Independence: Mapping a Multi-Planetary Species

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Creating Space Independence Maps

Abstract

The goal of SpaceX is an independent civilization on Mars - one that can operate permanently without further imports from Earth. Elon Musk has said this requires one million people and one million metric tons of cargo flown to Mars. But he also said this is only accurate within an order of magnitude either way. What would an efficient path to space settlement and independence architecture look like with these goals in mind?

This is a deeper dive into the first principles of life, humanity, technology, and civilization. By examining these definitive foundations, we build a cleaner set of questions for science, technology and enterprise to resolve.

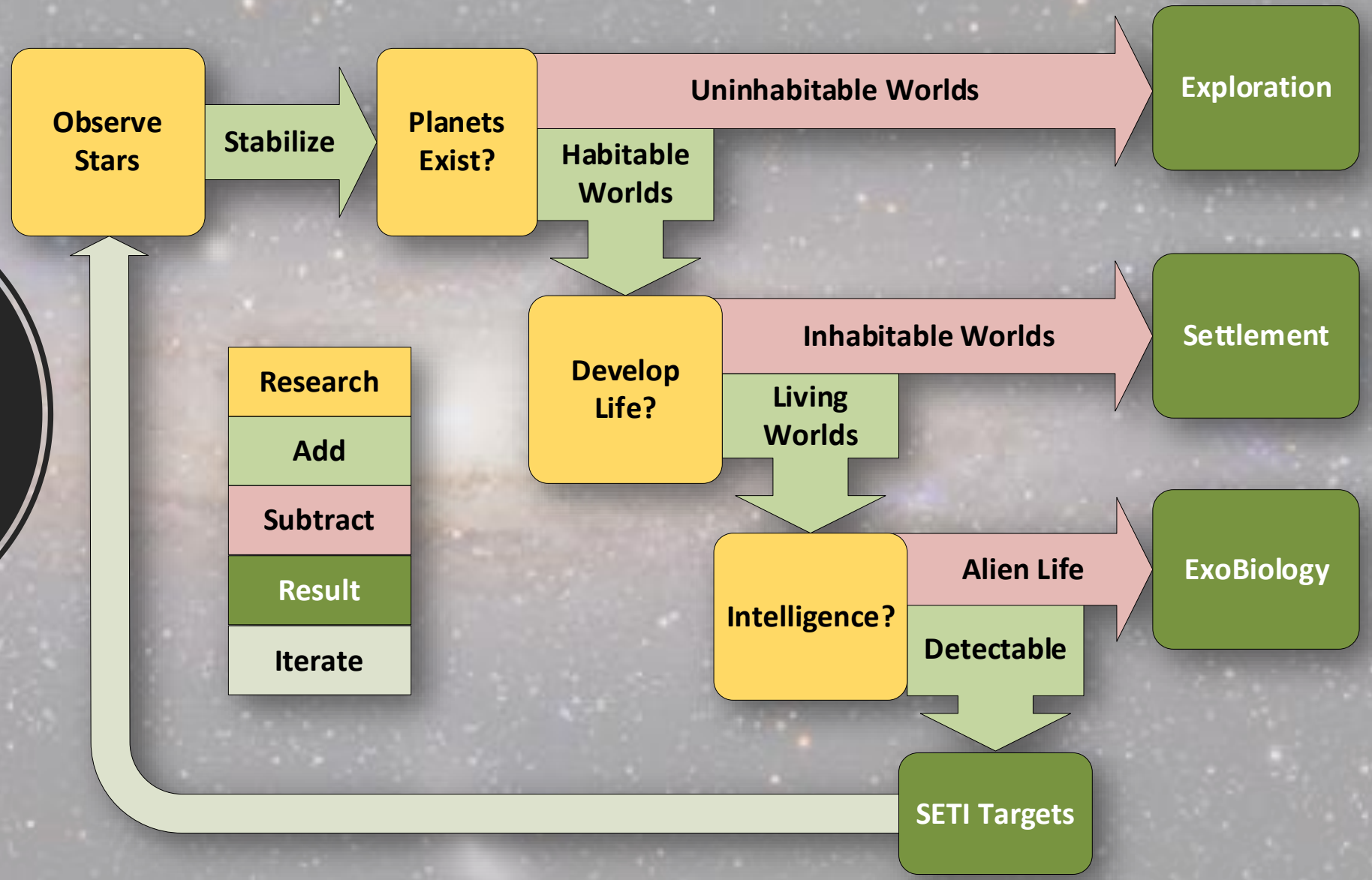
Note that this talk is not a map to the unknown future, but rather a star chart, compass, sextant, and theodolite for mapping unknown territory as we enter the future. It is the coordinate system and navigational language for finding efficient paths forward based on first principles from life itself. The result will be an eclectic mix of primitive and complex methods and systems to efficiently create the most independent civilization quickly. Such models can help developing civilizations and create antifragile technologies on Earth as well. It pursues the mechanics that make the machines of a multi-planet civilization possible.

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

First Principles, Precision Questions and Design Language

Drake Equation (Visual)



THE ROOT QUESTIONS: Theory

How far back in Evolution do you go to start over on a Sterile world?

How far back in Technology do you go to start over on an Uninhabited world?

How do you Accelerate to become a Peer World as quickly as possible?

Root Questions: Actionable

Habitability

- What places in the solar system are closest to habitable?

Biology

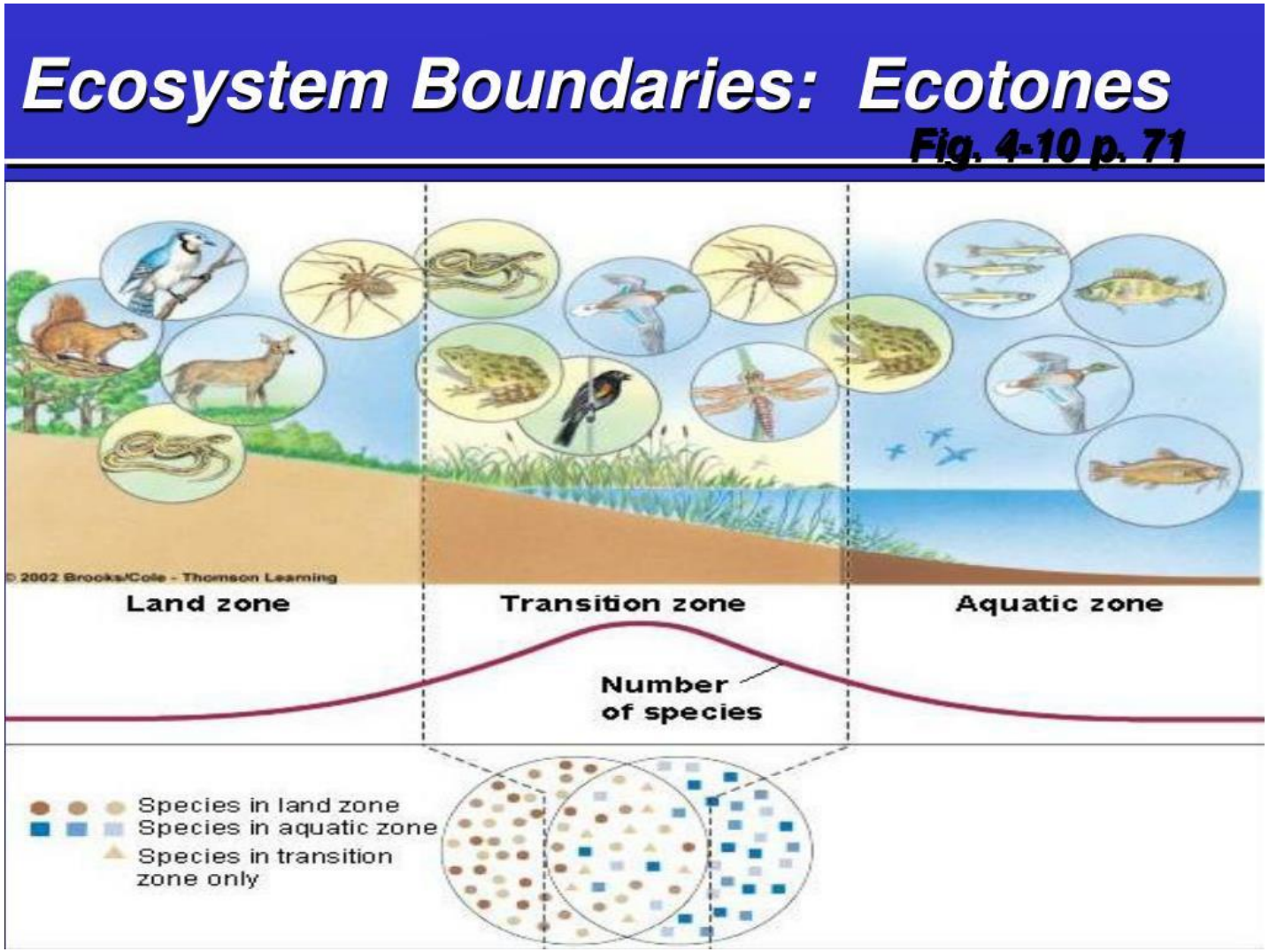
- What mix of ancient and engineered life is needed to create independence?

Humanity

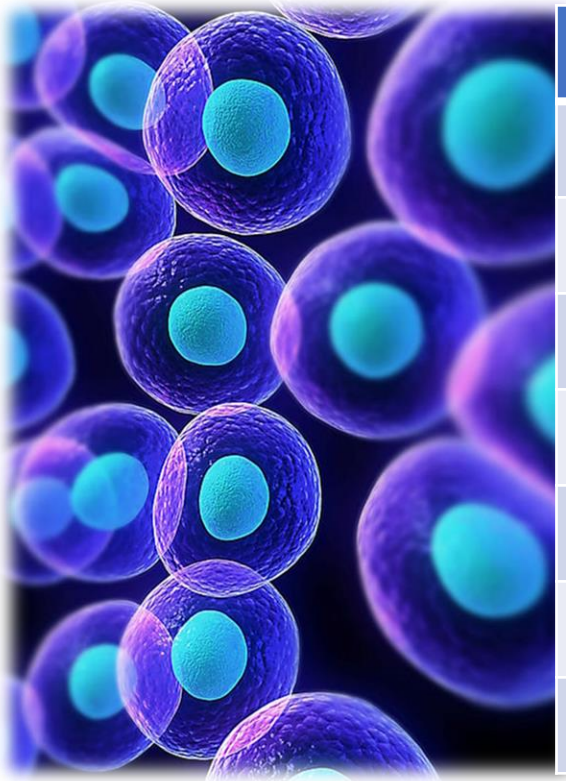
- What mix of early and advanced technology can replicate and advance itself?
- How quickly can off-world become near-peer?

Habitability: Shelter, Life Functions, and Human History Compression

Environment to Habitat: Boundary Layers



Traditional Life Functions: Defined



Cellular
Metabolism
Response
Homeostasis
Growth
Reproduction
Excretion
Nutrition

Organism
Movement
Sensitivity
Respiration
Growth
Reproduction
Excretion
Nutrition

Harmonized Life Functions

Abstraction
Movement
Sensitivity
Response
Homeostasis
Nutrition
Respiration
Excretion
Metabolism
Growth
Reproduction
Adaptation
Efficiency

First Principle Life Functions

Information Energy Matter

Abstraction	External Interaction	Energy Management	Repair & Replace
Movement	Active	Active	
Sensitivity	Active		
Response	Active		
Homeostasis	Active		
Nutrition	Active	Active	Active
Respiration	Active	Active	Active
Excretion		Active	Active
Metabolism	Active	Active	Active
Growth		Active	Active
Reproduction		Active	Active
Adaptation	Active	Active	Active
Efficiency	Active	Active	Active

Energy Density/Efficiency, 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]

Empowering Technology Revolutions

Energy

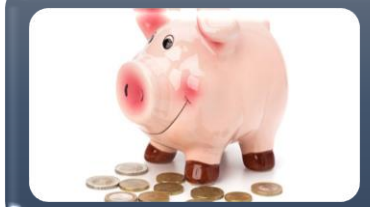
- Higher Density
- Affordable, Consistent, Safe

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 (Efficiency)

- Applies to All of the Above

Excitement

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

Autonomy Phases

Inception (Conception to Birth)

- Conception to Birth

Establishment (Childhood)

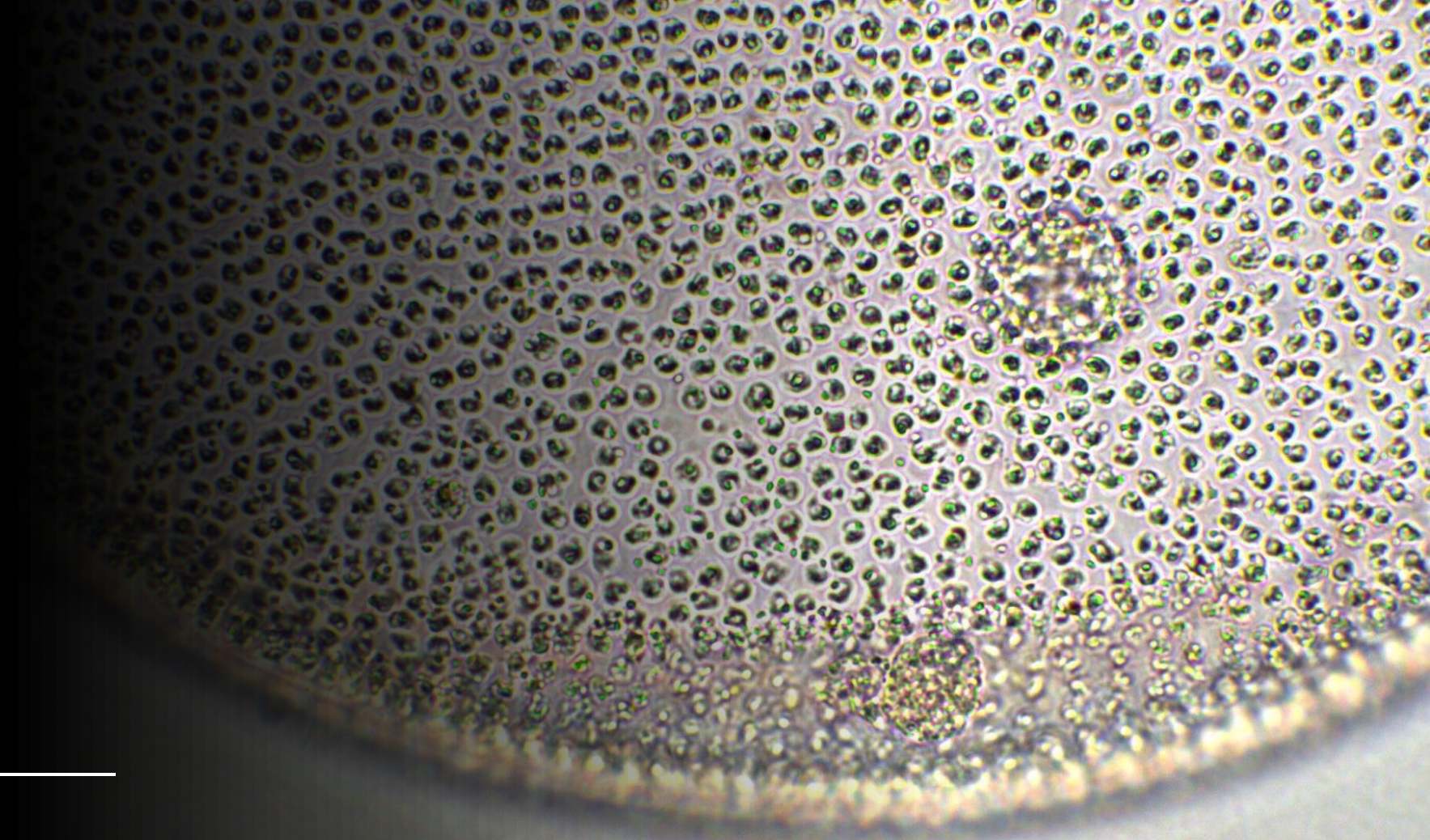
- Host of structures and businesses to provide basic goods and services independent of Earth

Acceleration (Apprentice to Parent)

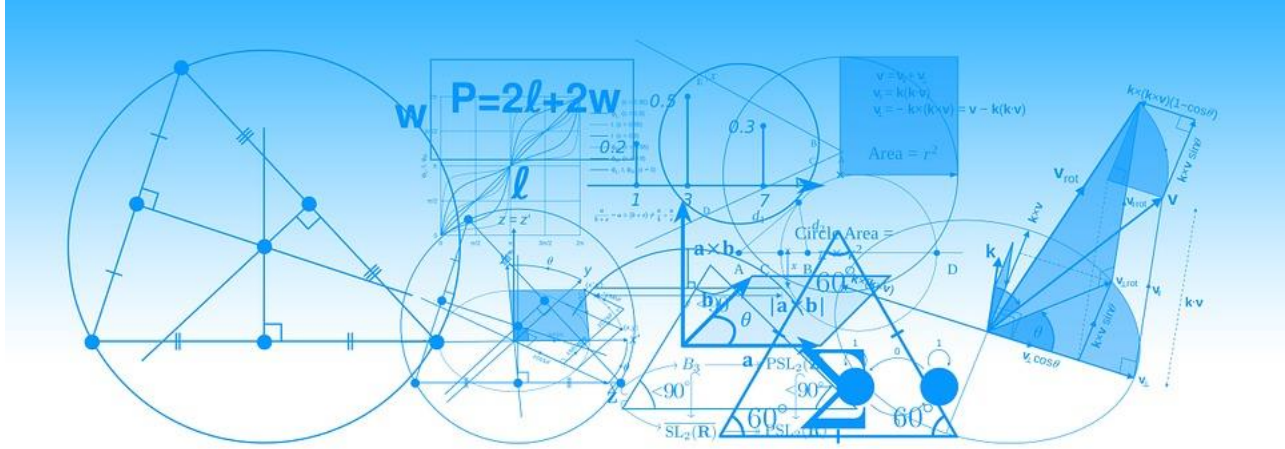
- Increase the trade balance domestically
- Make imports optional, then superfluous

Inception

Getting from Here to There



Metabolic Vectors



Flexible Capacity (Supplies)

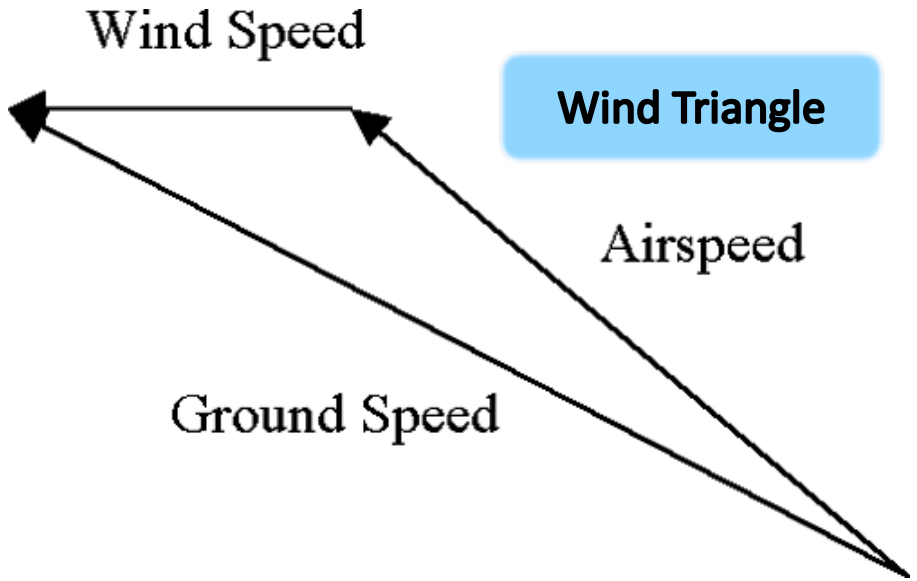
ENERGY

WORK

INDUSTRIAL CAPACITY

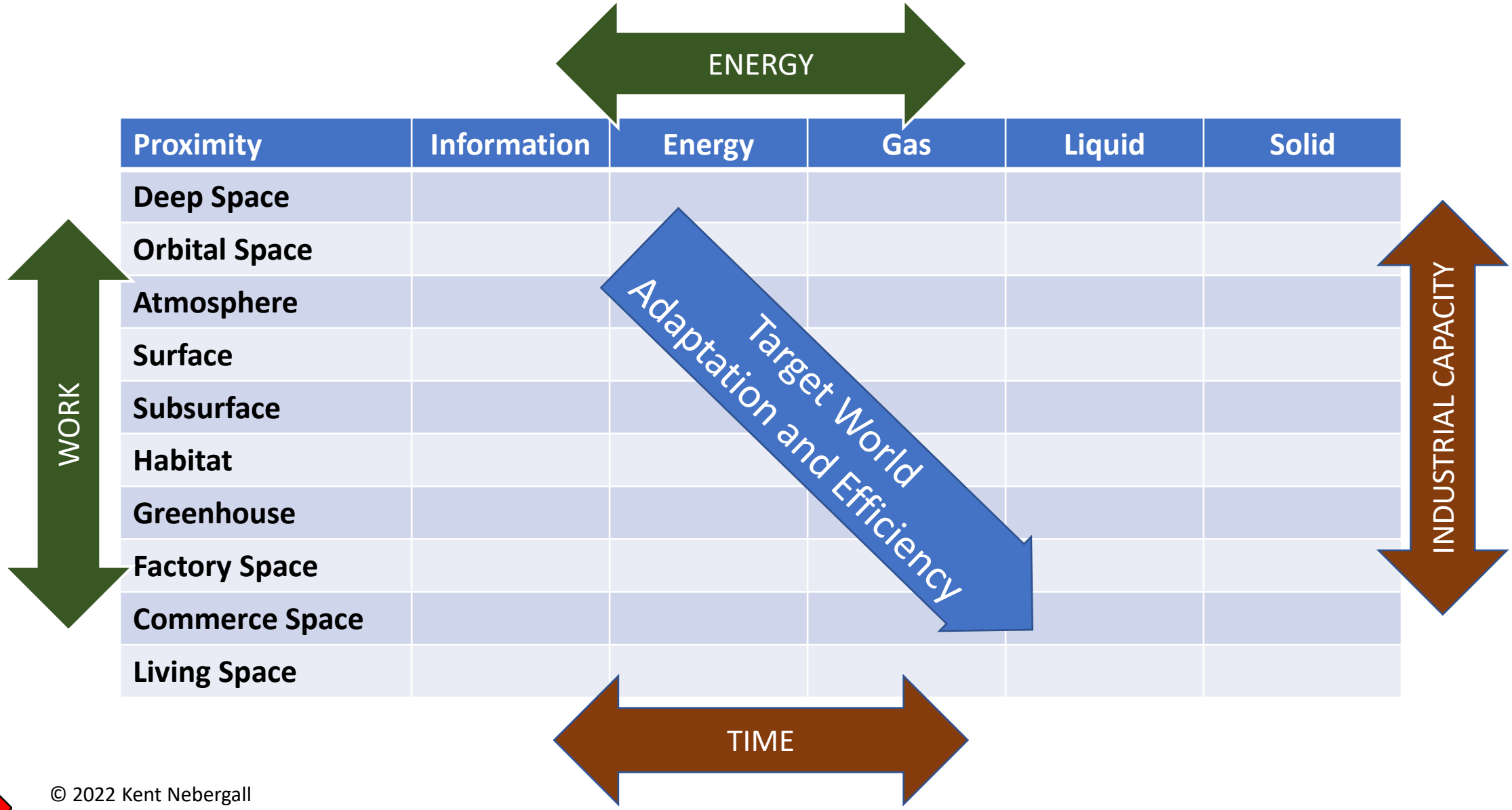
TIME

Fixed Capacity (Travelers)

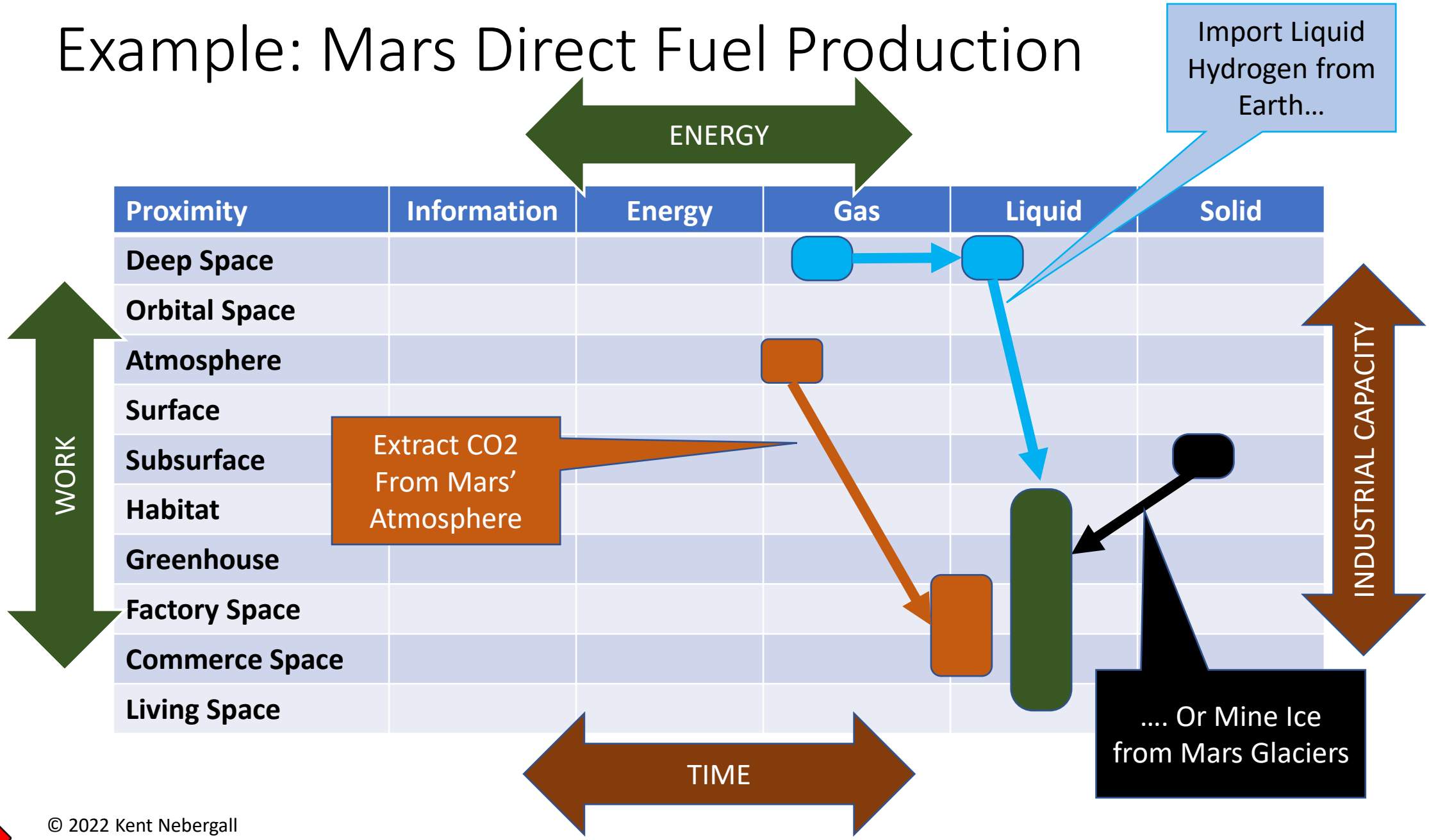


Wind Triangle

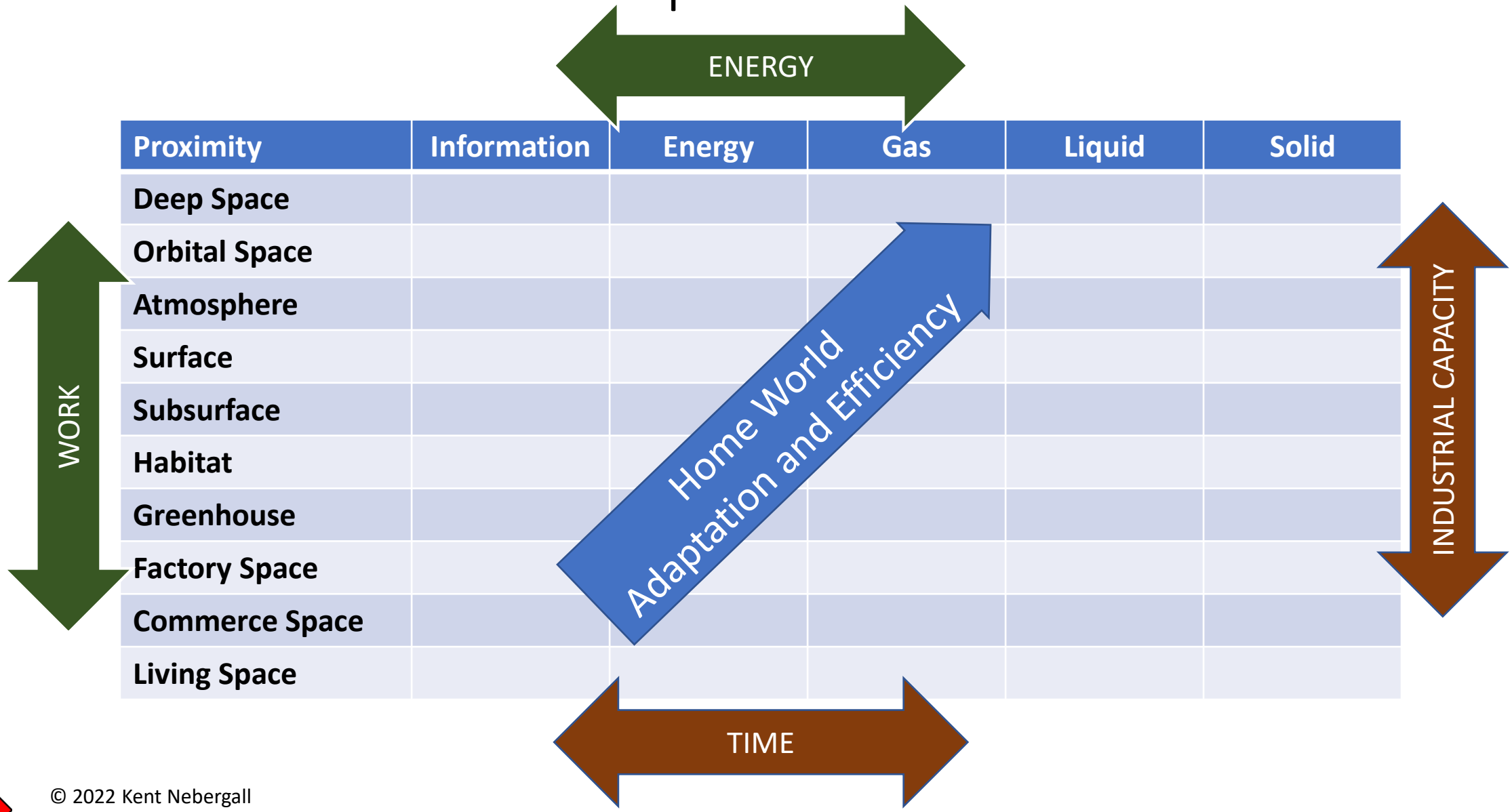
Metabolic Vector Map: Descent Flow



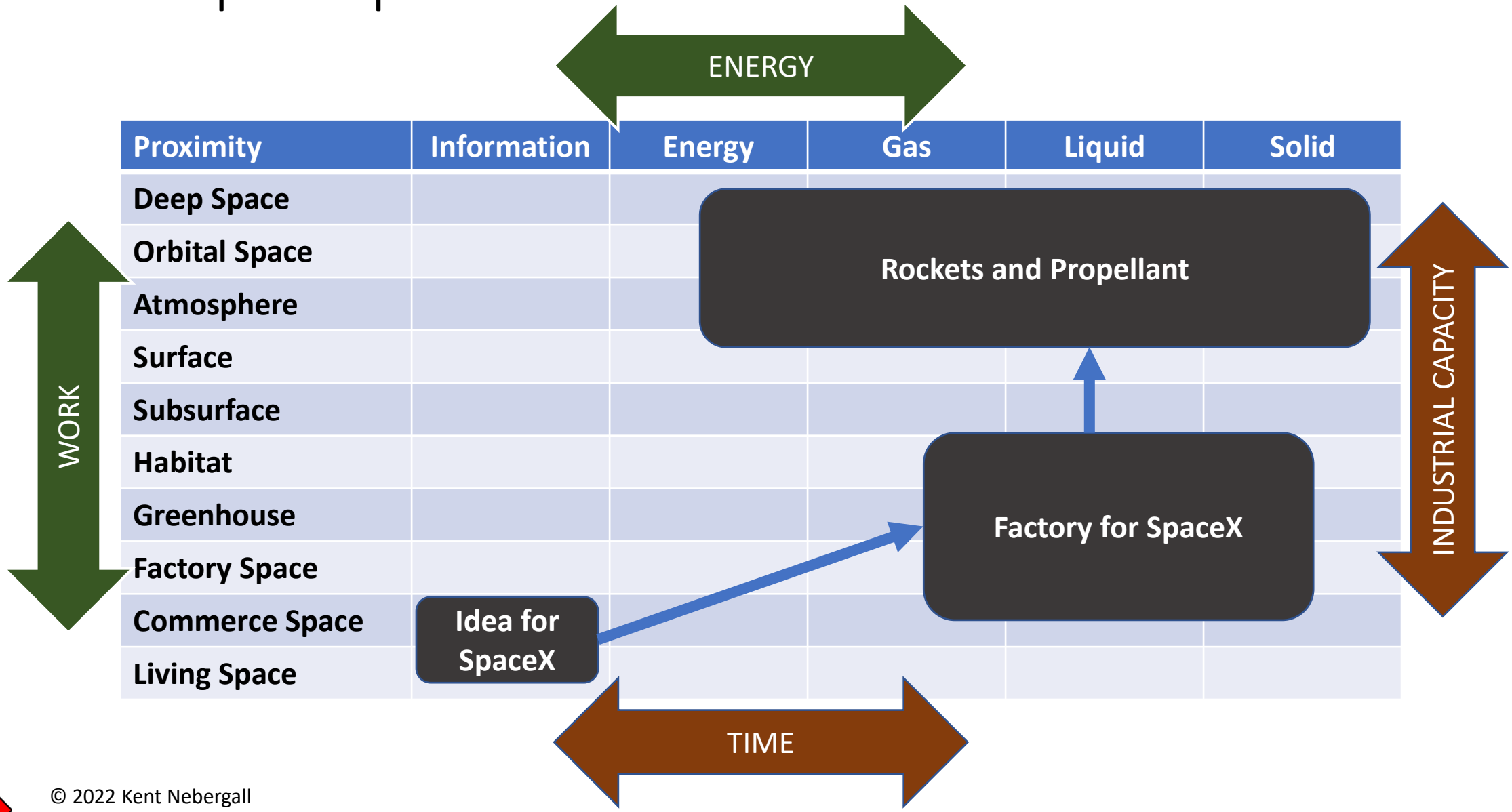
Example: Mars Direct Fuel Production



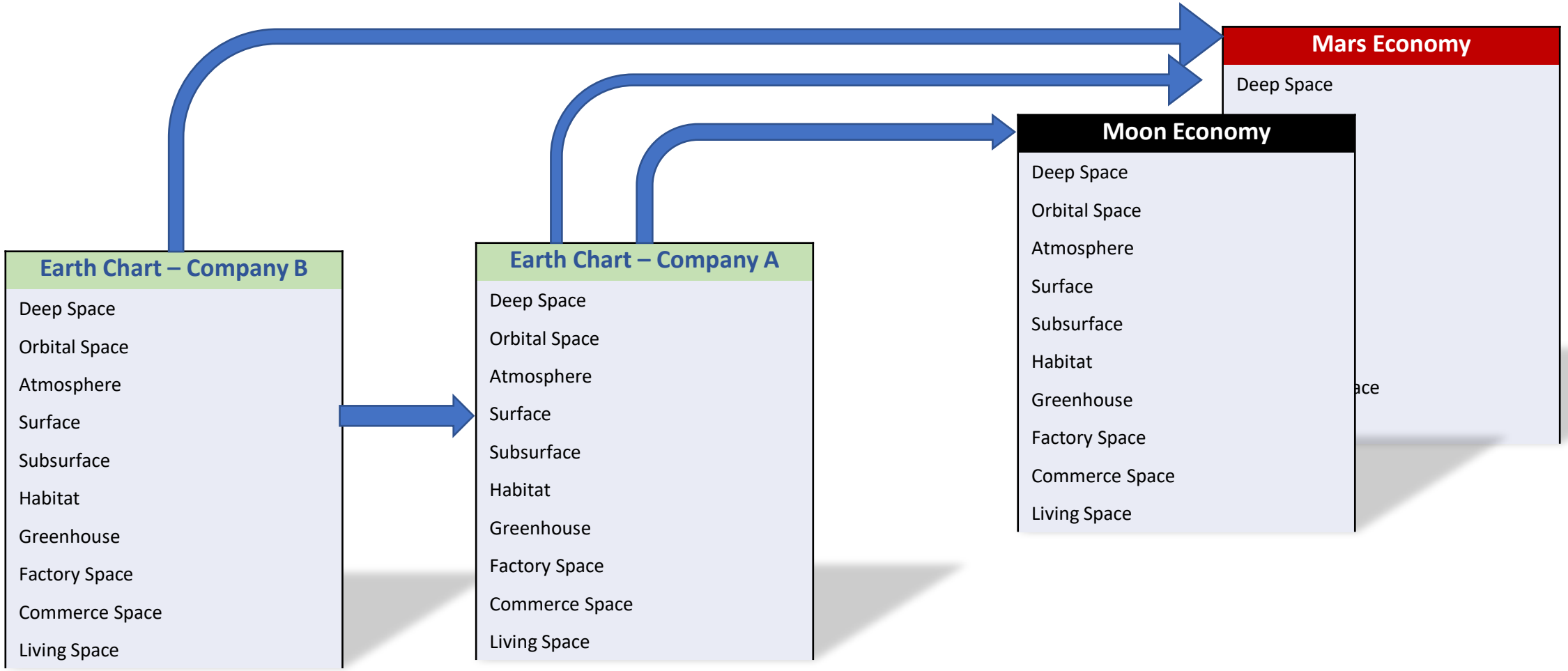
Metabolic Vector Map: Ascent Flow



Example: SpaceX



Multi-Planetary Efficiency Models



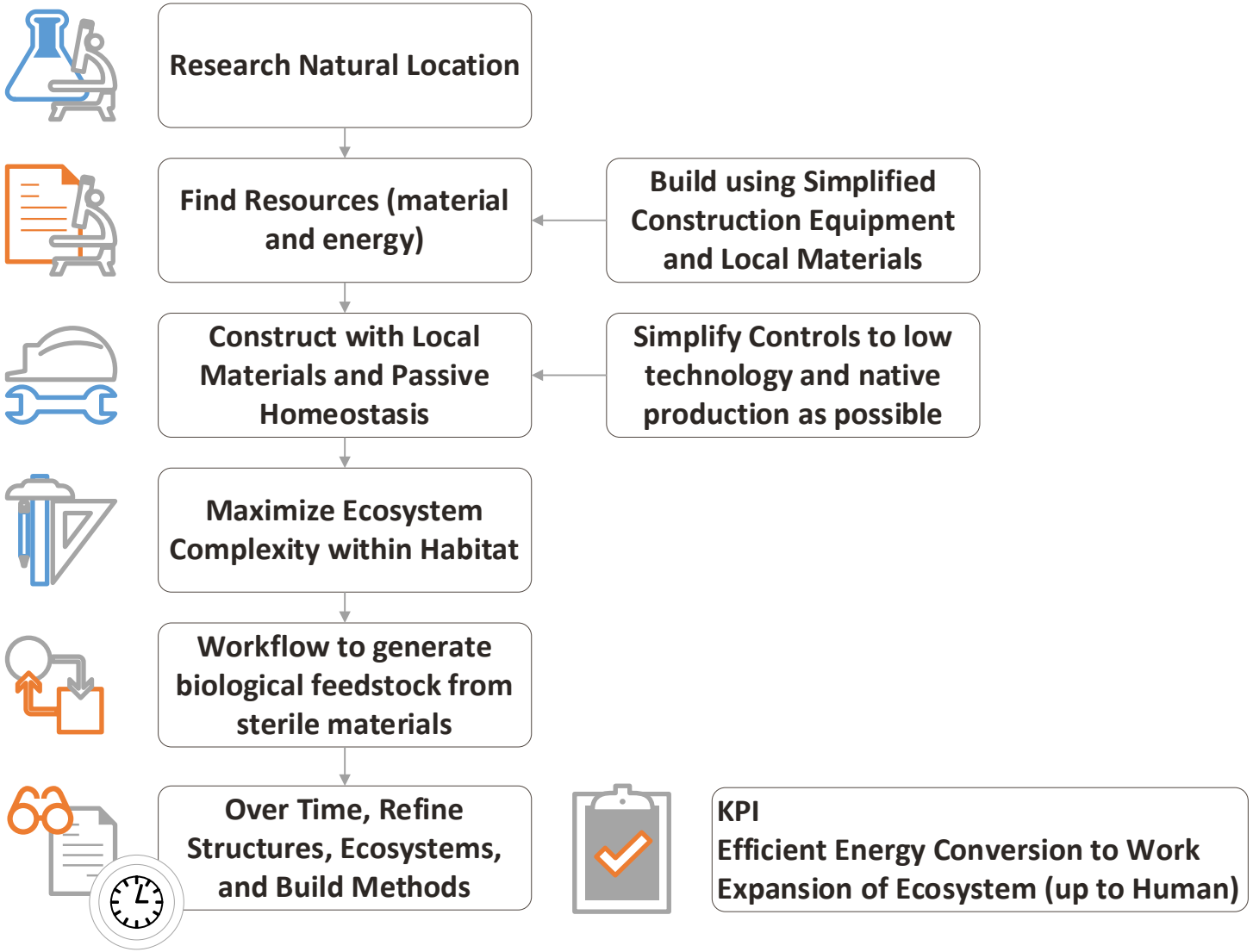
Establishment

First Closed Economic Services

Slow Approach

- **Slow expansion of non-human biomes with proximate resources and equipment – essentially dome biospheres with minimal maintenance to create habitation. Maintain as outposts to generate organic matter footholds.**
- **From there, slowly add complexity to established ecosystems and refinements to new ones based on experience – learn as you go.**

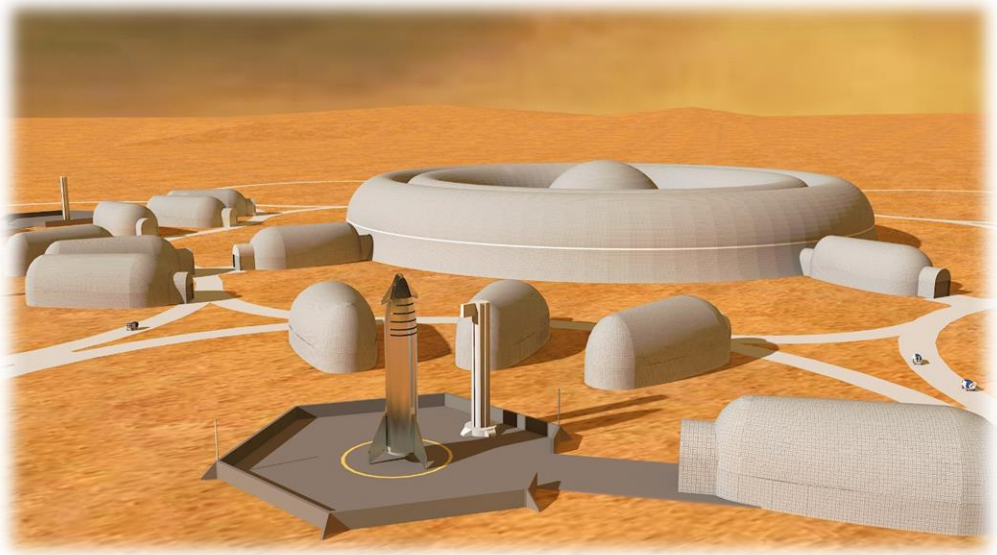
Slow Approach



Fast Approach

- **Start with large scale outpost and heavy machinery**
- **Build high-capacity core with lots of adaptive, modular hardware from Earth**
- **Replacing imported modules with local ones over time**

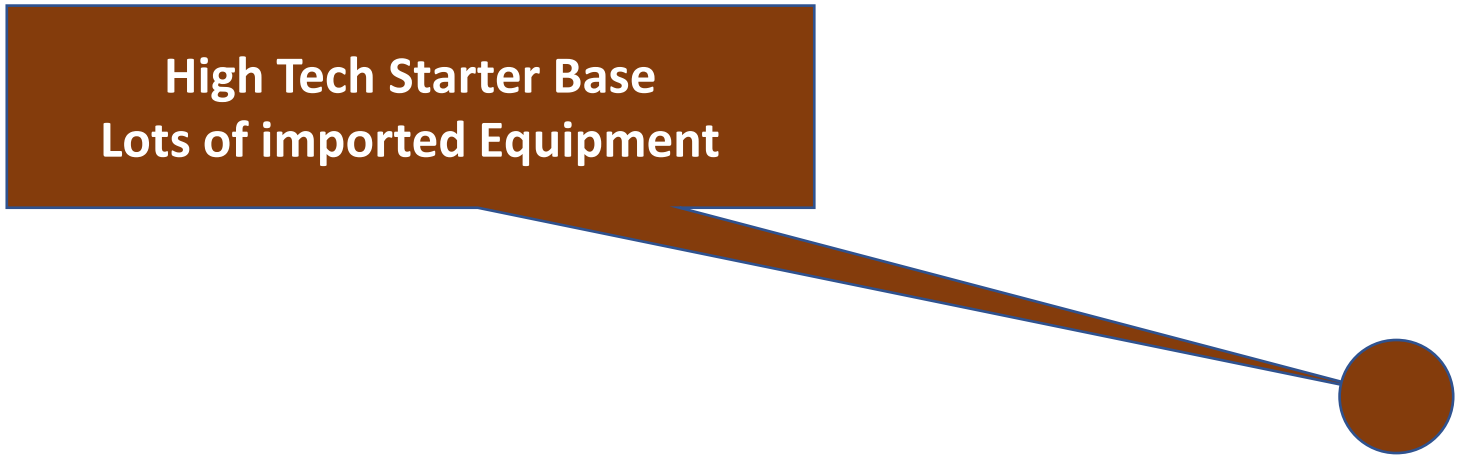
Fast Approach



- Research Natural Location
- Find Resources (material and energy)
  - Build using Simplified Construction Equipment and Local Materials
- Construct Massive Base with as much imported tech as possible
  - Have enough reserve tech to bridge from imports to localized resources
- Construct with Local Materials and Passive Homeostasis
  - Simplify Controls to low technology and native production as possible
- Maximize Ecosystem Complexity within Habitat
- Workflow to generate biological feedstock from sterile materials
- Over Time, Refine Structures, Ecosystems, and Build Methods

KPI
Efficient Energy Conversion to Work Expansion of Ecosystem (up to Human)

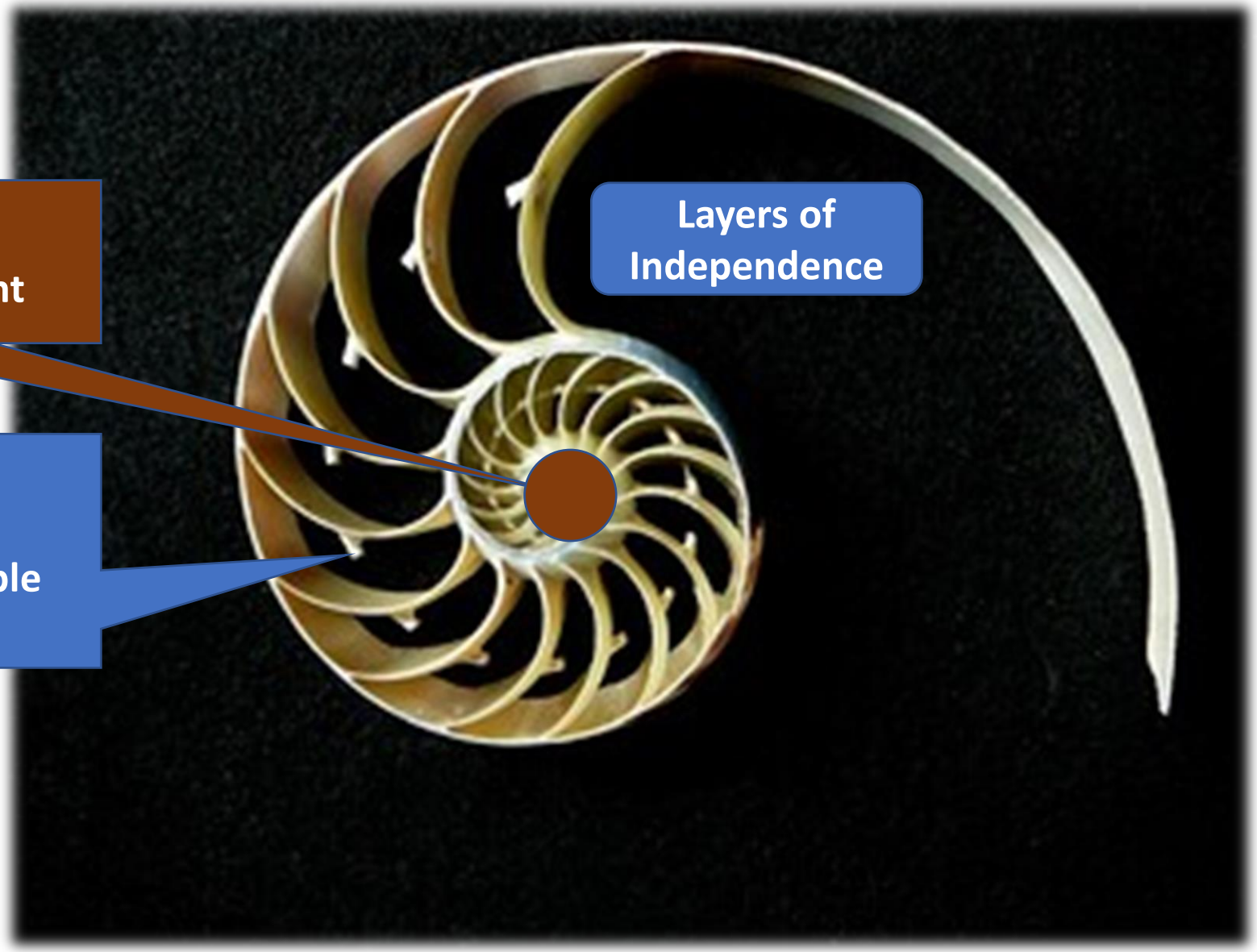
Hybrid Approach



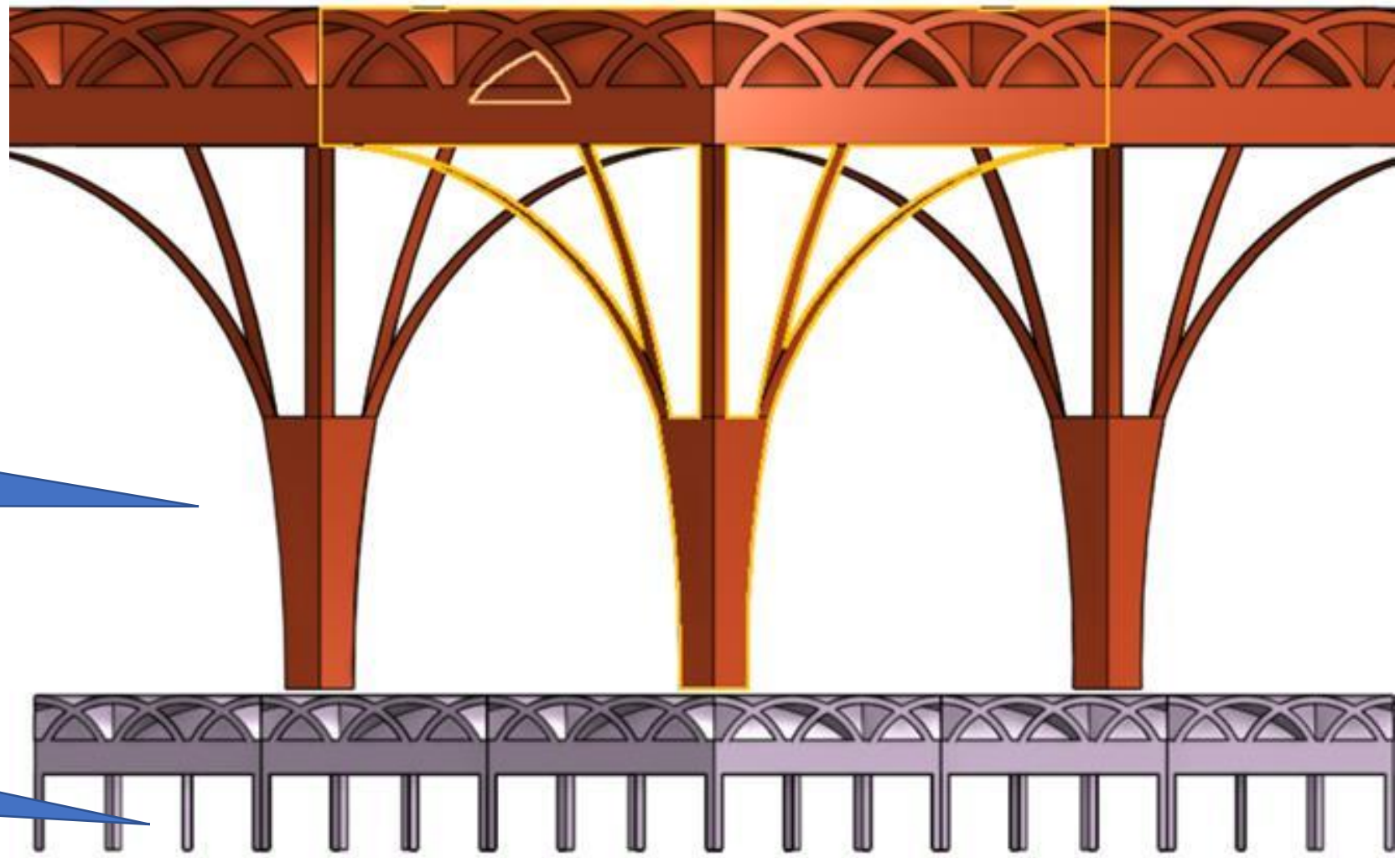
Hybrid Approach

High Tech Starter Base
Lots of imported Equipment

Sequential Low-Tech Cellular Growth, Each Larger and more capable than previous one

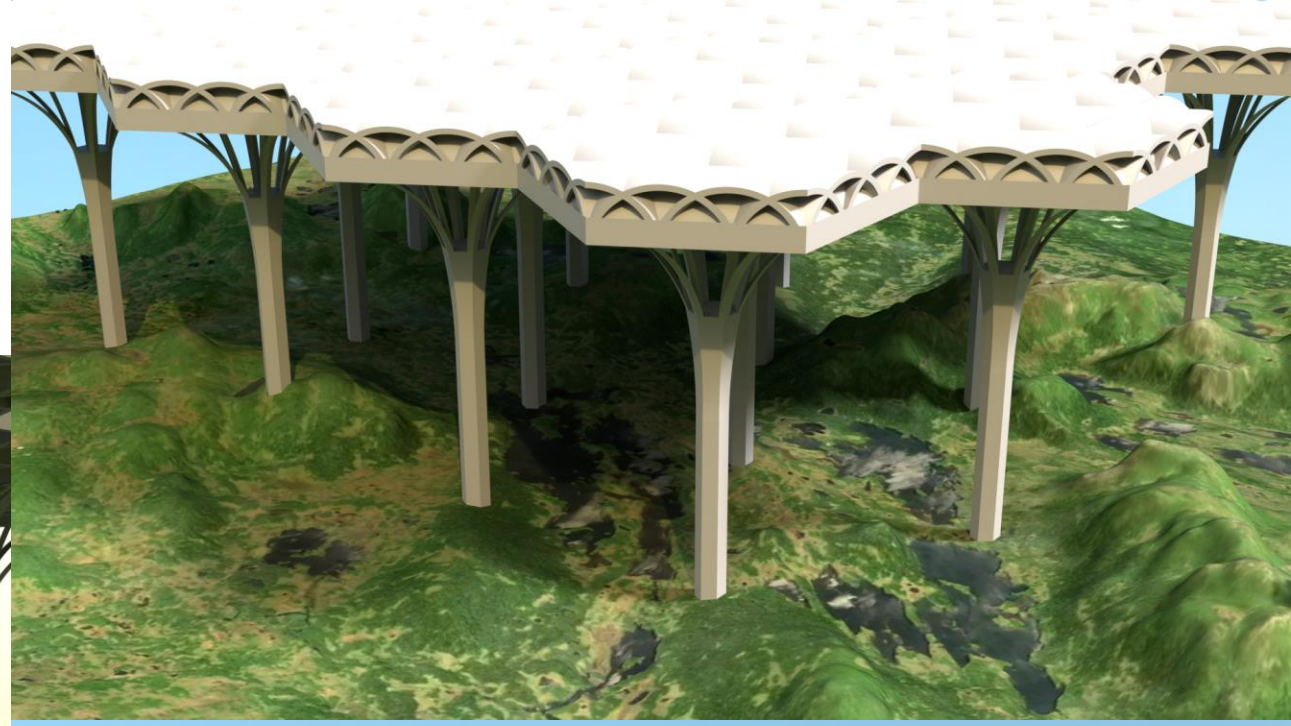


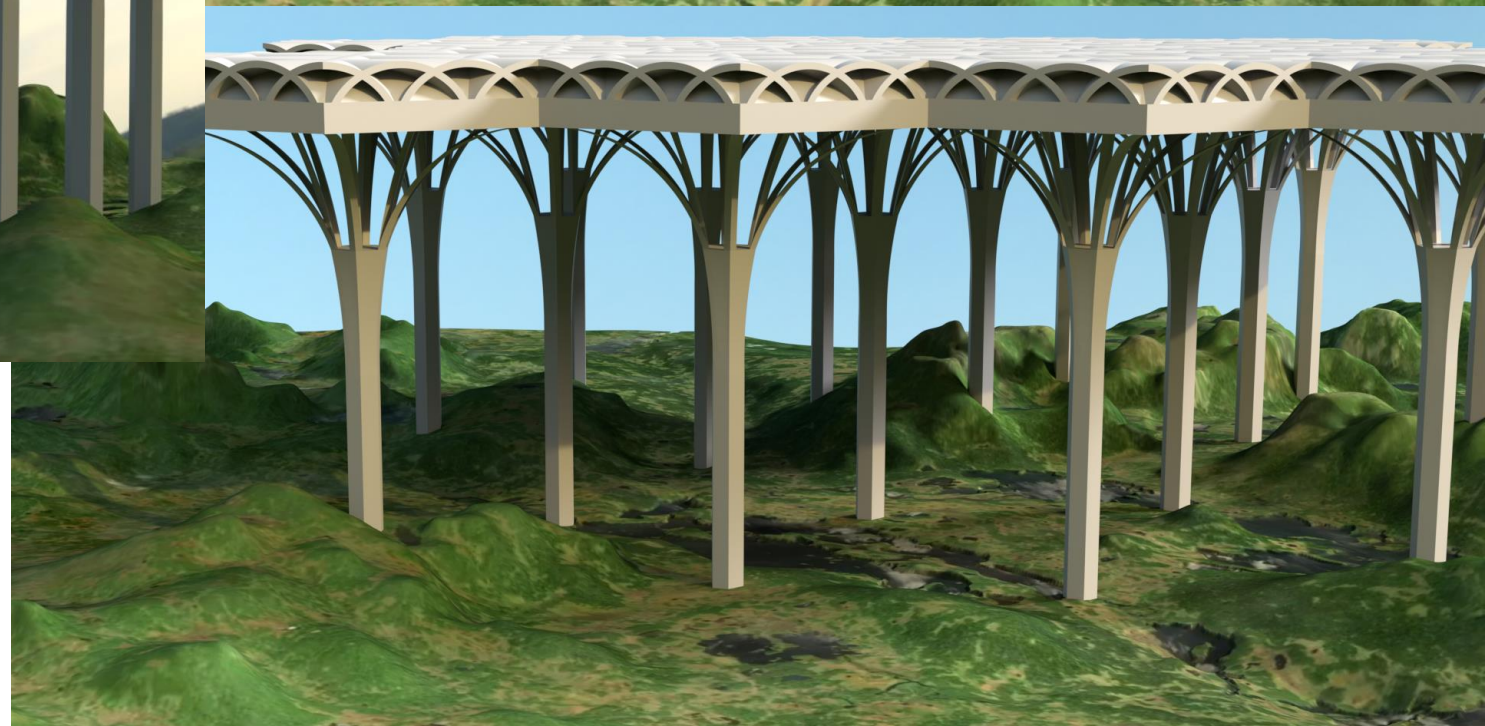
Enclosures



3D Illustration by Aarya Singh

Vertical Layering





3D Illustrations by Aarya Singh

Grand Challenges of Space Independence

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Space Junk	Life Support Closed Loop	Dust Issues	Food Growth	Food & Medical Autonomy
Microgravity (health issues)	Medical Entropy	Basic Power/ Propellant Production	Surface Mining and Extraction	Mining Autonomy
	Psychology	Return Flight to Earth (speed, mass, etc.)	Hybrid Manufacturing	Manufacturing Autonomy
	Mechanical Entropy	Planetary Protection	Reproduction	Genomic Sufficiency

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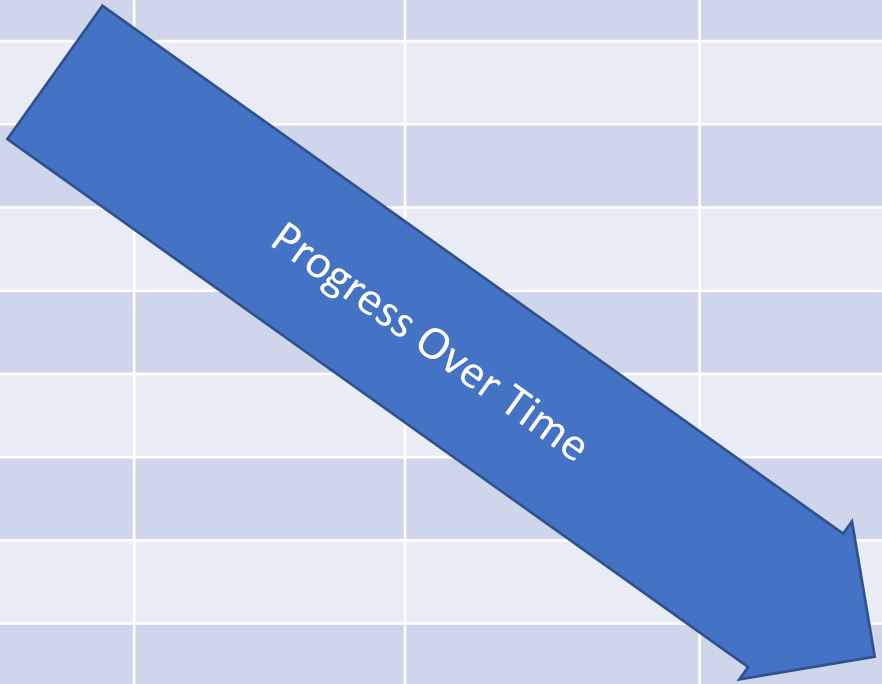
Acceleration

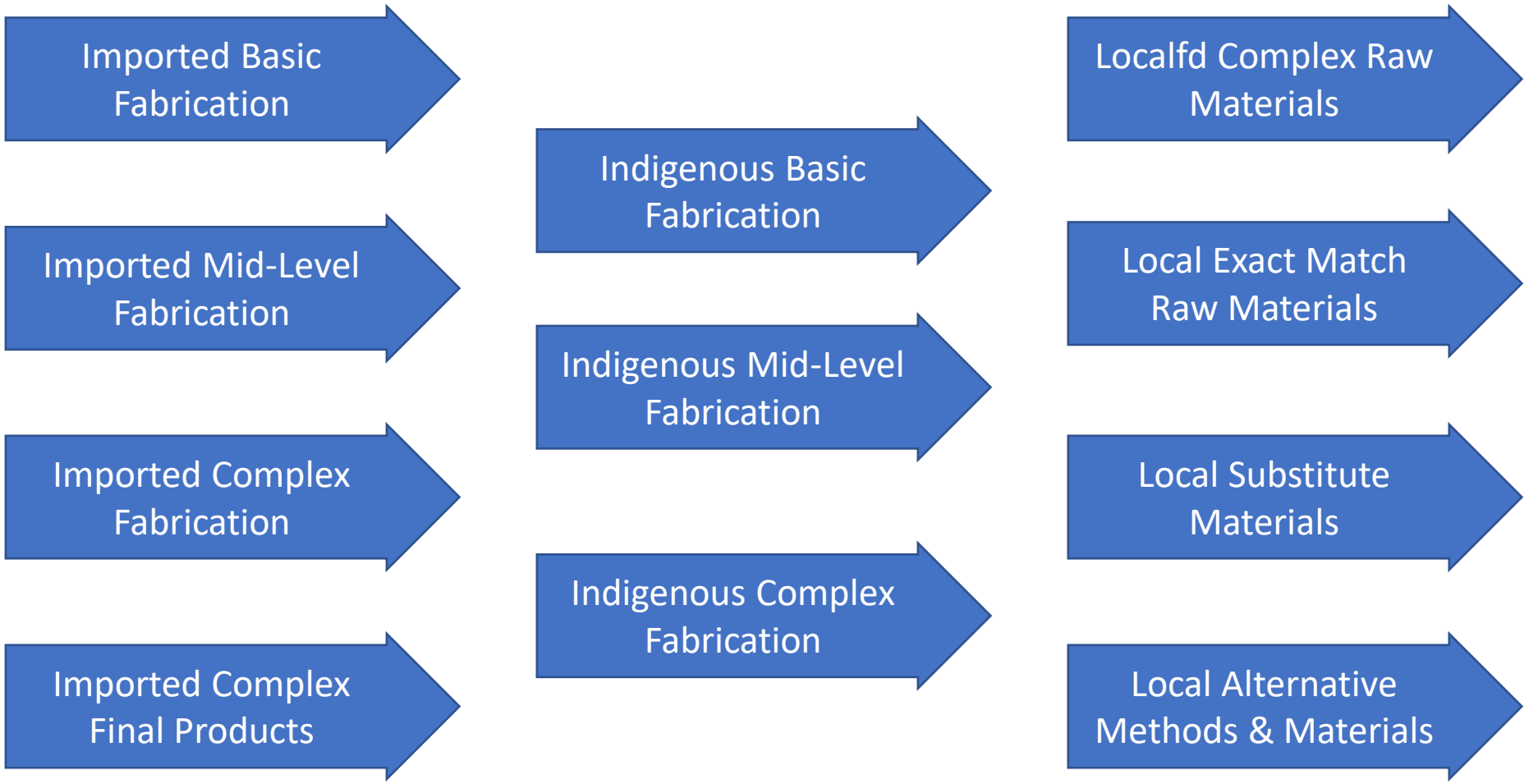
Modular Business for Technology Revolution

Technology Independence Vector Map

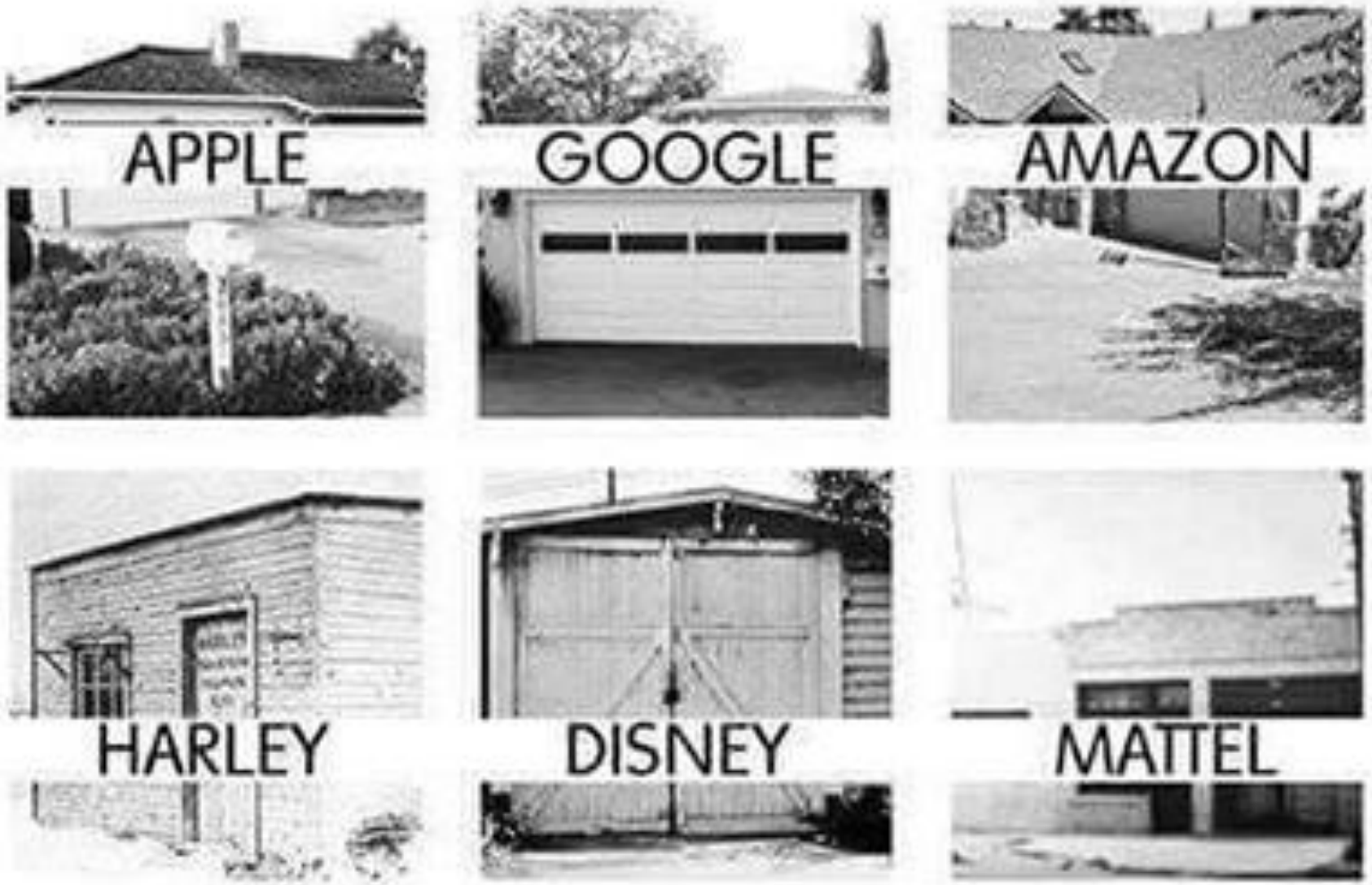
	Imported	Basic	Mid-Level	Complex	Peer Level
Raw Materials					
Refinement					
Repair					
Encasement					
Substitute Product					
Minimal Product					
Manual Process					
Computer Aided Work					
Automated Work					
AI Systems					



“Turing Complete” Technology



Minimum Viable "Garage" Startup



Minimum Industrial Modular Operation (MIMO)

- Team of 5-20 People
- All precision equipment fits in a 40-foot shipping container
- Pressurized workshop at 1000 cubic meters or less
- Able to turn electricity, data, and inputs into value-add goods and services with high efficiency
- Roadmap to replication with minimal technology input
  - Next shipping container from Earth should 3X+ the output, not double it.
- Roadmap to competitive differentiation over 5-10 years

MIMO Creation Requirements

Element	Parameters	Example
Modular Inputs and Tooling	Affordable access to modular finished goods for both tooling (instruments) and outputs (magnetic media, paper, glass, etc.)	Microchips (Apple, HP), recording tape and film, Instruments/studio equipment
Finite teams and Space	Should be workable by 2-7 people Space of a two-car garage for input to MVP	Apple I, Garage bands, HP, Scaled Composites, etc.
Ready access to skilled labor and competition	Generally a cluster of like-minded, market and tech leading, competitive operations in a narrow physical area. And a high-quality mini-team.	London rock bands, Start-ups in Silicon Valley, Venice glassworks, Milan and Dutch Masters, etc.
Ubiquitous and Affordable Utilities	Power, water, food, and so on abundant commodities. Not a lot of money devoted to basic survival or scarcity.	First world, urban concentrations with strong economies, third world labor pools.

MIMO Operational Requirements

Element	Parameters	Example
"Turing Complete" Workbench	Any input and output set is a fully adaptable work product to the task at hand. Start to finish prototypes.	Radios, computers, full range music (instruments and recording)
Adaptation	Right to repair/modify/customize and re-market that equipment.	Apple I, Classic rock music, glass works in Medieval Venice
Fully Knowable Toolbox	Full understanding ("Mozart Complete") of the manual to give creativity somewhere to grow with 100 percent understanding of building blocks.	Short manuals with early PCs Finite rules of music (3 chords to Mozart but all productive) Finite chemistry/metallurgy
Limitless Informational Output	Able to create art and science on the tools and share both the art and the tools with the markets. Give basis for tech and science revolutions	Software, Music, Art, etc. Progressive rock and art deco accompanied tech revolutions

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Garage-Scale Operations

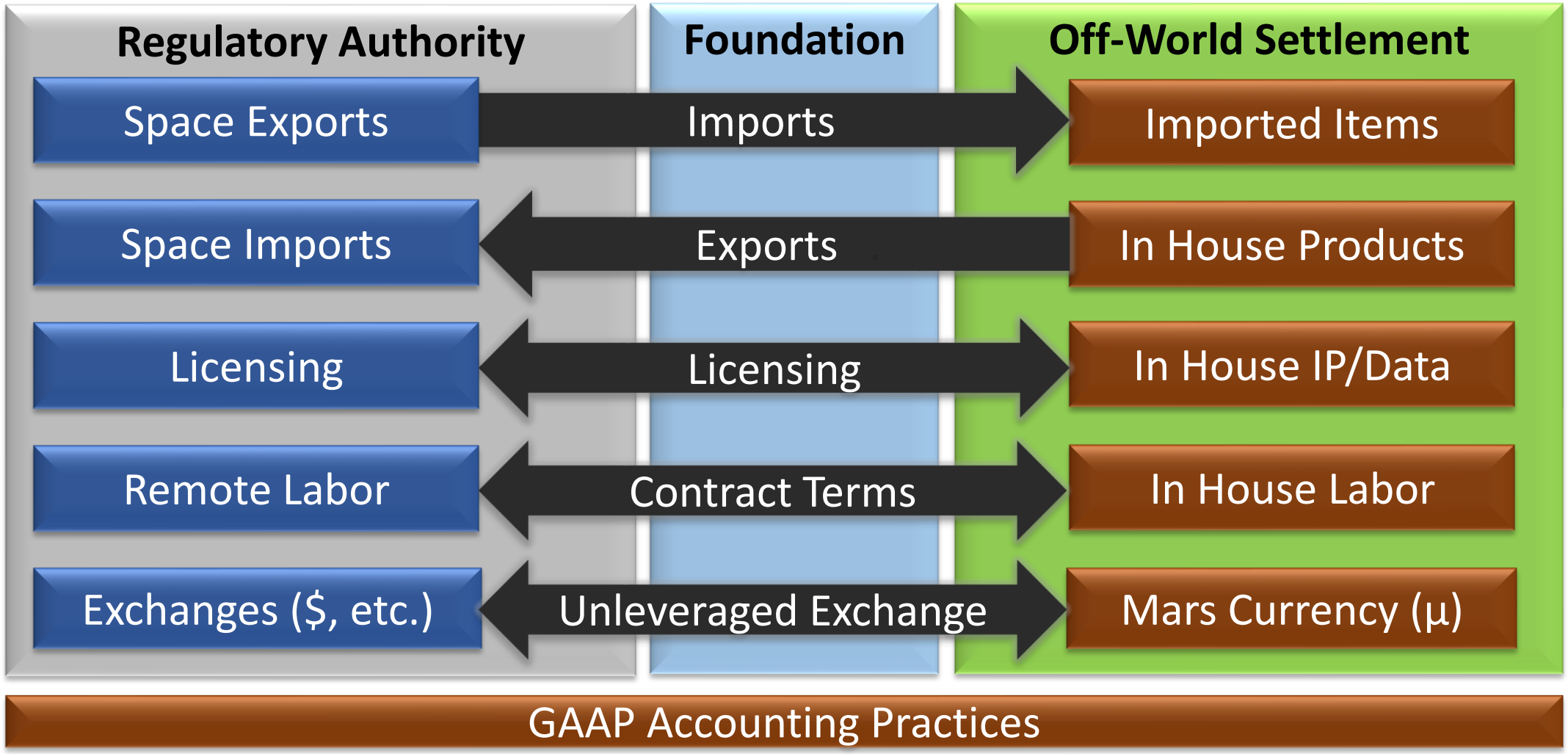
Incorporate several small-scale operations that focus on one area of input and output. Basically, an organ or tissue type in the body of the settlement.

Modular operations can scale up if they work well, or be replaced with one who can without putting the civilization at risk.

Keep things small and modular until at least self-sufficient to avoid risks from overdependence on poor performing operations.

- Atmosphere Processing
- Surface Preparation (Earthmoving)
- Basic Drilling for Volatiles
- Basic Mining
- Separation, Storage, Distribution
- Basic Mineral/Metal Extraction
- Organic Chemistry work (Plastics, etc.)
- Simple Foundry of Raw Ingots, Wire…

Economic Independence



Questions?

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