ISS National Laboratory
CENTER FOR THE ADVANCEMENT OF SCIENCE IN SPACE

International Space Station U.S. National Laboratory
Annual Report for Fiscal Year 2020

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About the International Space Station U.S. 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 (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.

Mission: We manage the International Space Station National Laboratory as a public service in order to benefit the U.S. taxpayer and to foster a scalable and sustainable low Earth orbit economy. We leverage our core competencies, facilitate public-private partnerships, and utilize the platform capabilities and unique operating environment of the space station. We create demand, incubate in-space business ventures, provide access for and awareness of fundamental science and technological innovation, and promote science literacy of the future workforce.

Vision: To be the Center of Excellence advancing U.S. leadership in commercial space, fostering science and innovation in microgravity and inspiring the next generation.

Executive Summary

The year 2020 brought the world many unexpected challenges, but CASIS was fortunate to be able to maintain operations with safety procedures in place, and we experienced (professionally) only minor setbacks in progress due to the COVID-19 pandemic. In fact, some adaptations to new tools and systems strengthened our operations and community outreach, and our renewed and more aligned collaborative approach with NASA led to positive evolutions of our processes, goals, and trajectory.

The CASIS board of directors rotated members and appointed a new interim chair, and CASIS worked in concert with NASA to develop more focused mission priorities based on ISS National Lab past successes. CASIS also established the guidelines and structure for a new User Advisory Committee to more formally solicit and consolidate input and perspectives from our community, incorporated more clarity and transparency in the CASIS proposal review and selection processes, and introduced a new Pioneer Allocation model that will provide Commercial Service Providers with more reliable access to the ISS National Lab as they mature their business models and expand their customer base.

The ISS National Lab also hit several major milestones and records in 2020. More than 500 investigations have launched to the ISS National Lab under CASIS management. A record 27 journal articles this year detailed results from ISS National Lab investigations, including findings from Merck & Co. related to its anticancer drug Keytruda®; results from the Mighty Mice in Space rodent research investigation; and seven publications on results related to research and development (R&D) sponsored by the National Science Foundation (NSF) in the areas of combustion, fluid dynamics, and transport phenomena. The 9th annual ISS Research and Development Conference, albeit virtual, reached record attendance, and CASIS digital media campaigns achieved more social engagements than in any previous year, reaching new audiences with key research developments associated with the ISS National Lab. Finally, the CASIS learn-at-home online initiative (in response to COVID-19) increased web traffic to education resources 10-fold.

CASIS collaborations with the National Institutes of Health (NIH) and NSF continued, with a total of 10 solicitations jointly issued over the past four years. More than $40 million in funding from these partners has been awarded to 37 projects, 14 of which have flown to the ISS National Lab—producing seven new peer-reviewed publications this year alone.

Despite a six-month period with only one crew member available for R&D, this year's crew-time utilization is higher than the five-year average, with in-orbit activities this year including investigations from Fortune 500 companies, academic institutions, small high-tech startups, and many others—also reflecting a diversity of funding sponsors, including Boeing, the Defense Advanced Research Projects Agency (DARPA), NSF, NIH, and the National Stem Cell Foundation.

Despite a volatile FY20 due to the pandemic, the ISS National Lab ecosystem reflected successful funding rounds, contract wins, and strategic transactions for ISS National Lab startup

investigators and Implementation Partners. Our data show that award and subsequent flight of an ISS National Lab project are key indicators of economic value creation for startup companies using the ISS National Lab for R&D. Moreover, CASIS grants this year were matched at a ratio of 1:12 by committed funding from third-party sponsors and the awarded institutions. More than 50% of new projects awarded over the past three years have only required ISS National Lab allocation—no grant funding—and almost $190 million in external, non-NASA funding has been committed to date in support of specific ISS National Lab R&D projects.

As FY20 came to a close, we neared the humbling anniversary of 20 years of continuous human presence in space. While 2020 was a challenging year for the world, this anniversary is a poignant reminder of humanity's resilience and achievement. Furthermore, 2020 successes in the development of NASA's Commercial Crew program are ushering in a new era of spaceflight from U.S. soil. The best is yet to come from science in low Earth orbit (LEO), and CASIS is honored to serve the public in pursuit of a shared future in space.

In-Orbit Activities: The ISS as a Research Platform

At a Glance

- More than 500 investigations have launched to the ISS National Lab under CASIS management, including more than 60 payloads delivered this year.
- Despite a six-month period with only one crew member available for R&D, this year's crew-time utilization of more than 750 hours is slightly higher than the five-year average of 735 hours per year.
- In-orbit activities this year included investigations from Fortune 500 companies, top medical universities, and others.
- Investigations reflect a diversity of funding sponsors, including Boeing, DARPA, NSF, NIH, and the National Stem Cell Foundation.

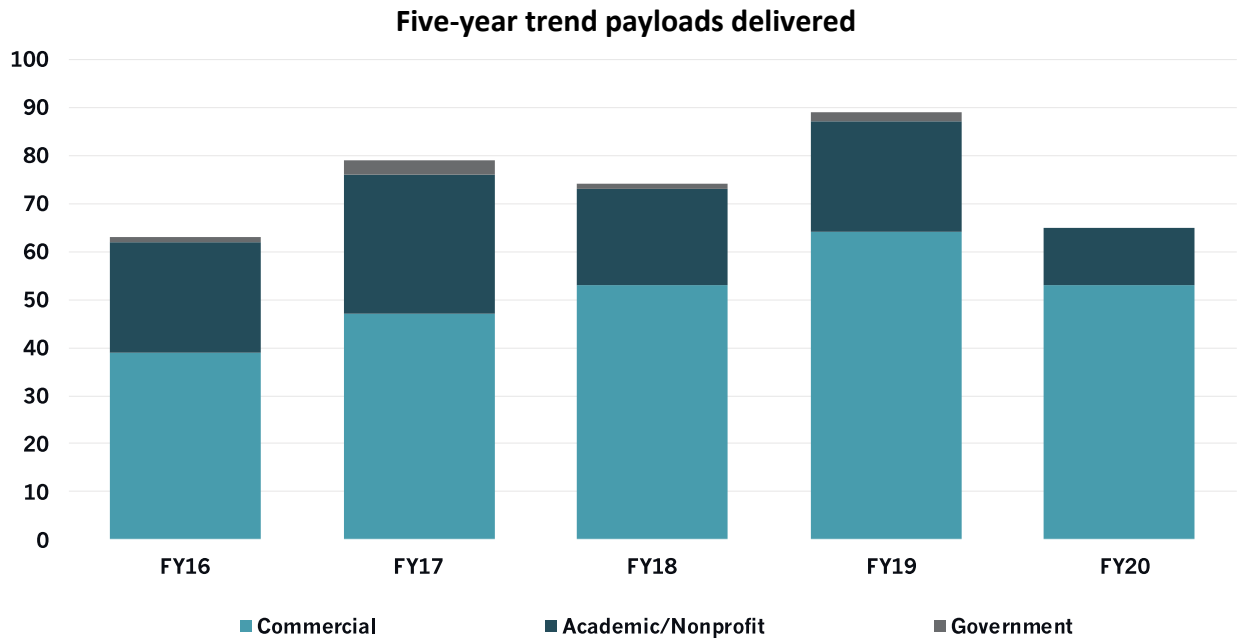
The ISS National Lab continued to maximize utilization and science return in fiscal year 2020 (FY20), despite facing challenges including the global pandemic and briefly reduced crew availability on station (as part of the transition for crew launch to the NASA Commercial Crew Program, which will ultimately increase crew time available for research on the ISS). Including the more than 60 payloads delivered this year, a total of 449 payloads have been delivered to the ISS National Lab since its transition to nonprofit management, representing more than 500 investigations launched over the nearly 10 years of CASIS operations.

The percentage of these payloads that represent projects from the private sector has steadily increased over the past decade, reaching more than 80% in FY20 and averaging approximately 70% over the past five years. Often, these investigations are fully funded by the research team or corporate sponsors. Examples of in-orbit activities associated with FY20 payloads include the following:

- As part of the historic SpaceX Demo-2 mission in July, NASA astronauts Douglas Hurley and Robert Behnken conducted two microfluidic science experiments from startups funded through the Boeing Technology in Space Prize (Qlibrium [formerly Cam Med; West Newton, MA] and 1Drop Diagnostics [Boston, MA]) as well as an investigation from Delta Faucet Company (Indianapolis, IN) that sought to improve its commercially available H2OKinetic® shower head technology.
- Several companies continued investigations focused on ZBLAN optical fiber production in space, and FOMS (San Diego, CA), the first company to hold a patent for technology to produce ZBLAN fibers in space, launched additional investigations twice in FY20.
- TIME (New York, NY), in collaboration with Felix & Paul Studios (Santa Monica, CA), filmed a virtual reality series onboard the ISS, called "Space Explorers: The ISS Experience."
- Techshot (Greenville, IN) used its BioFabrication Facility (BFF, the first U.S. bioprinter in space) to print a large volume of human heart cells into tissue-like constructs as well as a meniscus (the C-shaped cartilage of the knee) in space.

While some projects are fully automated, most require ISS crew members to meet the investigation's goals. This year, ISS National Lab investigations used 104% of the NASA-allocated crew time for R&D, reflecting more than 750 hours of work on exciting R&D aimed at benefitting people on Earth and advancing the economic development of LEO.

This year's crew-time utilization is slightly higher than the five-year average of 735 hours (albeit slightly less than the recording-breaking utilization in FY19 of nearly 1,000 hours)—but this number is notable considering there was only one crew member available for R&D activities for half the year. Availability of crew time fluctuates depending on a variety of factors, but CASIS has maintained more than 100% utilization in three of the past five years (FY17, FY19, and FY20).



Payloads are delivered as part of Commercial Resupply Services (CRS) missions, four of which launched in FY20:

- Northrup Grumman CRS-12 launched more than 20 payloads, including a radiation shielding technology demonstration from Lockheed Martin Corp. (in collaboration with StemRad) and a reflight of student research sponsored by Boeing through the Genes in Space yearly competition—this time building on the team's FY19 first-ever use of CRISPR gene editing technology in space.
- SpaceX CRS-19 carried diverse payloads including Mighty Mice in Space (rodent research sponsored by The Jackson Laboratory), the latest Anheuser-Busch investigation, and research from Aspen Neuroscience (funded by the National Stem Cell Foundation) related to Parkinson's disease and multiple sclerosis. Additionally, the return of SpaceX CRS-19 delivered home research from adidas and multiple investigations funded by the NSF.
- Northrup Grumman CRS-13 payloads included low-cost microsatellites developed by the DARPA, a student investigation in crop science and symbiosis, and a tissue and cell culturing facility (Mobile SpaceLab, from HNu Photonics).
- SpaceX CRS-20 included more research from adidas (materials science for improved athletic shoe technology), cardiac stem cell research from Emory University, feedstock for the meniscus bioprinting using the BFF, and other investigations—and the descent flight brought home investigations including rodent research samples from Baylor College of Medicine and several NIH-sponsored investigations from the Tissue Chips in Space initiative.

R&D Progress and Successes

At a Glance

- 27 journal articles detail results from ISS National Lab R&D, including findings from Merck & Co. related to the company's anticancer drug Keytruda® and results from the Mighty Mice in Space investigation.
- Two new products resulted from ISS National Lab R&D in the satellite and education sectors.
- Multiyear sponsorship of research solicitations by NSF continued in support of fundamental physical and biological sciences.
- Key areas of research continue to mature in both the fundamental and applied sciences, toward benefits to life on Earth and in support of the growing LEO economy.

FY20 was an impressive year for the release of peer-reviewed journal articles resulting from CASIS-sponsored ISS National Lab projects. The majority of the 27 published articles were from commercial users, including startups funded through the Boeing Technology in Space Prize. Peer-reviewed journal articles are a critical means to disseminate findings from fundamental R&D activities, and they not only advance scientific knowledge but also lend credibility, prestige, and merit to investigators who test hypotheses and demonstrate the capabilities of research

platforms like the ISS. Of note, a strong publication base often precedes commercial investment in a particular sector.

FY20 publications included the following:

- Investigators from Merck & Co. published results from their efforts to identify key variables in the crystallization of pembrolizumab, the active pharmaceutical agent in the cancer drug Keytruda®. Results from this project could lead to improvements in the manufacture, storage, and delivery of pembrolizumab, which could reduce costs and improve patient quality of life.
- A non-peer-reviewed publication detailing results from a project supported by the National Cancer Institute showed that the team was able to solve protein structures that they could not solve with Earth-grown crystals, including that of KRAS proteins bound to small-molecule inhibitors. Mutations in the RAS family of genes are responsible for more than 30% of all human cancers, including some of the deadliest (and most costly to treat) such as pancreatic, lung, and colon cancers.
- Results from an investigation led by the Mayo Clinic established the feasibility and safety of growing mesenchymal stem cells in space for human clinical applications on Earth.
- Seven papers detailed results from rodent research. Two discussed liver function and chronic stress, while five discussed changes to musculoskeletal health—one of which made the cover of *Advanced Therapeutics* and another (in *PNAS*, the second most cited scientific journal today) that detailed findings of the "Mighty Mice" investigation, which support the hypothesis that myostatin inhibition may be effective in preventing or treating muscle and bone loss not only in astronauts but also in people with disuse atrophy on Earth.
- Orbital Sidekick published results from its technology demonstration of a space-based, hyperspectral sensor system deployed on the ISS. For defense, hyperspectral technology can provide plume, camouflage, and target detection; detect chemical weapon signatures; identify military resources and troop movement; and aid with relief efforts.
- Seven publications detailed results related to R&D sponsored by NSF in the areas of combustion, fluid dynamics, and transport phenomena. Results from these fundamental science investigations promise to generate data on material and thermal flows at near atomic scale in the absence of gravity that will inform our ability to design more efficient mechanical and biomedical devices for use on Earth.
- Emulate, Inc., an NIH-sponsored commercial investigator who has gone one to raise substantial additional capital investment, published their research results. This publication, along with several additional articles on other ISS National Lab-sponsored research, showcased the value of the ISS for regenerative medicine and therapeutic development.
- Other publications detailed results in agricultural biocontrol, nanochannel drug delivery, and microalgae in spacecraft life support systems and food production.

In addition, three reviews and commentaries (co-authored or authored by NIH) focused on the value of microgravity research in stem cell biology and microphysiological systems (also called tissue chips), and another review discussed the value of the ISS for drug discovery and development.

These articles (citations for which can be found in Appendix E) join the 150 peer-reviewed articles from ISS National Lab investigations and the roughly 2,000 articles from ISS investigations internationally. They also complement the five patents, multiple spin-off companies, and 15 products to date resulting from ISS National Lab investigations. Additionally, two new products in FY20 demonstrate the capacity of the ISS National Lab to support applied R&D programs and private-sector objectives:

- Self-contained, payload-centric, Hyper-Integrated Satlets (HISats; small, mass-producible units) provide complete satellite functionality in a nanosatellite-scale package. From NovaWurks, Inc., this resilient and affordable modular satellite architecture was first developed in conjunction with the construction of DARPA spacecraft.
- Educational videos and other digital content from Nickelodeon's Slime in Space experiments were released to help students learn about microgravity research and topics such as fluid flow and materials engineering. The full video of demonstrations and curriculum on Nickelodeon's website have received more than 100,000 views.

In parallel, on the front end of the R&D project life cycle, two FY20 NSF-sponsored solicitations continued to support fundamental science that leverages the persistent microgravity environment of the ISS to advance scientific discovery for the benefit of Earth. Beginning in 2016, CASIS has partnered with the NSF Engineering Directorate to sponsor these annual research solicitations, which have resulted in five solicitations in the physical sciences area of Transport Phenomena (2016 through 2020) and three solicitations in the biomedical area of Tissue Engineering and Mechanobiology (2018 through 2020). These solicitation cycles have resulted in the award of 27 NSF peer-reviewed proposals representing 29 payloads—and the infusion of more than $18 million of non-NASA grant funding to the principal investigators via the NSF grant awards and funding for the Implementation Partners supporting their spaceflight investigations. (For a full list of FY20 R&D solicitations, see Appendix A.)

Quick Facts to Date for FY20 Key R&D Areas

Tissue Engineering and Regenerative Medicine: This broad field spans from cell-based studies to organoid growth and 3D printing of human tissues. Regenerative medicine research in space is aimed at improving health and longevity using tissue chips and a biofabrication facility to address larger challenges with real-world applications (e.g., to model and study human disease, allow higher-accuracy and personalized drug testing, or advance research to address the shortage of organs for transplantation). In microgravity, tissue chips also have the potential to accelerate pathways for understanding the mechanisms behind disease and developing new treatments. Both fundamental science investigations as well as technology development and demonstration in this area are poised to benefit life on Earth and the growing LEO economy.

CASIS Tissue Engineering and Regenerative Medicine to date:

- 28 payloads flown
- 51 investigations added to the portfolio (5 new this year)
- 8 Implementation Partners supporting these investigations
- $28 million in grant commitments from multiyear programs with NSF and NIH
- 30 peer-reviewed articles published

Advanced Materials: Microgravity allows researchers to observe, model, and exploit underlying physical mechanisms and dynamics that are typically masked by gravity-dependent phenomena in terrestrial studies of combustion, fluids, complex fluids, soft matter, and hard materials. Scientists can leverage these effects to develop next-generation production methods, improve understanding of mechanisms involved in material transformations, advance fundamental materials discovery, and test processes or manufacturing methods of novel design and synthesis pathways. Moreover, while Earth-based experiments are often conducted under artificial conditions to simulate extreme operational conditions, space is the ultimate test objective with simultaneous exposure to multiple environmental extremes, providing a mechanism for rapid failure mode and effect analysis of materials and components. Fundamental science investigations as well as technology development and demonstration in this area provide both terrestrial benefits and support for the expanding economy in LEO.

CASIS Advanced Materials to date:

- 24 payloads flown
- 30 investigations in the portfolio (5 new this year)
- 13 states represented by investigators
- 9 Implementation Partners supporting these investigations
- $13 million in grant commitments from multiyear programs in collaboration with NSF
- 3 patents and 1 product
- 3-fold increase in external (non-CASIS, non-NASA) funding over the last 3 years

In-Space Production Applications: The production of advanced materials or products via space-based manufacturing may be a viable commercial option for some sectors if either the quality or performance of the material is greatly improved and the mass-to-value ratio is advantageous. These benefits would provide a competitive advantage that may balance the long-term cost of space-based production—particularly if the commercialization of LEO continues to improve the availability and affordability of R&D onboard spaceflight platforms. Investigations in this area are largely proof of concept, with the expectation that some may progress to scalable, sustainable business models within the future LEO economy.

CASIS In-Space Production Applications to date:

- 19 payloads flown
- 8 investigations in the portfolio (1 new this year)
- 3 Implementation Partners supporting these investigations
- <5% of total project costs required CASIS funding
- 2 facilities in orbit (additive manufacturing facility and bioprinter)
- 3 companies attempting in-orbit manufacturing of the optical fiber ZBLAN
- 1 patent

Macromolecular Crystal Growth: High-quality crystals of organic molecules, such as proteins, can lead to improvements in drug development, formulation, manufacturing, and storage—as well as agricultural solutions that better protect crops and enhance plant growth. Moreover, inorganic crystal growth can reveal new information about materials such as semiconductors and scintillators used in a variety of applications. In microgravity, researchers are able to grow crystals

that are larger and/or more well-ordered with improved uniformity compared with crystals grown on Earth. Crystal growth for structure-based drug design, product enhancement, or intellectual-property generation provide important benefits to life on Earth and accelerate the economic development of LEO.

CASIS Macromolecular Crystal Growth to date:

- 24 payloads flown
- 25 investigations in the portfolio (1 new this year)
- 13 states represented by investigators
- 7 Implementation Partners supporting these investigations
- 8 peer-reviewed articles published
- 80%+ increase in external (non-CASIS, non-NASA) funding since FY15

Rodent Research: Scientists have used rodents as model organisms in human health studies for more than 100 years on Earth and for decades in space. Rodents are powerful models to study human disease due to their genetic similarities to humans and short life span, which enables studies on accelerated timescales. Rodent research provides accelerated models of disease for scientists to study the mechanisms behind disease, and rodents are used extensively in preclinical testing for new drugs. Space-based research using model organisms such as rodents provides insight into not only the effects of spaceflight on astronaut health but also effects that mimic human disease on Earth, such as bone loss, muscle wasting, heart disease, immune dysfunction, and other conditions. Rodent research on the ISS enables longer-term experiments in this unique environment, and such fundamental science and translational biology studies provide valuable insights that improve life on Earth.

CASIS Rodent Research to date:

- 16 payloads flown
- 33 investigations in the portfolio
- 15 states represented by investigators
- 4 Implementation Partners supporting these investigations
- 14 peer-reviewed articles published

Environmental Sustainability: The ISS National Lab also provides an ideal platform to evaluate technologies for improvements in ecosystem and atmospheric monitoring, membrane and water purification systems, green manufacturing processes including biodegradable polymers, and agricultural processes as potential solutions for a healthier planet. Sustainability bridges many of the science disciplines supported by the ISS and includes projects related to agriculture, the carbon cycle, Earth imaging, smart and green materials, and water quality. Both fundamental science investigations as well as technology development and demonstration in this area help us work toward solutions that benefit life on Earth now and in the future.

CASIS Environmental Sustainability to date:

- 14 payloads flown
- 31 investigations in the portfolio
- 6 states represented by investigators
- 60% of investigations are from the private sector
- 9 Implementation Partners supporting these investigations

- 4 peer-reviewed articles and 5 products
- CASIS funding is matched by 2.5-fold external (non-CASIS, non-NASA) funding

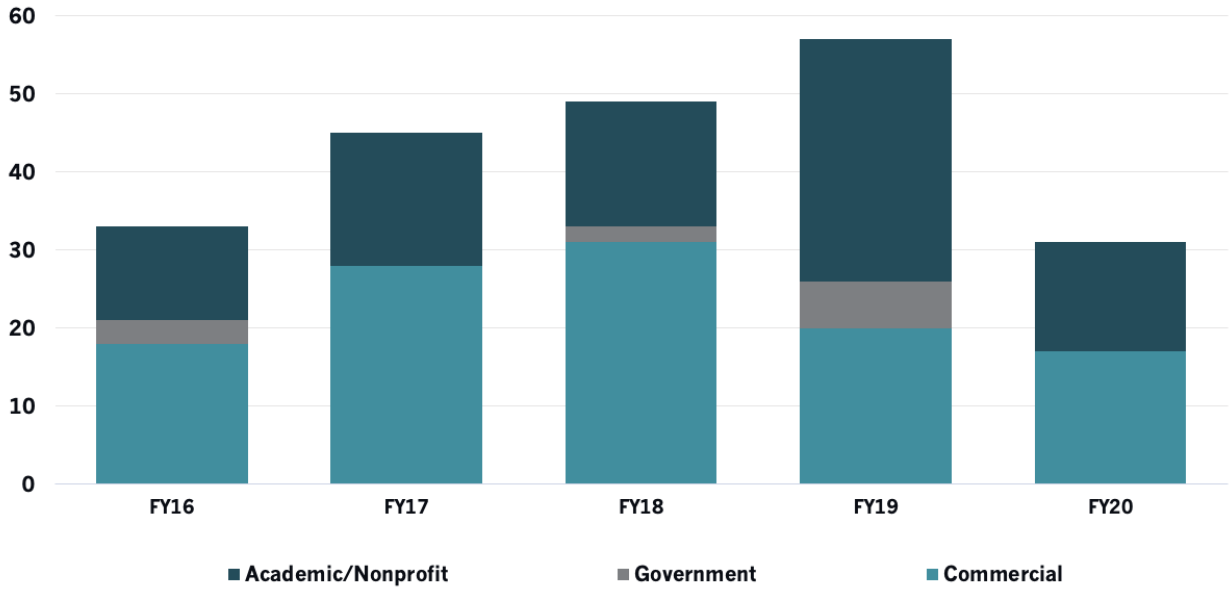
LEO Economy: Demand for Space as a Tool to Tackle R&D of National Importance

At a Glance

- CASIS funding was matched at a ratio of 1:12 by committed funding from third-party sponsors and the awarded institutions.
- More than 50% of new projects awarded over the past three years have only required ISS National Lab allocation—no grant funding.
- Almost $190 million in external, non-NASA funding has been committed to date in support of specific ISS National Lab R&D projects.
- Of the newly awarded projects, 55% of awards represent new-to-space users.

The ISS National Lab continued cultivating innovative R&D ideas from across the U.S. in FY20, spanning from the east coast to the west coast and including the first CASIS awards to institutions in Idaho (Boise State University) and New Hampshire (Dartmouth, in Hanover; refer to the project map on page 24 for more information). Multiple resource constraints and the global COVID-19 pandemic slowed the number of proposals submitted and awarded; however, more than 30 high-scoring proposals were still awarded flight opportunities this year.

Five-year trend in projects and programs selected by the ISS National Lab

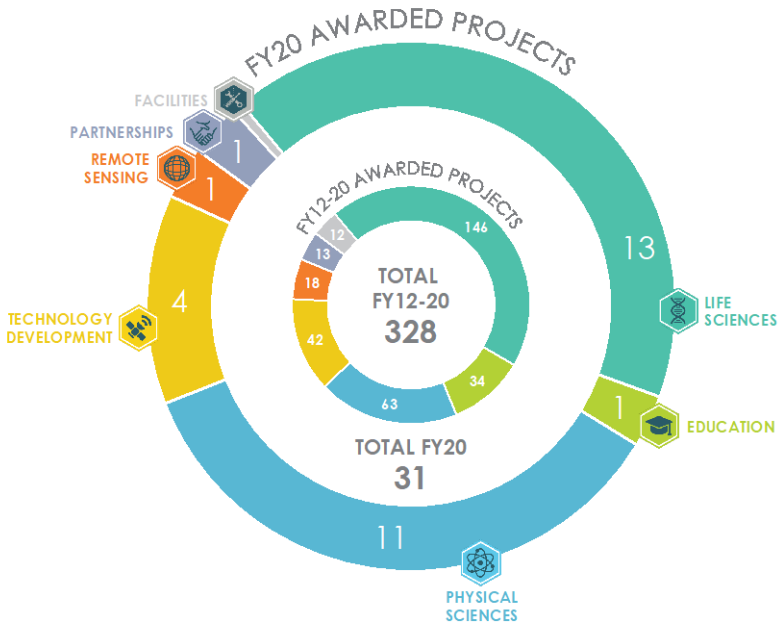


Continuing a historical trend, these new projects also involved significant cost sharing. In FY20, CASIS funding was matched at a ratio of 1:12 by committed funding from non-NASA, third-party sponsors and the awarded institutions themselves. In fact, more than 50% of new projects awarded over the past three years have only required ISS National Lab allocation—no grant funding was awarded to support the R&D activity. Almost $190 million in external, non-NASA funding has been committed to date in support of specific ISS National Lab R&D projects—more than half of which is from commercial entities. Multiyear, multiproject agreements with government and commercial sponsors represent more than $50 million of these cost-sharing funds.

Of the newly awarded projects, 45% came from investigators that had previously completed an ISS National Lab-sponsored project, for example:

- Implementation Partners Made In Space (Jacksonville, FL), Rhodium Scientific (San Antonio, TX), Space Tango (Lexington, KY), and Techshot (Greenville, IN) received new awards.
- LaunchPad Medical (Lowell, MA)—a previous recipient of the Boeing Technology in Space Prize that studied the effectiveness of an injectable bone adhesive (Tetranite®) in space—will launch a second experiment to study post-fracture bone healing using skeletal stem cells.
- Merck & Co. (Kenilworth, NJ), which published findings this year from previous work crystallizing pembrolizumab, the active pharmaceutical agent in the immuno-oncology drug Keytruda®, will fly more research related to monoclonal antibody crystallization.

Projects and programs selected by the ISS National Lab
FY20-selected and total to date



Examples from the 55% of awards representing new-to-space users include:

- Startups AXONIS Therapeutics (Cambridge, MA) and Encapsulate (Farmington, CT), this year's winners of the Boeing Technology in Space Prize, which will be studying breakthrough neuro-regenerative therapies and personalized cancer therapy screening, respectively.
- Nanohmics (Austin, TX), which will fly the world's smallest spectrograph to the ISS for a technology demonstration.
- Purdue (West Lafayette, IN), Dartmouth (Hanover, NH), Northeastern (Boston, MA), and other well-respected research universities.

Awarded projects continued to fall largely within the realms of biomedical and materials science, with a record number of proposals awarded in the area of advanced materials research—many utilizing the MISSE Flight Facility, which is operated by woman-owned small business Alpha Space Test & Research Alliance (Houston, TX).

Moreover, 75% of the awards this year resulted from research solicitations aimed at addressing national priorities; for example, the multiyear solicitations co-sponsored by NSF in the areas of Transport Phenomena and Tissue Engineering and Mechanobiology (nine awarded projects this year).

LEO Economy: Supply-Side Activities Showcase Growth of the Market

At a Glance

- FY20 Implementation Partner activities included the launch of new ISS capabilities as well as additional milestones and firsts for ISS R&D.
- CASIS introduced a new Pioneer Allocation model that will provide Commercial Service Providers with more reliable access to the ISS National Lab as they mature their business models and expand their customer base.
- In recognition of the 20th anniversary of continuous human habitation on the ISS, CASIS invited Implementation Partners to contribute perspectives and insights about what the future may hold for their companies and the space industry—showcased in an online essay series.
- Several Implementation Partners put their expertise to work to assist industries amidst the global COVID-19 pandemic.

The ISS National Lab continues to evolve as an in-space business incubator, supporting service providers that give researchers the ability to leverage state-of-the-art laboratory tools in nearly every avenue of science and technology development. As manager of the ISS National Lab, CASIS is working alongside our Implementation Partners (see Appendix B for a full list) to test, validate, and make available hardware, facilities, and capabilities that drive new areas of inquiry, expand utilization of the ISS, maximize science return, and demonstrate successful LEO-based business models.

Examples of FY20 activities by the growing community of Implementation Partners and Commercial Service Providers (CSPs, the subset of Implementation Partners that manage permanent facilities on station) include the following:

- Nanoracks passed an important milestone in February with its 250th satellite deployment via the Nanoracks External Cygnus Program, the first program to have leveraged a Commercial Resupply Services vehicle for anything other than cargo resupply.
- The Bartolomeo platform from Airbus successfully launched in March and was installed in April; it will support use of LEO for applications including remote sensing, in-orbit manufacturing, and materials science.
- Made In Space celebrated the five-year anniversary of additive manufacturing in orbit and delivered its new Commercial Polymer Recycling Facility designed to convert plastic waste into feedstock for additive manufacturing, toward establishment of a regenerative materials cycle to reduce material waste in orbit without increasing the carbon footprint on Earth.
- Craig Technologies launched its in-orbit external experimental facility, designed to conduct electronics testing and technology demonstration at reduced cost and schedule.
- Boston University and Space Tango tested a novel flow chemistry platform to explore microgravity's effects on chemical processes.

Establishing Reliable Access Via the "Pioneer Allocation"

As the ISS National Lab model evolves for future researchers and business cases, so too does the role of Implementation Partners—in particular CSPs. Beginning in 2012, both CASIS and NASA, via the enterprise of the ISS National Lab, have stimulated and increased investment and growth in the development of privately owned research facilities that are operating onboard the ISS. This growth in private facilities and companies that operate them has resulted in new R&D and technology capabilities for ISS users, enabled increased commercial utilization, and decreased barriers to entry for microgravity R&D.

This growth has also resulted in increased competition for ISS capacity and constrained resources (e.g., transportation, conditioned stowage, and crew time) associated with operating facilities for R&D onboard the ISS. This increased competition among the private facility owners creates obstacles that can inhibit further growth of commercial demand as well as additional private investment in ISS-dependent CSPs. This emerging bottleneck must be overcome to further attract new-to-space users, prevent the stagnation of demand, and further accelerate economic development of this segment of the LEO market. In order for private companies to continue to grow commercial utilization and thereby contribute to the national interest of developing a robust LEO economy, both CASIS and NASA recognize the need for CSPs to have at their disposal a consistent and predictable method and process for accessing a known quantity of ISS-related resources for use by their customers.

To address this important need, CASIS has created a method for identifying a sub-allocation of ISS National Lab resources for exclusive use by the CSPs and the clients they serve. This sub-allocation is titled "Pioneer Allocation" and is designed to incentivize CSP demand-generation efforts, foster an environment in which more in-space business-to-business (B2B) activity will

occur, provide higher confidence levels in capital markets, support the goal of increased commercial demand and utilization, and move the U.S. toward a future state where NASA is one of many customers in a robust LEO economy.

Promoting Implementation Partner Activities, Goals, and Successes

In an effort to more frequently and effectively engage with Implementation Partners, CASIS established a new monthly meeting in FY20 focused specifically on how to bring together communications representatives from these entities to better understand how CASIS can promote Implementation Partner business goals and success. These meetings foster discussion and transparency within the ISS National Lab community and have allowed us to promote Implementation Partner news and opportunities with improved detail and accuracy.

Also in FY20, in honor of the 20th year of continuous human habitation on the ISS, CASIS encouraged Implementation Partners to share their visions for the future of living and working in space, from the perspective of the private sector. In this online essay series, several Implementation Partners discussed how the ISS has already advanced their research and validated their business models, forecasting how their companies and the LEO market overall might look 20 years from now. Read more in the online series "Visions for the Future: The Next 20 Years in Space."

Finally, CASIS is proud to share that several ISS National Lab Implementation Partners used their skills, facilities, and knowledge to provide aid during the COVID-19 global health crisis in FY20:

- Made In Space used its facilities and resources to 3D print face shields and develop a rapid response ventilator adaptor, helping to address the critical shortage of personal protective equipment (PPE) and ventilators.
- Tec-Masters, Inc., the company that developed the original Solidification Using a Baffle in Sealed Ampoules (SUBSA) furnace for the ISS in 2002 as well as the refurbished SUBSA currently onboard the ISS, contributed much-needed PPE. Tec-Masters shifted its 3D printing efforts from the development of prototype hardware to the production of face shields to protect healthcare workers and first responders.
- Boeing, which supports the Technology in Space Prize and the Genes in Space student research competition, used one of its Dreamlifter aircraft to bring PPE to the United States from Hong Kong. Boeing helped transport 1.5 million medical-grade face masks for healthcare professionals.
- Teledyne Brown Engineering, the company that developed the Multi-User System for Earth Sensing (MUSES) Earth observation platform on the ISS, helped keep students engaged and learning during the crisis by culling through their educational materials to provide fun STEM learning activities that students can do at home.

For a full list of Implementation Partners and Commercial Service Providers, see Appendices B and C.

LEO Economy: ISS National Lab Investor Network and Capital Connections

At a Glance

- Despite a volatile FY20 due to the COVID-19 pandemic, the ISS National Lab ecosystem reflected successful funding rounds, contract wins, and strategic transactions for ISS National Lab startup investigators and Implementation Partners.
- The ISS National Lab Investor Network grew to 200 members in FY20, and CASIS has facilitated more than 840 introductions to date in support of capital raising efforts in our ecosystem.
- The annual investor pitch event held in conjunction with the FY20 virtual ISSRDC conference drew many new and returning venture firms as well as corporate investors.
- Award and subsequent flight of an ISS National Lab project are key indicators of economic value creation for startup companies using the ISS National Lab for R&D.

Despite the COVID-19 pandemic, the vitality and overall strength of the commercial space industry was demonstrated by several favorable outcomes in FY20. Many of this year's successes are a result of ISS National Lab Investor Network growth, timely monetary investments, and funding for the space industry and new ISS projects—successes that indicate continued utilization of the ISS as we move into FY21 and beyond. Several ISS National Lab Implementation Partners have notable achievements to report in FY20; for example, Made In Space (Jacksonville, FL) was acquired by Redwire and awarded funding to develop an in-space manufacturing solution (Archinaut One), and Axiom Space (Houston, TX) won NASA's NextSTEP Appendix I award to develop a habitable commercial module.

The ISS National Lab Investor Network Delivers Connections

The ISS National Lab Investor Network has grown to include 200 investment organizations in FY20, up 27% from FY19. This network consists primarily of venture capital (VC) firms followed by corporate venture investors, angel investor organizations, accelerators, private equity markets, and selected financial intermediaries that combined manage hundreds of billions of dollars of investment assets.

In line with the ISS National Lab's responsibilities to identify appropriate funding sources and match qualified research projects with such funding sources, CASIS has now made more than 840 capital introductions with venture and corporate investors, connecting these investment entities with 67 companies/startups in the ISS National Lab ecosystem. The feedback received from the ISS National Lab startup community indicates high value added from such connections, and while not all the resulting funding activity details have been publicly disclosed, CASIS internal estimates indicate that these introductions have supported and complemented financing strategies that have raised more than $400 million in capital.

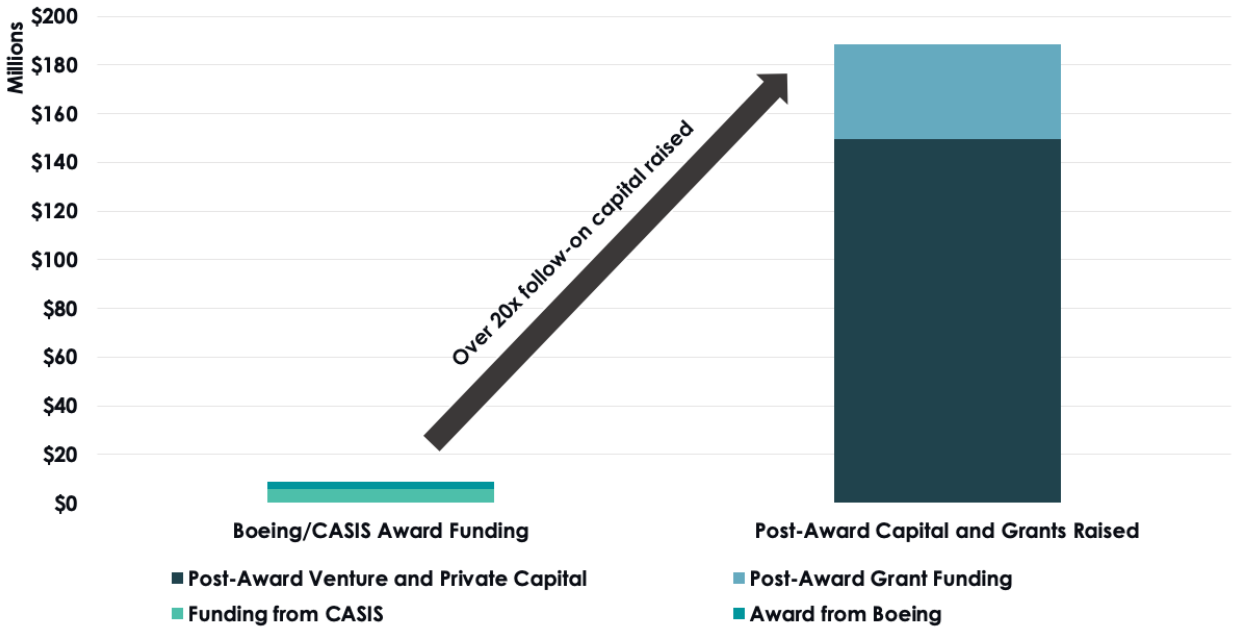
In response to the COVID-19 pandemic, CASIS chose to hold its annual ISS Research and Development Conference (ISSRDC) investor pitch event virtually in FY20. This year's theme, "Startups on the ISS: Innovation and Investment," attracted the attendance of marquee venture firms and corporate investors and included an exciting set of presentations across many of the industry verticals where CASIS has been facilitating R&D for years. Similar to prior pitch events, we were pleased to see several new investors join those with an already established presence in the industry and within our ecosystem. We continue to report strong growth in investor engagement in the ISS National Lab's capital markets ecosystem.

Assessing Fundraising Success of ISS Projects

One of the key indicators of economic value creation for startup companies using ISS National Lab R&D capabilities is their ability to raise third-party capital subsequent to award of a flight project and after execution of their technology or science investigation on station. The data we are seeing here is very encouraging.

Boeing Technology in Space Prize Impact: The ISS National Lab and Boeing [NYSE: BA] have a long history of partnering to grant up to $500,000 collectively toward innovative startup research through the Boeing Technology in Space Prize. This annual opportunity to engage with startups from the MassChallenge startup accelerator is designed to educate startup teams on how the unique space-based environment of the ISS National Lab could prove advantageous to their R&D. With the latest awards, two new flight projects will have the opportunity to leverage the microgravity environment onboard the ISS to enhance their products and business models.

Boeing Technology in Space Follow-on funding ($ millions)



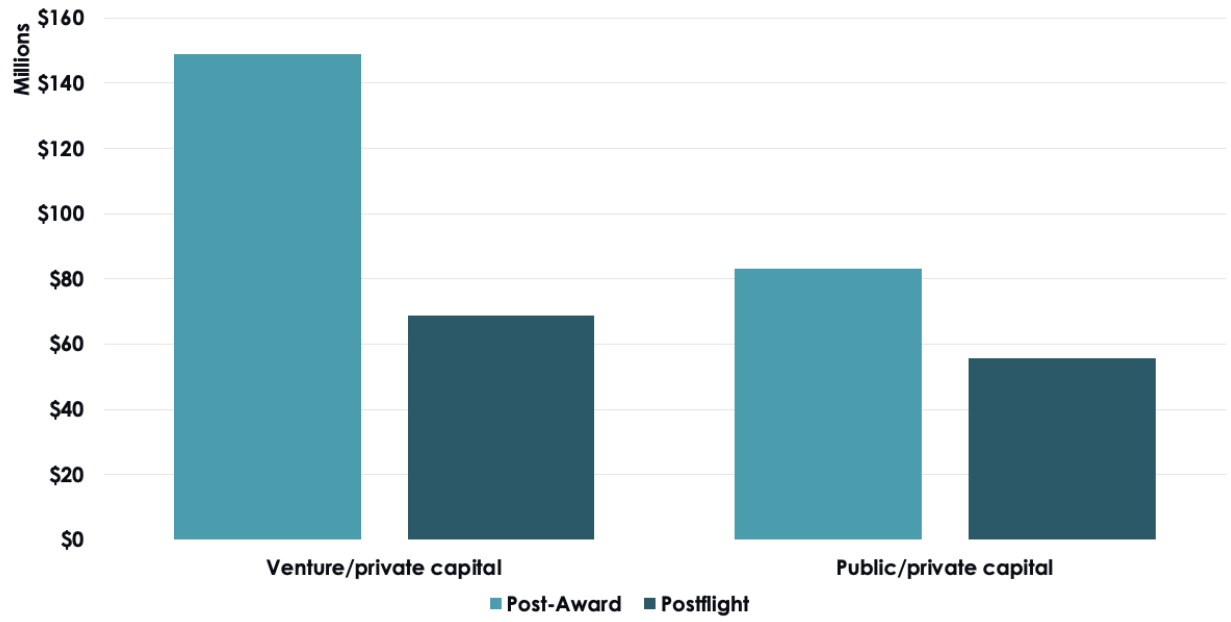
Source: Data from Discovery, Crunchbase, sec.gov, sbir.gov; ISS National Lab data and analysis

Since 2013, the Technology in Space Prize has provided $8.8 million in funding for 27 startups. Subsequent to these award announcements, we have seen these companies raise (combined) close to $150 million of venture capital and close to $40 million of private and public grant funding toward their future growth, which amounts to more than 20 times the total awarded amount. More than $30 million of that funding was raised postflight, with the rest of the funding preceding the launch or raised by companies conducting ground-study projects only.

Some of the notable funding successes among the Technology in Space Prize awardees during FY20 were seed capital raises by companies such as AXONIS Therapeutics (Cambridge, MA; $4 million seed round), LambdaVision (Farmington, CT; jointly with Space Tango [Lexington, KY] awarded a $5 million NASA grant), and LaunchPad Medical (Lowell, MA; up to $1.8 million in grant funding from the Michigan-Pittsburgh-Wyss Regenerative Medicine Resource Center).

Post-Award and Postflight Funding Progress: Similar successes with post-award and postflight funding exist outside of CASIS and Boeing as well for startup companies including Emulate (Boston, MA), Beryllium Discovery (Bedford, MA), Orbit Fab (Cupertino, CA), Orbital Sidekick (San Francisco, CA), and Lynk Global (Falls Church, VA). For example, Orbital Sidekick was selected as one of 20 companies to receive "big bet" funding through the Air Force's AFVentures, and Orbit Fab continued to execute on its funding strategies with a Securities Exchange Commission filing indicating sale of $1.1 million worth of its stock (while also securing a $250,000 NSF grant).

Post-Award and Postflight capital raised by startups ($ millions)



Source: Data from Discovery, Crunchbase, sec.gov, sbir.gov; ISS National Lab data and analysis

Looking at the combined data across our startup ecosystem, based on our estimates and publicly available data, we have seen these companies raise approximately $220 million (combined) of private and public funding following flight project award announcement, including close to $140 million following actual flight to the ISS.

In addition to CASIS-awarded startup projects, several ISS National Lab Commercial Service Providers have flown payloads and launched CubeSats with successful early-stage enterprises, including with Planet, Spire Global, Analytical Space, LambdaVision, Lynk, and others. Excluding overlapping engagements, and primarily driven by successes at Planet and Spire Global, we estimate from public data sources that these startups raised more than $460 million of capital subsequent to their flight projects. Additionally, in FY20, Space Tango was awarded three projects on biomedical application development through the Research Opportunities for ISS Utilization NASA Research Announcement (NRA), building on the company's successful ISS National Lab projects.

Industry Context: Volatility in the Financial Markets

The year started with continued strong investment momentum from a record-breaking 2019, although investor appetite had become somewhat more mixed. While VC funding positions remained strong and new investor entry continued, seasoned investors were increasingly focusing on achieved product-market fit and business execution progress. This market momentum was disrupted by COVID-19-driven retreat and reassessment of VC appetites for new investments. The broader financial market declined sharply, with the S&P 500 index dropping 35% in a little over a month, bottoming on March 23. This sell-off was followed by a relatively rapid rebound in public equity markets and deal activity.

In terms of impact on the NewSpace sector, the industry saw some rationalization and restructurings, and space infrastructure investment declined sharply in the third quarter of FY20. However, the deal activity rebounded in the final quarter, as evidenced by a close to $2-billion funding round by SpaceX, continued strong self-capitalization investments for Blue Origin, and several smaller albeit still very material funding rounds.

While the overall access to funding appears to have recovered, investor commentary from a panel discussion with leading VC and private-equity executives at the September session of ISSRDC pointed to some shifts in investor focus. This change is relative to the earlier years of NewSpace investment activity. Panel discussion highlighted an increased interest in geospatial intelligence and communications-driven applications, relative to infrastructure investments such as launch vehicles or satellite constellation assets (where many of the well-known venture firms have already made their commitments).

Investment opportunities in "second-degree" business models in the NewSpace ecosystem are generally viewed as still in their infancy, with opportunities in earlier stages of quantifiable demand formation and market maturation. In other words, even if there are demand indications from other emerging space companies that result in letters of intent or orders of future business, this demand has likely much more risk associated with it than, for example, an order book with

government or established telecommunications company customers. Seed investments are being made, but these opportunities need to mature before they are likely to access capital from later-stage investors. It remains to be seen whether some of the recently announced and sizable special-purpose acquisition company acquisitions will change investor perceptions.

Space Industry Successes Indicate Progress in the LEO Economy

In January 2020, NASA announced the selection of ISS National Lab Implementation Partner Axiom Space to provide at least one habitable commercial module to be attached to the ISS, shedding light on a potential path beyond the current ISS platform. In May, we saw the significant success of SpaceX's Demo-2 launch and the docking of Crew Dragon to the ISS followed by its subsequent successful return in early August, ushering in a new era of spaceflight from U.S. soil.

Per ISSRDC investor discussions, there are several positive signals supportive of the viability of commercially funded space stations, including space tourism with real customers willing to commit real dollars as well as an established and growing demand from microgravity research and satellite launch markets. However, questions remain on the depth of the overall market demand and the level of capital investment, including upfront capital costs, that this demand could support. It would be fair to assume that the role of government as a reliable buyer to further de-risk the revenue and cash flow outlook would go a long way to support such business models.

While the crowded landscape of planned small satellite constellations has started to rationalize, we are seeing the emergence of market leaders bound to benefit from the growing global demand for broadband data and geospatial information. The Starlink launch and deployment cadence remained impressive through 2020, and Kuiper received its Federal Communications Commission approvals. The ongoing pandemic has also highlighted additional use cases for LEO Earth observation data. In addition, the space sector is seeing strong interest and engagement from the defense industry, including interest in new constellations as well as unmanned orbital outposts and platforms, and the satellite servicing market is taking shape with Northrop Grumman's Mission Extension Vehicle deployments.

In June, we saw AE Industrial Partners portfolio company Redwire acquire ISS National Lab Commercial Service Provider Made In Space. This strategic investment complemented AE Industrial Partners' acquisitions of Adcole Space and Deep Space Systems earlier in the year, with the subsequent formation of Redwire. The Made In Space acquisition was followed by Redwire's acquisition of Roccor, a military and commercial hardware supplier in the small satellite market and a manufacturer of deployable structures for the space industry. Redwire's goal is to build a space platform company with advanced and highly competitive capabilities to deliver mission-critical solutions and high-reliability components for the next-generation space economy and related programs. As further evidence of the impact this team is having on the economic development of LEO, Made In Space President and Redwire Chief Operating Officer Andrew Rush was appointed Chairman of NASA Advisory Council Regulatory and Policy Committee.

From an ISS National Lab perspective, the Made In Space transaction is a positive indication of investor confidence in the long-term fundamentals of NewSpace economy opportunities, including increased recognition of value creation by in-space or in-orbit applications (manufacturing, servicing, and technology and infrastructure development). These in-orbit application opportunities build on and benefit from heavy private-sector investments in new launch vehicles, leading to reductions in costs and growth in access, as well as strong investments in human spaceflight capabilities with the recent commercial success. NASA's long-lasting commitment to private-sector engagement has been essential to the initial seeding and evolution of this ecosystem, and the agency's forward-looking programs are clearly a significant part of future demand.

Educational Outreach and Engagement

At a Glance

- In FY20, almost 3 million people engaged with the 23 partner programs within the Space Station Explorers consortium.
- The Space Station Ambassadors grew to more than 1,000 volunteers.
- The CASIS learn-at-home online initiative (in response to the COVID-19 pandemic) increased web traffic to education resources 10-fold.
- Nickelodeon's new Slime in Space teacher's guide helps educators leverage spaceflight demonstrations to engage and educate young students about non-Newtonian fluids.
- Spaceflight-experiment Space Station Explorers programs have reached more than 2.6 million students, and program participants represent 45% minority students and 46% female students.

The same assets that make the ISS a powerful laboratory for scientists also make it an invaluable platform for student research investigations and educational outreach. Space Station Explorers is a community of educators, learners, and organizations that make learning science, technology, engineering, and mathematics (STEM) fun and exciting through connections with the ISS National Lab. In FY20, almost 3 million people engaged with the 23 partner programs within the Space Station Explorers consortium. Moreover, the Space Station Ambassadors (empowered educators that receive training and exclusive access to program resources) grew to more than 1,000 volunteers—up from 800 in FY19.

Virtual Learning

This year, many students, teachers, and parents are relying on digital, virtual, and other unconventional education methods to keep children excited and engaged in STEM learning during the COVID-19 pandemic. In response to this transition, CASIS launched a learn-at-home online initiative to reach these children by highlighting activities and curriculum easily accomplished with materials found at home. The site has had more than 33,000 unique visitors (10 times the web traffic of typical CASIS STEM digital resources), and many Space Station

Explorers consortium members launched new or alternative projects to engage with students and teachers through this medium.

Also in response to the need for at-home STEM learning, partner program Story Time From Space experienced a substantial increase in engagement and media coverage, reaching more than 1.6 million students, educators, and adults as part of its targeted learn-at-home activities from January to September 2020. Through Story Time From Space, students are able to watch videos of astronauts reading STEM-themed books from inside the space station. Crew members also film videos onboard the ISS of science demonstrations related to the science themes in the books. All videos, along with accompanying educational materials, are available on the Story Time From Space website for free.

Space Station Explorers' newest partner products and programming were also well positioned to meet the needs of a virtual-hungry community of parents and educators. Nickelodeon's teacher's guide (part of the Slime in Space: A Virtual Field Trip, detailed on pages 8 and 28) helps educators leverage the spaceflight demonstrations to engage and educate young students about non-Newtonian fluids. Additionally, representatives from the ISS National Lab education team, in partnership with Felix & Paul Studios (the Emmy award-winning immersive entertainment studio) and TIME, conducted virtual reality experiences of the ISS for hundreds of student groups and the general public at the International Astronautical Congress held in Washington, D.C., this year, which has multiple programs specifically designed for local K-12 students. These digital assets continue to be available for use in learn-at-home environments.

20 Years of Student Science

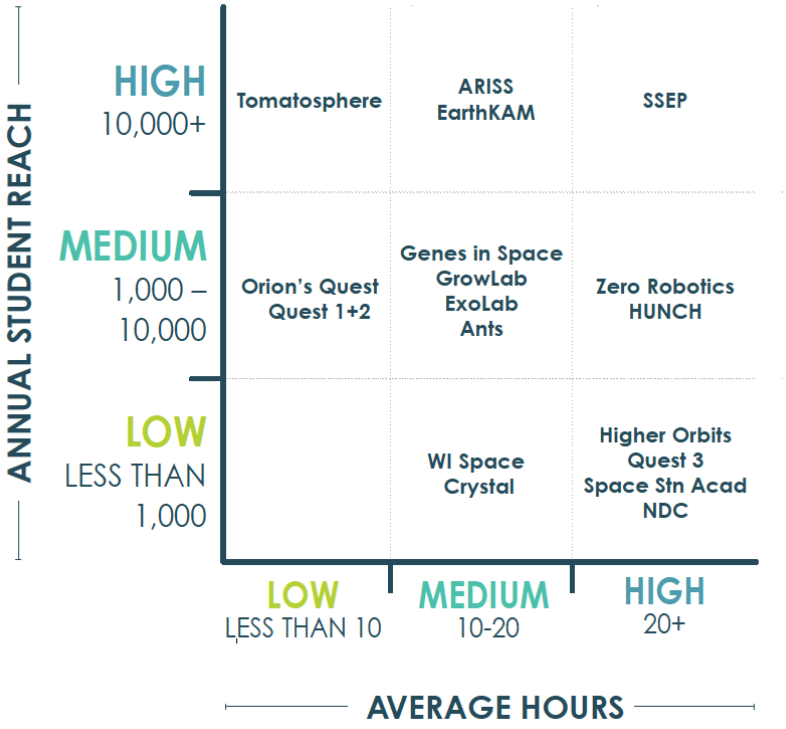
In honor of the 20th anniversary of continuous human presence in space and in adaptation to the global pandemic, CASIS partnered with Virtual Strides to raise $14,000 via a virtual race, the funding from which will be used to support a "Space Lab" within qualifying schools. CASIS also hosted a virtual NASA downlink event for students that had sent experiments to the ISS or participated in Space Station Explorers programs, allowing the students to have a live question-and-answer session with NASA astronaut Chris Cassidy. The event was also broadcast live from the ISS on NASA TV.

Also in honor of the 20th anniversary, the CASIS education team collected data from the 17 Space Station Explorers partner programs that have enabled *direct* student experiments on the ISS (i.e., programming that does not merely include activities that simply inform students about the ISS or classroom activities that might be hands-on and inquiry-based but do not directly involve experiments using the ISS). Data from his comprehensive study of the past 20 years of student experiments using the ISS was compiled into a report that highlighted several impactful findings.

In total, the 17 programs have supported more than 800 experiments from K-12 students in the U.S. (activities designed, launched, and operated on the ISS, or activities that used data from launched investigations). Over the past 20 years, more than 2.6 million students have participated in these spaceflight experiment programs. Several of these programs have extensive

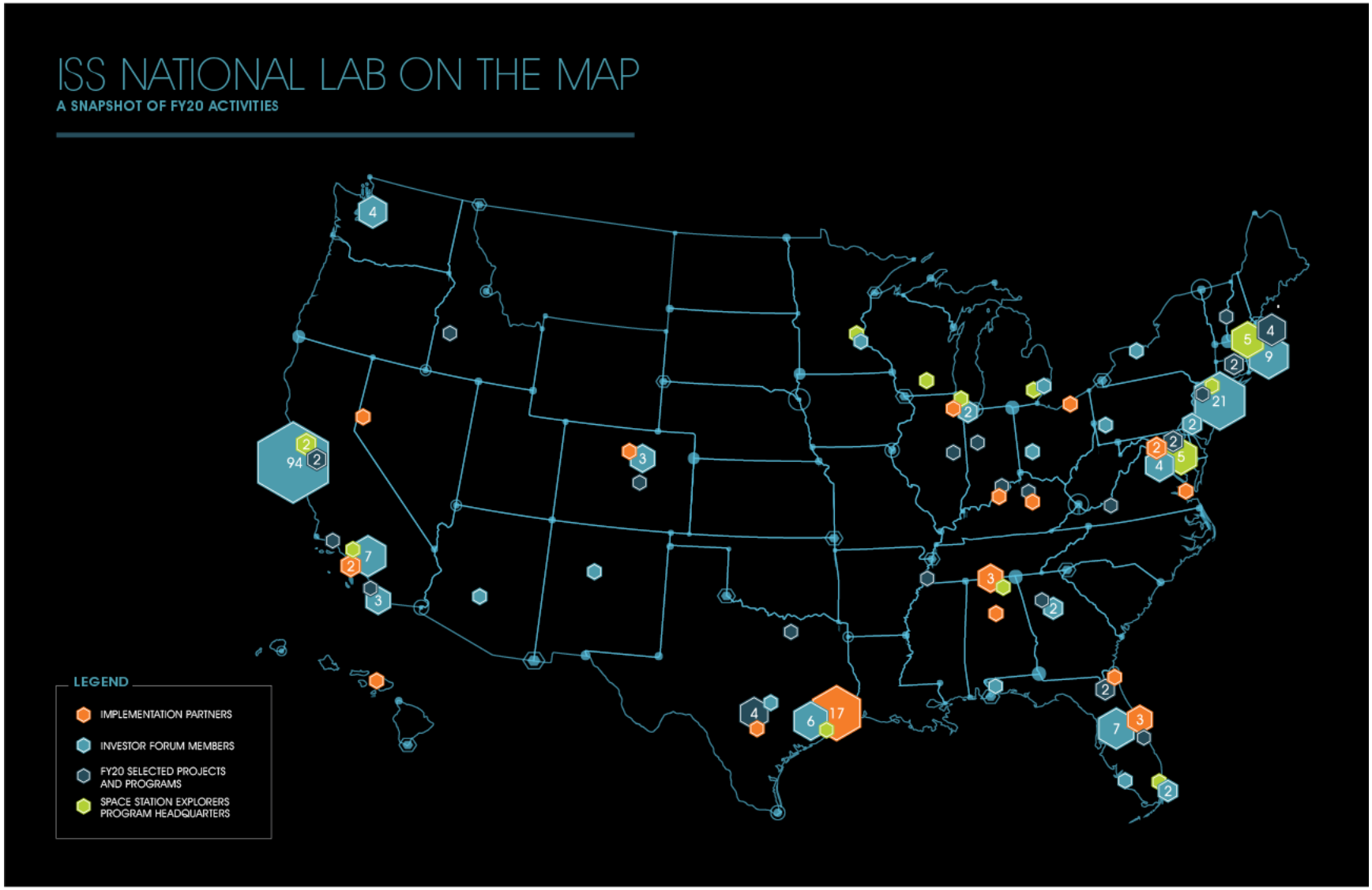
reach, with four programs reaching more than 10,000 students per year. Furthermore, many programs are in-depth experiences, requiring 20 hours or more of activities to participate.

Two-Axis Grid of Spaceflight Experiment Space Station Explorers Program Impact
(see Appendix D for acronym definitions)



It is noteworthy as well to examine the demographics of the participants: 45% of participants identified as minority and 46% as female. Six of the programs predate CASIS management of the ISS National Lab, but all are current members of the Space Station Explorers consortium, and many continued to send experiments to the ISS in FY20.

For more information about Space Station Explorers partner programs, see the map on page 24 and Appendix D.)


ISS NATIONAL LAB ON THE MAP
A SNAPSHOT OF FY20 ACTIVITIES
LEGEND
IMPLEMENTATION PARTNERS
INVESTOR FORUM MEMBERS
FY20 SELECTED PROJECTS AND PROGRAMS
SPACE STATION EXPLORERS PROGRAM HEADQUARTERS

Outreach and Stakeholder Engagement

At a Glance

- The 9th annual ISSRDC was held virtually in FY20 and included ISS programmatic updates from NASA leadership, discussions on commercial utilization, and the latest information on space investment trends.
- The ISS National Lab and NASA partnered to support two in-person Destination Station outreach events (San Jose, CA and Tampa, FL) in FY20, meeting with potential research collaborators.
- Continuing on the success of FY19, multiple high-level digital campaigns were developed and executed, creating more social engagements than in any previous year.
- In FY20, CASIS developed new methods to engage with the research community to highlight impactful ISS National Lab-sponsored science and technology development demonstrations.

FY20 ISS National Lab outreach and stakeholder engagement adopted a technologically creative approach to address the communication challenges presented by the COVID-19 pandemic. The critical move to a virtual format for the entirety of FY20 events supported our continued collaboration and engagement with stakeholders and collaborators. This year's virtual ISSRDC demonstrated a successful and well-attended online program, while targeted digital campaigns and other activities maintained and built on the community engagement achieved in FY19. New outreach methods, such as an ISS National Lab newsletter, coupled with increased collaboration efforts with NASA, allowed CASIS to deliver meaningful content focused on ISS National Lab partners, initiatives, and space-related activities.

2020 ISS R&D Conference

The 9th annual ISSRDC brought a new platform to the forefront: virtual. As the world adjusted to the devastating effects of COVID-19, many conferences and events shifted from in-person to virtual platforms. CASIS, NASA, and the American Astronautical Society collectively decided that a virtual conference format spread over multiple event days would provide a unique and safe path to bring together esteemed researchers with ISS program leadership to accurately convey the diversity of research being performed on station.

Over the years, ISSRDC has been a major driver to highlight previous research, upcoming collaborations, and trends that may shape research and investments in a robust future LEO economy. With the decision to go to a virtual ISSRDC "Online Series" in FY20, the program was also condensed into three days, spread out over three separate months.

- On Day 1, NASA leadership (including NASA Administrator Jim Bridenstine) provided programmatic updates impacting the ISS, and multiple plenary sessions focused on the rising LEO economy, with commercial launch partners and private-sector researchers discussing how they are leveraging the ISS to validate facilities and business models.

- On Day 2, researchers discussed applied R&D leading to the development and enhancement of commercial projects, executive leadership within Nasdaq moderated a space investment session, and additional plenary science sessions focused on NASA-driven initiatives including GeneLab and the Cold Atom Lab.
- On Day 3, the conference culminated with sessions highlighting the impact of 20 years of student research on the ISS, communications hardware of the future, and disease-related research seeking to improve human health on Earth.

While this year presented challenges, the conference generated more than 5,400 registrations from the space and aerospace communities, key stakeholders, researchers, entrepreneurs, media, and investors.

Additionally, virtual workshops and seminars associated with ISSRDC provided an opportunity for subject matter experts to discuss R&D opportunities, challenges, and future capabilities:

- Researchers, hardware providers, and business leaders joined the Additive Manufacturing In Space Workshop, in which panelists and participants reviewed existing research and discussed how rapid developments in additive manufacturing create new opportunities for advanced materials R&D—advancements that could drive manufacturing innovation for applications on Earth and in space.
- The Tissue Engineering and Regenerative Medicine in Space Seminar Series reviewed key research in the areas of tissue engineering and regenerative medicine conducted on the ISS National Lab in 2020 and examined how the future of this research could advance biomedical discovery and in-space production.
- The annual investor pitch event (detailed on page 17) attracted new and returning investors to participate in the ISS National Lab community.

Implementation Partner Successes Garner Visibility on a Global Scale

The International Astronautical Congress (IAC) is an annual global event sponsored by the International Astronautical Federation that attracts stakeholders from throughout the international space community: researchers, space agencies, industry leaders, policy makers, and media. Each year, the IAC changes location and theme. In 2019, the event, "Space: The Power of the Past, the Power of the Future," was held in October in Washington, D.C. Nearly 6,000 people from around the world attended the conference aimed at inspiring global innovations in space.

Participation in the IAC gave the ISS National Lab numerous opportunities to increase the visibility of the organization and enhance awareness of ISS National Lab-supported research among key domestic and international decisionmakers. ISS National Lab staff were available at the organization's exhibit booth throughout the conference and were joined by representatives from several ISS National Lab Implementation Partners. Participation at the ISS National Lab booth allowed these partners to exhibit their hardware and capabilities to an international audience.

Additionally, seven papers authored by ISS National Lab staff were selected for oral presentation in the IAC technical sessions. The presentations and accompanying papers covered a range of topics including remote sensing, protein crystal growth, and tissue engineering. Several

Implementation Partners also presented on topics such as materials testing in microgravity, new biofabrication capabilities on the ISS, and LEO commercialization. Through active engagement at the IAC, the ISS National Lab was able to demonstrate to a global audience how it continues to be an important part of the international space community.

Additional Events and Outreach

In FY20, CASIS representatives participated in multiple in-person and online conferences and events aligned with ISS National Lab strategic lines of business (see definitions on pages 29-30). A CASIS team member was co-chair for a SelectBIO event in San Diego, CA, that brought together many of the tissue engineering and regenerative medicine research partners that have or will be leveraging the ISS National Lab to discuss results. Multiple CASIS representatives participated in annual conferences such as the IAC and ASGSR to network and promote collaborations with other researchers conducting space-based studies. Additionally, attending the World Stem Cell Summit and SmallSat Symposium enabled CASIS team members to highlight the diverse research portfolio of the ISS National Lab and engage with potential new users. NASA and the ISS National Lab also collaborated on two Destination Station outreach events (in Tampa, FL, and San Jose, CA) to raise awareness and engage with potential research partners.

FY20 also brought with it multiple high-visibility collaborations that highlighted the role of a national lab in space and the unique investigations the ISS National Lab sponsors to further research, development, and education. Through these collaborations, the ISS National Lab was able to lead multiple digital campaigns that helped create more engagements than any previous year. Examples included an Earth Day takeover forged through a relationship with Instagram that ultimately included participation by NASA and astronauts Jessica Meir and Anne McClain. Also, as discussed on pages 8 and 23, Nickelodeon's Slime in Space: A Virtual Field Trip was released in FY20, with various demonstrations performed utilizing the company's iconic green slime to inspire and engage the next generation of researchers and explorers. Nickelodeon's Kids' Choice Awards featured Slime in Space, the full product for which includes a 20-minute feature video on the experiments conducted on station and lesson plans that reached more than 100,000 homes.

While the impacts of COVID-19 hindered the ability for in-person travel opportunities to meet with prospective research and media partners, it opened the door for leveraging technology in ways not previously utilized. For instance, prior to the Northrop Grumman CRS-14 launch, CASIS worked alongside multiple media and partner outlets (including NSF) to host virtual webinar sessions featuring researchers, NASA and ISS National Lab representatives, and NASA astronauts. The NSF session was moderated by CNN's Ashley Strickland and led to multiple mainstream media stories on NSF's funded research launching on that mission.

CASIS additionally continued development and distribution of *Upward* magazine, which highlights results of science sponsored by the ISS National Lab, while also instituting a new newsletter, "Science in Space Today," that reaches a wide audience monthly. The newsletter highlights facts, figures, and updates associated with current ISS National Lab events.

Future Directions

This year's annual report reflects not only the resilience of our organization but also continued engagement of our partners, collaborators, researchers, and funding agencies. In the face of a pandemic, each of our partners has worked in concert with the ISS National Lab to persevere and adapt despite challenges presented by COVID-19. In fact, we as an organization and as a country have learned to maintain our personal and professional connections by embracing technology and forging new and creative paths to achieve our goals.

FY20 brought with it the opportunity to establish a more formal and collaborative relationship with NASA, one we have embraced to better align our mutual objectives in support of national interests. As our nation's only orbiting laboratory, the ISS has become both a proof of concept for the value of sustained research initiatives in LEO and a pathfinder for the future space economy. We must act now to benefit from the unique value of the ISS as a research platform. CASIS is dedicated to maximizing return on U.S. investment in the ISS through support of research that aims to improve human health and develop technologies to reinforce U.S. relevancy in the global high-tech marketplace.

In FY20, CASIS has continued to work alongside NASA to ensure ISS National Lab activities deliver value to the nation. Working together, NASA and CASIS have begun implementing programmatic and organizational changes tailored to deliver the ISS National Lab into a new era under CASIS management. In order to streamline business efforts while enhancing ISS National Lab alignment with NASA, CASIS developed new lines of business that provide focus for all future space-based activities. The lines of business address concerns voiced by the independent review report, strengthen CASIS mission priorities, and compliment NASA's strategic plan.

Definitions for ISS National Lab 2020 Lines of Business

CASIS is committed to supporting the following lines of business. CASIS will prioritize and allocate ISS National Lab resources in accordance with programs and initiatives that support the goals and objectives associated with each line of business.

In-Space Production Applications: LEO-based applied R&D microgravity applications seeking to demonstrate space-based manufacturing and production activities that enable new business growth and capital investment, represent scalable and sustainable market opportunities, and produce reoccurring value with the potential to generate demand for and revenue from access to space.

Commercial Service Provider Utilization: An allocation of ISS National Lab crew time and upmass resources that will be utilized by Commercial Service Providers for the purpose of promoting, enabling, and facilitating their respective commercial demand-generation efforts, thereby contributing to the growth and development of the broader LEO market economy.

Technology Development/Demonstration: Applied R&D, translational science, technology readiness level maturation, and technology demonstration to improve products and/or processes that will produce positive economic impact. All projects with

an expressed commercial purpose or intent are included. Most of these will be sourced and/or serviced by Implementation Partners.

Fundamental Science: Peer-reviewed science that will lead to new discovery and knowledge, or advance our current understanding or knowledge, in various scientific disciplines through the use of microgravity, the extreme environments of space, or the unique vantage point of the ISS. Economic output from results is not required.

STEM Engagement and Educational Outreach: Programs, projects, and public-private partnerships that leverage the ISS and space-based research to advance U.S. leadership in space-based R&D and industry-related workforce development. These programs, projects, and partnerships will engage K-12 students and enhance higher education to promote diversity and outreach into underrepresented demographics.

In addition to this strategic evolution of ongoing CASIS activities, CASIS has instituted the establishment of the ISS National Lab User Advisory Committee (UAC). In accordance with our Cooperative Agreement with NASA, the UAC will consist of individuals representing organizations that have formal engagements with either NASA or CASIS to utilize the U.S. orbital segment of the ISS or provide commercial services for the operation of the ISS, including allocations within partner elements or via ISS research sponsored by other governmental agencies. The UAC will provide CASIS with user input and perspective about CASIS management of ISS National Lab resources, including suggestions regarding effective strategies for the utilization of the ISS National Lab as a platform for research, technology development, and education. We look forward to the insights generated by these groups.

UAC Structure

The UAC will have five subcommittees:

- *Applied Research and Development*
- *Commercial Service Providers (membership extended to all CSPs)*
- *Education*
- *Science*
- *Technology Demonstration*

Subcommittee membership:

- *Seven members per subcommittee*
- *Each subcommittee chair serves as a UAC voting member*
- *Two-year term for UAC and subcommittee members*

CASIS is also actively engaged with NASA to build detailed roadmaps for space-based R&D activities. Each roadmap will be a fluid strategic plan that NASA, the ISS National Lab, and the stakeholder community of other government agencies, private-sector industry, and academia that serve as members of the UAC will inform and review as a tool to:

1) Focus multipartner efforts on the sustainable and scalable evolution of fundamental and applied R&D programs that address national priorities leading to the commercialization of LEO.

2) Develop efficiencies for coordinating and implementing ISS utilization activities among stakeholders with similar R&D and/or economic interests.
3) Serve as a method of transparency in the communication of progress in the utilization of the ISS National Lab for the U.S. taxpayer.
4) Build a user community with improved communication focused on each roadmap area to address transitions from fundamental to applied science leading to commercialization.

Fine-Tuning ISS National Lab Project Selection

In the second half of FY20, CASIS began to investigate, outline, and develop a new proposal evaluation construct that focuses on leveraging external evaluators to provide feedback on the scientific, technical, and business portions of a proposal. The new process is intended to improve the fidelity and transparency of CASIS proposal selections, including the ability to provide tailored feedback for proposals not selected. Under the new evaluation construct, all proposals will be evaluated by at least two, and in most cases three, external (non-CASIS) evaluators. After conducting individual reviews, external evaluators will meet to determine a consensus rating for each proposal, documenting the strengths and weaknesses to justify a final evaluation rating.

In addition to the external evaluation, CASIS will continue to do an implementation feasibility and operations evaluation to assess each project's operational risks and the appropriateness of the ISS resource allocation, such as upmass, downmass, crew time, and facility utilization. Finally, proposals that have an expressed commercial intent will be evaluated from a business perspective using new criteria developed with the assistance of an external consultant. The new evaluation construct will be implemented in the first quarter of FY21.

Looking Forward

There have been some exciting developments in the space industry this year, particularly with respect to commercial activities in LEO. At the end of FY20, preparations are now in place to deliver crew members to the ISS from U.S. soil for the first time since the retirement of the Space Shuttle Program in July 2011. A transition to a reimagined commercial crew program undoubtably provides additional research time and broader opportunities for discovery for investigators using the ISS National Lab. However, we understand that the establishment of the program may require adjustment and take time to be successful, particularly with respect to future utilization and other supply chain logistics. The ISS National Lab continues to adjust accordingly and support our partners, investigators, and colleagues in the space community to the best of our ability, embracing our Core Values.

As the emerging space industry evolves into an established research and business environment over the next decade, we envision the ISS and the ISS National Lab as fuel for the engine of economic development. CASIS is equipped with the tools and experience to serve as the recruiting center for commercial R&D in space—inviting new collaborators and research partners to experience the unique advantages of conducting R&D in microgravity.

CASIS Core Values

Passion for the Mission: We are inspired and driven by the ISS and the incredible opportunity ahead of us. We understand and are humbled by what others have sacrificed to build the ISS. We embrace the role that the ISS National Lab plays in shaping the future of space research by maximizing the impact of this incredible laboratory.

Customer Focus: We are committed to our customers and understand that each and every one of us contributes to the user experience. As the conduits to the space station, we aim to do everything in our power to improve the customer journey and focus on our customers' objectives.

Teamwork: We believe in the power of inclusion and recognize that there is greater strength in working together to solve complex problems. We collaborate and build networks, harnessing the best ideas from inside and outside the organization. We treat our coworkers, partners, customers, and vendors with respect and appreciation.

Stewardship: We recognize the great responsibility that we have to maximize the use of the ISS to benefit life on Earth. We demonstrate good stewardship of our resources and put the mission above all else when making business decisions. We are accountable for our actions and expect our users, partners, and vendors to share in these values.

Inclusion: We believe in cultural awareness, teamwork, and the power of inclusion. We are not all the same, which is one of our greatest strengths. Through collaboration and network building, we channel the best ideas from diverse perspectives, cultures, and experiences both inside and outside the organization. We acknowledge the fundamental value and dignity of all individuals, and we respect our coworkers and external community.

Professionalism: We convey professionalism in all that we do. We insist on a culture of respect, communicating openly and transparently, using appropriate channels, and recognizing that words and actions matter, even behind closed doors. Each employee is an ambassador of the ISS National Lab and contributor to the ISS brand, and we all share in the responsibility to create a positive culture externally and internally. Each member of the organization should be a role model for others.

Commitment to Excellence: We take pride in our work and aspire to be the best we can be. We adhere to the highest standards of our professions and adopt best practices. We embrace new ideas and explore innovative ways of working, and we recognize that true excellence requires that each individual be able to work and learn in an atmosphere of respect, dignity, and acceptance. When faced with obstacles, we deepen our resolve to collaborate and persist with optimism.

Financials

Unaudited Summary Statement of Financial Position as of September 30

	2020	2019	2018
Total assets	$3,290,268	$3,068,246	$3,417,124
Total liabilities	$878,378	$721,220	$618,764
Total net assets	$2,411,890	$2,347,026	$2,798,360
Total liabilities and net assets	$3,290,268	$3,068,246	$3,417,124

Unaudited Summary Statement of Activities for Years Ended September 30

	2020	2019	2018
Total revenues and other support	$14,454,605	$15,796,555	$ 19,443,858
Total operating expenses	$14,389,740	$16,247,889	$ 18,303,271
Change in net assets	$64,865	($451,334)	$ 1,140,587
Net assets, beginning of the year	$2,347,025	$2,798,360	$ 1,657,773
Net assets, end of the year	$2,411,890	$2,347,026	$ 2,798,360