



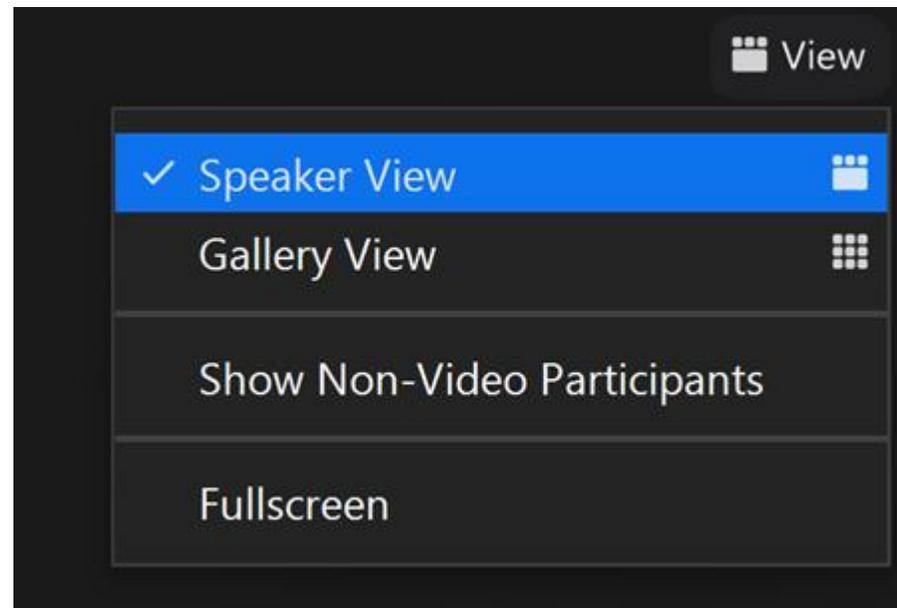
**KEYSTONE SPACE  
COLLABORATIVE**

# **Working Group**

**June 13, 2024**

# Housekeeping Notes

- All Attendees will be muted upon entry
- Please use Speaker View for the best experience
  - Upper right-hand corner
  - Click "Speaker View"





**KEYSTONE SPACE  
COLLABORATIVE**



University of  
**Pittsburgh**



**Babst | Calland**  
Attorneys at Law



**Carnegie  
Mellon  
University**



Appalachian  
Regional  
Commission



**Henry L. Hillman  
Foundation**

Richard  
King  
Mellon  
Foundation

**Thank you Keystone Space Sponsors!**



# June Working Group

## Agenda

- **Keystone Space Announcements & Updates**
  - Zoë Karabinus
- **International Space Station National Laboratory Overview & Update**
  - Michael Roberts
- **Open Discussion**



# 2024 ANNUAL CONFERENCE

October 28 - 29



Pittsburgh, PA

# June Working Group

## Keystone Space Announcements & Updates

**Early registration is open for the 2024 Keystone Space Annual Conference!** Join us for a gathering of national and regional stakeholders in the thriving commercial space industry, coming together to highlight and enhance the impact of our region.

**Don't miss out on discounted early registration!**  
**Scan the QR code to register now! →**



**Sponsorship opportunities for the 2024 Keystone Space Collaborative Annual Conference are now available!** By becoming a sponsor, you'll have the chance to showcase your business, make meaningful connections, and participate in engaging panels, insightful lectures, networking receptions, and more.



**Interested in sponsoring or exhibiting? Reach out to [info@keystonespace.org](mailto:info@keystonespace.org)**

Boost your company to new heights!

**SPONSORSHIP  
OPPORTUNITIES NOW  
AVAILABLE!**



**2024 ANNUAL  
CONFERENCE**

October 28 - 29



Pittsburgh, PA



# June Working Group

## Keystone Space Announcements & Updates

**Keystone Space is hiring! We're looking for a full-time Outreach Coordinator to join our team!** This position will be responsible for:

- Overseeing membership and sponsorship programs, including outreach and strategic initiatives to drive funding
- Spearheading the planning and execution of marketing initiatives to promote organizational objectives and foster engagement
- Supporting planning and management of various organizational events including networking sessions, workshops, seminars and the Keystone Space Annual Conference
- And many more important initiatives to grow the Keystone Space Collaborative and our impact

**Interested applicants should submit a resume and brief cover letter to [info@keystonespace.org](mailto:info@keystonespace.org)**



# June Working Group

## International Space Station National Laboratory Overview & Update



**Michael Roberts, PhD**  
**Chief Scientist**

International Space Station, National Laboratory



ISS NATIONAL LABORATORY

# ISS National Lab Programs, Partnerships, and Initiatives

Michael Roberts, PhD | Chief Scientific Officer

Keystone Space Collaborative Working Group, June Meeting

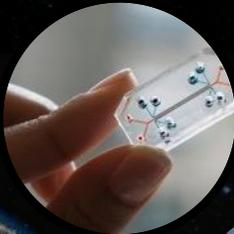
13 June 2024

# International Space Station: A Lab Off the Earth, For the Earth

A world-class laboratory in space enabling more than 4,400 researchers from 109 countries to conduct more than 3,000 experiments in the unique environment of low Earth orbit.



**Human Research**

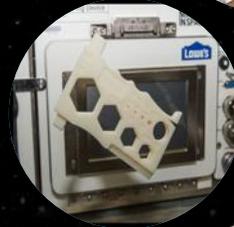
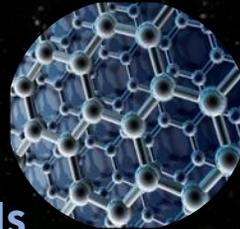


**Biology & Biotechnology**



**Combustion**

**Fluids & Materials**



**Advanced Materials & Manufacturing**



**STEM Engagement and Workforce Development**



**In-Space Production Applications (InSPA)**

*InSPA NRAs and NLRAs*

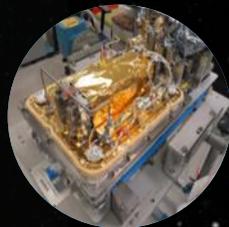


**Earth & Space Observation**



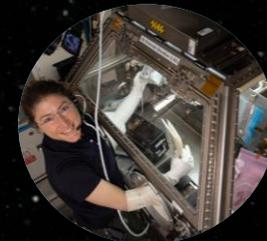
**ISS National Lab**

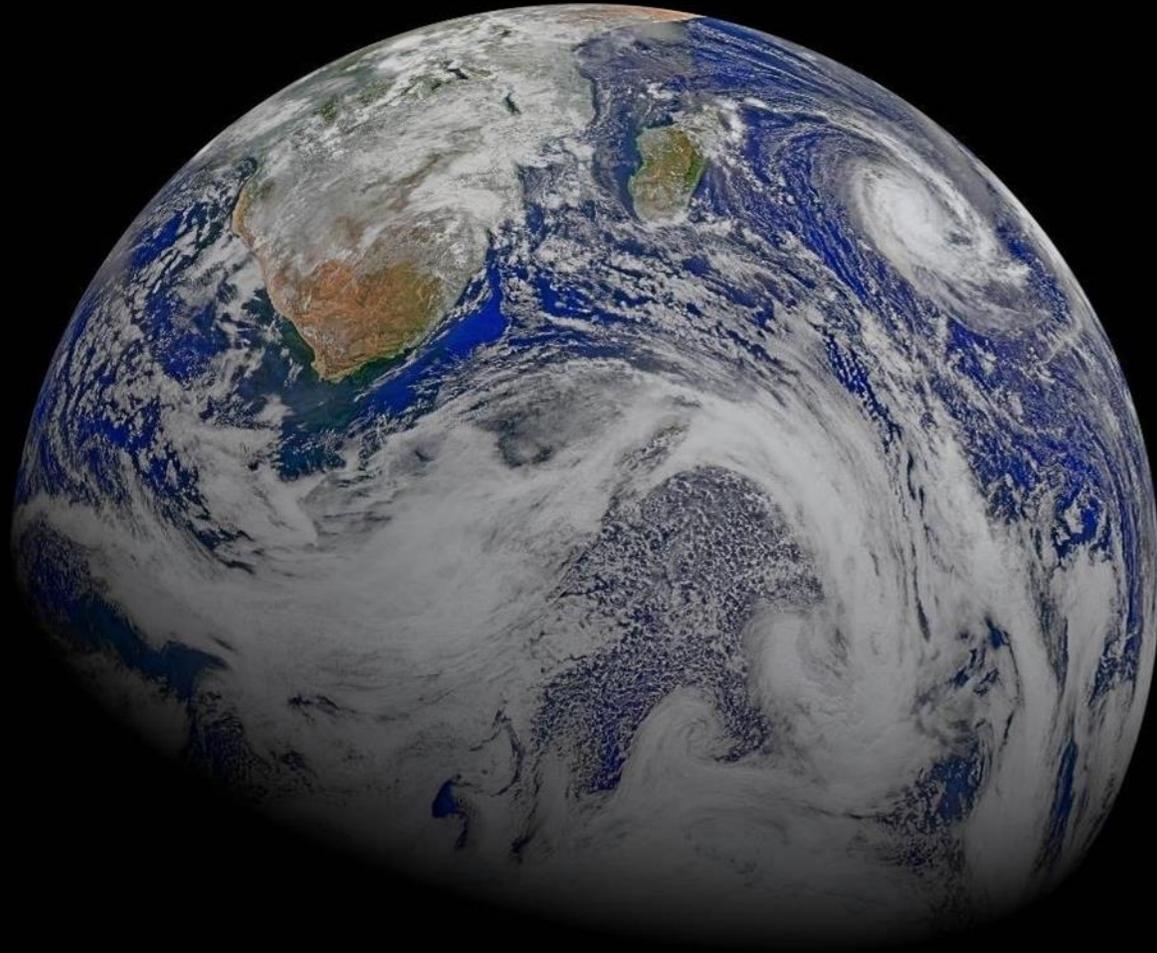
*Igniting Innovation NLRAs*



**Technology Demonstration**

**In-Space Biomanufacturing**





# **The Center for the Advancement Of Science In Space™ (CASIS™)**

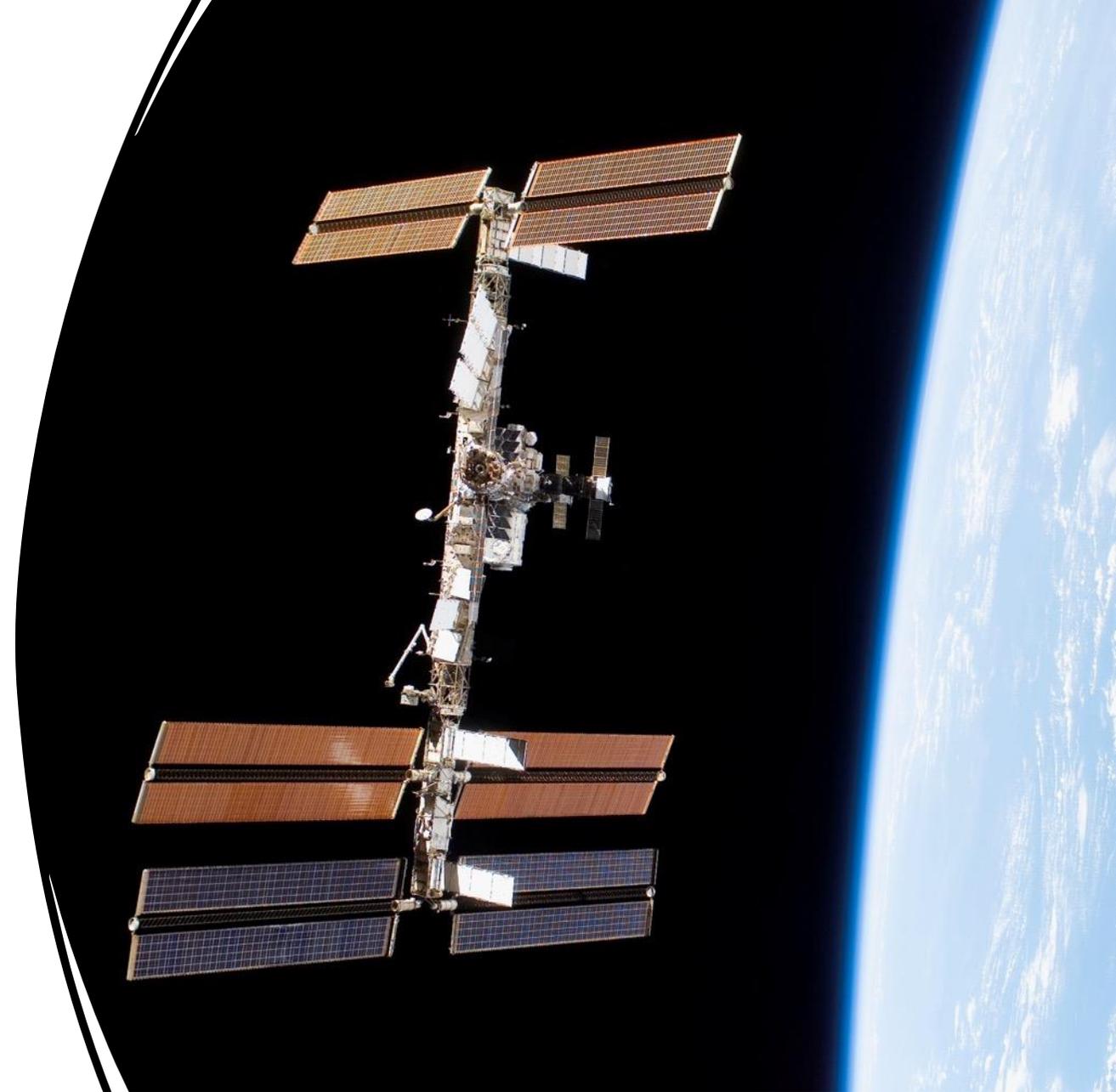
**Awarded a Cooperative Agreement in 2011 to  
work in partnership with NASA to manage the  
ISS National Laboratory® on the International  
Space Station (ISS).**

# ISS National Laboratory

**Offers a unique vantage point for scientific observation, technology development, and economic innovation in low Earth orbit that extends beyond NASA's exploration goals.**

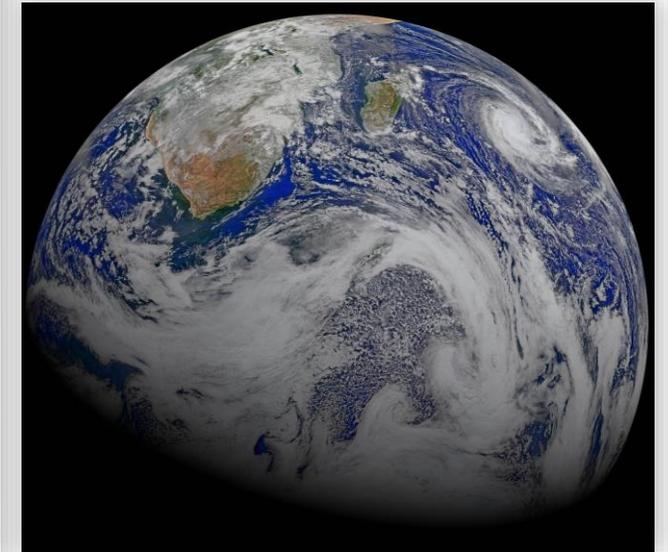
Access to space reveals features of biological and physical processes that cannot be seen or manipulated on Earth.

On the ISS, humans leverage microgravity and observe the planet to gain novel insight, identify challenges, understand human impacts on our surroundings, and improve lives here on Earth.



# ISS National Lab Portfolio by Strategic Focus Area

- Fundamental Science
- Technology Development & Demonstration
- In-Space Production Applications (InSPA)
- Commercial Service Provider Utilization
- STEM Engagement & Workforce Development





# Partnering with the NASA In Space Production Applications program to Accelerate Advanced Manufacturing

- As of the end of FY2023, NASA and the ISS National Lab have invested over \$60M and awarded over 25 InSPA awards via NRAs and NLRAs to U.S. entities seeking to demonstrate the production of advanced materials and products on the International Space Station.
- InSPA awards help companies raise the technological readiness level of manufacturing processes and products by leveraging  $\mu$ g to accelerate their transition to market, propelling U.S. industry toward the sustainable, scalable, and profitable demand for services and products manufactured in low Earth orbit for use on Earth.



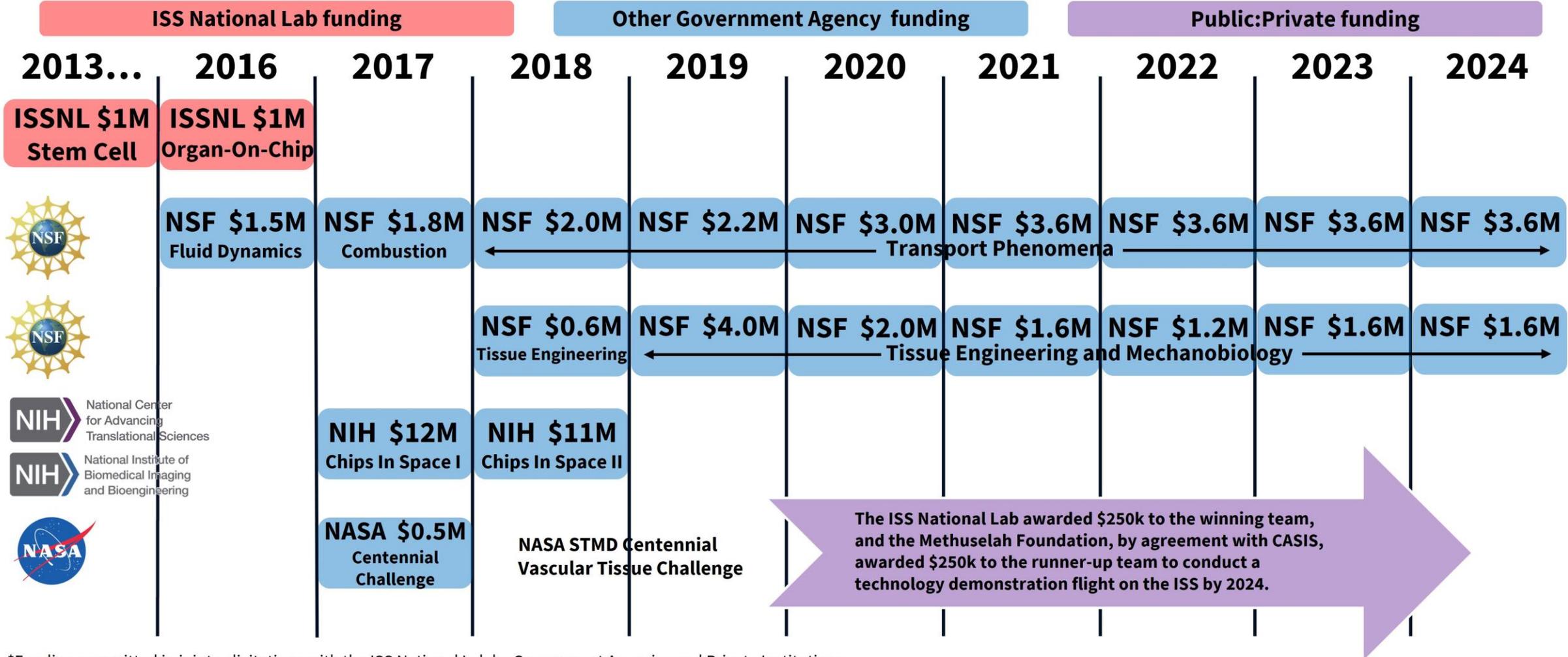
# Partnering with NASA Biological & Physical Sciences (BPS) to Address National Priorities including the Cancer Moonshot

Launched a new initiative in 2023 in partnership with the NASA BPS program:

***“Igniting Innovation: Science in Space to Cure Disease on Earth”***

- R&D moving us toward translational research and transformative applications to aid in the fight against cancer and other diseases that benefit from accelerated cell and tissue models in microgravity
- ISS National Lab to award 2 or more grants in July-2024 to support transformative technology development and in-space biomanufacturing R&D

# Partnering with Other U.S. Government Agencies To Support In Space R&D

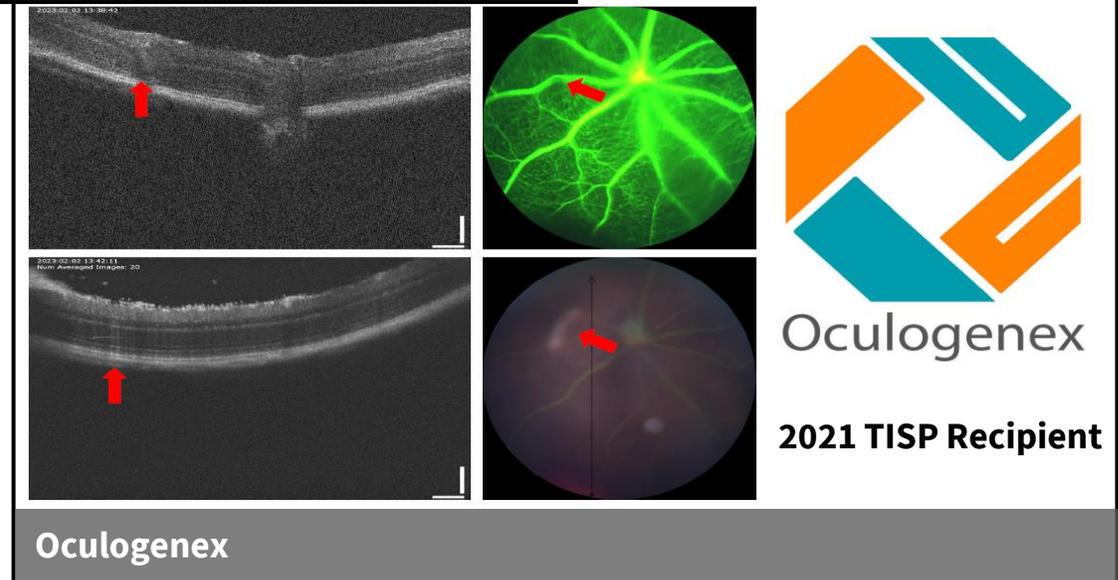
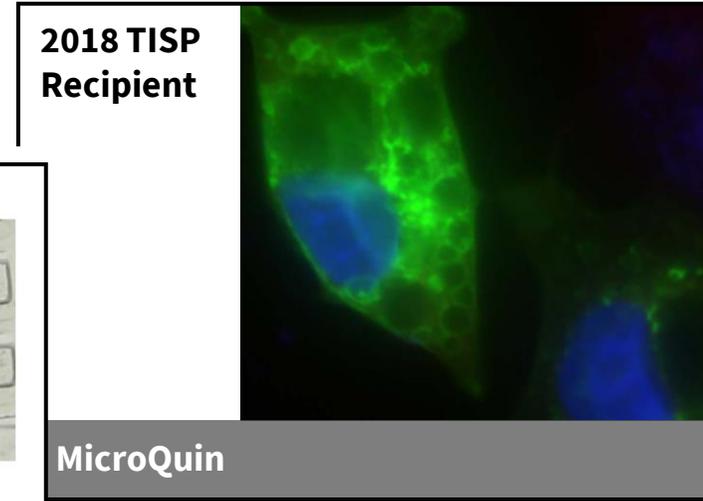
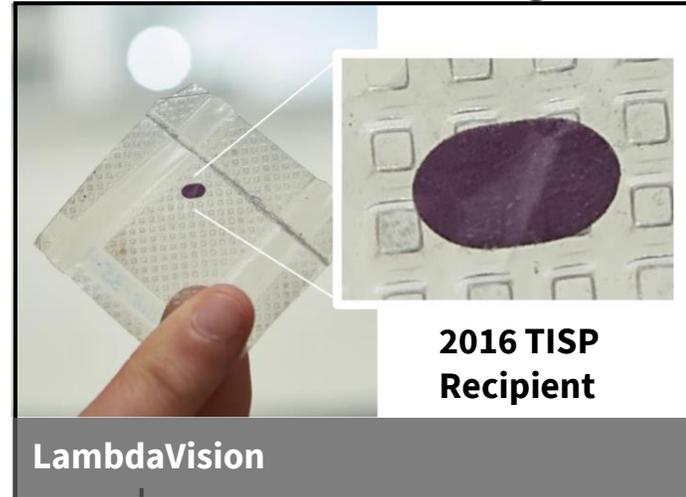


\*Funding committed in joint solicitations with the ISS National Lab by Government Agencies and Private Institutions

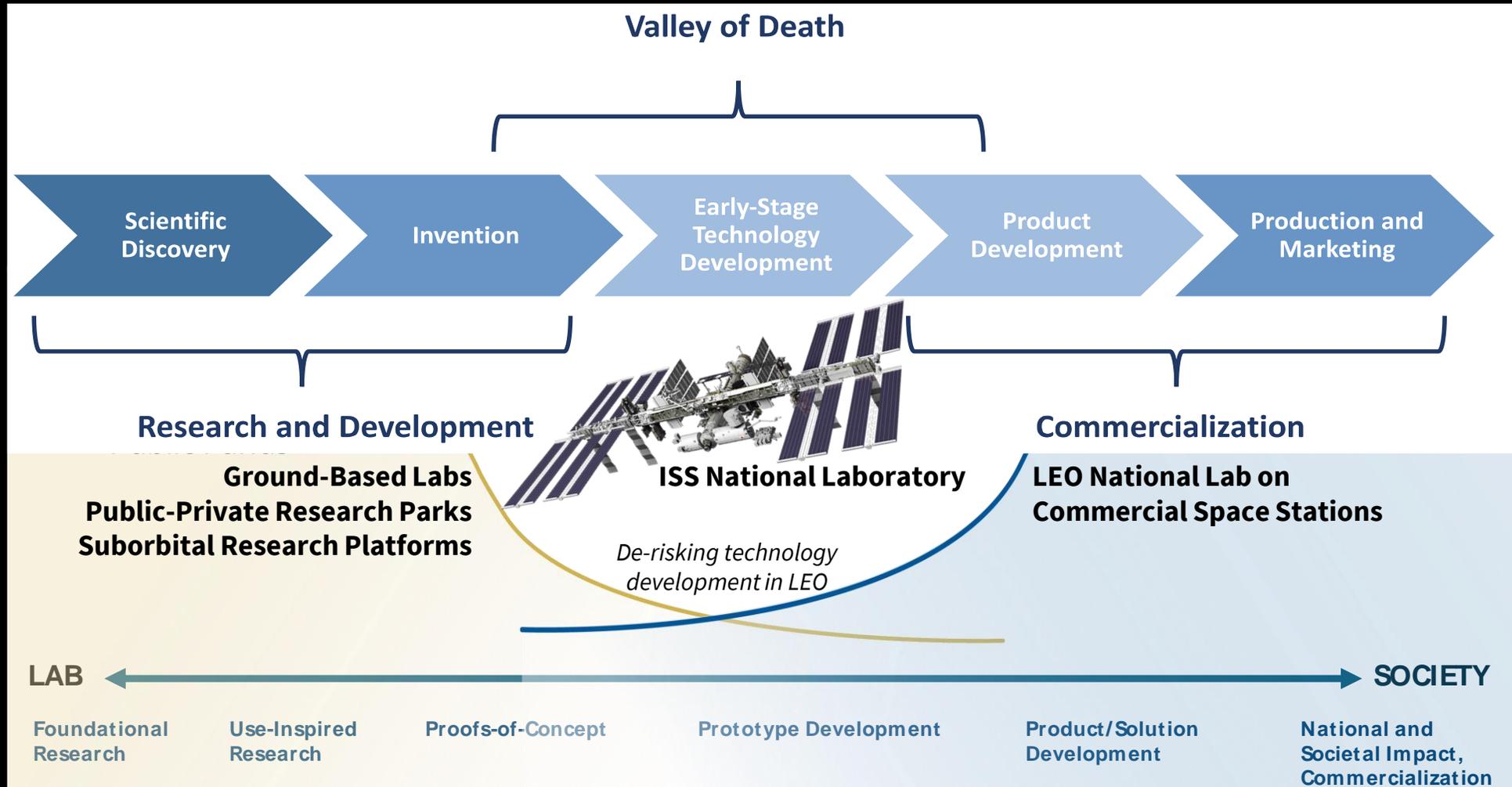
# Partnering with Start-up Companies via the CASIS-Boeing Technology In Space Prize Awarded annually at MassChallenge

## Past Awards

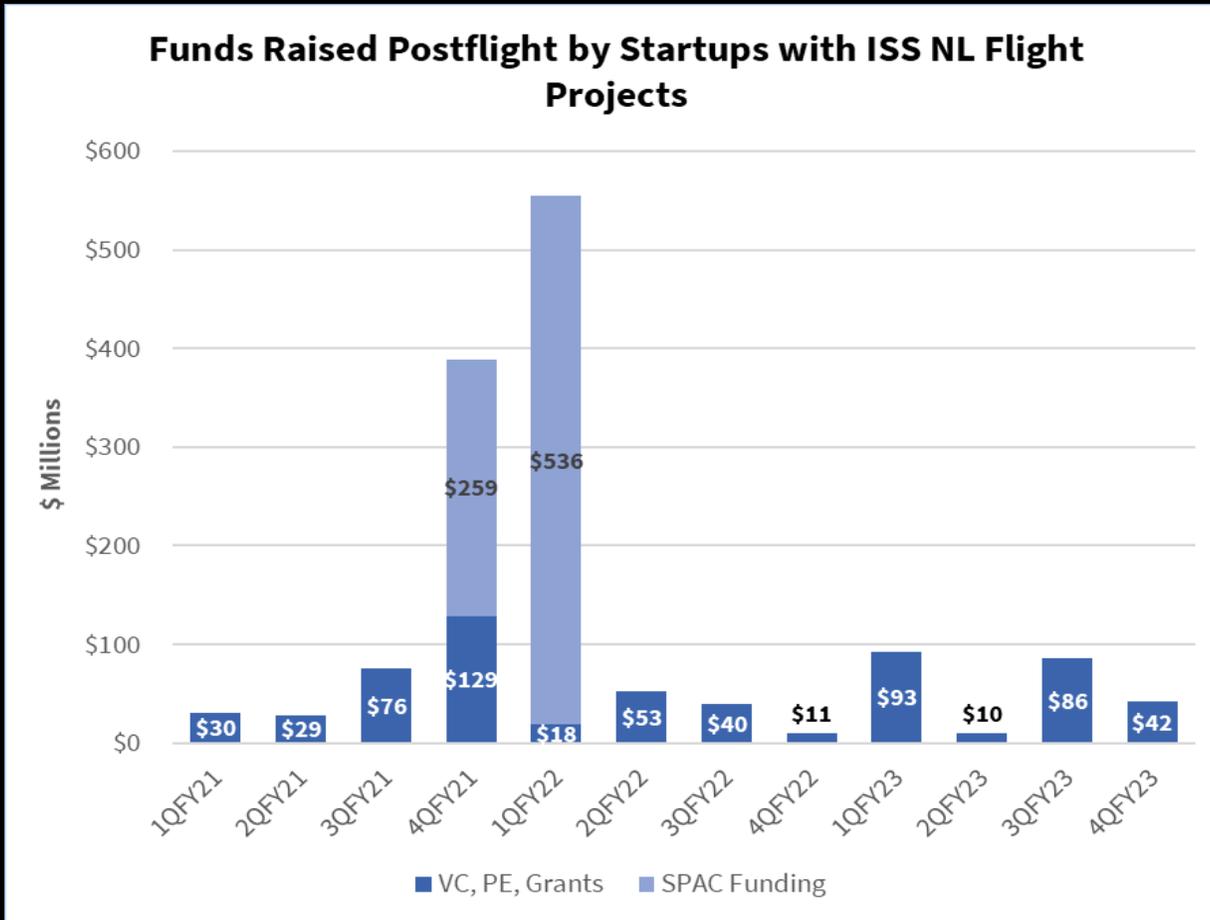
	<b>2023</b>
	Flux Works Symphony Biosciences
<b>2022</b>	
MachineBio	<b>2021</b>
	Krtkl Inc. Oculogenex
<b>2019</b>	
Axonis Therapeutics Encapsulate LLC	<b>2018</b>
	Kernal Biologics, Inc. MicroQuin
<b>2017</b>	
Cellino Biotech, Inc. Guardian Technologies MakerHealth	<b>2016</b>
	Angiex, Inc. Dover Lifesciences LambdaVision, Inc.



# Space Enables Value Creation and Accelerates Innovation to Translation



# Postflight Funding for ISS National Lab-Supported Startups



## Postflight funding in FY23 **\$231M**

- Startup interest remains strong, but lower capital availability continues to affect ISS National Lab post-award/postflight capital metrics.
- CLD realignment and NASA budget uncertainty highlights risks to emerging markets and customers' business models, particularly for those contemplating in-space manufacturing.

All-time postflight funding **\$2.1B**

All-time external funding **\$286M**

NASA's investment in CASIS **\$192M**

- Has resulted in **\$2.4B** in funding, a **12x multiplier**.

*Note: 3QFY23 data as of 10/4/23 and may not accurately capture all capital raising activity in the quarter.*

# Microgravity affects the physical properties of materials and mechanisms of transport (that in turn have profound effects upon biological systems)

## Microgravity removes gravity-dependent physical phenomena including:

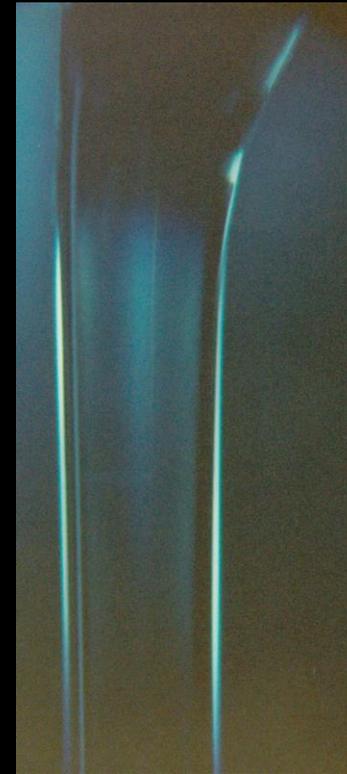
- Buoyancy-driven convection
- Density-driven segregation
- Matter-container interaction

## Resulting in fundamental changes in physical (and biological) systems:

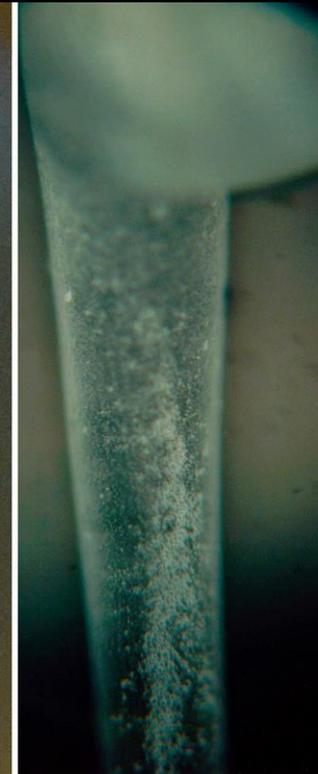
- Heat and mass transport
- Interfacial dynamics
- Multiphase system dynamics
- Solidification kinetics and thermodynamics
- Fluid dynamics

# For example, microgravity reduces nucleation during solidification processes

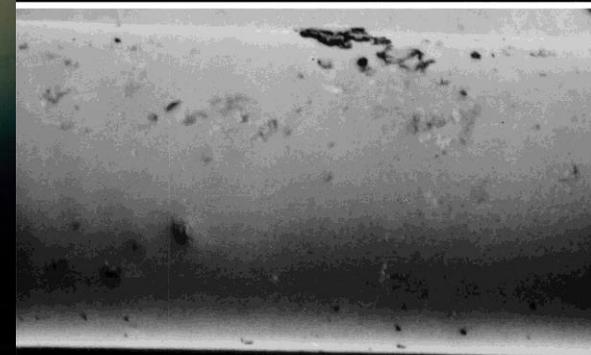
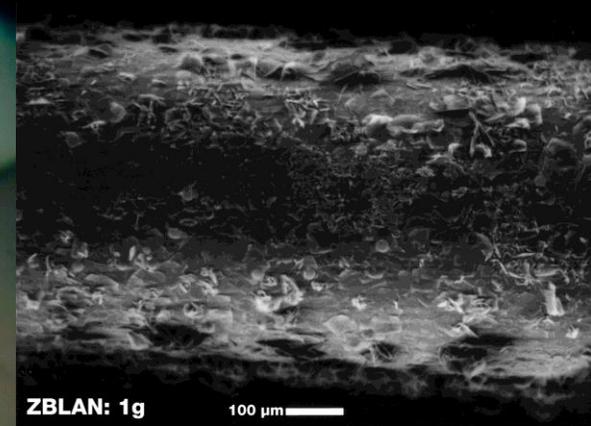
- ZBLAN has long been among the most promising of high-value, exotic optical fibers for optical signal transmission in the infrared range (IR to  $\sim 5 \mu\text{m}$ ) for multiple applications without significant signal attenuation
- The intrinsic loss limit of  $\sim 0.001\text{dB/km}$  far exceeds doped silica and other materials, but imperfections introduced during melt and solidification on Earth remain a challenge
- Microgravity mitigates the driving force for compositional segregation and crystal nucleation in the melt during solidification
- In addition to metallic glass, other high-value, high-entropy, metal alloys and ceramics benefit from microgravity processing



Microgravity  
( $\mu\text{g}$ )



Normal Gravity  
(1g)



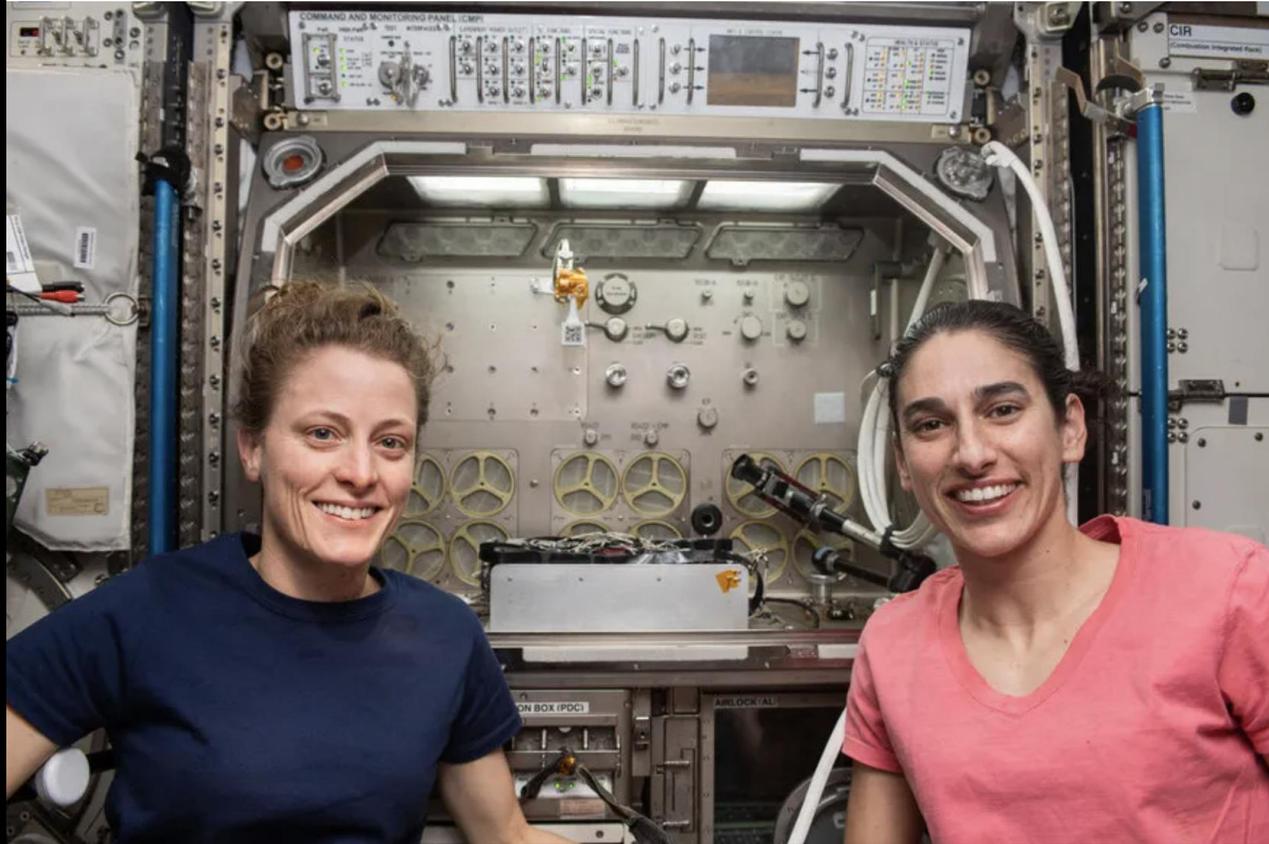
**ZBLAN Optical Fibers**  
 $\text{ZrF}_4\text{-BaF}_2\text{-LaF}_3\text{-AlF}_3\text{-NaF}$

# And progress toward in-space manufacturing continues....

## Flawless Photonics Kicking Glass

Silicon Valley startup produces more than 5 kilometers of ZBLAN in two weeks

Debra Werner February 23, 2024



**SPACENEWS**  
BUSINESS | POLITICS | PERSPECTIVE

Astronauts Loral O'Hara and Jasmin Moghbeli (from left) are pictured in front of the Microgravity Science Glovebox, a research facility for conducting biology and physics experiments in the International Space Station's Destiny laboratory module. Moghbeli installed Flawless Photonics' machine for drawing optical fiber in space in the Microgravity Science Glovebox.

Source: <https://spacenews.com/flawless-photonics-kicking-glass/>



# Unprecedented Technological Advancements in Crystallization

- Analysis of 50 years of crystallization experiments in space
- 90% of all published crystallization data demonstrate some improvement in one or more quantitative metrics
  - Size, structure, uniformity, resolution limit, mosaicity
- Near absence of gravity eliminates convection, eddy-currents, and sedimentation during crystallization
- This enables advances in drug discovery, drug development, pre-clinical testing, and manufacturing

## An Analysis of Publicly Available Microgravity Crystallization Data: Emergent Themes Across Crystal Types

Hannah Wright, Amari Williams, Ashley Wilkinson, Lynn Harper, Ken Savin, and Anne M. Wilson\*



Cite This: *Cryst. Growth Des.* 2022, 22, 6849–6851



Read Online

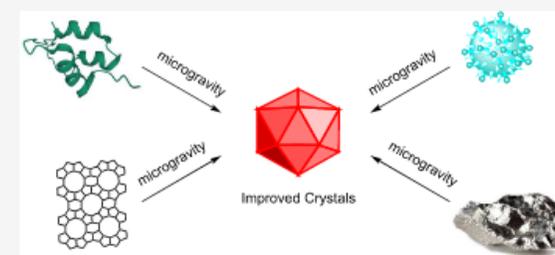
ACCESS |

Metrics & More

Article Recommendations

Supporting Information

**ABSTRACT:** A retrospective analysis, curation, and organization into searchable databases of public domain data of crystals grown in microgravity was undertaken. The data were then analyzed and marked for improved results (size, structure, uniformity, resolution limit, and/or mosaicity). Overall, 90% of the crystals analyzed showed improvement in one or more of the metrics utilized for analysis.



Microgravity crystallization efforts have been undertaken since 1973 with Apollo and Skylab, advanced with Mir, the Space Shuttle, and individual recovery satellites, and has continued with the International Space Station and Tiangong. Reviews of crystallization data have demonstrated some of the aspects of improvement to the crystals produced in microgravity.<sup>1–6</sup> There it is known that there have been numerous crystals produced in microgravity, especially proteins,<sup>7</sup> but the data for most of these crystals are proprietary. However, a searchable compendium of the public domain crystal data is still needed in order for researchers to evaluate the data, identify opportunities, and come to their own conclusions. In order to address this need, we developed such a searchable database and performed an initial meta-analysis.

Included in our database are the compounds by name,

ground. With repeat experiments involving the same compounds removed, there are 187 unique compounds (130 macromolecules and 61 inorganics) that have been crystallized in space. This data set underwent an initial, more detailed analysis. The authors acknowledge a predisposition in the literature toward publishing results that are favorable (positive outcome bias).<sup>8</sup> Even with this caveat, a preliminary evaluation of the aggregated crystal data is warranted.

Improvements in crystals grown in microgravity versus ground experiments were evaluated using the following metrics: size, structurally better, more uniform, improved resolution limit, and improved mosaicity (see Table 1). Not all studies reported the same information as separate metrics are appropriate for different applications. For example, improved resolution limit and mosaicity are metrics that apply to

[pubs.acs.org/doi/full/10.1021/acs.cgd.2c01056](https://pubs.acs.org/doi/full/10.1021/acs.cgd.2c01056)

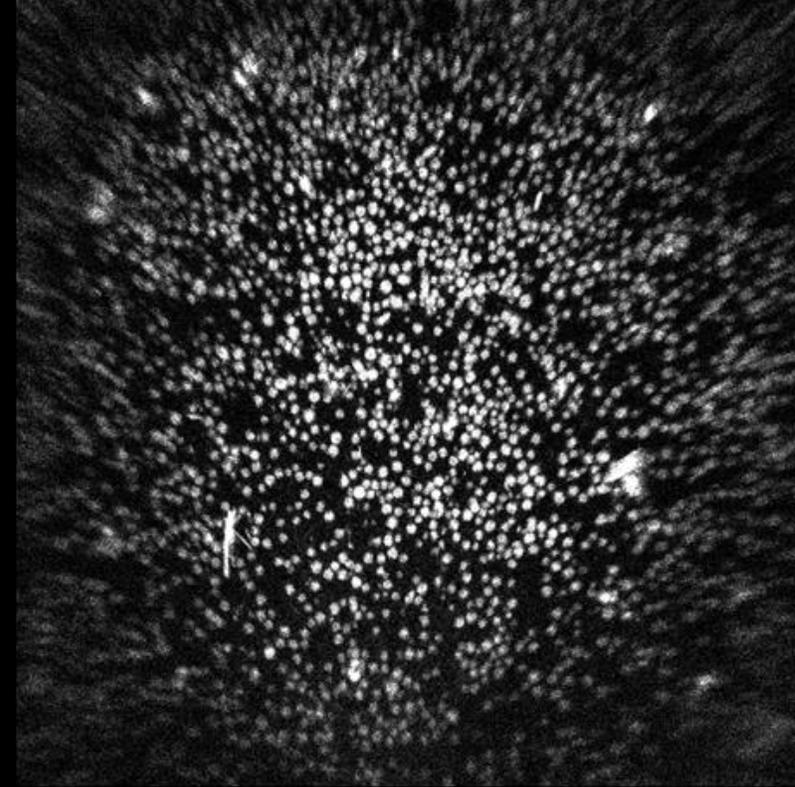
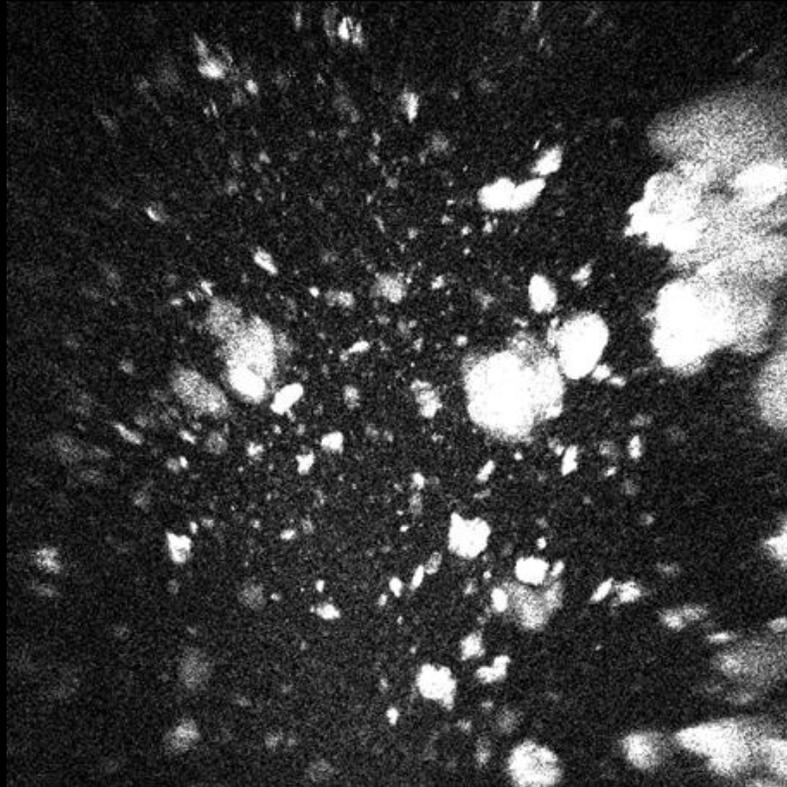


# Merck Keytruda<sup>®</sup> Study

## Ground

## Microgravity

Merck  
Keytruda<sup>®</sup>



Crystallization of the active pharmaceutical ingredient in Keytruda<sup>®</sup>, *pembrolizumab*, in microgravity achieved greatly improved homodispersity (shown on the right). This discovery promises to reduce manufacturing costs by limiting purification steps and to increase drug safety and efficacy to improve the quality of life for patients on Earth.

# InSPA Biomanufacturing

Startup company LambdaVision, initially funded through an ISS National Lab and Boeing Technology in Space Prize, is working with Space Tango to improve the process of in-space manufacturing by **layer-by-layer, thin-layer deposition** of the protein bacteriorhodopsin to manufacture artificial retinas with superior performance for the treatment of macular degeneration and retinitis pigmentosa on Earth.

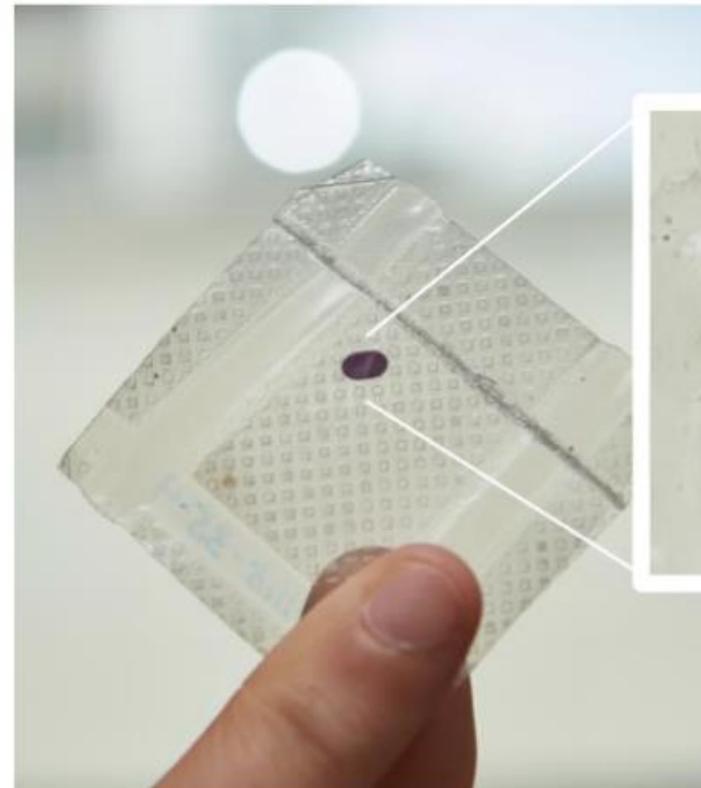


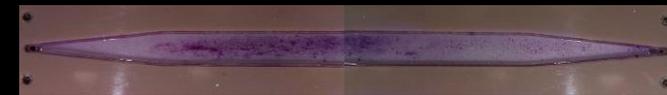
Image credit: LambdaVision

LambdaVision & Space Tango achieved their target of 200-layers of protein/polymer matrix with near perfect autonomous operations on their 5<sup>th</sup> flight.

Preflight



Demo 4  
(200 layers)



Demo 5  
(200 layers)



Image Credit: NASA and LambdaVision





# In-SPA: In-Space Production Applications Fuels Value Creation

In-SPA builds on 50+ years of  $\mu$ g research in space to accelerate the translation and application of new technologies on Earth that benefit humanity, from subatomic through global scale.

Medical Advances from Space for 50+ years

Quantum Subatomic



Cold Atom Lab

Molecular



Crystals  
Pharma  
Industrial  
Semiconductors

Thin Films



Medical Devices  
Artificial Retinas  
Nerve Regen

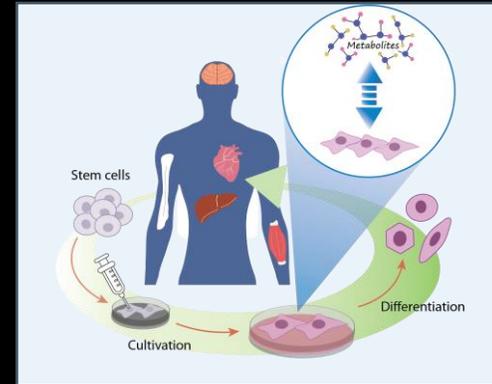
Semiconductors

Alloys and Photonics



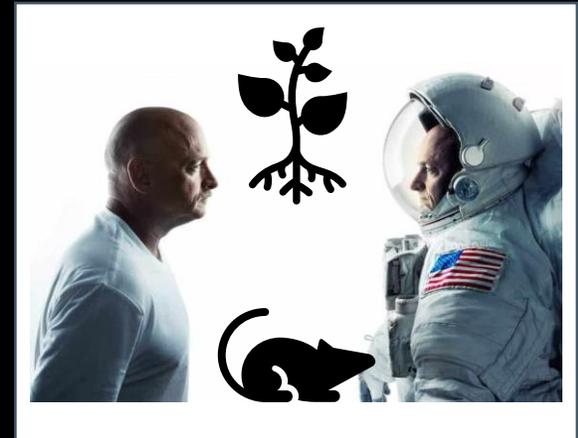
ZBLAN Optical Fibers  
Semiconductors

Cells and Tissues



Cancer  
Neurodegenerative  
Stem Cells  
3D Tissues  
Artificial Organs

Whole Organisms



Microbes  
Plants  
Animals  
Humans

High-throughput 11.9 km optical fiber manufactured on the ISS to commercial lengths

Space-manufactured artificial retinas ready for animal trials, Semiconductors in parabolic testing

90% of crystals manufactured in space since 1973 improved in structure, uniformity, size, or reduction of defects

Manufacturing Bose-Einstein condensates in space near absolute zero since 2019

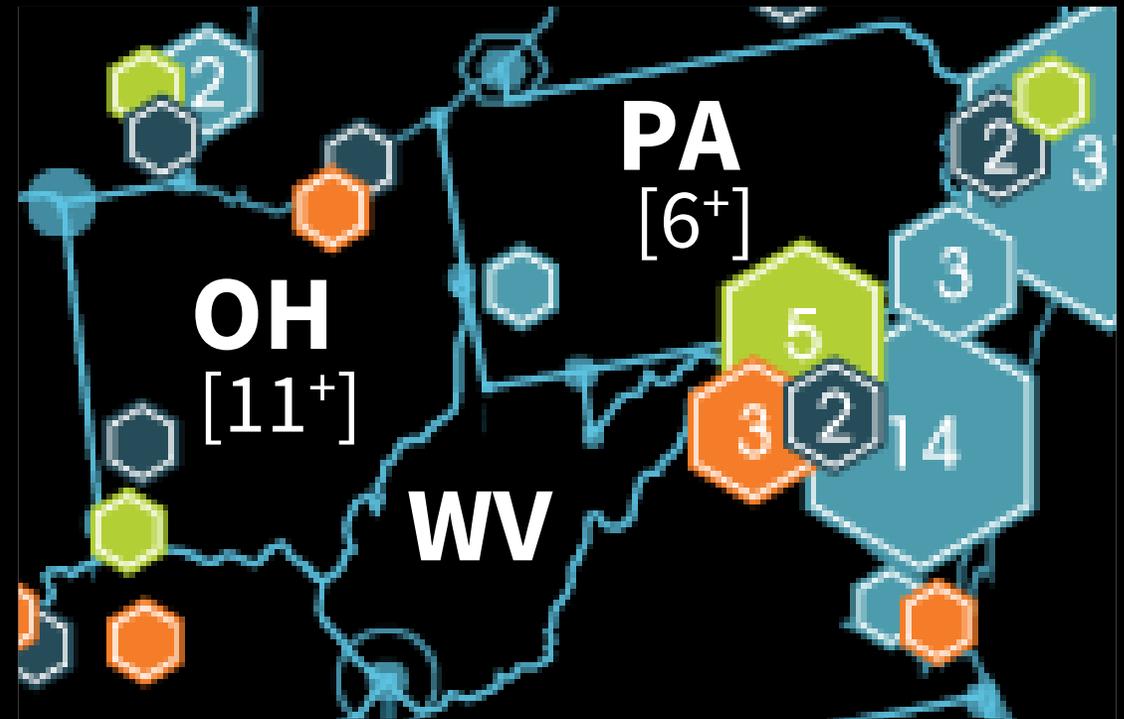
# ISS National Lab Partners and Projects from the Keystone Space Collaborative

## OHIO

-  NASA Glenn Research Center (Cleveland)
-  Zin Technologies [Voyager Space] (Cleveland)
-  USAF AFRL (Wright-Patterson AFB)
-  Cornerstone Research Group Inc. (Miamisburg)
-  Goodyear Tire & Rubber Co. (Akron)
-  Northrop Grumman (Cincinnati)
-  Procter & Gamble (Cincinnati)
-  Case Western University (Cleveland)
-  University of Toledo

## PENNSYLVANIA

-  Astrobotic Technology (Pittsburgh)
-  GlaxoSmithKline (Philadelphia)
-  Children's Hospital of Philadelphia
-  Lehigh University
-  University of Pittsburgh



## LEGEND

-  Implementation Partners
-  Investor Network Members
-  ISSNL Sponsored Projects and Institutions
-  Space Station Explorers Program Partners



# After the ISS

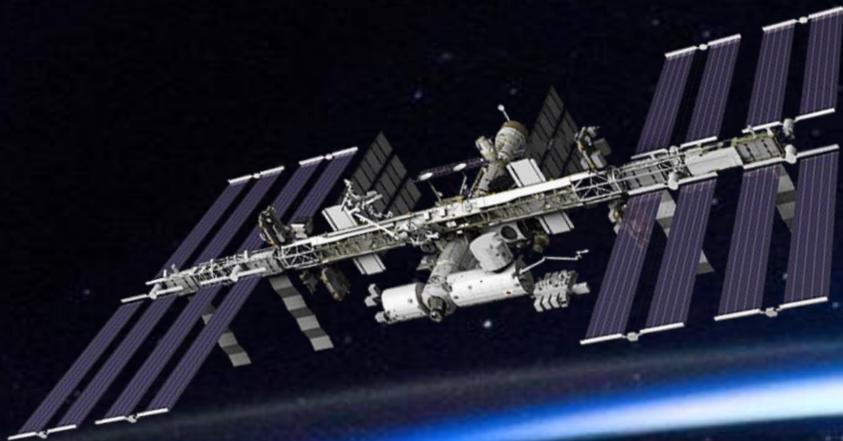
- The ISS will be deorbited around 2030.
- Commercial LEO Destinations (CLDs) will be operating in low Earth orbit before 2030.
- A planned transition from the ISS National Lab to a National Lab operating on multiple CLD platforms is under study.

# 2000 – 2030<sup>ish</sup>

2000-2010 DECADE OF ASSEMBLY

2010-2020 DECADE OF UTILIZATION

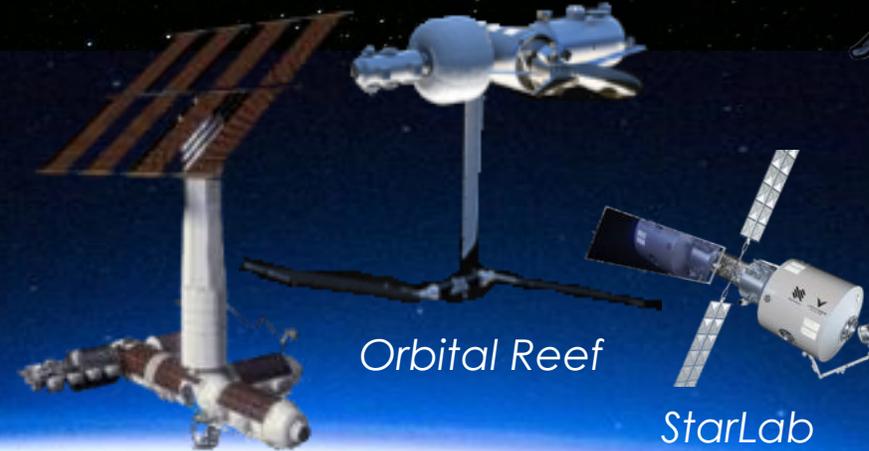
2020-2030 DECADE OF RESULTS



**International Space Station**

# 2026<sup>ish</sup> – the future

TRANSITION TO COMMERCIAL LEO DESTINATIONS  
& A NEW LEO NATIONAL LAB CONCEPT



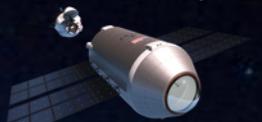
*Orbital Reef*

*StarLab*

*Axiom Station*



*SpaceX  
Starship*



*Vast  
Haven-1*



*Varda*

**Commercial LEO Destinations**

**Free-flyer Commercial Space Stations and  
Microgravity Manufacturing Platforms**

*Northrop Grumman  
Space Station*





# THANK YOU

Discover the unique advantages of research in microgravity with the ISS National Lab.



**ISS National Lab**



**ISS\_CASIS**



**ISS National Lab**



**ISS National Lab**



**ISSNationalLab.org**

**mroberts@ISSNationalLab.org**

All images courtesy of NASA or the ISS National Lab unless otherwise stated.



# ISSRDC

## 13th Annual International Space Station Research and Development Conference (ISSRDC)

July 29 - August 1, 2024 | Boston, MA



## ISSRDC Day 1 – Tuesday, July 30

Opening Keynote – Lugo/Weigel/Mulholland, ISS Astronaut Downlink

Igniting Innovation Announcement

Panel – Trailblazing New Frontiers in Science on the Space Station

Fireside Chats– Boeing with Starliner Astronaut Suni Williams; MASS Challenge

Panel – Human Factors of Spaceflight

Technical Sessions, Networking Reception

## Pre-Conference – Monday, July 29

Workshop: Biomanufacturing in space & Workforce Development

Workshop: Production of advanced materials in space

Opening Reception

## ISSRDC Day 2 – Wednesday, July 31

Morning Keynote – Dr. Kate Darling (MIT) – Human–Robot Interaction

Lightning Talk – Vast Space

Lunch Keynote – Jim Free, Associate Administrator, NASA

Panel – LEO Research Continuity

Fireside Chat – Technology Development on ISS and Future Platforms

Lightning Talk – Aurelia Ekblaw, the Aurelia Institute

Panel – Investing in Space – the Path Forward

Technical Sessions, Networking Reception

## ISSRDC Day 3 – Thursday, August 1

Panel – ISS International Partners

Lightning Talk – European Space Agency Space Rider

Panel – Accessibility to Low Earth Orbit (STEM)

Lunch Keynote – Astronaut Woody Hoburg, NASA

Technical Sessions

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



# ISSRDC

*Day 1 Session*

## Trailblazing New Frontiers in Science on the Space Station

International Space Station  
Research & Development Conference

July 29 - August 1, 2024 | Boston, MA

**#ISSRDC**

***Day 1***  
**Tuesday, July 30**

**Morning Keynote:**

**Ray Lugo**, CEO, ISS National Lab

**Dana Weigel**, Director, ISS Program Office, NASA

**John Mulholland**, Vice President, Boeing

**Live Astronaut Downlink From the ISS**

**Plenary: Trailblazing New Frontiers in Science on the ISS**

**Tony Atala**, M.D., WFIRM

**Catriona Jamieson**, M.D., Ph.D., UCSD

**Adrian Radocea**, Ph.D., Varda Space

**Ken Savin**, Ph.D., Redwire Space

<https://www.issnationallab.org/release-issrdc2024-trailblazing-panel/>



International Space Station  
Research & Development Conference

July 29 - August 1, 2024  
Boston, MA

**#ISSRDC**

***Day 2 Morning Keynote***  
**Wednesday, July 31**



**Dr. Kate Darling**

Leading Expert in Social Robotics &  
MIT Media Lab Research Scientist

<https://www.issnationallab.org/release-issrdc2024-kate-darling-mit/>



International Space Station  
Research & Development Conference

July 29 - August 1, 2024  
Boston, MA

**#ISSRDC**

***Day 2 Luncheon Keynote***  
**Wednesday, July 31**



**Jim Free**  
NASA Associate Administrator



International Space Station  
Research & Development Conference

July 29 - August 1, 2024  
Boston, MA

**#ISSRDC**

***Day 3 Luncheon Keynote***  
**Thursday, August 1**



**Warren "Woody" Hoburg**  
NASA Astronaut



# ISSRDC

International Space Station Research  
and Development Conference

---

July 29 – Aug 1, 2024 | Boston, MA

**REGISTER NOW**

***<https://issconference.org/about/conference-rates/event-registration/>***





# Open Discussion

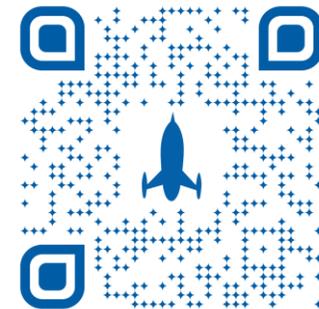
## Q&A

- Needs?
- Opportunities?
- Connections?



# KEYSTONE SPACE COLLABORATIVE

# Thank You!



**Next Working Group: Thursday, July 18, 2024**  
**Register now on our website!**