AXIOM SPACE

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The Pharmaceutical Drug Discovery Process

Discovery Research → Lead Discovery → Pre-Clinical → Clinical → FDA Review → Post-Market

Long
Complex
Expensive
Uncertain

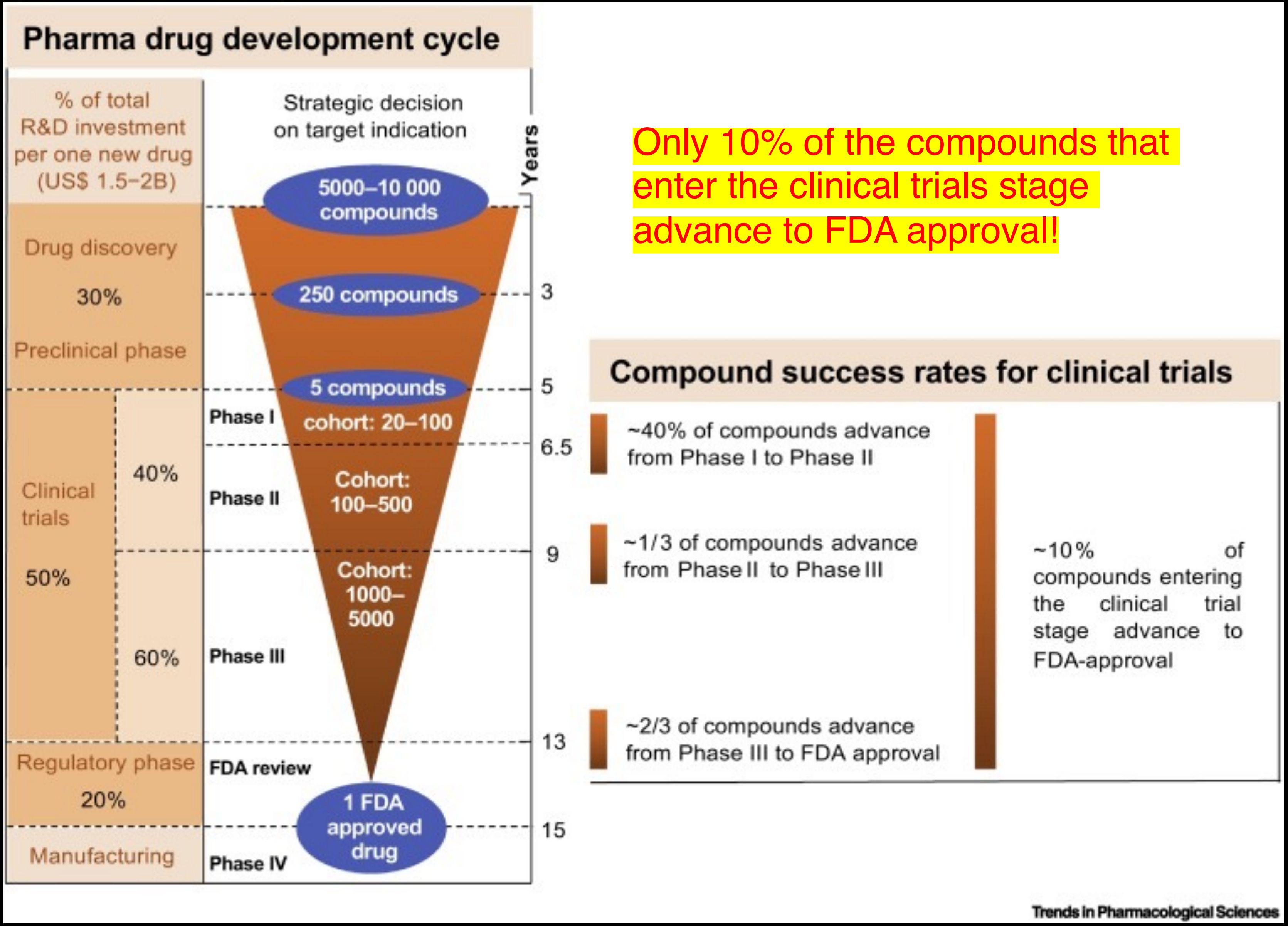
Discovery Research
- Disease
- Target ID
- Target Validation
- Target Selection

Lead Discovery
- Assay Development
- HTS
- Lead ID
- Lead Validation
- Lead Optimization

Pre-Clinical
- Safety
- ADME
- DMPK
- GLP Tox
- Formulation
- API

Clinical
- Phase 1
- Phase 2
- Phase 3

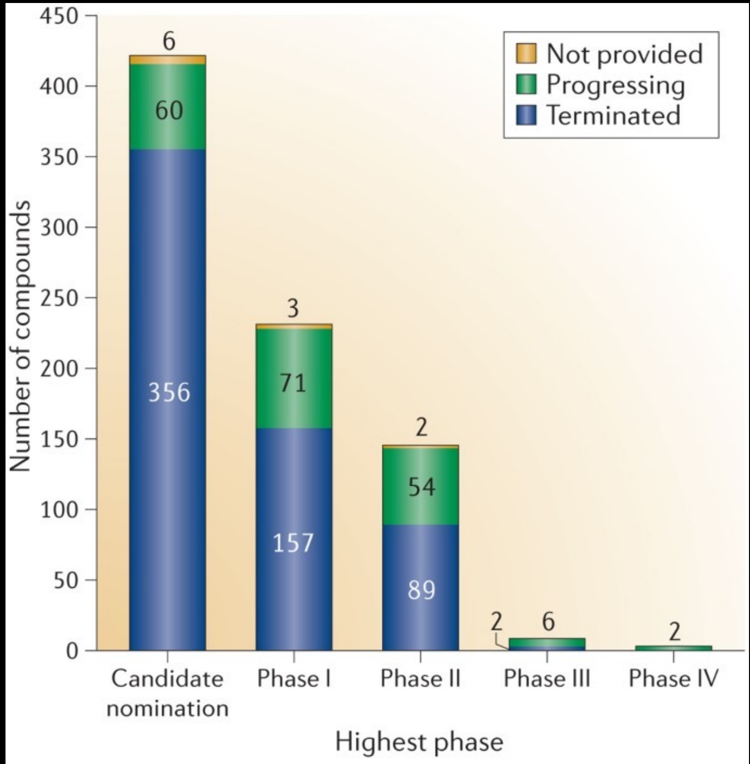
High failure rate in pharmaceutical drug discovery



Only 10% of the compounds that enter the clinical trials stage advance to FDA approval!

Image: S. Harrer et al., 2019 Trends in Pharmacological Sciences

Pharma’s key challenge: drug attrition rates



Total

422	231	145	8	2

Ratio of progressing:terminated

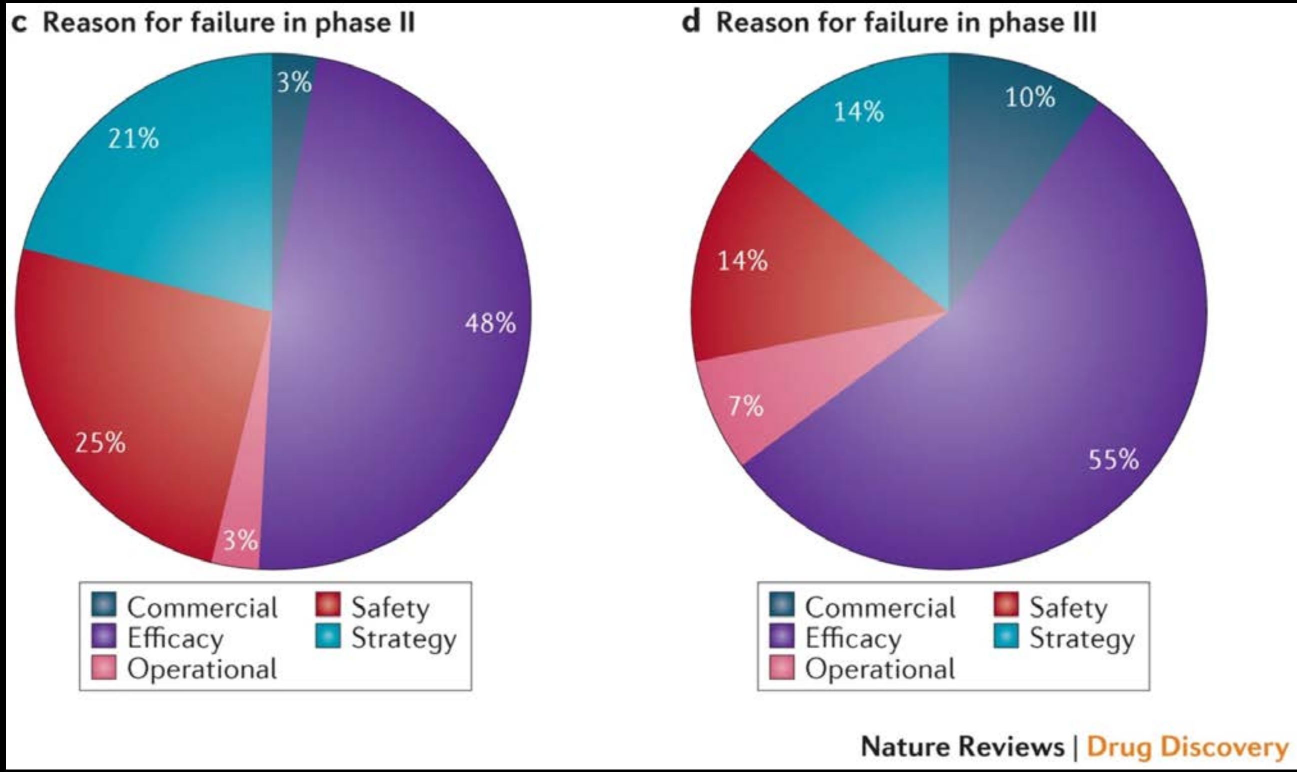
0.17	0.45	0.61	3.00	–

Nature Reviews | Drug Discovery

Images: MJ Waring et al., 2015 Nature Reviews Drug Discovery

Safety & **Toxicology** the largest sources of failure

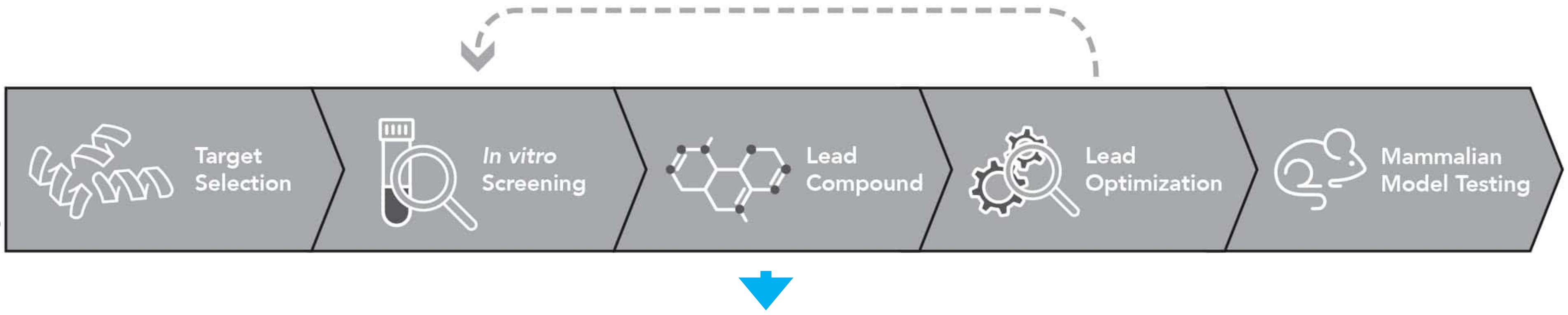
Efficacy & Safety reason for failure



Images: RK Harrison 2016 Nature Reviews Drug Discovery

Innovations in Pharmaceutical Drug Discovery

Target-based



Phenotypic drug screening (for small molecules) with better disease models

Phenotype

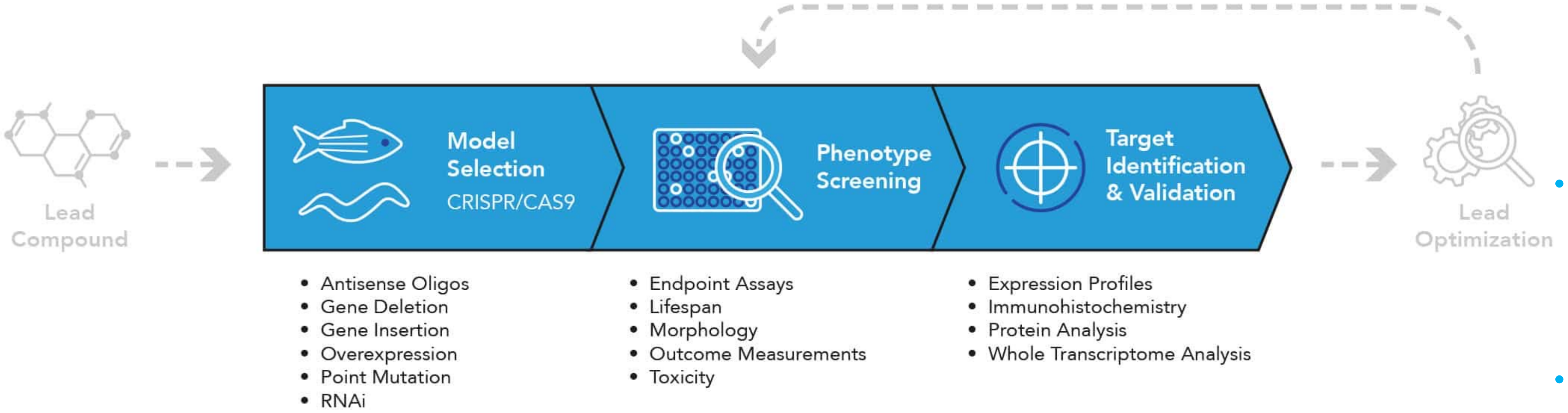
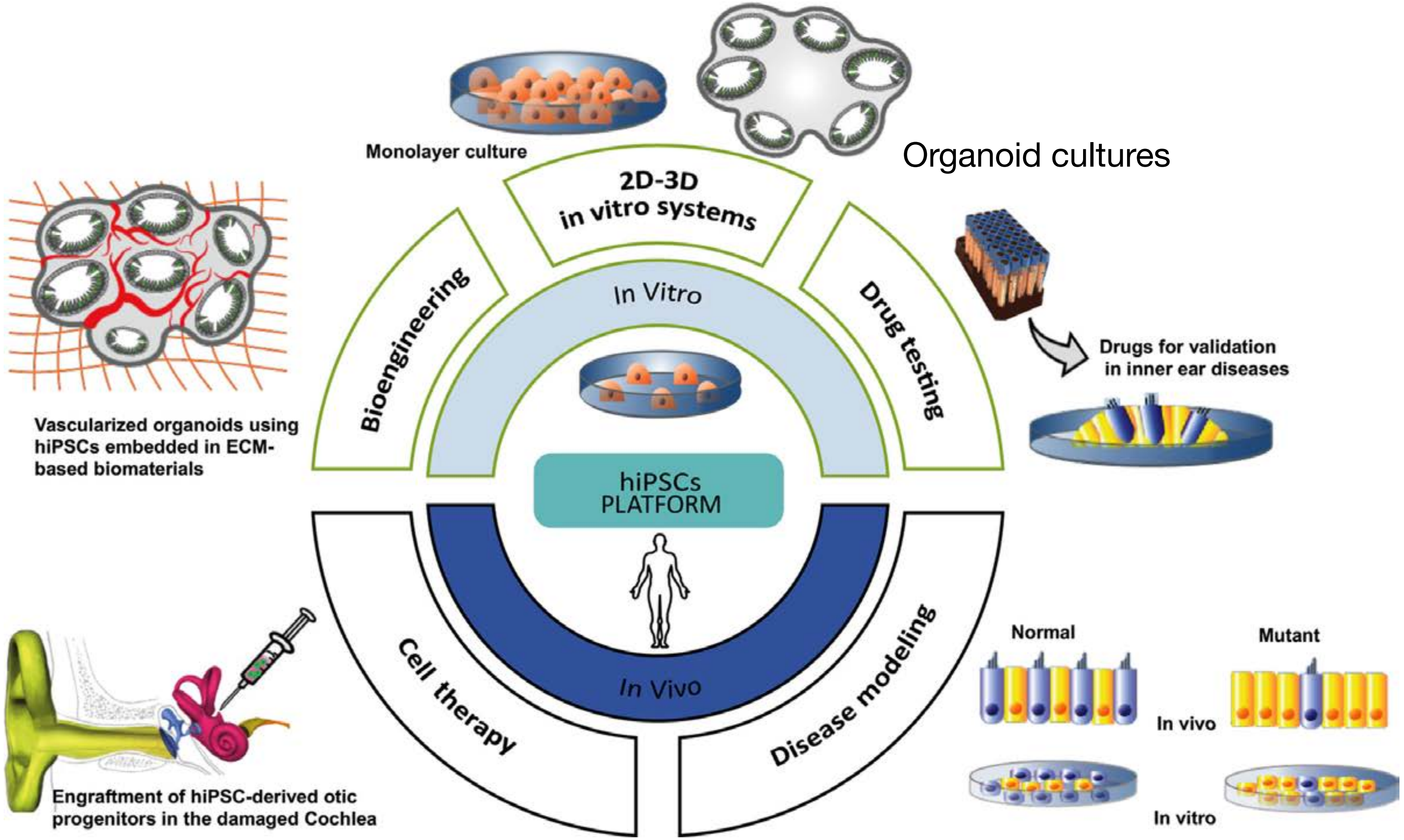


Image: K. McCormick, 2020 InVivoBiosystems.com

- The assay must be representative, thus similar in genetics or complexity.
- Genetic or biological methods for inducing disease state better than other artificial methods.
- The phenotypic readout should be representative of the disease.

Innovations in Pharmaceutical Drug Discovery

STEM CELLS AS A DRUG DISCOVERY PLATFORM



Images: A Zine et al., 2021 Stem Cells

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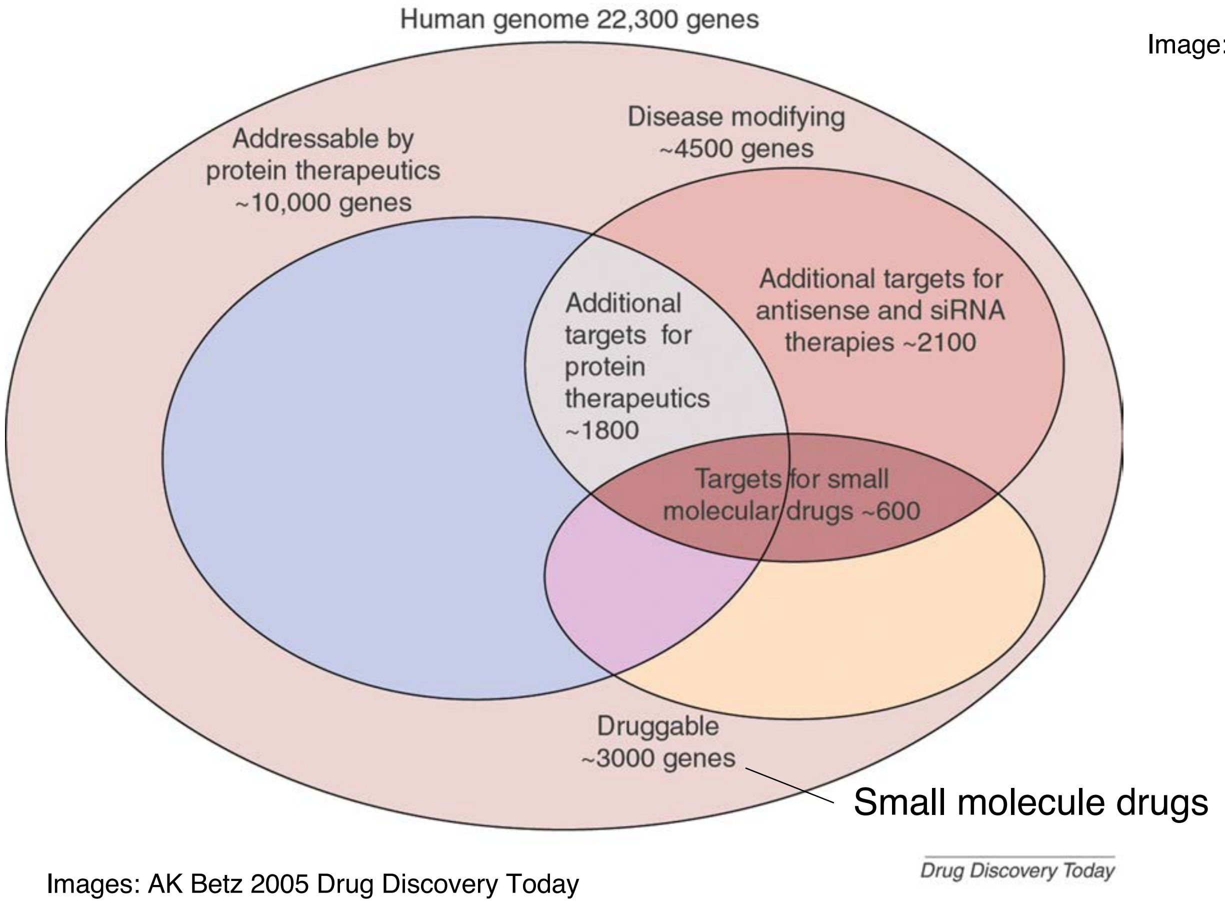
Innovations in Pharmaceutical Drug Discovery

ARTIFICIAL INTELLIGENCE & MACHINE LEARNING FOR UNDRUGGABLE TARGETS

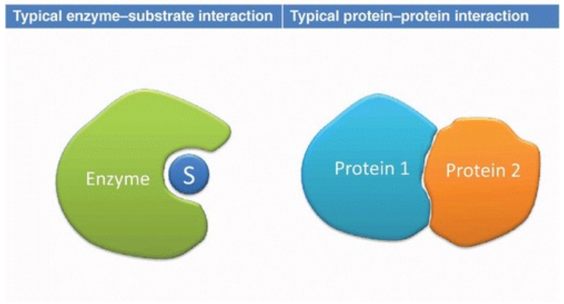
The druggable genome: ~3,000 genes!



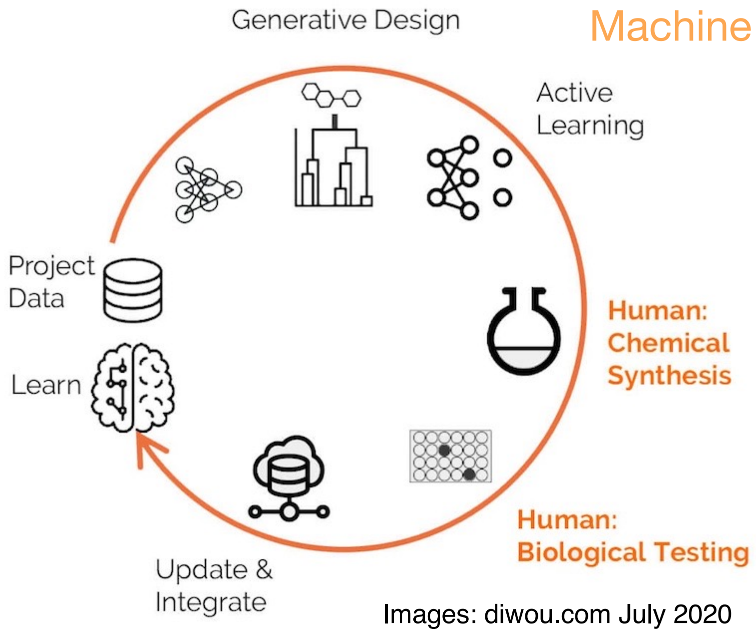
Images: AK Betz 2005 Drug Discovery Today

drugging the **undruggable**: Protein-Protein Interactions (PPI)

Image: A Sawyer 2020 BioTechniques



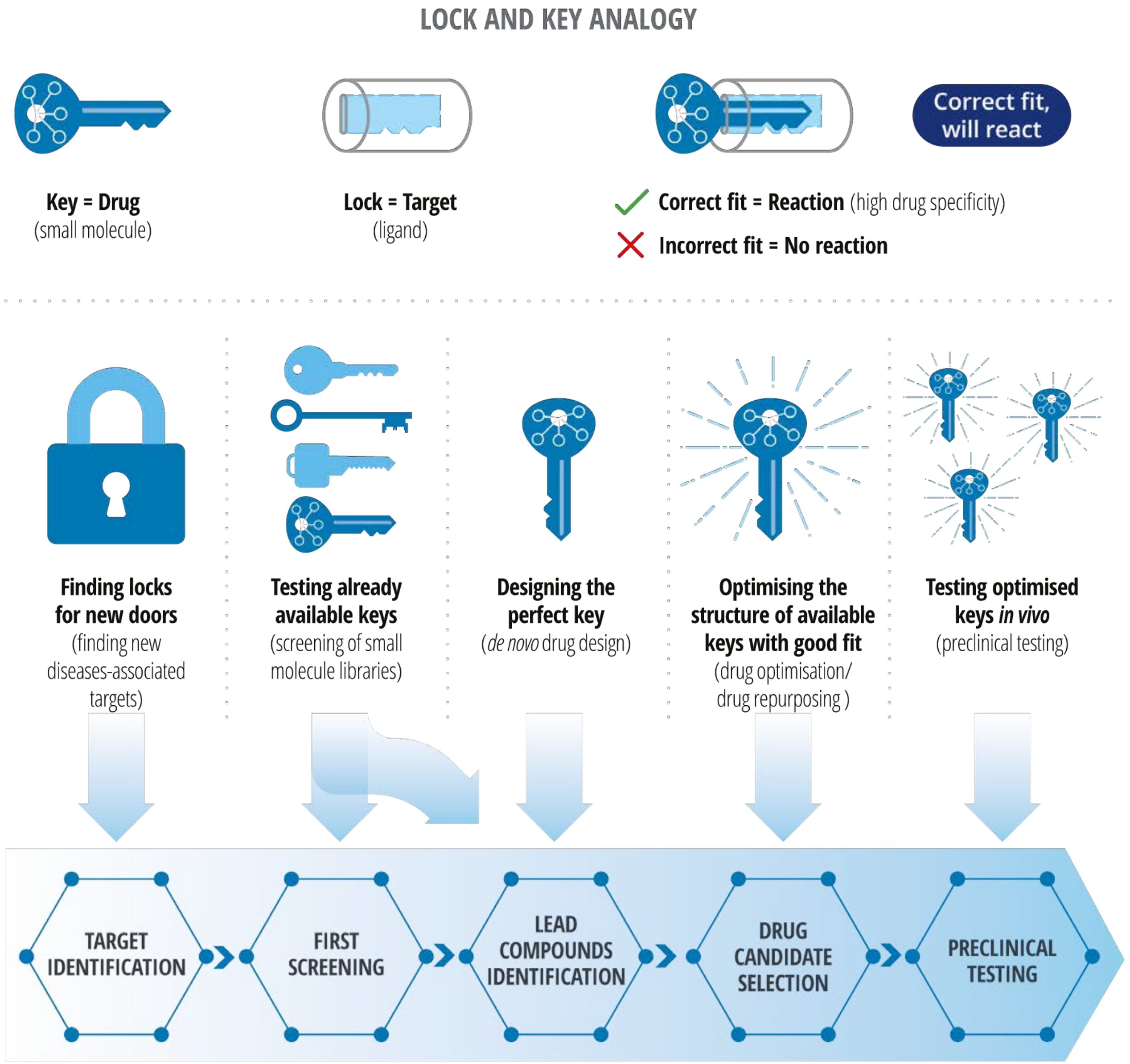
in silico drug discovery: Artificial Intelligence & Machine Learning



Images: diwou.com July 2020

Pharmaceutical drug discovery is complex.

How do space and microgravity support pharmaceutical drug discovery & development?



Source: Deloitte analysis.

Deloitte Insights | deloitte.com/insights

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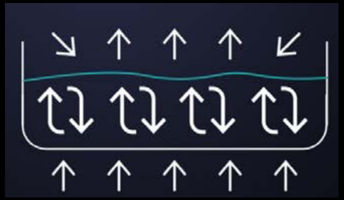
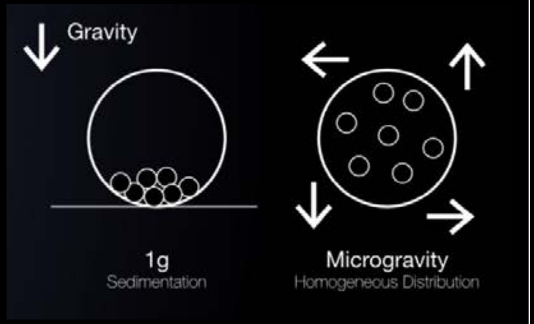
Low Earth Orbit (LEO) is unique





Space environment:

space radiation ▪ extreme temperatures ▪ near complete vacuum ▪ **microgravity "weightlessness"**

Microgravity in Low-Earth Orbit (LEO) unveils changes in fundamental physics:

no density gradients ▪ no gravity-driven convection ▪ no sedimentation ▪ reduced interfacial surface tension ▪ levitation for container-less processing

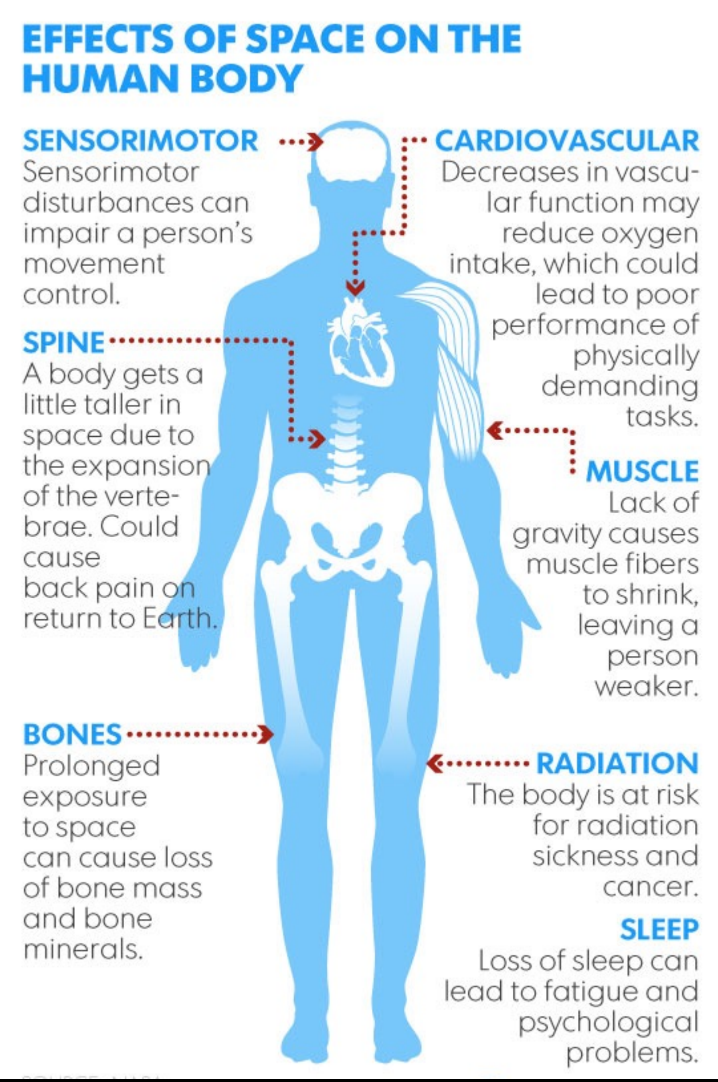
These changes facilitate:

novel insights into biological processes and materials science

These insights can be:

leveraged into new products and breakthrough innovations

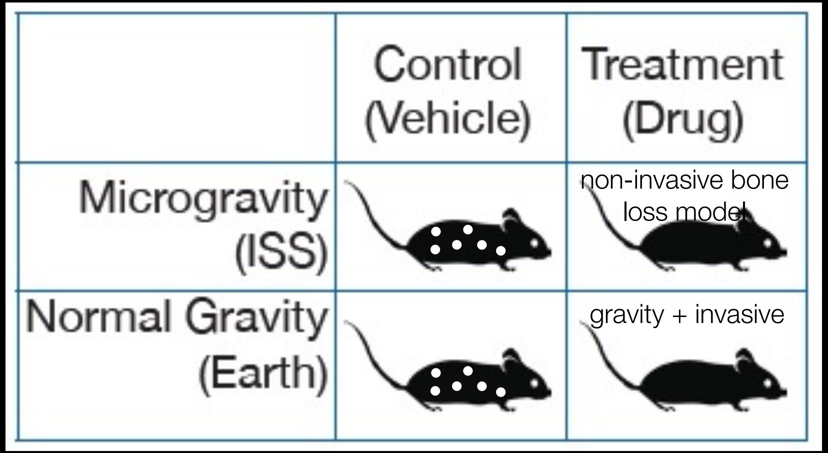
Accelerated Disease Modeling ➤ Accelerated Discovery



Despite the advantages of rodent models on Earth, diseases that affect bones and muscles, such as osteoporosis and muscle atrophy, can be difficult to model in Earth-bound rodents, because effects of gravity are ever-present.

Amgen utilized rodent model for bone loss study in microgravity to test osteoporosis drugs.

Mice with osteoporosis drug experienced reduced bone loss in microgravity.



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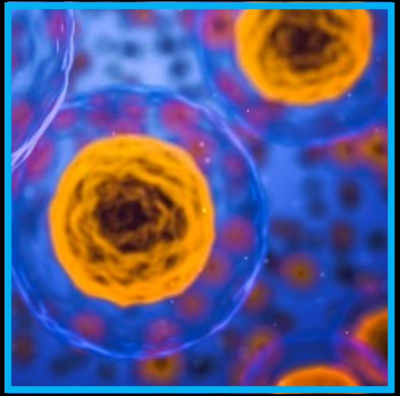
Regenerative Medicine in Space

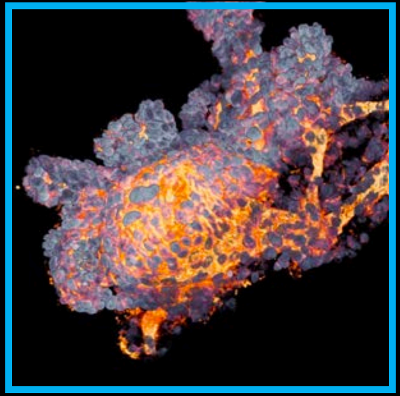
{stem cells, organoids, tissue chips, 3D bioprinting}

Stem Cell Expansion



Early research points to symmetric self-renewal of stem cells in space. Possibility of producing 2x as many stem cells in space compared to Earth is an advantage

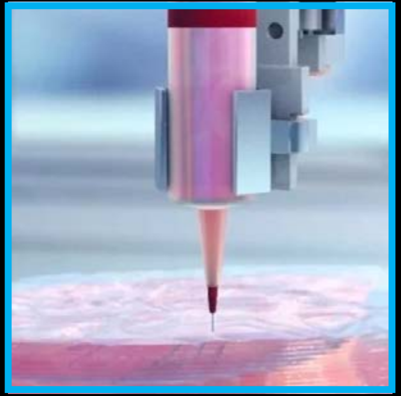
Organoids



Brain organoids as 3D models for Alzheimer's and Parkinson's Disease in microgravity where aging is accelerated.

Proof of concept studies in progress.

3D Bioprinting



3D bioprinted tissues in microgravity:

- Eliminate the risk of collapse
- Enable organ growth w/o scaffolds
- Use of lower viscosity bioinks
- Form more complex geometries

In microgravity:

- No convection
- No micro-currents
- No sedimentation
- Reduced shear stress

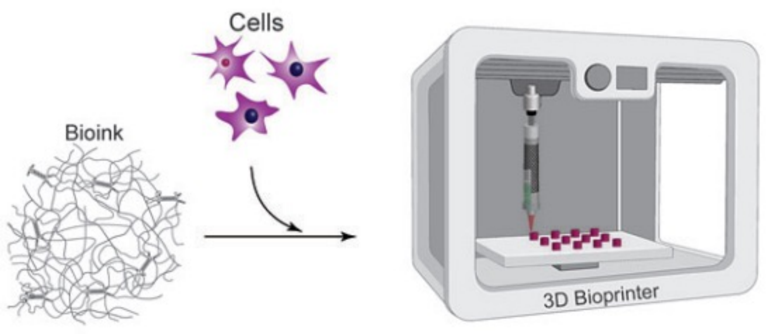
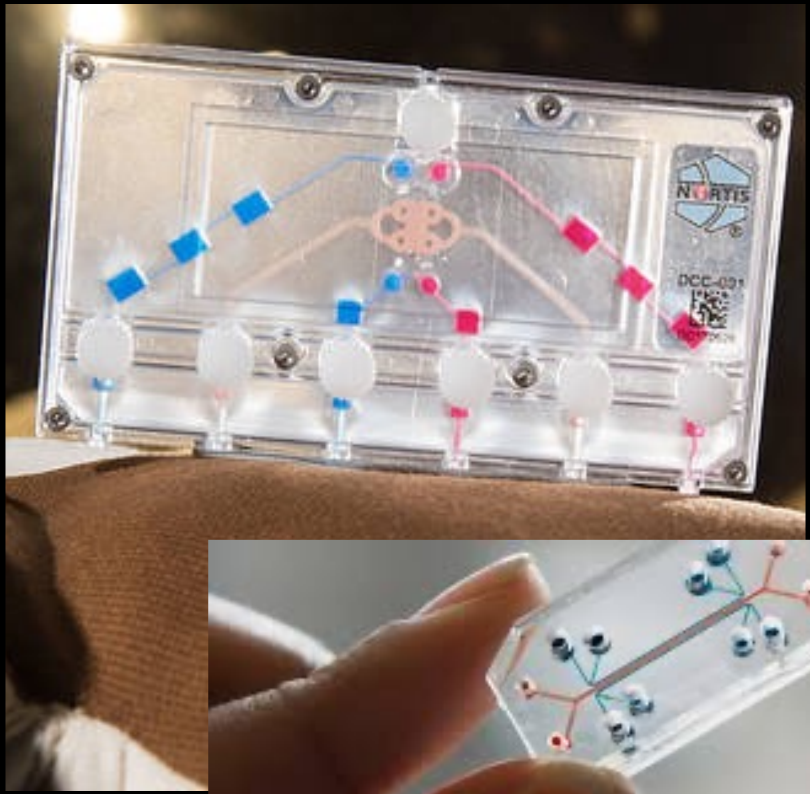
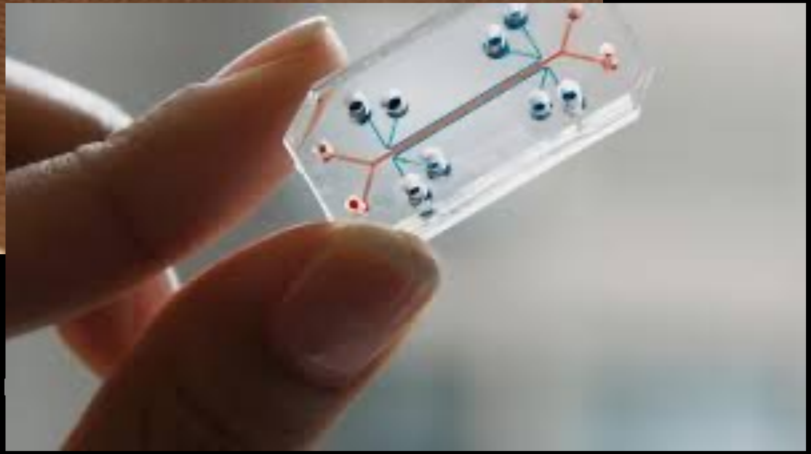


Figure: KA Deo et al., 2020 Tissue Engineering

Microphysiological "tissue chips" in Space

Microfluidic devices are lined with bioengineered human organs and tissues for drug development, disease modeling, and personalized medicine. These devices are miniaturized, automated, and personalized – lending themselves to use in orbit. Early studies with tissue chips in space have focused on cardiac dysfunction, sarcopenia, immunosenescence.





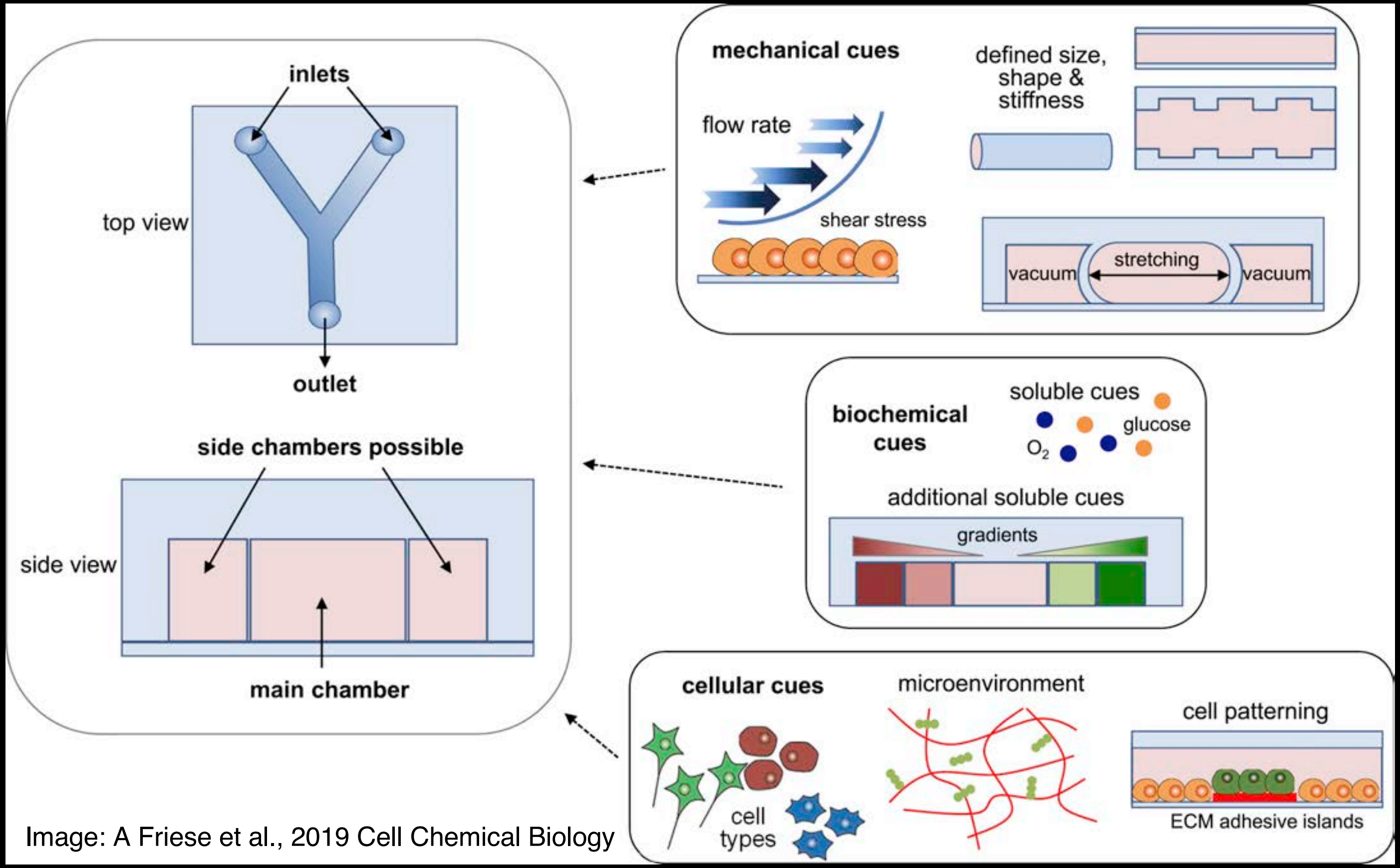


Image: A Friese et al., 2019 Cell Chemical Biology

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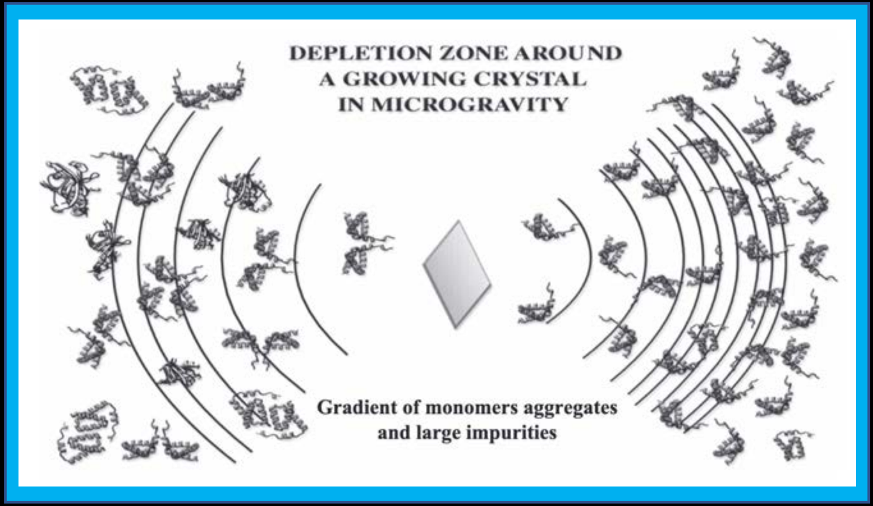
Protein Crystal Growth in Space

- Protein crystallization is an essential step to obtaining the 3D structures of a protein. However, protein crystals on Earth are often limited in size and quality
- Microgravity is an ideal environment for growing diffraction quality protein crystals – single, large, highly organized – compared to those grown in 1g. (Reicher 2019)
- Microgravity has proven to be an improved environment for "hard to crystalize/grow" proteins (e.g. membrane proteins). (Scott & Vonortas 2019)
- Lack of buoyancy-driven convection currents, lack of sedimentation, and slower, more uniform diffusion-driven movement of molecules into a crystal lattice during crystallization in a microgravity environment results in larger, more well-ordered crystals that have higher diffraction resolution and lower mosaicity.



Microgravity → Reduced convection flow
→ Protein depletion zone (PDZ) and impurity depletion zone (IDZ) formed around a growing crystal
→ These depletion zones decrease impurities on the surface of the crystal, resulting in high quality crystal growth

MICROGRAVITY PROTEIN CRYSTALLIZATION:

- Structure-based drug design
- Uniform crystalline suspensions for drug formulation & delivery, manufacturing, and storage

Flow Chemistry & API {Active Pharmaceutical Ingredient} **Manufacturing in Space**

Flow chemistry in space can enable complex chemical reactions that are difficult to achieve on Earth.

- API and High Potency API (HPAPI) manufacturing process is highly toxic and dangerous.
- API & HPAPI manufacturing also has an environmental impact.
- Off-shoring API manufacturing to space will mitigate both risks.

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Pharma in Space – notable studies

Amgen

Tested efficacy of Prolia and Evenity for **osteoporosis** in a mice aboard the ISS. Mice with drug experienced reduced bone loss in microgravity.

Eli Lilly

Studying **lyophilization** in orbit to improve issues with stratification of freeze-dried matter.

Sanofi

Studying the effects of microgravity on the **immune** response.

Novartis

Rodent research on **muscle** atrophy.

Astra Zeneca

Utilizing the ISS to study **nanoparticle** formation in orbit with goal to optimize manufacturing process for drug delivery.

Merck

Demonstrated **PCG** is enhanced in orbit. Applying insights to improve manufacturing, storage, and delivery of Keytruda, resulting in lower costs and better patient quality of life.

Bristol Myers Squibb

Studying **PCG** in orbit to enhance biologics development & manufacturing.

Data source: ISSNationalLab.org

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Studies in microgravity can accelerate pharmaceutical drug discovery & development.

Discovery Research → **Lead Discovery** → **Pre-Clinical**

Discovery Research

Accelerated disease modeling

Less invasive disease modeling:
- bone & muscle,
- age-related diseases (AD, PD, aging)

Physiological model systems to:
- interrogate mechanisms of action of potential therapeutics
- screen drug compounds
- conduct proof of concept studies

Lead Discovery

Protein crystal structure for enhanced drug design

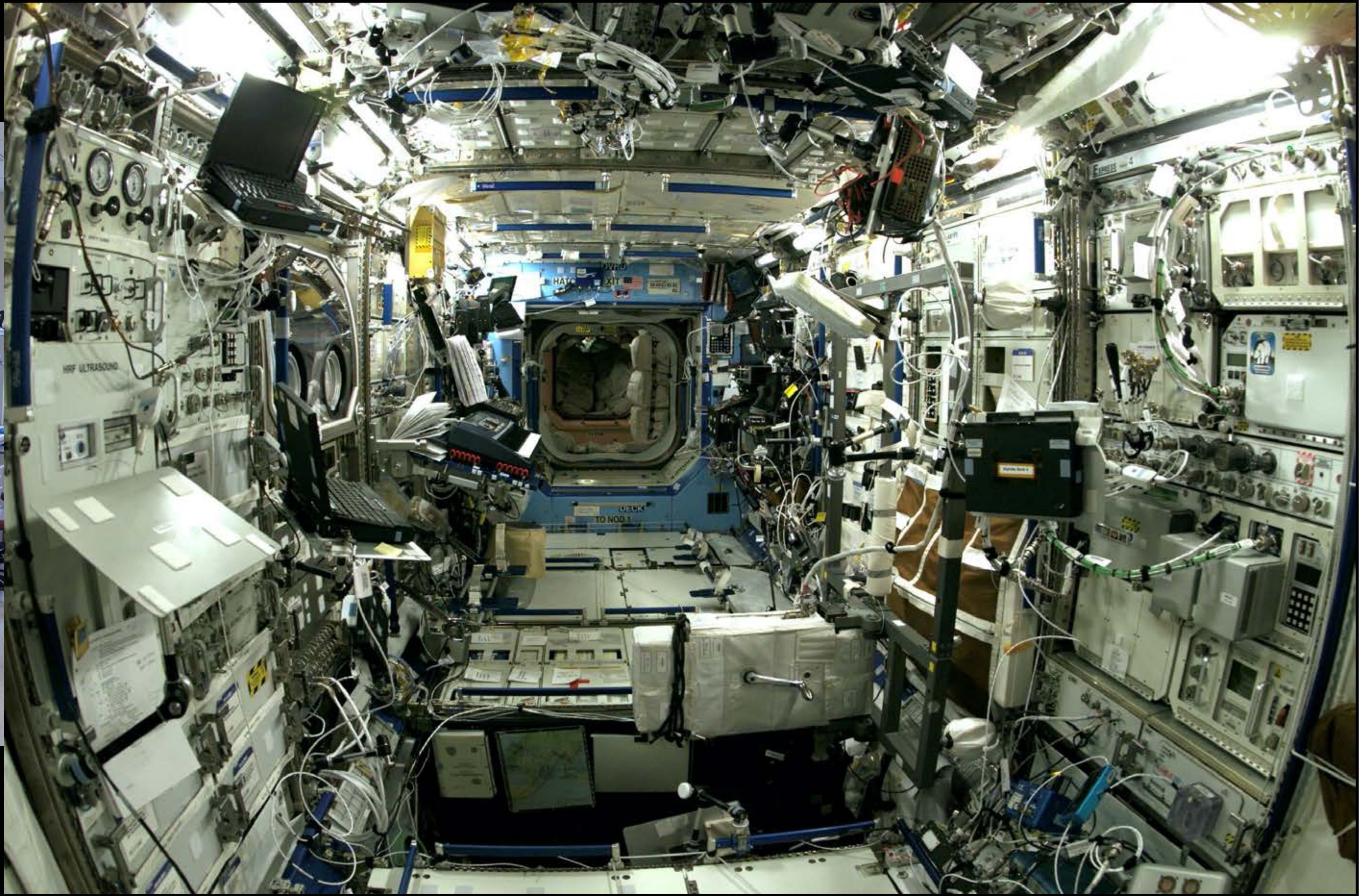
Pre-Clinical

Medicinal Chemistry

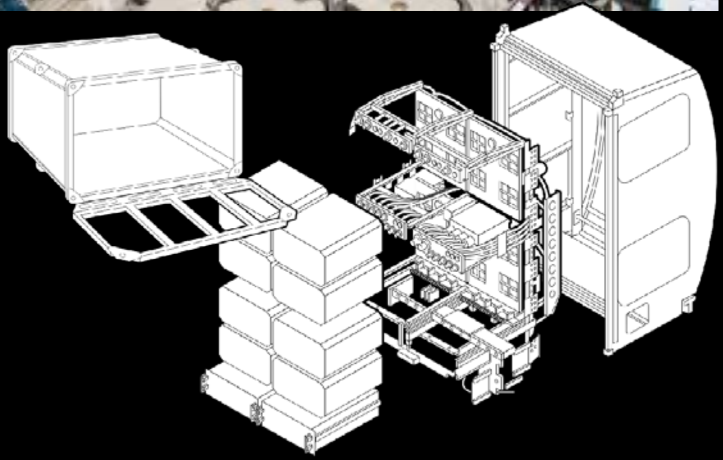
API & HPAPI manufacturing

Drug reformulation

Earth Lab vs Space Lab

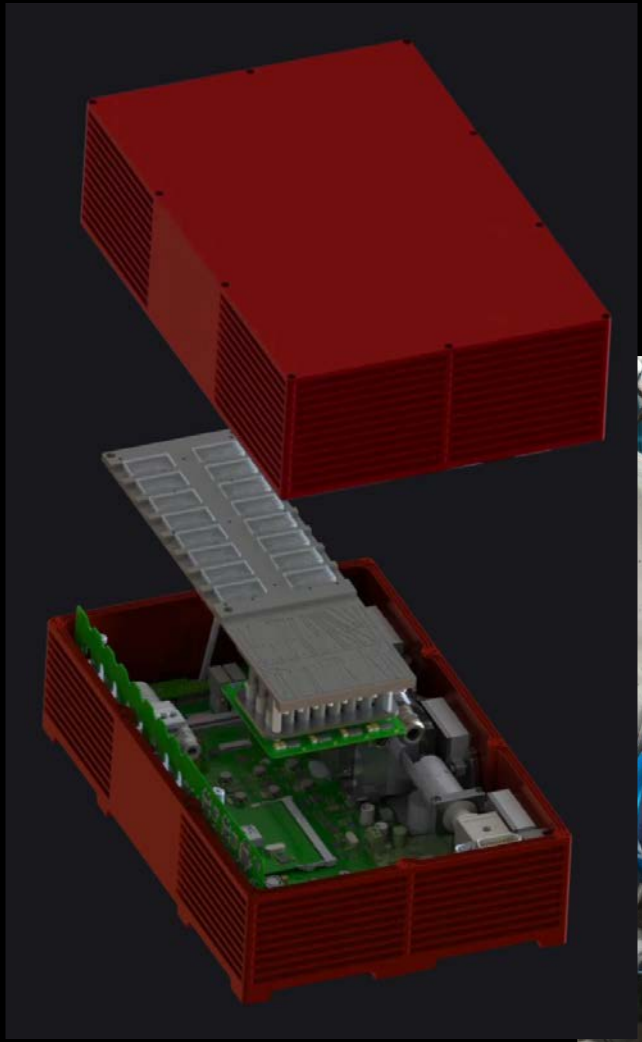


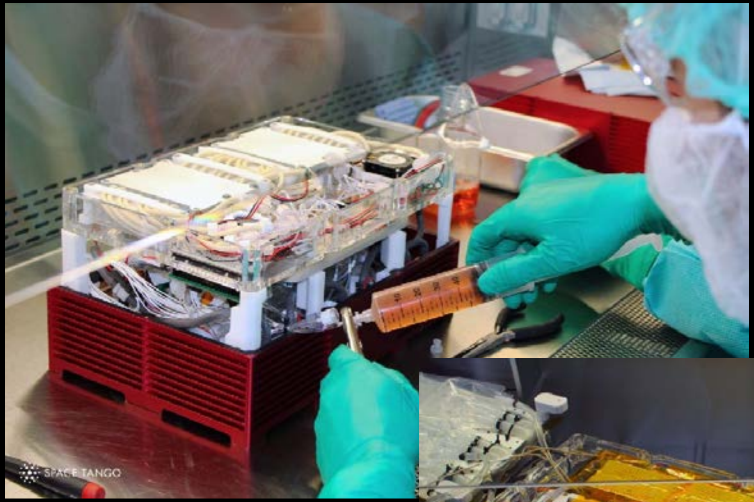
Experiments in Space



Hardware on the ISS is contained within these “Express Racks”

Cell Culture in Space (automated)





Cell Culture in Space (manual)

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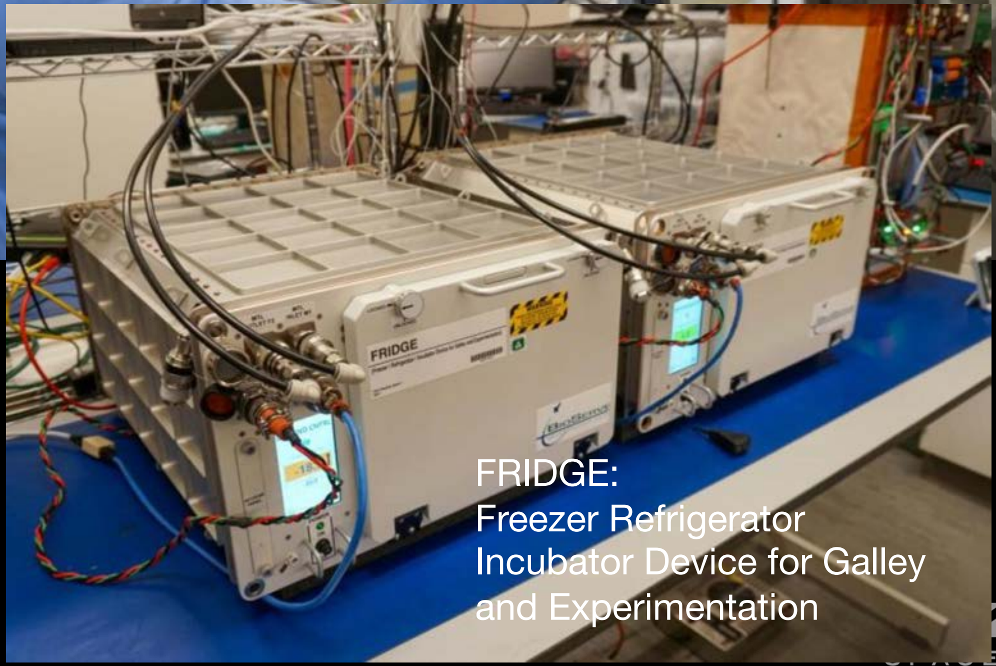
Lab Equipment in Space

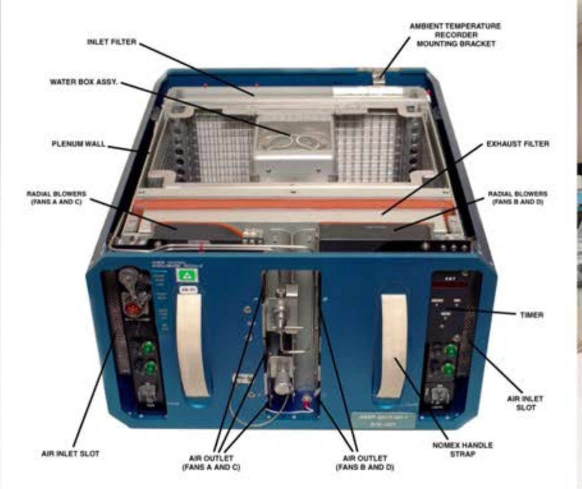


FRIDGE:
Freezer Refrigerator Incubator Device for Galley and Experimentation

Animal Experiments in Space

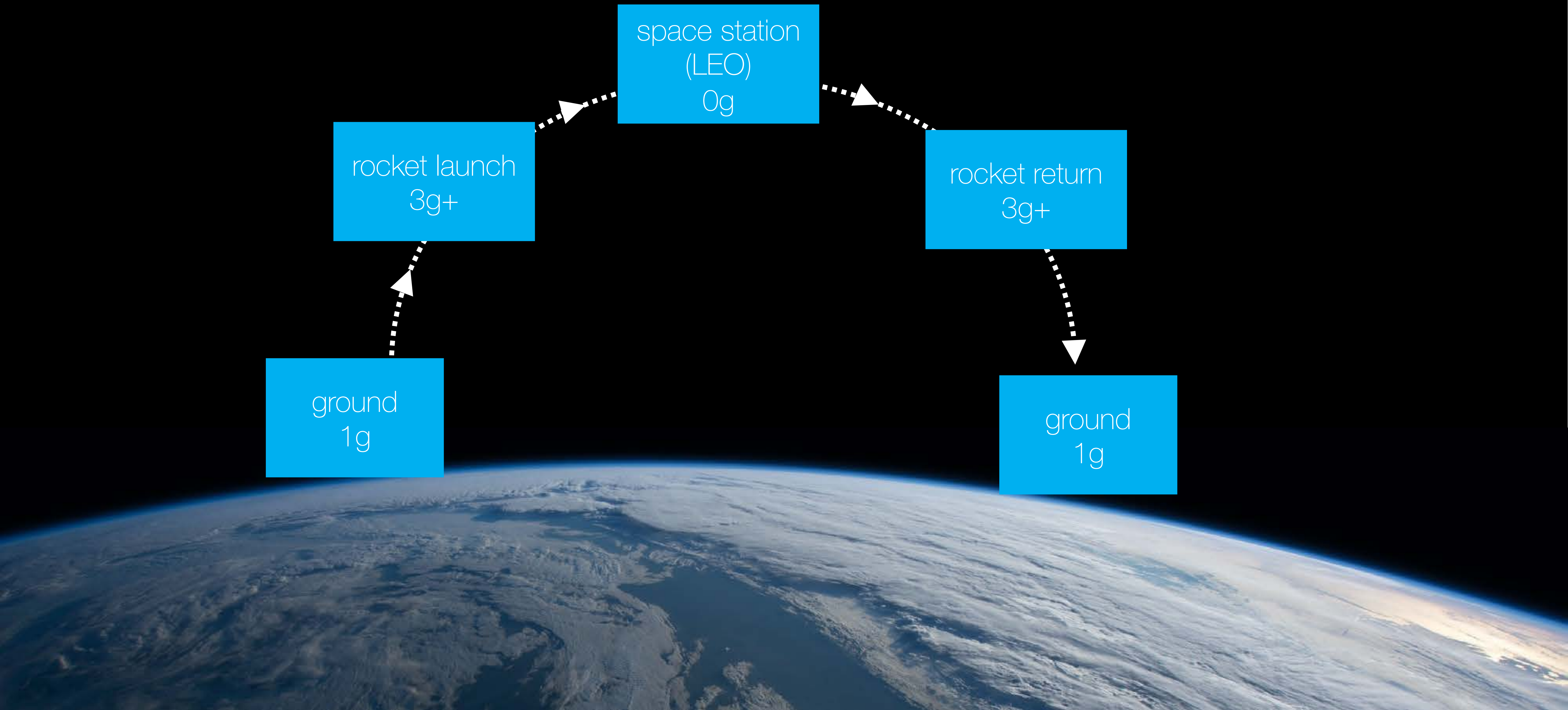
BONE
DENSITOMETER

RODENT
HABITAT



DROSOPHILA MODULE

Space Experiments: the “control” factor



BUILDING FOR SPACEFLIGHT

"The only way to discover the limits of the possible is to go beyond them, into the impossible." – Sir Arthur C. Clarke

microgravity ▪ extreme temperatures ▪ ionizing radiation ▪ atomic oxygen ▪ ultra-vacuum

how can we leverage the unique space environment for benefit to humanity?
{products, processes, services}

Lab bench on Earth → Automation on Earth → Automation for Space → Scale-up

pushes the boundaries of innovation

FEATURES	BENEFITS
miniaturization	smaller footprint
"ruggedization"	lower cost
automation	accessibility
lighter weight	ease of use
refined materials	mobility
revised microfluidics	new markets
	new uses

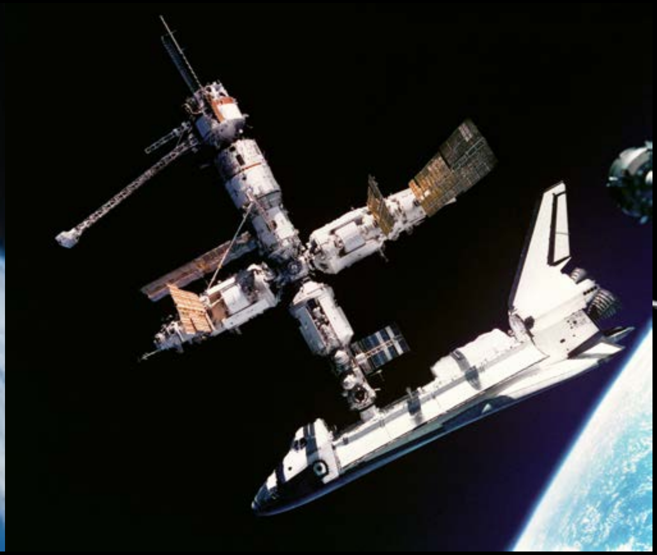
extreme environments
desert, ocean, mountain, arctic
remote areas
under-resourced, rural
STEM, DIY
other

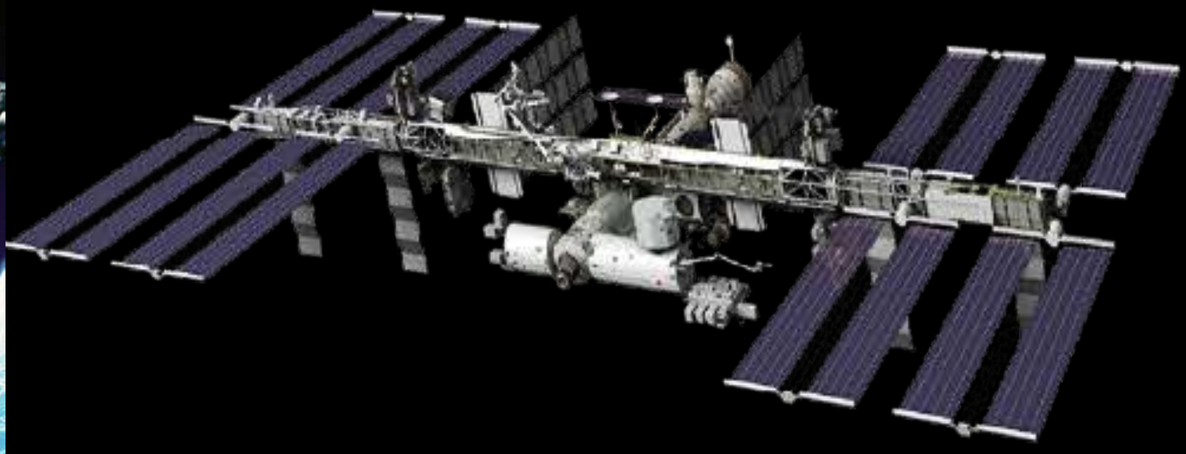
AXIOM SPACE

Humanity’s Next Chapter

Introducing Axiom Space

Space Stations





Skylab
1973

Mir
1986-2001

International Space Station
2000 ~ 2030
Retiring “soon”

Images not drawn to scale

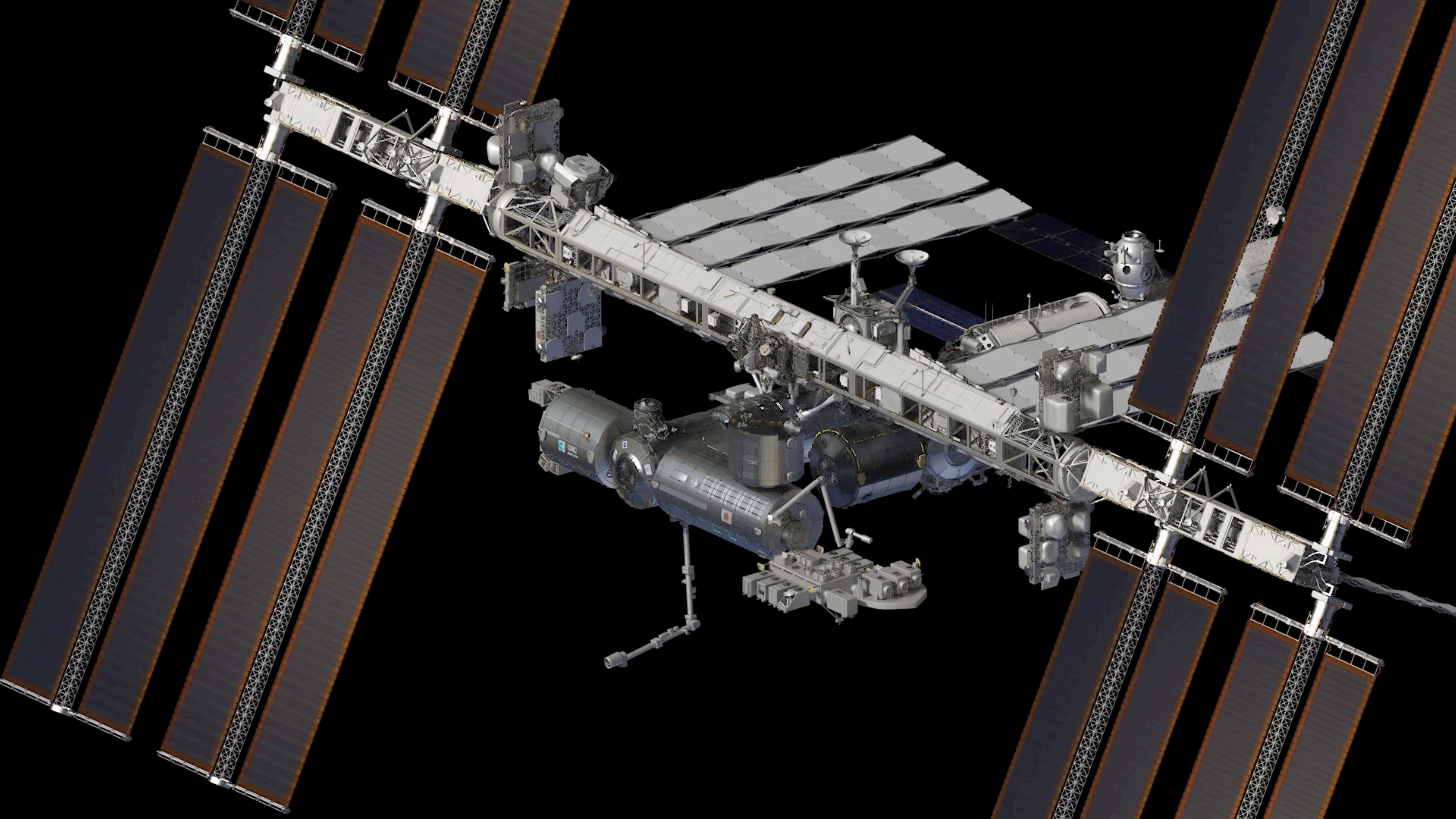
Our Vision

A thriving home in space that benefits every human, everywhere.

AXIOM SPACE

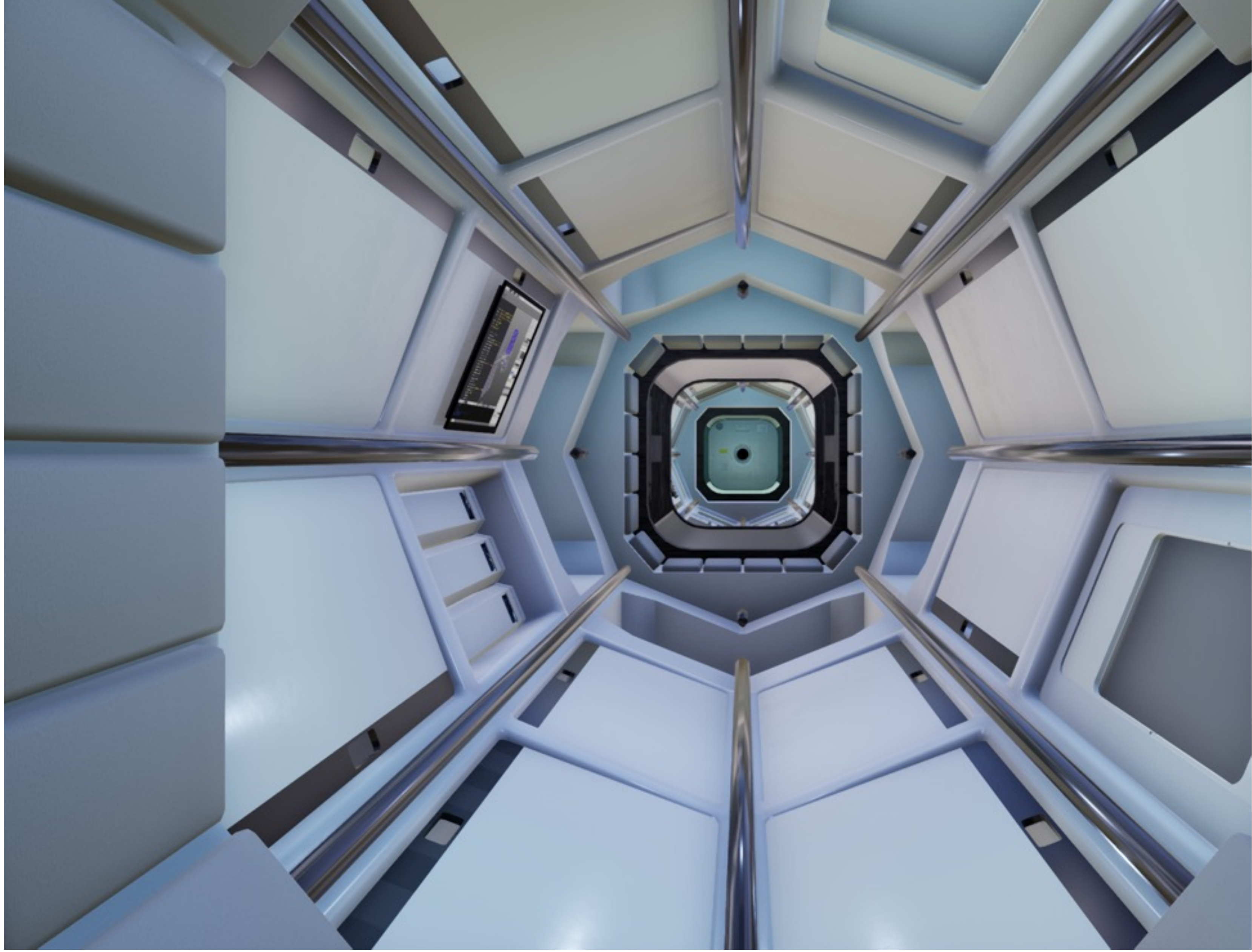
Our Mission

Improve life on earth
and foster possibilities
beyond it
by building and operating
the world's first commercial
space station.




Axiom Earth Observatory

Axiom Habitat 1



Axiom
Crew Quarters

Designed by renowned French architect and designer Philippe Starck

Co-founders: Unrivaled Experience

DR. KAM GHAFFARIAN
EXECUTIVE CHAIRMAN

Founded and, for 20 years, owned the 2,500-person company that trained US and other astronauts

36 years human spaceflight experience

MICHAEL T. SUFFREDINI
PRESIDENT & CEO

NASA International Space Station Program Manager from 2005 to 2015

Oversaw construction of ISS and its transition into a customer-facing discovery platform








AXIOM SPACE

Axiom Space Supports Diverse Global Market Segments

Human Spaceflight

- Professional, Sovereign & Private astronauts
- 10-30-60-90-180-day missions
- NASA-level training
- Mission planning & management
- US rocket launch

On-orbit Services

- Research
- In-Space Manufacturing
- Brand & Media Partnerships

Deep Space Exploration

- Near-Earth platform for science in prep for Moon & Mars
- Sub-systems tech demo & maturation
- Human performance studies for deep space missions

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Human Spaceflight: Ax1 Mission Jan 2022

Michael Lopez-Alegria
Ax1 Commander

Larry Connor
Ax1 Pilot

Eytan Stibbe
Ax1 Mission Specialist

Mark Pathy
Ax1 Mission Specialist

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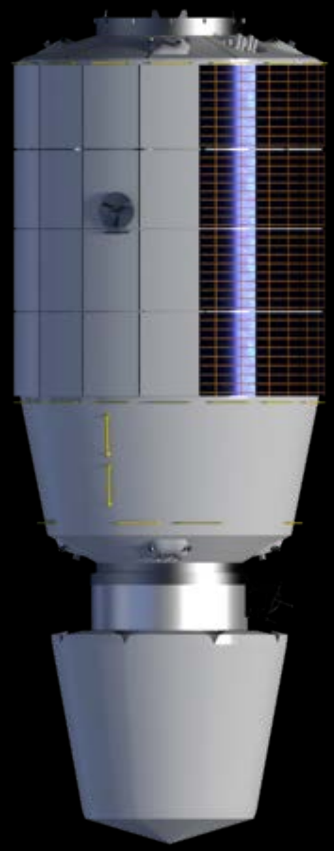
Orbital Lab for Research & Manufacturing



Key Features

- State-of-the-art, next-gen orbital lab equipment
- Flexible and cost-effective interfaces
- High-bandwidth communication link to onboard research
- Highly-networked platform with significant onboard computation resources available
- Pressurized & unpressurized research accommodations
- Continuously human-tended platform
- Modular & expandable
- Rapid integration and access to orbit
- Frequent (reliable) crew & cargo launch & return

MANUFACTURING
◇
COMMERCIAL R&D
◇
TECHNOLOGY DEVELOPMENT
◇
EXPLORATION
◇
RESEARCH
life & physical sciences
human, Earth, space
other
◇
EDU
{streamed}

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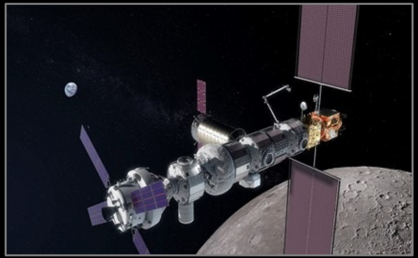
Deep Space Exploration

Axiom Station will be the basecamp for the world's space exploration initiatives

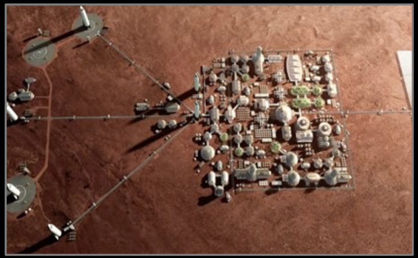


NASA
Lunar Orbiting Gateway

NASA
Artemis Lunar Program

European Space Agency
Lunar Village

SpaceX
Mars Mission



SpaceX
Mars Colony

United Arab Emirates
Mars 2117 Colony

A near-Earth platform for:

- National and science initiatives in preparation for Moon & Mars missions
- Integrated systems testing & maturation of critical hardware {ECLSS}
- Sub-system technology demonstration and maturation
- Human performance studies
  - Long duration, in-situ astronaut training and testing
  - In-space isolation & logistics studies
  - Human factors, medical, and psychological research

We are at an exciting point in humanity's timeline of history.

"New Space" is open and accessible to anyone

Space is an opportunity for:

> innovation
> invention
> entrepreneurship

Your Invention here

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STARS Scholarship

Science Technology Art and Research in Space Scholarship

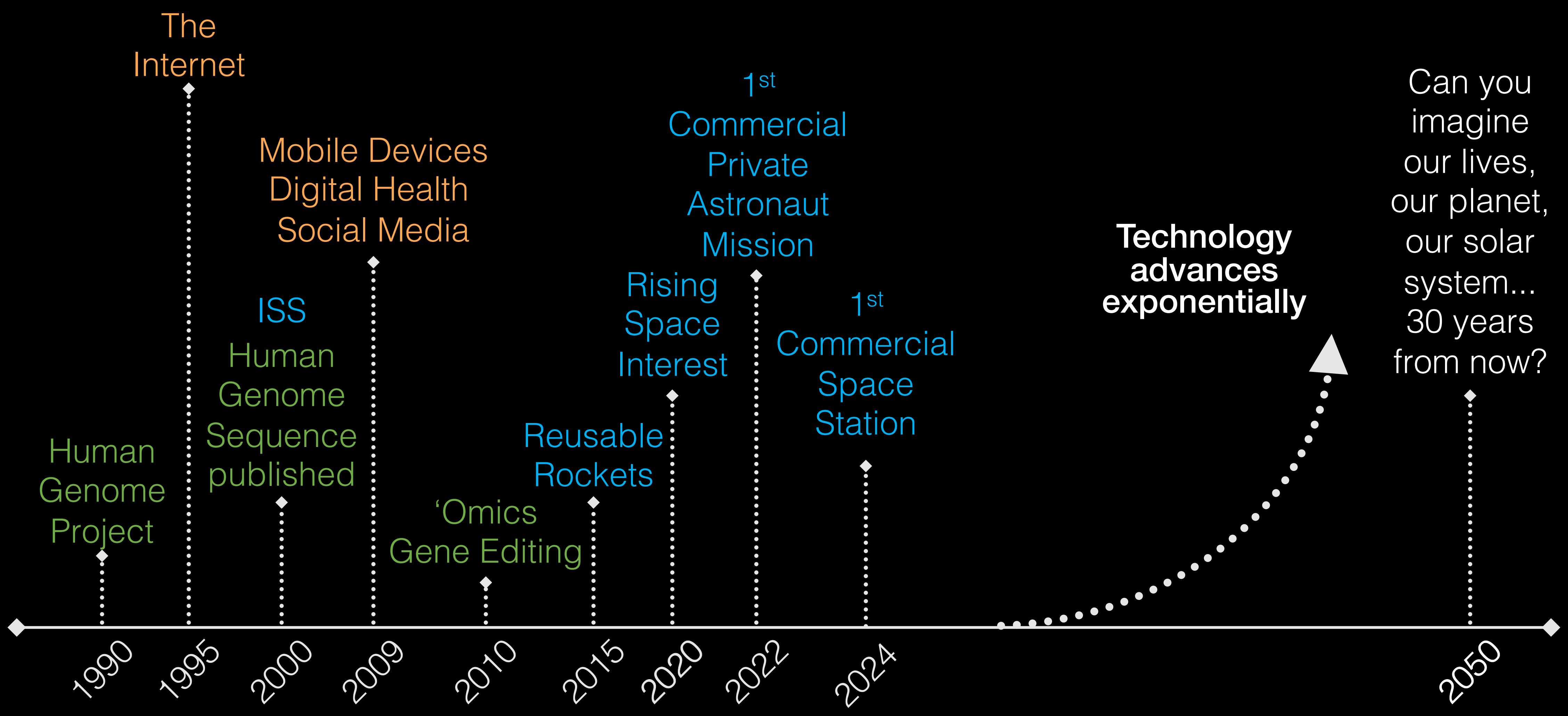
How would you use the space environment to change the world?

Three $1,000 scholarships will be awarded.
Open to undergrad or grad students in a degree program.

axiomspace.com/stars

Applications due June 30, 2021

The future is here.



How do biotech & pharma in space align with UN's SDGs?

SUSTAINABLE DEVELOPMENT GOALS

17 GOALS TO TRANSFORM OUR WORLD

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