ISS NATIONAL LABORATORY®

International Space Station National Laboratory
Annual Report for Fiscal Year 2022

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About the International Space Station National Laboratory: The International Space Station (ISS) is a one-of-a-kind laboratory that enables research and technology development not possible on Earth. As a public service enterprise, the ISS National Lab allows researchers to leverage this multiuser facility to improve quality of life on Earth, mature space-based business models, advance science literacy in the future workforce, and expand a sustainable and scalable market in low Earth orbit. Through this orbiting national laboratory, research resources on the ISS are available to support non-NASA science, technology, and education initiatives from U.S. government agencies, academic institutions, and the private sector. The Center for the Advancement of Science in Space, Inc. (CASIS) manages the ISS National Lab, under Cooperative Agreement with NASA, facilitating access to its permanent microgravity research environment, a powerful vantage point in low Earth orbit, and the extreme and varied conditions of space. To learn more about the ISS National Lab, visit www.ISSNationalLab.org.

Executive Summary

In fiscal year 2022 (FY22), the International Space Station (ISS) National Laboratory made great strides in its mission to return value to the nation and enable a sustainable economy in low Earth orbit (LEO). This year, NASA extended its Cooperative Agreement with CASIS to manage the ISS National Lab through 2027. The first two decades of ISS operations were dedicated to assembling the space station and validating its capabilities. Now, this third decade is the decade of results. These results are crucial for demonstrating the value of space-based research and development (R&D) to support the establishment of and transition to future commercial LEO destinations.

> ***"The NASA partnership with the ISS National Lab has never been stronger. NASA was pleased to extend our Cooperative Agreement with CASIS to ensure the ISS National Lab's contributions to the decade of results will continue. This extension provides continuity for the user community while we work together to evolve the national lab model later in the decade to support the transition to commercial low Earth orbit destinations."***
>
> *– Robyn Gatens, NASA Director of the International Space Station*

In terms of results, FY22 was a record-setting year for the ISS National Lab. This year, nearly 50 peer-reviewed articles related to ISS National Lab-sponsored research were published—the highest number ever identified in a fiscal year. Close to 70 percent of these publications were related to fundamental science funded by the U.S. National Science Foundation (NSF), building a solid knowledge base to enable future applied R&D. Additionally, in FY22, two patents were granted to companies for intellectual property related to their space-based research, and four commercial products stemmed from ISS National Lab-sponsored R&D. One of these products, the virtual reality exhibit "ISS Experience: The Infinite," attracted 174,000 viewers as it traveled to multiple U.S. cities.

In FY22, the ISS National Lab continued to expand the LEO marketplace by driving demand in key R&D areas, supporting supply-side growth, and fostering increased investment into the LEO economy. This year, 75 ISS National Lab-sponsored payloads launched to station. Of those, 85 percent represented research from commercial entities, underscoring the continued strong demand for space-based R&D among industry users. The ISS National Lab selected 46 new projects for flight in FY22 and achieved a 30 percent improvement in the average time from solicitation close to notification of selection compared with FY21. Of the newly selected projects, 60 percent were from new-to-space users, demonstrating the success of ISS National Lab research solicitations in reaching new communities.

CASIS continues to work with other government agencies to bring in funding to support ISS National Lab-sponsored research in both the physical and life sciences. In FY22, more than 25 percent of newly selected projects were from annual joint solicitations with NSF. In total, through multiyear partnerships with CASIS, NSF and the National Institutes of Health (NIH) have provided more than $40 million in funding, supporting nearly 60 ISS National Lab-sponsored investigations.

On the supply side, the ISS National Lab continued to facilitate business growth in the diverse community of companies and organizations that provide services related to payload development. There are now 39 Implementation Partners, with the addition of one new partner this year. In FY22, more than 80 percent of CASIS funding was used to cover Implementation Partner costs for investigators conducting ISS National Lab-sponsored research. The 24 ISS National Lab commercial facilities now include launch-on-demand facilities that are highly utilized. Additionally, Implementation Partner Axiom Space achieved a historic first with the launch of the first all-private astronaut crew on the Axiom Mission 1, which executed more than 25 ISS National Lab-sponsored payloads.

In FY22, the all-time cumulative amount of capital raised by startups following flight of ISS National Lab-sponsored projects reached more than $1.8 billion. The first quarter of FY22 was record-setting, with more than $550 million of private and public capital and grant funding raised by startups postflight. Additionally, the ISS National Lab expanded its investor network, reaching nearly 280 members in FY22. To date, CASIS has facilitated more than 1,200 capital introductions between startups and investors in this network.

As a key part of its mission, the ISS National Lab works to shape the next generation of leaders essential to the future LEO economy. In FY22, more than 9.5 million people participated in ISS National Lab educational partner programs. To further engage educators and students, the ISS National Lab released Expedition Space Lab, a new online tool that provides educators easy access to ISS-related lessons and resources. Additionally, in FY22, the ISS National Lab selected recipients of the inaugural James A. Abrahamson Space Leader Fellowship, which prepares college students for careers in the space industry.

FY22 marked the 11th annual ISS Research and Development Conference (ISSRDC), held in person for the first time since the start of the COVID-19 pandemic. ISSRDC 2022, held in Washington, D.C., brought together researchers, entrepreneurs, policymakers, investors, and others in the space community to discuss the next decade of space station R&D.

This year, CASIS expanded its board of directors, welcoming four new board members: Margaret Jenny, John Sheets, Waleed Abdalati (former NASA chief scientist), and David Radzanowski (former NASA chief financial officer). Additionally, Francisco Cordova joined CASIS as the chief operating officer for the ISS National Lab, and Michael Roberts was named ISS National Lab chief scientist. Throughout the year, the ISS National Lab User Advisory Committee (UAC), which held two public meetings in FY22, provided recommendations to the CASIS chief executive officer

"The ISS National Lab User Advisory Committee, along with the overall user community and the general public, has utilized a new web portal set up by CASIS to facilitate communication, allowing stakeholders to offer feedback, ask questions, share concerns, and help improve how users access the unique research facilities on the ISS. We look forward to continued success in providing the scientific community with access to R&D in low Earth orbit while balancing the limited resources in demand by our user community."

– Douglas Matson, ISS National Lab User Advisory Committee Chair

on revisions to the committee's original charter as well as guidance regarding the allocation and utilization of ISS National Lab resources.

For a snapshot of FY22 activities across the U.S., see the map in Appendix D.

A Personal Note From Ramon Lugo, Principal Investigator and CEO of CASIS:

I want to express my thanks not only to the CASIS team but also to our stakeholder community for helping us achieve the results documented in this Annual Report. It has been said by many that little of importance can be accomplished by a single person or organization. It is only through strong partnerships that we collectively find new and innovative ways to use the ISS to solve problems and generate solutions for humankind. We continue to work closely with NASA, our research and technology development community, the investment community, and commercial partners to create new opportunities to impact humanity. I look forward to the new year, as we have big plans and expect to engage the space community in helping us prepare the ISS National Lab for the transition to commercial LEO destinations. Please take the time to read this report, and feel free to share it with family, friends, and colleagues.

FY22 Metrics

ISS NATIONAL LAB UTILIZATION AND OPERATIONS TARGET METRICS

TARGET METRIC	FY22 Total	FY22 Target	FY22 Stretch
FUNDAMENTAL SCIENCE			
1) Fundamental Science projects selected	15	10	13
2) External funding supporting Fundamental Science users of the ISS National Lab	$6.4M	$5M	N/A
APPLIED RESEARCH & DEVELOPMENT			
3) Applied Research & Development projects selected	9	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	13

6) Ratio of external funding to CASIS funding (self-reported) supporting Technology Demonstration users of the ISS National Lab (cumulative)	5:1	3:1	5:1
EDUCATION & OUTREACH			
7) Education & Outreach projects selected	7	7	9
8) Total individuals participating in ISS National Lab Education & Outreach programs and projects (self-reported)	9,581,875	2M	4M
9) Total individual users of ISS National Lab online education products (self-reported)	17,601,335	5M	8M
PROPOSAL MANAGEMENT			
10) Time from solicitation close to selection/nonselection notification (cumulative)	63 days	≤75 days	N/A

ISS NATIONAL LAB UTILIZATION AND OPERATIONS TRACKING METRICS

The following metrics have no target for FY22 but will be tracked internally and discussed in face-to-face meetings with NASA.

TRACKING METRIC	FY22 Total
1) Commercial Service Provider Facility Utilization payloads delivered	**55**
(a) **Percentage of Commercial Service Provider Facility Utilization payloads flown that meet the minimum research objectives**	**98%[a]**
(b) **Percentage of Commercial Service Provider Facility Utilization payloads flown that meet the payload integration expectations**	**19%**
2) Education & Outreach payloads delivered	**1**
3) Fundamental Science payloads delivered	**9**
(a) **Percentage of Fundamental Science payloads flown that meet the minimum research objectives**	**85%[a]**
(b) **Percentage of Fundamental Science payloads flown that meet the payload integration expectations**	**11%**
4) Applied Research & Development payloads delivered	**2**
(a) **Percentage of Applied Research & Development payloads flown that meet the payload integration expectations**	**0%**
5) Technology Demonstration payloads delivered	**8**
(a) **Percentage of Technology Demonstration payloads flown that meet the minimum research objectives**	**85%[a]**
(b) **Percentage of Technology Demonstration payloads flown that meet the payload integration expectations**	**38%**
6) Total ISS National Lab-sponsored payloads delivered	**75**
7) Total external funding committed	**$18,469,397**
8) Multiplier on CASIS grant funding committed (cumulative)	**4:1**

9) Funds raised post award and postflight by startup companies with ISS National Lab-sponsored flight projects	
(a) **Funds raised postflight**	**$658.4M**
(b) **Funds raised post award**	**$714.0M**
10) Users by new/returning	
(a) **ISS National Lab return users**	**18**
(b) **ISS National Lab new users**	**28**
11) Users by type	
(a) **Commercial**	**18**
(b) **Academic/nonprofit**	**27**
(c) **Government agency**	**1**
12) ISS National Lab concepts received	**262**
13) ISS National Lab proposals received	**108**
(a) **Total proposals with a rating of very good or excellent**	**25**
(b) **Proposals not selected with a rating of very good or excellent**	**1**
14) ISS National Lab projects selected	**46**
15) Active solicitations	**6**
16) Time from selection notification to agreement draft sent to principal investigator (cumulative)	**44 days**
17) New commercial facilities added	**0**
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)	**73%**
(a) **Ascent flight resources**	
Upmass	**102%**
Cold stowage	**43%**
Big bags	**75%**
Powered lockers	**67%**
(b) **Facility resources (reported in Q2 and Q4)**	
Commercial facilities	**55%**
JEM airlock	**100%**
Life Sciences Glovebox	**59%**
Microgravity Science Glovebox	**110%**
22) Number of payloads that did not turnover per the nominal delivery schedule	**20**
Principal investigators	**1**
Implementation Partners	**18**
CASIS	**0**
NASA	**1**
23) Number of reflight experiments flown	**3**

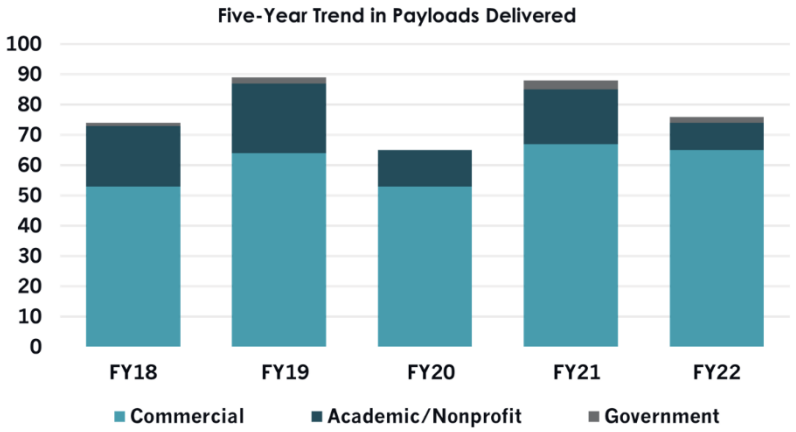
Fundamental Science	**2**
Applied Research & Development	**0**
Technology Demonstration	**1**
Education and Outreach	**0**
Commercial Service Provider Utilization	**0**
24) Number of payloads ready to fly that were left on the ground due to limited upmass	**7**
25) Number of payloads removed from the manifest after the freeze date because the principal investigator/payload could not make the flight	**9**

Note: Resource data is projected/estimated based on payload requirements in the queue at the start of FY2022.

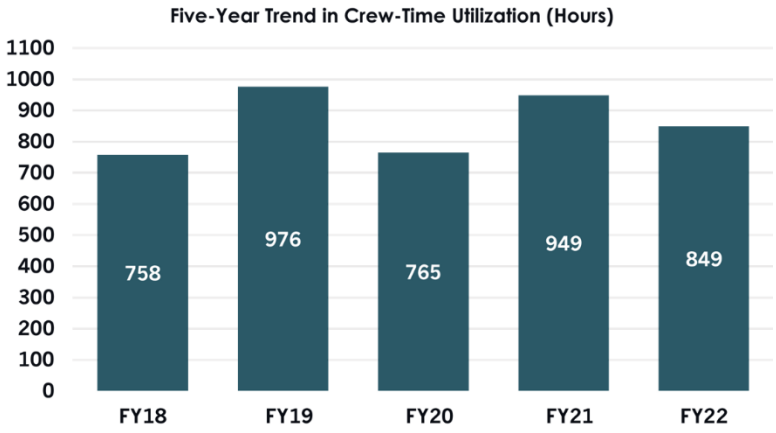
a. Pending further analysis.

In-Orbit Activities: The ISS as a Research Platform

In FY22, the ISS National Lab continued to facilitate access to the space station for diverse and nontraditional users to maximize the use of this powerful platform to demonstrate the value of space-based R&D. This year, **75 payloads sponsored by the ISS National Lab were delivered** to the orbiting laboratory. This brings the total number of ISS National Lab-sponsored payloads delivered in the 11 years of CASIS management to more than 600. Private-sector utilization of the ISS National Lab continues to increase, with **more than 85 percent of payloads delivered this year representing projects from industry partners**.



In FY22, the **ISS National Lab utilized nearly 850 crew-time hours**, which is on par with the average over the last five years. The availability of crew time fluctuates depending on a variety of factors. While the demand for payload delivery was comparable to FY21, the ISS National Lab was limited by fewer Commercial Resupply Services (CRS) mission launches in FY22. There were three CRS launches this year compared with five in FY21, yet the ISS National Lab's overall utilization of crew time allocated by NASA was only slightly less (73 percent compared with 76 percent last year).



In FY22, ISS National Lab-sponsored payloads launched on three CRS missions (SpaceX CRS-24, Northrop Grumman CRS-17, and SpaceX CRS-25). Astronauts that launched on two commercial crew missions (SpaceX Crew-3 and SpaceX Crew-4) worked on many ISS National Lab-sponsored research projects while on station. The **first all-private astronaut mission to the ISS, Axiom Mission 1**, launched this year. More than 25 ISS National Lab-sponsored payloads were executed by the Axiom Mission 1 crew.

In-orbit activities in FY22 included projects from several large commercial companies:

- Global consumer care company Colgate-Palmolive launched the first-ever private-sector skin health experiment to improve consumer products for better skin health.
- Lockheed Martin Corporation (in collaboration with StemRad) continued to test the AstroRad radiation shielding vest designed to protect astronauts on missions beyond LEO.
- Multinational pharmaceutical company Merck & Co. continued protein crystallization R&D to improve its cancer immunotherapy drug Keytruda®.
- Procter & Gamble tested its Tide to Go Pens and Tide to Go Wipes in space to help make Tide products more sustainable and improve products for customers on Earth.

"By leveraging the ISS National Lab, Lockheed Martin and StemRad have worked to validate the AstroRad Vest, a radiation shielding wearable designed to protect astronauts. Through this important technology demonstration, we are pushing the boundaries of innovation in ways that will bring scientific and technological merit to humanity and further business models that can ensure economic vitality in space beyond the ISS."

– Kathleen Coderre, Deputy Manager, Deep Space Exploration Advanced Programs, Lockheed Martin Company

Startups awarded the Technology in Space Prize that conducted R&D on station this year include:

- LambdaVision continued R&D to develop the company's artificial retina that restores vision in those blinded by retinal degenerative diseases.
- MicroQuin used 3D cell culture to study the onset and progression of cancer and test the company's new cancer therapeutic for prostate and breast cancer.

Multiple projects funded by other government agencies launched in FY22, for example:

- Two NIH-funded tissue chip experiments could lead to new treatments for patients on Earth: a University of Florida project studying muscle loss and a University of California, San Francisco project studying immune system function in response to aging.
- An NSF-funded project from Arizona State University and Rensselaer Polytechnic Institute studied protein aggregation to improve pharmaceutical manufacturing.
- Another NSF-funded project from the City College of New York studied the structure and stability of foams and emulsions for improved and eco-friendly products.

FY22 in-orbit activities included studies from several academic and research institutions:

- A Clemson University project funded by Target Corporation through the ISS Cotton Sustainability Challenge could help improve commercial agriculture on Earth.
- The National Stem Cell Foundation examined neurodegeneration in 3D culture using cells from multiple sclerosis and Parkinson's patients—the first time this has been done on station—to better understand the underlining genetics of these diseases.
- The University of Notre Dame studied bubble dynamics on nanostructured surfaces for applications in medical diagnostics and water purification methods.

In-orbit activities also included student-led research, for example:

- A Genes in Space™ student experiment tested a method that could be used to analyze water quality in orbit and remote areas on Earth.

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

- A project from Rhodium Scientific, in collaboration with Lawrence Berkeley National Laboratory, tested the ability of bacteria to protect DNA during the stresses of spaceflight.
- The Aegis MISSE Flight Facility supported a Massachusetts Institute of Technology project that tested a new aerospace electronic textile and a Georgia Tech Research Institute project that tested a new method to visually assess the integrity of spacecraft materials.

"The ISS National Lab has proven to be an invaluable partner that Rhodium Scientific has leveraged to conduct compelling R&D and validate our life science quality assurance processes and capabilities in LEO. In doing so, we are furthering space-based research innovations for our collaborators and bringing a return on their investment that benefits the scientific community and humanity."

– Olivia Gamez Holzhaus, Founder and CEO of Rhodium Scientific

R&D Progress and Successes

This was a record-setting year for results and subsequent successes stemming from ISS National Lab-sponsored R&D. **Nearly 50 peer-reviewed publications** related to ISS National Lab-sponsored research were published in FY22 (citations for which are in Appendix C)—the most ever identified in a single fiscal year. This brings the total number of peer-reviewed publications related to R&D sponsored by the ISS National Lab to more than 200. These publications disseminate valuable findings from ISS-based research that form the knowledge base for future applied research to build on.

This year, 32 publications are related to research from NSF/CASIS joint solicitations (15 on tissue engineering and mechanobiology, and 17 on transport phenomena, combustion, and fluid dynamics). For example:

- Researchers at the Palo Alto Veterans Research Institute published three peer-reviewed articles about developing a model of sarcopenia (muscle loss due to aging) using

engineered skeletal muscle to study muscle deterioration and test potential treatments for muscle wasting.

- A research team from the University of Maryland observed gaseous spherical cool diffusion flames on the ISS, representing the first time such flames have been observed in space or on the ground. A better understanding of cool flames could help improve engine efficiency and lead to cleaner emissions.
- Case Western Reserve University researchers showed how flame spread could be accelerated or suppressed during combustion in structures with confined geometries. Findings can be used to assess potential fire hazards in confined spaces (e.g., vehicles, tunnels, buildings, and spacecraft) and inform future fire codes.

"Since 2016, the National Science Foundation has worked with the ISS National Lab to enable fundamental science in low Earth orbit. Insights gained from research conducted through this partnership will impact future energy sources, microelectronics, health, and other technologies that benefit life on Earth. Through collaborations such as these, we are expanding opportunities for researchers across the U.S."

– Susan Margulies, NSF Assistant Director for Engineering

Other examples of publications from FY22 include the following:

- Researchers from Emory University found that microgravity increases the proliferation of heart muscle cells derived from induced pluripotent stem cells—findings with important applications in regenerative medicine, disease modeling, and drug discovery. This investigation built upon the research team's preliminary ground validation study.
- With microgravity-grown protein crystals, University of Toledo researchers were able to use neutron diffraction to determine the structure of an enzyme involved in the ability of salmonella and other bacteria to cause infection—something that had never been achieved on Earth. Results led to more accurate structural models of the enzyme, which could help develop improved antibiotics.
- University of Alabama Birmingham researchers published results that shed light on why space-grown protein crystals often have higher quality than Earth-grown ones. Findings could help predict which proteins may benefit most from crystallization in microgravity.
- A publication discussed the detection of cosmic rays over an eight-year period on the ISS from the Alpha Magnetic Spectrometer-02, a particle physics detector seeking to advance knowledge of the universe and its origin.
- Two publications detail results from Genes in Space student-led investigations: one developed a technique to monitor the immune system of astronauts in space, and another proposed a way to monitor DNA changes in astronauts as they are happening.

Additionally, a perspective paper was published in Stem Cell Reports discussing the outcomes of a Biomanufacturing in Space Symposium that the ISS National Lab co-hosted. The symposium was the first step in developing a roadmap to establish a sustainable biomanufacturing market in

LEO. ISS National Lab staff also authored a conference proceedings paper on in-space production applications published in TechConnect Briefs.

In FY22, **two patents related to ISS National Lab-sponsored research were granted**: one to Hewlett Packard Enterprise for a novel electronic cooling system related to the Spaceborne Computer and one to Made In Space (acquired by Redwire Space) for a sensor system for optical fiber manufacturing. A third patent was filed by the University of Alaska Anchorage related to biofuel production.

ISS National Lab-sponsored research also led to four products this fiscal year:

- The latest formulation of Procter and Gamble's (P&G) Febreze Unstopables® Touch Fabric Spray is the first P&G product to incorporate materials based on the company's ISS National Lab-sponsored research.
- More than 200 hours of footage captured through an ISS National Lab-sponsored project was used to create the Emmy-winning virtual reality series "Space Explorers: The ISS Experience" produced by Felix & Paul Studios in association with TIME. The fourth and final episode of the series, featuring the first spacewalk ever filmed in cinematic virtual reality, was released in FY22.
- Felix & Paul Studios also used the footage to produce "Space Explorers: The Infinite," a traveling interactive exhibit in which viewers put on virtual reality headsets to experience what it is like to be an astronaut on the space station.
- Redwire Space achieved a significant milestone for LEO commercialization with the first sale of an optical crystal produced in its Industrial Crystallization Facility onboard the ISS—one of the first times a space-produced materials product has been sold on Earth.

> ***"As the ISS National Lab progresses from a science test bed to a user facility for applied science and commercial development, we are seeing impactful results from the past decade of ISS National Lab-sponsored R&D. These results demonstrate the value the ISS National Lab will continue to provide as the nation drives toward the LEO economy of the future."***
>
> *– Elizabeth Cantwell, CASIS Board of Directors Chair*

LEO Economic Development: Demand

The ISS National Lab continues to increase demand for space-based R&D among a broad range of users to expand the LEO economy and return value to the nation. Opportunities to conduct research through the ISS National Lab are a significant benefit to industry, U.S. government agencies, and academic institutions, as evidenced by their willingness to commit funding to support space-based projects. This year, **CASIS funding for newly selected projects was matched at a ratio of 4:1** by committed funding from non-NASA, third-party entities and the selected institutions themselves. To date**, nearly $260 million in external, non-NASA funding has been committed** to support specific R&D projects sponsored by the ISS National Lab.

Targeted ISS National Lab research announcements (NLRAs) drive demand in areas with the greatest potential to develop sustainable markets. Of the **46 projects selected for flight opportunities in FY22**, more than 40 percent were through NLRAs in strategic focus areas:

- Technology advancement (10 projects)
- The in-space production applications areas of advanced materials (2 projects) and tissue engineering (1 project)
- Digital engagement and higher education (7 projects)

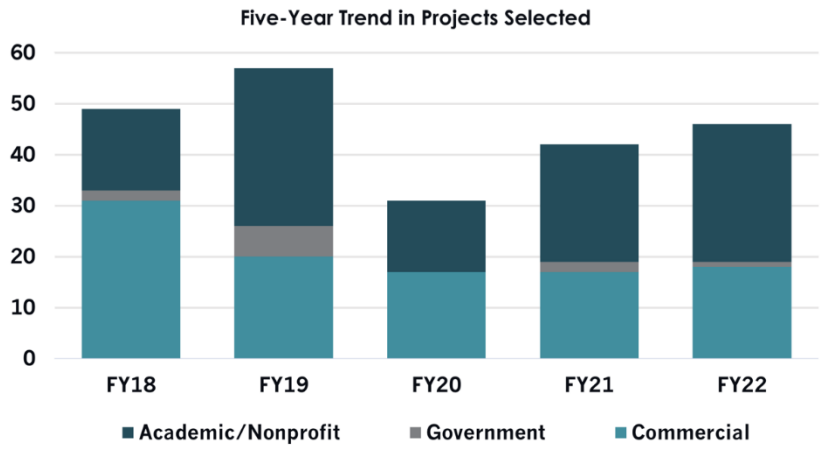
The **ISS National Lab works in close alignment with NASA on these strategic areas**, and in FY22, two projects were selected through the NASA Vascular Tissue Challenge, and five were selected through NASA's In-Space Production Research Announcement.

"The ISS National Lab and NASA are working together to enable U.S. industry to develop cutting-edge manufacturing technologies that benefit from microgravity to produce amazing medical therapies and advanced materials for use on Earth. Support from the experts at the ISS National Lab is critical to the success of the in-space production applications portfolio and continued U.S. leadership in LEO."

- Kevin Engelbert, NASA Portfolio Manager for In-Space Production Applications

The ISS National Lab continues to build on its **powerful multiyear collaboration with NSF** to advance fundamental research and establish the knowledge base for future applied R&D. This year, CASIS and NSF issued two annual joint solicitations: one in tissue engineering (5 selected projects) and one in the physical sciences area of transport phenomena (7 selected projects).

In FY22, the ISS National Lab also **partnered with Estée Lauder on the ISS National Lab Sustainability Challenge: Beyond Plastics**, and the company funded two projects selected through the challenge. Additionally, the ISS National Lab continues to support innovative startup companies identified through the MassChallenge accelerator program. This year, two projects were awarded the **Technology in Space Prize, funded by CASIS and Boeing in partnership with MassChallenge**.



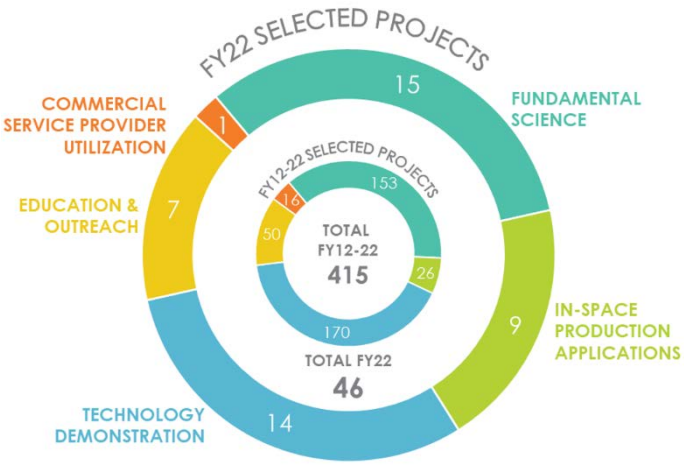
(For a full list of FY22 solicitations, see Appendix A. For a full list of all selected ISS National Lab-sponsored projects, see the ISS National Lab Project Pipeline.)

Of the newly selected projects this year, **60 percent were from new-to-space users**, demonstrating the success of ISS National Lab solicitations in reaching new research communities. Projects from new-to-space users include two studies from Wake Forest University to produce thick, vascularized liver tissue for regenerative medicine applications and an investigation from Lawrence Livermore National Laboratory to test volumetric additive manufacturing for organ production in space. Investigations from return users include a project from HySpeed Computing to demonstrate the real-time streaming of ultra-high-resolution imagery from space and an experiment from the University of Connecticut to advance commercial in-space manufacturing of nanomaterials for cartilage tissue repair on Earth.

"The NASA Vascular Tissue Challenge and our ISS National Lab-sponsored project provided an opportunity for our team to push the boundaries of tissue engineering. To use the ISS to successfully mature engineered human tissue containing vascularity would be a significant stride forward in regenerative medicine and would help improve understanding of how the space environment affects the human body."

- Tony Atala, Director, Wake Forest Institute for Regenerative Medicine

To inform ISS National Lab strategic focus areas and direct the future of LEO commercialization, the ISS National Lab continually gathers input from thought leaders and subject matter experts. In FY22, the ISS National Lab hosted a **second phase of the Biomanufacturing in Space Symposium.** The symposium sought to develop a national roadmap for R&D advancing space-based biomanufacturing toward commercial product development and clinical application on Earth. Additionally, two workshops were held in conjunction with ISSRDC 2022—one on the broad area of in-space production applications and another specifically focused on biomanufacturing. Through these workshops, the ISS National Lab and NASA shared progress in these key areas and gathered input from the space community to establish a future vision to move these areas forward.



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

LEO Economic Development: Supply

The ISS National Lab continues to create demand that fosters supply-side growth of the LEO economy and supports the community of Implementation Partners (companies and organizations that offer services related to payload development). With the addition of LaMont Aerospace this year, there are **39 ISS National Lab Implementation Partners** (see a full list in the Implementation Partner directory) that range from well-established aerospace companies to innovative startups. These Implementation Partners provide a wide variety of capabilities and services that allow researchers to translate their ground-based R&D to successful spaceflight projects.

To facilitate business-to-business relationships for space-based R&D, the ISS National Lab continues to connect Implementation Partners with users via an online Implementation Partner Portal. In FY22, **82 percent of CASIS funding was used to cover Implementation Partner costs** for researchers. The ISS National Lab also continues to collaborate with Implementation Partners through bi-annual Implementation Partner workshops that guide supply-side economic development in LEO.

There are currently **17 Commercial Service Providers** (the subset of Implementation Partners that own and operate facilities on the ISS or are developing future facilities) and **24 ISS National Lab commercial facilities** (full list in Appendix B). This year, the definition of an ISS National Lab commercial facility was broadened to include launch-on-demand facilities due to a significant increase in their utilization. Facility updates in FY22 included an upgraded version of Space Tango's TangoLab facility and successful testing of Nanoracks' Bishop Airlock to dispose of waste from the ISS, representing the first open-close cycle of the commercial airlock.

FY22 key Implementation Partner milestones include the following:

- Axiom Space achieved a historic first when the company launched four astronauts on Axiom Mission 1, the first all-private astronaut mission to the ISS.
- Intuitive Machines announced its plans to become a publicly traded company through a merger with Inflection Point Acquisition Corp. on the Nasdaq exchange.

"The ISS National Lab plays an integral role in the utilization of this incredible orbiting learning platform, and NASA strongly values this partnership to open access and opportunity to researchers and innovators. In the coming years, the ISS National Lab will continue to be an essential component by enabling space-based research that will bring value to humanity and build commerce in LEO as we begin the transition to commercial destinations in LEO."

- Joel Montalbano, NASA ISS Program Manager

- Sierra Space announced a $1.4 billion Series A investment of primary capital, the first capital raise for the company.
- Techshot Inc., which operates the BioFabrication Facility and Multi-use Variable-gravity Platform on station, was acquired by Redwire Space.
- Several Implementation Partners and Commercial Service Providers were announced as teammates for two U.S. companies that NASA selected to develop designs for space stations and other commercial destinations in space.

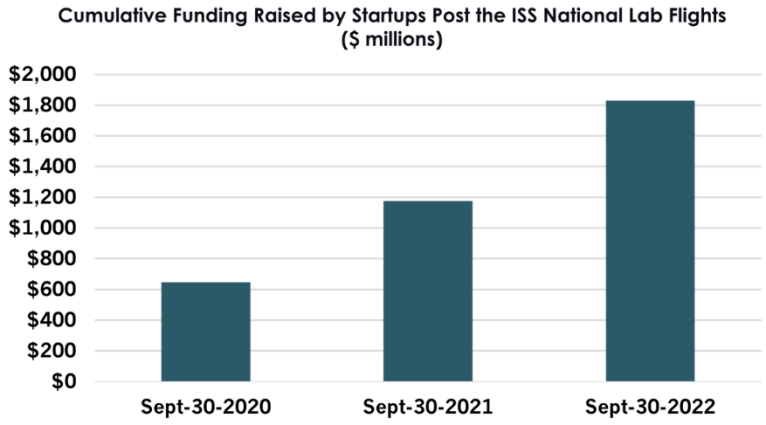
"The ISS National Lab has helped build demand for research and manufacturing in space and has served as an incubator for the development and testing of new technologies and enterprise models. The fact that there may be multiple private commercial space stations following the ISS speaks to the foresight of the legislation that created the ISS National Lab and the ability of CASIS to execute its mission."

- Rich Boling, VP at Redwire Space

LEO Economic Development: Investor Network and Capital Connections

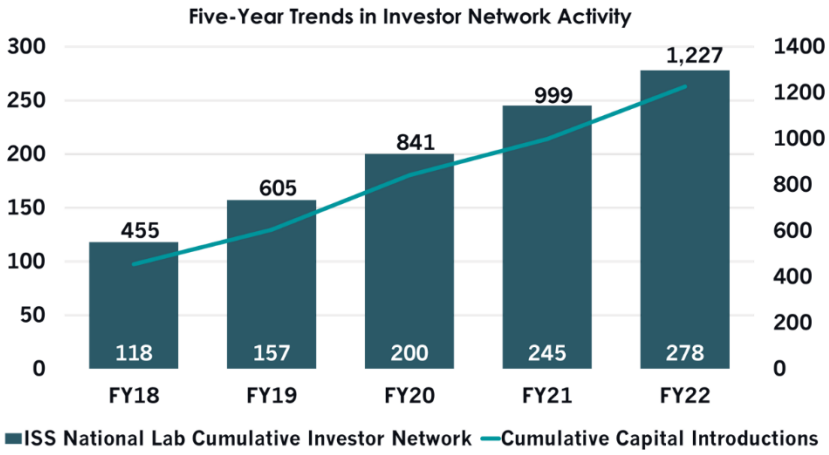
This was a record year in terms of post-flight capital raised by companies conducting research and technology development through the ISS National Lab. The **FY22 total funding raised postflight by startups with ISS National Lab flight projects amounted to $658 million, and all-time cumulative funding amount reached more than $1.8 billion**. Including companies that have been awarded a flight project that has not yet flown to the ISS, the respective totals amount to $714 million for FY22 and close to $2 billion for the all-time cumulative total.

This year included several capital-raising successes by companies that have flown projects through the ISS National Lab, ranging from public market entry by Planet to earlier-stage financial and strategic capital access by Apogeo Space (formerly GP Advanced Projects), Hedron Space, Kernal Biologics, Lynk, Lonestar, NSLComm, Optisys, SatRevolution, and several others.



The ISS National Lab's investor engagement continued to expand during FY22, despite the challenging market conditions. The **ISS National Lab's investor network has grown to include 278 venture capital, private equity, corporate, angel, and other financial investors**. To date, **CASIS has facilitated more than 1,200 capital introductions between startups and investors** in the ISS National Lab network, with FY22 being one of the most active years of such activity. The ISS National Lab's investor ecosystem remains a source of capital connections and possible funding for early-stage companies planning studies on the ISS.

This year, the **ISS National Lab held its seventh annual investor event**, showcasing nine promising startups across remote sensing, materials processing, orbital logistics and services, data processing and computing, and R&D instrumentation sectors. All these companies have either flown or are looking to fly their technology and research to the ISS.



Industry Context

Macroeconomic and geopolitical conditions changed significantly during the fiscal year. The first quarter of FY22 still benefited from favorable public and private market conditions, but capital access tightened significantly as the calendar year 2022 unfolded. Per Pitchbook and NVCA's reported quarterly data, the overall U.S. venture capital investment activity peaked in the December 2021 quarter. During the third quarter of 2022, this investment activity declined 40 percent quarter-over-quarter and 52 percent year-over-year. Space startups saw similar trends. Per Space Capital data, the space economy funding for infrastructure and distribution segment startups declined 41 percent year-over-year in the September quarter, and, if we look at the funding data excluding funding to some of the more established companies, as well as 2021 Special Purpose Acquisition Company (SPAC) transactions, then conditions were softer with third quarter 2022 totals down 59 percent from year-ago levels.

The Federal Reserve's sizable interest rate hikes to fight inflation have raised the cost of capital for investors, making delayed payout and higher-risk businesses more expensive to fund. From the investor dialogue within the ISS National Lab ecosystem, there is continued interest and willingness to assess new investment opportunities; however, the investment criteria have tightened significantly. The prospects of broadly slower economic growth have affected the pace of private-sector technology adoption. While there clearly is "dry powder" from recent years' venture capital and private equity fund capital raising activity, these is no rush of deployment in the current environment where pricing has yet to bottom. Strategic investors remain engaged, and in some cases are increasing commitment levels, but the actual deployment of capital is likely to be driven by the merits of specific innovation rather than by overall lower market valuation levels. Under the current economic conditions, unlocking and scaling sizable commercial markets for several less-mature space applications may see some delays and may require near-term support from the government and defense sectors to sustain and spur innovation.

Educational Outreach and Engagement

Working with academic and industry partners to utilize the space station to inspire students and advance science literacy is a key focus area for the ISS National Lab. Each year, the ISS National Lab engages students and educators in powerful science, technology, engineering, and mathematics (STEM) education programs through Space Station Explorers—a community of educators, learners, and organizations that leverage the unique platform of the ISS National Lab to provide valuable educational experiences for students in grades K-12 and higher education.

In FY22, **more than 9.5 million people participated in the 25 partner programs within the Space Station Explorers community** (see full list on the Space Station Explorers partner program page), nearly triple the number of individuals reached in FY21. Additionally, the **ISS National Lab's online resources were accessed by more than 17.6 million online users**. This year, nearly 40 percent of participants in Space Station Explorers partner programs were female, and more than 30 percent represented underserved communities. The **ISS National Lab gained five new partner programs in FY22**: PocketLab, Beyond School Hours, the National Center for Simulation, the SETI Institute, and the University of California, San Francisco.

> ***"Whether contacting astronauts on the ISS or designing a microgravity experiment, educators can provide their students with many pathways to STEM careers through participation in Space Station Explorers partner programs. It is critical to equip students with the technical skills that will be required in the future workforce, and the ISS National Lab is a valuable tool to accomplish this."***
>
> *- Melissa Pore, Educator at Bishop O'Connell High School in Virginia, Space Station Ambassador, and ISS National Lab User Advisory Committee member*

Space Station Explorers partner programs with far reach in FY22 include the following:

- ARISS (Amateur Radio on the ISS), a free program that allows students to talk directly with ISS crew members via ham radio, reached more than 160,000 people.
- ISS-Above, which offers a small device that provides ISS location alerts and live video streaming from space, reached more than 88,000 people.
- Sally Ride EarthKam, a free program that allows students to take digital images of Earth from the ISS, reached more than 100,000 people.
- Story Time From Space, a free program that provides video recordings of astronauts reading books from onboard the space station, reached more than 5.8 million people.
- Tomatosphere™, a free program in which students compare the growth of tomato plants from seeds flown on the ISS versus seeds that remained on Earth, reached more than 190,000 people.

The Space Station Ambassador program, through which educators, leaders, and lifelong learners share information on Space Station Explorers activities with their communities, continued to expand this year. The program gained more than 400 members in FY22, bringing the total to more than 2,000 Ambassadors. This year, two Space Station Ambassadors were selected to

receive Space Station Explorers Exceptional Ambassador Awards, and one was selected to receive the first Tony So Excellence in Education Award.

Additional key educational activities in FY22 include the following:

- The ISS National Lab launched Expedition Space Lab, an online tool that provides educators with easy access to free ISS-related lessons and activities to integrate into their curriculum. It also highlights additional Space Station Explorer partner program resources that have associated costs but provide a more engaging learning experience.
- Through an inaugural funding opportunity this year, the ISS National Lab selected five organizations to receive funding to purchase Expedition Space Station resources.
- The ISS National Lab selected three recipients for the inaugural 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.
- Mattel released its "You Can Be Anything" YouTube series episode featuring footage of two Barbie dolls onboard the ISS, resulting in more than 170,000 views. The dolls launched to station earlier in the year as part of an ISS National Lab-sponsored project from Mattel to capture footage to inspire young girls to pursue STEM careers. The project's launch led to 78 million media impressions and more than 1.8 million social media impressions.
- At ISSRDC 2022, the Genes in Space™ program announced the winner of its annual student research competition: a North Carolina high school student whose experiment could lead to a better understanding of aging and cancer development.

Outreach and Stakeholder Engagement

The ISS National Lab continued to enhance its ability to communicate R&D progress and results in FY22. A wide variety of content showcased the diversity of ISS National Lab activities through targeted press releases, *Upward* features, and engaging ISS360 articles. Efforts to expand the ISS National Lab's social media presence and digital storytelling have led to **more than 532,000 followers across all social media platforms, a 15 percent increase in followers from FY21**. This year, **ISS National Lab representatives participated in more than 60 speaking engagements** to highlight impactful ISS National Lab-sponsored R&D and increase awareness of research opportunities available through the orbiting laboratory.

This year marked the **11th annual ISSRDC, held July 23-28 in Washington, D.C.,** and hosted by CASIS, NASA, and the American Astronautical Society (AAS). The conference, which was held in person for the first time since the start of the COVID-19 pandemic, was **attended by nearly 800 people.** With the theme "Decade of Results," ISSRDC 2022 included several notable sessions, including a live downlink from the ISS with two crew members who discussed the station's value as a powerful research platform. In a joint panel session, ISS National Lab and NASA leadership discussed the next decade of space station R&D. The conference also featured a STEM education panel on the importance of inspiring students to pursue STEM careers, and Deputy Secretary of Education Cindy Marten gave a keynote address on equality and accessibility in STEM education.

Following the conference, a series of ISS360 articles highlighted panels, keynotes, and other activities from ISSRDC 2022.

In FY22, the ISS National Lab continued collaborating with NASA on several outreach events. The ISS National Lab facilitated a media event in Boston focused on STEM education that featured NASA astronaut Kate Rubins, miniPCR and Genes in Space representatives, and local students. The ISS National Lab also worked with NASA to host two virtual Destination Station outreach events, which provided stakeholders and leaders from well-known companies with meaningful information on ISS research capabilities and funding opportunities. One Destination Station event featured NASA astronaut Victor Glover, and the other gathered nearly 600 Starbucks employees to discuss how the ISS can be used to advance science and technology development.

Also, in FY22, the ISS National Lab hosted a virtual event to discuss how the orbiting platform can facilitate plastics alternatives research and to highlight finalists in the ISS National Lab Sustainability Challenge: Beyond Plastics. The two projects selected through the challenge, which Estée Lauder funded, were announced at ISSRDC.

Examples of FY22 key speaking engagements include the following:

- ISS National Lab Chief Scientist Michael Roberts was invited to moderate a plenary session at the 2022 American Society for Gravitational and Space Research (ASGSR) Conference.
- Together with NASA, the ISS National Lab facilitated a live ISS downlink featuring NASA astronaut Kjell Lindgren during a main-stage session at BIO International, the largest biomedical conference in the world. The ISS National Lab also facilitated a life sciences session with representatives from several Implementation Partners and companies that have conducted research on the space station. This is the tenth year the ISS National Lab has participated in the conference, which attracts leaders from around the world in the biotechnology and pharmaceutical industries.
- The ISS National Lab participated in the invite-only White House Office of Science and Technology Microgravity R&D Workshop, along with leaders from NASA, industry, academia, and other government agencies. Participants discussed key areas for future space-based research and what is needed to enable a sustainable R&D ecosystem in LEO.
- At the American Institute of Aeronautics and Astronautics ASCEND conference, the ISS National Lab participated in a panel session on private-sector users of the space station.
- At the American Chemical Society's Fall meeting, the ISS National Lab participated in an invite-only roundtable on the future of in-space chemistry.

In FY22, high-profile media coverage brought visibility to the many ways the ISS National Lab is leveraged to advance research and technology development. Examples include the following:

- The first archaeological experiment in space was covered in CNN, NPR, Smithsonian Magazine, PBS, and Scientific American.
- Colgate-Palmolive's skin health investigation and the ISS National Lab Sustainability Challenge: Beyond Plastics were covered in Smithsonian Magazine, SyFy, Happi, MIT Tech Review, Space.com, Space News, Glossy, and Cosmetics Business.
- ISS National Lab staff were interviewed for an article published by Agritecture on space-based agriculture.

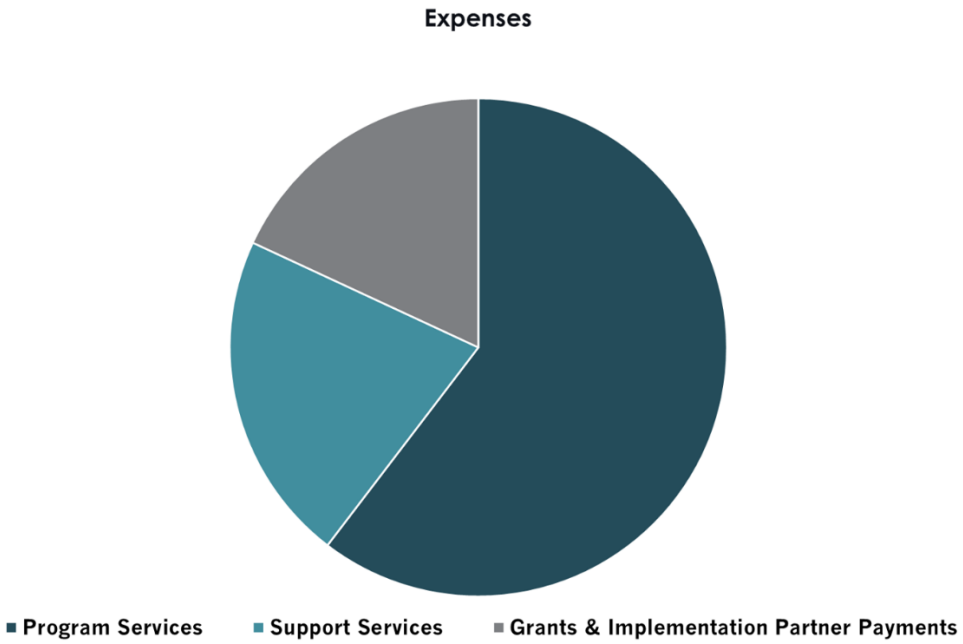
Financials

Unaudited Summary Statement of Financial Position as of September 30

	2022	2021	2020
Total assets	$3,532,300	$3,267,484	$3,290,268
Total liabilities	$1,117,753	$958,197	$878,378
Total net assets	$2,414,547	$2,309,287	$2,411,890
Total liabilities and net assets	$3,532,300	$3,267,484	$3,290,268

Unaudited Summary Statement of Activities for Years Ended September 30

	2022	2021	2020
Total revenues and other support	$12,732,065	$12,176,689	$14,454,605
Total operating expenses	$12,626,805	$12,279,292	$14,389,740
Change in net assets	$105,260	($102,603)	$64,865
Net assets, beginning of the year	$2,309,287	$2,411,890	$2,347,025
Net assets, end of the year	$2,414,547	$2,309,287	$2,411,890



Appendices (available in a separate document)

To view the full Appendices, visit www.issnationallab.org/ar2022.

A. *FY22 Solicitations*
B. *ISS National Lab Commercial Facilities*
C. *Peer-Reviewed Journal Publications and Books*
D. *ISS National Lab on the Map*

In Memoriam: Joseph H. Hastings

We would like to pay tribute to CASIS employee Joseph H. Hastings, who passed on April 12, 2022. Joe proudly served the organization for ten years as the finance director and treasurer. Joe was dedicated to the organization's mission and was one of the initial employees at the start of CASIS in 2011. Joe had the respect and admiration of the team. He was caring and supportive to us all, earning the nickname "Papa Joe" with anyone he met. We are grateful for his many contributions to the organization over the years, he will always be warmly remembered.