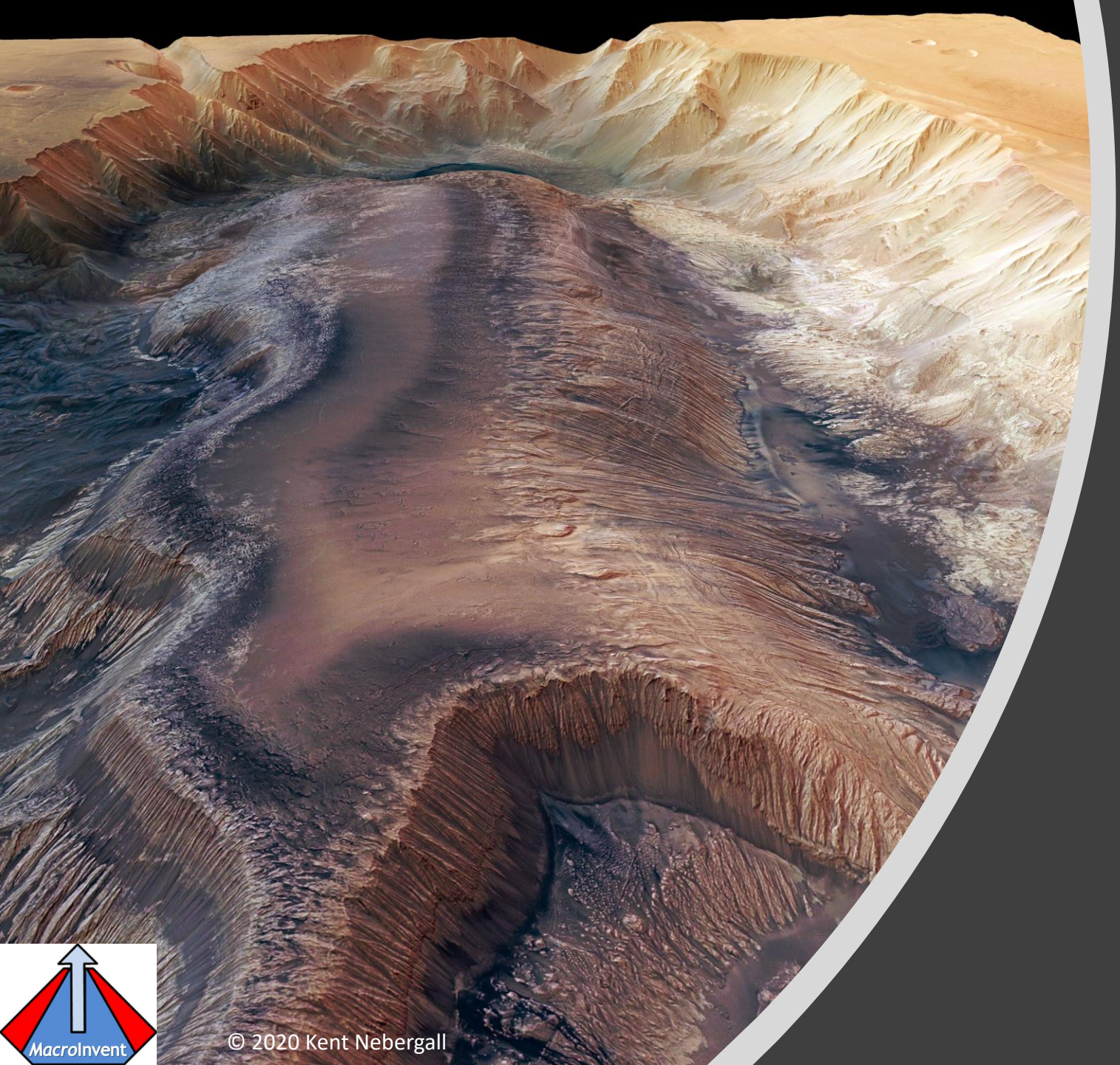

ParaTerraforming Hebes Chasma

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DEFINED: Terraforming a smaller, enclosed section of the surface of a planet. Typically a canyon, crater, or valley large enough for an entire ecosystem.

SCALE: Bigger than a dome or city, smaller than a planet

Demands less resources

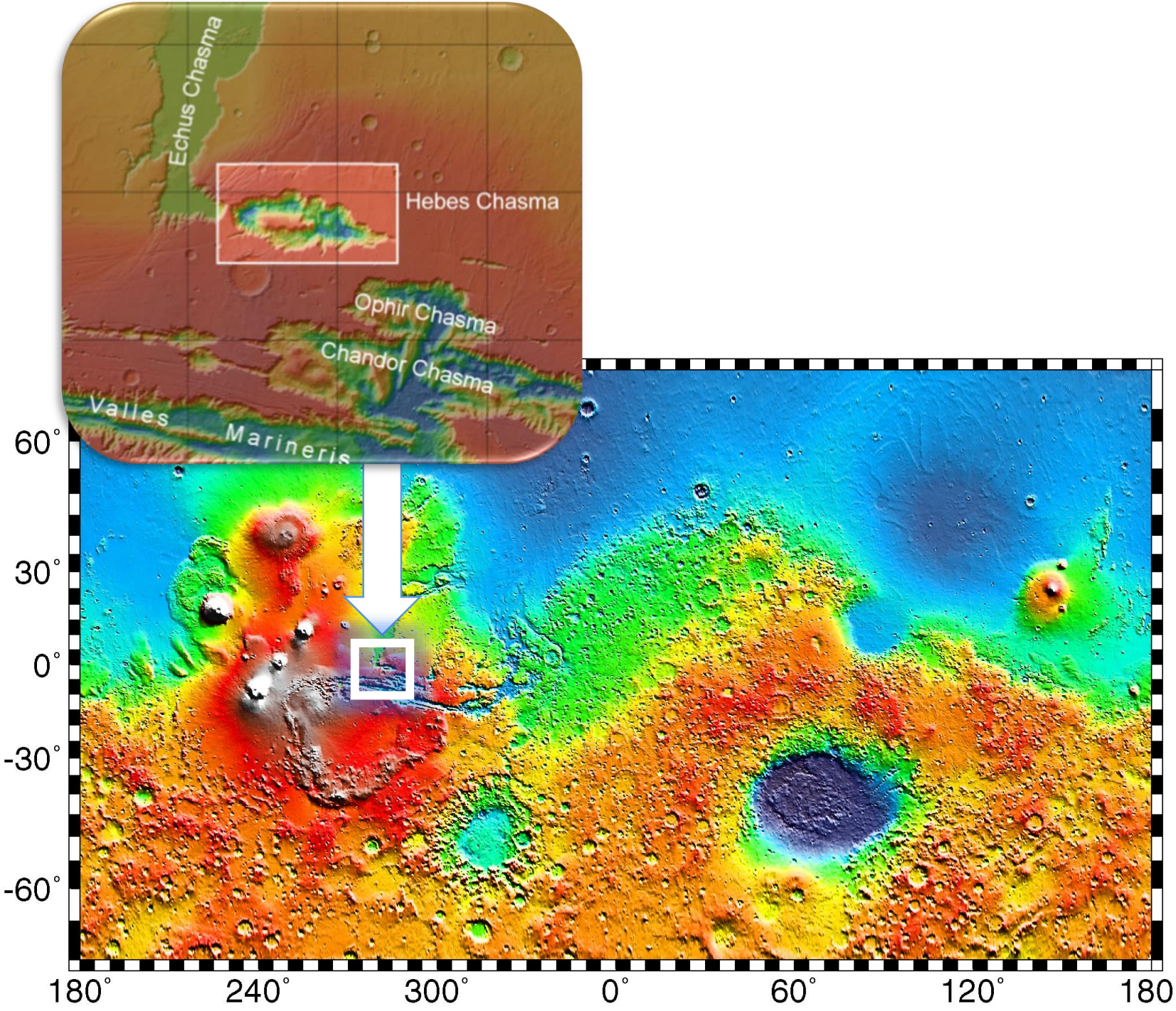
Can be done faster and as practice for full terraforming

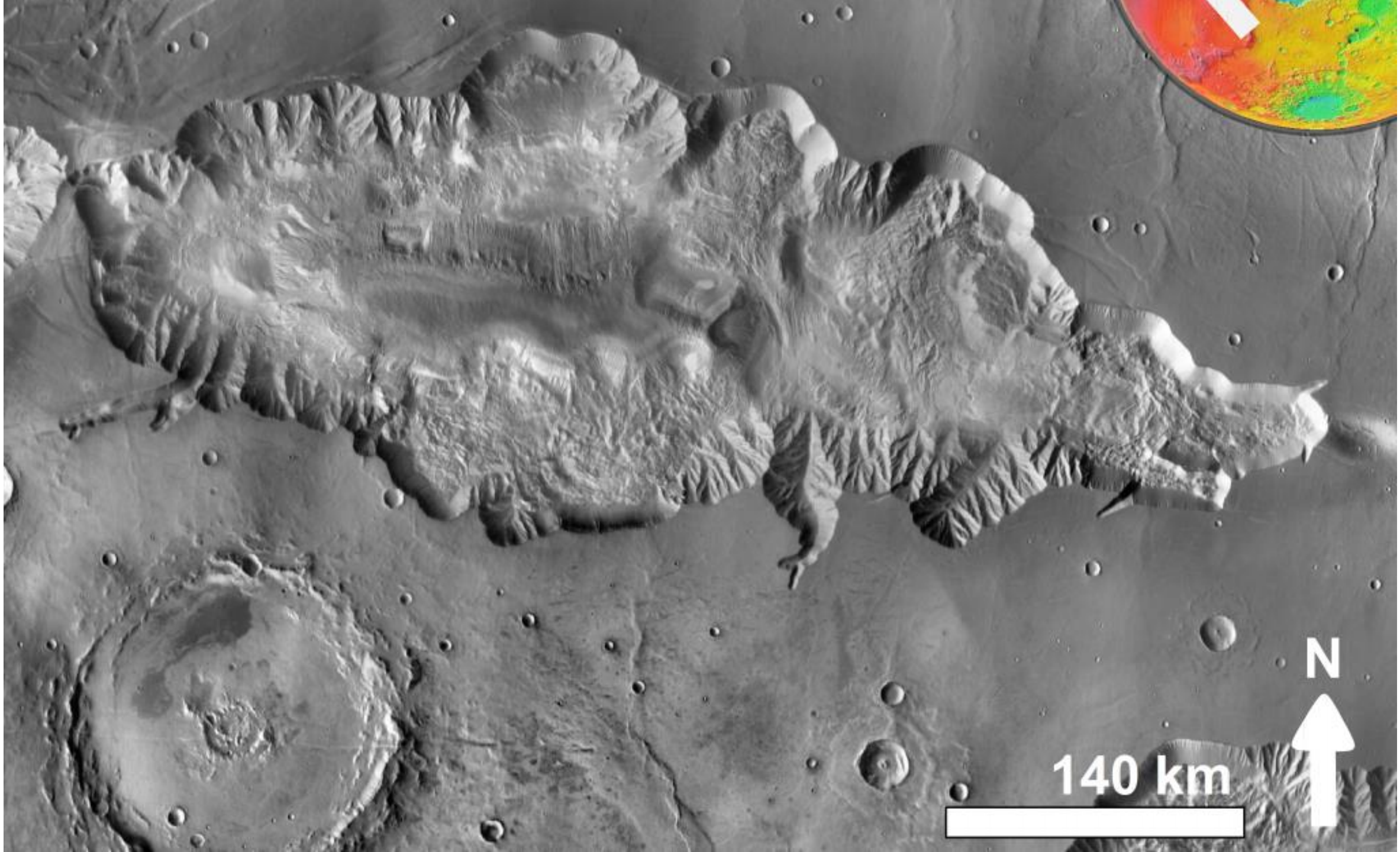
Allows different zones to be isolated from each other for broader biodiversity

What is ParaTerraforming?

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

Site Prep

Mining to Agriculture to Ecosystem

Name	Definition
Survey	Take core samples and determine potential for resource extraction and construction to and including bedrock.
Open Mining	Remove overburden and do initial sort on types of soil/rock for resource extraction.
Foundation Work	Prepare the space remaining for enclosure with lower dome set.
Chemical Detoxification	All industrial and toxic materials removed from clays, rock, etc. Remaining tailings that have use as topsoil or subsoil moved to next phase.
Microbiome Enrichment	Incorporate biological waste and beneficial bacteria/etc into material to make into basic soil. Enrich with nitrogen or other nutrients as possible.
Phytomining and Enrichment	Plants grown that fix nitrogen, convert to organics, and extract trace metals that are not beneficial to biome. Trace metals can go into industrial inputs.
Agricultural Use	Use the soils in greenhouses and permaculture food forests with settlements.
Artificial Ecosystem Use	Convert the soils to the various biomes, and place in domes for the biomes.

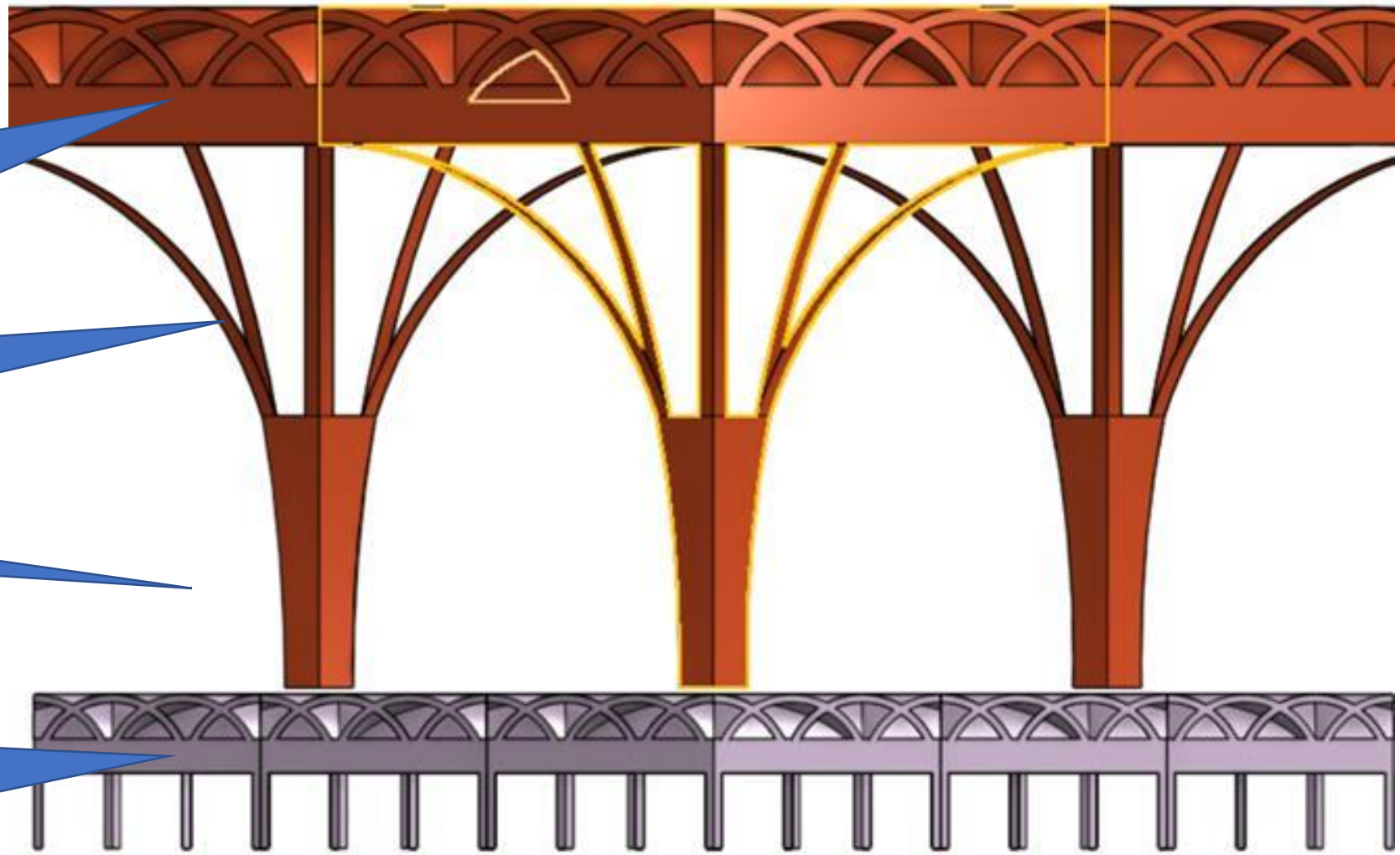
Enclosures

Roof Enclosure
Air pressure supported
GCR Shielding

Tree Columns
Visually open

Ecosystem Space

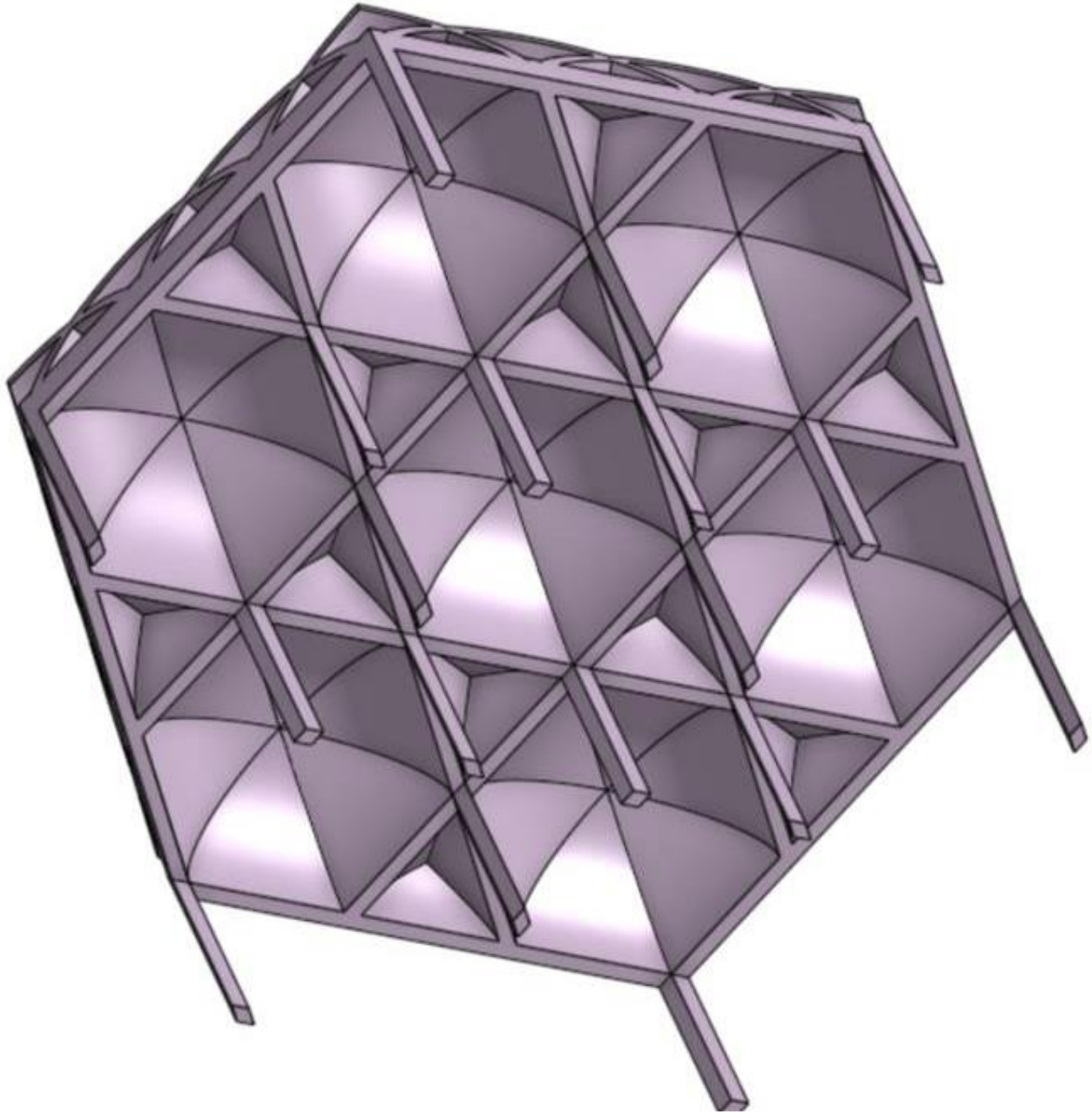
“Basement”
Heating, Transport,
Agriculture, Centrifuge
Habitats



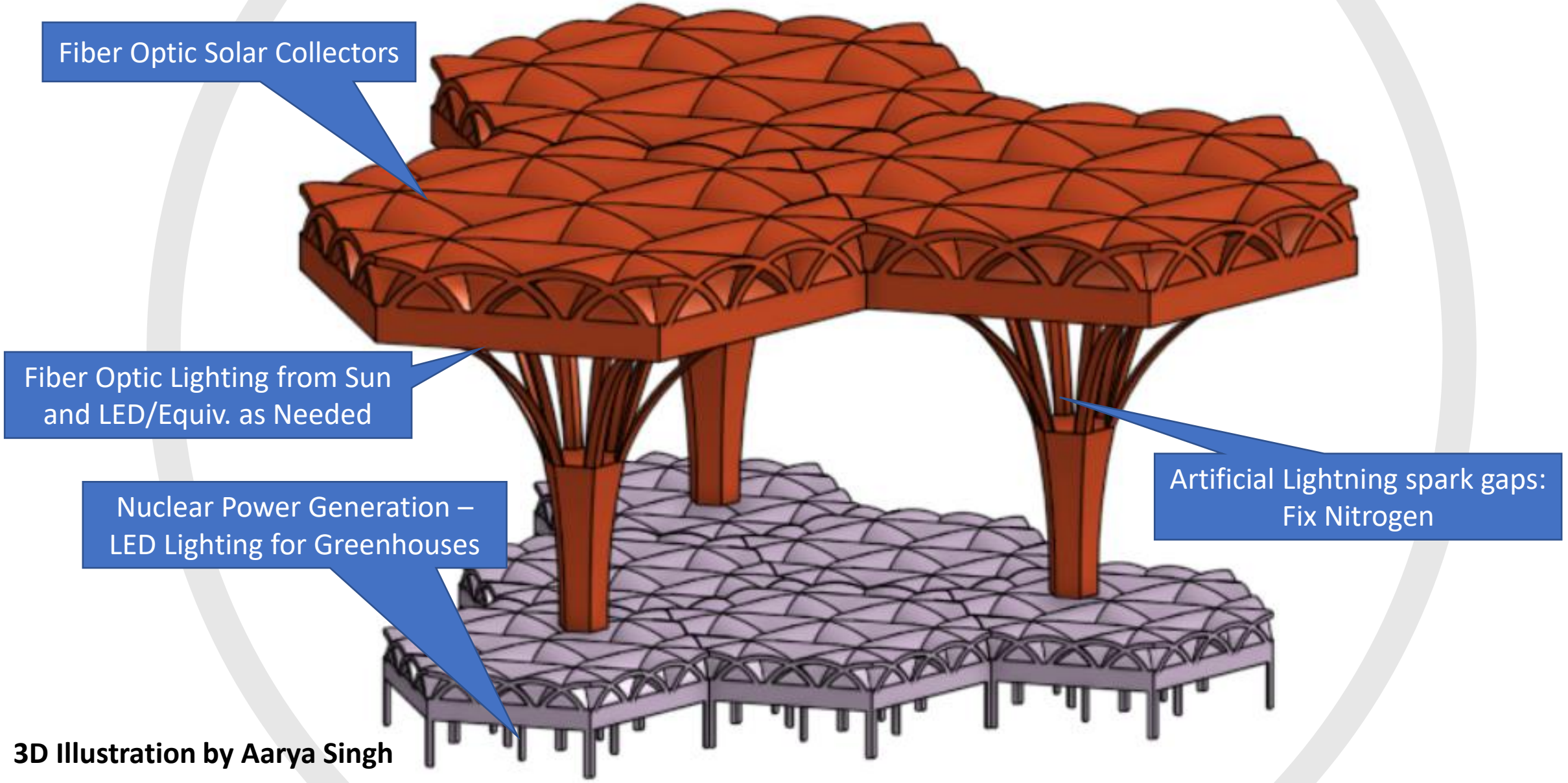
3D Illustration by Aarya Singh

First Stage: Dome Details

- Sides 500 meters across for low level domes
- Hexagonal grid across entire surface
- 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



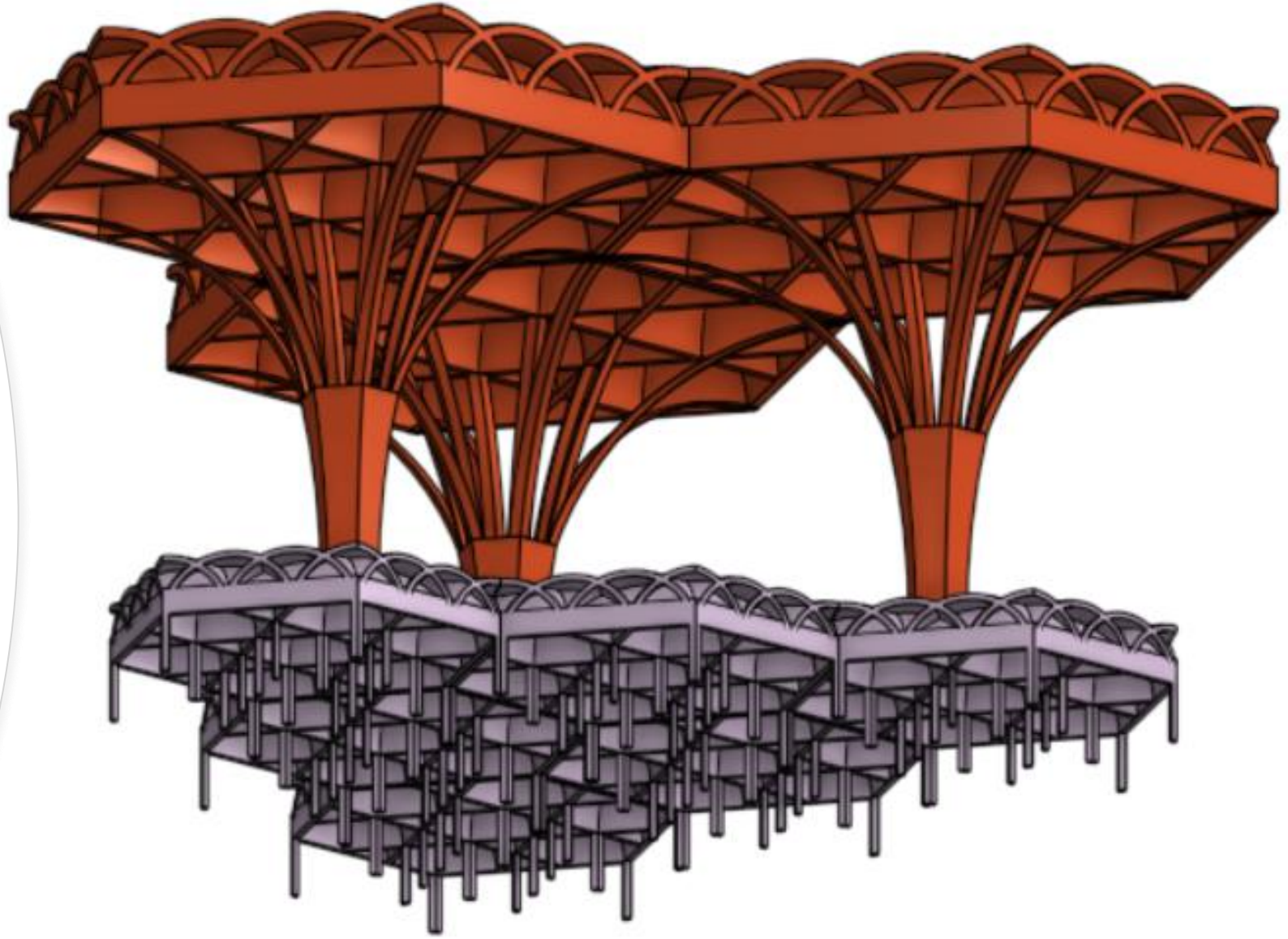
3D Illustration by Aarya Singh



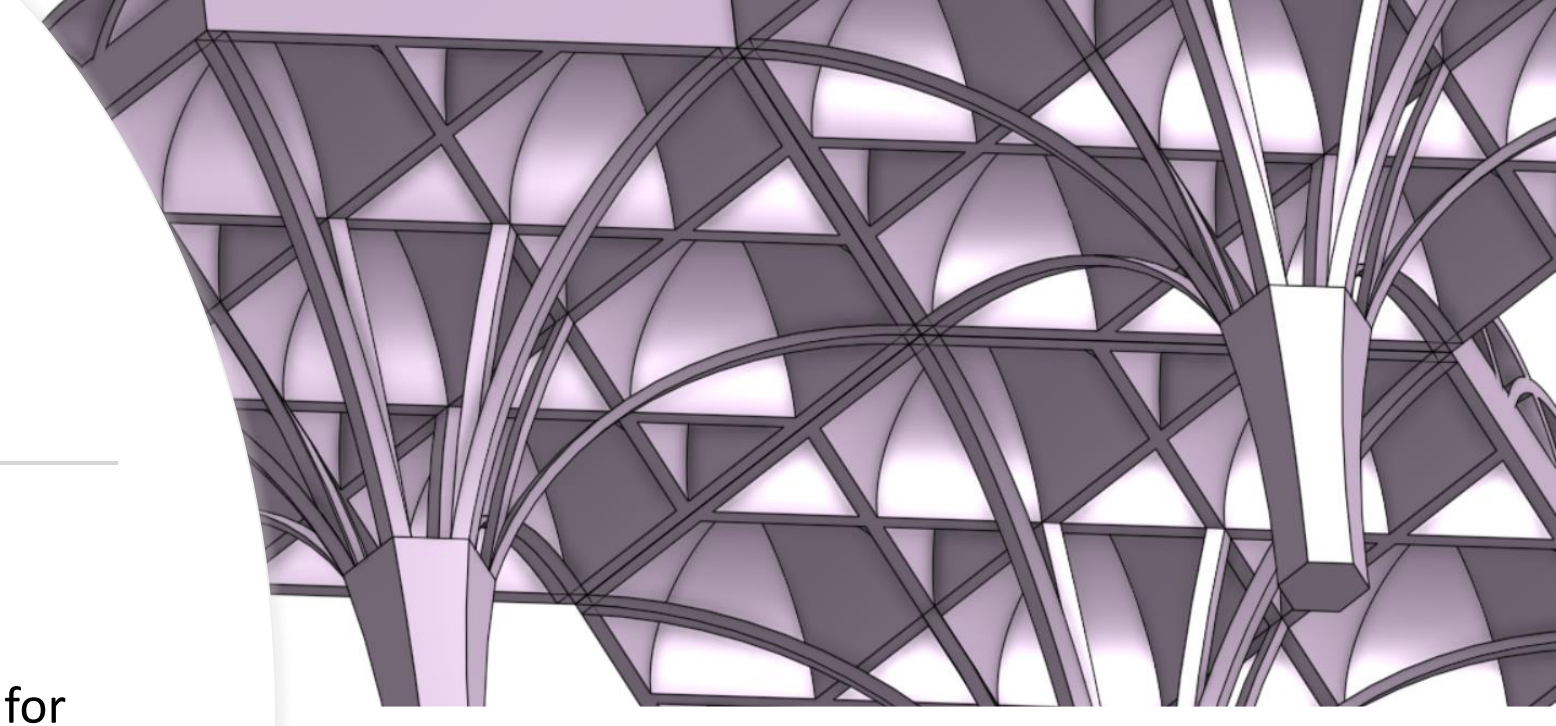
3D Illustration by Aarya Singh

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.

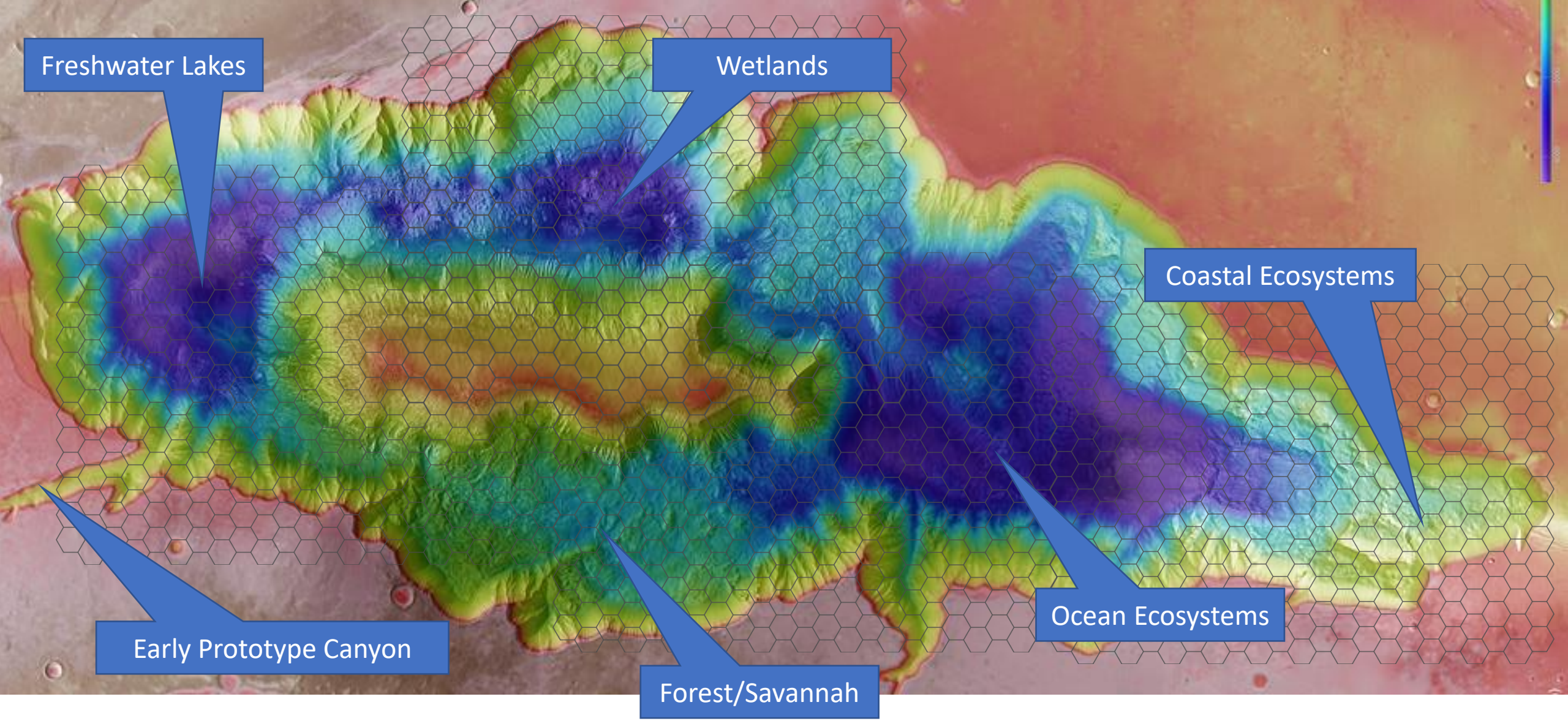


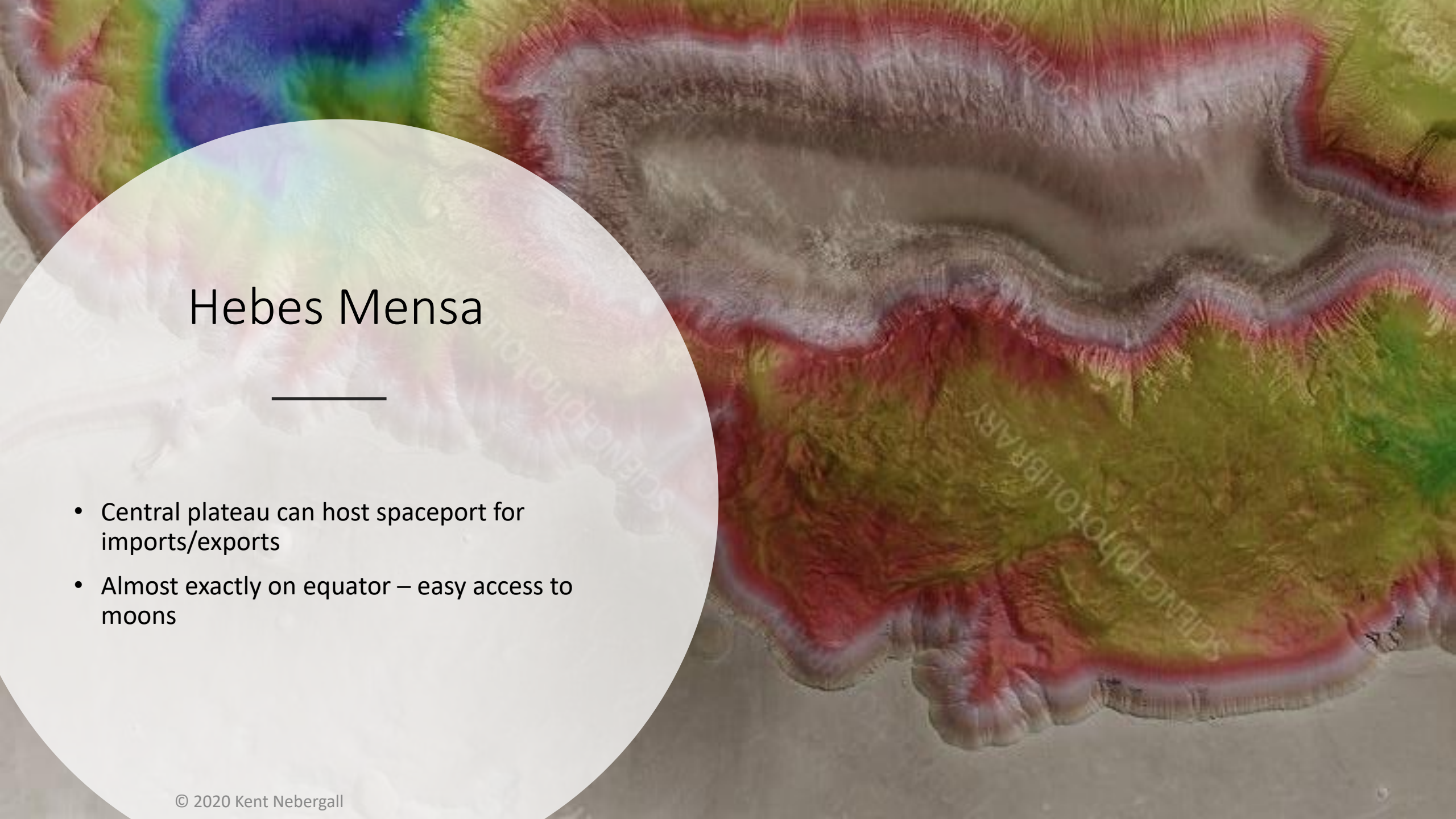
3D Illustration by Aarya Singh



- Partially inspired by
  La Sagrada Familia, Barcelona.
- Tree and branch pattern of biomimicry for canopy over ecosystems
- Provides many light source angles.

3D Illustration by Aarya Singh

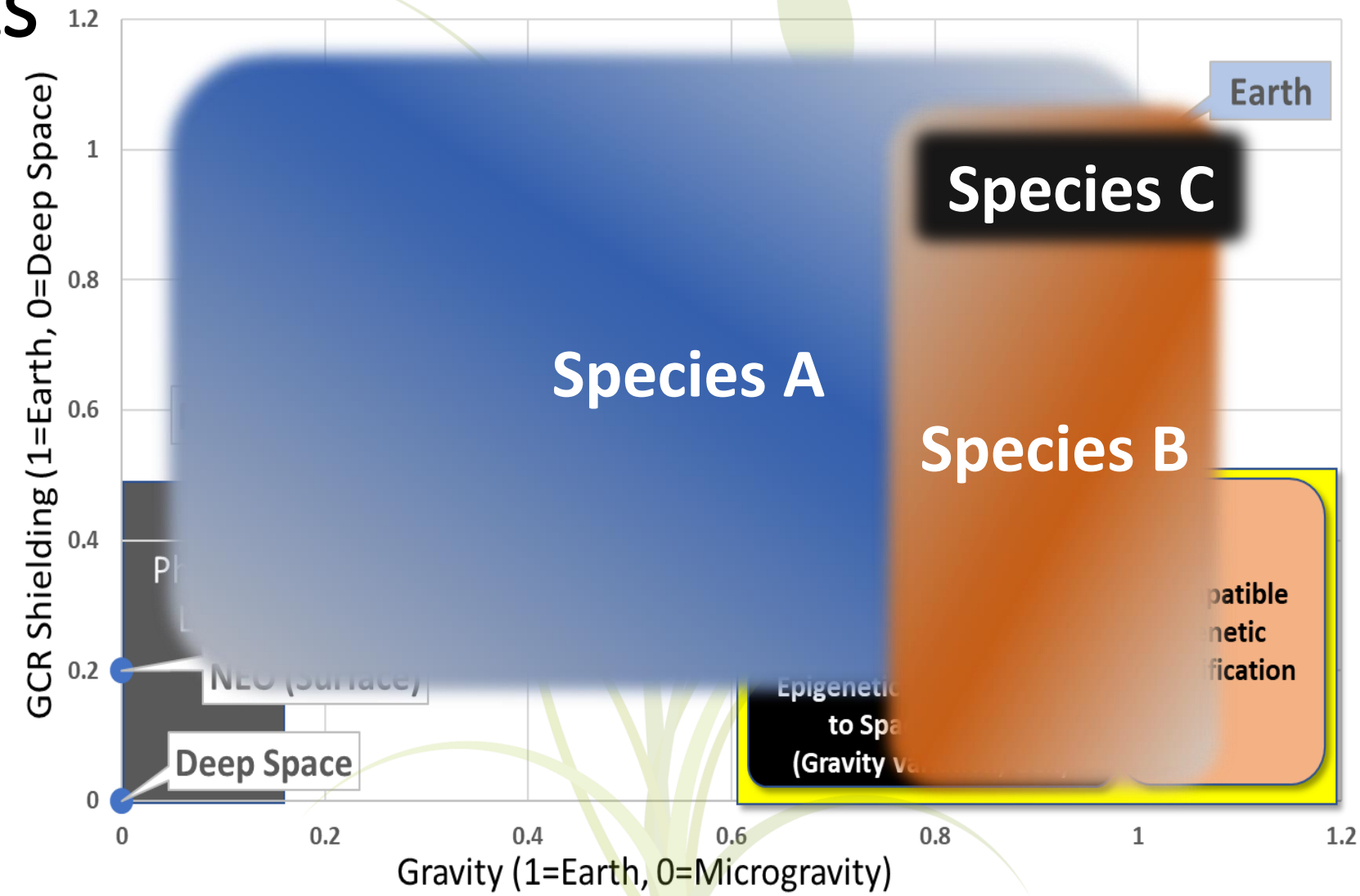




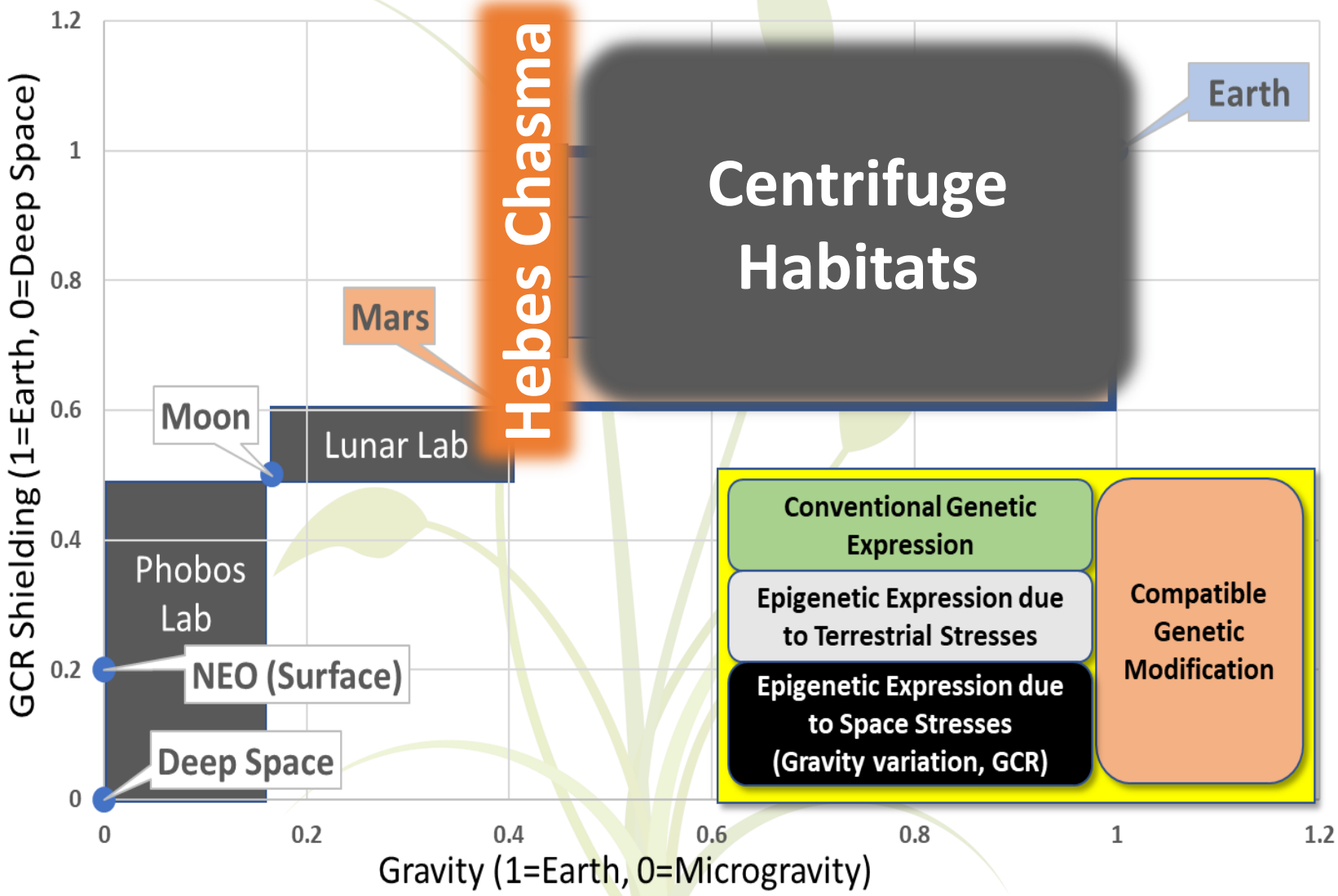
Hebes Mensa

- Central plateau can host spaceport for imports/exports
- Almost exactly on equator – easy access to moons

Species Limits

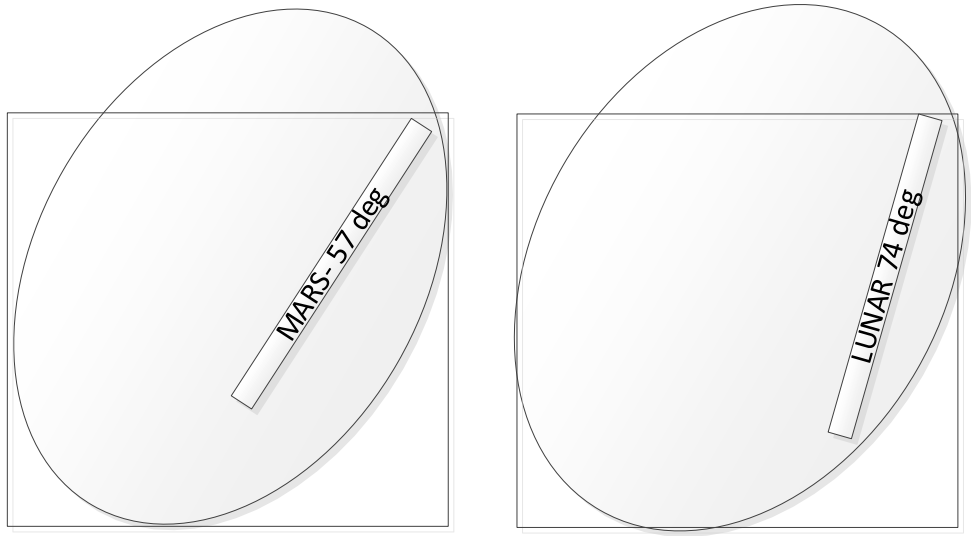


Epigenetics

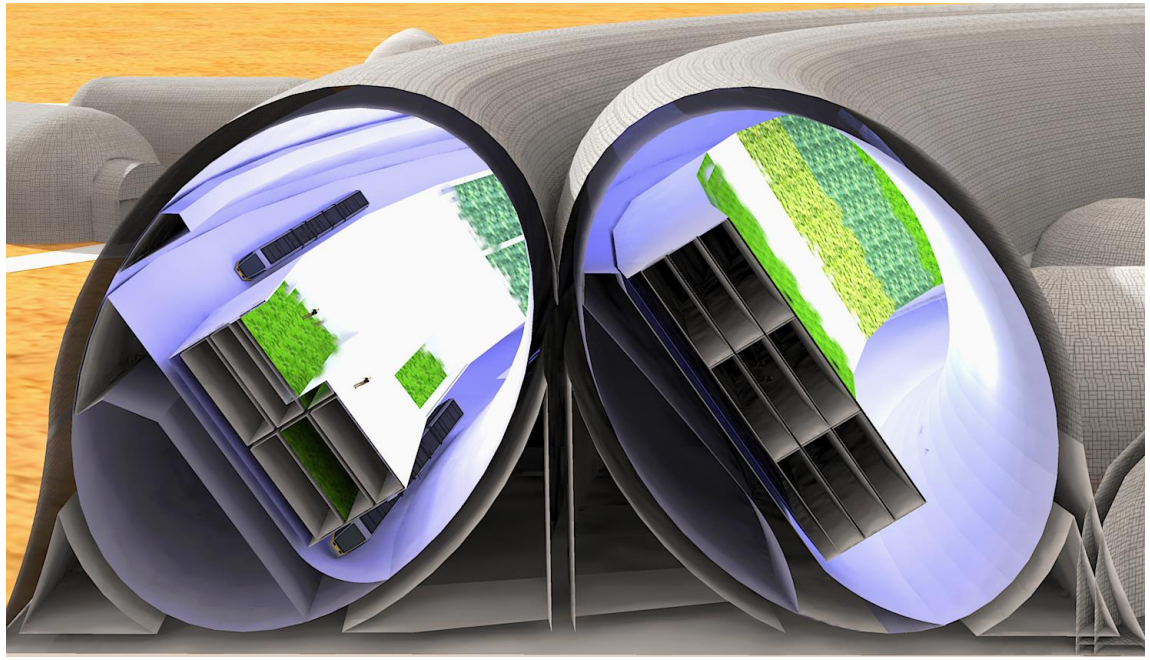


Centrifuge Rings

- For species where gravity must be more than Mars provides, surface rings can be built and fit within the dome sub structure.



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.

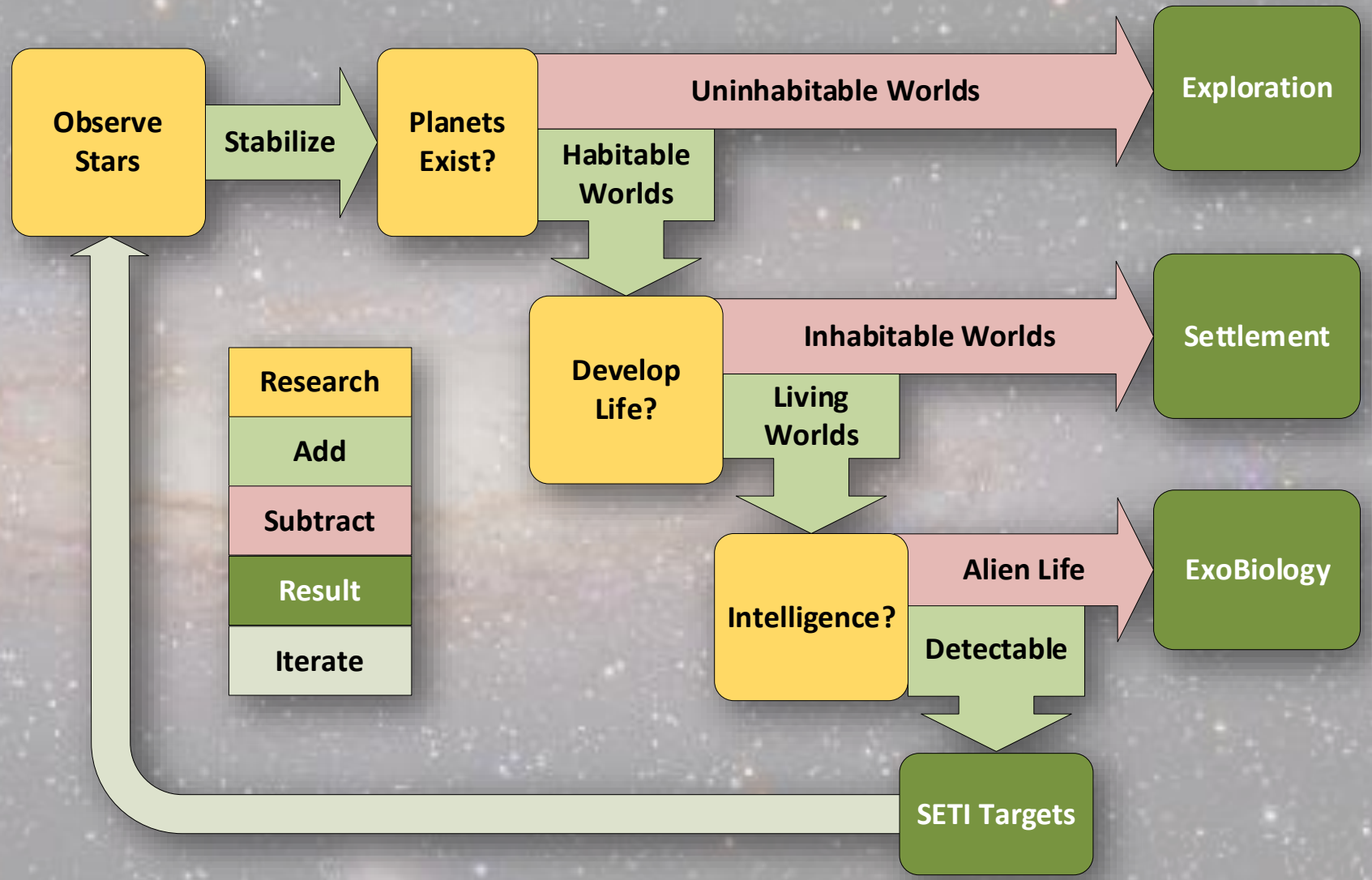


3D Illustration by Michel Lamontagne

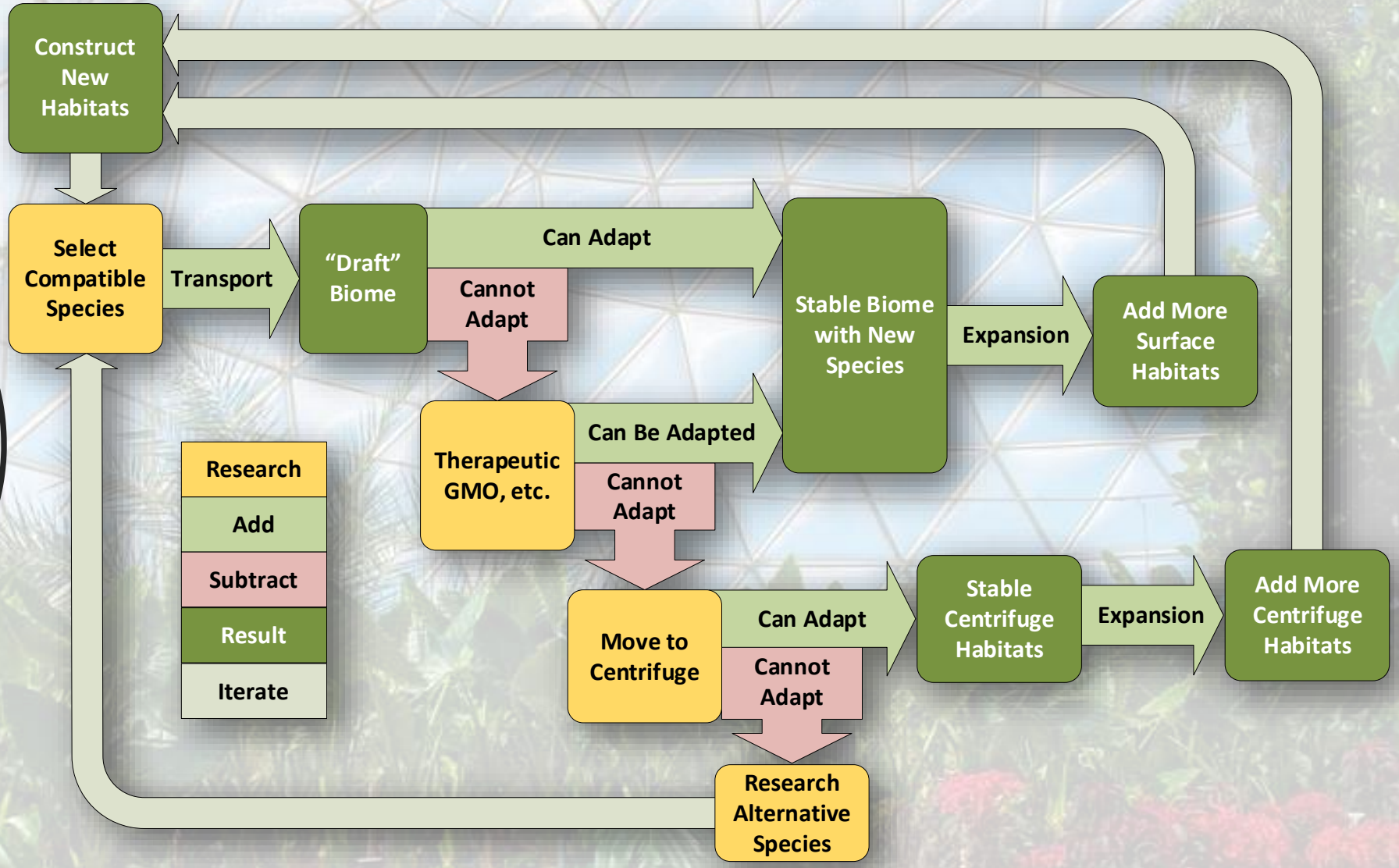
The Terraforming “Drake Equation”

- Equation of percentages
- Some are known, some will take years or centuries to find
- Becomes multi-generational project to work out complete answer.

Drake Equation (Visual)



Terraforming Biome Workflow



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

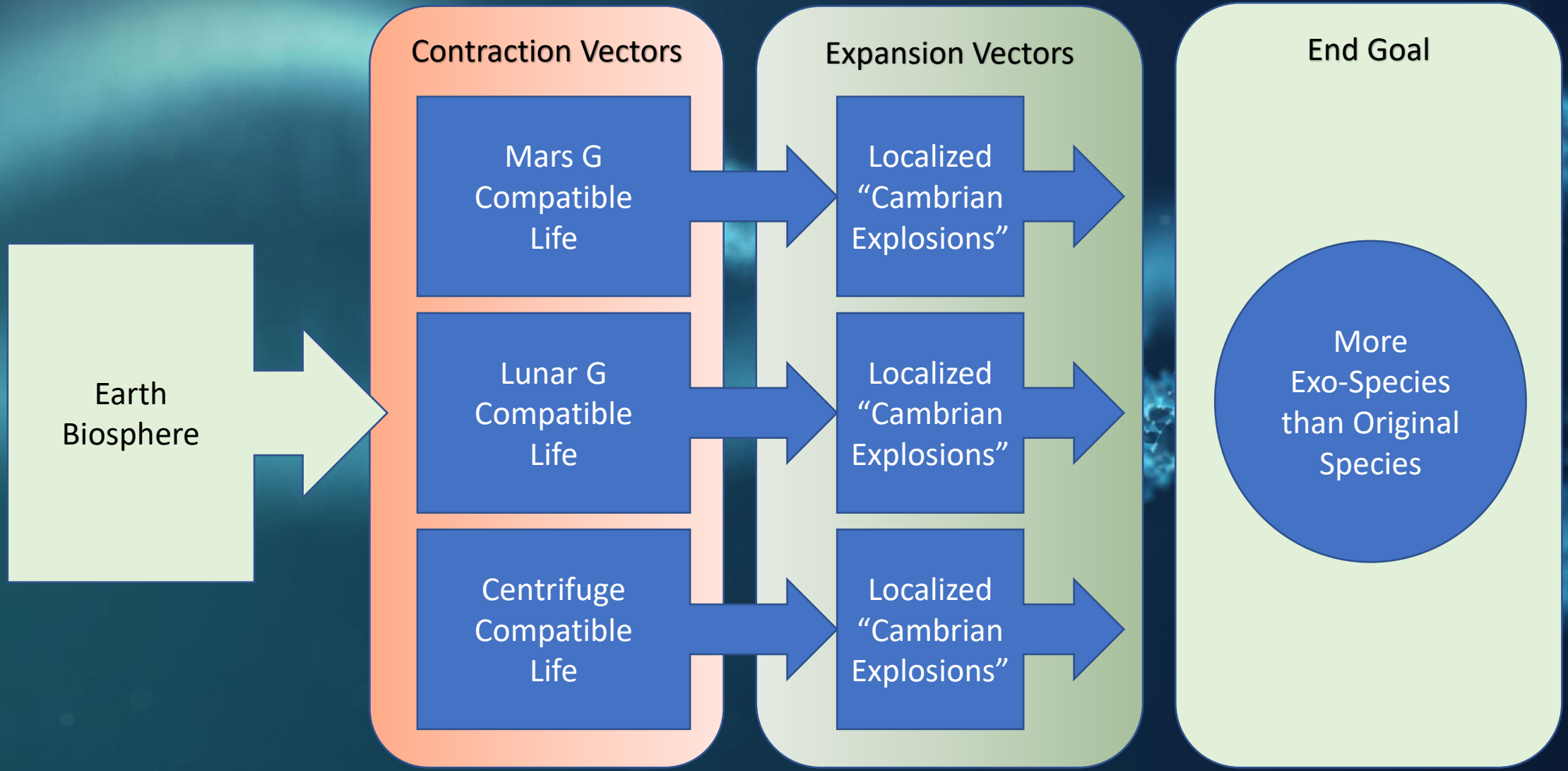
Active Countermeasures

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.

Evolutionary Bowtie Effect



Thanks!
Questions?

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