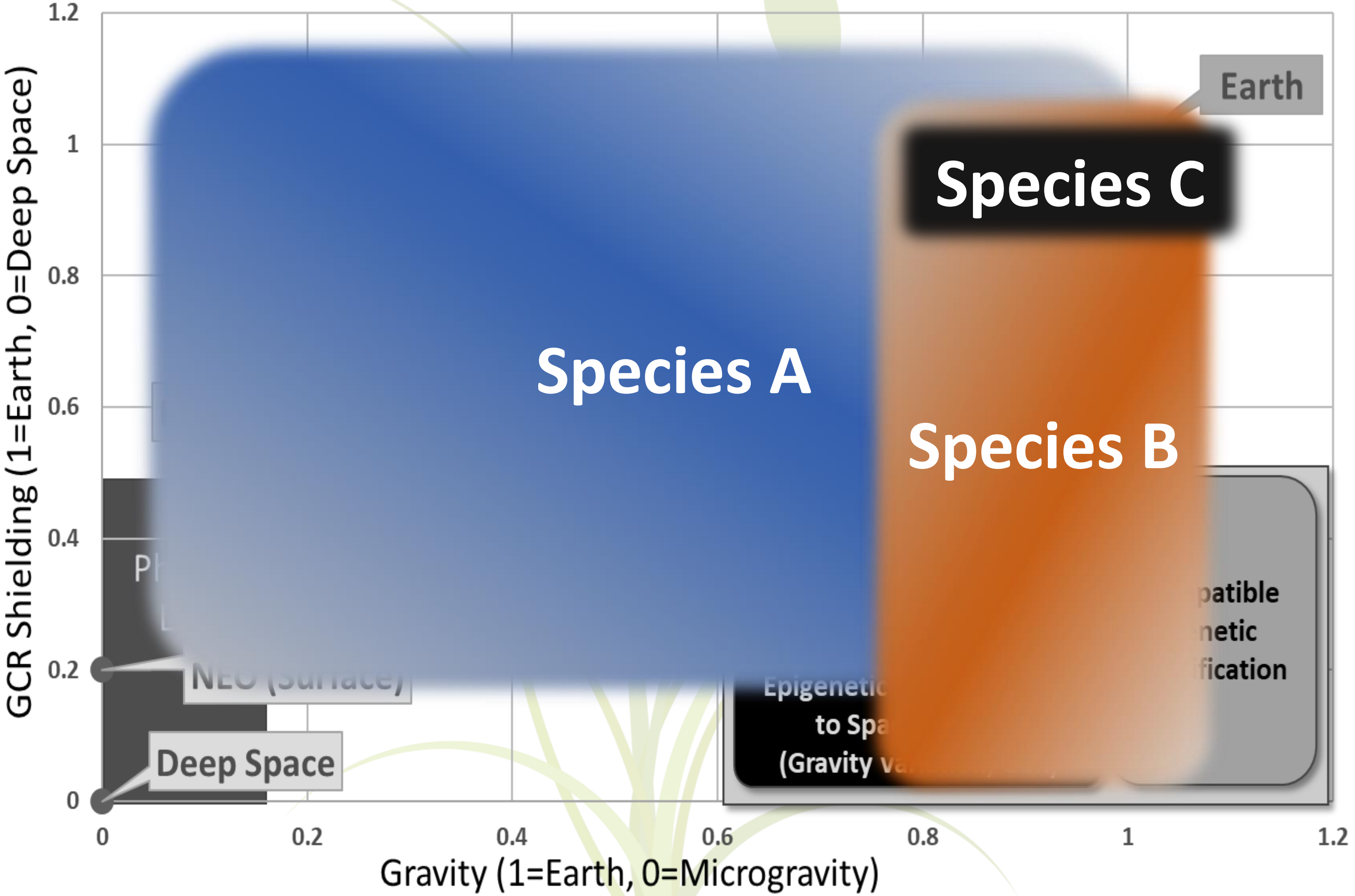
The Purpose

WHY?



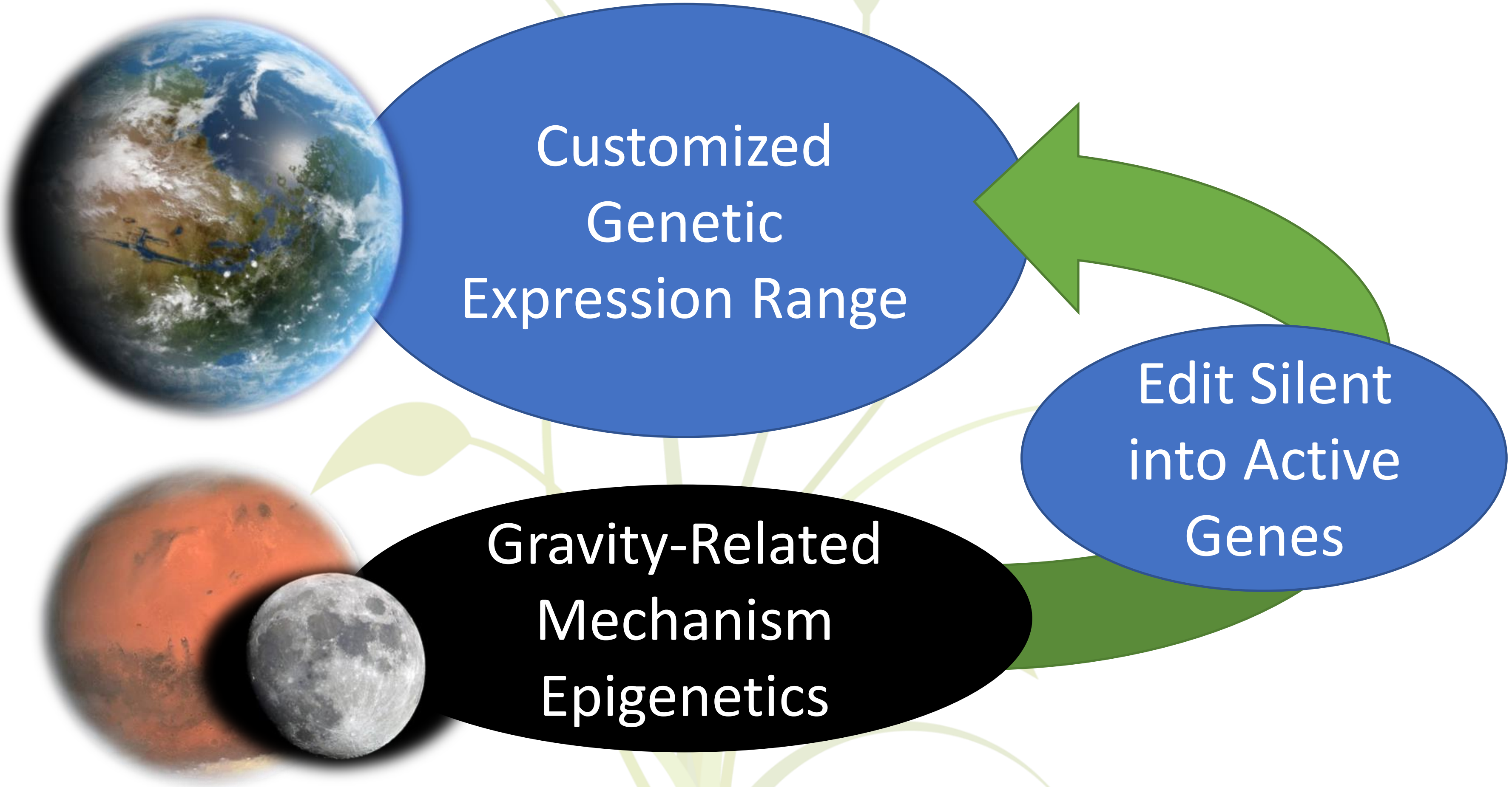
Earth
4-6 m ice dome
Lab
Hab
2-3 m ice dome
Rings
1 m ice dome
Greenhouses
Mars
Moon
Lunar Lab
Phobos Lab
NEO (Surface)
Deep Space
Conventional Genetic Expression
Epigenetic Expression due to Terrestrial Stresses
Epigenetic Expression due to Space Stresses (Gravity variation, GCR)
Compatible Genetic Modification
GCR Shielding (1=Earth, 0=Deep Space)
Gravity (1=Earth, 0=Microgravity)
0
0.2
0.4
0.6
0.8
1
1.2

The Purpose

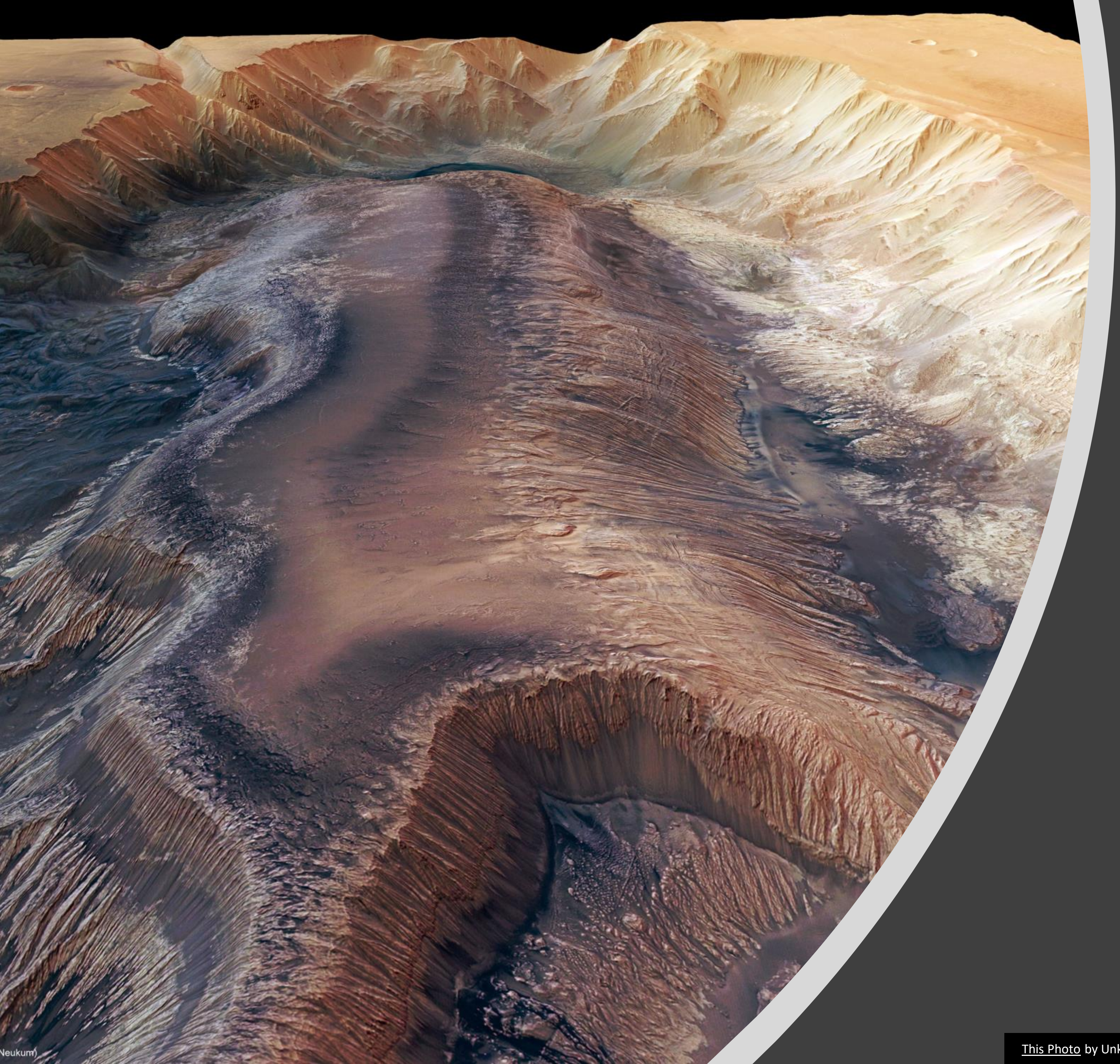


Earth
Species C
Species A
Species B
Deep Space
Epigenetic
to Spa
(Gravity va
patible
netic
fication
0
0.2
0.4
0.6
0.8
1
1.2
GCR Shielding (1=Earth, 0=Deep Space)
Gravity (1=Earth, 0=Microgravity)

Mechanism Epigenetics



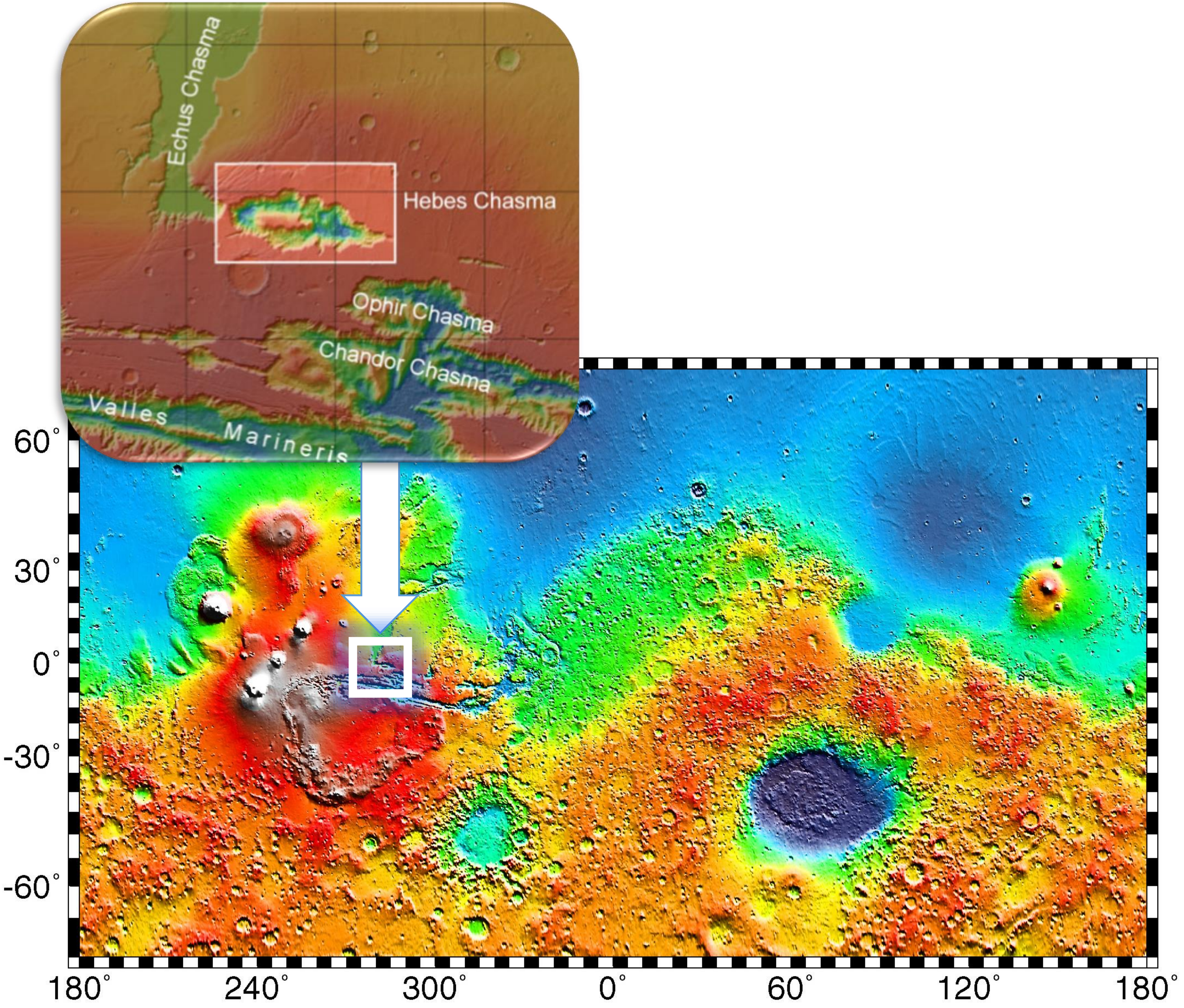
[Understanding Epigenetics Research in Space | NASA]

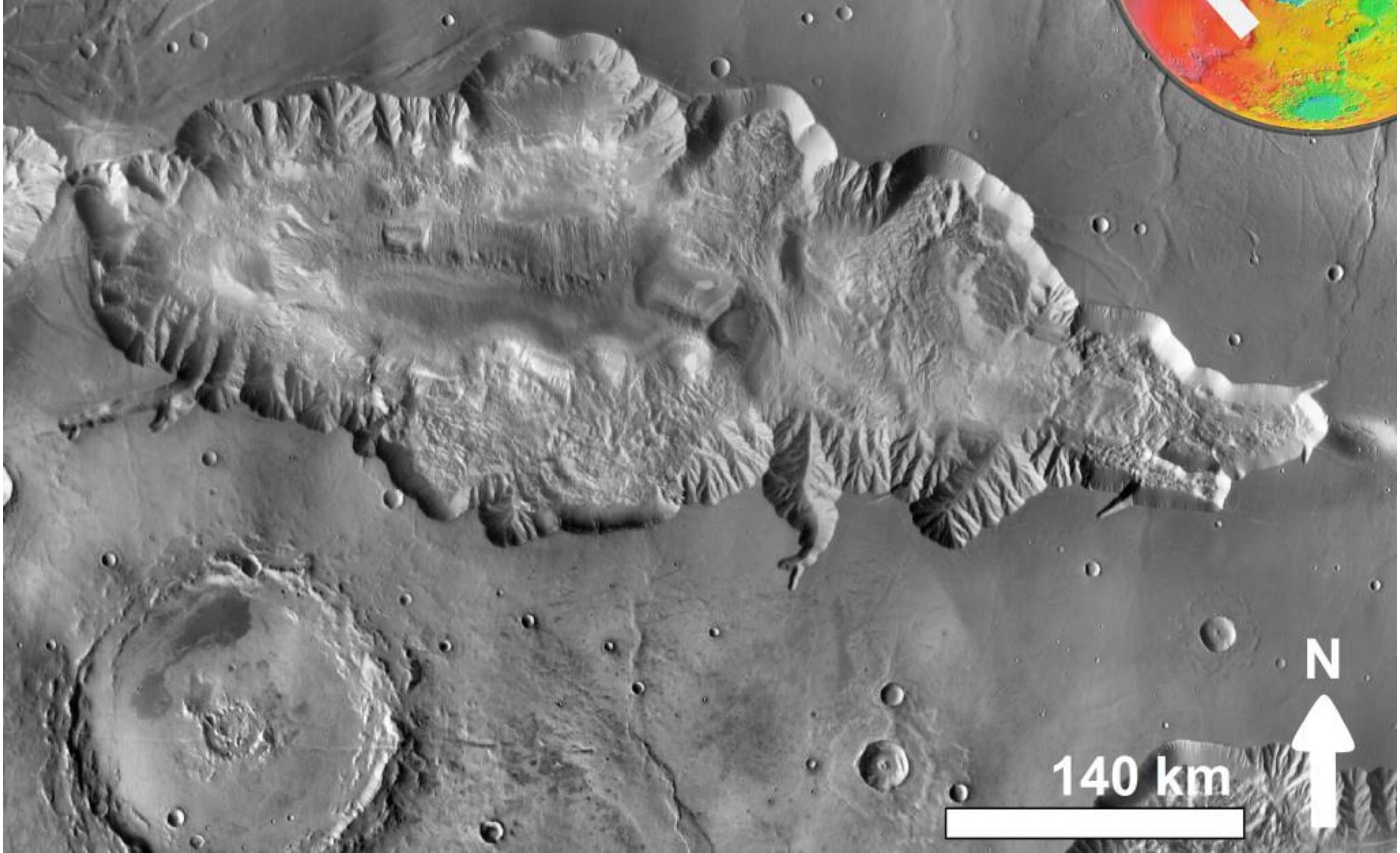


ParaTerraforming Hebes Chasma

Hebes Chasma

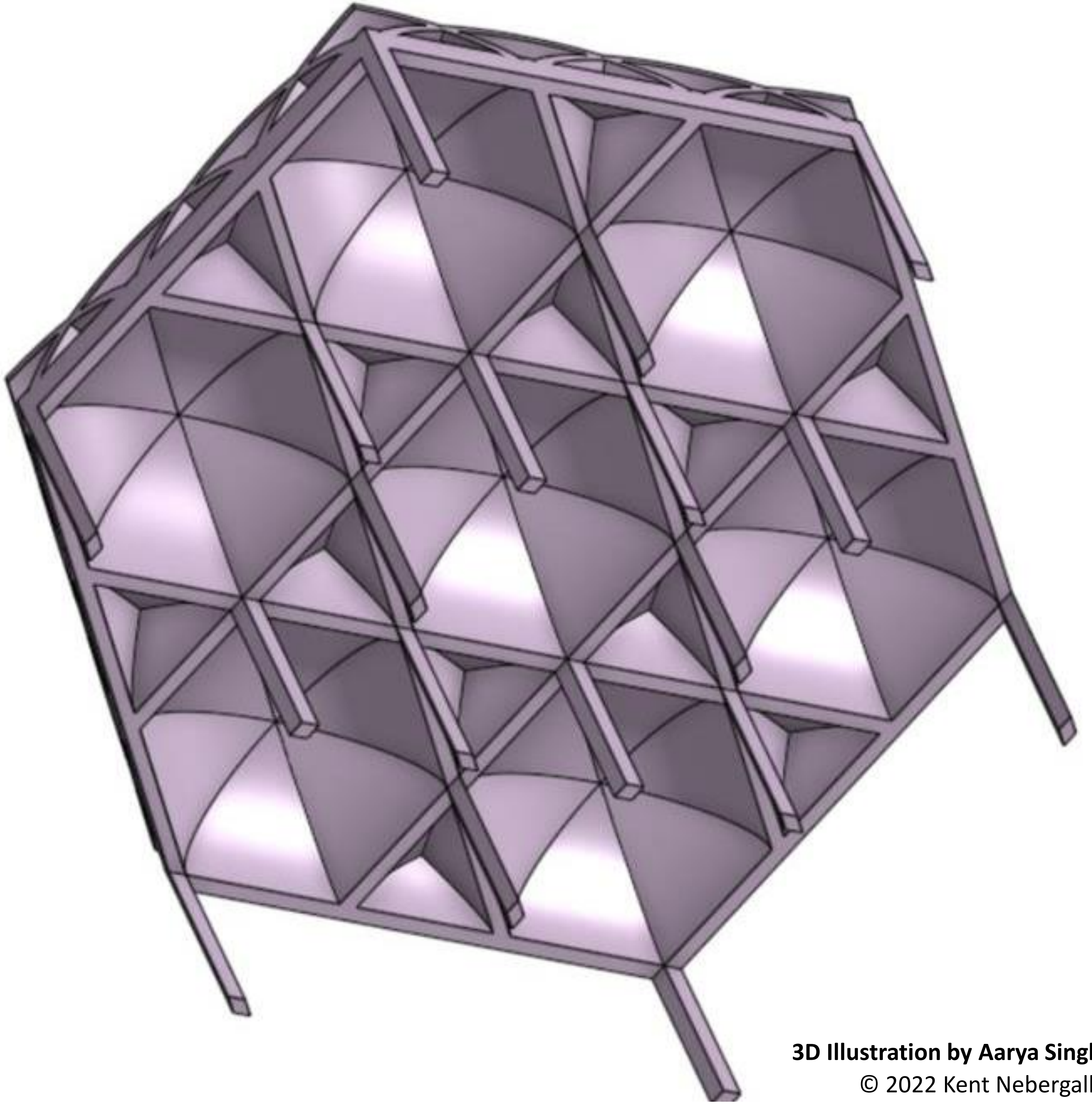
- "Small" enclosed canyon the size of Lake Erie (320 x 130 km, ~32,600 km^2)
- 5-6 km deep
- 0.023% of Surface




N
140 km

“Basement” Dome Details

- Hexagonal grid across canyon floor
- Contains reactors for power, light, and waste heat to drive ecosystems
- NOTE: 500 meters is big enough to put spinning ring ecosystems within some domes for Earth gravity levels



3D Illustration by Aarya Singh

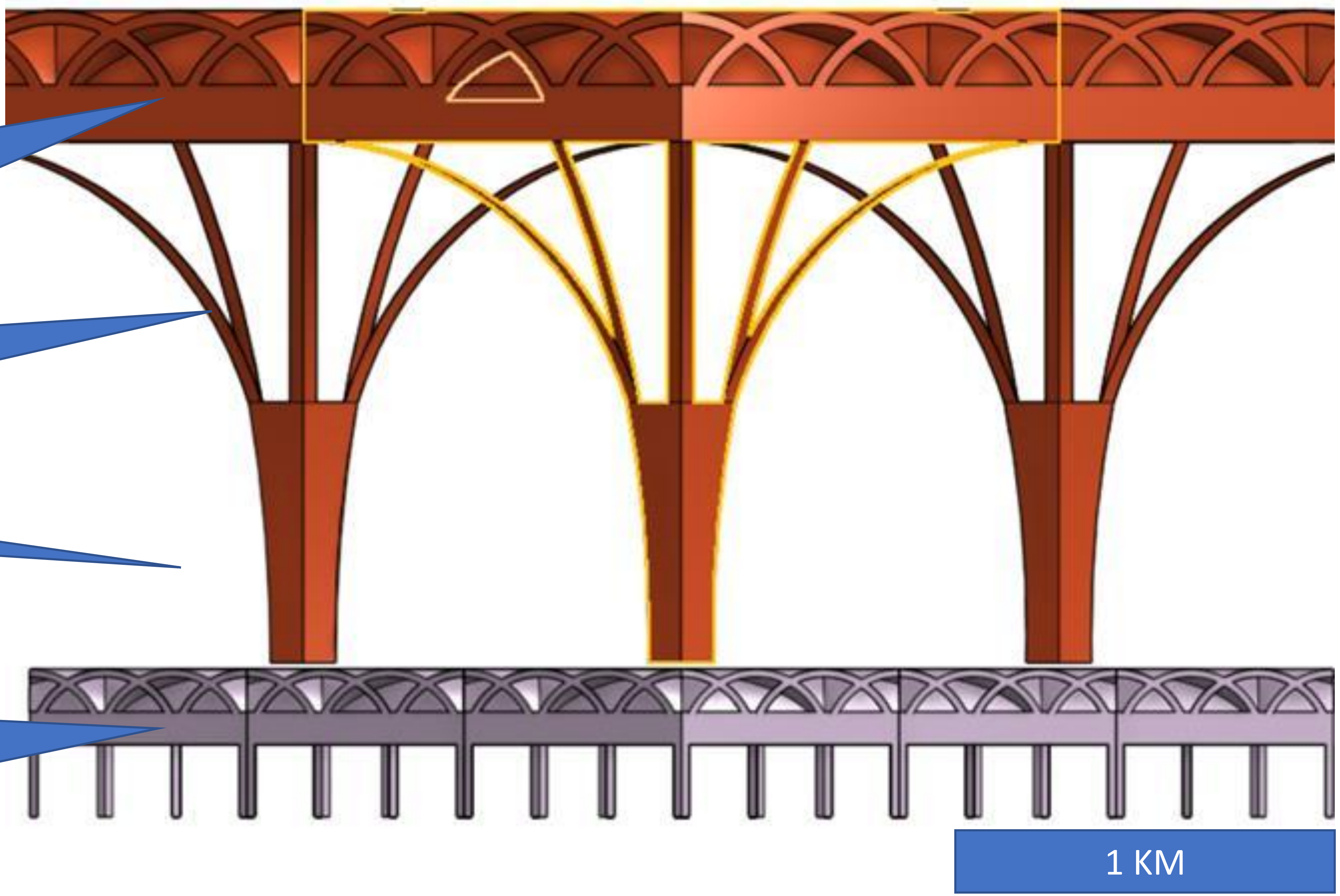
Enclosures

Roof Enclosure
Air pressure supported
GCR Shielding

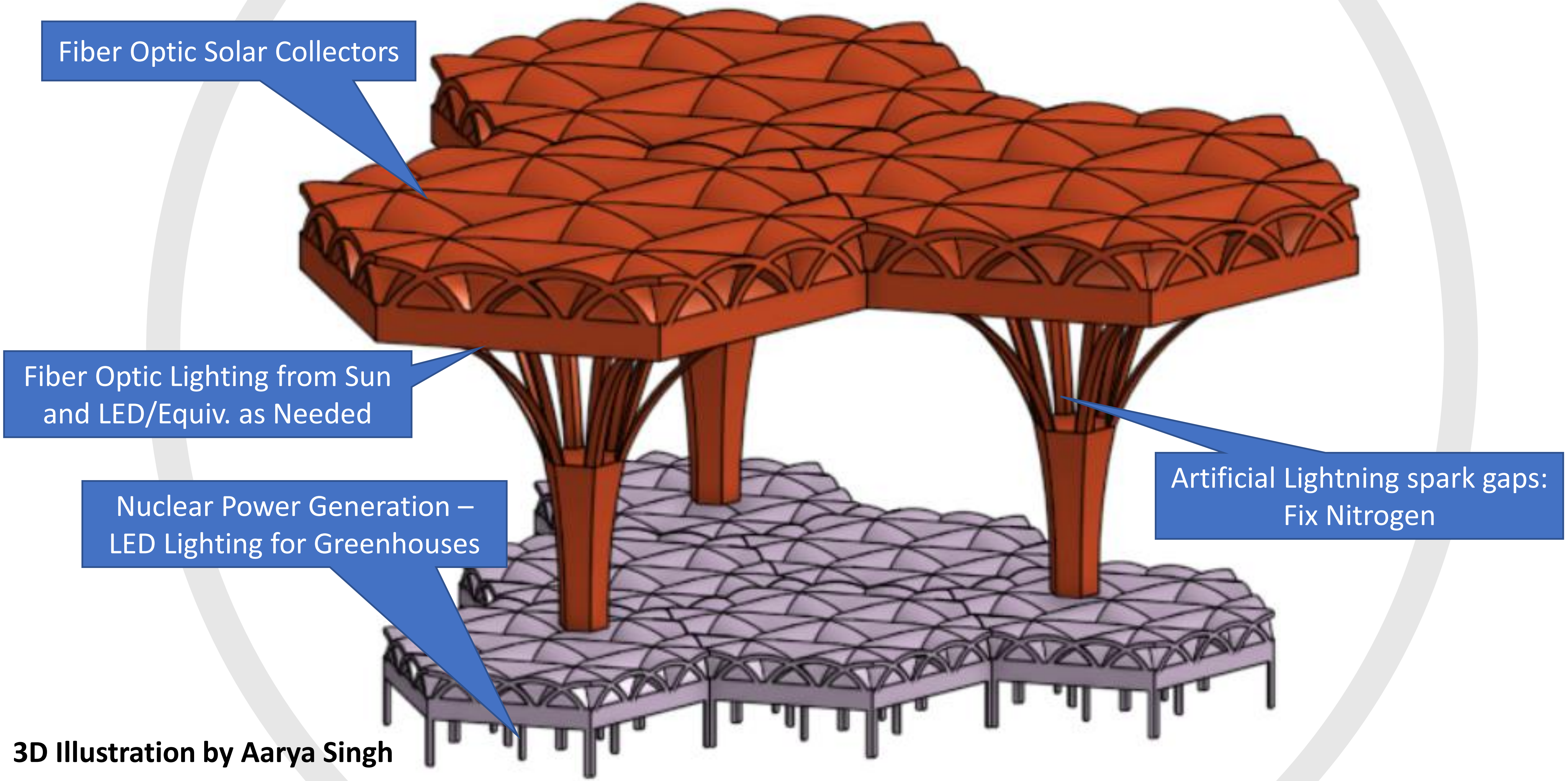
Tree Columns
Visually open

Ecosystem Space

“Basement”
Heating, Transport,
Agriculture, Centrifuge
Habitats



3D Illustration by Aarya Singh

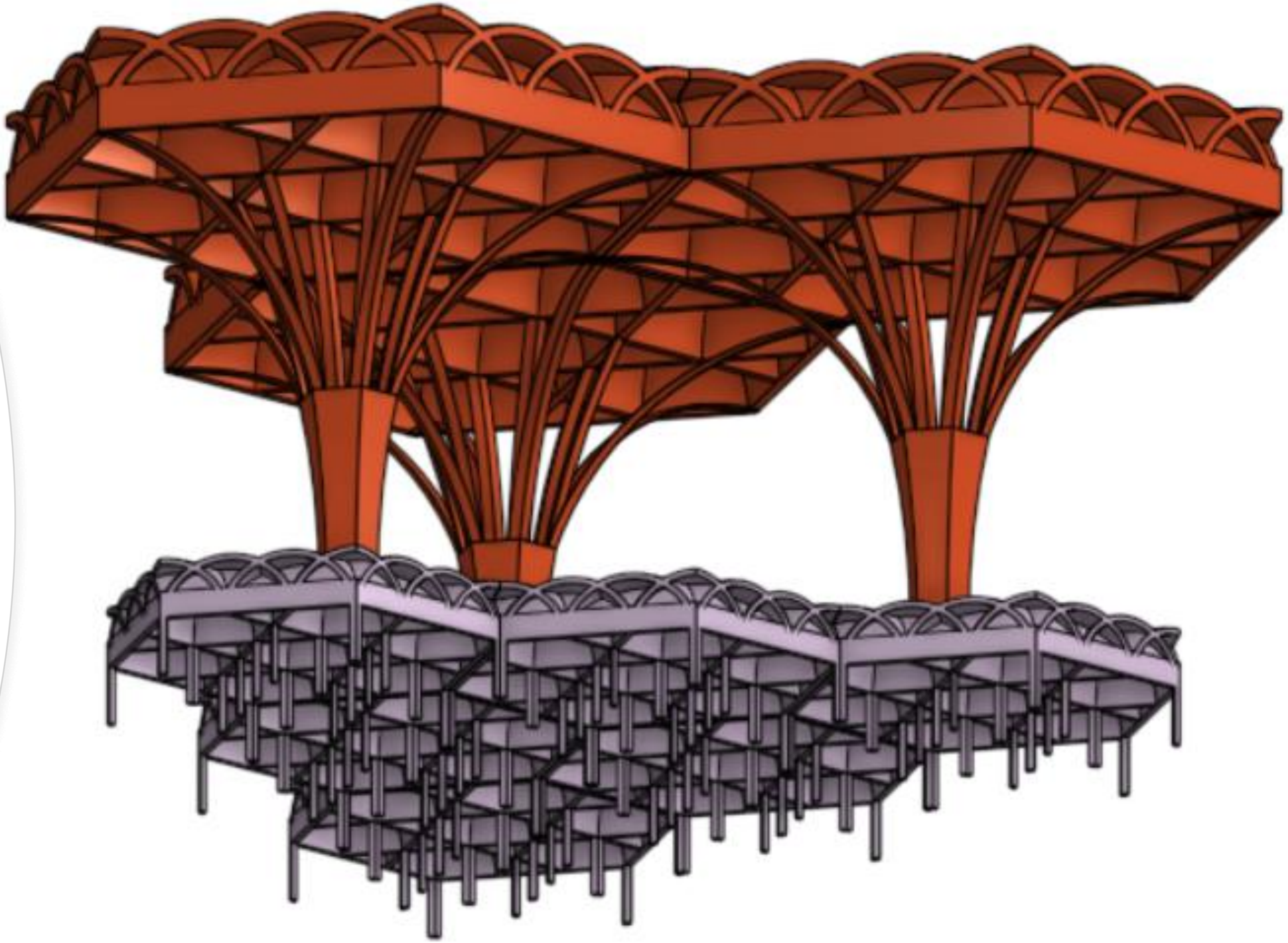


3D Illustration by Aarya Singh

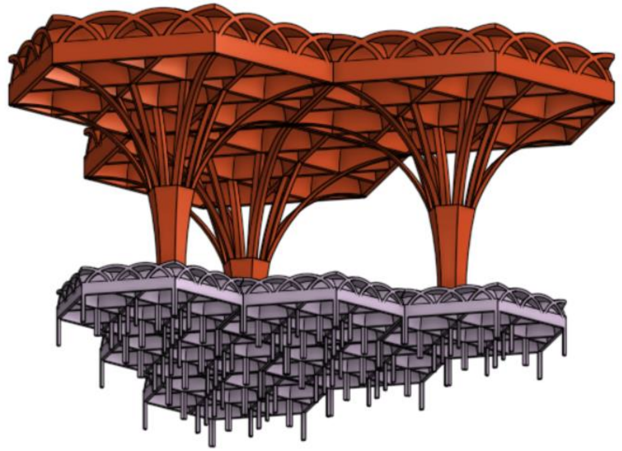
Base View

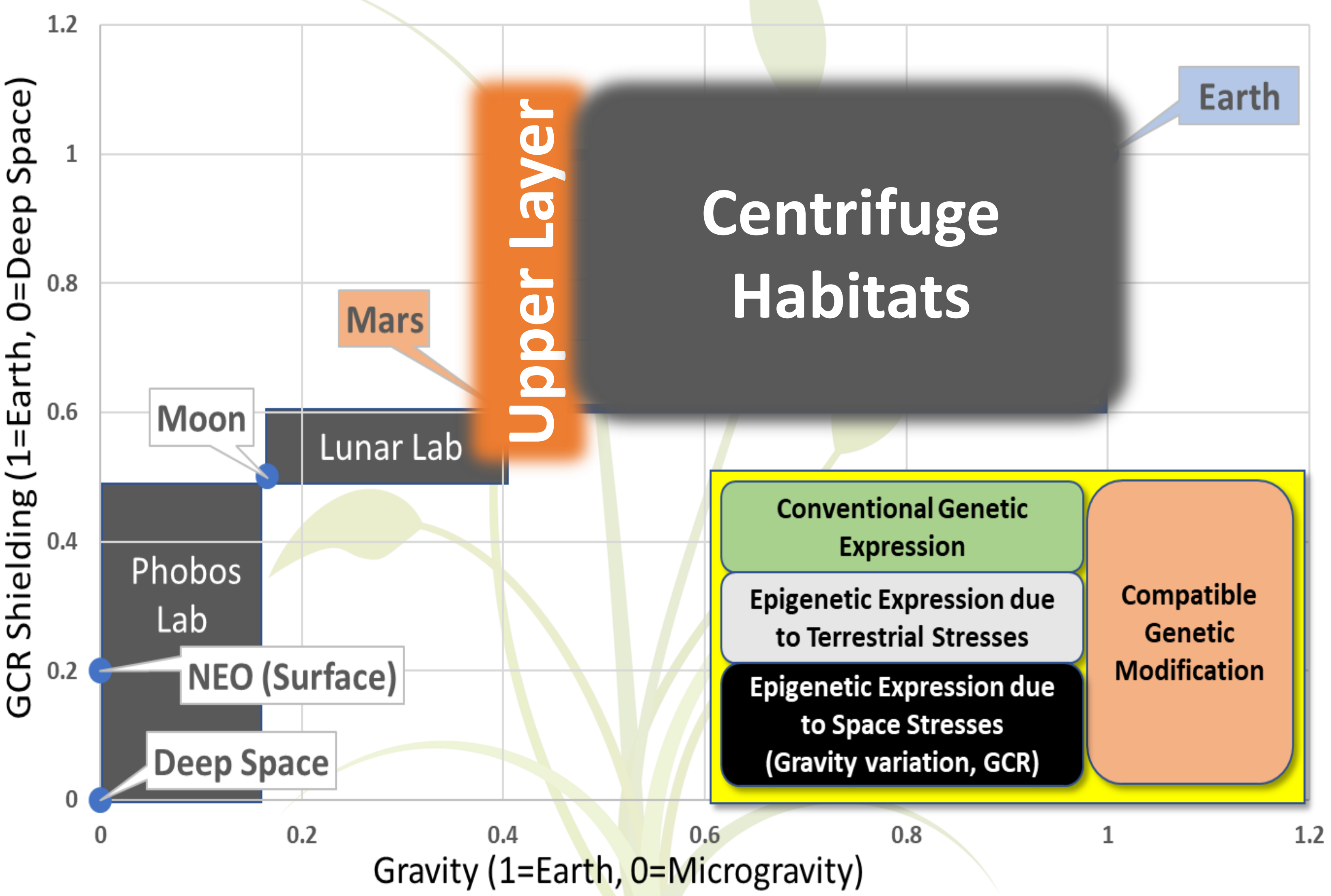
- View up into ceiling fairly open
- Roof can be a kilometer or more high.
- Sub-layer can step up or down to match bedrock
- Enclosure is zoned with drop-curtains to prevent blow-out if meteor strikes roof
- Roof blocks GCR to Earth-like levels
- Rain is mostly simulated, but roof high enough for clouds to form.

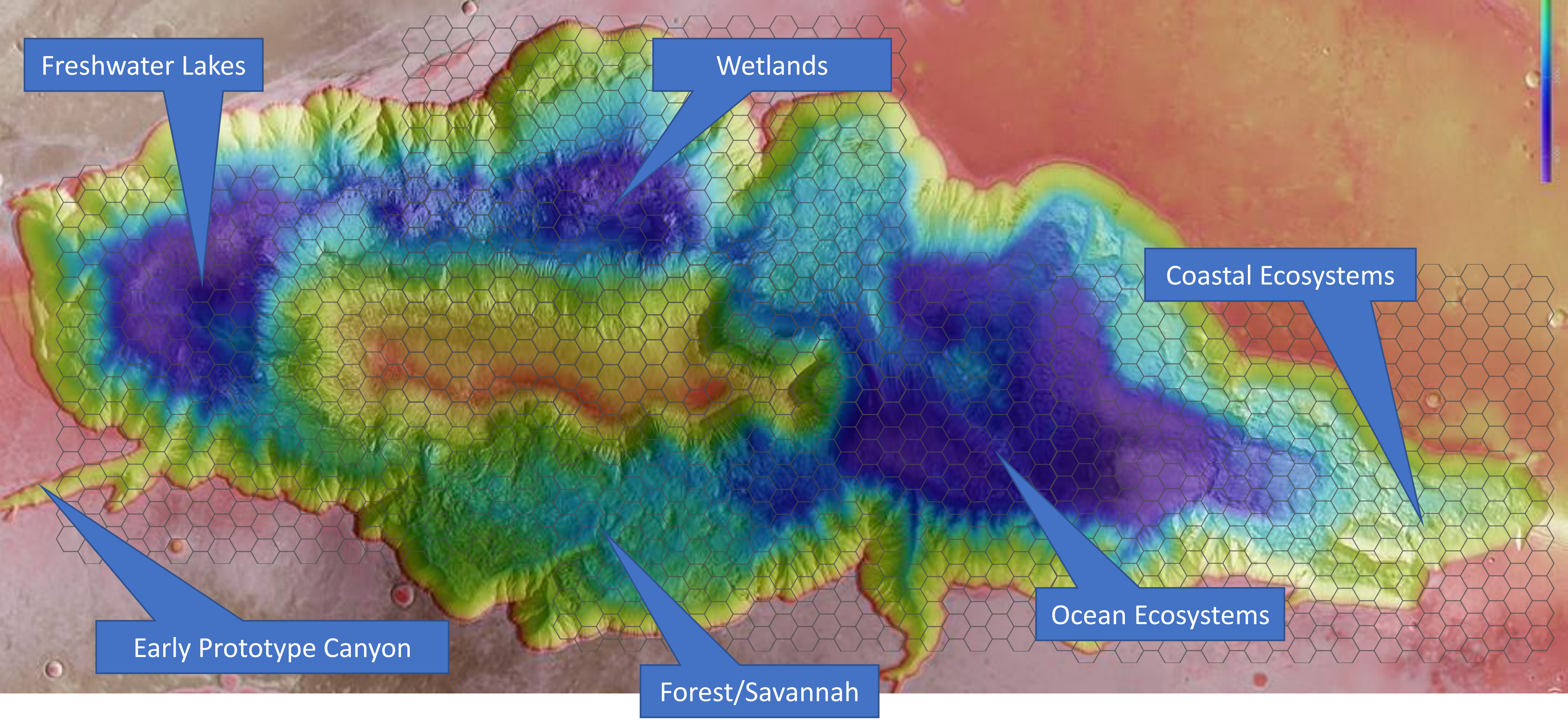
3D Illustration by Aarya Singh



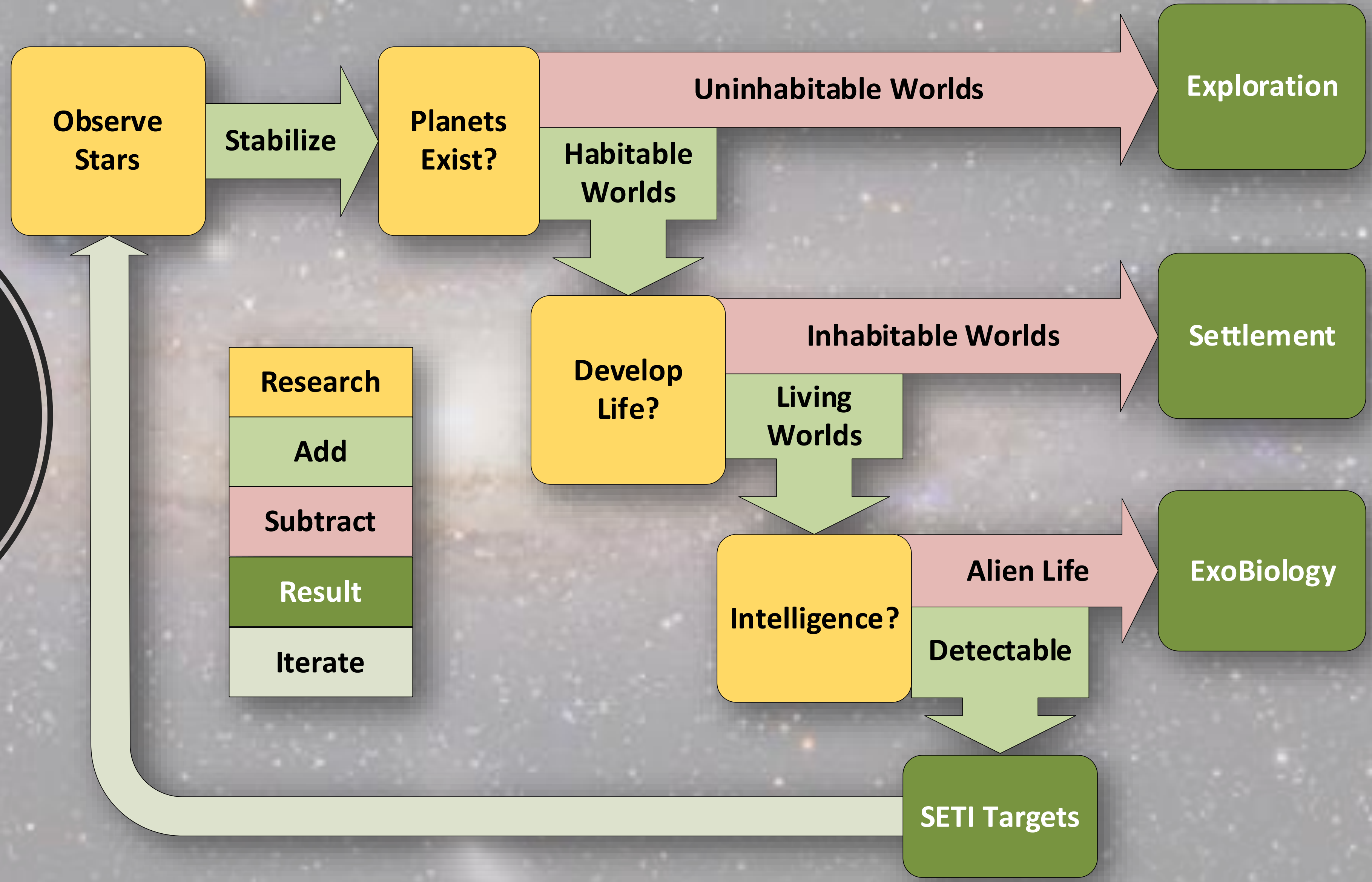
Epigenetics



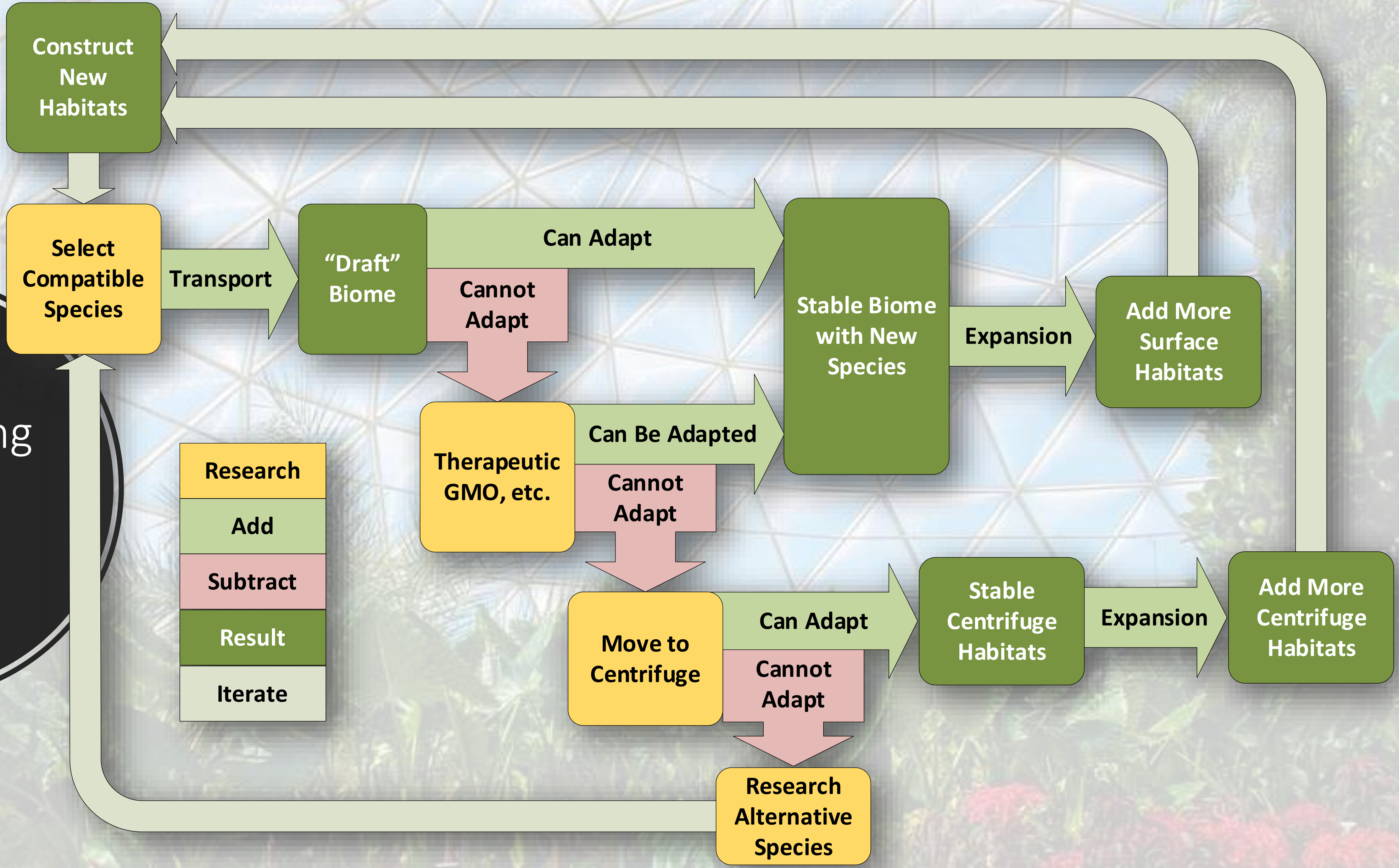



Freshwater Lakes
Wetlands
Coastal Ecosystems
Early Prototype Canyon
Forest/Savannah
Ocean Ecosystems

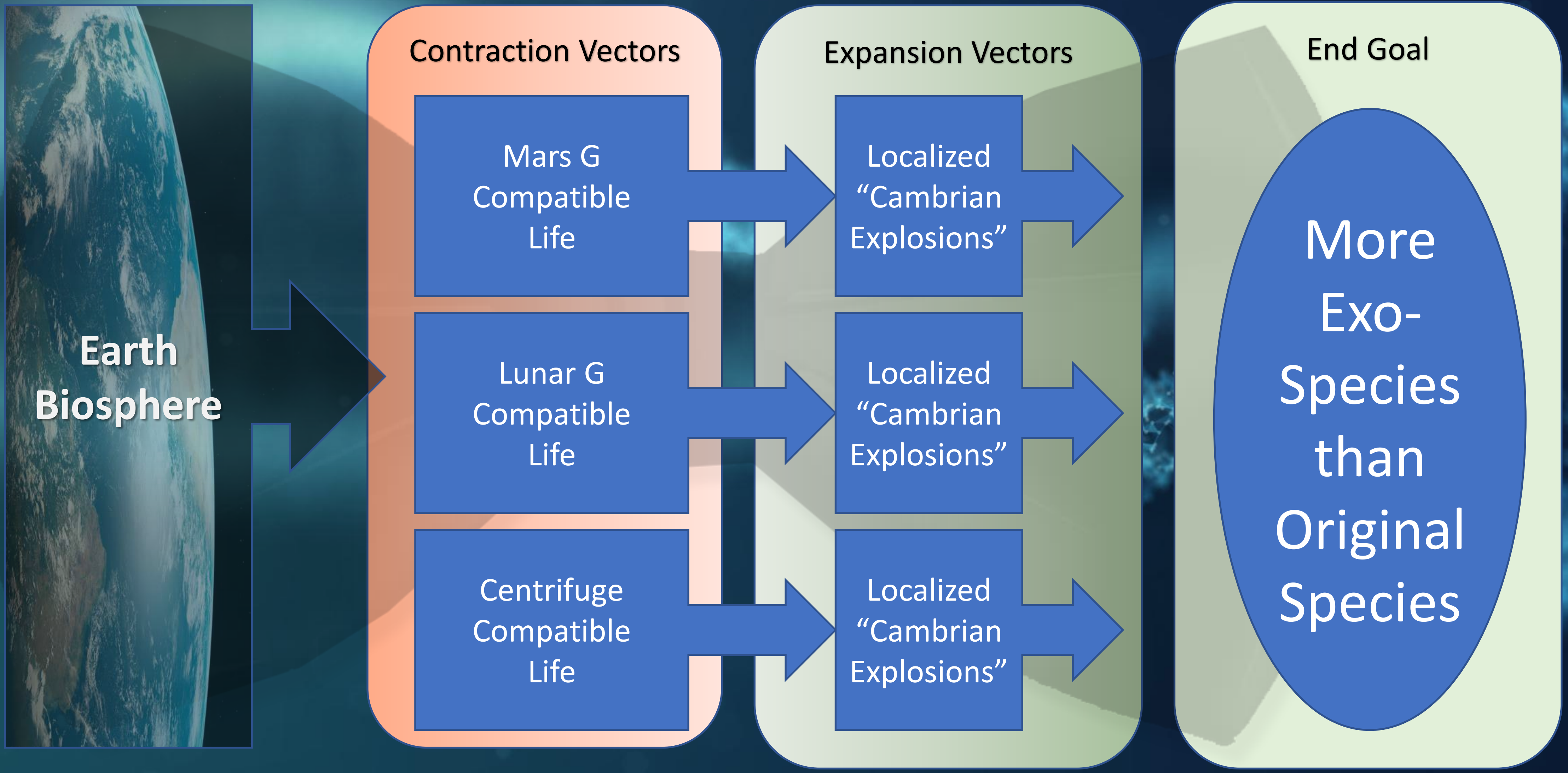
Drake Equation (Visual)



Terraforming Biome Workflow



Evolutionary Bowtie Effect



Data Lakes for Biome Management

Earth Species Parameters	
Territory	Enclosure type
	Territory Area
	Ecosystem Depth
Climate	Temperature Range
	Humidity Range
Interdependence	Required Species
	Reliant Species
	Accepted Species
	Excluded Species
	Minerals and water
	Oxygen/etc. needs
Waste Parameters	Biological output
	Microbiome notes

Artificial Biome	
Environment	Volume Available
	Gravity Level
	Radiation Level Range
	Pressure Range
	Temperature Range
Habitat	Day/Night/Brightness
	Mineral Resources
	Soil Types/ Chemistry
	Other Species
	Microbiome
	Water Chemistry

Stress Impacts	
Health Stress	Direct Impact on Species
	Impact on Required Species
Genetic Stress	Epigenetic Impacts
	Gestation Impact
	Generational Impact
Behavioral Impacts	Feeding/Hunting/Evading/Play
	Biological Functions

Observation Scale	
Granularity - Population	Per Individual
	Per Generational Unit
	Per Self-Sustaining Population
Granularity - Time	As Observed (Real Time)
	Daily
	Per Life Cycle Phase
	Yearly (Earth Imposed)
	Yearly (Mars Adapted)
	Generational

Active Countermeasures

Remediation Method	Description
Natural Selection	Percentage of poorly-adapting creatures that do not breed in the ecosystem naturally.
Artificial Selection	Active farming of generations to promote most beneficial traits for the artificial ecosystem.
Genetic Modification	Can the species be modified and can the traits be passed to future generations?
Food Chain Modification	Can GMO foods be engineered to overcome issues and can those species be added to the ecosystem over generations?
Nutrient Modification	Can the environment itself be supplemented with higher oxygen levels, more calcium in soil, etc. to offset ill effects of artificial system? Will these resources need to be replaced periodically from outside or are they recycled in the food chain?
Habitat Modification	Can new artificial habitats be built that offset the effects and the species be transplanted there?
Replacement	Find another species from Earth (or another habitat) that adapts to this niche better and test.

Biology Conclusions

Area	Description
Apex Additions	As habitats expand, more plants, bigger herbivores, and more apex predators can be supported by the environment.
Mars is Not Earth	The mix of species that work together on Mars may be from unexpected combinations of environments from Earth, mixing continents and ecosystems.
Epigenetics and Exo-Species	Plants and animals will use the lower gravity as an opportunity to find new survival strategies. This will happen fastest in smaller animals with fast generations.
Exo-habitats	Experimental Habitats with higher oxygen, etc, may cause interesting effects.
Biodiversity	Population will grow in species that adapt and shrink in ones that cannot adapt naturally or be modified to survive. This will settle into equilibrium.
Limits	How much Mars territory to terraform is limited by the needs of species that can adapt to Mars, plus the Exo-habitat variations of Mars. This increases over time as more species become exo-species.

Technology Revolutions

Building from First Principles

Paying for Payloads

Energy Density, Invention, Information

Energy System	Utilization Inventions	Information
Human Power	Hunting, Gathering, Migration, Villages, Basic Farming, Textiles	Language
Fire	Metallurgy, Sterilization/Cooking, Light, Heat	Engineering
Animal Power	Farming, Roads, Cities, Travel, Mass Warfare, Writing, Trade	Math
Wind Power	Ocean going vessels, Navigation	Celestial Navigation
Steam (Wood)	Fast transport on rail/oceans. Paddle-wheels/wood boats.	Telegraph
Steam (Coal)	Ironclad ships with screw propellers. Steel and other alloys.	Fast News
Petroleum (Kerosene)	Indoor lighting, advanced industrial chemistry of petroleum.	[Radio]
Electricity	Indoor lighting, Distributed mechanical/heat power.	Telephone
Petroleum (Gasoline)	Internal combustion, Cars, Aircraft, early rockets.	[Television]
Chemical Rockets	Moon landings, Solar system exploration, etc.	Satellites
Nuclear Power	Nuclear power plant, Submarines/Aircraft carriers, NERVA.	[Computers]

Ingredients for Technology Revolutions

Energy

- Higher Density
- Affordable, Consistent, Safe

Invention and Convergence

- Capacity Envelope Expansion (Superpowers)
- Factorial complexities (2!=2, 3!=6, 4!=24, 5!=120, etc.)

Information

- Science Drives Engineering. Vice Versa.
- Communication Drives Factorial Expansion

Affordability

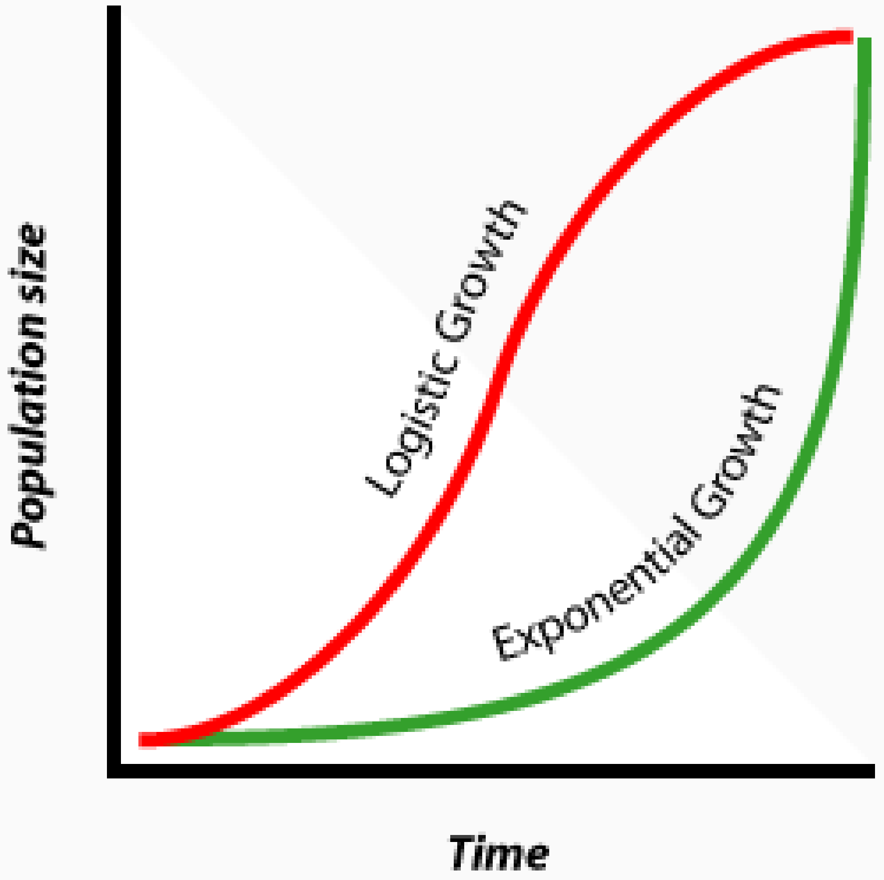
- Applies to All of the Above

Excitement

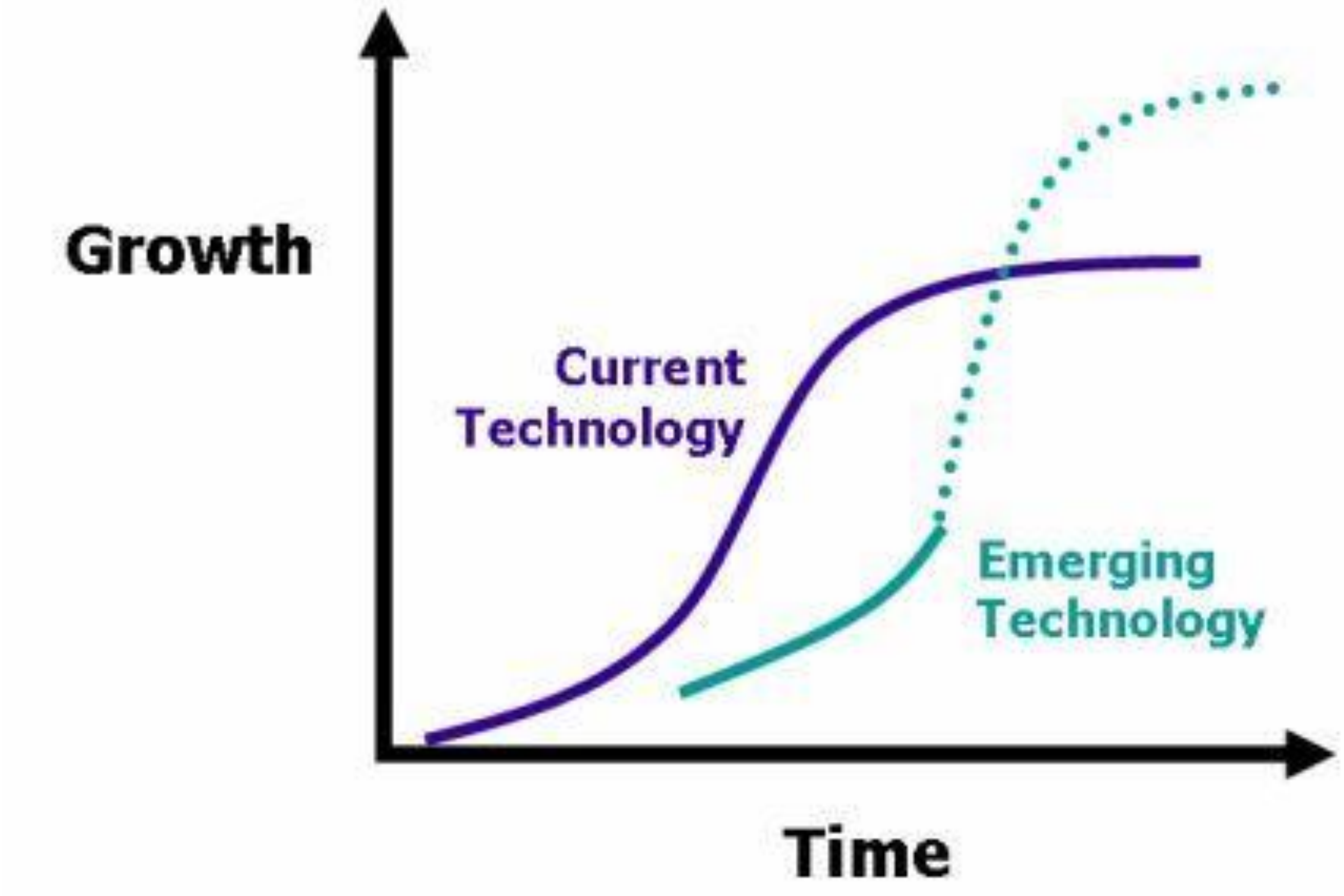
- Boring Science and Technology Doesn’t Explode Interest
- Superpowers, Comfort, Novelty

The "S Curve of Technology"

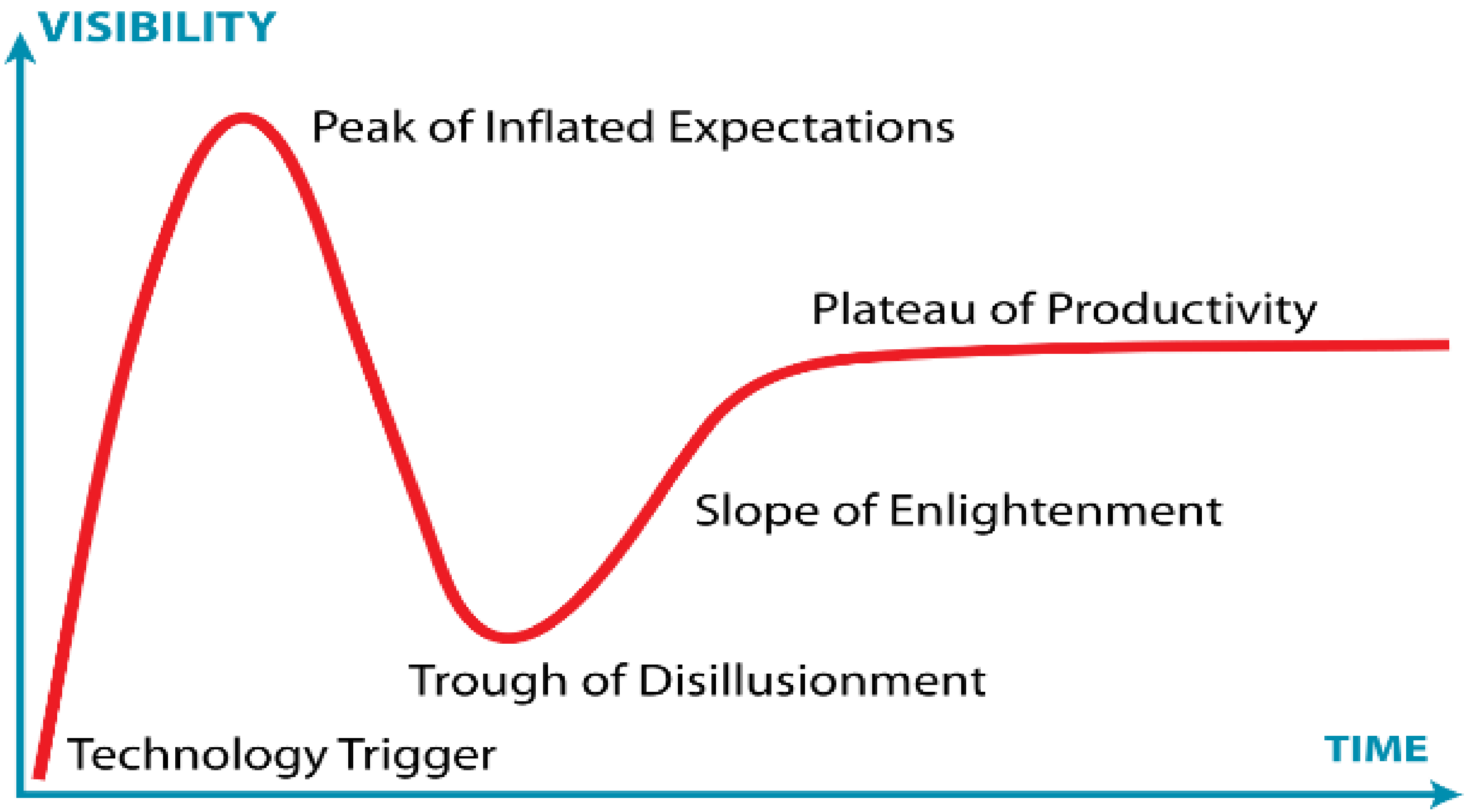
- The aerospace and early electronics revolutions were thought to be exponential.
- During the early space age, this lead to hope of fast solar system settlement.
- Had the curve continued, we would have hit light speed by the year 2010.



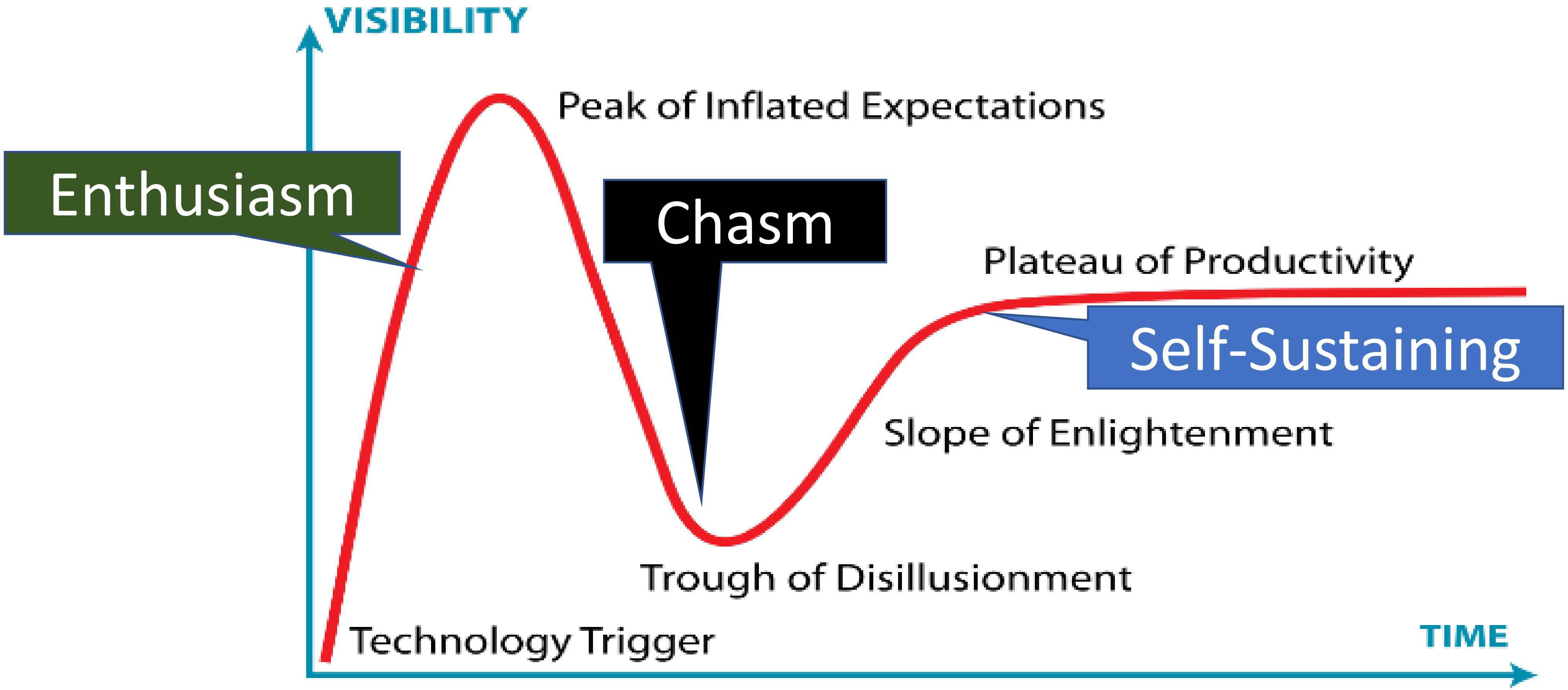
1970’s Stagnation Versus NewSpace Revolution



Gartner Hype Cycle



Business Model – Three Environments



Business Model Waves

Enthusiasm

Self-Sustaining

Sponsorship/Collectable Wave

- Collectables given to show sponsorship of payloads
- Selling Lunar/Mars material and space-flown hardware

"MarsSpec"/Competition Show Wave

- Hybrid of MilSpec and UL Listing product certification
- Democratizes manufacturing of space-rated products

Epigenetic/ Intellectual Property Wave

- Genetic research on effects of low gravity on crops, etc.
- Space-grown products export, Intellectual property economy

MarsSpec

Fast, Safe, Standard, Adaptable

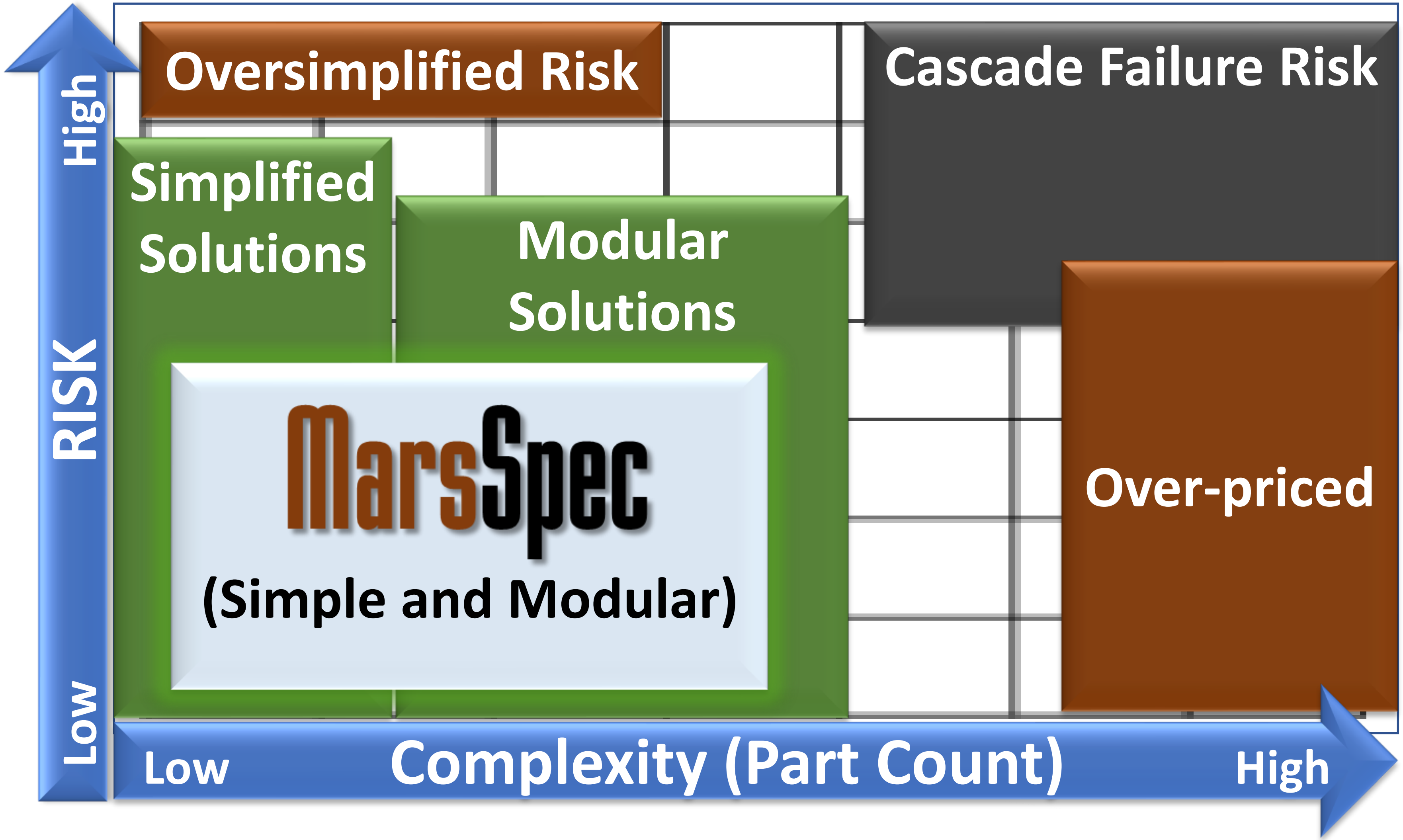
Principles

- Space Rated
- Simplified
- Modular
- Documented

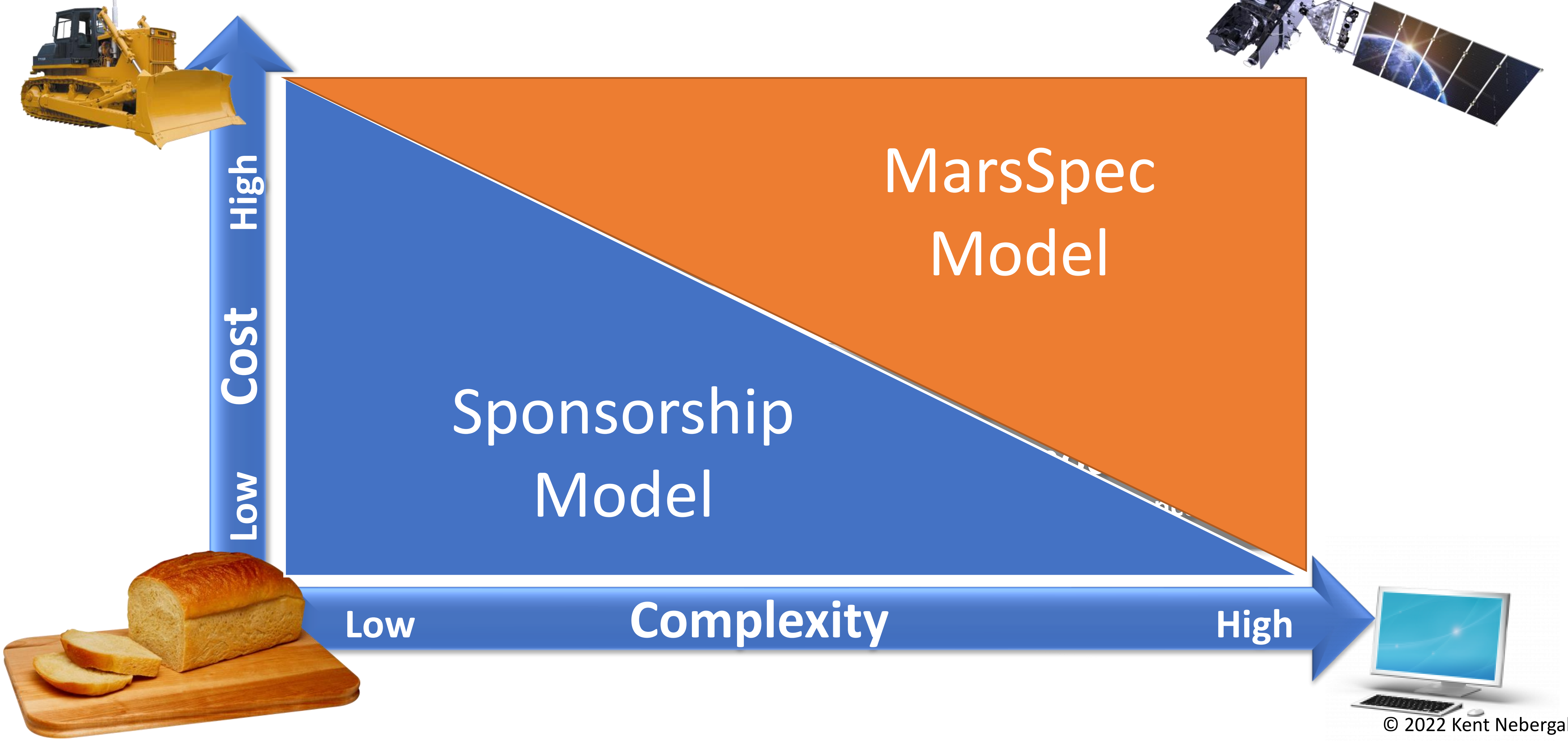
Right To…

- Repair
- Bypass
- Recycle/Repurpose
- Smart Contract IP

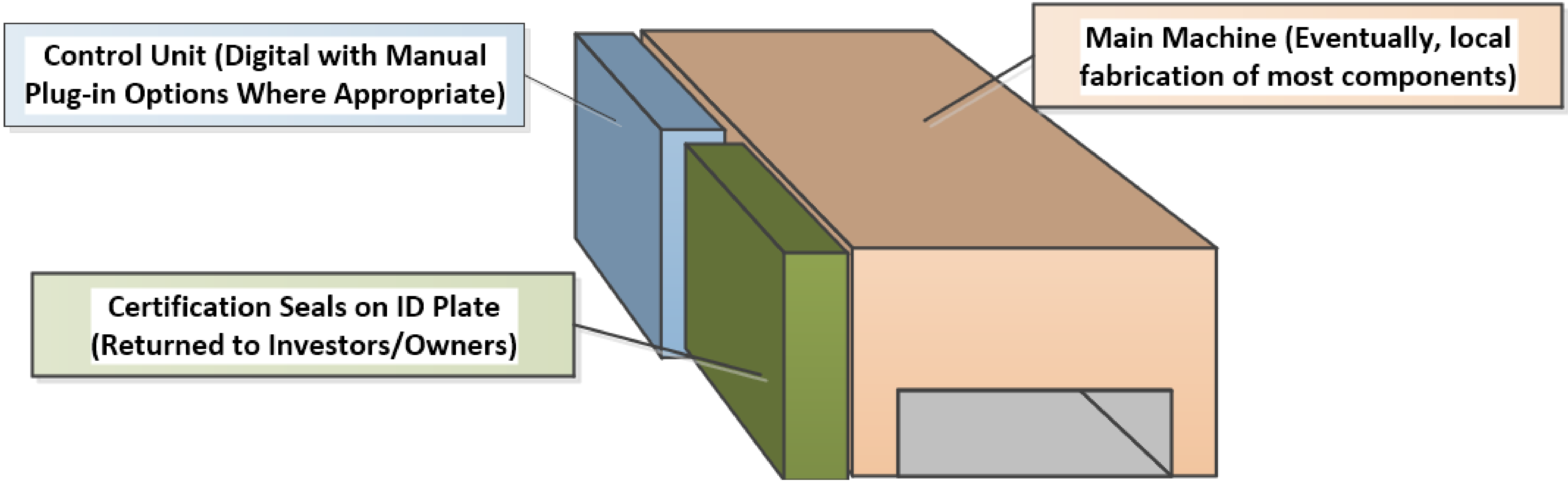
Fast, Safe, Standard, Adaptable



First Wave Funding Models



Certification Seals



Invention/Investment Convergence Engines

MarsSpec

- Robust systems
- Democratization of Space Innovations to All Markets

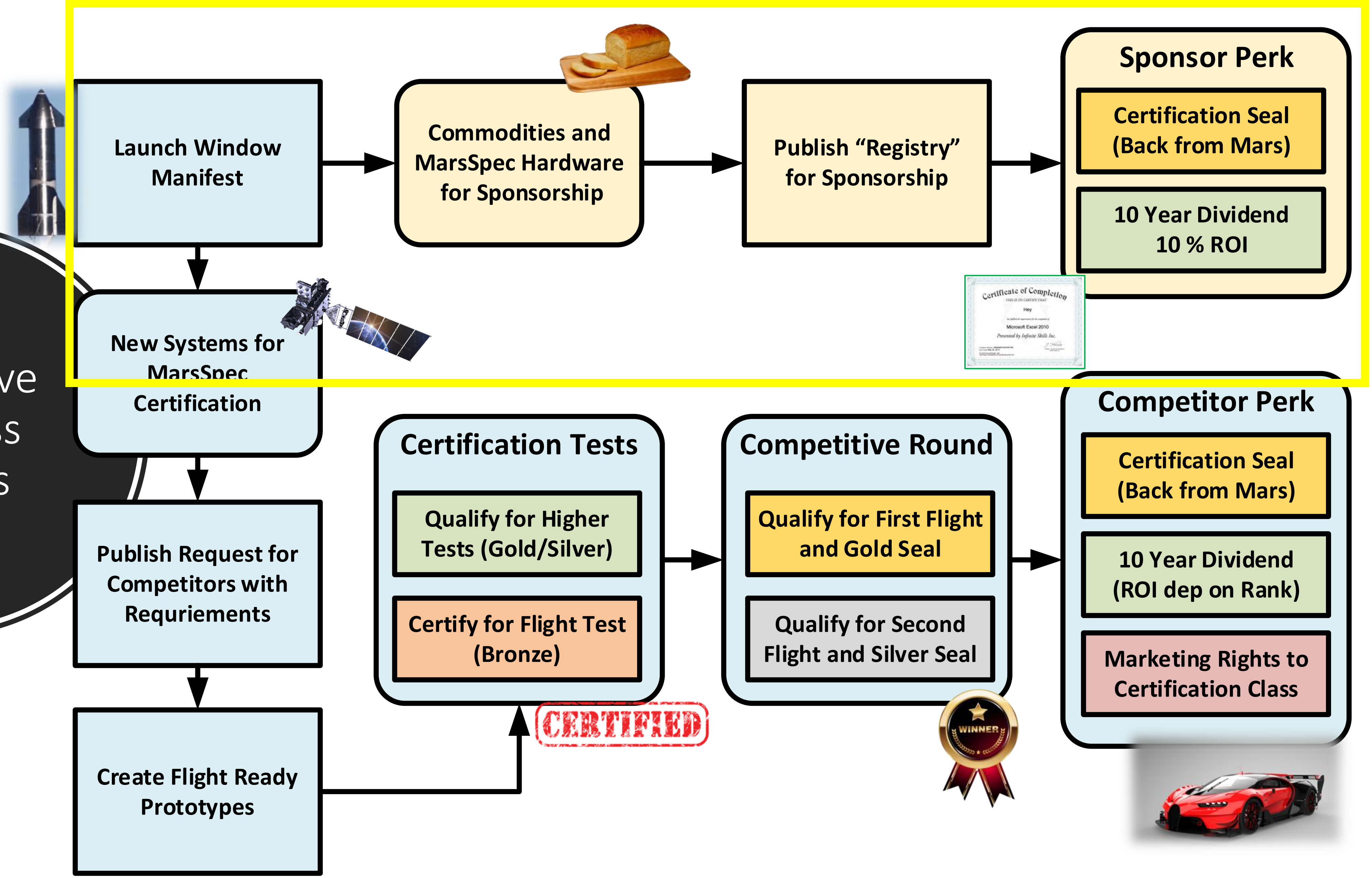
Certification Seals

- Investment (Corporate Bond Equivalent)
- Space-Flown Collectables
- Sponsorship of Early Flight Articles

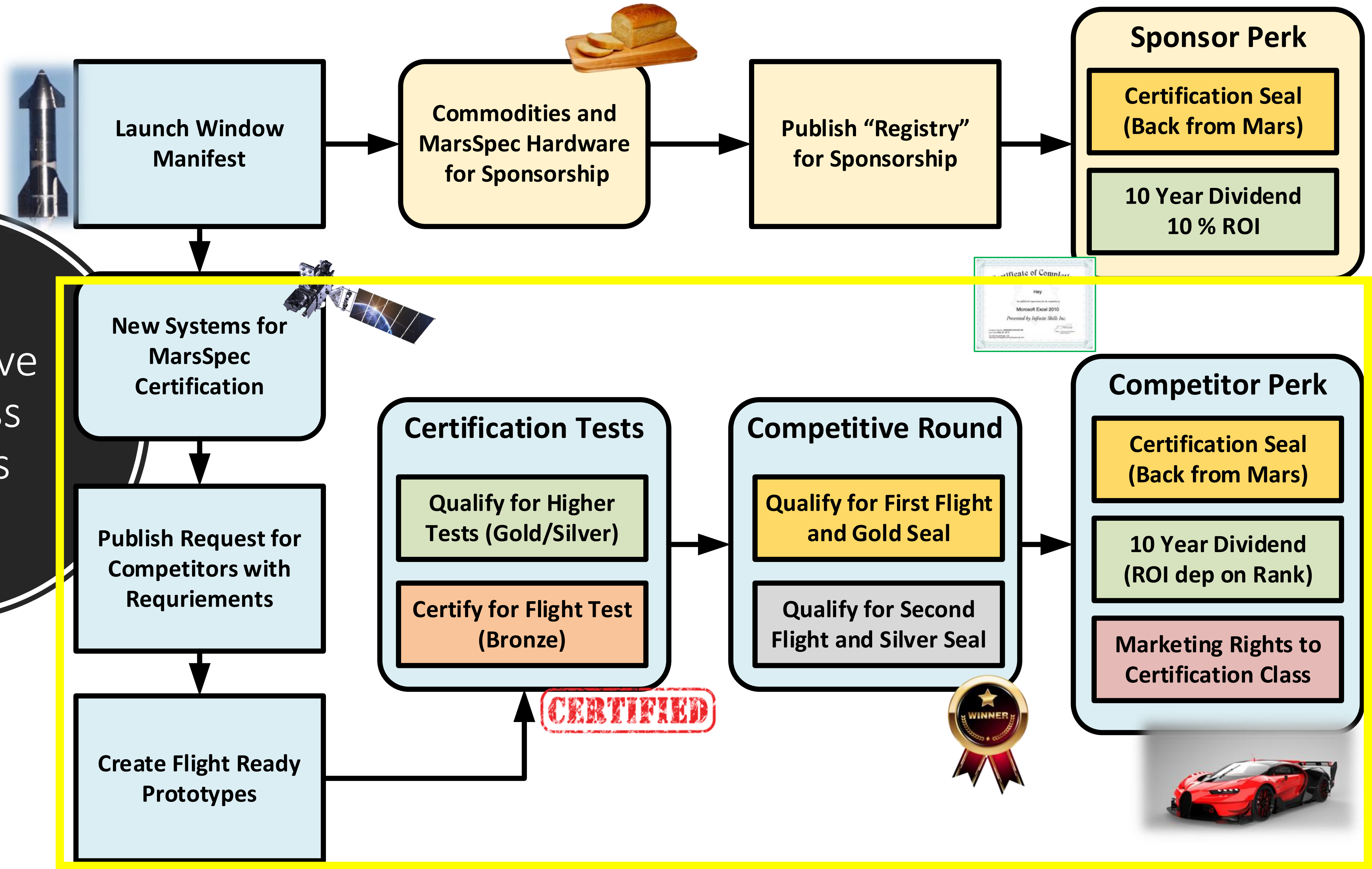
Intellectual Property Smart Contracts

- Fast, Fair Patent protection and Primary Research Funding
- AI Accelerated Literature Searches
- External interfaces via Foundation to isolate in-house innovation

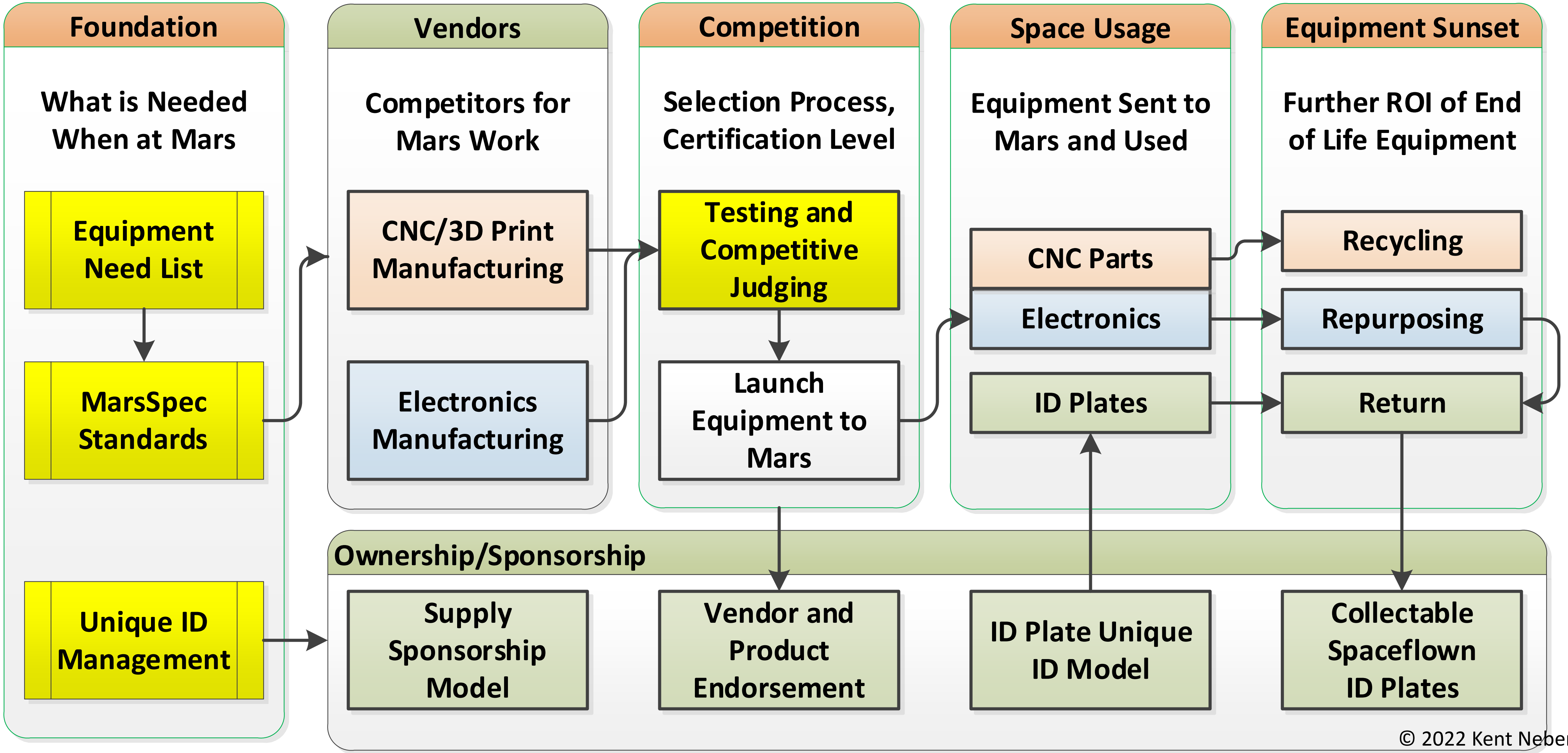
First Wave Business Models



First Wave Business Models

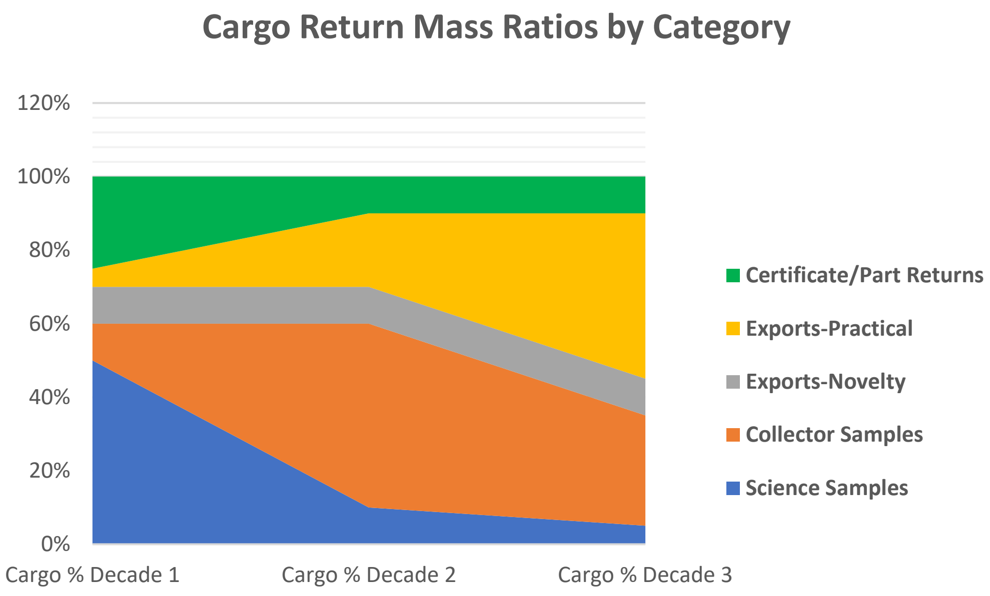


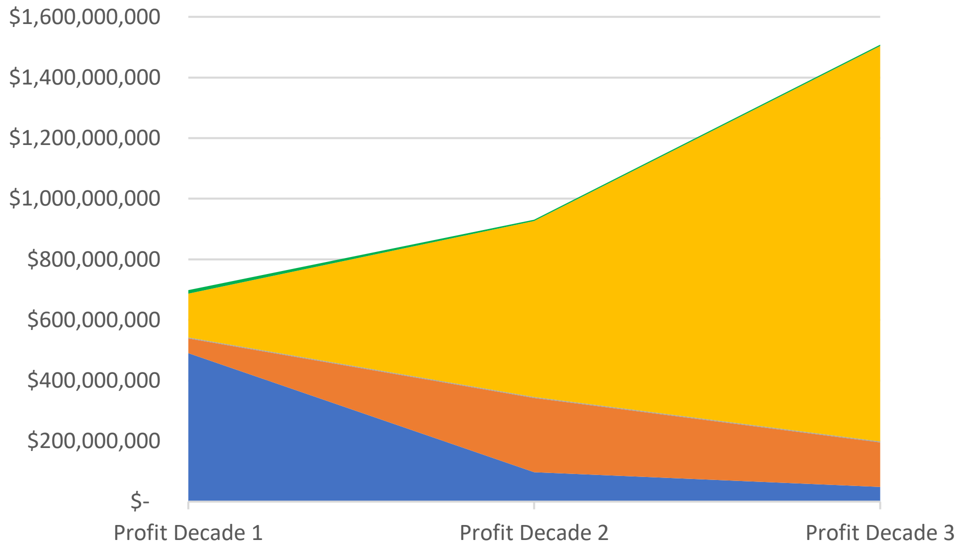
MarsSpec Development Process



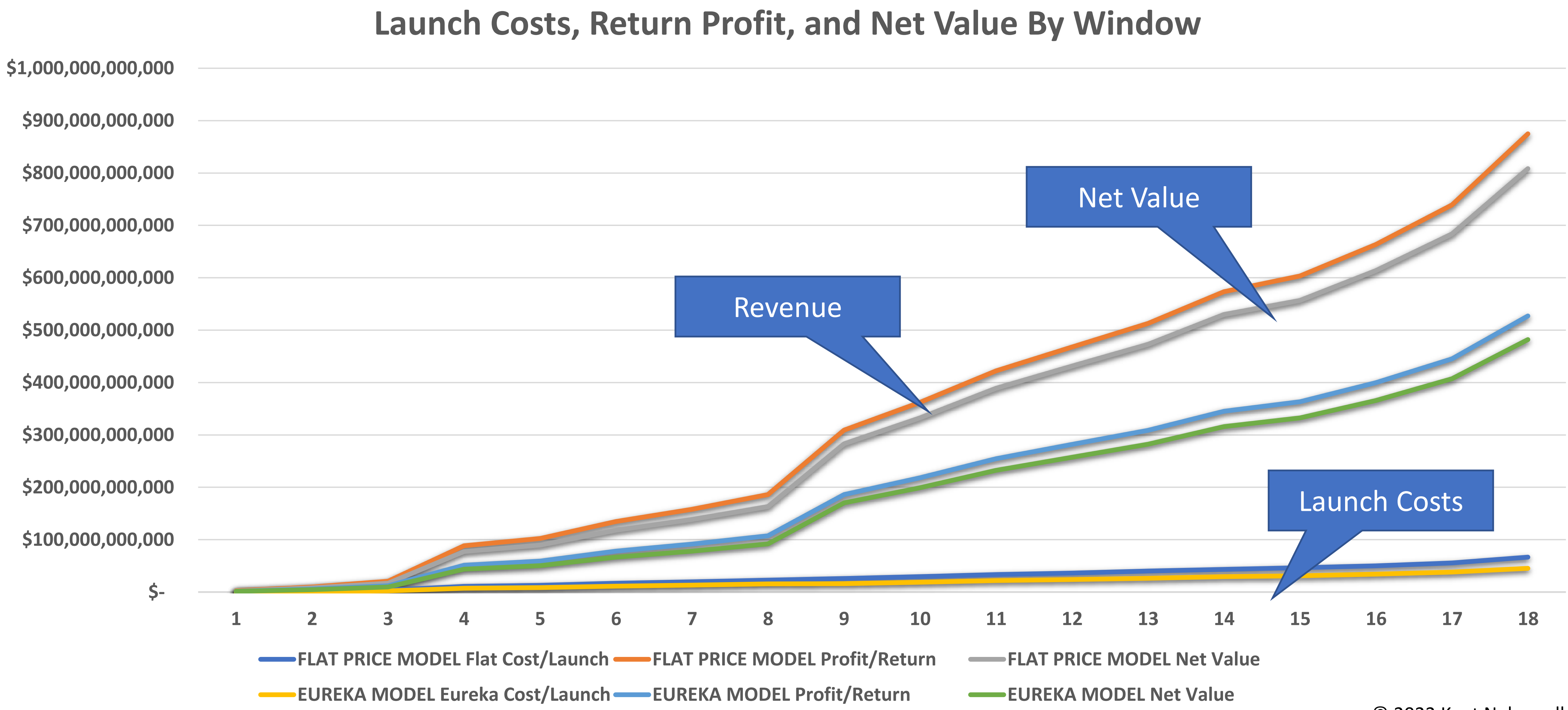
Growth and Market Shift

Date	Year	E2M Sorties	M2E Sorties	Population
2039	0	7	4	60
2041	2	16	14	100
2043	4	36	30	300
2046	6	100	95	800
2048	8	115	110	1200
2050	10	150	145	2500
2052	12	175	170	3500
2054	15	205	200	4200
2056	17	235	205	10,000
2058	19	266	240	15,000
2061	21	300	280	18,000
2063	23	325	310	20,000
2065	25	360	340	22,000
2067	27	390	380	24,000
2069	30	420	400	26,000
2071	32	450	440	28,000
2073	34	500	490	30,000
2075	36	600	580	36,000





Economic Model Summary



Thank you!

Questions?

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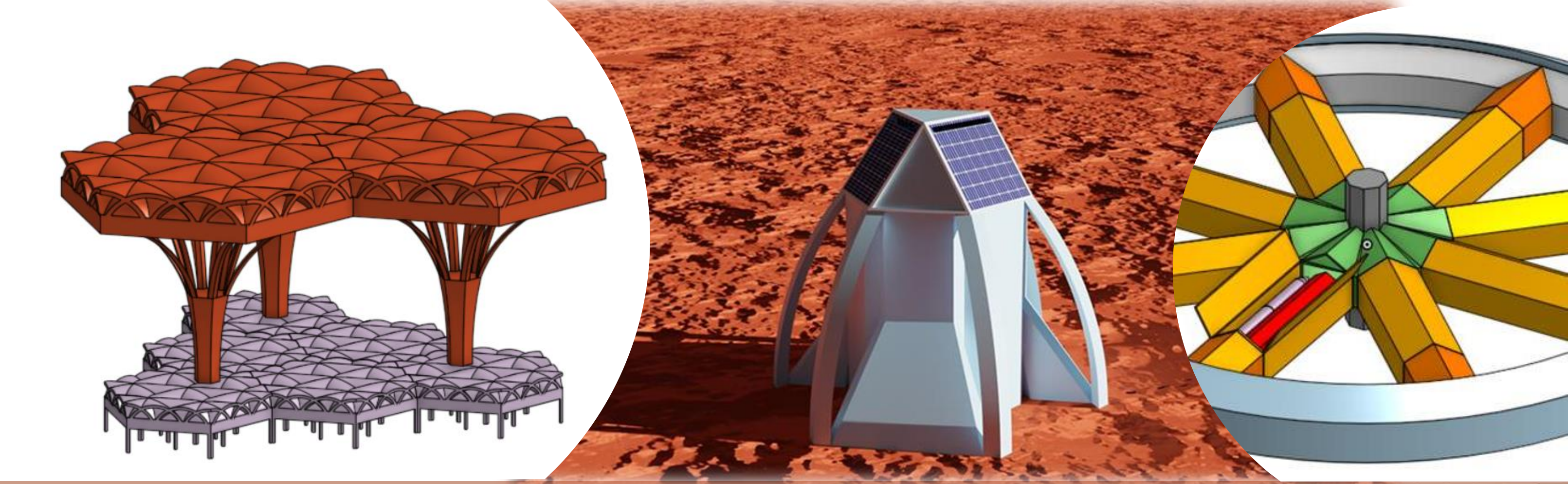
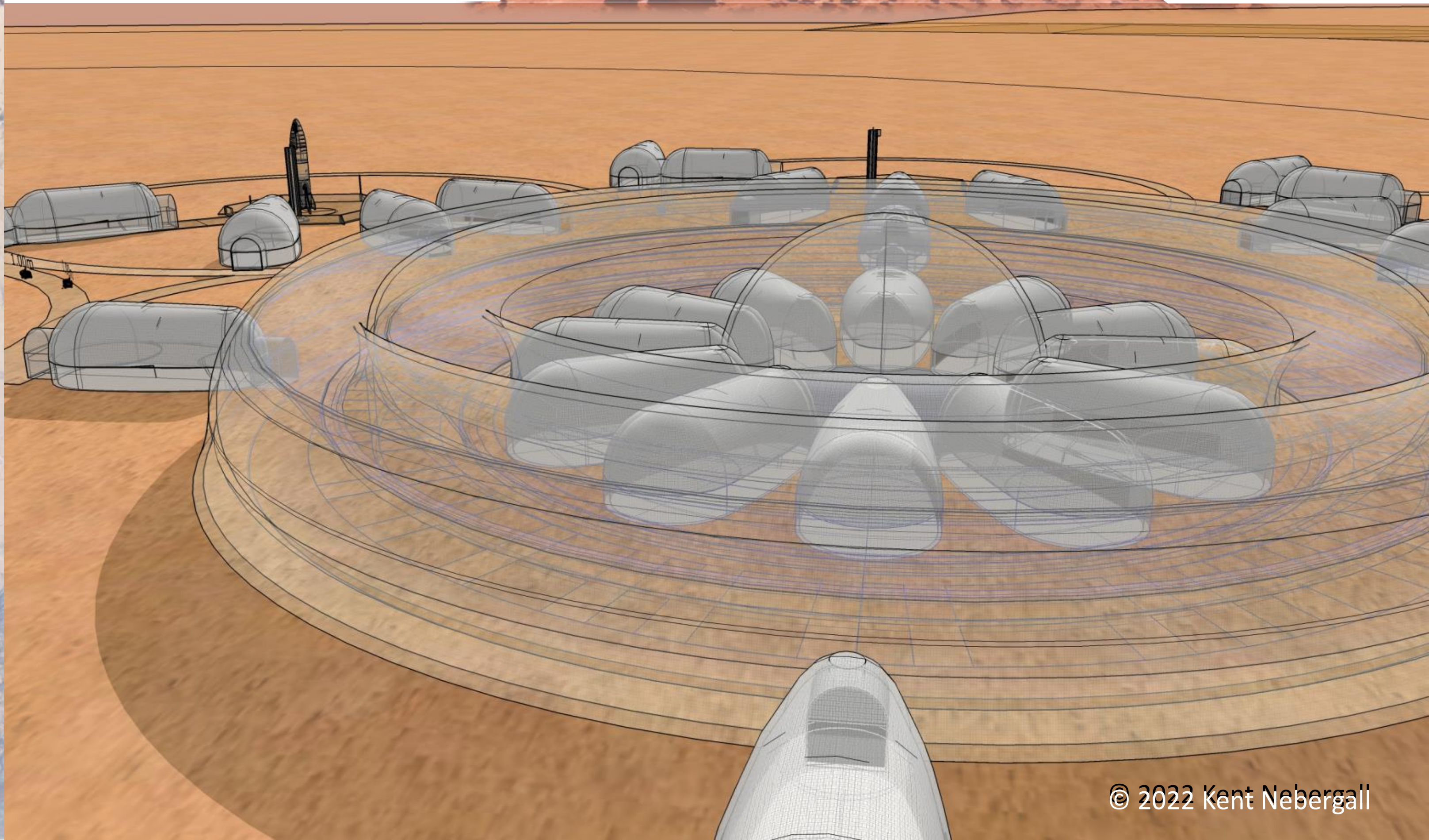
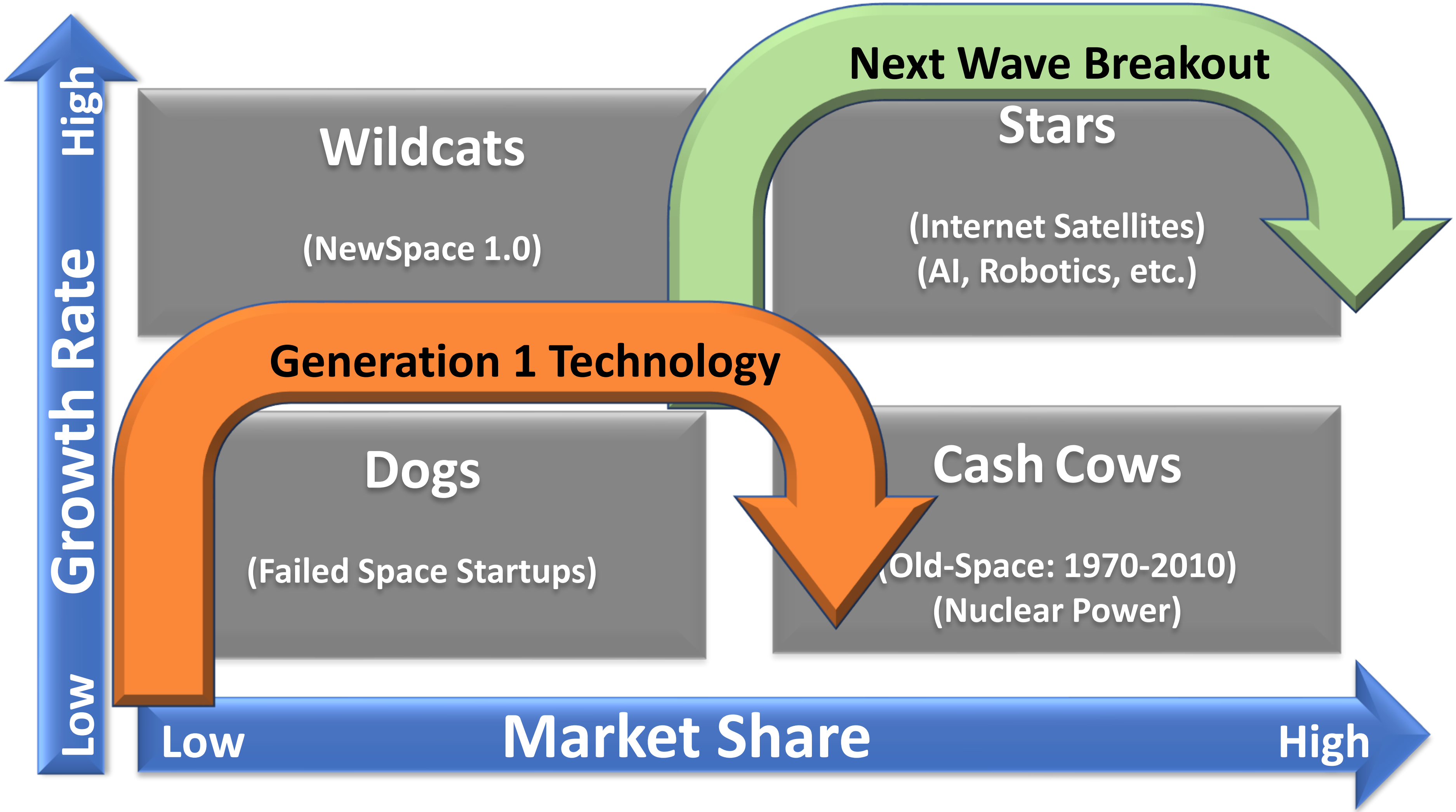
Aarya Singh

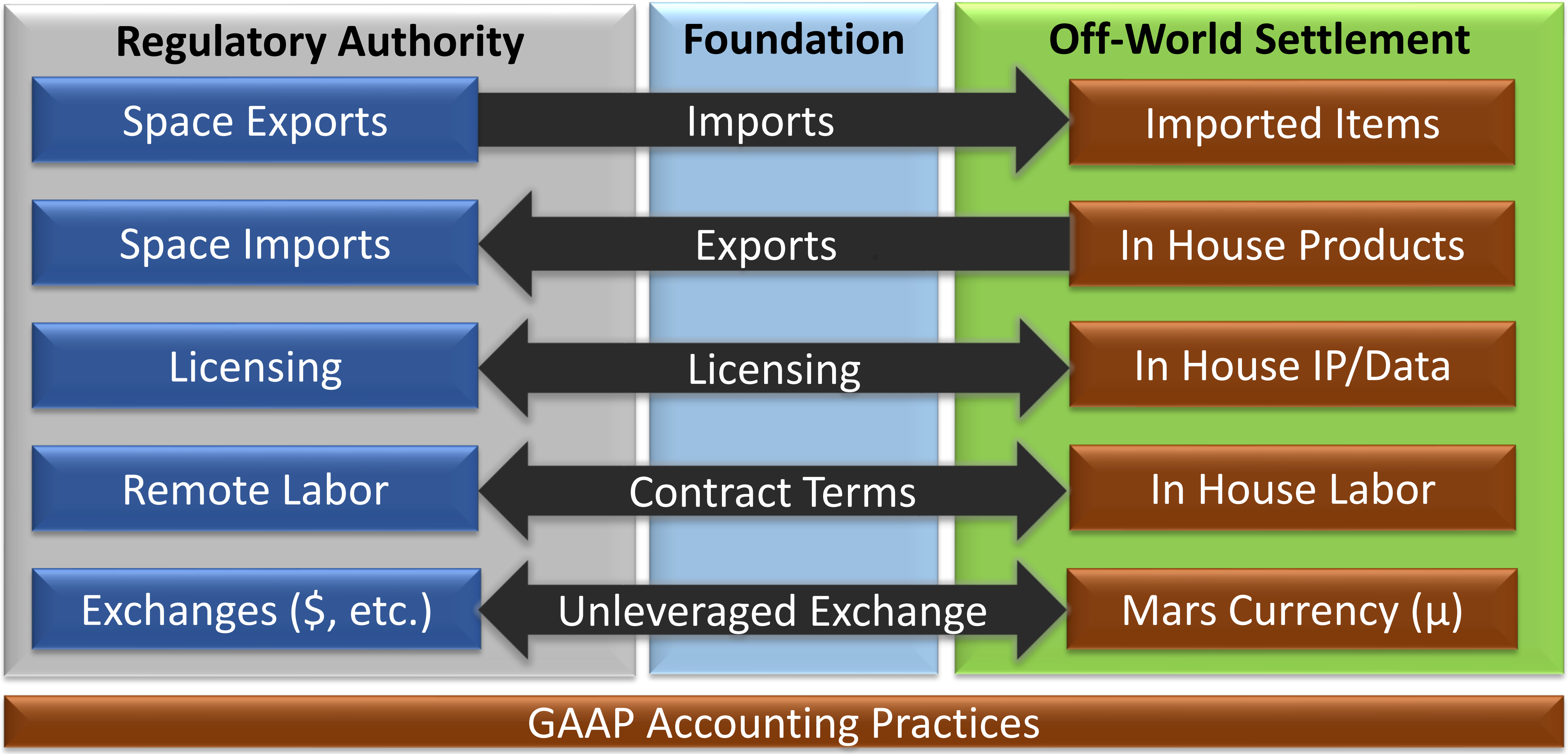




Boston Box and Diffusion Overlap



Economic Independence



Launch/Payload Cost Model