International Space Station National Laboratory
Annual Report for Fiscal Year 2023

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Center for the Advancement of Science in Space, Inc.

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About the ISS National Laboratory

Every day, 250 miles above our planet, amazing research and technology development to improve life on Earth takes place onboard the International Space Station (ISS). Researchers from academic institutions, private industry, and U.S. government agencies conduct investigations sponsored by the ISS National Laboratory® that leverage unique conditions found only in space. From improving quality of life for cancer patients to developing innovative treatments for osteoporosis, identifying potential solutions to address climate change, and even one day manufacturing artificial tissue and organs in space, we're enabling a broad community of dreamers and doers to solve some of the world's most pressing challenges. The Center for the Advancement of Science in Space™ (CASIS™) manages the ISS National Lab, under Cooperative Agreement with NASA. Visit our website at www.ISSNationalLab.org.

Mission:

We manage the premier space laboratory, providing expertise, connection, and inspiration to visionaries.

Vision:

To be the leading source for innovation in space, enabling life-changing benefits for humanity.

Core Values:

Integrity – We always strive to be true to ourselves and do the right thing.
Service – We work as a team with humility of heart and trust in each other.
Stewardship – We treasure our responsibility to fulfill our mission with care and excellence.

Strategic Priorities:

- Develop and maintain organizational resources to successfully manage the ISS National Lab to enable cutting edge research, technology development, and educational outreach in LEO.
- Establish, foster, and maintain public-private partnerships that maximize value creation from ISS National Lab resources.
- Serve all current and future stakeholders as "honest brokers," providing impartial access to resources and information as a trusted neutral partner.
- Be the recognized experts in managing a space-based national lab.

Executive Summary

The many accomplishments of the International Space Station (ISS) National Laboratory in fiscal year 2023 (FY23) are indicative of its ongoing success in facilitating cutting-edge research and technology development (R&D) in space to benefit humanity and in establishing a robust economy in low Earth orbit (LEO). The ISS National Lab continues to play a crucial role in demonstrating the value of space-based R&D and in building the operational and cooperative infrastructure to drive broad market expansion and set the stage for a smooth transition to the commercial LEO destinations (CLDs) of the future.

FY23 was a record-breaking year in terms of launches and payloads delivered to the orbiting laboratory, signaling an increased and regular cadence of access to LEO through the ISS National Lab. More than 80 percent of ISS National Lab payloads delivered this year were from commercial entities, and $20.5 million of private-sector funding was committed to support ISS National Lab-sponsored projects—demonstrating an increasing interest in space-based R&D among industry users and their willingness to invest their own money in such endeavors.

> ***"The ISS National Lab saw another record year in 2023, with the most projects delivered in a single year and meeting or exceeding all targets. We are well into the decade of results from research on the ISS, expanding its use in new, exciting, and innovative ways while growing government and commercial partnerships that will continue on commercial low Earth orbit destinations."***
>
> *– Robyn Gatens, NASA Director of the International Space Station*

Additionally, several ISS National Lab users are returning to conduct follow-on research, indicating the value of iterative R&D. To further enable multiphase research, the ISS National Lab partnered with NASA's Biological and Physical Sciences (BPS) Division for the first time on a new solicitation to advance critical research on cancer and other diseases. ISS National Lab solicitations have also extended accessibility to new research communities, as more than 70 percent of newly selected projects this year were from new-to-space users.

CASIS continues to foster public-private partnerships that maximize value creation from ISS National lab resources, maintaining longstanding collaborations with U.S. government agencies such as the U.S. National Science Foundation (NSF) and the National Institutes of Health (NIH). In FY23, nearly 40 peer-reviewed publications related to ISS National Lab-sponsored research were published, and of those, more than half were from investigations funded by NSF and NIH to advance fundamental science. Additionally, a growing number of patents and products related to ISS National Lab-sponsored research demonstrates the tangible value of space-based R&D.

To enhance the supply side of the LEO economy, the ISS National Lab continues to facilitate business growth for companies and organizations that offer services related to payload development. In FY23, more than 80 percent of CASIS funding was used to cover researcher costs for such Implementation Partner services, and more than 60 percent of payloads delivered were

flown through agreements that allow Commercial Service Providers to supply their customers with easy access to the facilities they own and operate on station.

Despite challenging capital market conditions in FY23, $230.5 million in funding was raised postflight by startups with ISS National Lab-sponsored projects, bringing the all-time cumulative total to nearly $2.1 billion. To date, CASIS has facilitated more than 1,300 capital introductions between startups and investors in the ISS National Lab investor network.

A robust space industry workforce is vital to the success of the LEO economy, and the ISS National Lab continues to support workforce development through the James A. Abrahamson Space Leader Fellowship program, which helps college students position themselves for careers in the space industry.

In FY23, high-quality content, strategic marketing campaigns, and intensified public relations efforts led to a significant increase in awareness of ISS National Lab activities and successful results. Three new issues of *Upward* magazine garnered nearly 50,000 online page views, and targeted press releases resulted in more than 17,000 media pickups. Additionally, nearly 900 people attended the 12th annual ISS Research and Development Conference (ISSRDC) in Seattle to engage with key players directing the future of R&D in LEO.

"Research and technology development on the ISS is hitting on all cylinders. We are privileged to be a part of NASA's decade of results as we fulfill the goals set forth for the ISS National Lab. The board has never been more excited with the performance of the ISS National Lab team and its cooperative relationship with NASA. We look forward to many more successes in the coming years."

– David Radzanowski, Chair of the CASIS Board of Directors

This year, CASIS continued to grow and evolve and made great strides in optimizing business systems management and in filling open positions across the organization. CASIS also expanded its board of directors, with the addition of Sol Glasner and former NASA Johnson Space Center Chief Financial Officer Dorothy Rasco.

For a snapshot of ISS National Lab FY23 activities across the U.S., see the map in Appendix C.

A Personal Note From Ramon Lugo, CEO of CASIS:

As I enter the third year of my tenure with the ISS National Lab, I look back on the amazing accomplishments of the past year. FY23 has been a remarkable year for our organization, marked by exceptional performance, groundbreaking achievements, and a renewed sense of purpose. I am exceedingly proud of the team's dedication and resilience, which have been instrumental in driving success.

Through seamless collaboration with NASA and our industry partners, we streamlined operations and consistently exceeded expectations, delivering more than 100 payloads to station and achieving amazing results that demonstrate the value of space-based R&D. This year, we hosted our most successful ISSRDC to date, attracting nearly 900 attendees and generating unparalleled engagement. The event showcased our industry leadership and solidified our position as a thought leader in our field. This sets a high bar for the future, and we are ready to deliver.

We have maintained a close and productive partnership with NASA, working together to advance our shared goals. NASA's support has been invaluable in enabling us to execute our R&D initiatives, and it will be critical in facing the challenges that lie ahead. Similarly, nothing we accomplish is without the support of our industry and academic partners.

We are excited about the future of our organization and are confident we can achieve even greater accomplishments in the years to come. We have set ambitious goals for the coming year, and we are committed to investing in our people and our programs to ensure continued success. The future is bright, made brighter by the strength of the ISS National Lab and our collaborations with NASA, U.S. government agencies, and our partners in industry and academia. I look forward to increasing engagement with our stakeholders in FY24 and the many successes ahead as we work to carry out our incredible mission.

FY23 Metrics

ISS NATIONAL LAB UTILIZATION AND OPERATIONS TARGET METRICS

TARGET METRIC	FY23 Total	FY23 Target	FY23 Stretch
FUNDAMENTAL SCIENCE			
1) Fundamental Science projects selected	10	10	15
2) External funding supporting Fundamental Science users of the ISS National Lab	$4.3M	$4M	N/A
APPLIED RESEARCH & DEVELOPMENT			
3) Applied Research & Development projects selected	8	8	N/A
4) Ratio of external funding to CASIS funding (self-reported) supporting Applied Research & Development users of the ISS National Lab (cumulative)	1:1	1:1	2:1
TECHNOLOGY DEMONSTRATION			
5) Technology Demonstration projects selected	14	12	15
6) Ratio of external funding to CASIS funding (self-reported) supporting Technology Demonstration users of the ISS National Lab (cumulative)	8:1	4:1	6:1
EDUCATION & OUTREACH			
7) Education & Outreach projects selected	9	7	9
8) Total individuals participating in ISS National Lab Education & Outreach programs and projects (self-reported)	10,478,642	2M	4M
9) Total individual users of ISS National Lab online education products (self-reported)	25,872,446	5M	8M
PROPOSAL MANAGEMENT			
10) Time from solicitation close to selection/nonselection notification (cumulative)	63	≤65 days	N/A

ISS NATIONAL LAB UTILIZATION AND OPERATIONS TRACKING METRICS

The following metrics had no target for FY23 but were tracked internally and discussed in face-to-face meetings with NASA.

TRACKING METRIC	FY23 Total
1) Commercial Service Provider Facility Utilization payloads delivered	**75**
(a) **Percentage of Commercial Service Provider Facility Utilization payloads flown that meet the minimum research objectives (previous fiscal year quarter)** [a]	**97%**
(b) **Percentage of Commercial Service Provider Facility Utilization payloads flown that meet the payload integration expectations**	**58%**
2) Education & Outreach payloads delivered	**3**

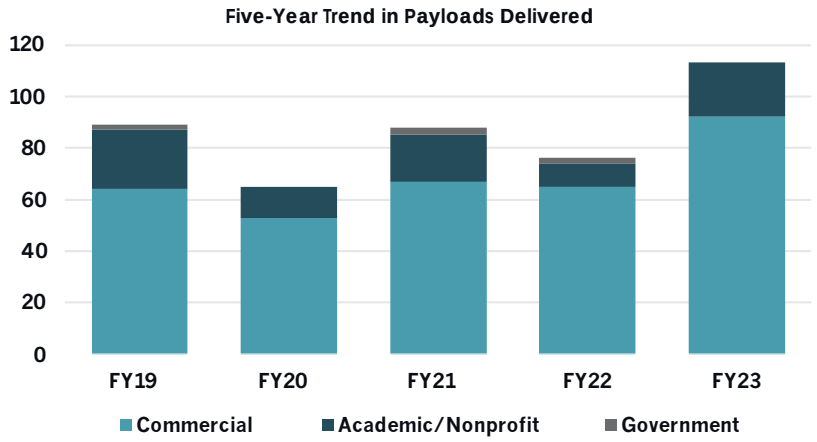
3) Fundamental Science payloads delivered	**18**
(a) **Percentage of Fundamental Science payloads flown that meet the minimum research objectives (previous fiscal year quarter)** [a]	**67%**
(b) **Percentage of Fundamental Science payloads flown that meet the payload integration expectations**	**67%**
4) Applied Research & Development payloads delivered	**7**
(a) **Percentage of Applied Research & Development payloads flown that meet the payload integration expectations**	**57%**
5) Technology Demonstration payloads delivered	**10**
(a) **Percentage of Technology Demonstration payloads flown that meet the minimum research objectives (previous fiscal year quarter)** [a]	**90%**
(b) **Percentage of Technology Demonstration payloads flown that meet the payload integration expectations**	**40%**
6) Total ISS National Lab-sponsored payloads delivered	**113**
7) Total external funding committed	**$26,041,199**
8) Multiplier on CASIS grant funding committed (cumulative)	**5:1**
9) Funds raised post award and postflight by startup companies with ISS National Lab-sponsored flight projects	
(a) **Funds raised postflight**	**$230.5M**
(b) **Funds raised post award**	**$240.9M**
10) Users by new/returning	
(a) **ISS National Lab return users**	**13**
(b) **ISS National Lab new users**	**29**
11) Users by type	
(a) **Commercial**	**19**
(b) **Academic/nonprofit**	**23**
(c) **Government agency**	**0**
12) ISS National Lab concepts received	**368**
13) ISS National Lab proposals received	**141**
13.1) ISS National Lab proposals reviewed	**116**
(a) **Total reviewed proposals rated very good or excellent**	**37**
(b) **Total reviewed proposals rated very good or excellent and not selected**	**10**
14) ISS National Lab projects selected	**42**
15) Active solicitations	**11**
16) Time from selection notification to agreement draft sent to principal investigator (cumulative)	**58**
17) New commercial facilities added	**1**
18) Commercial facilities (cumulative)	**24**
19) New Umbrella User Agreements executed	**1**
20) Percentage of Commercial Service Providers that have an active Umbrella User Agreement	**100%**
21) Crew time (actual vs. increment pair – 3 months allocation)	**59%**
(a) **Ascent flight resources**	
Upmass	**112%**
Cold stowage	**40%**
Big bags	**30%**

Powered lockers	43%
(b) Facility resources (reported in Q2 and Q4)	
Commercial facilities	36%
JEM airlock	150%
Life Sciences Glovebox	125%
Microgravity Science Glovebox	67%
22) Number of payloads that did not turnover per the nominal delivery schedule	24
Principal investigators	2
Implementation Partners	21
CASIS	0
NASA	1
23) Number of reflight experiments flown	5
Fundamental Science	3
Applied Research & Development	0
Technology Demonstration	0
Education and Outreach	0
Commercial Service Provider Utilization	2
24) Number of payloads ready to fly that were left on the ground due to limited resources (upmass, crew time, cold stowage, etc.)	26
25) Number of payloads removed from the manifest after the freeze date because the principal investigator/payload could not make the flight	4

a. Data is from previous fiscal year quarter. Determination of whether a payload met research objectives often cannot be determined until the payload has been returned to the investigator and review of initial data has taken place.

In-Orbit Activities: The ISS as a Research Platform

In FY23, the ISS National Lab continued to maximize space station utilization by facilitating access for a wide variety of users to conduct R&D that provides value to humanity and expands the LEO economy. This year, **113 ISS National Lab-sponsored payloads were delivered** to station—the most ever in a single fiscal year. Of these, **more than 80 percent were from commercial entities**, demonstrating a continued interest in and growing demand for space-based R&D among industry users. Since transition to CASIS management in 2012, the ISS National Lab has sponsored more than 700 payloads that have been delivered to station.



In FY23, **five Commercial Resupply Services (CRS) missions** (Northrop Grumman (NG)-18, SpaceX CRS-26, SpaceX CRS-27, SpaceX CRS-28, and NG-19) carried ISS National Lab-sponsored payloads to the space station. Additionally, astronauts that launched to station on **three commercial crew missions** (SpaceX Crew-5, SpaceX Crew-6, and SpaceX Crew-7) worked on many ISS National Lab-sponsored investigations during their time on the ISS. **The second all-private astronaut mission, Axiom Mission 2, also launched to station in FY23**, carrying more than 20 payloads sponsored by the ISS National Lab.

This year, many industry partners conducted R&D on station—from large commercial companies to innovative startups that were awarded the Technology in Space Prize (funded by CASIS and Boeing in partnership with the MassChallenge startup accelerator program):

- Madison Square Garden Entertainment Corp. tested a high-resolution camera system to guide the design of cameras that will capture space imagery on future missions for the MSG Sphere in Las Vegas.
- The Aerospace Corporation launched the world's first and only space-based hacking sandbox, a type of cyber security technology that enables testing to identify methods for preventing the hacking of satellite systems.
- Startup RevBio (formerly LaunchPad Medical) continued research on its proprietary, patented bone adhesive, Tetranite, to heal fractured bones faster.
- Startup MakerHealth explored ways to optimize its modular biochemical manufacturing platform, AmpliRX, which could significantly reduce the cost of drug manufacturing.
- Startup Axonis used a 3D self-assembled human brain model to advance neurological disease modeling that could lead to new treatments for Alzheimer's and Parkinson's disease.

> ***"Thanks to the access provided by the ISS National Lab, we can advance our mission to improve the quality of our drug products and identify new types of drugs to meet the unmet medical needs of our patients. It really opens the horizons and allows us to be innovative in our work."***
>
> *– Robert Garmise, Associate Director of Material Science and Engineering at Bristol Myers Squibb*

Multiple investigations that launched in FY23 sought to advance the key focus area of in-space production applications, for example:

- Global pharmaceutical company Bristol Myers Squibb aimed to produce improved crystallized biotherapeutic compounds in space to refine drug formulation and enhance patient products.
- Redwire Corporation's BioFabrication Facility (BFF) produced the first full-sized, 3D printed human meniscus (knee cartilage) in space, opening the door to new treatments for meniscal injuries.

- Startup LambdaVision continued research to develop its protein-based artificial retina to restore vision in patients blinded by degenerative eye diseases.
- Stanford University launched a semiconductor investigation to improve the synthesis of materials for devices that convert sunlight into electricity for solar energy applications.

U.S. government agencies continued to support space-based fundamental science, for example:

- NIH-funded cardiac tissue chip studies from Johns Hopkins and Stanford University aimed to improve heart failure modeling that could lead to new heart disease treatments.
- An NSF-funded project from Emory University continued research examining heart muscle cells as they mature into tissue-like structures for regenerative medicine applications.
- An NSF-funded project from Rensselaer Polytechnic Institute continued research to improve the efficiency of heat pipes used to prevent electronics from overheating.
- An NSF-funded project from Stanford University and the University of California, Berkeley aimed to produce superior graphene aerogel materials that can be used to develop better batteries, improve oil spill cleanup methods, and create next-generation space suits.

"With the support of the ISS National Lab and NASA, LambdaVision has been fortunate to fly eight missions to the ISS since 2018. These flight opportunities have allowed us to make significant progress on the in-space production capabilities of our protein-based artificial retina, which has enabled further development and commercialization of the technology. We are grateful for this partnership and look forward to additional flights in 2024."

– Nicole Wagner, CEO of LambdaVision

In-orbit activities included studies from several academic and research institutions, for example:

- Sanford Stem Cell Institute continued its space-based cancer research with two projects, one exploring how cancer spreads and the other investigating new cancer treatments.
- Wake Forest Institute for Regenerative Medicine studied bioengineered liver and kidney tissues on station to lay the foundation for future in-space production of human tissues.
- The University of Southern California used Astrobee robots to test a new autonomous spacecraft docking system.

Multiple student-led research projects also launched this year, for example:

- A Genes in Space™ student project tested a new method for measuring DNA length in space, expanding the research capabilities available on station.
- Student investigations from the STARWard STEM program and Student Spaceflight Experiments Program focused on a variety of topics, such as microgravity's effects on seed germination and microbial solutions for food waste.

Examples of in-orbit activities for projects supported by Commercial Service Providers include:

- BioServe Space Technologies at the University of Colorado Boulder partnered with Sierra Space on a project to validate in-space stem cell production for clinical applications.
- Aegis Aerospace supported a project from L3Harris Technologies that used the MISSE Flight Facility to test 3D printed materials for satellite manufacturing.
- In a project supported by the Defense Advanced Research Projects Agency (DARPA), Rhodium Scientific and the University of Florida studied microgravity's effects on the production of therapeutics derived from bacteria and yeast.

"BioServe Space Technologies has successfully partnered with the ISS National Lab on more than 35 spaceflight projects supporting a wide range of life sciences including mammalian cell culture, organoids, engineered tissues, organ-on-a-chip, protein crystal growth, and drug delivery. Together BioServe and the ISS National Lab are creating the foundation for utilizing the microgravity environment to benefit humanity."

– Stefanie Countryman, Director of BioServe Space Technologies

This year, crew time intensive solar array upgrade missions affected ISS National Lab crew time utilization (around 60%, compared with 73% last year). However, the ISS National Lab utilized nearly 785 crew time hours in FY23, which is only slightly lower than the previous five-year average.

R&D Progress and Successes

R&D sponsored by the ISS National Lab continues to yield valuable results and tangible successes, as demonstrated by the numerous peer-reviewed publications, patents, and new products this year. In FY23, **nearly 40 peer-reviewed articles related to ISS National Lab-sponsored research** were published (citations for which are in Appendix B)—the second most ever identified in a single fiscal year. This brings the total number of peer-reviewed articles related to ISS National Lab R&D to more than 350. These published results provide a strong foundation for future applied research that will lead to valuable applications that benefit humanity.

This year, 23 publications were related to projects awarded through joint solicitations with NSF, 13 on tissue engineering and mechanobiology and 10 in the physical science area of transport phenomena. For example:

- University of Connecticut researchers published a review of research using tissue chips with integrated biosensors in space to better understand human physiology and disease.
- A research team from Auburn University published results detailing how micro-structured surfaces could be used to enhance the movement of vapor and increase the rate of heat transfer, which could lead to new technologies that better remove heat in electronics.

Other examples of FY23 publications include the following:

- Researchers from the University of Florida published results from an NIH-funded investigation testing a tissue chip system that cultures and electrically stimulates human skeletal muscle cells. The system could be used to test therapeutics for muscle wasting. This study builds on past ISS National Lab-sponsored research.
- One publication discusses research from the University of Toledo that developed cost-effective hardware to crystallize proteins in microgravity. Space-grown crystals could provide new insights into the structure of proteins that are important for drug development.
- Researchers from Georgia Tech Applied Research Corporation published four articles related to research that used the Aegis MISSE Flight Facility to study the endurance of spacecraft materials. The team captured images of the materials changing color during exposure to harsh space conditions, and results could lead to new ways to visually track the health of spacecraft during flight.
- One publication discussed research that used Hewlett Packard Enterprise's Spaceborne Computer-2 (SBC-2) to test neural network models for in-space computing.
- Two publications are related to the Alpha Magnetic Spectrometer-02, a particle physics detector seeking to advance knowledge of the universe and its origin. One provides highlights from the detector's 11 years in orbit and the other discusses the detection of cosmic rays over an 11-year period.

"Over the last five years, the NCATS and ISS National Lab partnership on the Tissue Chips in Space initiative has provided a myriad of lessons learned, including how to develop and pressure-test tissue chips for flight to station and for their miniaturization and automation. More importantly, it has led to a fundamental understanding of the molecular underpinnings associated with accelerated aging effects due to microgravity and to the development of strategies to mitigate those effects that could lead to translational benefits on Earth."

– Danilo Tagle, Director of the Office of Special Initiatives at the National Center for Advancing Translational Sciences (NCATS), NIH

In FY23, five patents related to ISS National Lab-sponsored research were identified:

- Astrobotic Technology Inc. has a patent pending for a machine-learning algorithm to detect anomalies in machinery by "making sense" of distinctive audio patterns they emit.
- A team of researchers from the University of California, Los Angeles filed a patent for a new systemic osteoporosis therapy that both slows bone breakdown and builds new bone. Two FY23 publications are also related to this team's research.
- adidas has a patent pending for a strategically weighted ball that induces a "spin flip" under high enough rotational speed.
- Cam Med (now Qlibrium™) was granted a patent for an electrochemistry system and method to generate gas bubbles in a microfluidic device for improved drug delivery.
- Micro-gRx filed a patent for a tissue chip system to culture and electrically stimulate human skeletal muscle cells.

"From the past organ-on-a-chip challenge and the Tissue Chips in Space initiative to today and looking forward, the ISS National Lab team members have been my partners, collaborators, sponsors, and advocates. We have listened, learned, and grown together, and that has made a difference in our research."

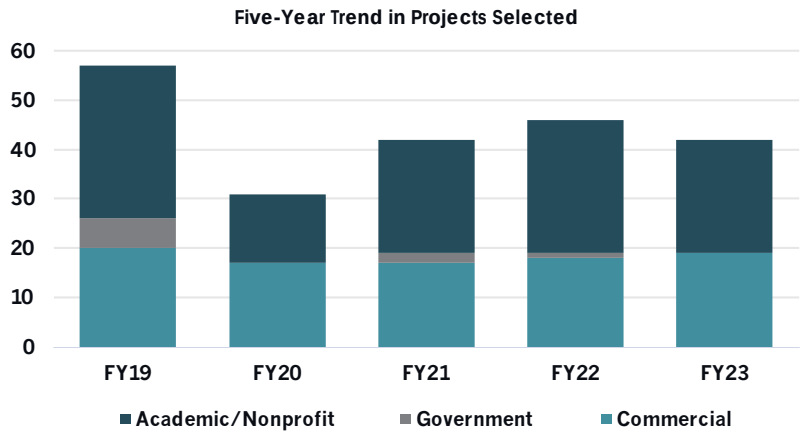
– Siobhan Malany, Principal Investigator at the University of Florida, Founder of Micro-gRx

This year, a new product also resulted from ISS National Lab-sponsored research. Felix and Paul Studios released a new virtual reality (VR) series called "Space Explorers: Blue Marble" that was created using imagery taken from station. This is the second VR series from Felix and Paul Studios using ISS imagery—the first was the Emmy award-winning series "Space Explorers: The ISS Experience."

Additionally, in FY23, the ISS National Lab published three issues of *Upward* magazine, showcasing successful results from ISS National Lab-sponsored R&D.

- Issue 6.1 highlighted results from a project to advance technology for Gas Stations in Space™, a rodent research investigation that could lead to new therapies for muscle and bone loss, and a protein crystallization experiment looking for a cancer cure.
- Issue 6.2 detailed results from a project on cool flames that could lead to higher-efficiency internal combustion engines, an investigation to better understand how fire spreads, and stem cell research that could lead to new treatments for heart disease.
- Issue 6.3 featured results from a tissue chip experiment on immune system aging, an investigation that could lead to valuable improvements in pharmaceutical manufacturing, and a project that provided important insights into plant behavior in space and on Earth.

LEO Economic Development: Demand



In FY23, the ISS National Lab continued to play a critical role in establishing a robust LEO economy by increasing demand for space-based R&D among diverse users. Industry, U.S. government agencies, and academic institutions are committing increasing amounts of their own funding to support R&D on station, demonstrating a growing recognition of the value provided by LEO-based research platforms. **This year, $26 million in external, non-NASA funding was committed** to support specific R&D projects sponsored by the ISS National Lab (a 44% increase over last year), bringing the total amount of such funding committed to date to more than $285 million. Furthermore, **CASIS funding for newly selected projects in FY23 was matched 5:1** by committed funding from non-NASA, third-party entities and the selected institutions themselves—an increase over last year's ratio of 4:1.

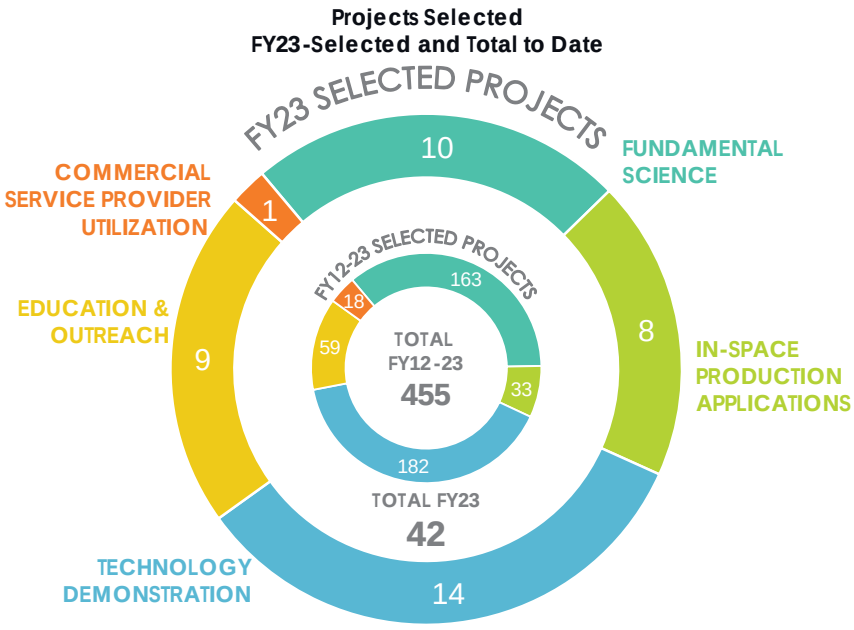
To advance R&D in key areas identified as having high potential to develop into sustainable markets, CASIS issued several targeted ISS National Lab research announcements (NLRAs) this year. Of the **42 projects selected for flight opportunities in FY23**, more than 60 percent were through NLRAs in the following strategic focus areas:

- Technology advancement (14 projects)
- The in-space production applications areas of advanced materials (3 projects) and tissue engineering and biomanufacturing (2 projects)
- Workforce development and higher education (9 projects)

The **ISS National Lab continues to work closely with NASA on these strategic focus areas**, and in FY23, three ISS National Lab-sponsored projects were selected through NASA in-space production applications research announcements. This year, the ISS National Lab also partnered with NASA's Biological and Physical Sciences (BPS) Division to announce Igniting Innovation: Science in Space to Cure Disease on Earth, a new ISS National Lab solicitation seeking multiflight translational research to address the goals of the President's Cancer Moonshot initiative and advance studies on other human diseases.

> ***"The ISS National Laboratory is a key partner to NASA, helping to stimulate demand and interest for utilizing the unique orbiting outpost for the benefit of humanity. As we look toward 2030 and beyond for future destinations, we hope to continue our collaboration with the national lab, enabling access and opportunity for researchers, students, companies, and innovators alike."***
>
> *– Joel Montalbano, NASA ISS Program Manager*

In FY23, CASIS continued to foster public-private partnerships that maximize value creation from ISS National Lab resources. CASIS has maintained a **powerful multiyear collaboration with NSF** to advance critical fundamental science through space-based research. CASIS and NSF issued two annual joint solicitations this year: one in tissue engineering and mechanobiology (3 selected projects) and one in the physical science area of transport phenomena (6 selected projects).



Note: This chart represents the ISS National Lab's strategic focus areas, which were implemented in FY21. Projects selected before FY21 were recategorized post-selection as accurately as possible using the new classification system.

Nearly 70 percent of newly awarded projects this year were from new-to-space users, demonstrating the ability of ISS National Lab solicitations to successfully draw in new research communities. Projects from new-to-space users include an investigation by Rolls-Royce to test how ceramic matrix composite materials perform in the space environment, a project by CisLunar Industries USA to demonstrate its in-space foundry technology, and a Princeton University study of microgravity's influence on bacterial biofilm transport. Additionally, new-to-space startup Machine Bio Inc. was awarded this year's **Technology in Space Prize, funded by CASIS and Boeing in partnership with the MassChallenge startup accelerator program**. Machine Bio seeks to leverage the ISS National Lab to validate proprietary technology that synthesizes protein from a DNA template in a single step—a valuable capability for future space-based R&D.

"The world is increasingly looking to space for answers to questions about improving human health, and the National Stem Cell Foundation (NSCF) has been funding important work through the ISS National Lab since 2018. Findings from each mission are used to refine questions for the next about how and why neurodegeneration occurs in diseases like Parkinson's and progressive multiple sclerosis. NSCF is delighted to be funding this innovative science at the frontier of new therapeutic discoveries.

– Paula Grisanti, CEO of the National Stem Cell Foundation

This year, selected investigations from return users include a National Stem Cell Foundation study using stem cell-derived brain organoid models to study neurodegenerative diseases, a project

from SyNRGE to produce antifungal compounds that may prevent a disease that threatens banana production worldwide, and a Johns Hopkins investigation that builds on previous cardiac tissue chip research.

(For a full list of FY23 solicitations, see the ISS National Lab Previous Opportunities page. For a full list of all selected ISS National Lab-sponsored projects, see the ISS National Lab Project Pipeline.)

The ISS National Lab continually brings together subject matter experts and thought leaders from industry, academia, and U.S. government agencies to discuss how to maximize use of the orbiting laboratory to advance strategic focus areas toward sustainable markets. This year, the ISS National Lab hosted two workshops at ISSRDC 2023—one on the broad area of in-space production applications and another specifically focused on biomanufacturing. During the workshops, the ISS National Lab and NASA shared progress in these critical areas and gathered input from attendees to guide the future vision to move these areas forward.

LEO Economic Development: Supply

The ISS National Lab continues to support the growing community of Implementation Partners (companies and organizations that offer services related to payload development) and generate demand that promotes supply-side growth of the LEO economy. From aerospace companies with decades of experience to new startups just getting established, these organizations continue to expand the services and capabilities offered to researchers for successful implementation of their space-based R&D.

Through an online Implementation Partner Portal, the ISS National Lab connects users with Implementation Partners that can help translate their ground-based research into flight-ready payloads. In FY23, **more than 80 percent of CASIS funding was used to cover Implementation Partner costs** for researchers. To enhance collaboration with Implementation Partners and identify ways to bolster supply-side economic development in LEO, the ISS National Lab continues to host bi-annual Implementation Partner workshops.

"CASIS and the ISS National Lab have been instrumental in pioneering space-based research and manufacturing, setting a precedent we're proud to follow at Tec-Masters, Inc. Our MaRVIn facility represents a leap forward in space processing, a testament to the groundbreaking work initiated by CASIS. We are excited to contribute to this legacy, advancing the frontier of space exploration and its beneficial impacts on Earth."

– Reggie Spivey, Chief Operating Officer of Tec-Masters, Inc.

In FY23, the ISS National Lab gained two new Implementation Partners, Blue Origin and Skycorp, bringing the **total number of Implementation Partners to 36** (see a full list in the Implementation Partner directory). The number dropped slightly (from 39 last year) due to several Implementation Partners being absorbed into parent companies.

Currently, there are **24 ISS National Lab commercial facilities supported by 16 Commercial Service Providers** (the subset of Implementation Partners that own and operate facilities on the ISS or are developing future facilities). This number includes the addition of Blue Origin as a new Commercial Service Provider this year. In FY23, more than 60 percent of ISS National Lab-sponsored payloads delivered to station were projects flown through Commercial Service Provider Resource Request Forms (RRFs). This RRF pathway allows Commercial Service Providers to more easily provide their customers with access to the commercial facilities they own and operate on station. See the full list of commercial facilities in Appendix A.

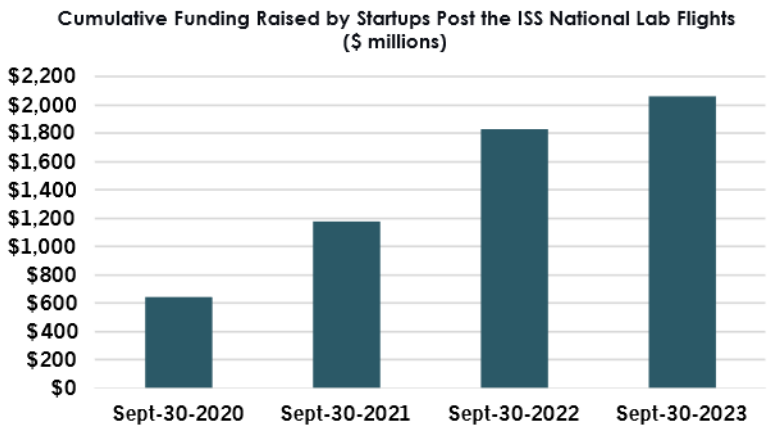
FY23 facility updates include an upgraded version of Redwire's BioFabrication Facility, which is capable of printing biological tissues in space. These upgrades provide improved temperature regulation and advanced imaging. Additionally, BioServe Space Technologies completed validation of a new facility, the BioServe Centrifuge. This device can be used to separate substances of differing densities, an important capability for several fields of research.

Key Implementation Partner milestones in FY23 include the following:

- Axiom Space launched four of its astronauts on Axiom Mission 2.
- Blue Origin, Northrop Grumman, and Sierra Space were awarded unfunded Space Act Agreements as part of NASA's second Collaborations for Commercial Space Capabilities (CCSC-2) initiative, designed to advance commercial space efforts by providing access to NASA resources.
- Nanoracks, a Voyager Space company, installed a new, self-built payload, Gambit, to its Bishop Airlock on the ISS. Gambit provides advanced testing capabilities with a suite of sensors, robust data collection capabilities, and innovative robotic development.
- Sierra Space completed a fifth, sub-scale test of its LIFE™ (Large Integrated Flexible Environment) habitat, an inflatable module that serves as a three-story commercial habitation and a science and bio-pharma platform.
- Voyager Space acquired Implementation Partner ZIN Technologies Inc.

LEO Economic Development: Investor Network and Capital Connections

In FY23, several early-stage companies that have conducted R&D through the ISS National Lab delivered capital-raising successes, despite challenging capital market conditions. This year, the **total funding raised postflight by startups with ISS National Lab flight projects was $230.5 million, bringing the all-time cumulative total to nearly $2.1 billion**.

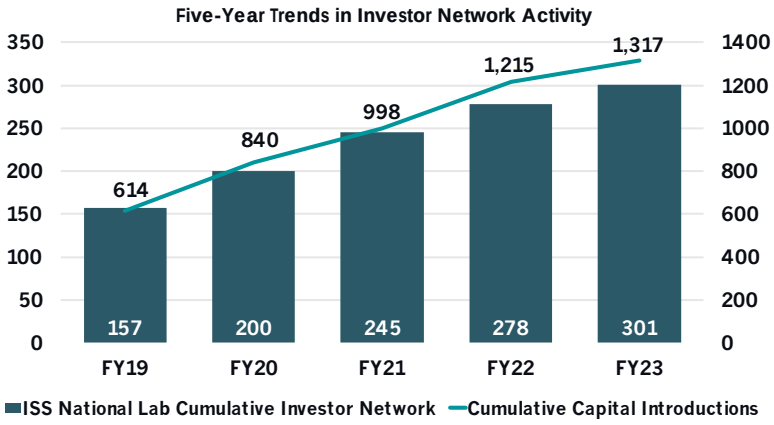


Including companies that have been awarded a flight project that has not yet flown to the ISS,

the respective totals amount to $240.9 million for FY23 and more than $2.2 billion for the all-time cumulative total.

This year, grant funding events outnumbered private capital raise announcements, and companies in the ISS National Lab ecosystem that secured funding include Orbital Sidekick, Orbit Fab, Lynk Global, Rev Bio, MicroQuin, Tympanogen, Redwire, Kall Morris Inc., GITAI, and several others.

The **ISS National Lab investor network continued to expand in FY23 and now includes more than 300 financial investors**, including venture capital, private equity, corporate, and angel investors. To date, **CASIS has facilitated more than 1,300 capital introductions between startups and investors** in the ISS National Lab investor network.



This year, the **ISS National Lab hosted its eighth annual investor event**, highlighting seven innovative startups across the data processing and computing, biomedical manufacturing, orbital logistics, and remote sensing sectors. These investor events continue to provide a valuable opportunity to connect investors with entrepreneurs in the ISS National Lab ecosystem.

Industry Context

The space sector has not been immune to the capital access headwinds of FY23, as evidenced by a 45 percent decline in the broader venture capital investment activity in the U.S. during the year. This constrained environment is likely to persist into 2024. However, as evidenced by data from the third quarter of 2023, funding conditions for the space sector, particularly for companies in earlier stages, appear to be stabilizing on the private markets. This is a welcome development following the declines from the 2021 levels.

While the number of deals has increased despite difficult conditions, the market remains very selective with raised performance requirements and reduced valuations. Some space infrastructure projects have seen an increased need to engage foreign capital due to the lack or reticence of domestic funding sources. Even in earlier stages, there appears to be less investor willingness to lean into proof-of-concept-level risk than there was during the recent high-liquidity years. Furthermore, conversations with several specialized venture capitalists have pointed to a lengthy process to raise their next funds, and some of the "space tourist" investors have pulled back from the space arena.

Also affecting risk capital access is the current valuation picture of the publicly traded, nascent space companies that are in various stages of finding their footing in the post-SPAC world. While there have been several follow-up financings, implying some funding access, these deals have been executed at steeply discounted valuations to the initial listing prices. Reduced valuations should not come as a surprise, given the broad inability to meet the financial targets announced during the IPO process as well as slow progress to positive cash flow generation. The good news is that these markets are starting to clear little by little, with separation emerging between those who can perform and those who cannot. This rationalization process is expected to continue well into 2024.

Overall, the space industry is expected to continue to innovate strongly but also adjust within its resource limits. Several organizations have already begun getting leaner on headcount and more targeted in their capital allocation plans, including toward R&D. Further revisions to various space infrastructure strategies are likely, which obviously has implications for business plans reliant on such yet-to-be-built infrastructure. Consolidation for both revenue base expansion and fixed cost absorption remains as topical as ever. The silver lining here is that a successful funding event is now likely to be a stronger validation of capability, performance, and opportunity than during the boom years.

"Investing in the space industry requires substantial patience and capital. Since 2021, both of these crucial elements remain in short supply, with investors pivoting toward profitability rather than investing in long-term, capital-intensive ventures. This shift compels startups to promptly demonstrate tangible progress with potential customers.

The ISS National Lab stands out as a valuable avenue for startups, providing access to space, a reputable brand endorsement, and opportunities for engaging partnerships. These factors closely align with the criteria that investors typically consider when making investment decisions."

– Mislav Tolusic, Co-Managing Partner and Chief Investment Officer of Marlinspike Partners

Educational Outreach and Workforce Development

Inspiring the next generation of space industry workers and advancing science literacy among our nation's students is a key focus area for the ISS National Lab. In FY23, the number of **users that accessed ISS National Lab online educational products surpassed 25.5 million.** Additionally, **more than 10 million people participated in the 25 partner programs within Space Station Explorers**, a community of educators, learners, and organizations that leverages the unique platform of the ISS National Lab to provide valuable educational experiences for students in grades K-12 and higher education. The **ISS National Lab also gained three new educational partners in FY23**: Club for the Future (Blue Origin's educational foundation), Limitless Space Institute, and Luminary Labs.

Through Space Station Explorers, the ISS National Lab provides access to impactful science, technology, engineering, and mathematics (STEM) educational programs that allow students to engage directly with astronauts on station, track the ISS from their classroom, and even design their own experiments to be done on the orbiting laboratory. By engaging students in Space Station Explorers programs, the ISS National Lab aims to promote diversity and outreach into underserved demographics. For example, in FY23:

- Partner program Magnitude.io provided powerful educational opportunities for underrepresented communities through an investigation that allowed students to study the sequestration of carbon by plants on station. This investigation was awarded through an ISS National Lab research announcement focused on educational outreach and workforce development.
- ARISS (Amateur Radio on the ISS), a free program that allows students to talk with ISS crew members via ham radio, hosted its first-ever contact in Antarctica with 50 students at the remote Esperanza Base Research Station's school. ARISS can now boast supporting schools on all seven continents.

The **Space Station Ambassador program** provides a means for educators, leaders, and lifelong learners to share information on Space Station Explorers activities with their communities. This year, the ISS National Lab presented two ambassadors with awards, one receiving the Space Station Explorers Exceptional Ambassador Award and the other receiving the Tony So Excellence in Education Award.

Additional key educational and workforce development activities in FY23 include the following:

- At ISSRDC 2023, the Genes in Space™ program announced the winner of its annual student research competition: Isabel Jiang, a California high school student whose experiment could help researchers understand why latent viruses reactivate.
- The ISS National Lab selected a recipient for the 2023 James A. Abrahamson Space Leader Fellowship, a 12-month advanced learning experience for undergraduate and graduate students to develop the skills and knowledge for space-related careers.
- The ISS National Lab STEM education team directly interacted with more than 250 undergraduate and graduate students at the second annual Astronaut Memorial Foundation Career and Networking Event, fielding questions about careers within the space industry and other STEM fields.
- The ISS National Lab presented awards to two graduate students for their posters at the annual American Society for Gravitational and Space Research (ASGSR) conference.

> ***"This fellowship has been a great opportunity for me. It has helped me gain experience with the research I want to get into, which ultimately helped me earn a spot in the U.S. National Science Foundation's Graduate Research Fellowship Program."***
>
> *– Taylor Peterson, a 2022 recipient of the James A. Abrahamson Space Leader Fellowship*

- The new Student Mission Control online tool and curriculum, developed by the ISS National Lab in collaboration with the University of California, Berkley and ARISS through an NSF-funded grant, was pilot tested with a group of high school educators in California. Through the tool, students can engage in computer science-focused learning activities that use real data from sensors on the ISS.
- To highlight student experiments launching on SpaceX CRS-26, the ISS National Lab hosted a launch event at NASA's Kennedy Space Center that included a student poster session and provided an opportunity for the students to present their research.
- For the Space Foundation's 38th Space Symposium, the ISS National Lab sponsored the teacher liaison breakfast with a keynote address from Emmy-winning TV host and social media influencer Steve Spangler.
- ISS National Lab User Advisory Committee (UAC) education sub-committee chair Stephen White and UAC member Melissa Poore attended the U.S. Department of Education YOU Belong in STEM National Coordinating Conference.

Outreach and Stakeholder Engagement

In FY23, the ISS National Lab achieved significant success in reaching broader, more diverse audiences through strategic efforts to increase website traffic, social media engagement, and media coverage. The ISS National Lab engaged stakeholders through a variety of high-quality content, including press releases, *Upward* (official magazine of the ISS National Lab), ISS360 articles, and **a new monthly newsletter, *Space Station Spotlight***. The newsletter was developed to serve as a hub for the space community to stay informed about ISS National Lab activities, funding opportunities, R&D on station, successful results, Implementation Partner news, the state of the industry, and workforce development efforts.

This year, the ISS National Lab **revitalized *Upward*, releasing three new issues showcasing results** that demonstrate how investments in space-based R&D translate into groundbreaking discoveries with real-world applications. This results-driven digital storytelling coupled with marketing campaigns to ensure the magazine reaches its target audience led to **nearly 50,000 online page views, more than 18,000 downloads of *Upward* content, and nearly 4,000 new subscribers.**

Marketing campaigns and other strategic efforts to expand awareness of ISS National Lab activities also led to an 11 percent increase in ISS National Lab social media followers from FY22, with **more than 593,000 followers across all social media platforms**.

In FY23, a significant expansion of public relations efforts and targeted **press releases resulted in more than 17,000 media pickups, a 475-percent increase over last year.** High-profile media coverage highlighted how researchers are leveraging the ISS National Lab to advance R&D in ways not possible on Earth. Examples include the following:

- An article published by the Wall Street Journal that discussed how biomedical research in space is helping patients on Earth was featured in the journal's health section.

- An ISS National Lab Axiom Mission 2 video featuring astronauts Peggy Whitson and John Shoffner that explored the importance of making space accessible for private citizens led to coverage in Gizmodo and Yahoo, among several other media outlets.
- ISS National Lab public relations outreach on CRS launches earned media coverage in the Boston Business Journal, United Press International, Atlanta News First, 7News WHDH Boston, Cardiac Vascular News, Fierce Biotech, R&D World, and many others.
- An ISS National Lab collaboration with Redwire, Microsoft, and Marvel Studios to promote an education outreach initiative inspired by "Guardians of the Galaxy Vol. 3" resulted in national media coverage, including Gizmodo and Fast Company articles.

This year marked the **12th annual ISS Research and Development Conference (ISSRDC), held July 31-August 3 in Seattle.** The conference, hosted by CASIS, NASA, and the American Astronautical Society (AAS), was **attended by nearly 900 people**, including new conference sponsors and exhibit hall participants. With the theme "Innovating in the New Space Age: Accelerating Commercialization and Science in Space Through 2030," ISSRDC 2023 included several notable sessions. A panel session on the future of R&D in LEO discussed national strategy and policy objectives to successfully transition from the ISS to CLDs of the future. In a keynote address, Susan Margulies, who leads NSF's Directorate for Engineering, spoke about the value of fundamental research in space and discussed examples of NSF-funded investigations leveraging the ISS National Lab. The conference also featured science communicator Maynard Okereke, known as the Hip Hop M.D., who moderated a panel discussion on the future space workforce and how to fill gaps in the industry.

During the conference, the ISS National Lab announced a partnership with Privateer Space to host a white label version of the company's Wayfinder tool on the ISS National Lab website. Wayfinder provides real-time data and visualization of satellites and space debris in Earth's orbit, making space traffic information more readily available to ISS National Lab users and the expanding LEO economy.

ISS National Lab representatives participated in more than 40 speaking engagements to highlight the valuable R&D platform available through the orbiting laboratory and increase awareness of research funding opportunities.

> ***"This year, Privateer proudly announced a data and information sharing partnership with the ISS National Lab, expanding Wayfinder's reach as a tracking and information tool. Working with the ISS National Lab and its target audiences furthers our goal of keeping space safe and sustainable for both satellites and humans—and making it more accessible to problem-solvers everywhere."***
>
> – *Alex Fielding, CEO of Privateer Space*

Examples of FY23 key speaking engagements include the following:

- ISS National Lab Chief Scientific Officer Michael Roberts led a panel session at the 2022 American Society for Gravitational and Space Research (ASGSR) Annual Meeting

discussing the current role of the ISS National Lab and the transition from the ISS to future CLDs.

- The ISS National Lab co-organized a symposium on materials testing in space at the Materials Research Society's Spring Meeting with NASA, JAXA, and Aegis Aerospace.
- The ISS National Lab organized and sponsored a workshop on stem cells in space at the International Society for Stem Cell Research Conference.
- ISS National Lab staff participated in several workshops funded by the National Institute of Standards and Technology Manufacturing USA Technology Roadmap Program, including a workshop on in-space manufacturing of semiconductors and a series of workshops on in-space servicing, assembly, and manufacturing.
- The ISS National Lab and NASA hosted a live downlink at the Consumer Electronics Show (CES), the largest technology conference in the world. ISS National Lab staff also facilitated a panel session moderated by CNN's Jackie Wattles, including Commercial Service Provider Redwire and ISS National Lab user Procter & Gamble.
- ISS National Lab staff presented at several key industry conferences, including the 38th annual Space Symposium, ASCEND, SelectBio's Space Summit, the Biomanufacturing World Summit, the World Stem Cell Summit, the TechConnect World Innovation Conference and Expo, the National Academies Space Science Week 2023, the 2023 International Conference on Biofabrication, and the FAA Commercial Space Transportation Conference.

Financials

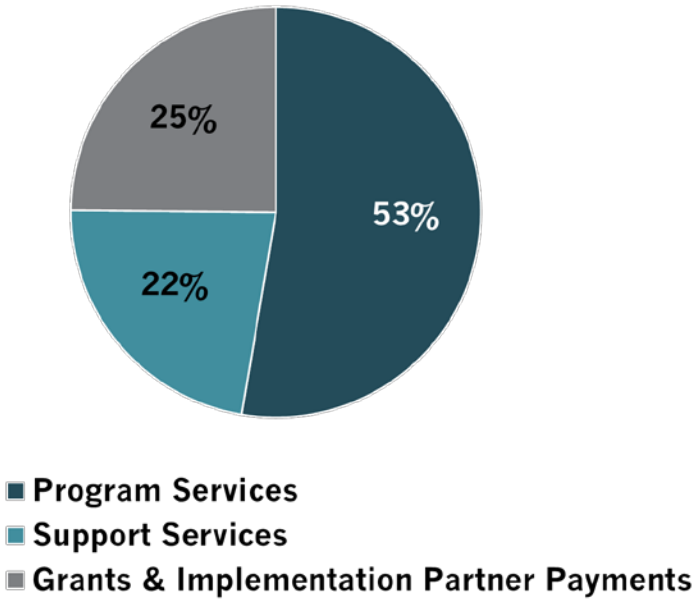
Unaudited Summary Statement of Financial Position as of September 30

	2023	2022	2021
Total assets	6,721,509	3,532,300	3,267,484
Total liabilities	3,705,243	1,117,753	958,197
Total net assets	3,016,266	2,414,547	2,309,287
Total liabilities and net assets	6,721,509	3,532,300	3,267,484

Unaudited Summary Statement of Activities for Years Ended September 30

	2023	2022	2021
Total revenues and other support	17,806,312	12,732,065	12,176,689
Total operating expenses	17,204,593	12,626,805	12,279,292
Change in net assets	601,719	105,260	-102,603
Net assets, beginning of the year	2,414,547	2,309,287	2,411,890
Net assets, end of the year	3,016,266	2,414,547	2,309,287

FY23 Expenses



Appendix A: ISS National Lab Commercial Facilities

Institution	ISS Commercial Facilities	Type	Location
Aegis Aerospace Inc.	• MISSE Flight Facility	• On station	• External
BioServe Space Technologies	• Space Automated Bioproduct Lab (SABL) • Space Automated Laboratory Incubator (SALI) • BioServe Centrifuge	• On station • On station • On station	• Internal • Internal • Internal
Craig Technologies	• Space Station Integrated Kinetic Launcher for Orbital Payload Systems (SSIKLOPS)* • Flight Test Platform (FTP)	• On station • Launch on demand	• Deployer • External
HNu Photonics, LLC	• Mobile SpaceLab	• Launch on demand	• Internal
LaMont Aerospace	• STaARS-EF-1	• On station	• Internal
Nanoracks, LLC	• Nanoracks Mainframe Alpha (Nanode) • Nanoracks CubeSat Deployer (NRCSD) • Nanoracks External Platform (NREP)	• On station • Launch on demand • On station	• Internal • Deployer • External

	• Nanoracks Plate Reader • Nanoracks Kaber MicroSat Deployer (Kaber) • BISHOP Airlock • Nanoracks BlackBox	• On station • On station • On station • Launch on demand	• Internal • Deployer • External • Internal
ProXops, LLC	• Faraday Research Facility	• Launch on demand	• Internal
Redwire Space, Inc.	• Additive Manufacturing Facility (AMF)	• On station	• Internal
Redwire Space Technologies, Inc.	• ADvanced Space Experiment Processor (ADSEP) • Multi-use Variable-gravity Platform • BioFabrication Facility (BFF)	• On station • On station • On station	• Internal • Internal • Internal
Rhodium Scientific	• Rhodium Science Chambers	• Launch on demand	• Internal
Space Tango	• TangoLab • Powered Ascent Utility Locker (PAUL)	• On station • Launch on demand	• Internal • Internal
Teledyne Brown Engineering, Inc.	• Multi-User System for Earth Sensing (MUSES)	• On station	• External

*Management of facility transferred from NASA

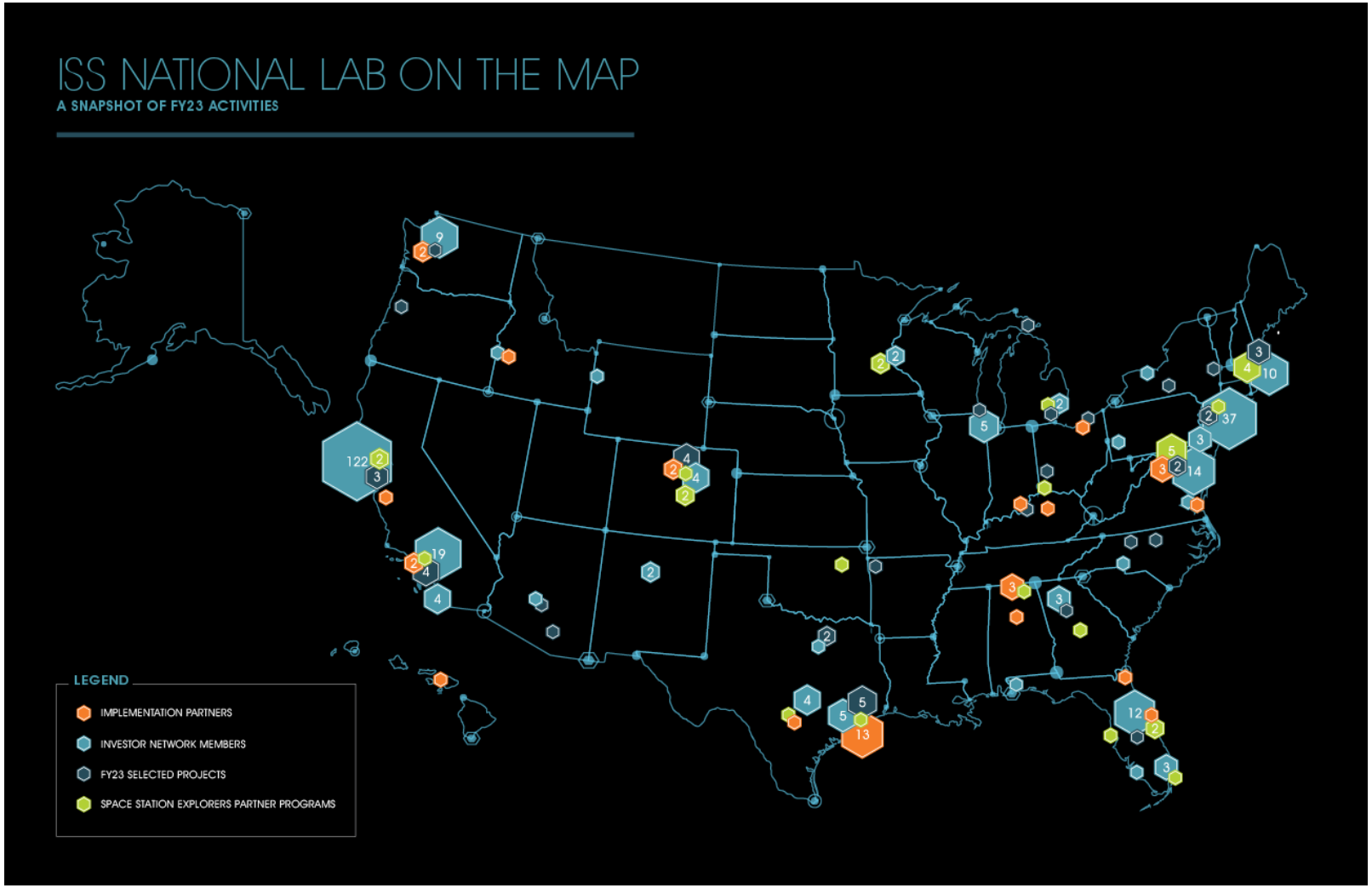
Appendix B: Peer-Reviewed Journal Publications

1. Aguilar M, Cavasonza LA, Ambrosi G, et al. Temporal structures in electron spectra and charge sign effects in galactic cosmic rays. Phys Rev Lett. 2023;130(16):161001.
2. Alon DM, Mittelman K, Stibbe E, et al. CRISPR-based genetic diagnostics in microgravity. Biosens Bioelectron. 2023;237:115479.
3. Bedree JK, Kerns K, Chen T, et al. Specific host metabolite and gut microbiome alterations are associated with bone loss during spaceflight. Cell Rep. 2023:112299.
4. Cai G, Nguyen A, Bashirzadeh Y, et al. Compressive stress drives adhesion-dependent unjamming transitions in breast cancer cell migration. Fron Cell Dev. 2022;10.
5. Chaney H, Lu K. New findings related to carbothermal reduction of polysiloxane-derived ceramics. Ceramics Int. 2023;49:10193-10197.
6. Chaney H, Lu K. New insight into SiOC atomic structure evolution during early stage of pyrolysis. Jour Am Ceramic Soc. 2023;106:2737-2743.
7. Chaney H, Lu K. ReaxFF Simulation of Pyrolysis Behaviors of Polysiloxane Precursors with Different Carbon Content. Chemistry of Materials. 2023;35:3902-3910.
8. Chaney H, Zhou Y, Lu K. Understanding SiOC atomic structures via synchrotron X-ray and reactive force field potential studies. Mat Today Chem. 2023;29:101429.
9. Cho YJ, Lu K. A materials informatics approach for composition and property prediction of polymer-derived silicon oxycarbides. Mat Today Adv. 2023;18:100384.
10. Collman S, Plis EA, Shah JR, et al. Operational procedure for handling of spacecraft materials sensitive to atmospheric exposure. Jour of Space and Rock. 2023;60(2).

11. Dinesh B, Livesay J, Ignatius IB, et al. Pattern formation in Faraday instability—experimental validation of theoretical models. Phil Trans Royal Soc A. 2023:381;20220081.
12. Dunkel E, Swope J, Candela A, et al. Benchmarking deep learning models on myriad and Snapdragon processors for space applications. J Aerospace Info Sys. 2023;0.0:1–15.
13. El Khoury R, Ramirez SP, Loyola CD, et al. Demonstration of doxorubicin's cardiotoxicity and screening using a 3D bioprinted spheroidal droplet-based system. RSC advances. 2023;13(12):8338-8351.
14. Enrriques A, Howard S, Timsina R, et al. Atomic force microscopy cantilever-based nanoindentation: Mechanical property measurements at the nanoscale in air and fluid. Jour Vis Exp. 2022;190:e64497.
15. Ganesh SC, Koplik J, Morris JF, et al. Dynamics of a surface tension driven colloidal motor based on an active Janus particle encapsulated in a liquid drop. Journal of Fluid Mec. 2023;958:A12.
16. Ghanbariamin D, Samandari M, Ghelich, P et al. Cleanroom-free fabrication of microneedles for multimodal drug delivery. Small. 2023;19.
17. Ha, P, Kwak JH, Zhang Y, et al. Bisphosphonate conjugation enhances the bone-specificity of NELL-1-based systemic therapy for spaceflight-induced bone loss in mice. npj Micrograv. 2023;9:75.
18. Hwang H, Liu R, Eldridge R, et al. Chronic ethanol exposure induces mitochondrial dysfunction and alters gene expression and metabolism in human cardiac spheroids. Alcohol: Clin and Exper Rsrch. 2023;47.
19. Joddar B, Loyola CD, Ramirez SP, et al. Inhibition of ERK 1/2 pathway downregulates YAP1/TAZ signaling in human cardiomyocytes exposed to hyperglycemic conditions. Biochem and Biophys Research Comms. 2023;648:72-80.
20. Kober UA, Ogbuoji EA, Hutchinson JA, et al. Equilibration of precipitants in a counter-diffusion apparatus for protein crystallization. J Appl Crystallogr. 2023;56(4):1-9.
21. McMackin PM, Adam JA, Riley FP, et al. Single-camera PTV within interfacially sheared drops in microgravity. Exp in Fluids. 2023;64:154.
22. Nagri S, Rice O, Chen Y. Nanomedicine strategies for central nervous system (CNS) diseases. Front Biomat Sci. 2023;2.
23. Parafati, M, Giza, S, Shenoy, TS, et al. Human skeletal muscle tissue chip autonomous payload reveals changes in fiber type and metabolic gene expression due to spaceflight. npj Micrograv. 2023;9:77.
24. Perez MR, da Silva VA, Cortez PE, et al. 3D-Bioprinted Cardiac Tissues and Their Potential for Disease Modeling. J 3D Print Med. 2023;7(3).
25. Plis EA, Bengston MT, Engelhart DP, et al. Ground testing of the 16th materials International Space Station experiment materials. Jour of Space and Rock. 2023;60(2).
26. Rubin J, van Wijnen AJ, Uzer G. Architectural control of mesenchymal stem cell phenotype through nuclear actin. Nucleus. 2022;13(1):35-48.
27. Sapowadia A, Ghanbariamin D, Zhou L, et al. Biomaterial drug delivery systems for prominent ocular diseases. Pharmaceutics. 2023;15.

28. Shishkina V, Kostin A, Volodkin A, et al. The Remodeling of Dermal Collagen Fibrous Structures in Mice under Zero Gravity: The Role of Mast Cells. Int J Mol Sci. 2023;24(3):1939.
29. Sokolovskiy A, Shah J, Collman S. Space Radiation Effects on Surface and Bulk Resistivity of Polymeric Materials. Jour Astro Sci. 2023;70:41.
30. Sridhar K, Narayanan V, Bhavnani S. Asymmetric Sawtooth and Cavity-Enhanced Nucleation-Driven Transport (ASCENT) experiment aboard the International Space Station. Microgravity Outcomes. 2023;22:1-7.
31. Vagelli V, Graziani M. The AMS-02 detector on the ISS - Status and highlights after 11 years on orbit. J Phys Conf Series. 2023; 2429:012002.
32. Vigil C, Daubenspeck A, Coia H, et al. Matrix-assisted laser desorption/ionization analysis of the brain proteome of microgravity-exposed mice from the International Space Station. Front Space Technol. 2022;3:971229.
33. Waddell KA, Lee HJ, Nayagam V, et al. Cool diffusion flames in a stably stratified stagnation flow. Combust Flame. 2023;254:112852.
34. Walsh JSP, Gorman AC, Salmond W. Visual displays in space station culture: An archaeological analysis. Curr Anthropol. 2021;62(6):804–818.
35. Weng Y, Han S, Sekyi M, et al. Self-assembled matrigel-free iPSC-derived liver organoids demonstrate wide-ranging highly differentiated liver functions. Stem Cells. 2022;41.
36. Westrick S, Lambrecht S, Sokolovskiy A, et al. Influence of high-energy electron bombardment on the material properties of spacecraft polymers. Jour Astro Sci. 2023;70:40.
37. Yau A, Jogdand A, Chen Y. Blood-brain-barrier modeling with tissue chips for research applications in space and on Earth. Front Space Tech. 2023;4.
38. Yau A, Wang Z, Ponthempilly N, et al. Biosensor integrated tissue chips and their applications on Earth and in space. Biosens and Bioelec. 2023;222.

Appendix C: ISS National Lab on the Map



In Memoriam: Greg Summers

The CASIS team would like to recognize our friend and colleague Greg Summers, who passed away after a brave battle with cancer on March 25, 2023. Greg had been fighting cancer for two years, and we were hopeful he was on the path to recovery. The news of his passing was startling, as it was such a sudden and significant loss. Greg was among the first employees to join CASIS in 2011. He was dedicated to keeping our IT systems running and safe, and he provided valuable experience and guidance as the organization grew. Greg was also a dedicated husband and father who was always there for his family. He lived life to the fullest and was gifted at storytelling, often captivating those around him with laughter, kindness, and his genuine humility. He provides a shining example of how one should live life. We lost Greg too soon and miss him greatly, but we think of him often and will remember him always. We will forever honor Greg by continuing to embody his kindness and generosity in all that we do.