

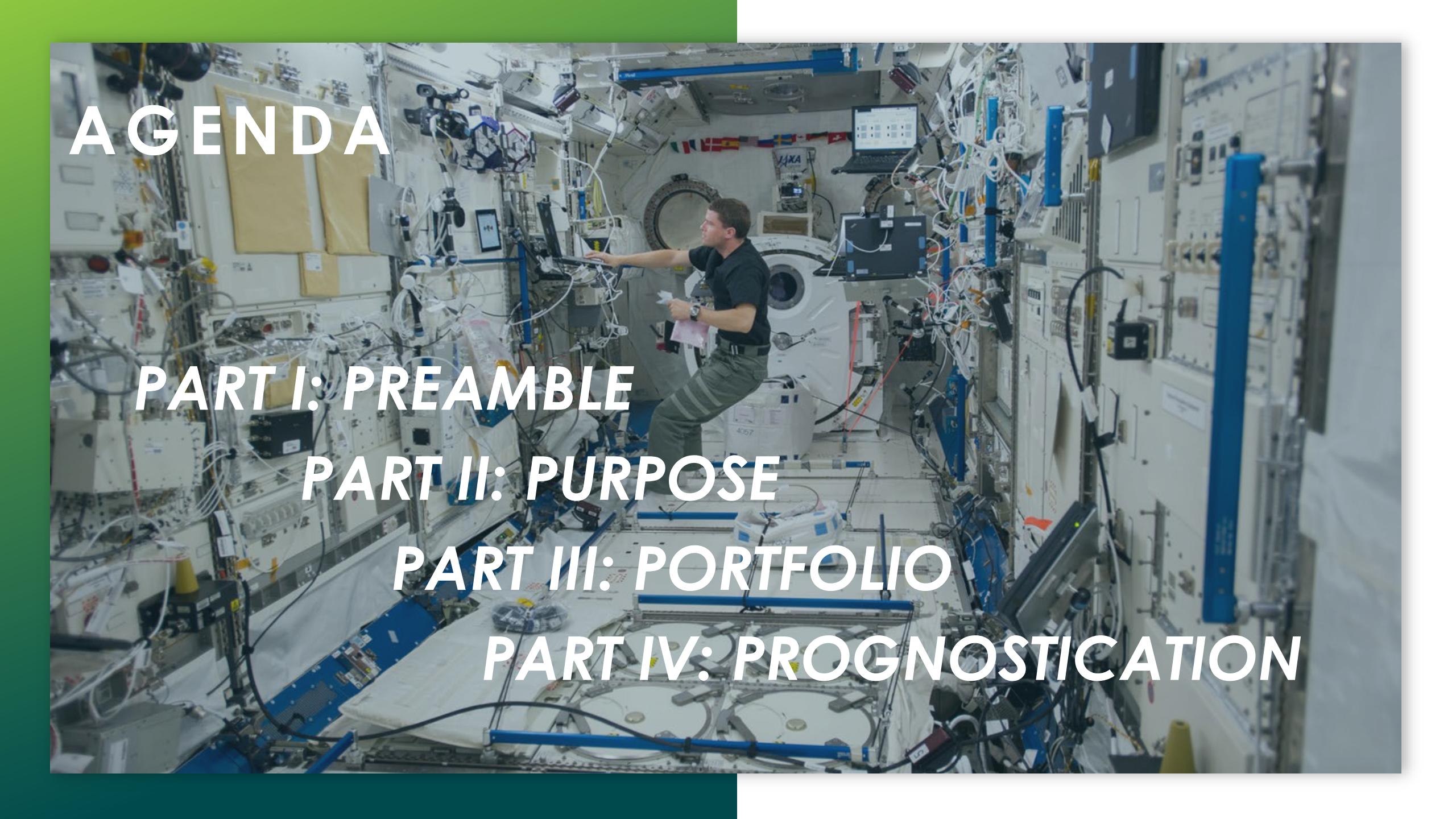


INTERNATIONAL SPACE STATION NATIONAL LABORATORY: THE NEXT DECADE OF RESULTS

Ray Lugo, Chief Executive Officer,
Michael Roberts, PhD, Chief Scientist

Briefing for the Decadal Survey on Biological and
Physical Sciences Research in Space 2023-2032

Meeting #5
4 May 2022

A photograph of an astronaut in a dark blue shirt and olive green cargo pants working inside a space station module. The astronaut is standing on a platform, reaching out to a piece of equipment. The module is filled with various scientific instruments, cables, and equipment. A laptop is visible on a shelf in the background. The overall environment is a complex, high-tech space station interior.

AGENDA

PART I: PREAMBLE

PART II: PURPOSE

PART III: PORTFOLIO

PART IV: PROGNOSTICATION

ISS NATIONAL LAB MISSION

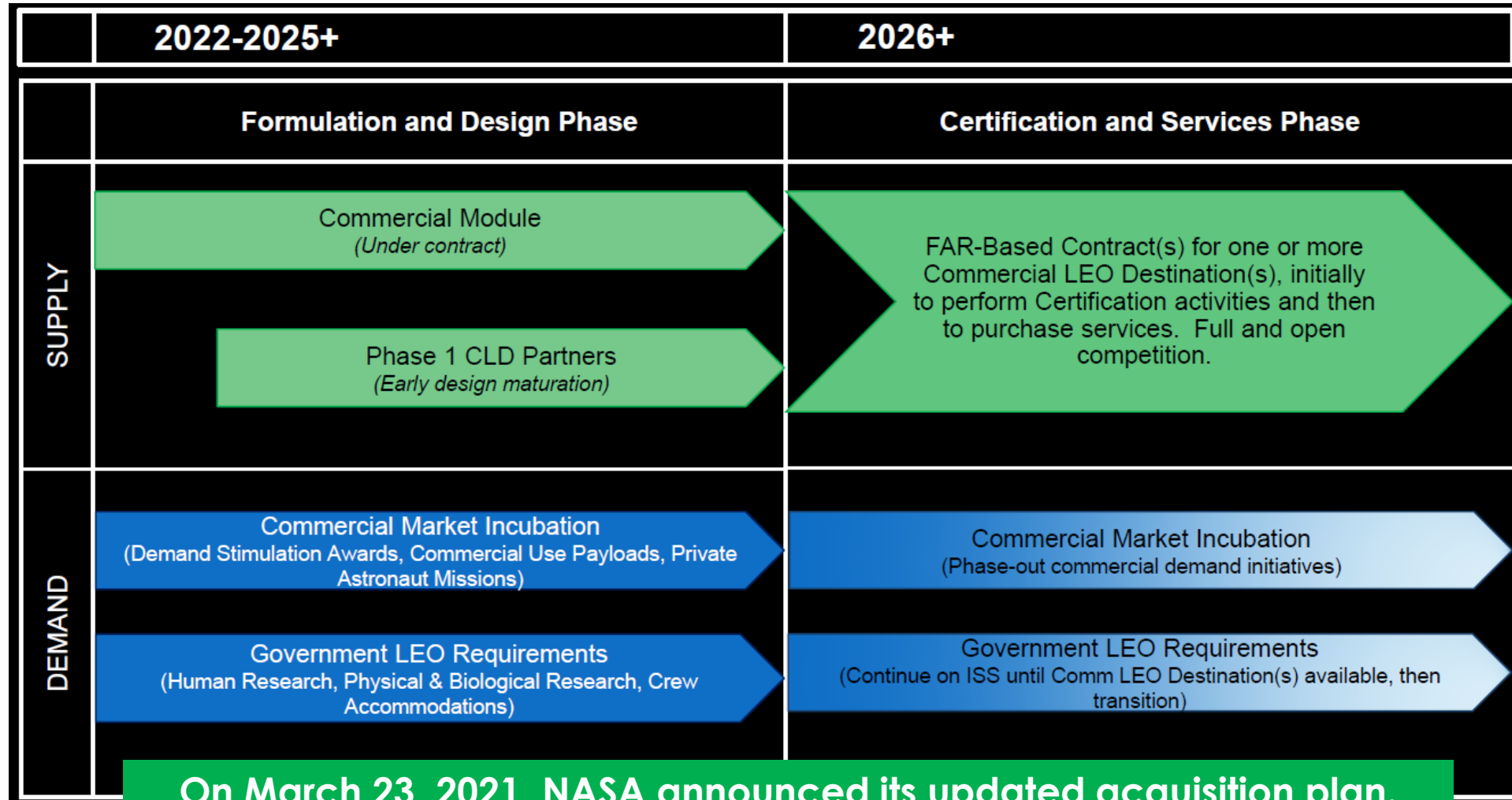
To manage the ISS National Lab as a public service for R&D to benefit the U.S. taxpayer and to foster a scalable and sustainable low Earth orbit economy.

We leverage our core competencies, facilitate public-private partnerships, and utilize the platform capabilities and unique operating environment of the space station.

We create demand, incubate in-space business ventures, provide access for and awareness of discovery science and technological innovation, and promote science literacy of the future workforce.

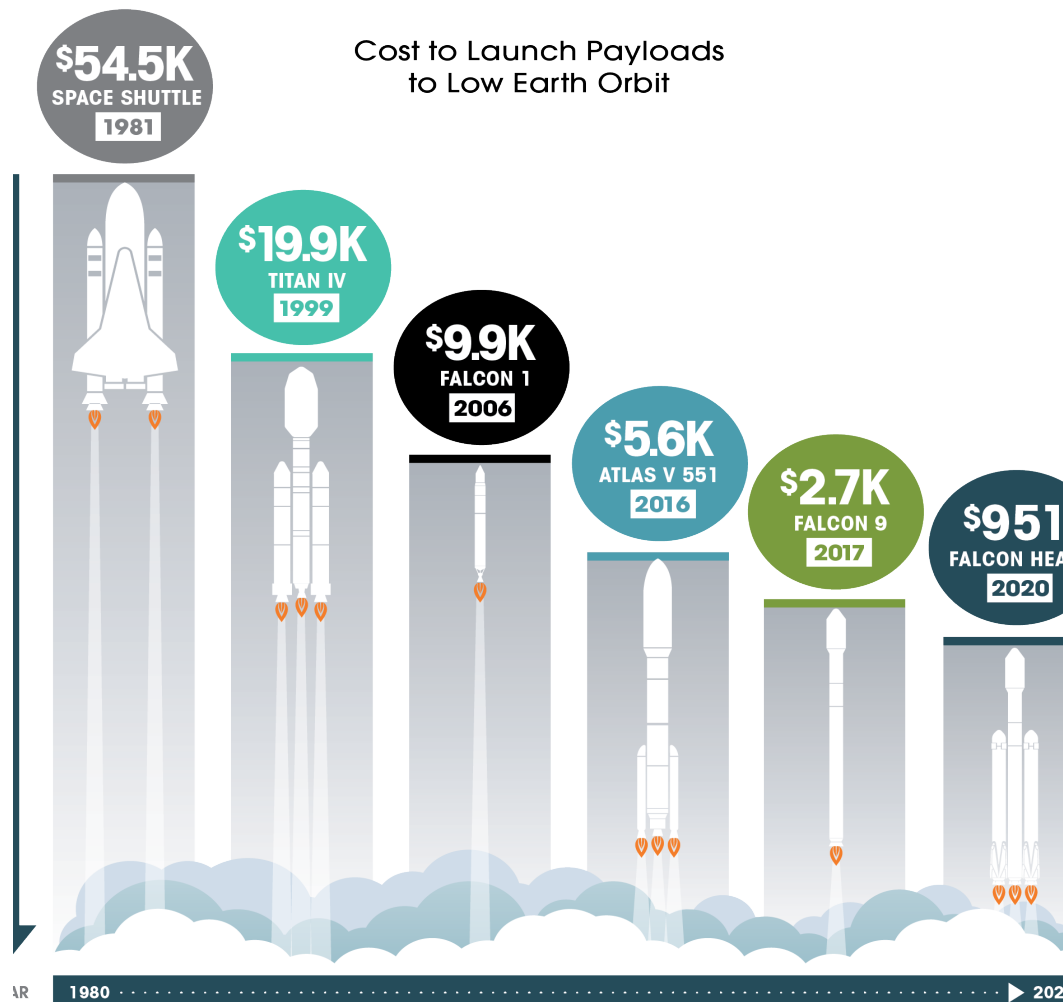


NASA MISSION: THE ACQUISITION OF COMMERCIAL LEO DESTINATIONS (CLDs)



Source: NASA

NASA MISSION: ACCESS TO LEO



FEBRUARY-2020



Illustration of Axiom concept.
Credit: Axiom Space

NASA Selects First Commercial Destination Module for ISS

NASA awarded **Axiom Space** a firm-fixed price, IDIQ contract with a maximum value of up to **\$140M** over an up to seven-year period. In addition, the Ax-1 private astronaut mission launched to ISS April 8, 2022 and a 2nd PAM was awarded to Axiom for 2023.

DECEMBER-2021



Illustration of Starlab.
Credit: Nanoracks

NASA Selects 3 Companies to Develop Commercial LEO Destinations in Space

The largest award, **\$160M**, went to the Nanoracks team including Voyager Space and Lockheed Martin. The team announced a space station concept called *Starlab* October 21 that could be ready as soon as 2027.

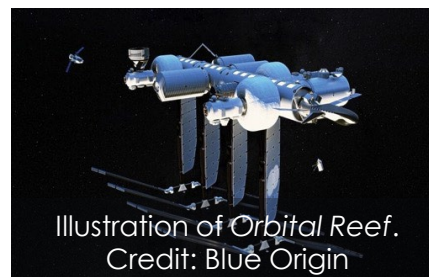


Illustration of Orbital Reef.
Credit: Blue Origin

A 2nd award, valued at **\$130M**, went to a **Blue Origin** team for the *Orbital Reef* space station concept announced Oct 25. The team includes Boeing, Redwire and Sierra Space, among others, with a goal of entering initial operations in the latter half of the 2020s.



Illustration of HALO concept.
Credit: Northrop Grumman

The 3rd award, worth **\$125.6M**, went to a **Northrop Grumman** concept based on the (1) Cygnus CRS spacecraft, (2) *Mission Extension Vehicle* satellite servicing program, and (3) *Habitation and Logistics Outpost* (HALO) module it is building for NASA's lunar Gateway.

\$555M

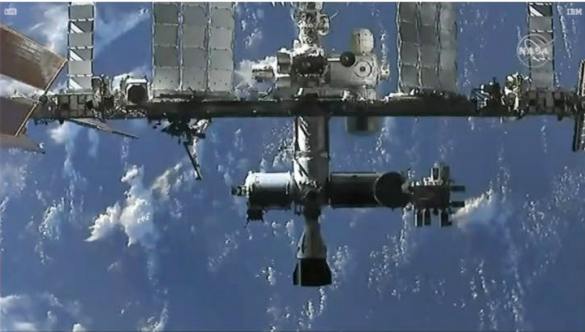
NASA MISSION: TRANSITION FROM ISS



NASA Blogs Home

Biden-Harris Administration Extends Space Station Operations Through 2030

Brian Dunbar
December 31, 2021
Uncategorized

The space station is viewed from the SpaceX Cargo Dragon during its automated approach before docking.
Credit: NASA TV

NASA Administrator Bill Nelson announced today the Biden-Harris Administration's commitment to extend International Space Station (ISS) operations through 2030, and to work with our international partners in Europe (ESA, European Space Agency), Japan (JAXA, Japan Aerospace Exploration Agency), Canada (CSA, Canadian Space Agency), and Russia (State Space Corporation Roscosmos) to enable continuation of the groundbreaking research being conducted in this unique orbiting laboratory through the rest of this decade.

RECENT POSTS

- [Cosmonauts Prep for Spacewalk as Astronauts Work Science and Maintenance](#)
- [Dragon, Spacewalk Preps Amidst Space Botany and Biology Research](#)
- [Crew Starts Week with Space Agriculture, Human Cells and Spacesuits](#)
- [Biology, Agriculture Studies as Astronaut Begins Record-Breaking Spree](#)
- [Space Biology, Science Hardware Work Keeping Station Crew Busy](#)

RECENT COMMENTS

- [Siphelele charles mntungwa](#) on [Space Biology, Science Hardware Work Keeping Station Crew Busy](#)
- [Mark Garcia](#) on [Last Week of 2021 Sees New Space Research Kick Off](#)
- [Mark Garcia](#) on [Dragon Checks, Biology and Spacewalk Preps Fill Crew Day](#)
- [Mark Garcia](#) on [Crew Kicks off 2022 with Biology, Botany and Spacewalk Preps](#)
- [Nazia](#) on [Dragon Checks, Biology and Spacewalk Preps Fill Crew Day](#)

ARCHIVES



International Space Station Transition Report

pursuant to
Section 303(c)(2) of the NASA Transition Authorization Act of 2017 (P.L. 115-10)

January 2022

<https://www.nasa.gov/feature/nasa-provides-updated-international-space-station-transition-plan>

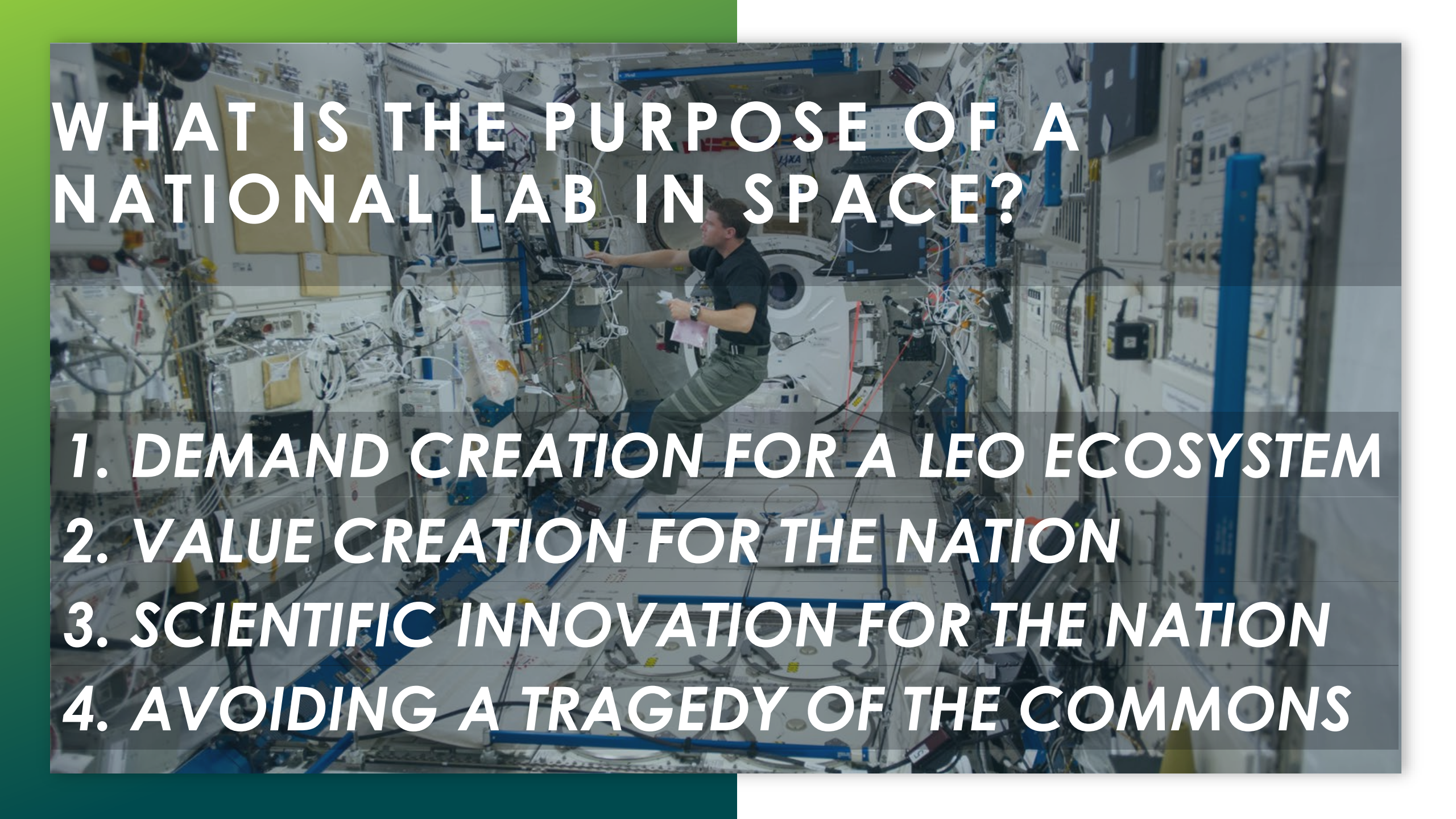
AGENDA

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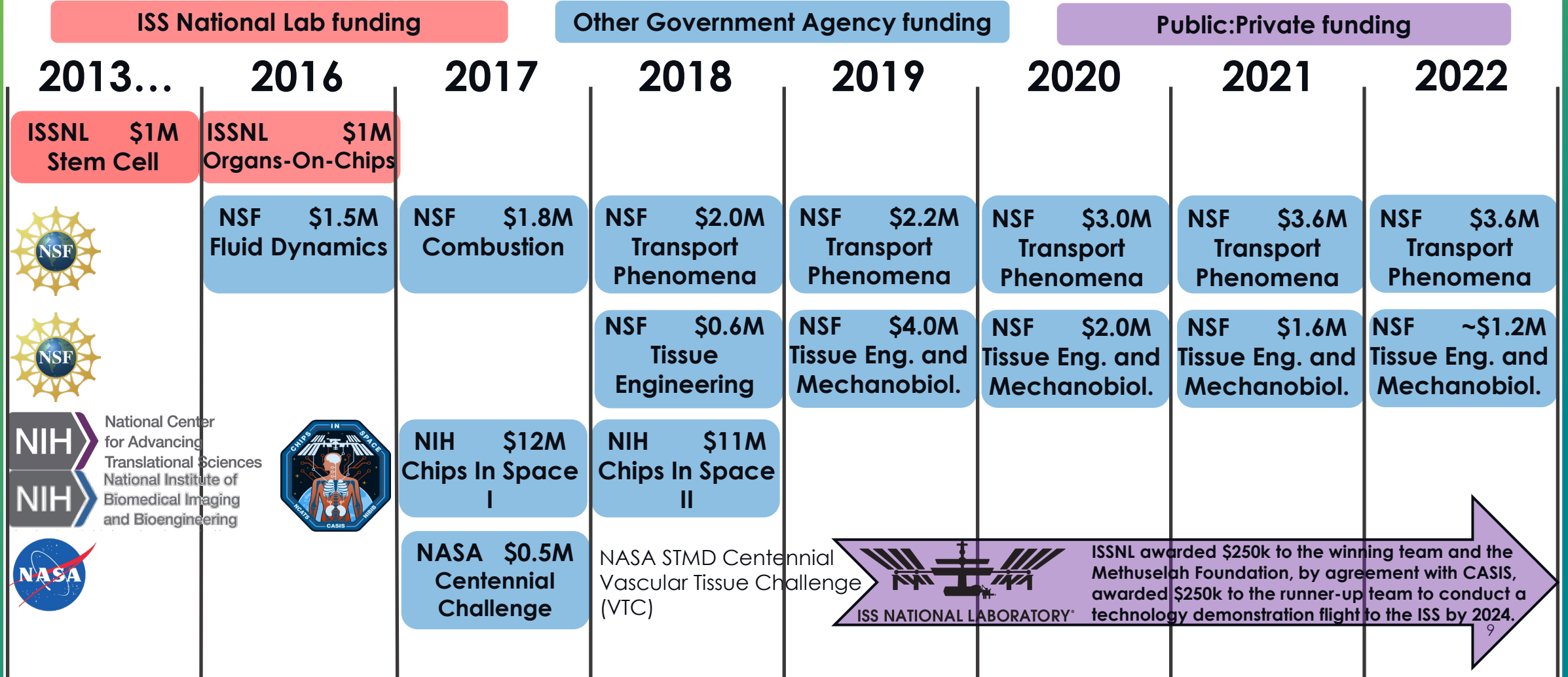
PART IV: PROGNOSTICATION

A photograph of an astronaut in a dark blue shirt and olive green cargo pants working inside a space station module. The astronaut is standing on a platform, reaching out to adjust equipment. The background is filled with various scientific instruments, cables, and structural elements of the station, creating a complex and technical environment.

WHAT IS THE PURPOSE OF A NATIONAL LAB IN SPACE?

1. DEMAND CREATION FOR A LEO ECOSYSTEM
2. VALUE CREATION FOR THE NATION
3. SCIENTIFIC INNOVATION FOR THE NATION
4. AVOIDING A TRAGEDY OF THE COMMONS

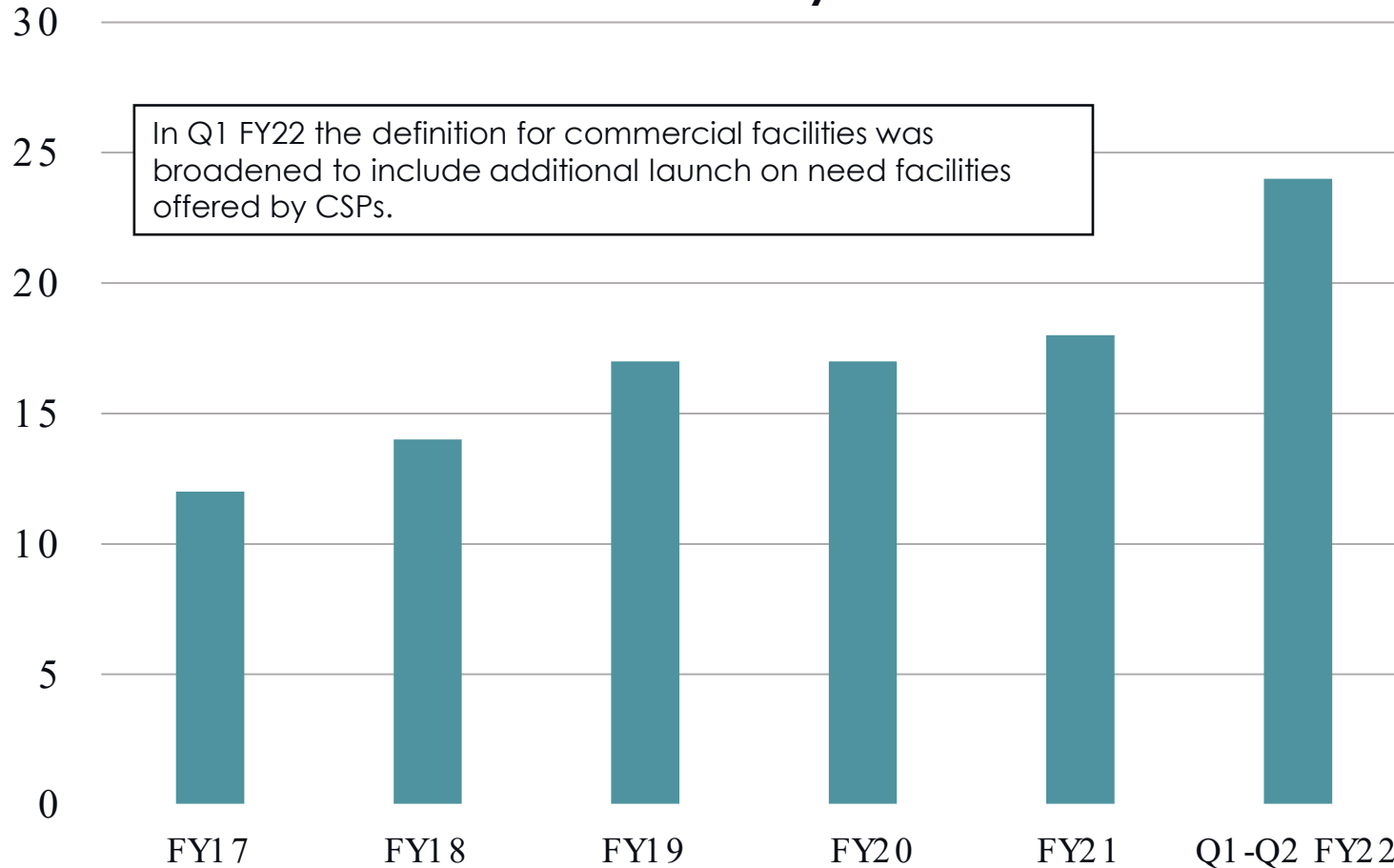
DEMAND CREATION: FUNDAMENTAL SCIENCE ON ISS FUNDED* BY OTHERS



*Funding committed in joint solicitations with ISS National Lab by other government agencies (OGAs) and others

DEMAND CREATION: ISS NATIONAL LAB COMMERCIAL FACILITIES

Cumulative Facility Count



Thru Q2 FY22

Aegis Aerospace Inc.

BioServe Space Technologies

Craig Technologies

Hnu Photonics, LLC

Lamont Aerospace

Nanoracks, LLC

OmniTeq, LLC

ProXops, LLC

Redwire Space

Rhodium Scientific

Space Tango, Inc.

STaARS

Techshot, Inc.

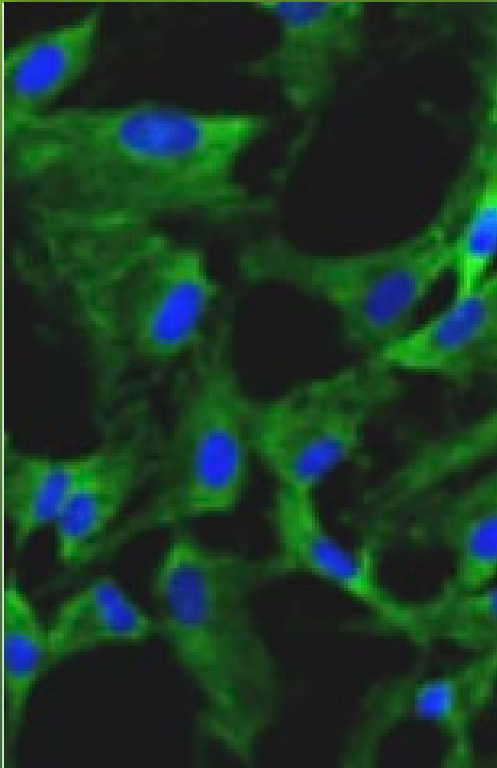
Teledyne Brown Engineering, Inc.

VALUE CREATION: BIOMANUFACTURING IN SPACE WORKSHOP

The ISS is a unique laboratory in LEO with capabilities to advance stem cell research, disease modeling, tissue engineering, regenerative medicine, and biofabrication.

The workshop seeks to **identify the most innovative scientific approaches in biomanufacturing enabled by LEO** that can enable the development and translation of therapeutics and interventions for terrestrial use as well as the steps needed to validate that the technologies are clinically ready and economically viable.

Technical areas of primary interest are stem cells, organoids, microphysiological systems, and biofabrication - collectively termed biomanufacturing here - and how AI/automation can be integrated in orbit to improve iteration and throughput to enhance their development for clinical and manufacturing applications on Earth.



VALUE CREATION: STAKEHOLDER WORKSHOPS

ISS National Lab has supported
stem cell research, drug
discovery, and medical device
technology development
since 2013

NIH and NSF co-sponsor annual
MPS/organoid payloads

The ISS has multiple
biofabrication facilities



VALUE CREATION: ROADMAPS TO THE FUTURE

Opportunities for Biomanufacturing in Low Earth Orbit: Current Status and Future Directions

<https://www.preprints.org/manuscript/202108.0044/v1>

Biomanufacturing in Low Earth Orbit for Regenerative Medicine

<https://doi.org/10.1016/j.stemcr.2021.12.001>





I. CLINICAL APPLICATIONS OF SPACE-ENABLED R&D

Atrophy is a process involving the breakdown and loss of tissue. Aging is one example of progressive tissue degeneration, whereby muscle mass declines up to 2% a year after age 50, while bone loss occurs at an average rate of 3-5% per decade.

Targeting the myostatin/activin A signaling pathway had significant beneficial effects in protecting against both muscle and bone loss in microgravity.

Targeting myostatin/activin A protects against skeletal muscle and bone loss during spaceflight

Se-Jin Lee^{a,b,1}, Adam Lehar^a, Jessica U. Meir^c, Christina Koch^c, Andrew Morgan^c, Lara E. Warren^d, Renata Rydzik^e, Daniel W. Youngstrom^f, Harshpreet Chandok^a, Joshy George^a, Joseph Gogain^f, Michael Michaud^a, Thomas A. Stoklasek^a, Yewei Liu^a, and Emily L. Germain-Lee^{g,h}

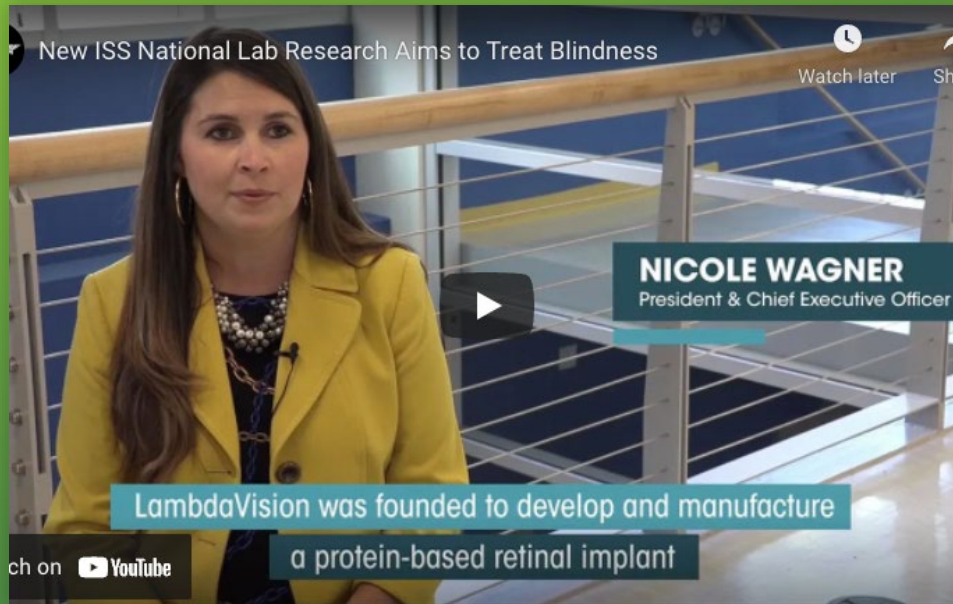
^aThe Jackson Laboratory for Genomic Medicine, Farmington, CT 06032; ^bDepartment of Genetics and Genome Sciences, University of Connecticut School of Medicine, Farmington, CT 06030; ^cThe National Aeronautics and Space Administration, NASA Johnson Space Center, Houston, TX 77058; ^dCenter for the Advancement of Science in Space, Houston, TX 77058; ^eDepartment of Orthopaedic Surgery, University of Connecticut School of Medicine, Farmington, CT 06030; ^fSomaLogic, Inc., Boulder, CO 80301; ^gDepartment of Pediatrics, University of Connecticut School of Medicine, Farmington, CT 06030; and ^hConnecticut Children's Center for Rare Bone Disorders, Farmington, CT 06032

Contributed by Se-Jin Lee, August 4, 2020 (sent for review July 14, 2020; reviewed by Shalender Bhasin and Paul Gregorevic)

Among the physiological consequences of extended spaceflight are loss of skeletal muscle and bone mass. One signaling pathway that plays an important role in maintaining muscle and bone homeostasis is that regulated by the secreted signaling proteins, myostatin (MSTN) and activin A. Here, we used both genetic and pharmacological approaches to investigate the effect of targeting MSTN/activin A signaling in mice that were sent to the International Space Station. *Wild type* mice lost significant muscle and bone mass during the 33 d spent in microgravity. Muscle weights

signaling and, as a result, can induce significant muscle growth when given systemically to *wild type* mice (13). Indeed, by blocking both ligands, this decoy receptor can induce significantly more muscle growth than other MSTN inhibitors, and at high doses, ACVR2B/Fc can induce over 50% muscle growth in just 2 wk.

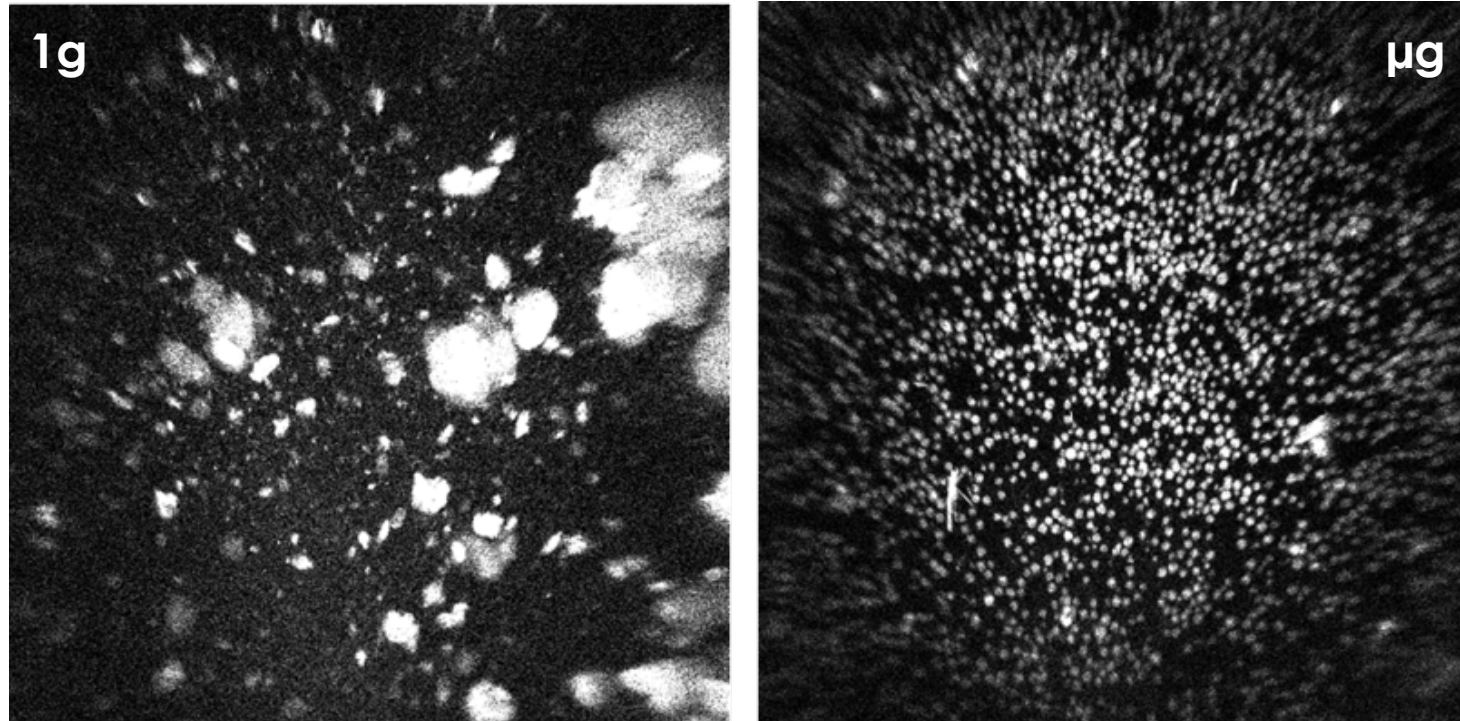
Moreover, because this decoy receptor can block not only MSTN but also activin A, systemic administration of ACVR2B/Fc can also lead to significant increases in bone density (18–20).



II. INDUSTRIAL AND CLINICAL APPLICATIONS OF SPACE-ENABLED R&D

LambdaVision, an innovative biomedical startup, has leveraged ISS National Lab resources for in-space production applications to improve manufacturing of the company's artificial retina to restore vision in those blinded by retinal degenerative diseases. A series of investigations in partnership with ISS National Lab Commercial Service Provider Space Tango are improving the quality of the artificial retina by limiting imperfections that occur during manufacturing on Earth.

III. INDUSTRIAL AND CLINICAL APPLICATIONS OF SPACE-ENABLED R&D



UV imaging of a ground control sample (L) and spaceflight sample (R).

Merck & Company's Keytruda® crystal investigation, showing the more uniform size and distribution of crystals grown in microgravity. Keytruda®, a cancer immunotherapy drug, is one of Merck & Co.'s top selling products.

THE ISS NATIONAL LAB AS A CATALYST FOR SCIENTIFIC INNOVATION

15 April 2022

NASA selects eight proposals submitted in response to a NASA Research Announcement seeking In Space Production Applications (InSPA) flight demonstrations on the ISS National Lab. The selected proposals have a total award value of up to \$21M through FY2025.



Apr 15, 2022

NASA Selects Proposals to Enable Manufacturing In Space for Earth



Following a decade of assembly of the International Space Station and the subsequent decade of research onboard the ISS National Lab, NASA moves boldly into the decade of results with the award of new and promising technologies for in-space manufacturing of advanced materials and products for use on Earth. With more than 21 years of continuous occupation, the International Space Station continues to demonstrate the benefits of microgravity not just for discovery but for the development of new technologies and products that have the potential to improve the quality of life on Earth.

Decades of microgravity research have laid the foundation for U.S. industry to demonstrate the unique market value of in-space manufacturing, technology advancement, and drug development with the help of NASA's investment in dedicated transportation and research time for ISS National Laboratory investigations. To date, NASA has provided seed money in excess of \$38 million for more than a dozen technologies to enable innovative companies to mature their concepts and [stimulate demand](#) for future markets. The awards are a key element of NASA's goal to develop a robust economy in low-Earth orbit where NASA will be one of many customers.

BIOMATERIALS

- *Biomanufacturing of Drug-Delivery Medical Devices*, Auxilium Biotechnologies, Inc., San Diego, CA
- *Expansion of Hematopoietic Stem Cells for Clinical Application*, BioServe Space Technologies and the University of Colorado, Boulder, CO
- *Establishing Production of Stem Cell Therapies*, Cedars-Sinai Regenerative Medicine Institute, Los Angeles, CA
- *Volumetric Additive Manufacturing for Organ Production*, Lawrence Livermore National Laboratory, Livermore, CA
- *Pharmaceutical In-space Laboratory (PIL)*, Redwire Corporation Inc., Greenville, IN
- *Biomimetic Fabrication of Multifunctional DNA-inspired Nanomaterials*, University of Connecticut, Storrs, CT

ADVANCED MATERIALS

- *Fabrication of Flawless Glass in Microgravity*, Flawless Photonics, Inc., Los Altos Hills, CA
- *Semimetal-Semiconductor Composite Bulk Crystals*, United Semiconductors, LLC, Los Alamitos, CA

THE ISS NATIONAL LAB AS A CATALYST FOR SCIENTIFIC INNOVATION

1 March 2022

4 Agencies Select 8 Research Projects to Extend Longevity of 3D Tissue Chips to 6 Months

NASA-SMD, FDA, NIH, and the Department of Health and Human Services Biomedical Advanced Research and Development Authority (BARDA), announce the award of 8 contracts in a multi-agency collaboration that will extend tissue viability and physiological function to a minimum of 6 months using automated engineering capabilities for real-time online readouts in complex human in vitro models, such as tissue chips or microphysiological systems. The selected studies aim to fund the development and validation of tissue chips which can function successfully for 6 months or longer in an automated fashion, to be used for modeling of acute and/or chronic exposures (e.g., to drugs and other compounds, radiation, environmental hazards, infection, microgravity exposure, etc.). When fully implemented, approximately \$16M will be awarded in fiscal years 2022-2025.

- **Elizabeth Blaber**, Rensselaer Polytechnic Institute, *Understanding the Brain-Liver-Gut Axis during Spaceflight and Aging*
- **Joel Blanchard**, ICAHN School of Medicine at Mount Sinai, *Identification of Biomarkers and Pathological Mechanisms via Longitudinal Analysis of Neurological and Cerebrovascular Responses to Neurotoxic Stress Using a Multi-cellular Integrated Model of the Human Brain*
- **Guohao Dai**, Northeastern University, *Bioengineer Long-lasting 3D Neurovascular Microphysiological System to Model Chronic Inflammation-mediated Neurodegeneration*
- **Abhishek Jain**, Texas A&M, *Long-term Patient iPSC Vessel Chip Model to Assess Stressors of Atherosclerosis and mRNA Therapeutics*
- **Christopher Porada**, Wake Forest University, *Long-lived Single- and Multi-organ Tissue Equivalent (OTE) Platforms to Model the Response of Human Tissues to Various Stressors*
- **Gordana Vunjak-Novakovic**, Columbia University, *MORPH: Multi-Organ Repair Post Hypoxia*
- **Joseph Wu**, Stanford University, *Assessing Long-Term Effects of Radiation Exposure in Engineered Heart & Vascular Tissues*
- **Catherine Yeung**, University of Washington, *Extended Culture of Kidney MPS and Organoids to Model Acute and Chronic Exposure to Drugs and Environmental Toxins*

THE ISS NATIONAL LAB AS A CATALYST FOR SCIENTIFIC INNOVATION

Axiom Space Establishes a Winston-Salem Presence in the Regenerative Medicine Hub
Published April 19th, 2022

Partnership with WFIRM and ReMDO will Pioneer Biomanufacturing in Space

Regenerative medicine manufacturing in space is the next frontier and will be possible due to a new three-way partnership between Axiom Space, which is building the world's first commercial space station, the [RegenMed Development Organization \(ReMDO\)](#), the first organization dedicated to advancing regenerative medicine manufacturing scale-up and automation, and the [Wake Forest Institute of Regenerative Medicine \(WFIRM\)](#), an international leader in translating scientific discovery into clinical therapies.



ISSNL awarded \$250k to the winning team and the Methuselah Foundation, by agreement with CASIS, awarded \$250k to the runner-up team to conduct a technology demonstration flight to the ISS by 2024.

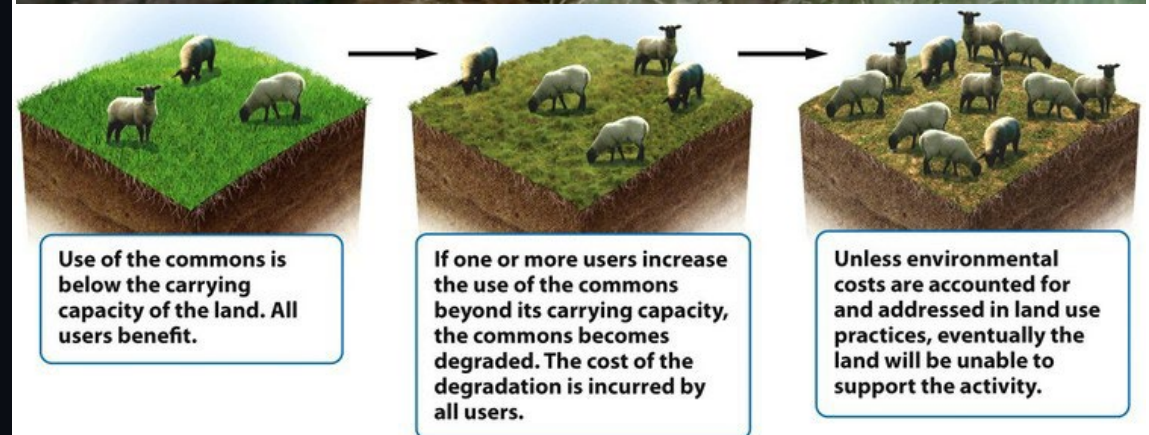


AVOIDING A TRAGEDY OF THE COMMONS

“I didn’t know we had a National Lab. I thought we were an autonomous collective.”

Top image and misquote courtesy of **Monty Python and *The Holy Grail*** (1975).

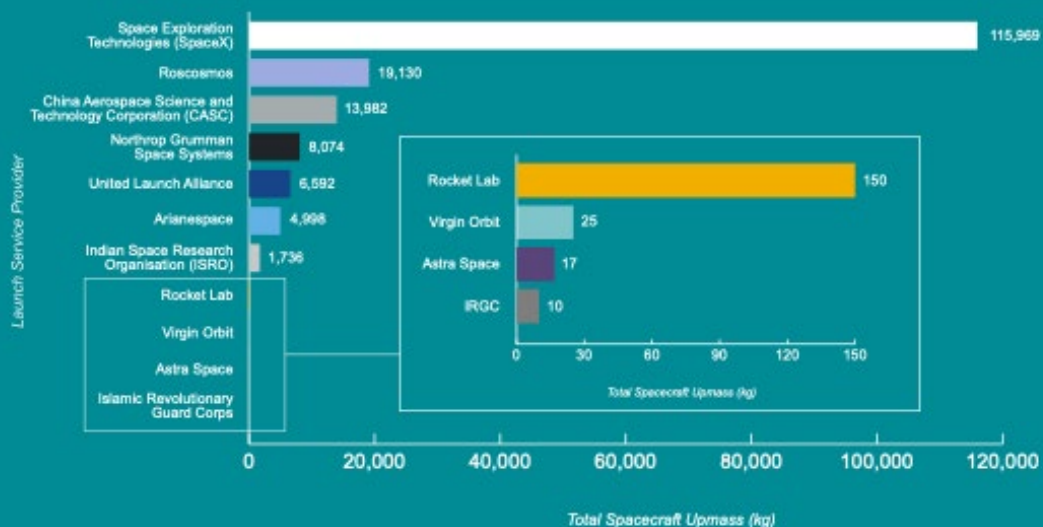
Bottom image from Figure 29.2,
Environmental Science for AP®, 2nd Ed. ©
2015 W.H. Freeman and Co.



AVOIDING A TRAGEDY OF THE COMMONS

Spacecraft Upmass Carried by Launch Provider

SpaceX launched about 115,900 kg of spacecraft upmass in Q1, followed by Roscosmos with about 19,000 kg

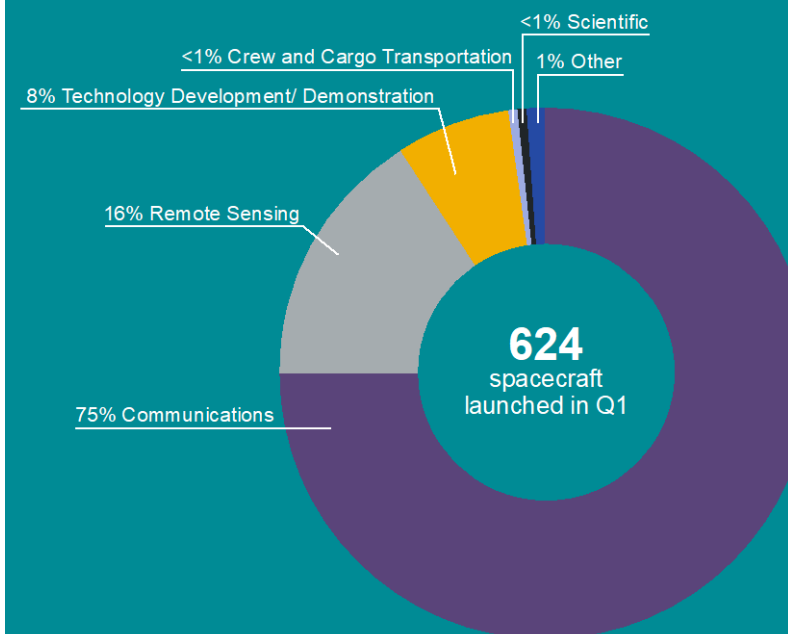


Includes estimates of spacecraft mass when not publicly disclosed

BRYCE
TECH

Spacecraft by Service Type

Driven by continued deployment of the OneWeb and Starlink constellations, most spacecraft launched in Q1 were communications satellites



BRYCE
TECH

AGENDA

PART I: PREAMBLE

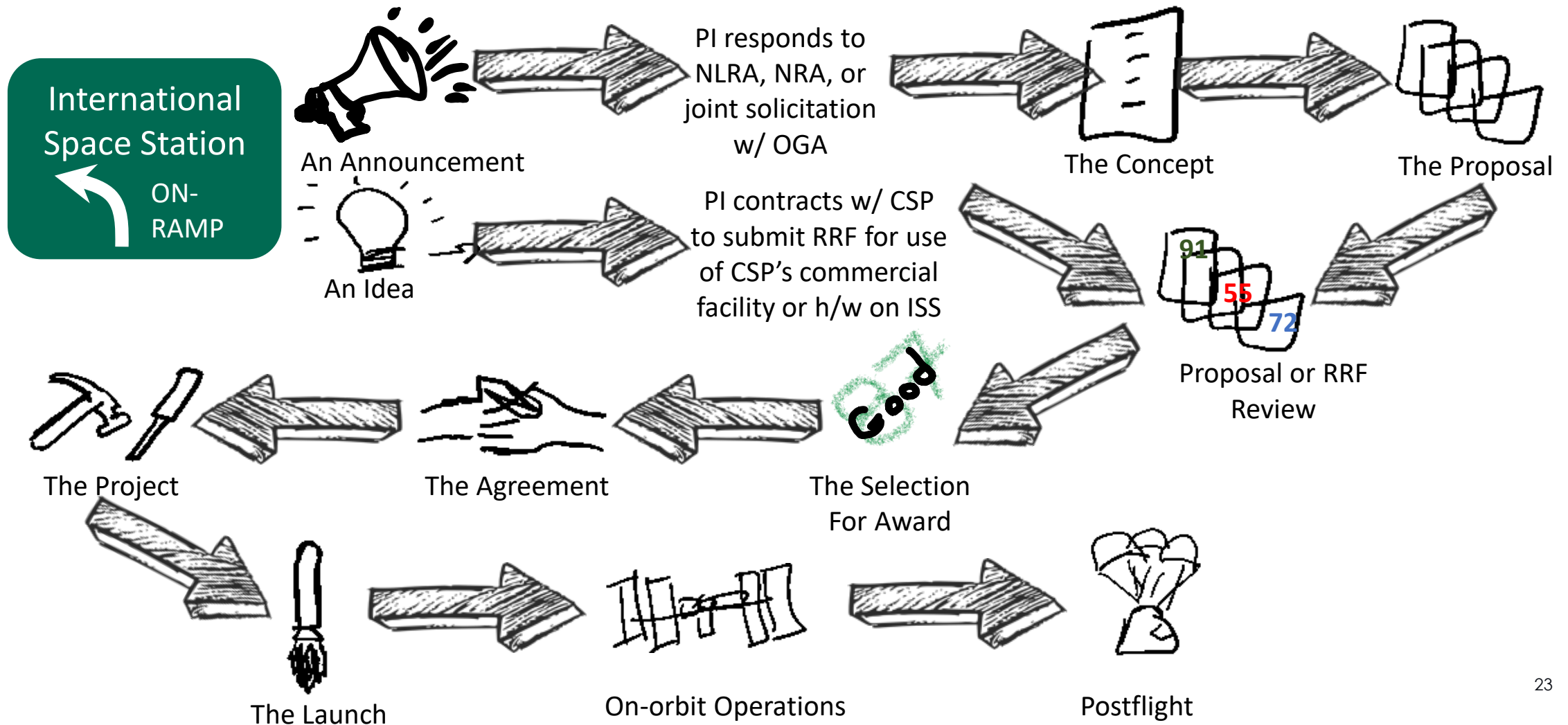
PART II: PURPOSE

PART III: PORTFOLIO

PART IV: PROGNOSTICATION



ISS NATIONAL LAB PATHWAYS



ISS NATIONAL LAB PORTFOLIO

**FUNDAMENTAL
SCIENCE**



**TECHNOLOGY
DEVELOPMENT**



**STEM
ENGAGEMENT**



**InSPA: IN-SPACE
PRODUCTION
APPLICATIONS**

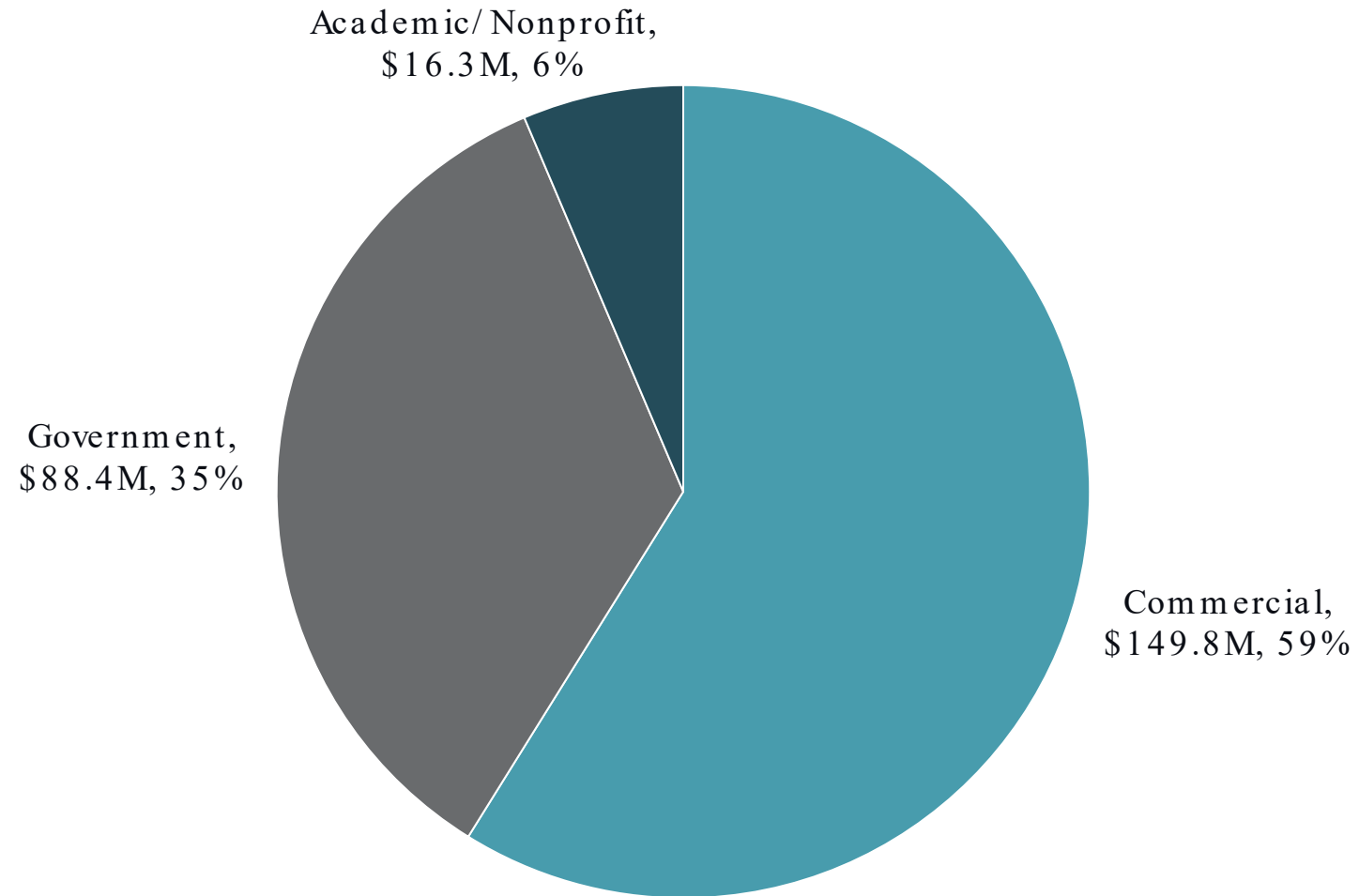


**COMMERCIAL
UTILIZATION**



ISS NATIONAL LAB EXTERNAL FUNDING

CUMULATIVE, ALL TIME



Thru Q2 FY22

CONFIDENTIAL • DO NOT DISTRIBUTE

ISS NATIONAL LAB PORTFOLIO

\$419M

188

**ACADEMIC, NONPROFIT, &
NON-NASA GOVERNMENT
AGENCY PROJECTS**

Emory, MIT, MJFF, ORNL, et al

197

INDUSTRY PROJECTS

*AstraZeneca, Delta Faucet,
Goodyear, Merck, Novartis,
Procter Gamble, et al*

14

**COMMERCIAL
SERVICE PROVIDERS**

*Aegis Aerospace, Axiom
Space, BioServe, Nanoracks,
Redwire, Sierra Space, Space
Tango, et al*

23

**COMMERCIAL
IMPLEMENTATION PARTNERS**

*Bionetics, Felix & Paul, Leidos
Innovations, Rhodium
Scientific, SEOPS, Teledyne
Brown Engineering, et al*

**INDUSTRY FUNDING
PARTNERS**

*Apple, Boeing,
Estee Lauder,
Target, et al*

260

**MEMBER
INVESTOR
NETWORK**

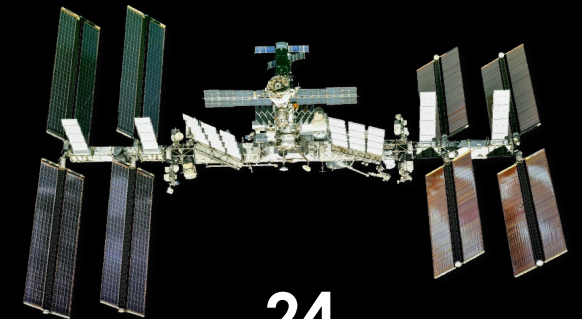
**GOVERNMENT
AGENCY FUNDING
PARTNERS**

DoD, NSF, NIH, et al

**>560
PAYLOADS**

**\$165M
NASA**

**\$254M
EXTERNAL
FUNDING**



24

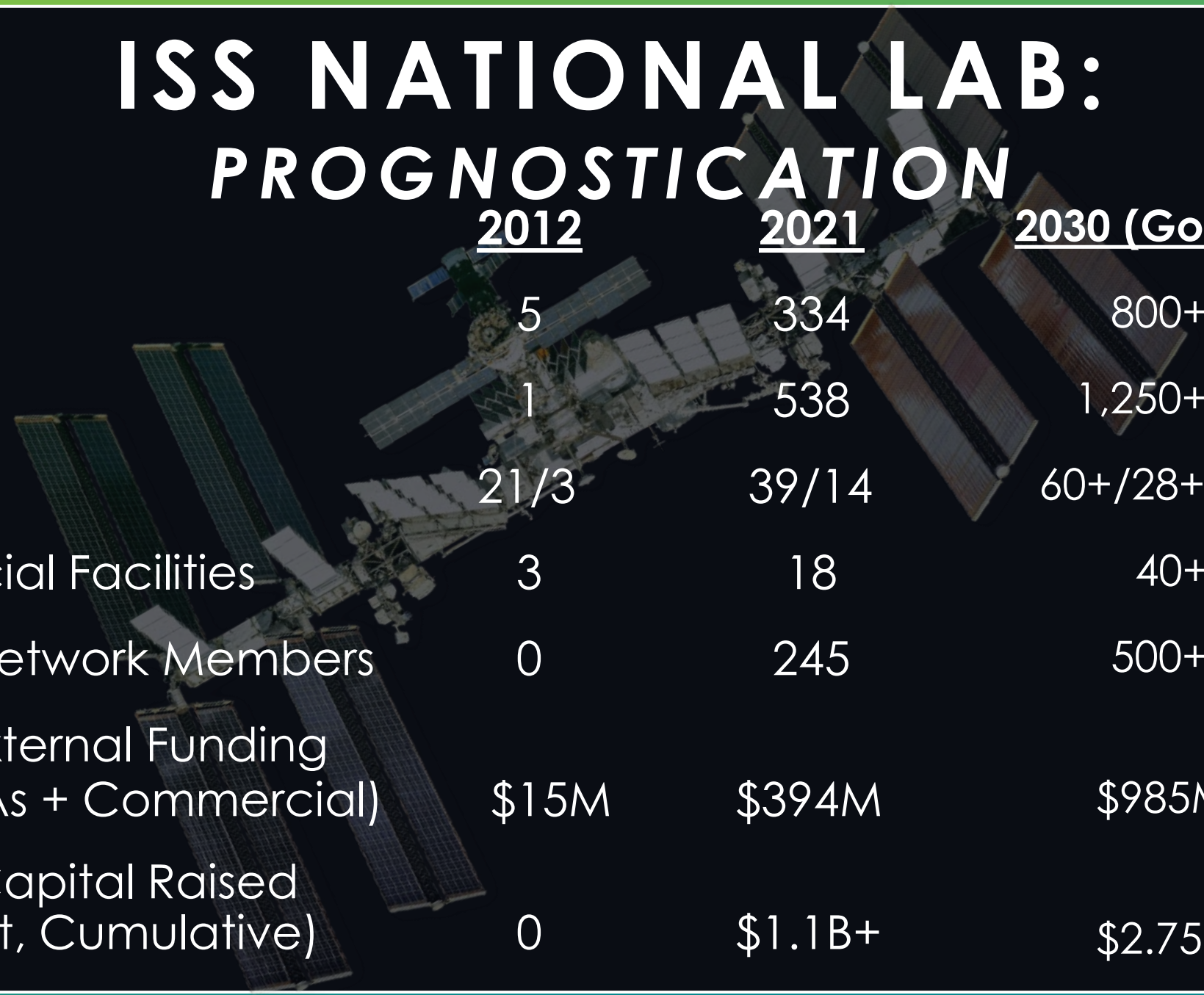
**COMMERCIAL
LAB FACILITIES**

**CAPITAL RAISED BY
START-UPS POST AWARD**

\$1.8B

Through Q2 FY22

ISS NATIONAL LAB: PROGNOSTICATION



	<u>2012</u>	<u>2021</u>	<u>2030 (Goals)</u>
Projects	5	334	800+
Payloads	1	538	1,250+
IPs/CSPs	21/3	39/14	60+/28+
Commercial Facilities	3	18	40+
Investor Network Members	0	245	500+
NASA + External Funding (incl. OGAs + Commercial)	\$15M	\$394M	\$985M
Start-Up Capital Raised (Post Flight, Cumulative)	0	\$1.1B+	\$2.75B

Register Now • Last Day for Early Bird Pricing is May 27



WASHINGTON, D.C.
JULY 25-28, 2022
DECADE OF RESULTS

REGISTER NOW

ISS NATIONAL LABORATORY

NASA

American Astronautical Society

<https://www.issconference.org/>

<https://www.issconference.org/>

WORKSHOP: LEVERAGING THE MICROGRAVITY ENVIRONMENT FOR IN-SPACE PRODUCTION APPLICATIONS

Workshop Date and Time: Monday, July 25, 8 a.m. ET

The In-Space Production Applications (InSPA) Workshop introduces the research community to new opportunities to leverage the space environment to produce novel materials, biological and inorganic alike. This workshop is hosted jointly by the NASA ISS Business and Economic Development Office and the ISS National Lab. The workshop will feature discussion from both organizations on their individual and collaborative initiatives to develop and demonstrate the manufacturing of advanced materials and other high-value products on the ISS for use on the Earth. Topics of discussion will include advanced materials and manufacturing, crystal production, thin-film deposition, and tissue engineering and regenerative medicine. The workshop will feature presentations from NASA, the ISS National Lab, and other governmental agencies and will provide opportunities for feedback from the research and commercial communities.

WORKSHOP: BIOMANUFACTURING IN SPACE

Workshop Date and Time: Monday, July 25, 12 p.m. ET

In 2020, the Center for the Advancement of Science in Space, Inc. (CASIS), manager of the ISS National Lab, and the University of Pittsburgh's McGowan Institute for Regenerative Medicine hosted a Biomanufacturing in Space Symposium. In a series of virtual working sessions, the symposium gathered thought leaders in the areas of tissue engineering, regenerative medicine, and space-based research to identify the most promising opportunities to leverage the ISS for research and technology development to advance space-based biomanufacturing. The symposium was meant to serve as the first step in developing a roadmap to establish a robust and sustainable market for biomanufacturing in space. A perspective paper discussing the goals and outcomes of the symposium was published in [Preprints](#). Additionally, a peer-reviewed version of the perspective paper was published in [Stem Cell Reports](#). Since then, CASIS and NASA have worked to issue several funding opportunities based, in part, on the outcomes from the symposium. During this workshop, we will discuss the results of the previous symposium; address the work done by CASIS, NASA, and others since; and solicit feedback on next steps.

PUBLIC MEETING: ISS NATIONAL LABORATORY USER ADVISORY COMMITTEE

Meeting Date and Time: Monday, July 25, 2:30 p.m. ET

The ISS National Laboratory User Advisory Committee (UAC) provides CASIS with user input and perspective about the management of ISS National Lab resources. Conference registrants are invited to attend the UAC meeting to hear the latest updates and provide feedback to the committee.

EVENT: WOMEN'S NETWORKING BREAKFAST

Breakfast Date and Time: Thursday, July 28, 7:15 a.m. ET

Start your conference day with coffee, a light breakfast, and a lively speed-networking session. Share your experiences with other women in aerospace who are making big and bold impacts across the industry. Join us for a fun morning session with inspirational women.



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NASA, Apollo 8, Bill Anders
Processing: Jim Weigang

**In the 1960s,
our nation set
forth on a
voyage of
discovery to
the moon...
and
rediscovered
our planet.**

Image courtesy of NASA.



**In the 1980s,
our nation
joined with
other nations to
start humans
on a course to
continuously
live and work
in space... and
rediscovered
ourselves.**

Image courtesy of NASA.



**In the 2020s,
where will our
imaginations
and voyages
to scientific
discovery
take us?**

Image courtesy of NASA.