



Agile Space Analogs as Progress Accelerators

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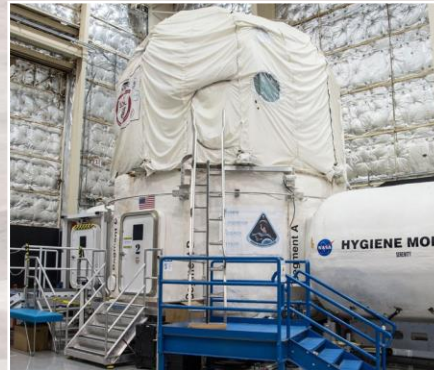
What is a Mars Science Analog?

Geology Only



Rover/Suit
Testing in
Geology

Hab Only



Isolation
simulator
Closed loop
life support

Hab in Geology



End to end
Immersion
simulation

Digital Twin Analog



Training with
possible BIM
simulation

Simulation Timeline

Accelerating, but Not Fast Enough

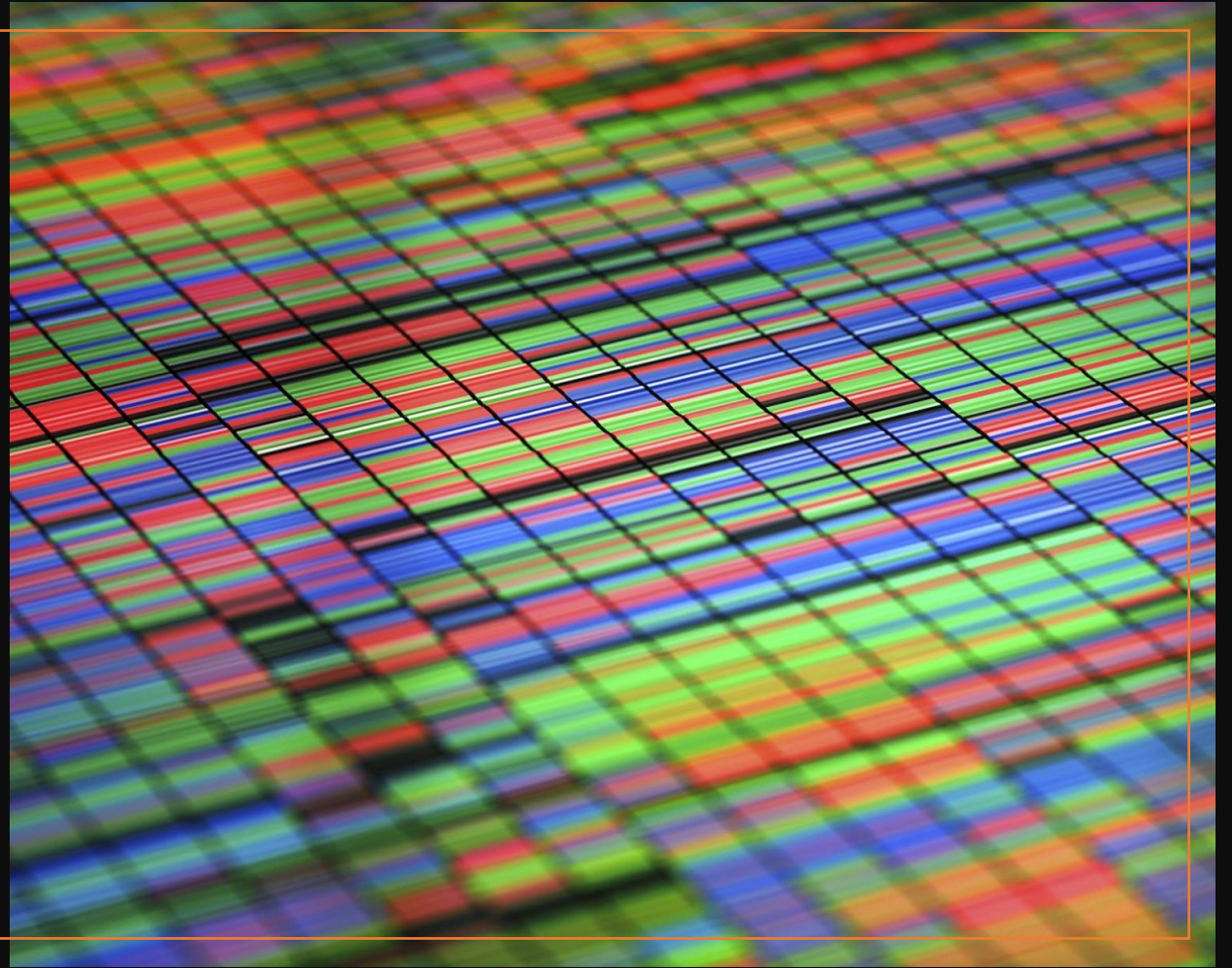
Discontinued

Active

Year	Facility/Project	Habitat Design	EVA Facility
1990	Lunar-Mars Life Support Test (NASA)	Indoor closed loop life support	None
1991-1994	Biosphere 2 (original)	Closed loop massive habitat	Internal EVA
1997-2010	Desert RATS (NASA)	Complex camper/rovers and habs	EVA suits, vehicles, habs, robots.
1997	Haughton-Mars Project (NASA)	Basic large tent-style hab	EVA, Field Geology
2001	NEEMO – NASA	Underwater hab	Diving work
2001	MDRS and Flashline MARS – Mars Society	Hab simulation/ workflows	EVA suits, vehicles, habs, robots, VR
2007	Pavilion Lake Research Project (Canada)	None	Astronauts run robot subs to find microbes
2009 (500 days)	Mars500 (Russia)	Large hab, closed life support loop	Tiny indoor yard
2010	HI-SEAS (Hawaii)	Large hab, dome	Open volcanic ara, EVA
2013	HERA	Large indoor hab – resources, psychology	None
2014	SIRIUS (Russia)	Large indoor hab – resources, psychology	Tiny indoor yard
2017	LunAres Poland	(not mentioned)	EVA work
2019	Analog-1 (ESA)	ISS	ESA Rover in Desert controlled from ISS
2020	NEEMO NEMO (NASA)	NASA underwater hab	Diving work.
2023	CHAPEA (NASA)	3D printed indoor habitat	Tiny indoor yard
2023	SAM – BioSphere 2 Adjunct	Closed loop life support habitat	Covered Mars yard with pressurized EVA.

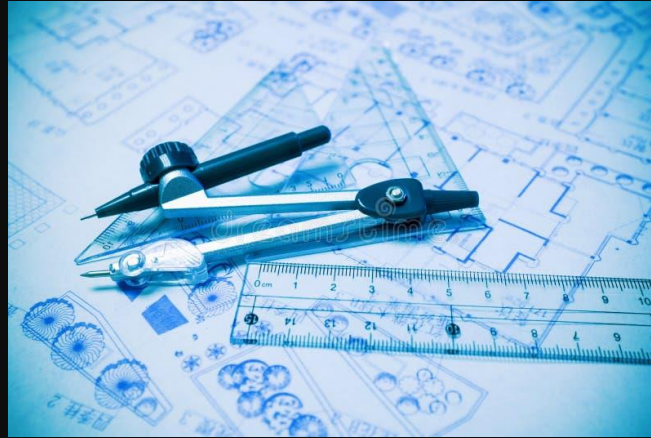
Focus and Acceleration

- Relevance Filters
- Modularization
- Commercialization



Relevance Filters

- Solving Space Settlement Challenges
- Solution Space Mapping
- Key Performance Indicators





Grand Challenges of Space Independence

Launch/LEO	Deep Space	Exploration	Settlement	Independence
Affordable Launch	Solar Flares	Moon Landing	Air/Water	Transport Autonomy
Large Vehicle Launch	GCR: Cell Damage	Mars EDL	Power and Propellant	Chem-E Autonomy
Orbital Refueling/ Mass Fraction beyond Earth Orbit	Medication/ Food Expiration	Spacesuit Lifespan	Base Construction	Construction Autonomy
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
Digital Twin Analogs	Psychology	Return Flight to Earth (speed, mass, etc.)	Hybrid Manufacturing	Manufacturing Autonomy
Field Science Analogs	Mechanical Entropy	Planetary Protection	Reproduction	Genomic Sufficiency
Lab/Workshop Analogs				



Research should answer the following...

What Space Settlement Challenges are you Addressing?

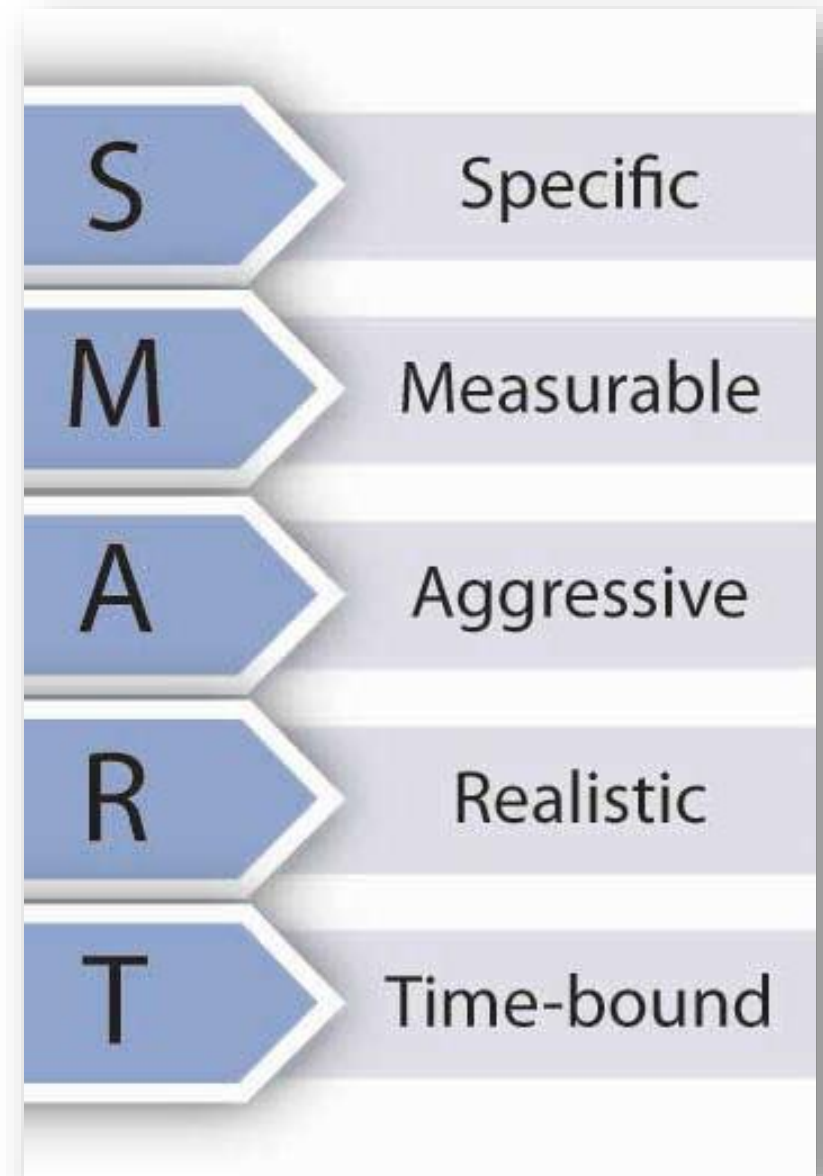
- Grand Challenge Category
- Specific Challenge

How are you Addressing Them?

- Analog Type (Hab, Geo, Digital)
- Specific Experiment Workbench

If you Succeed, What Challenge is Resolved and By How Much?

- Key Performance Indicator
- Solution Space Method, Value



A close-up photograph of several Jerusalem artichokes (Helianthus tuberosus) on a wooden surface. The tubers are light brown with some reddish-brown spots and are of various sizes and shapes.

Example: Plant growth for food

What Space Settlement Challenges are you Addressing?

- Food Growth/Expiration
- Grow Jerusalem artichoke in simulant

How are you Addressing Them?

- Analog/LED Greenhouse
- LED or filtered light, simulant

If you Succeed, What Challenge is Resolved and By How Much?

- Growth, nutrient assessment, inputs
- Nutrient Output: Resource Input ratios



Documentation

Before: Experiment Design, Proposal

- Standardized Research Submission
- Analog Workbench needs, etc.

During: Documentation

- Standard Lab Notebook, EVA Logs
- Log inputs, results, samples, findings

After: KPI and Publication

- LaTeX or Jupyter Notebooks support (if appropriate).
- KPI to a Dashboard
- Publish, Cross-reference, Peer Review

Modularization

- Modular Labs
- Containerized Experiments
- Rapid, Open Information Exchange for Design and Results





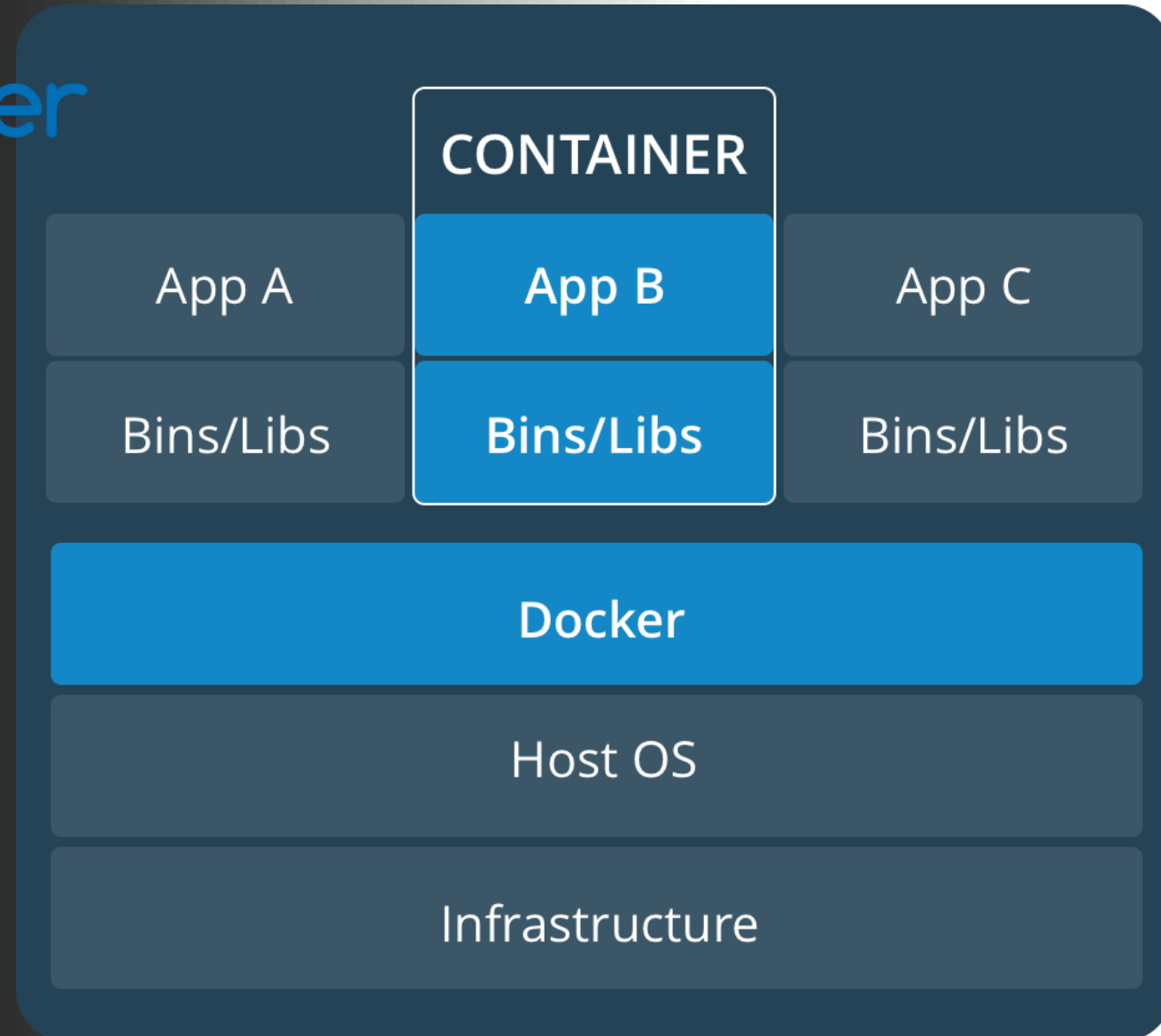
Modular Labs: McDonalds Innovation Center

- All equipment in McDonalds is modular
- The test kitchen can be configured to resemble any McDonalds, worldwide.
- They do time motion studies with crew from local stores, fake customers reading receipts from actual orders at that restaurant.
- They can A/B test different restaurant configurations for speed, accuracy, other KPI.



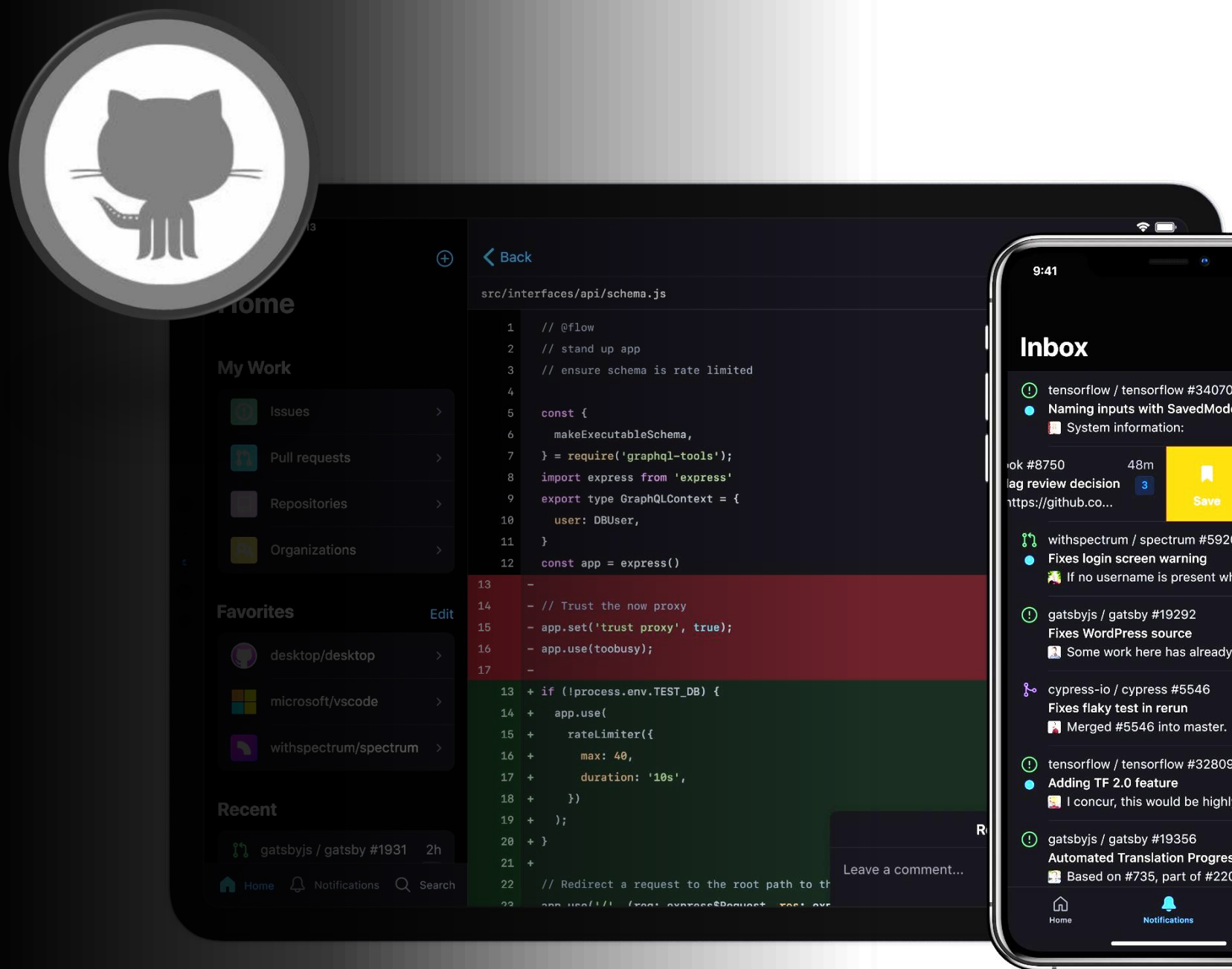
Containerized Experiments: Docker

- Common warehouse for applications where the environment itself is part of the bundle.
- The software can therefore be run on any operating system and version reliably, without conflicts.
- Can deploy thousands of times for parallel work.

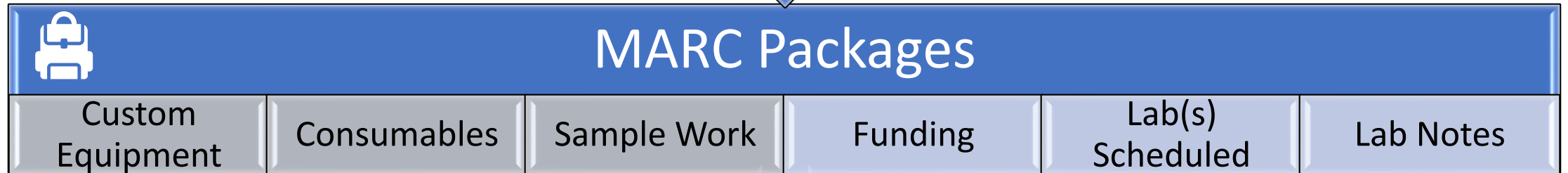


Design Information - GitHub

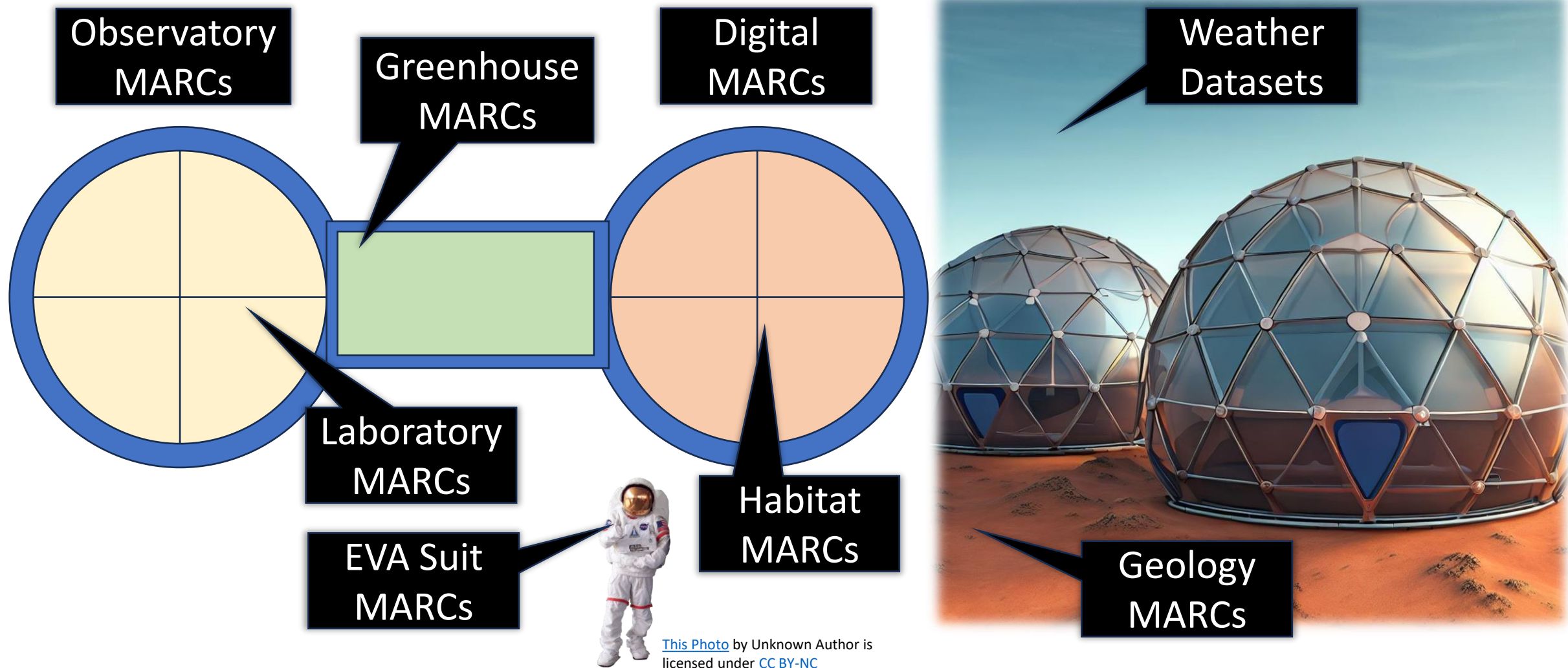
- Code can be publicly shared or in private/proprietary locations.
- Code can be downloaded, modified, repaired and then shared back in a customized form to expand the options available to others. (Forked).
- All versioning, project management, and security is built in.
- Not just for software.
- Can use AI CoPilot to help with finding, building, and testing code.



Modular Analog Research Container (MARC)

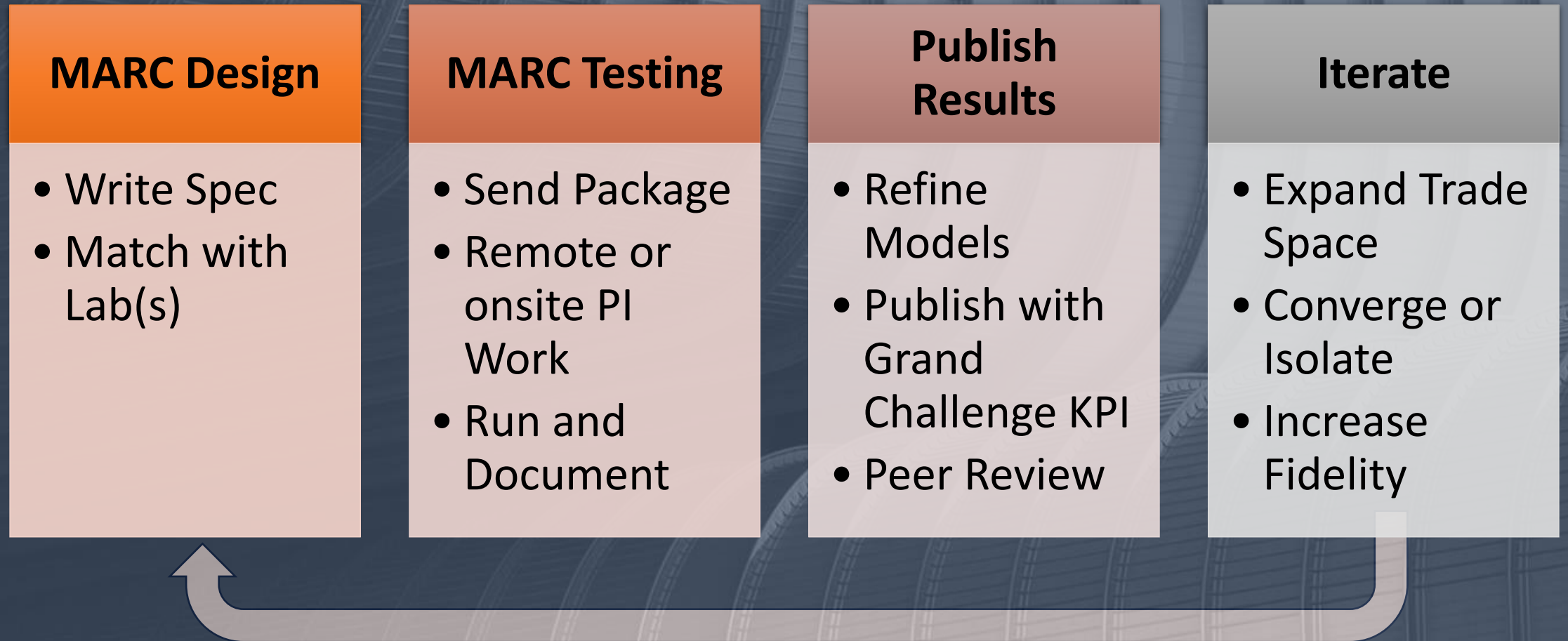


MARC-Compatible Analog Station



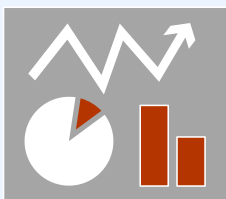
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Research Refinement Lifecycle



MARC Infrastructure

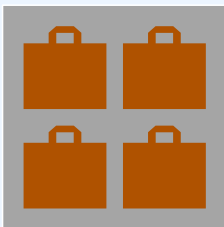
Analog Research Exchange



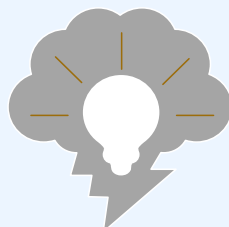
**Grand Challenge
Dashboard**



**Knowledgebase/
Publication Engine**

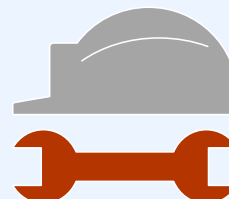


**MARC
Specifications**

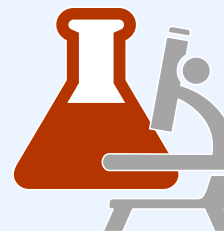


LLM AI

MARC Compatible Labs



Facilities



Lab Space



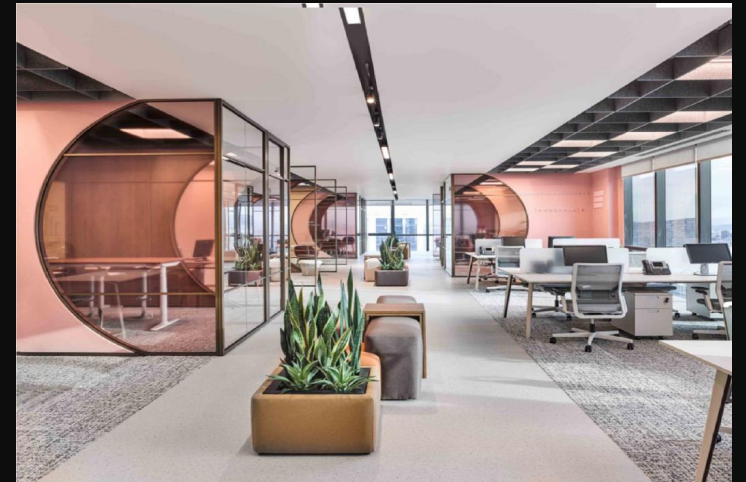
**Lab Notebook
Software**



**MARC
Packages**

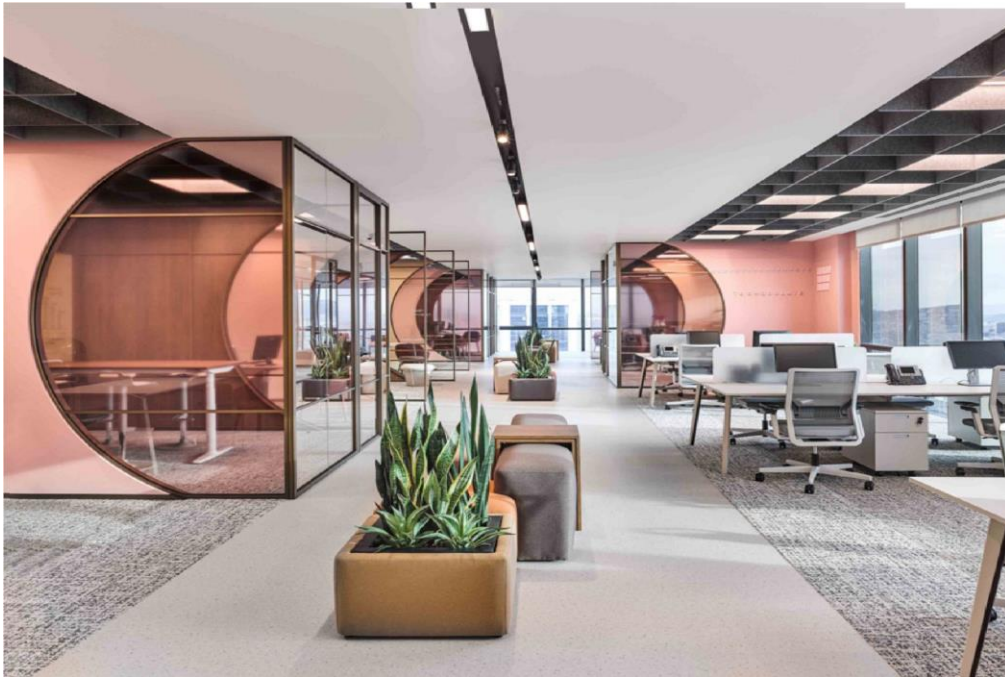
From MARC Labs to Start-Ups

The Method that makes
The (Factory) Machine that makes
The (Surface) Machine.



Modular Operations

Incubator –
MARC for Start-Up Companies (MTI?)



**Atmosphere
Processing**

**Surface Preparation
(Earthmoving)**

**Basic Drilling for
Volatiles**

Basic Mining

**Separation, Storage,
Distribution**

**Basic Mineral/
Metal Extraction**

**Organic Chemistry
work (Plastics, etc.)**

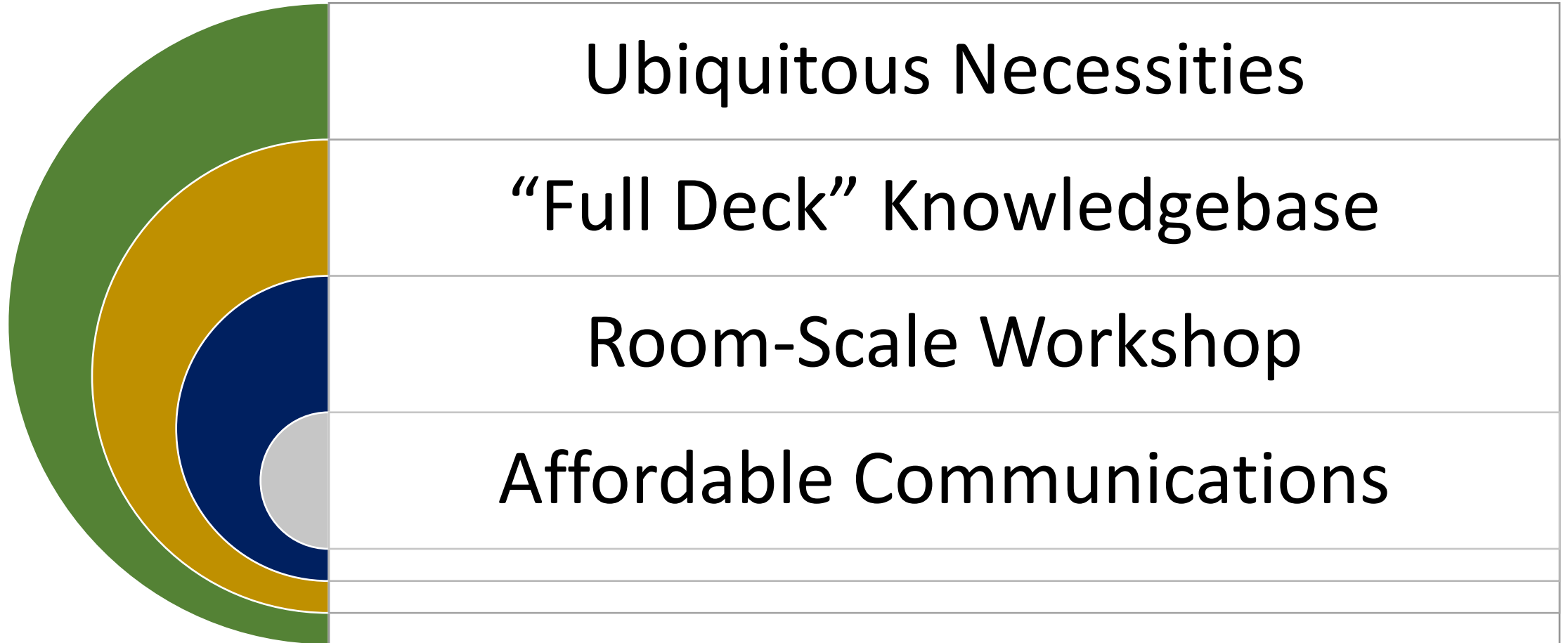
**Simple Foundry of
Raw Ingots, Wire...**

Minimum
Viable
“Garage”
Startup





Common Elements of Technology Revolution Workshops





Modular Technology Revolution Workshops



Team of 5-20 People
(plus robots)



All equipment in 1
shipping container



Pressurized Workshop
of 1000 Cubic Meters



Ready access to power,
data, and value-add
commodities



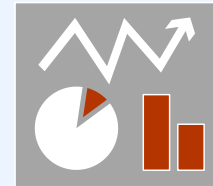
Full Deck Technology
(Versatile/Simple)



Now What?

- Publish a Common MARC Lab Template
 - Adopt the MARC Lab Spec for all present and future analog programs
 - Design the MARC Experiment Template
 - Create a submission site for MARC Projects
 - Match Experiments to Labs, track results
 - May be a GitHub project, or self-hosted item
 - Host the Analog Research Exchange
 - May itself be something that can be localized for data protection.
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Analog Research Exchange



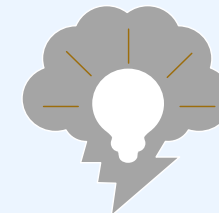
**Grand Challenge
Dashboard**



**Knowledgebase/
Publication Engine**



**MARC
Specifications**



LLM AI

Thank you!

Questions?

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