INTERNATIONAL SPACE STATION

BENEFITS for Humanity

2022

The International Space Station (ISS) *Benefits for Humanity 2022 full publication includes a compilation of benefits being realized from station activities. This issue expands the spectrum of the impact of space station to include scientific, societal, exploration, and economic benefits as part of a growing low-Earth orbit economy. Below is an illustrative sampling of the broad array of research sponsored by the space station's international partnership and the benefits that have resulted.*

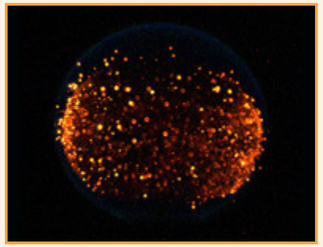
SCIENTIFIC BENEFITS

The International Space Station is a robust scientific laboratory with dozens of research facilities, capabilities for autonomous research and monitoring, and an array of tools and observational instruments. At any one time, this microgravity lab hosts hundreds of investigations spanning every major scientific discipline from physics to microbiology.

DNA sequencing was performed in space for the first time as part of NASA's Biomolecule Sequencer investigation. Real-time DNA analysis capabilities on station, and future exploration missions, allow crews to identify microbes, diagnose infectious disease, and collect genomic and genetic data concerning crew health without having to wait for ground-based analysis.

This flame was one of many ignited within the Combustion Integrated Rack. One experiment led to the discovery of "**cool flames**," a previously unknown form of combustion, while others focused on soot produced in different conditions. The study provided data that could **help reduce pollutant production in combustion** on Earth.

The station has hosted many investigations of fluid behaviors, taking advantage of the microgravity environment to study aspects of physics often masked by gravity. The ESA (European Space Agency) Reference mUltiscale Boiling Investigation (RUBI) experiment analyzed a very different type of bubble formed during boiling. Boiling in microgravity takes place in slow motion and produces larger bubbles, allowing scientists to observe and measure effects that are too fast and too small on Earth and providing a more complete understanding of heat transfer during boiling. This information could be applied to **cooling electronics** such as laptops more efficiently.



SOCIETAL BENEFITS

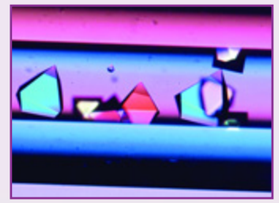
In addition to scientific discovery and exploration technologies, the International Space Station provides a unique vantage point at the edge of Earth's atmosphere for monitoring climate change and provides benefits on Earth through spinoff technologies and inspiring future generations.

Station hosts many external instruments aimed at **understanding the changing environment** of our home planet. Data from NASA's ECOsystem Spaceborne Thermal Radiometer Experiment on Space Station (ECOSTRESS) payload, which measures subtle changes in temperature to identify plant stress, have been employed in efforts to reduce heat absorbed by city surfaces, better allocate water, reduce fire risk, search for geothermal energy sources, track mosquitos, **help farmers** water their fields efficiently, and more. Advances in X-ray technologies produced for NASA's Neutron star Interior Composition Explorer (NICER), a telescope helping unravel the mysteries of our universe, are also being used to reduce the size and complexity of computed tomography (CT) scanners. This technology could lead to **CT scans** that expose patients to less radiation and expand capabilities for remote doctors.

Millions of students around the world have participated in station downlinks and STEM programs, including Amateur Radio on the International Space Station (ARISS) events, Sally Ride EarthKam, StoryTime from Space,

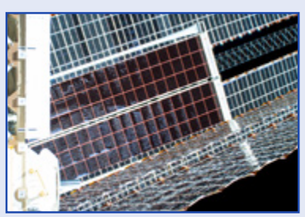
and numerous plant growth experiments. These programs help **inspire the next generation** of scientists.

A series of protein crystal growth (PCG) studies from the Japan Aerospace Exploration Agency (JAXA) have provided the precise structures of many proteins and could result in development of drugs to **treat breast cancer, gum disease, and muscular dystrophy**. A study of the protein structure associated with Duchenne Muscular Dystrophy (DMD) in particular has led to clinical trials of a drug that may slow the progression of DMD by half, potentially doubling the lifespan of many patients.



EXPLORATION BENEFITS

The International Space Station is the ideal test bed for demonstrating and improving technologies needed to explore farther into space and to stay there longer. New power generation, air and water recycling, carbon dioxide removal, communications, and computing systems are among the exploration-enabling technologies being tested and proven on the station. Researchers also study how humans adapt to and work in space, grow plants in microgravity, and more.



Aging-like changes, including arterial thickening and stiffening, accelerate in many station crew members. The Canadian Space Agency (CSA) Vascular, Vascular Echo, and Vascular Aging experiments study these changes. Results could help researchers to develop effective countermeasures to **maintain astronaut health** on future long-duration missions.

Studies employing NASA's Veggie Production System help researchers identify the best methods for growing crops in space, providing fresh food security for future missions to the Moon and Mars. On Earth, the same principles can be applied to improve **food production** in remote environments.

The Twins Study compared NASA astronaut Scott Kelly to his twin on Earth during a nearly year-long mission on the orbiting laboratory in order to examine **fluid shifts** in the body, changes in the structure of the eye, and other physical responses to long-term space flight.

ECONOMIC BENEFITS

The International Space Station nurtures a growing commercial space economy that includes commercial research, satellite services, and in-space manufacturing. Many of the tools and processes developed for use in space have launched new and thriving businesses on the ground, while growing participation of private entities in supporting station activities is helping to bring more commercial players into the space marketplace.

Researchers believe that **optical fibers** used for ultra-high-speed broadband communications and remote sensing could exhibit far superior qualities when produced in microgravity. Several studies, including the ISS National Laboratory-sponsored Optical Fiber Production in Microgravity, are putting this theory to the test, seeing whether low-Earth orbit can become the commercial manufacturing location of these fibers.

Russian space agency ROSCOSMOS and company 3D Bioprinting Solutions launched the Organ.Aut bioprinter to culture cartilage cells using a magnetic field on the space station. The bioprinter also created thyroid gland tissue spheroids. This effort is part of the initiative to test the viability of commercial **manufacturing of organs in orbit**.

U.S.-based company Planet created a collection of CubeSats with the mission to photograph the entire Earth every day and turned to station to test its business model. The first flock of "Doves" (small satellites) was released from station in 2014. Planet has now built and successfully deployed 450 satellites, with more than 200 currently in orbit. Planet illustrates how the space station can provide early access to space, allowing new **business models to prove themselves and attract the investment**. Small satellites are playing an increasing role in exploration, technology demonstration, scientific research, and educational investigations.

BENEFITS
for Humanity

On November 2, 2020, the International Space Station entered its third decade of human-tended operation and science. The first decade of station was the decade of construction; the second decade, moving from initial research to full utilization. We are now in the decade of results.

During the past twenty years, the space station evolved from an outpost on the edge of space into a highly capable microgravity laboratory. Now results are compounding, new benefits are materializing, and the third decade is building on this previous work.

This orbiting laboratory enables researchers from around the world to take advantage of microgravity, exposure to space, and a unique perspective on Earth to conduct groundbreaking experiments through an environment made accessible by the space station. Although the International Space Station is a partnership between many nations, each with distinct goals, every partner shares a unified goal: to use this amazing laboratory for the betterment of humanity. With more than 20 years of experiments now conducted on the station, more breakthroughs are materializing than ever before.

Benefits for Humanity 2022 highlights the diversification of benefits stemming from microgravity research—for society, science, exploration, and the economy. This edition focuses on new areas of scientific study, future technologies for the exploration of the Moon and Mars, lives saved, and numerous companies and jobs created.

The International Space Station advances scientific understanding of our planet, improves human health, develops advanced technologies, and provides a space platform that inspires and educates the leaders of tomorrow — a legacy and influence that will be felt for decades to come.

For more information on the International Space Station Benefits for Humanity publication, including where to find the full publication, go to: https://www.nasa.gov/stationbenefits

The International Space Station Benefits for Humanity 2022 is a product of the International Space Station Program Science Forum (PSF), which includes the National Aeronautics and Space Administration (NASA), Canadian Space Agency (CSA), European Space Agency (ESA), Japan Aerospace Exploration Agency (JAXA), State Space Corporation ROSCOSMOS (ROSCOSMOS), and the Italian Space Agency (ASI).

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