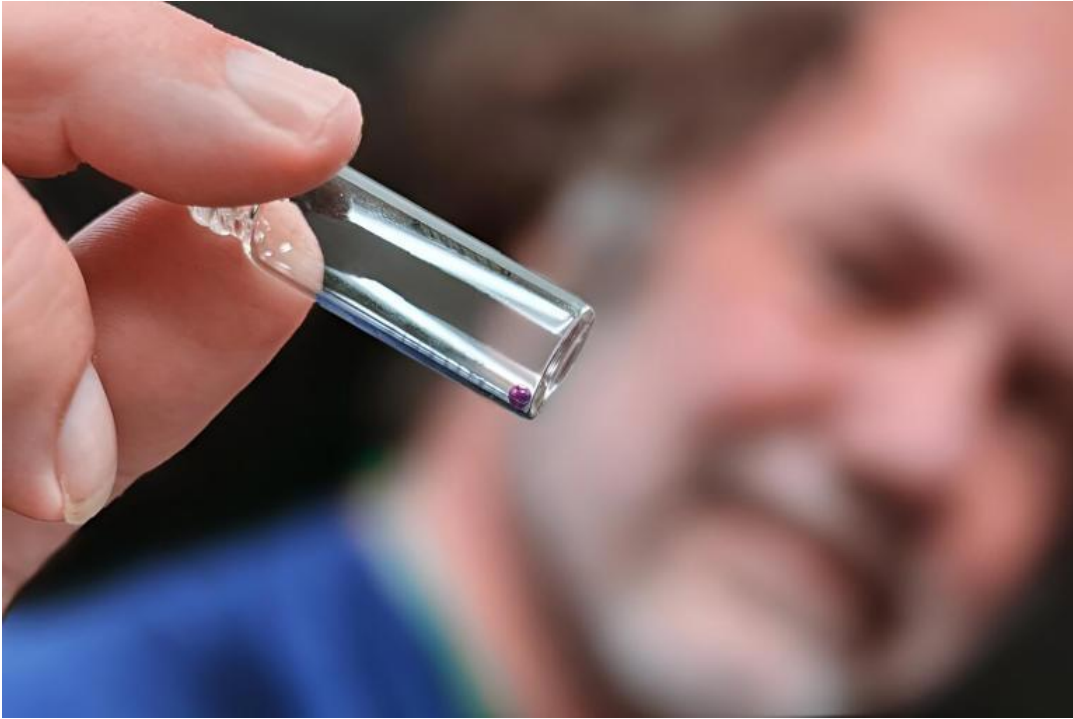


# SPACE-BASED MANUFACTURING



A team of scientists from nine institutions in government, academia and industry discovered that many kinds of glass have similar atomic structure and can successfully be made in space. A bead of space glass is shown in the image. Credit: Phoenix Pleasant/ORNL, U.S. Dept. of Energy© Provided by Phys.org

**T**hanks to human ingenuity and zero gravity, we reap important benefits from science in space. Consider smart phones with built-in navigation systems and cameras.

Such transformational technologies seem to blend into the rhythm of our everyday lives overnight. But they emerged from years of discoveries and developments of materials that can withstand harsh environments outside our atmosphere. They evolve from decades of laying foundations in basic science to understand how atoms behave in different materials under different conditions.

Building on this past, a global team of researchers has set a new benchmark for future experiments making materials in space rather than for space. The team included members from the Department of Energy's Oak Ridge and Argonne national laboratories, Materials Development, Inc., NASA, the Japan Aerospace Exploration Agency, or JAXA, ISIS Neutron and Muon Source, Alfred University

and the University of New Mexico. Together, they discovered that many kinds of glass, including ones that could be developed for next-generation optical devices, have similar atomic structure and arrangements and can successfully be made in space.

The team's paper is [published](#) in the journal *npj Microgravity*.

"The idea is to feel out the mechanisms behind space-based manufacturing, which can lead to materials that are not necessarily available on Earth," said Jörg Neuefeind, who joined ORNL in 2004 to build an instrument called NOMAD at the lab's Spallation Neutron Source (SNS). NOMAD, the fastest neutron diffractometer in the world, helps scientists measure the arrangement of atoms by seeing how neutrons bounce off them. NOMAD is one of 20 instruments at SNS that help scientists answer big questions and spur countless innovations, like drugs that more effectively treat diseases, more reliable aircraft and rocket engines, cars with better gas mileage and batteries that are safer, charge faster and last longer.

**Related video:** Astronomers Might Finally Know Just How Fast the Universe is Expanding (Dailymotion)

JAXA operators on Earth made and melted glass aboard the International Space Station (ISS), via remote control using a levitator. Levitators are used to suspend material samples during experiments to avoid interference from contact with other materials.

Once the next ISS mission ended months later and the space glass was brought to Earth, researchers used a combination of techniques that included neutrons, X-rays and powerful microscopes to measure and compare glass made and melted celestially versus terrestrially.

"We found that with containerless techniques, such as the levitator, we can create unconventional glasses in microgravity," said JAXA's Takehiko Ishikawa, pioneer of the electrostatic levitator used to make the glass beads aboard the ISS.

The researchers relied on NOMAD at SNS to study the glass samples with neutrons and beamlines at Argonne's Advanced Photon Source to study the samples with X-rays. Both SNS and APS are DOE Office of Science user facilities.

"There's only so much material you can fly up to space and get back, and that was actually one of the reasons NOMAD was so well-suited to this experiment," said Stephen Wilke of Materials Development Inc., and a visiting scientist at Argonne. "We were getting back just single beads of glass about an eighth inch in diameter, which are very difficult to measure in terms of atomic structure. Since NOMAD excels at measuring extremely small samples, it allowed us to easily compare single beads we made in the lab with those made on the space station."

## Mysteries of glass

Glass, it turns out, is not so clear cut. Unlike crystalline solids, such as salt, glass atoms do not have a uniform structure. Its unusual atomic arrangement, though remarkably stable, is perhaps best described as a random network of molecules that share coordinate atoms. Neither entirely solid nor entirely liquid, glass also comes in different forms, including polymer, oxide and metallic, such as for eyeglass lenses, fiber optic threads, and hardware for deep space missions.

In 2022, Neufeind, Wilke and Rick Weber, an industry subject matter expert on glass, experimented with two oxides of neodymium and titanium and [discovered](#) a potential for optical applications. The combination of these two elements exhibits unusual strengths not seen in similar research campaigns. These findings led them to pursue their current studies with NASA.

"[The experiment in 2022] taught us something really remarkable," said Weber, of Materials Development Inc. "One of the glasses has a network that's completely different from a normal, four-coordinate network typical of silica. These glasses have a six-coordinate network. They're really out there. It's exciting from a glass science perspective. But as a practical matter, it also means more opportunities for doing new things with optical materials and new kinds of devices."

Scientists often use neutrons and X-rays in parallel to collect data no other techniques can produce, allowing us to understand the arrangement of atoms of different elements within a sample. Neutrons helped the team see the lighter elements in the space glass, like oxygen, while X-rays helped them see the heavier elements, such as neodymium and titanium. If significant differences existed between the space glass and terrestrial glass, they likely would have

shown up in the oxide sublattice, or arrangement of the oxygen atoms, in the distribution of the heavy atoms, or both.

Neutrons will become ever more important tools to unlock the mysteries of matter as scientists explore new frontiers, space notwithstanding.

"We must understand not only the effects of space on matter but also its effects on how things form," Neufeind said. "Because of their unique properties, neutrons are part of solving these kinds of puzzles."



Why Is Space So Cold? It Has To Do With Kinetic Energy

Judging only by the blistering summer sun, you'd be forgiven for assuming that space is a hothouse. But despite the tremendous energy pouring out of trillions and trillions of stars, our universe is surprisingly arctic.

To understand why, we first need to wrap our heads around temperature because its true nature isn't obvious when you burn your hand on the stove or dive into an icy lake. When scientists talk about hot and cold, they're referring to the average kinetic energy of a system (whether it be a snowball or an entire galaxy), which is based on the motion of its particles: the more they jiggle, the hotter they are.

But far from stars, planets, and other cohesive objects, in empty tracts of the cosmos, the concentration of particles drops precipitously - and so does the thermometer.

"Most of space is cold," says Emily Hardegree-Ullman, an astronomy professor at Colorado State University, "because there is just nothing to possess kinetic energy."

And because they're so far apart, the few particles in this near-vacuum can't transfer much heat via conduction and convection, relying instead on the less efficient method of radiation.

## The Temperature in Space

Obviously, it isn't cold everywhere. Earth's atmosphere maintains a mild, life-giving climate; other planets in our solar system undergo extreme temperature swings ([Mercury](#), for example, pendulums from 800 degrees Fahrenheit during the day to negative 280 degrees at night); our sun's corona blazes at 2 million degrees, and quasar 3C273 - a spiraling disk of plasma around a black hole in the constellation Virgo - [has been estimated](#) to reach the mind-melting figure of 18 trillion degrees.

## Potentially Habitable Super-Earth Has Water Vapor in Atmosphere

Nevertheless, these space heaters (pun very much intended) are few and far between, vastly outweighed by, well, a whole lotta nothing. Most of the universe is filled only by the cosmic microwave background, a sparse but pervasive radiation that's been cooling off ever since the Big Bang.

To picture this, Hardegree-Ullman likes to imagine the observable universe as a giant bubble, its inner surface like a faint star that fully surrounds us.

"The light from that surface has been stretched out over billions of years as it has traveled toward us," she says, "so by the time it reaches Earth, it looks like it comes from the surface of a star that is only 3 [degrees] Kelvin."

## Why Is it so Cold in Space?

In other words, when we consider the entire universe as one giant system, the average kinetic energy equates to a spine-chilling negative 454 degrees Fahrenheit. It's only getting colder over time, and even now, temperatures plunge farther in certain regions. The record goes to the [Boomerang Nebula](#), which registered just 1 degree Kelvin above absolute zero - nearly negative 460 degrees Fahrenheit - when [scientists measured it](#) in 1995.

In fact, a smidge above 0 Kelvin would seem to be the theoretical limit on temperature.

"In order for a system to achieve absolute zero," Hardegree-Ullman explains, "all its particles would have to come to a rest."

Yet we know that isn't possible because, as quantum mechanics tells us, we can never pin down both the position and the velocity of a particle with perfect certainty.

Ironically (given its generally cozy conditions), our own planet is actually the source of the coldest temperatures ever documented. Scientists routinely get closer to absolute zero than anything you'd find in space. The best success so far

came in 2021, when a team of German researchers reported they had cooled rubidium atoms to an astonishing [38 trillionths of a degree](#) above 0 Kelvin.

Still, as if in homage to extraterrestrial frigidness, they simulated microgravity by dropping the system from a tower, allowing them to squeeze out a bit more energy. When it comes to cold, we couldn't ask for a better teacher than space.

**I**n a breakthrough that could be the future of military space, researchers have taken a big leap toward developing an operational warp drive, something that has been isolated to date within the realm of science fiction.

The idea of warp drives, which the "Star Trek" sci-fi franchise has made a household name, operates on the concept of space-time bending, forming a "warp bubble" to compress space in front of and expand it at the back of a spaceship so that theoretically it could travel at extra-ordinary velocities. In theory, the technology demanded exotic forms of negative energy. Recent research indicates otherwise.

This may soon be possible, as a team of physicists from the University of Alabama in Huntsville, together with the Advanced Propulsion Laboratory at Applied Physics in New York, developed a new model making warp drives possible without negative energy. In their paper published in the journal *Classical and Quantum Gravity*, the researchers describe a new, advanced blending of traditional and novel gravitational techniques for the creation of a warp bubble that will facilitate the transportation of objects at high, yet still subluminal, speeds.

"This work changes the conversation about warp drives," said Jared Fuchs, the principal author of the paper. The team realized that warp drives could become a reality by producing this first-of-its-kind model. The new model does away with exotic energy and instead uses a stable matter shell combined with a shift vector distribution, which closely approximates the Alcubierre metric proposed in 1994 by Mexican physicist Miguel Alcubierre.

Such research has immense military implications in the area: if one could travel at close to light speed, this would revolutionize strategic mobility in effecting rapid deployment over vast distances. It would be a huge tactical advantage, as forces could deal on short notice with changing threats and execute operations at unequaled time scales.

CEO of Applied Physics Gianni Martire was quick to point out that, while mankind is nowhere near prepared for interstellar voyages, the research effort brings in an exciting new age of possibilities. Work by the team could be a stepping stone on the long road to efficient interstellar flight, marking the beginning of what Martire calls the "Warp Age."

The researchers caveated their promising results by saying a working warp drive remains very far off from the past horizon. Their current theoretical model needs considerably more validation and refinement. Building such a warp drive engine is well beyond the available technology frontiers in the present, and big strides must be made in solving energy generation and materials science.

But the only steps that mattered, though very necessary and important, have been the ones Fuchs and his team have been able to record. They proceeded to fine-tune their models and to work in hand with other scientific fields, and the dream of warp drives now becomes tantalizing, not just for military strategists, but for other scientists across the board. The potential to travel the cosmos at previously impossible speed gives a new frontier to explore and to defend, a future not too distant when these boundaries of space will promise an end to be formidable.

The detailed physics of this revolutionary way of space travel is available for free via the journal *Classical and Quantum Gravity*. With human civilization now at the brink of entering a new realm of space exploration, such a dream regarding warp drives taking humanity to the stars seems rather close to fulfillment.

**T**he United States Space Force is partnering with the Indian government to establish a new factory that will manufacture semiconductors, which are microchips essential for building next-generation technologies.

[Space-based sensors](#) and spacecraft (not to mention nearly all computers, TVs, mobile phones, cars, game consoles, etc.) rely on semiconductors. The integrated circuits are perhaps more commonly referred to as microchips, or simply "chips." They are the "brains" that nearly every modern electronic device relies on. However, for years, the world has faced a global semiconductor supply shortage — and that shortage [peaked in 2021](#) during the COVID-19 pandemic.

Meanwhile, [U.S. Space Force](#) leaders have been hammering home the fact that the service [needs new cutting-edge technologies](#) in order to out-compete its competitors. So, to help the U.S. develop and acquire those technologies, the White House and the government of India signed the "U.S.-India Comprehensive Global and Strategic Partnership" this week, part of which includes a "strategic technology partnership" between two Indian technology firms and the U.S. Space Force that will help establish a new semiconductor factory.

The factory will develop chips for use in "advanced sensing, communication, and power electronics for national security, next generation telecommunications, and green energy applications," according to a White House [statement](#), which calls the agreement the "defining partnership of the 21st century."

Specifically, the factory will be aimed at developing infrared, gallium nitride and silicon carbide chips, which are some of the most advanced forms of semiconductors. Gallium nitride (or GaN) chips can be incorporated into spacecraft with innovative instruments like synthetic aperture radar, for instance, and used to create communication systems with "five- to ten-fold signal strength and data transmission rates" compared to previous technologies, [according to the European Space Agency](#).

Beyond in-space sensing and communications, GaN technologies are also being incorporated into terrestrial radar systems and [electronic warfare](#) platforms, which are used to disrupt, deny, or degrade the use of radio, radar, infrared or other frequency bands of the [electromagnetic spectrum](#).

The U.S. Space Force has been [testing portable satellite jammers](#) in recent years and even creating units dedicated to [targeting other nations' spacecraft](#) with electronic warfare systems. As the service looks to expand its ability to project force and protect its own units from such attacks, the need for new technologies that depend on a steady supply chain of next-generation semiconductors will only grow.



The U.S. Space Force's Remote Modular Terminal (RMT), a new satellite jamming system under development. (Image credit: U.S. Space Force photo by Isaac Blancas)

The need for new cutting-edge technologies isn't the only reason the U.S. Space Force and White House are partnering with India to develop a new semiconductor factory.

Currently, the world's largest producer of semiconductors is Taiwan, but geopolitical tensions with China have been compelling Western nations to [seek new supply chains](#) elsewhere. China claims Taiwan as part of its own, and [fears of a Chinese invasion](#) of the island nation have been rising for years.

To that end, President Biden signed the [CHIPS Act](#) in 2022, which provided \$52.7 billion of American investment in semiconductor manufacturing and research to "keep the United States the leader in the industries of tomorrow."

This week's partnership with India stems from that act.

# Breakthrough Discovery: Astronomers Detect Massive Carbon Molecules in Space, Revealing Key to Planet Formation

**Astronomers have detected one of the largest carbon-based molecules ever discovered in deep space, identified as pyrene, within the Taurus molecular cloud, located 430 light-years from Earth.**

The molecule, a type of **polycyclic aromatic hydrocarbon (PAH)**, is of significant interest because it offers new clues about the distribution of **carbon**, a fundamental building block of life, throughout the cosmos. [The discovery](#), published in **Science**, bridges the gap between ancient interstellar clouds and the materials found in our solar system, providing critical insights into how carbon-rich molecules could have contributed to the formation of planets and life.

## Pyrene and Its Importance in Astrochemistry

**Pyrene**, a molecule composed of four fused carbon rings, is one of the largest PAHs found in space and plays a key role in the **carbon cycle** of the universe. PAHs are among the most abundant organic molecules in [space](#), accounting for an estimated **10-25%** of carbon found in the interstellar medium. Their resilience to ultraviolet radiation and ability to persist in extreme environments make them valuable markers for studying the life cycles of stars and the origins of carbon in the universe.

Researchers detected **cyanopyrene**, a modified version of pyrene, using the **Green Bank Telescope** in West Virginia. This technique allows scientists to observe the characteristic “fingerprints” of molecules as they transition between different energy states, revealing their presence in interstellar clouds. **Brett McGuire**, assistant professor of chemistry at MIT and co-author of the study, explained the significance of the find: “One of the big questions in star and planet formation is how much of the chemical inventory from that early molecular cloud is inherited and forms the base components of the solar system. What we're looking at is the start and the end, and they're showing the same thing.”

# Connecting Ancient Space Clouds to Our Solar System

The detection of pyrene in the **Taurus molecular cloud (TMC-1)** is notable because this cloud is thought to resemble the type of dust and gas that eventually gave rise to our own **solar system**. The discovery supports the hypothesis that much of the **carbon** present in our solar system today, including that found in meteorites and comets, was inherited from ancient interstellar clouds. This idea is bolstered by a recent finding that large amounts of pyrene were detected in samples collected from the near-Earth asteroid **Ryugu** by the **Hayabusa2** mission.

“This is the strongest evidence ever of a direct molecular inheritance from the cold cloud all the way through to the actual rocks in the solar system,” McGuire noted. The presence of pyrene in both the TMC-1 cloud and the Ryugu asteroid suggests that the molecules found in early interstellar clouds were likely incorporated into **planetary bodies** and asteroids, which eventually contributed to the chemical makeup of planets like Earth.

## A Surprise Discovery in Cold Space

The discovery of pyrene in the TMC-1 cloud was unexpected, given that PAHs are typically associated with **high-temperature environments**, such as those produced by the combustion of fossil fuels on Earth or the **death throes of stars**. The **temperature** in the cloud, however, was measured at just **10 Kelvin (-263 degrees Celsius)**, an extremely cold environment where scientists did not expect to find such complex molecules. This raises new questions about how PAHs form and survive in such conditions.

According to **Ilsa Cooke**, assistant professor at the University of British Columbia and co-author of the study, “By learning more about how these molecules form and are transported in space, we learn more about our own solar system and so, the life within it.” The resilience of these carbon-rich molecules suggests that they could survive the journey from distant interstellar clouds to regions where stars

and planets form, contributing to the chemical inventory of newly born planetary systems.

## Implications for the Origins of Life and Future Research

This discovery marks a significant step forward in understanding the **chemical processes** that precede **planet formation**. The presence of large PAH molecules like pyrene in both interstellar clouds and asteroids suggests that these compounds could be widespread in the universe, potentially playing a role in the **origins of life** by delivering essential carbon-based materials to planets in the early stages of their development.

The research team now plans to search for even larger PAH molecules in interstellar clouds, which could provide further insights into how complex organic molecules form and are distributed in space. These findings also prompt further investigation into whether pyrene and other PAHs formed in cold environments like TMC-1 or if they were transported from regions of the universe where **high-energy processes**, such as supernovae or the winds from dying stars, are more common.

## Discovery of carbon-storing molecules in a distant interstellar cloud may shed light on how our own solar system formed

The Taurus Molecular Cloud, in which TMC-1 is located, appears in the top portion of the image as a dark cloud blocking the light from the background stars as seen from Charlottesville, VA. Credit: Brett A. McGuire

**A** team led by researchers at MIT has discovered that a distant interstellar cloud contains an abundance of pyrene, a type of large, carbon-containing molecule known as a polycyclic aromatic hydrocarbon (PAH).

The discovery of pyrene in this far-off cloud, which is similar to the collection of dust and gas that eventually became our own solar system, suggests that pyrene may have been the source of much of the carbon in our solar system. That hypothesis is also supported by a recent finding that samples returned from the near-Earth asteroid Ryugu contain large quantities of pyrene.

McGuire and Ilsa Cooke, an assistant professor of chemistry at the University of British Columbia, are the senior authors of a paper [describing the findings](#) in *Science*. Gabi Wenzel, an MIT postdoc in McGuire's group, is the lead author of the study.

## Carbon in space

PAHs, which contain rings of carbon atoms fused together, are believed to store 10 to 25% of the carbon that exists in space. More than 40 years ago, scientists using infrared telescopes began detecting features that are thought to belong to vibrational modes of PAHs in space, but this technique couldn't reveal exactly which types of PAHs were out there.

"Since the PAH hypothesis was developed in the 1980s, many people have accepted that PAHs are in space, and they have been found in meteorites, comets, and asteroid samples, but we can't really use infrared spectroscopy to unambiguously identify individual PAHs in space," Wenzel says.

In 2018, a team led by McGuire reported the discovery of benzonitrile—a six-carbon ring attached to a nitrile (carbon-nitrogen) group—in TMC-1. To make this discovery, they used the GBT, which can detect molecules in space by their rotational spectra—distinctive patterns of light that molecules give off as they tumble through space. In 2021, his team detected the first individual PAHs in space: two isomers of cyanonaphthalene, which consists of two rings fused together, with a nitrile group attached to one ring.

On Earth, PAHs commonly occur as byproducts of burning fossil fuels, and they're also found in char marks on grilled food. Their discovery in TMC-1, which is only about 10 kelvins, suggested that it may also be possible for them to form at very low temperatures.

The fact that PAHs have also been found in meteorites, asteroids, and comets has led many scientists to hypothesize that PAHs are the source of much of the carbon that formed our own solar system. In 2023, researchers in Japan found large quantities of pyrene in samples returned from the asteroid Ryugu during the Hayabusa2 mission, along with smaller PAHs including naphthalene.

That discovery motivated McGuire and his colleagues to look for pyrene in TMC-1. Pyrene, which contains four rings, is larger than any of the other PAHs that have been detected in space. In fact, it's the third-largest molecule identified in space, and the largest ever detected using radio astronomy.

Before looking for these molecules in space, the researchers first had to synthesize cyanopyrene in the laboratory. The cyano or nitrile group is necessary for the molecule to emit a signal that a radio telescope can detect. The synthesis was performed by MIT postdoc Shuo Zhang in the group of Alison Wendlandt, an MIT associate professor of chemistry.

Then, the researchers analyzed the signals that the molecules emit in the laboratory, which are exactly the same as the signals that they emit in space.

Using the GBT, the researchers found these signatures throughout TMC-1. They also found that cyanopyrene accounts for about 0.1% of all the carbon found in the cloud, which sounds small but is significant when one considers the thousands of different types of carbon-containing molecules that exist in space, McGuire says.

"While 0.1% doesn't sound like a large number, most carbon is trapped in carbon monoxide (CO), the second-most abundant molecule in the universe besides molecular hydrogen. If we set CO aside, one in every few hundred or so remaining carbon atoms is in pyrene. Imagine the thousands of different molecules that are out there, nearly all of them with many different carbon atoms in them, and one in a few hundred is in pyrene," he says. "That is an absolutely massive abundance. An almost unbelievable sink of carbon. It's an interstellar island of stability."

Ewine van Dishoeck, a professor of molecular astrophysics at Leiden Observatory in the Netherlands, called the discovery "unexpected and exciting."

"It builds on their earlier discoveries of smaller aromatic molecules, but to make the jump now to the pyrene family is huge. Not only does it demonstrate that a significant fraction of carbon is locked up in these molecules, but it also points to different formation routes of aromatics than have been considered so far," says van Dishoeck, who was not involved in the research.

## An abundance of pyrene

Interstellar clouds like TMC-1 may eventually give rise to stars, as clumps of dust and gas coalesce into larger bodies and begin to heat up. Planets, asteroids, and comets arise from some of the gas and dust that surround young stars. Scientists can't look back in time at the interstellar cloud that gave rise to our own solar system, but the discovery of pyrene in TMC-1, along with the presence of large amounts of pyrene in the asteroid Ryugu, suggests that pyrene may have been the source of much of the carbon in our own solar system.

"We now have, I would venture to say, the strongest evidence ever of this direct molecular inheritance from the cold cloud all the way through to the actual rocks in the solar system," McGuire says.

The researchers now plan to look for even larger PAH molecules in TMC-1. They also hope to investigate the question of whether the pyrene found in TMC-1 was formed within the cold cloud or whether it arrived from elsewhere in the universe, possibly from the high-energy combustion processes that surround dying stars.

**More information:** Gabi Wenzel et al, Detection of interstellar 1-cyanopyrene: a four-ring polycyclic aromatic hydrocarbon, *Science* (2024). DOI: [10.1126/science.adq6391](https://doi.org/10.1126/science.adq6391). [www.science.org/doi/10.1126/science.adq6391](https://www.science.org/doi/10.1126/science.adq6391)

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Provided by Massachusetts Institute of Technology

# **‘Out-of-this-world’ liver tissue grown in space could transform organ donation**

**I**n a significant step forward for tissue engineering, scientists are employing the microgravity environment aboard the International Space Station (ISS) to create human liver tissue with superior functionality.

Unlike the traditional Earth-bound approach that uses synthetic frameworks to guide cell growth, the microgravity environment allows cells to self-assemble naturally.

As a result, the liver tissues formed in space show enhanced differentiation and functionality compared to those grown in terrestrial conditions.

## **Microgravity: A game-changer for tissue engineering**

On Earth, artificial scaffolds or culture plates are used to provide a structure for cells to grow, but these foreign materials can interfere with cellular function. In space, however, the absence of gravity allows cells to float freely and self-organize without the need for external matrices.

This results in tissues that more closely mimic natural physiology, a key factor in creating viable implants for medical purposes.

“Our findings indicate that microgravity conditions enable the development of liver tissues with better differentiation and functionality than those cultured on Earth,” [said](#) Dr. Tammy T. Chang, a professor of surgery at the University of California, San Francisco.

“This represents a critical step toward creating viable liver tissue implants that could serve as an alternative or adjunct to traditional liver transplants.”

## “Tissue Orb” and cryopreservation

A central component of the project is the development of a custom bioreactor, known as the “Tissue Orb,” which is specifically designed to support tissue self-assembly in space. This bioreactor features an artificial blood vessel system and automated media exchange, simulating the natural blood flow and nutrient exchange that human tissues experience in the body.

By replicating these conditions in the microgravity environment, the team hopes to create more functional tissues suitable for transplantation or other medical applications.

One of the major challenges the team faces is preserving and transporting the engineered tissues back to Earth. To address this, the research includes developing advanced cryopreservation techniques. The next phase of the project will test isochoric supercooling, a method that allows tissues to be stored at sub-freezing temperatures without causing cellular damage

If successful, this preservation method could significantly extend the shelf life of the engineered tissues, making them viable for transport and use in a range of medical scenarios, including disease modeling, [drug testing](#), and ultimately, therapeutic implantation.

## Future implications

This project is set to pave the way for future advancements in space-based biomedical research and manufacturing. The ability to grow complex tissues in microgravity offers a novel approach to [tissue](#) engineering— it could transform the production of other biological materials in space.

Additionally, the research aims to explore how these advancements could eventually be applied to whole organ preservation, potentially solving one of the biggest challenges in [organ](#) transplantation: the limited availability of viable organs.

The spaceflight experiment is slated for launch in February 2025. This collaboration highlights the increasing role of space exploration in advancing biomedical research, offering exciting opportunities for both space and Earth-based medical science.

The experimental results of this study will be presented at the American College of Surgeons (ACS) Clinical Congress 2024 in San Francisco, California.

## **Molecular symmetry can govern crystallization pathways in highly supersaturated solutions, researchers find**

**I**n the search for new materials to be used in space environments, researchers are focusing on the crystallization of substances. By accurately observing and understanding the crystallization process of a substance, they can adjust particle arrangements to enhance performance or control the formation process to create desired materials.

The Korea Research Institute of Standards and Science (KRISS) has become the first in the world to observe the structural evolution of solute molecules in extremely supersaturated aqueous solutions, revealing that changes in molecular symmetry impact on the formation of new metastable material phases. The research is [published](#) in the journal *Nature Communications*.

In the 1890s, the German chemist Wilhelm Ostwald recognized that supersaturated solutions often preferred to transform into a metastable intermediate phase rather than a thermodynamically stable one during crystallization, called Ostwald's step rule. To date, various hypotheses have been proposed to explain the origin of this phenomenon, with the leading hypothesis being that changes in the molecular structure of solutes in the solution would be the main factor.

The experimental verification of the solutes molecular symmetry requires the in-situ measurement of the solution structure in a highly supersaturated solution.

However, in a conventional experimental environment, it is very difficult to reach even twice its well-known solubility limit value.

The KRISS Space Metrology Group succeeded in achieving supersaturation levels exceeding four times the characteristic solubility limit value by levitating solution droplet using a self-developed electrostatic levitation device. They became the first in the world to observe the process where the molecular symmetry of solutes changes, altering the crystallization pathways and forming new material phases.

Senior research scientist Yong Chan Cho from the KRISS Space Metrology Group stated, "This achievement identifies the key factors in the formation of new material phases and suggests methodologies for forming the desired material phases. It can serve as a new milestone in the development of new materials for extreme environments such as space, and in new material research in the bio and medical fields."

In addition, the research group succeeded in implementing ultra-high-temperature environments exceeding 4,000 K (3,726°C) using the electrostatic levitation device and precisely measuring the thermal properties of heat-resistant materials such as tungsten (W), rhenium (Re), osmium (Os), and tantalum (Ta).

These precise thermal property values for ultra-high-temperature heat-resistant materials, used in space launch vehicles, aircraft engines, and nuclear fusion reactors, are expected to enhance the safety and efficiency of their designs.

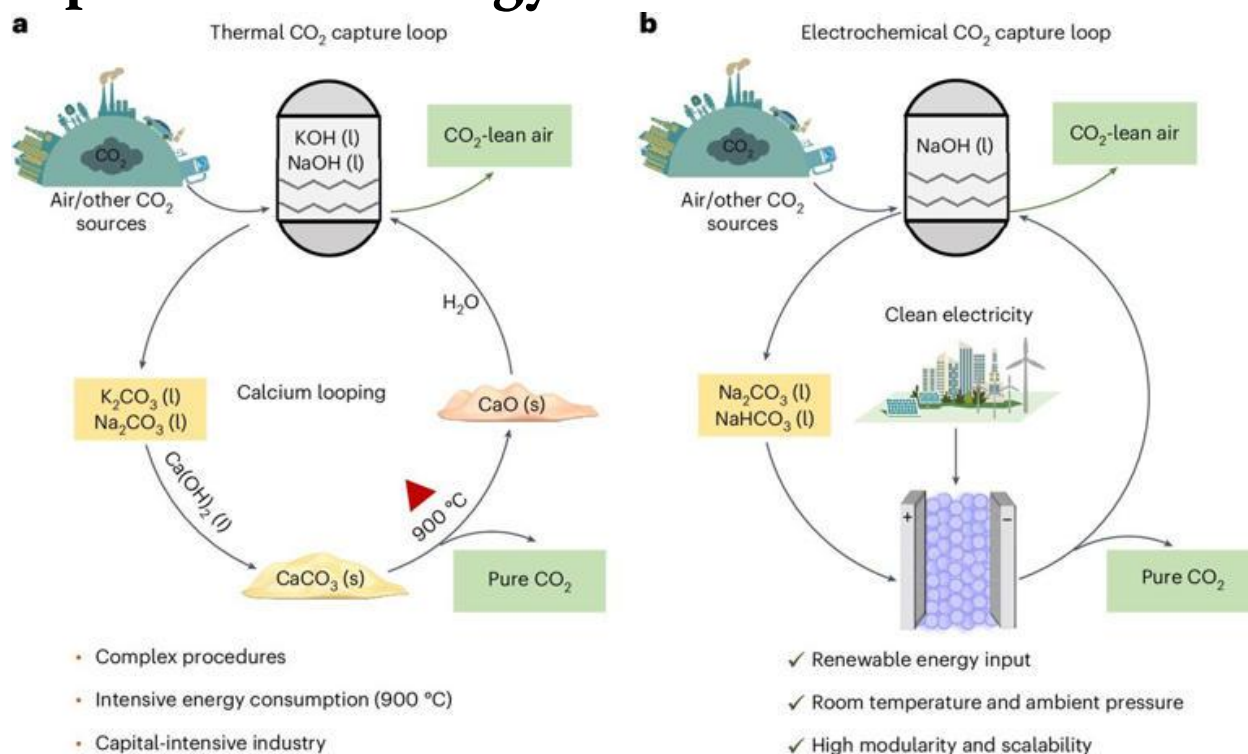
Principal research scientist Geun Woo Lee from the Space Metrology Group said, "Using the electrostatic levitation device, we can implement a microgravity environment similar to space to precisely measure the thermophysical properties of materials. Currently, advanced aerospace nations are conducting various experiments on the ground using this device to reduce costs and increase research efficiency."

In the future, the research group plans to establish an integrated measurement platform to precisely measure the properties of materials in extreme environments such as ultra-high temperatures, supersaturation, and ultra-high pressures, based on the electrostatic levitation device.

**More information:** Yong Chan Cho et al, Impact of molecular symmetry on crystallization pathways in highly supersaturated  $\text{KH}_2\text{PO}_4$  solutions, *Nature Communications* (2024). DOI: [10.1038/s41467-024-47503-1](https://doi.org/10.1038/s41467-024-47503-1)

Provided by National Research Council of Science and Technology

## Electrochemical reactor could make direct air capture more energy efficient



Comparison between thermal and electrochemical CO<sub>2</sub> regeneration in the CO<sub>2</sub>-carbonate carbon capture loop. a, Schematic illustration of the pilot-scale CO<sub>2</sub> capture process via calcium carbonate looping. The CO<sub>2</sub> regeneration step involves high-temperature (900 °C) annealing of calcium carbonate, which consumes natural gas and a large portion of overall energy consumption. b, Schematic illustration of the electrochemical CO<sub>2</sub> regeneration from carbonate or bicarbonate solutions in our solid electrolyte reactor for a complete carbon capture loop. Credit: Nature Energy (2024). DOI: [10.1038/s41560-024-01654-z](https://doi.org/10.1038/s41560-024-01654-z)

Rice University researchers have developed an electrochemical reactor that has the potential to drastically reduce energy consumption for direct air capture, the removal of carbon dioxide directly from the atmosphere.

The new reactor design could be a part of the solution to the pressing problem of emission impacts on the climate and biosphere by enabling more agile and scalable carbon dioxide mitigation strategies.

A [study](#) in *Nature Energy* describes the specialized reactor as having a modular, three-chambered structure with a carefully engineered porous solid electrolyte layer at its core. Haotian Wang, a Rice chemical and biomolecular engineer whose lab has been researching industrial decarbonization and energy conversion and storage solutions, said the work "represents a big milestone in carbon capture from the atmosphere."

"Our research findings present an opportunity to make carbon capture more cost-effective and practically viable across a wide range of industries," said Wang, the corresponding author on the study and associate professor of chemical and biomolecular engineering.

The device has achieved industrially relevant rates of carbon dioxide regeneration from carbon-containing solutions. Its performance metrics, including its long-term stability and adaptability to different cathode and anode reactions, showcase its potential for wide-scale industrial use.

"One of the major draws of this technology is its flexibility," said Wang, explaining that it works with different chemistries and can be used to cogenerate hydrogen. "Hydrogen coproduction during direct air capture could translate into dramatically lower capital and operation costs for downstream manufacturing of net-zero fuels or chemicals."

The new technology offers an alternative to the use of high temperatures in direct air capture processes, which often involve running a mixed gas stream through high-pH liquids in order to filter out carbon dioxide, an acidic gas. This first step of the process ties up the carbon and oxygen atoms in the gas molecules to other compounds in the liquid, forming new bonds of varying degrees of strength depending on the type of chemical used to trap the carbon dioxide.

The next major step in the process involves retrieving the carbon dioxide from these solutions, which can be done using either heat, chemical reactions or electrochemical processes.

Zhiwei Fang, a Rice postdoctoral researcher who is a study co-first author, said conventional direct air capture technologies tend to use high-temperature processes to regenerate carbon dioxide from sorbent, or the carbon dioxide-filtering agent.

"Our work focused on using electrical energy instead of thermal energy to regenerate carbon dioxide," Fang said, adding that the approach has several additional benefits, including it works at room temperature, needs no additional chemicals and generates no unwanted byproducts.

The types of chemicals used to trap the carbon dioxide have different drawbacks and advantages. Amine-based sorbents are the most widely used, in part because they tend to form weaker bonds, which means less energy is required to take the carbon dioxide back out of the solution. However, they are highly toxic and unstable. Even though basic water-based solutions using sorbents like sodium hydroxide and potassium hydroxide are a greener alternative, they require much higher temperatures to release the carbon dioxide back out.

"Our reactor can efficiently split carbonate and bicarbonate solutions, producing alkaline absorbent in one chamber and high-purity carbon dioxide in a separate chamber," said Wang. "Our innovative approach optimizes electrical inputs to efficiently control ion movement and mass transfer, reducing energy barriers."

Wang said he hopes the research will motivate more industries to pursue sustainable processes and fuel the momentum toward a net-zero future.

Other authors on the study are former Rice postdoctoral researcher Xiao Zhang and Rice doctoral alumni and former postdoctoral scientists Peng Zhu and Yang Xia.

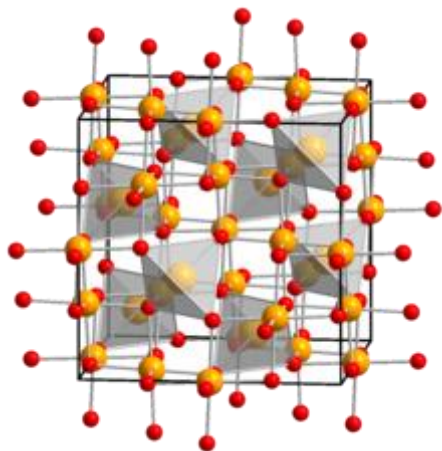
**More information:** Xiao Zhang et al, Electrochemical regeneration of high-purity CO<sub>2</sub> from (bi)carbonates in a porous solid electrolyte reactor for efficient carbon capture, *Nature Energy* (2024). [DOI: 10.1038/s41560-024-01654-z](https://doi.org/10.1038/s41560-024-01654-z)

Provided by Rice University

# Aluminium oxynitride

"ALON" redirects here. For other uses, see [Alon \(disambiguation\)](#).

## Aluminium oxynitride



Spinel structure of ALON

### Names

#### [Systematic IUPAC name](#)

Aluminium oxynitride

### Identifiers

#### [CAS Number](#)

- [12633-97-5](#) ✓

#### Abbreviations

ALON

### Properties

#### [Chemical formula](#)

$(\text{AlN})_x \cdot (\text{Al}_2\text{O}_3)_{1-x}$ ,  
 $0.30 \leq x \leq 0.37$

#### Appearance

White or transparent solid

#### [Density](#)

3.691–3.696 [g/cm<sup>3</sup>\[1\]](#)

#### [Melting point](#)

~2150 [°C\[1\]](#)

#### [Solubility in water](#)

insoluble

<a href="#">Refractive index</a> ( $n_b$ )	1.79 <sup>[2]</sup>
<b>Structure</b>	
<a href="#">Crystal structure</a>	cubic <a href="#">spinel</a>
<a href="#">Lattice constant</a>	$a = 794.6$ pm <sup>[2]</sup>
<p>Except where otherwise noted, data are given for materials in their <a href="#">standard state</a> (at 25 °C [77 °F], 100 kPa).</p> <p style="text-align: center;"> <span style="color: green;">✓</span> <a href="#">verify</a> (what is <span style="color: red;">✗</span> ?)  <a href="#">Infobox references</a> </p>	

**Aluminium oxynitride** (marketed under the name **ALON** by [Surmet Corporation](#)<sup>[3]</sup>) is a [transparent ceramic](#) composed of [aluminium](#), [oxygen](#) and [nitrogen](#). Aluminium oxynitride is optically transparent ( $\geq 80\%$ ) in the [near-ultraviolet](#), visible, and mid-wave-[infrared](#) regions of the electromagnetic spectrum. It is four times as hard as [fused silica glass](#), 85% as hard as [sapphire](#), and nearly 115% as hard as [magnesium aluminate spinel](#). It can be fabricated into transparent windows, plates, domes, rods, tubes, and other forms using conventional ceramic powder processing techniques.<sup>[citation needed](#)</sup>

Aluminium oxynitride is the hardest polycrystalline transparent ceramic available commercially.<sup>[2]</sup> Because of its relatively low weight, distinctive optical and mechanical properties, and resistance to oxidation or radiation, it shows promise for applications such as [bulletproof](#), blast-resistant, and optoelectronic windows.<sup>[4]</sup> Aluminium oxynitride-based armor has been shown to stop multiple armor-piercing projectiles of up to [.50 BMG](#).<sup>[5]</sup>

## Properties

Aluminium oxynitride is resistant to various acids, bases, and water.<sup>[6]</sup>

### Mechanical

Aluminium oxynitride has the following mechanical properties:<sup>[2]</sup>

- [Compressive strength](#) 2.68 GPa
- [Flexural strength](#) 0.38–0.7 GPa
- [Fracture toughness](#) 2.0 MPa·m<sup>1/2</sup>
- [Knoop hardness](#) 1800 kg/mm<sup>2</sup> (0.2 kg load)
- [Poisson ratio](#) 0.24
- [Shear modulus](#) 135 GPa
- [Young's modulus](#) 334 GPa

### Thermal and optical

Aluminium oxynitride has the following thermal and optical properties:<sup>[2]</sup>

- [Specific heat](#) 0.781 J/(g·°C)
- [Thermal conductivity](#) 12.3 W/(m·°C)
- [Thermal expansion coefficient](#)  $\sim 4.7 \times 10^{-6}/^{\circ}\text{C}$
- Transparency range 200–5000 nm

## Applications

Aluminium oxynitride is used for infrared-optical windows, with greater than 80% transparency at wavelengths below about 4 micrometers, dropping to near zero at about 6 micrometers.<sup>[8]</sup> It has also been demonstrated as an [interface passivation](#) layer in some [semiconductor](#)-related applications.<sup>[9]</sup>

Aluminium oxynitride has less than half the weight and thickness of glass-based transparent armor.<sup>[10]</sup> Aluminium oxynitride armor of 1.6-inch (41 mm; 4.1 cm) thickness is capable of stopping [.50 BMG](#) armor-piercing rounds, which can penetrate 3.7 inches (94 mm; 9.4 cm) of [traditional glass laminate](#).<sup>[8][11]</sup>

In 2005, the [United States Air Force](#) began testing aluminium oxynitride-based armor.<sup>[12]</sup>

## Manufacture

Aluminium oxynitride can be fabricated as windows, plates, domes, rods, tubes and other forms using conventional ceramic powder processing techniques. Its composition can vary slightly: the aluminium content from about 30% to 36%, which has been reported to affect the bulk and shear moduli by only 1–2%.<sup>[13]</sup> The fabricated greenware is subjected to heat treatment (densification) at elevated temperatures followed by [grinding](#) and [polishing](#) to [transparency](#). It can withstand temperatures of about 2,100 °C (2,370 K) in inert atmospheres. The grinding and polishing substantially improves the [impact resistance](#) and other mechanical properties of armor.<sup>[7]</sup>

## Patents

Patents related to aluminium oxynitride include:

- Aluminium oxynitride having improved optical characteristics and method of manufacture TM Hartnett, RL Gentilman [U.S. patent 4,481,300](#), 1984
- Process for producing polycrystalline cubic aluminium oxynitride JW McCauley [U.S. patent 4,241,000](#), 1980
- Transparent aluminium oxynitride and method of manufacture RL Gentilman, EA Maguire [U.S. patent 4,520,116](#), 1985; [U.S. patent 4,720,362](#), 1988
- Transparent aluminium oxynitride-based ceramic article JP Mathers [U.S. patent 5,231,062](#), 1993

# NASA says that warp drive is getting closer to reality

The sci-fi TV series [Star Trek](#) has captivated audiences since it first aired, blending real-life science with fiction in ways that have sparked technological innovations. One of the most fascinating concepts presented in the series is warp drive, an idea that has challenged Einstein's Theory of Relativity by proposing travel at speeds exceeding that of light.

Theoretical physicist Miguel Alcubierre developed the Alcubierre drive in 1994, a theory suggesting that a bubble within space-time could twist distances, making [faster-than-light travel](#) possible. This idea, while theoretically sound, was deemed impractical by many.

However, Joseph Agnew, an undergraduate from the [University of Alabama](#), aimed to test this theory. "Mathematically if you fulfill all the energy requirements, they can't prove that it doesn't work," Agnew stated in a university press release.

He explained, "Suppose you have a craft that's in the bubble. What you would do is, you'd compress space-time ahead of the craft and expand space-time behind it."

A ring-shaped warp drive device could transport a football-shaped starship (center) to effective speeds faster than light. The concept was first proposed by Mexican physicist Miguel Alcubierre. (CREDIT: Harold White)© The Brighter Side of News

[Einstein's theory](#), however, presents a significant challenge. According to relativity, as objects travel faster, they gain mass, making it increasingly difficult to achieve acceleration. Essentially, reaching the speed of light is impossible because it would require infinite energy.

So, what exactly is warp drive? Often referred to as the holy grail of space exploration, [warp drive](#) is a propulsion system concept that would allow travel faster than light. With such a system, humanity could theoretically reach any corner of the galaxy.

Despite the constraints of [Einstein's Theory of Relativity](#), the idea of warp drive remains compelling. While traditional views on interstellar travel at light speed

seem absurd, science fiction writers have fueled our hopes with imaginative depictions of such journeys.

Related Stories:

[Research breakthrough tests warp speed effect](#) [What is warp drive and is it even a really a thing? Physicist explains](#) [Is warp drive really possible? Physicist explains](#)

Einstein's theory explains that nothing can travel faster than light due to the infinite energy required to accelerate an object to that speed. [Photons](#), the particles of light, avoid this problem because they have no mass. Consequently, a spacecraft traveling at light speed is currently impossible.

There are, however, two potential loopholes. First, the focus could shift from achieving light speed to approaching it as closely as possible. Second, the Alcubierre warp drive theory proposes bending the laws of physics to circumvent the universal speed limit. By warping space-time, this drive could enable travel at ten times the [speed of light](#) without violating general relativity.

The theory posits that a spacecraft could sit within a [warp bubble](#) surrounded by a ring of negative mass. This ring would compress space-time ahead of the ship and expand it behind, allowing for faster-than-light travel. Within the bubble, the spacecraft would still adhere to the universal speed limit while moving at extraordinary speeds relative to outside observers.

The Alcubierre Warp Drive Model. The blue area below the plane represents contracted space while red and raised area represent expanded space. (CREDIT: Harold White)© The Brighter Side of News

A significant challenge to this theory is the enormous amount of mass-energy required. To propel a spacecraft using the Alcubierre drive, one would need mass equivalent to that of [Jupiter](#). According to Einstein's equation,  $E=mc^2$ , this represents an immense amount of energy, far beyond what the universe can currently provide.

Dr. Harold "Sonny" White, a NASA mechanical engineer and physicist, is working to address this issue. He believes it might be possible to reduce the [mass-energy requirement](#) by altering the shape of the negative mass ring. This could potentially lower the mass needed to around 700 kg.

White leads a team of physicists and engineers at NASA in building the White-Juday Warp Field Interferometer, a device designed to detect and generate the

tinest warp bubbles. While this technology might not immediately enable travel to distant [galaxies like Andromeda](#), it represents a significant step toward making warp drive a reality.

[https://youtu.be/l4u4wV\\_dOi0](https://youtu.be/l4u4wV_dOi0)

Despite these advancements, we remain far from achieving interstellar travel and warp drive. Yet, ongoing technological progress brings us closer to finding the answers. [Star Trek](#) predicted the invention of warp drive in 2063. While that date remains in the future, continued research and innovation may one day turn this science fiction concept into science fact.

Other theories for the development of warp drive

Aside from Joseph Agnew's Alcubierre model theory, here are some other [warp drive](#) theories and concepts currently being explored:

**White-Juday Warp Field Interferometer** Harold "Sonny" White, a NASA scientist, proposed adjustments to the Alcubierre model to make the concept more feasible. He suggested that shaping the warp bubble into a torus could reduce the energy requirements by orders of magnitude, theoretically making it possible to create a smaller [warp bubble](#) around a craft. Challenges: Despite energy reductions in theory, creating even this smaller warp bubble still demands technologies and materials that are currently beyond our reach.

**Casimir Effect and Negative Energy** The Casimir effect demonstrates how quantum fluctuations between two closely spaced objects can create negative energy, which may contribute to warp drive development. This approach is still in the early stages and primarily focuses on understanding if and how we can harness [negative energy](#) on a larger scale. Challenges: Controlling and generating enough negative energy is currently beyond our technological capabilities, and more research into quantum field theory is needed.

**Manipulating Extra Dimensions (Brane Cosmology)** Some theories in string theory and brane cosmology propose that our universe may have extra spatial dimensions. If this is true, it might be possible to "shortcut" through these dimensions, effectively enabling faster-than-light travel without violating relativity. This idea is closely related to the concept of wormholes, another theoretical method for [FTL travel](#). Challenges: This theory is still highly speculative and lacks empirical support, as no direct evidence of extra dimensions or brane structures has been found.

Brane cosmology propose that our universe may have extra spatial dimensions. (CREDIT: CC BY-SA 4.0)© The Brighter Side of News

**Warp Drive with Quantum Field Theory Adjustments** Some researchers have explored modifications to quantum field theory that could make warp drives more feasible. This approach involves exploring how [quantum fields](#) interact with spacetime and whether these interactions can be controlled or utilized to create stable warp bubbles. **Challenges:** Current quantum field theory modifications remain largely theoretical, and experimental methods to test these ideas are not yet available. **Dark Energy Manipulation** Since dark energy is thought to drive the accelerated expansion of the universe, some have theorized that manipulating dark energy could enable us to create similar expansion and contraction effects in local space around a spacecraft. **Challenges:** [Dark energy](#) is one of the least understood aspects of physics, and manipulating it remains speculative. Researchers would first need to identify a way to harness dark energy in controlled settings.

Each of these theories faces significant obstacles due to the requirement for exotic matter, negative energy, or extremely advanced technologies that we do not yet possess. However, advances in quantum field theory, energy manipulation, and fundamental physics could potentially make warp drive—or something like it—more feasible in the far future.

# Next-generation space materials blast off for tests on ISS



Credit: NASA

**A** new generation of space materials left Earth on November 5 as they head to the International Space Station (ISS) to undergo testing in the brutal conditions of low Earth orbit.

Developed at the University of Bristol, these high-performance materials could be used to build future space stations, spacecraft for interplanetary travel or a new ISS.

They will be placed on the Bartolomeo platform, located on the front of the ISS, where they will orbit Earth up to 9,000 times over the next 12 to 18 months at speeds of 17,000 mph.

The carbon fiber–reinforced composites will need to survive temperatures between  $-150^{\circ}\text{C}$  and  $+120^{\circ}\text{C}$ , space debris traveling seven times faster than a bullet, severe electromagnetic radiation, high vacuum conditions, and atomic oxygen, which erodes even the toughest materials.

Prof Ian Hamerton, Professor of Polymers and Sustainable Composites at the Bristol Composites Institute, said, "Space is the most challenging environment for which to design new materials. You're pitting your materials expertise, skills and ingenuity against extremes of temperature, mechanical stress, radiation, high speed impacts and more.

"Any one of those might be difficult, and, unfortunately, gaining access to repair them is not an easy option, so the materials we build must survive without maintenance.

"The opportunity to test our materials in the proving ground of space is priceless and will help our University of Bristol scientists on the ground improve fiber-reinforced materials for next-generation space missions."

There are four laboratory-made polymers heading to the ISS, each of which has been reinforced with carbon fibers and two contain nanoparticles. All four are the result of University of Bristol research and one is patented.

If the materials cope in the harsh environment, they could be used to create longer-lasting space components, allowing spacecraft to travel further, and spend more time in space.

Future communities on new planets will need protection against galactic cosmic radiation. Dr. Ali Kandemir, Senior Research Associate at the University of Bristol, is one of several Bristol researchers, supported by the UK Space Agency (UKSA), examining the effects of simulated galactic cosmic radiation on the materials, in a European Space Agency (ESA) project.

Dr. Kandemir said, "We want materials that are resilient in the space environment and, importantly, materials that can shield humans from that radiation.

"We also want to make these materials sustainable, so that when they reach the end of their life they can be recycled and used again for the same purpose."

The launch of the Space X Dragon CRS-2 spacecraft this morning is the culmination of five years of work for Prof Hamerton and his team.

It has included the efforts of early career researchers, postgraduates and several Aerospace Engineering undergraduates at the University of Bristol, whose final year research projects have been linked to the space materials project.

The practical support of the University of Bristol-hosted National Composites Center (NCC) was crucial to the scale up of the composite materials.

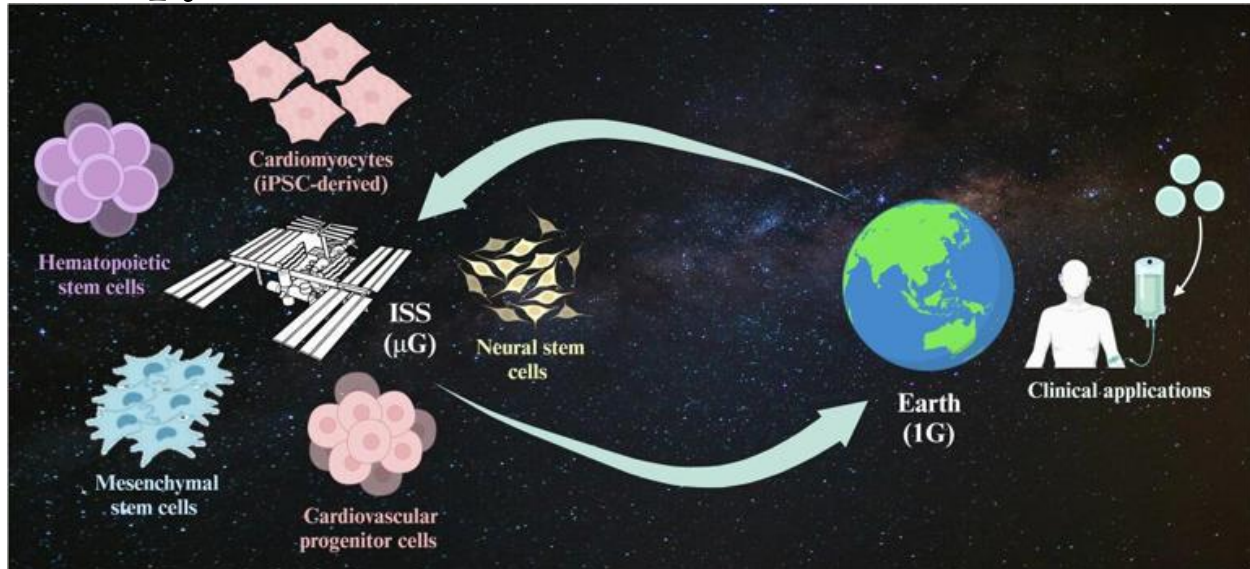
Prof Kate Robson Brown, Vice-President for Research, Innovation and Impact at University College Dublin, and a collaborator on the project, said, "After nearly five years of research to develop novel composite materials for space applications, it is very exciting to see our experiment launch to the International Space Station.

"I am proud to be part of this mission, and to be working with the multidisciplinary and multisector research team to deliver integrated real world and digital testing for innovative materials which will help to drive growth in the new space economy.

"This mission also demonstrates how space research funding creates career changing opportunities for early career researchers and Ph.D. students in a sector of huge value to both Ireland and the U.K."

Provided by University of Bristol

# Space: A new frontier for exploring stem cell therapy



Schematic diagram showing different types of stem cells grown in microgravity ( $\mu\text{G}$ ) on the International Space Station (ISS) and their return to Earth (1 G) for potential clinical applications. Credit: Nature (2024). DOI: 10.1038/s41526-024-00425-0

**S**tem cells grown in microgravity aboard the International Space Station (ISS) have unique qualities that could one day help accelerate new biotherapies and heal complex disease, two Mayo Clinic researchers say.

The research analysis by Fay Abdul Ghani and Abba Zubair, M.D., Ph.D., published in [npj Microgravity](#), finds microgravity can strengthen the regenerative potential of cells. Dr. Zubair is a laboratory medicine expert and medical director for the Center for Regenerative Biotherapeutics at Mayo Clinic in Florida. Abdul Ghani is a Mayo Clinic research technologist. Microgravity is weightlessness or near-zero gravity.

"Studying stem cells in space has uncovered cell mechanisms that would otherwise be undetected or unknown within the presence of normal gravity," says Dr. Zubair. "That discovery indicates a broader scientific value to this research, including potential clinical applications."

Dr. Zubair has launched stem cell experiments from his lab on three different missions to the ISS. His review paper provides data on the scientific question, "Is space the ideal environment for growing large numbers of stem cells?" Another key concern is whether cells grown in space could maintain their strength and function after splashdown on Earth.

"The goal of almost all space flight in which stem cells are studied is to enhance growth of large amounts of safe and high-quality clinical-grade stem cells with minimal cell differentiation," says Dr. Zubair. "Our hope is to study these space-grown cells to improve treatment for age-related conditions such as stroke, dementia, neurodegenerative diseases and cancer."

## The challenges of growing stem cells on Earth

Adult stem cells found in bone marrow and adipose (fat) tissue do not divide and differentiate into specialized cells. As a result, the number of adult stem cells in any one patient is limited. To obtain enough stem cells for clinical research or patient use, cells must be multiplied and expanded. It's an expensive, time-consuming process with inconsistent results.

Through research on the International Space Station, scientists gained new understanding of how cells multiply, function and morph into specialized cells. Importantly, they've also discovered microgravity fosters better cell growth and function compared to those cultured in an Earth lab setting.

"The space environment offers an advantage to the growth of stem cells by providing a more natural three-dimensional state for their expansion, which closely resembles growth of cells in the human body. That's in comparison to the two-dimensional culture environment available on Earth that is less likely to imitate human tissue," says Dr. Zubair.

## Discoveries from stem cells grown in space

The immediate value of the interstellar stem cell research may be in growing tissue for disease modeling. Space-cultured stem cells could be used to recreate

lifelike models of cancer and other diseases in a petri dish. Researchers can then use these models to track disease progression and test new therapies to stop it.

A comprehensive review of papers from the Mayo Clinic and other academic health centers shows space research has applications well beyond the lab. Several stem cell lines grown in weightlessness have shown clinical potential:

- Mesenchymal stem cells are adult stem cells that secrete growth factors with potential for healing. Dr. Zubair's team has documented that mesenchymal stem cells expanded in microgravity have greater immunosuppressant capabilities than those grown on Earth.
- Hematopoietic stem cells have blood regenerative abilities to fight infection, stop bleeding and carry oxygen. Hematopoietic stem cells grown aboard the ISS have shown the ability to expand and differentiate into red or white blood cells that could one day be used to manage patients with blood cancers.
- Cardiovascular progenitor cells provide the building blocks for blood vessels and heart muscle. They play a crucial role in repairing muscle. Growing cardiovascular progenitor cells in space could someday provide new options for repairing tissue damaged by heart attack.
- Neural stem cells are found in the central nervous system and play a key role in brain development, maintenance and repair. Neural cells expanded in a gravity-free environment and maintained their regenerative capabilities on Earth. Researchers are studying whether neural cells grown in space could offer replacement therapy for diseases of the central nervous system.

## Hurdles to healing

Despite the promise of extraterrestrial stem cell research, researchers are faced with many challenges. Cells could lose their strength and ability to function after long-term exposure to microgravity.

Over time, space radiation could damage DNA and affect the growth of cells. Another concern is whether cells grown in microgravity could turn cancerous. Dr. Zubair's team, however, found no evidence of chromosomal damage that could trigger cancer in mesenchymal stem cells cultured in space.

Stem cell research in the cosmos is in its early stages, and the full effects of multiplying cells in weightlessness are not fully understood. More scientific data, research and funding are needed to help researchers fully comprehend the clinical potential of space-expanded cells.

"The space research conducted so far is just a starting point. A broader perspective about stem cell applications is possible as research continues to explore the use of space to advance regenerative medicine," writes Dr. Zubair.

**More information:** Fay Ghani et al, Discoveries from human stem cell research in space that are relevant to advancing cellular therapies on Earth, *npj Microgravity* (2024). [DOI: 10.1038/s41526-024-00425-0](https://doi.org/10.1038/s41526-024-00425-0)

Provided by Mayo Clinic

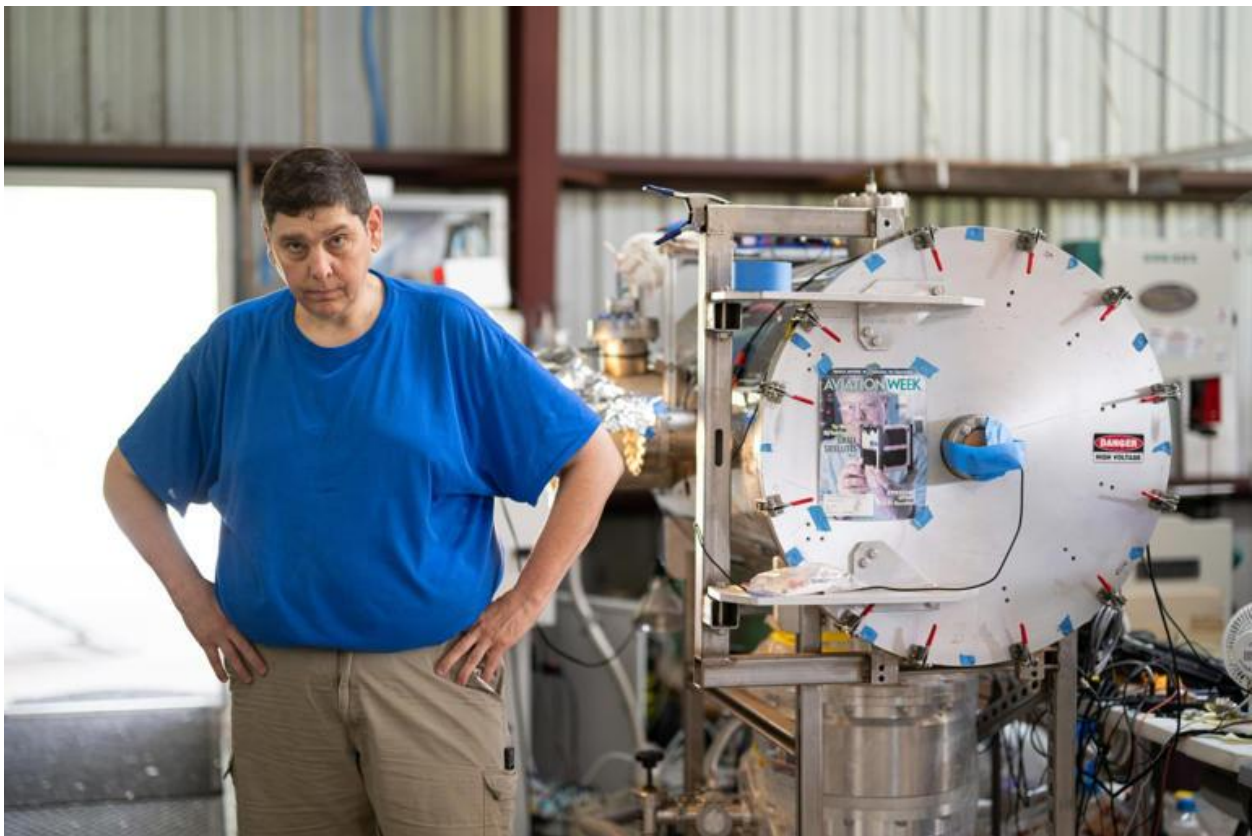
This story was originally published on [Medical Xpress](#). Subscribe to our [newsletter](#) for the latest sci-tech news updates.

# NASA engineer developed a propellant-less rocket that defies conventional laws of physics

In a recent revelation, Dr. Charles Buhler, a seasoned NASA engineer and co-founder of [Exodus Propulsion Technologies](#), unveiled a groundbreaking achievement: their propellantless propulsion drive has demonstrated the capability to counteract Earth's gravity, defying conventional laws of physics.

With a wealth of experience from NASA's most iconic missions under his belt, including the [Space Shuttle](#) and the [International Space Station \(ISS\)](#), Dr. Buhler and his team perceive this discovery as a monumental breakthrough set to redefine the landscape of space travel for centuries to come.

Dr. Buhler emphasized the significance of their finding, stating, "The most important message to convey to the public is that a major discovery occurred."



Dr. Charles Buhler, a seasoned NASA engineer and co-founder of Exodus Propulsion Technologies. (CREDIT: Exodus Propulsion Technologies)© The Brighter Side of News

Their innovation, harnessing electric fields to generate sustainable thrust without expelling mass, represents a paradigm shift in [propulsion physics](#). Buhler envisions this newfound force propelling objects into space for the next millennium, heralding a new era in exploration.

Unveiling their discovery at the [Alternative Propulsion Energy Conference \(APEC\)](#), Dr. Buhler shared insights into their journey. Despite initial skepticism, their pursuit led them to electrostatics, a field in which Dr. Buhler is an eminent authority.

Collaborating with a diverse team from prestigious institutions and industries, their collective expertise culminated in a breakthrough that defied conventional expectations.

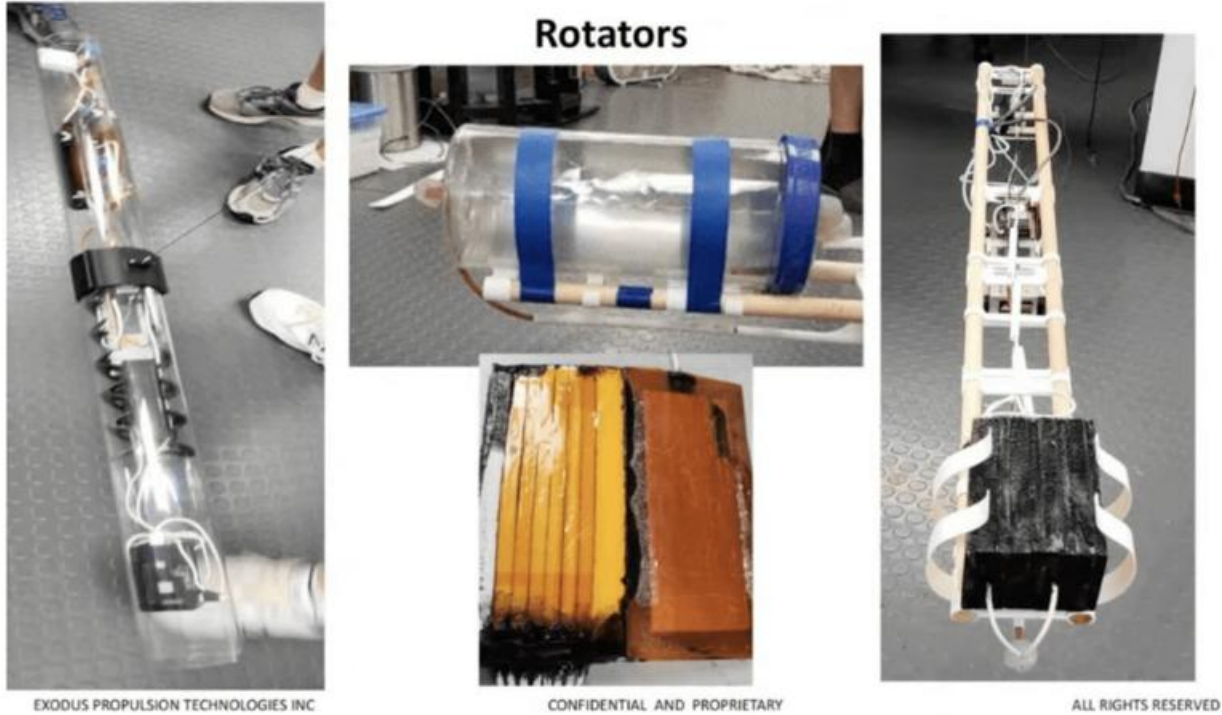
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[Cutting-edge rocket engine could accelerate to 99% the speed of light](#) [Plastic waste-powered rocket could sustainably travel to Mars](#) [Giant catapult defies gravity by launching satellites into orbit without the need of rocket fuel](#)

Over a span of decades, the team meticulously conducted experiments, culminating in their propellantless propulsion drive.

Through iterative refinement and rigorous testing, they achieved thrust measurements exceeding previous limits. Notably, their latest iteration exhibited a remarkable feat: generating thrust equivalent to one [Earth gravity](#), a milestone in their quest.

Detailing their methodology, Dr. Buhler explained the significance of their tests conducted in a custom-made vacuum chamber simulating deep space conditions. These experiments validated their [propulsion drive's efficacy](#), eliminating alternative explanations and solidifying their patent.



Their innovation, harnessing electric fields to generate sustainable thrust without expelling mass, represents a paradigm shift in propulsion physics. (CREDIT: Exodus Propulsion Technologies)© The Brighter Side of News

Despite their pioneering success, Dr. Buhler acknowledged the existence of competing concepts like the [EM Drive](#) and Quantum Drive. While these initiatives showcase potential, Exodus Propulsion Technologies' breakthrough offers a unique perspective.

Dr. Buhler welcomes collaboration with interested parties, offering their expertise to advance propulsion technologies mutually.

Notably, their experiments unveiled intriguing phenomena, including [sustained thrust](#) without continuous electrical input. Such anomalies prompt further inquiry and underscore the complexity of the underlying physics. Seeking funding for space demonstrations, Dr. Buhler envisions expanding their understanding and inspiring scientific exploration.

<https://youtu.be/WhsKMWOYuYo>

Reflecting on the broader implications, Dr. Buhler emphasized the role of science in dissecting their discovery's implications.

While their experiments provide empirical evidence, understanding the underlying principles remains a collective endeavor. He remains optimistic that

their findings could illuminate profound scientific inquiries, challenging conventional understanding.

Dr. Buhler's revelation marks a pivotal moment in space exploration, unlocking new possibilities for [propulsion technologies](#).

A few of the hundreds of tests the team ran on their propellantless propulsion drive between 2016 and 2023. (CREDIT: Exodus Propulsion Technologies, Buhler, et al.)© The Brighter Side of News

As scientists delve deeper into the mysteries of their discovery, the horizon of human exploration expands, propelled by ingenuity and curiosity.

## Quantum experiment arrives at space station aboard NASA's SpaceX CRS-31

The International Space Station is viewed from a camera aboard the approaching SpaceX Dragon cargo spacecraft. The SpaceX Dragon Freedom crew spacecraft is pictured (at center) docked to the Harmony module's space-facing port. Credit: NASA

**A**fter launching at 9:29 p.m. EST Nov. 4, the SpaceX Dragon capsule docked at the International Space Station at 9:52 a.m. EST Nov. 5. The spacecraft carried more than 6,000 pounds of scientific investigations and cargo to the orbiting laboratory on SpaceX's 31st commercial resupply services mission for NASA.

Included in the payload is a technology demonstration called [SEAQUE](#) (Space Entanglement and Annealing Quantum Experiment). Developed at NASA's Jet Propulsion Laboratory in Southern California, SEAQUE will experiment with technologies that, if successful, will enable communication on a quantum level using entanglement.

Researchers will focus on validating in space a new technology, enabling easier and more robust communication between two quantum systems across large distances. The research from this experiment could lead to developing building

blocks for communicating between equipment such as quantum computers with enhanced security.

SEAQUE will be installed on the exterior of the space station using a Materials International Space Station Experiment (MISSE) mounting location.

**More information:** Read more about the experiment [here](#), and find out more about NASA's SpaceX CRS-31 [here](#).

Provided by NASA

## Living In Space Won't Be Easy

### In This Article...

- Since 1961, human beings have been venturing into space.
- There are plans to put outposts on the Moon and Mars.
- Scientists are working on protecting humans from the unavoidable hazards of living in space, including protecting us from ourselves.

## The Hazards Humans Face Living in Space

It's not a matter of *whether* humans will build outposts on the Moon and Mars - in other words, live in space - it's a matter of *when*. The United States is serious about developing an outpost on the moon. The Defense Advanced Research Projects Agency (DARPA) is already conducting a 10-Year Lunar Architecture (LunA-10) Capability Study for that very purpose.

Elon Musk, the founder of SpaceX, has long stated the company's goal of colonizing Mars. In October 2023, Musk said the company could land a spacecraft on the Red Planet 3 to 4 years from now. SpaceX is also a collaborator, along with other major companies, in the LunA-10 study.

But amid all the optimism is a very unforgiving reality, operating in space is fraught with dangers. Scientists, engineers, medical professionals, and other experts are working hard to meet the challenges. Interplanetary travel will bring new challenges for human health and well-being. Some of the best minds in the world are working to find solutions, as well as to identify and anticipate unforeseen hazards.

Next, we'll take a look at several known challenges that humans will have to overcome to live in space or at an outpost on the Moon or Mars.

## Spaceflight-Associated Neuro-Ocular Syndrome (SANS)

On Earth, our bodies have to continually fight gravity to pump fluid to our heads. But in space, without gravity, the fluids pumped into our craniums won't be pulled back down and will not fully drain. Fluids will pool in both the face and the skull. This condition is called Spaceflight Associated Neuro-ocular Syndrome (SANS).

Our bodies will resolve puffiness in the face after a few days and acclimating to microgravity. However, that does not occur for the cerebrospinal fluid surrounding the brain. This fluid can take months or years for the changes to reverse after long-term spaceflight.

Worse, this fluid buildup puts additional pressure on the brain, pushing it against the skull. In turn, the fluid-filled ventricles (cavities) within the brain expand. This exerts pressure on the eyeballs resulting in vision changes requiring glasses.

All the symptoms of SANS are still not fully understood. Effective solutions are still something researchers are working on. However, there are several ideas. These include creating artificial gravity. Having astronauts wear specialized negative-pressure suits that will draw fluid from their heads.

# Radiation Risks

On Earth, the planet's magnetic shield - the geomagnetic field - protects all living organisms from cosmic radiation. This magnetosphere extends from Earth's interior out into space, well beyond the orbit of the moon, according to the NOAA. About 60,000 kilometers sunward, according to the ESA.

However, outside this zone, highly charged particles of solar radiation or cosmic radiation can penetrate through the bodies of astronauts and damage cells. Therefore, with deployment in space, humans have an increased risk of cancer, radiation, and a host of other issues.

Currently, spacecrafts are shielded to mitigate the risk of radiation. Astronauts are also closely monitored for radiation exposure.

Longer durations spent in space increase the risk. Radiation can damage tissues in a way that could affect astronauts' behavior, cognition, and general health.

However, travel to Mars could pose immediate radiation issues. Several potential solutions have been proposed. One is creating habitats that have an insulating layer of water. Water effectively blocks radiation.

Another solution is shielding habitats with a layer of regolith. Regolith includes dust, broken rocks, and other related materials. It is readily available on Earth, the Moon, Mars, and some asteroids.

A more controversial idea is to combine spacecraft shielding and biological protection. This would involve the use of gene editing on astronauts.

# Microbiome Dangers

The human microbiome is the aggregate of all microbiota that reside on or within human tissues and biofluids. Our microbiome includes complex cultures of bacteria, fungi, protozoa, and viruses.

Studies of astronauts who stayed on the International Space Station (ISS) found that the human microbiome becomes unbalanced in space. Researchers are still trying to understand the shift of the microbiome in low Earth orbit. Experts are concerned that it is likely that different alterations of the microbiome may occur during extended trips into deeper space.

For example, consider commensal bacteria that help instigate the body's immune response. Cosmic radiation could increase the mutation rate of these bacteria. This may result in new and unexpected interactions between these bacteria and their human host.

Despite these concerns, simple solutions may prove to be effective. For example, maintaining a healthy diet combined with prebiotics and probiotics. A simple solution might be yogurt. Other solutions could be pills or fecal transplants.

## Protecting Humans From Themselves

Ever been on a long, uncomfortable trip with people or family in tight conditions? Certain situations can bring out the worst sides of people. In space, conditions are cramped, and you can't pull over for a pit stop.

Understanding these issues in human nature, researchers are working on ways to prevent infighting. This begins with a thorough crew selection process. Finding people who can get along helps ensure travel harmony.

The standards, therefore, aren't as simple as picking the most excellent astronauts. Assembling a cohesive crew is a matter of looking at the group's dynamic as a whole.

This has made researchers study the complex nature of isolated groups. For example, running analog missions – simulations of living on the Moon or Mars – hosted on Earth.

Ultimately, no matter how cohesive a group may be, human nature always prevails. Frustrations are likely to occur when people are confined in a stressful environment for months on end.

Ideas that have long been a part of science fiction material – astronauts in a medical cooling or a hibernation state – are being seriously researched. Such studies are ongoing.

For now, space organizations will have to balance an astronaut's talents with their ability to play a cooperative role and keep a cool head.

## **Scientists built the world's first laser-powered tractor beam**

scientists have been working on a new type of optical manipulation: using laser light to create an optical tractor beam to pull objects.

Researchers have developed a way to use laser light to pull a macroscopic object. Although microscopic optical tractor beams have been demonstrated before, this is one of the first times that laser pulling has been used on larger objects. Light contains both energy and momentum that can be used for various types of optical manipulation such as levitation and rotation. Optical tweezers, for example, are commonly used scientific instruments that use laser light to hold and manipulate tiny objects such as atoms or cells. For the last ten years, scientists have been working on a new type of optical manipulation: using laser light to create an optical tractor beam that could pull objects.

"In previous studies, the light pulling force was too small to pull a macroscopical object," said research team member Lei Wang from QingDao University of Science and Technology in China. "With our new approach, the light pulling force has a much larger

amplitude. In fact, it is more than three orders of magnitudes larger than the light pressure used to drive a solar sail, which uses the momentum of photons to exert a small pushing force."

In the journal *Optics Express*, Wang and colleagues demonstrate that macroscopic graphene-SiO<sub>2</sub> composite objects they designed can be used for laser pulling in a rarefied gas environment. This type of environment has a pressure much lower than atmospheric pressure.

"Our technique provides a non-contact and long-distance pulling approach, which may be useful for various scientific experiments," said Wang. "The rarefied gas environment we used to demonstrate the technique is similar to what is found on Mars. Therefore, it might have the potential for one day manipulating vehicles or aircraft on Mars."

The video shows a torsional—or turning—pendulum device made from the graphene-SiO<sub>2</sub> composite structure. When it is irradiated with laser light, the pendulum turns toward the light. (CREDIT: Lei Wang, QingDao University of Science and Technology)

## **Creating enough force**

In the new work, the researchers designed a special graphene-SiO<sub>2</sub> composite structure specifically for laser pulling. When irradiated with a laser, the structure creates a reversed temperature difference, meaning that the side facing away from the laser gets hotter.

Light contains both energy and momentum that can be used for various types of optical manipulation such as levitation and rotation. (CREDIT: Creative Commons)

When objects made from the graphene-SiO<sub>2</sub> composite structure are irradiated by a laser beam, gas molecules on their back side receive more energy and push the object toward the light source. Combining this with the low air pressure of a rarefied gas environment allowed the researchers to obtain a laser pulling force strong enough to move macroscopic objects.

Using a torsional—or turning—pendulum device made from their graphene-SiO<sub>2</sub> composite structure, the researchers demonstrated the laser pulling phenomenon in a way that was visible to the naked eye. They then used a traditional gravity pendulum to quantitatively measure the laser pulling force. Both devices were about five centimeters long.

Researchers showed that laser light can be used to pull a macroscopic object toward it. To do this they developed a graphene-SiO<sub>2</sub> composite structure that gets hot on the side facing away from the laser. This causes gas molecules on the back to receive more energy, pushing the object toward the light source. (Credit: Lei Wang, QingDao University of Science and Technology)

## **Repeatable, tunable pulling**

"We found that the pulling force was more than three orders of magnitudes larger than the light pressure," said Wang. "In addition, the laser pulling is repeatable, and the force can be tuned by changing the laser power."

The researchers caution that this work is only a proof of concept and that many aspects of the technique would need improvement before it would be practical. For example, a systematic theoretical model is needed to accurately predict the laser pulling force for given parameters including the geometry of object, laser energy and the surrounding media.

Experimental facilities and results of the laser pulling force measurement by using the gravity pendulum. Size and material details of the gravity pendulum device. (CREDIT: Optica)

The researchers would also like to improve the laser pulling strategy so that it can work for a wider range of air pressures.

"Our work demonstrates that flexible light manipulation of a macroscopical object is feasible when the interactions between the light, object and medium are carefully controlled," said Wang. "It also shows the complexity of laser-matter interactions and that many phenomena are far from being understood on both on macro and micro scales."

## **Stem cells grown in space show ‘super powers’ — but there’s a catch**

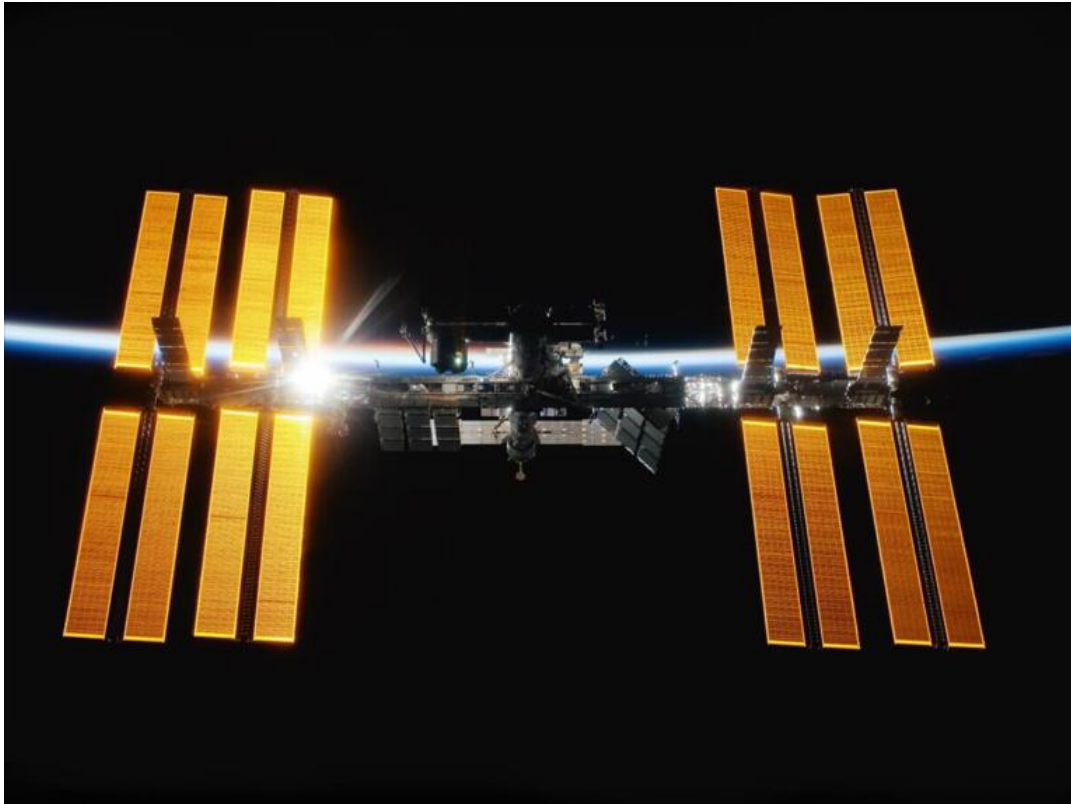
**JACKSONVILLE, Fla.** — While Jeff Bezos and Elon Musk race to send tourists to space, scientists have found a more practical use for the final frontier: growing better medicines. It turns out that the International Space Station, orbiting 250 miles above Earth, might be the perfect laboratory for cultivating human stem cells.

A recent review published in [NPJ Microgravity](#) shows that stem cells grown in the microgravity environment of space possess unique qualities that could accelerate the development of new treatments for complex diseases. This discovery represents a significant breakthrough in [regenerative medicine](#), potentially offering new ways to treat conditions ranging from stroke to cancer.

"Studying [stem cells](#) in space has uncovered cell mechanisms that would otherwise be undetected or unknown within the presence of normal gravity," says Dr. Abba Zubair, a laboratory medicine expert and medical director for the Center for Regenerative Biotherapeutics at Mayo Clinic in Florida, in a media release.

One of the biggest challenges in stem cell therapy on Earth is growing enough cells for treatment. Adult stem cells, found in bone marrow and fat tissue, don't readily divide and transform into specialized cells. This limitation means that obtaining sufficient quantities for research or patient treatment requires a costly and time-consuming process that often yields inconsistent results.

Space offers a unique solution to this problem. In [the microgravity environment](#) of the ISS, cells can grow in three dimensions more naturally, similar to how they develop in the human body. This is a significant advantage over traditional two-dimensional cell cultures used in Earth-bound laboratories, which less accurately represent human tissue.



International Space Station (credit: NASA/Unsplash)

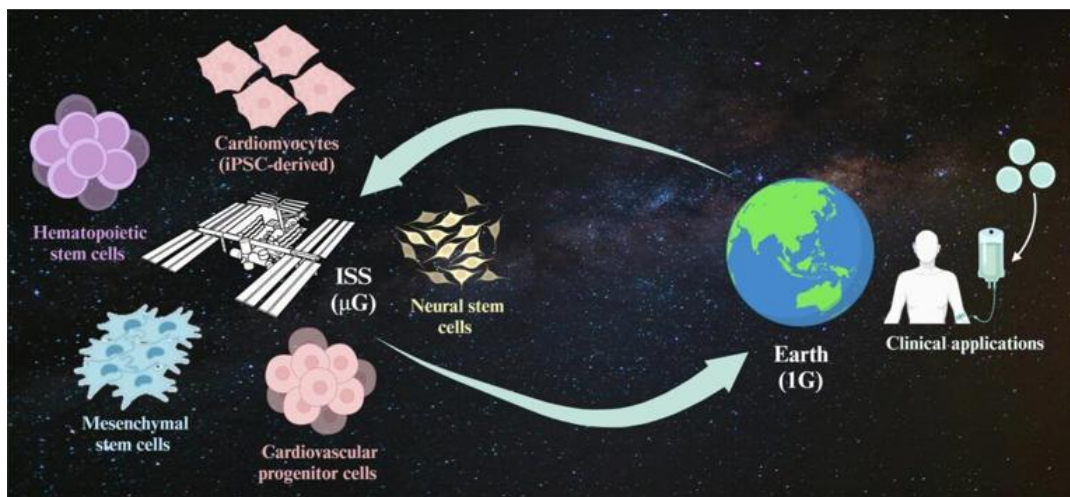
The research team, led by Dr. Zubair and research technologist Fay Abdul Ghani at Mayo Clinic, analyzed multiple studies conducted on the ISS over the past decade. They examined five main types of stem cells, each with potential therapeutic applications:

**Mesenchymal stem cells**, which can develop into bone, cartilage, and fat cells, showed enhanced ability to suppress immune responses when grown in space – a crucial feature for treating inflammatory conditions. Dr. Zubair’s team documented that these cells had greater immunosuppressant capabilities than their Earth-grown counterparts.

**Hematopoietic stem cells**, which produce blood cells, demonstrated the ability to expand and differentiate into red or white blood cells during space cultivation. This finding could lead to new treatments for blood cancers.

**Cardiovascular progenitor cells**, which provide building blocks for blood vessels and heart muscle, showed promise for potentially repairing tissue damaged by heart attacks when grown in the space environment.

**Neural stem cells**, found in the central nervous system, maintained their regenerative capabilities even after returning to Earth from space. This discovery could lead to replacement therapy for diseases of the central nervous system.



Schematic diagram showing different types of stem cells grown in microgravity ( $\mu\text{G}$ ) on the International Space Station (ISS) and their return to Earth (1 G) for potential clinical applications. (Created with BioRender.com)

The immediate value of this interstellar research may be in growing tissue for disease modeling. [Space-cultured stem cells](#) could be used to create lifelike models of cancer and other diseases in laboratory dishes, allowing researchers to track disease progression and test new therapies.

However, significant challenges remain. Scientists must ensure that cells maintain their strength and function after long-term exposure to microgravity. There are concerns about potential [DNA damage from space radiation](#) and whether cells might become cancerous. Encouragingly, Dr. Zubair's team found no evidence of chromosomal damage that could trigger cancer in mesenchymal stem cells cultured in space.

Through research on the ISS, scientists have gained a new understanding of how cells multiply, function, and transform into specialized cells. Importantly, they've discovered that microgravity fosters better cell growth and function compared to Earth-based laboratory settings. However, stem cell research in space remains in its early stages, and more scientific data, research, and funding are needed to fully understand the clinical potential of space-expanded cells.

"The space research conducted so far is just a starting point. A broader perspective about stem cell applications is possible as research continues to explore the use of space to advance regenerative medicine," Dr. Zubair notes.

## Paper Summary

### **Methodology**

The research team conducted a comprehensive review of various studies performed on the International Space Station, examining how different types of stem cells behaved in microgravity. They analyzed data from multiple experiments that sent stem cells to space for periods ranging from 11 days to 5.5 weeks. The cells were grown in specialized containers on the ISS, then returned to Earth for detailed analysis. Scientists examined the cells' physical characteristics, genetic expression, ability to multiply, and capacity to develop into specialized cell types. They compared these results with identical cells grown on Earth under normal gravity conditions.

### **Key Results**

The review revealed several significant findings across different stem cell types. Mesenchymal stem cells maintained their characteristics and showed enhanced immunosuppressive capabilities. Cardiac-related stem cells demonstrated improved proliferation and development into heart muscle cells. Neural stem cells preserved their ability to multiply and develop into neurons.

Many cell types showed increased proliferation rates in space while maintaining their undifferentiated state. The three-dimensional growth environment in microgravity appeared to better mimic natural conditions in the human body compared to traditional two-dimensional cell cultures on Earth.

### **Study Limitations**

Several important limitations were noted. The studies had relatively small sample sizes and short durations. The effects of cosmic radiation on long-term cell growth and genetic stability remain uncertain. The high cost and limited access to space create challenges for replicating and expanding these studies.

There's also conflicting evidence about how some stem cells respond to microgravity, with some studies showing decreased proliferation or altered differentiation patterns. The research team noted that different types of stem cells may respond differently to the space environment, and optimal cell culture conditions still need to be established.

### **Discussion & Takeaways**

The research suggests that space-based stem cell cultivation could offer unique advantages for regenerative medicine. The microgravity environment appears to support more natural three-dimensional cell growth and may enhance certain beneficial characteristics of stem cells. This could potentially lead to more effective treatments for conditions ranging from heart disease to neurological disorders.

However, significant technological, logistical, and regulatory challenges must be overcome before space-grown stem cells can be used in clinical applications. The research team emphasizes the need for further studies to better understand the mechanisms behind microgravity's effects on stem cells and to establish standardized protocols for space-based cell cultivation.

### **Funding & Disclosures**

The review article was published in cooperation with the Biodesign Institute at Arizona State University, with support from NASA. The authors declared no competing interests. The research was conducted at Mayo Clinic's Center for Regenerative Biotherapeutics and Department of Laboratory Medicine and Pathology in Jacksonville, Florida.

## **First Two-Leaf Plant Grows on the Moon, Thanks to China**

**P**lanting a seed in the harsh environment of the Moon and seeing it sprout leaves is an incredible feat! That's exactly what a Chinese mission recently achieved, which marked the first time a plant has grown on the lunar surface.

Scientists planted a cotton seed and monitored it until it sprouted two leaves. It might not seem like much, but this is a massive milestone in space exploration and an exciting step toward possible future space colonies.

### **A Tiny Plant Sprouts on the Moon**

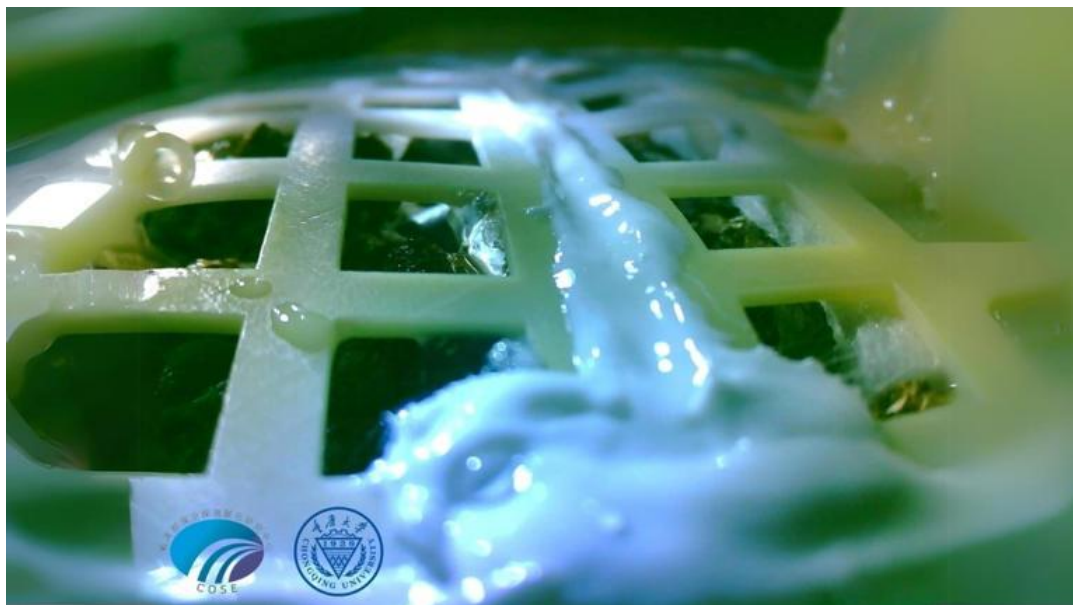


Image Credit: Chongqing University

In January 2019, China's Chang'e 4 probe (named after the Chinese moon goddess) made the first-ever landing on the Moon's far side at 10:26 am, as announced by China's state media. ([ref](#))

The probe touched down in the Von Kármán crater within the South Pole-Aitken Basin. This region, likely formed by a massive asteroid impact, may reveal clues about the Moon's inner composition.

Launched on December 8, 2018, the mission also carried a biosphere called the Lunar Micro Ecosystem (LME), containing six lifeforms: potato seeds, cotton seeds, rapeseeds, yeast, fruit fly eggs, and *Arabidopsis thaliana*, a small plant in the mustard family, mimicking Earth-like conditions. ([ref](#))

All the seeds China sent to the Moon died—except the cotton seed, which grew two small leaves before succumbing to the cold after about two weeks. This tiny green shoot sprouted inside a canister on the Chang'e-4 lunar lander, marking the first biological growth on the Moon's surface. ([ref](#))

The experiment, led by scientist Xie Gengxin, shows the potential to grow plants in space, a major step toward long-term space missions and future outposts on other planets.

## The Different Sides of the Moon



Image Credit: Chongqing University

China's Chang'e 4 mission, carrying instruments from China, Sweden, and Germany, is studying the Moon's environment, cosmic radiation, and solar wind effects. The mission's rover, Yutu 2 (Jade Rabbit), is conducting experiments in the Von Kármán crater.

China planned more lunar missions, with Chang'e 5 set to return lunar samples to Earth. This mission landed in Oceanus Procellarum, a dark region in the Moon's northwest. The site, near Mons Rümker, was believed to have young volcanic rocks.

Samples returned to Earth were about 2 billion years old, much younger than the 3.1 to 4.4 billion-year-old samples from NASA's Apollo missions. ([ref](#))

Successing missions also include Chang'e 6, which collected lunar samples from the far side and successfully returned 4.28 lbs of material to Earth in June 2024.

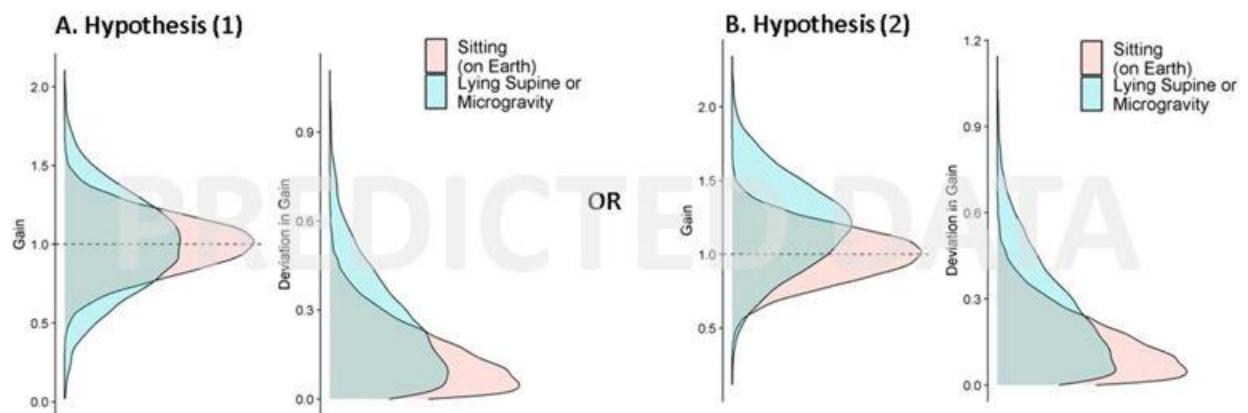
A study of the Chang'e 6 samples revealed that the far side material is looser and more porous than near-side samples, with more light-colored particles like feldspar and glass. These differences suggest the area was impacted by material from distant regions, such as asteroid impacts.

The far side samples also contain less KREEP (potassium, rare-earth elements, and phosphorus) compared to near-side samples. This difference could help explain why the far side of the Moon is so distinct from the near side.

The researchers concluded that “these insights are expected to lead to new concepts and theories regarding the origin and evolution of the Moon.” (ref) Wu Yanhua, deputy head of the China National Space Administration (CNSA), stated at a press conference that peaceful space exploration is a shared global goal.

China aims to collaborate with the international community to develop a sustainable and beneficial space industry, promoting progress for humanity and peaceful development. (ref)

## Astronauts have surprising ability to know how far they 'fly' in space



Predictions. Predicted distributions of the self-motion gains (as a measure of accuracy, see methods for definitions) and the self-motion deviations (as a measure of precision, higher deviations mean lower precision) for the two postures sitting upright (red) and supine (blue). Exposure to microgravity was hypothesized to show the same trends as when supine. Either the gain may become noisier (Hypothesis 1, see panel A) or both noisier and with a higher gain (Hypothesis 2, see panel B). Different panels depict the expected data when Hypotheses 1a and 1b are true (A) or when Hypotheses 2a and 2b are true (B). Credit: npj Microgravity (2024). DOI: 10.1038/s41526-024-00376-6© Provided by Phys.org

**N**ew research led by York University finds astronauts have a surprising ability to orient themselves and gauge distance traveled while free from the pull of gravity.

The findings of the study, done in collaboration with the Canadian Space Agency and NASA, have implications for crew safety in space and could potentially give

clues to how aging affects people's balance systems here on Earth, says the study's lead Faculty of Health Professor Laurence Harris.

"It has been repeatedly shown that the perception of gravity influences perceptual skill. The most profound way of looking at the influence of gravity is to take it away, which is why we took our research into space," says Harris, an expert on vision and the perception of motion who also heads up the Multisensory Integration Lab and is the former director of the Centre for Vision Research at York.

"We've had a steady presence for close to a quarter century in space, and with space efforts only increasing as we plan to go back to the moon and beyond, answering health-and-safety questions only becomes more important. Based on our findings it seems as though humans are surprisingly able to compensate adequately for the lack of an Earth-normal environment using vision."

Harris and collaborators—who include Lassonde School of Engineering professors Robert Allison and Michael Jenkin and two generations of York postdocs and graduate students Björn Jörges, Nils Bury, Meaghan McManus, and Ambika Bansal—studied a dozen astronauts aboard the International Space Station, which orbits about 400 kilometers from the Earth's surface.

Here, Earth's gravity is approximately canceled out by centrifugal force generated by the orbiting of the station. In the resulting microgravity, the way people move is more like flying, says Harris.

"People have previously anecdotally reported that they felt they were moving faster or further than they really were in space, so this provided some motivation actually to record this," he explains.

The researchers compared the performance of a dozen astronauts—six men and six women—before, during, and after their year-long missions to the space station and found that their sense of how far they traveled remained largely intact.

Space missions are busy endeavors and it took the researchers several days to connect with the astronauts once they arrived at the space station. Harris says that it's possible their research was unable to capture early adaptation that may

have occurred in those first few days, and "it's still a good news message because it says that whatever adaptation happens, happens very quickly."

Space missions are not without risk. As the ISS orbits the Earth, it is sometimes hit with small objects that could penetrate the vessel, requiring astronauts to move to safety.

"On a number of occasions during our experiment, the ISS had to perform evasive maneuvers," recalls Harris. "Astronauts need to be able to go to safe places or escape hatches on the ISS quickly and efficiently in an emergency. So, it was very reassuring to find that they were actually able to do this quite precisely."

The study, [published](#) recently in *npj Microgravity*, has been a decade in the making and represents the first of three papers that will emerge from the research investigating the effects of microgravity exposure on different perceptual skills including the estimation of body tilt, traveled distance, and object size.

Harris says research shows exposure to microgravity mimics the aging process on a largely physiological level—wasting of bones and muscles, changes in hormonal functioning, and increased susceptibility to infection—but this paper finds that self-motion is mainly unaffected, suggesting the balance issues that frequently come from old age may not be related to the vestibular system.

"It suggests that the mechanism for the perception of movement in older people should be relatively unaffected and that the issues involved in falling may not be so much in terms of the perception of how far they've moved, but perhaps more to do with how they're able to convert that into a balance reflex."

**More information:** Björn Jörges et al, The effects of long-term exposure to microgravity and body orientation relative to gravity on perceived traveled distance, *npj Microgravity* (2024). [DOI: 10.1038/s41526-024-00376-6](https://doi.org/10.1038/s41526-024-00376-6)

Provided by York University

# Stem Cells Grown in Space Turn Out to Have a Surprise Advantage

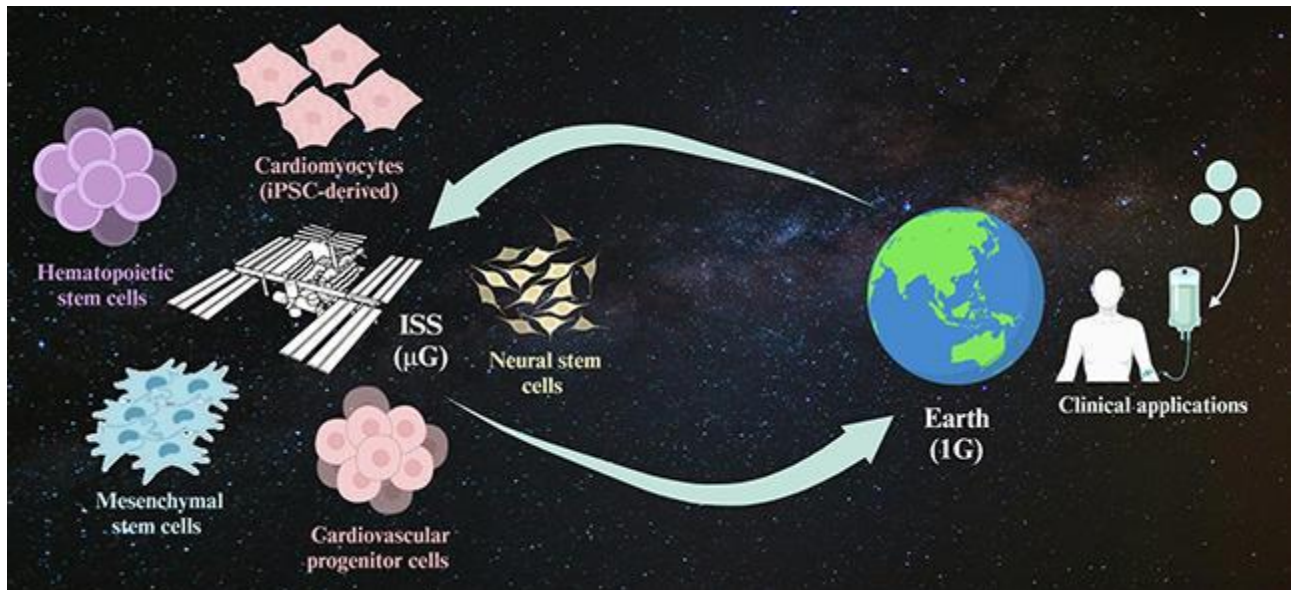


International Space Station

[Stem cells](#) are special in the way they can keep on replicating, and turn themselves into many other types of cell. Now scientists have discovered how their superpowers get a remarkable boost when they're grown in space.

The microgravity environment increases some of the regenerative capacities of [stem cells](#) even further, researchers from the Mayo Clinic in Florida have found, based on experiments carried out on the International Space Station (ISS).

As stem cells play such a crucial role in the body's repair process, with their ability to quickly replicate and differentiate, these findings could help in the study of [disease prevention and treatment](#).



Several experiments have been run on the ISS. ((Ghani & Zubair, NPJ Microgravity , 2024))

"Studying stem cells in space has uncovered cell mechanisms that would otherwise be undetected or unknown within the presence of normal gravity," [says](#) pathologist Abba Zubair, from the Mayo Clinic.

"That discovery indicates a broader scientific value to this research, including potential clinical applications."

On board the ISS, the team specifically looked at the behavior of adult stem cells, which are more limited in how they divide and transform compared to embryonic stem cells. Adult stem cells are often grown outside the body by scientists to study and [treat disease](#), but it's a challenging, time-consuming, and expensive process.

What this study shows is that space labs could solve some of these issues. A variety of [stem cell](#) types were tested, with positive results for all of them: [mesenchymal stem cells](#) (MSCs), for example, were shown to be better at managing immune system responses and reducing inflammation when grown in microgravity.



One of the experiments being undertaken. ( Mayo Clinic )

For several of the stem cell types tested, the scientists observed general improvements in the way the cells were expanding, and in the stability of their replication, even after their return to Earth. There's lots more work to do here, but the potential is there to grow stem cells in greater numbers and more quickly in microgravity.

"The space environment offers an advantage to the growth of stem cells by providing a more natural three-dimensional state for their expansion, which closely resembles growth of cells in the human body," [says](#) Zubair.

"That's in comparison to the two-dimensional culture environment available on Earth that is less likely to imitate human tissue."

Ordinarily, our adult stem cells are up to the job of managing normal wear and tear on the body. However, when something goes wrong an extra infusion of lab-grown cells can make all the difference – as numerous emerging therapies [have shown](#).

The team behind the research is also confident that space-grown cells will help in the treatment of conditions [related to growing older](#), including strokes, [cancer](#), and neurodegenerative diseases like dementia.

"The space research conducted so far is just a starting point," [says](#) Zubair. "A broader perspective about stem cell applications is possible as research continues to explore the use of space to advance regenerative medicine."

The research has been published in [NPJ Microgravity](#).

## **Space Force plans to award 20 contracts for commercial reserve by 2026**



Space Force plans to award 20 contracts for commercial reserve by 2026

The Space Force expects to award as many as 20 contracts over the next two years for private companies to join its Commercial Augmentation Space Reserve, which will create a mechanism for the military to better leverage commercial capabilities both in peacetime and during a conflict.

Air Force Secretary Frank Kendall, who provides civilian oversight for the Space Force, approved the Commercial Space Office's plan for the program, known as CASR, last year. Since then, the office has developed an implementation strategy, which includes writing contractual language for companies that will participate in the reserve.

Vice Chief of Space Operations Gen. Michael Guetlein said this week the service plans to award five contracts in 2025 and another 15 in 2026. Those arrangements will detail the level of commercial capability the service needs in peacetime and provide a mechanism and pricing structure that will allow the service to access more capacity during a conflict.

"We've got a few things to work through about governance and contracting strategies, but we hope to have our first five contracts in '25 and then another 15 contracts or so in '26," he said Wednesday at the National Security Innovation Forum in Washington.

The Space Force's acquisition arm, Space Systems Command, announced last year it was [planning to create a commercial space reserve](#). The team met with industry in February 2023 and formed a task force soon after to work through [legal, policy, contracting and programmatic concerns](#).

The resulting strategy factors in those concerns as well as feedback from dozens of companies to ensure both the government and industry understand the requirements and risks associated with leaning more heavily on commercial systems during a crisis.

The U.S. will need programs like CASR that provide options for excess capacity as it prepares for the possibility of a future conflict with China or Russia, Guetlein said. He argued that the military's posture in the past has been to strive for

efficiency and perfect solutions when buying new systems, but that approach may not work against a peer adversary.

"What we know about this next fight is it's not going to be efficient," he said. "And we're going to have to get comfortable with being inefficient. That means I need redundant capabilities, excess capacity, proliferation."

Developing an acquisition and contracting strategy for CASR has also required the Space Force to work through some of the trickier questions about how much it should rely on commercial capabilities during wartime. Those concerns were illuminated in September 2023 when [SpaceX founder Elon Musk revealed](#) he had opted not to activate his company's Starlink communication satellites in certain regions of Ukraine due to fears that Ukraine's use of the service to launch an attack on Russia would escalate the war. The company provided Starlink terminals to Ukraine in the early days of the conflict and, at the time, was not performing those services through a contract with the U.S. military.

The service is still working through language to include in CASR contracts that addresses these types of "denial of service" scenarios, a Space Force official told reporters this week. The service is also working with the Office of the Secretary of Defense to study options for potentially compensating CASR companies whose space systems are targeted by an adversary.

"As part of CASR and then also part of this study, we are looking into potential wartime insurance," the official said. "I do feel like that is going to be a policy decision."

Companies selected for the reserve will participate in Defense Department war games, with the first CASR event slated for February 2025. Those exercises will help the Space Force get a sense of how much capacity is needed in different regions where the military operates.

The service has initial funding from Congress for CASR but is still determining how much funding it will need for the program moving forward, according to Lt. Gen. Philip Garrant, head of Space Systems Command.

Speaking Wednesday at a Defense Writers Group event in Washington, Garrant said he is working with SSC program offices to ensure that CASR needs are factored into a program's acquisition strategy.

"We don't want these teams to have to be doing everything as an afterthought," he said. "We want it to be part of the original conversation."

## Scientists grow human brains in space to treat Alzheimer's

Scientists have grown tiny human brains in space to research new treatments for [Alzheimer's](#), Parkinson's and spinal injuries.

The low gravity environment on the [International Space Station](#) (ISS) enabled researchers to grow brain organoids in just 72 hours. This process can take months on Earth.

The organoids, which are artificially-grown masses of cells that mimic the structure and function of a human organ, allowed researchers to test a new method for curing [currently untreatable neurological diseases](#).

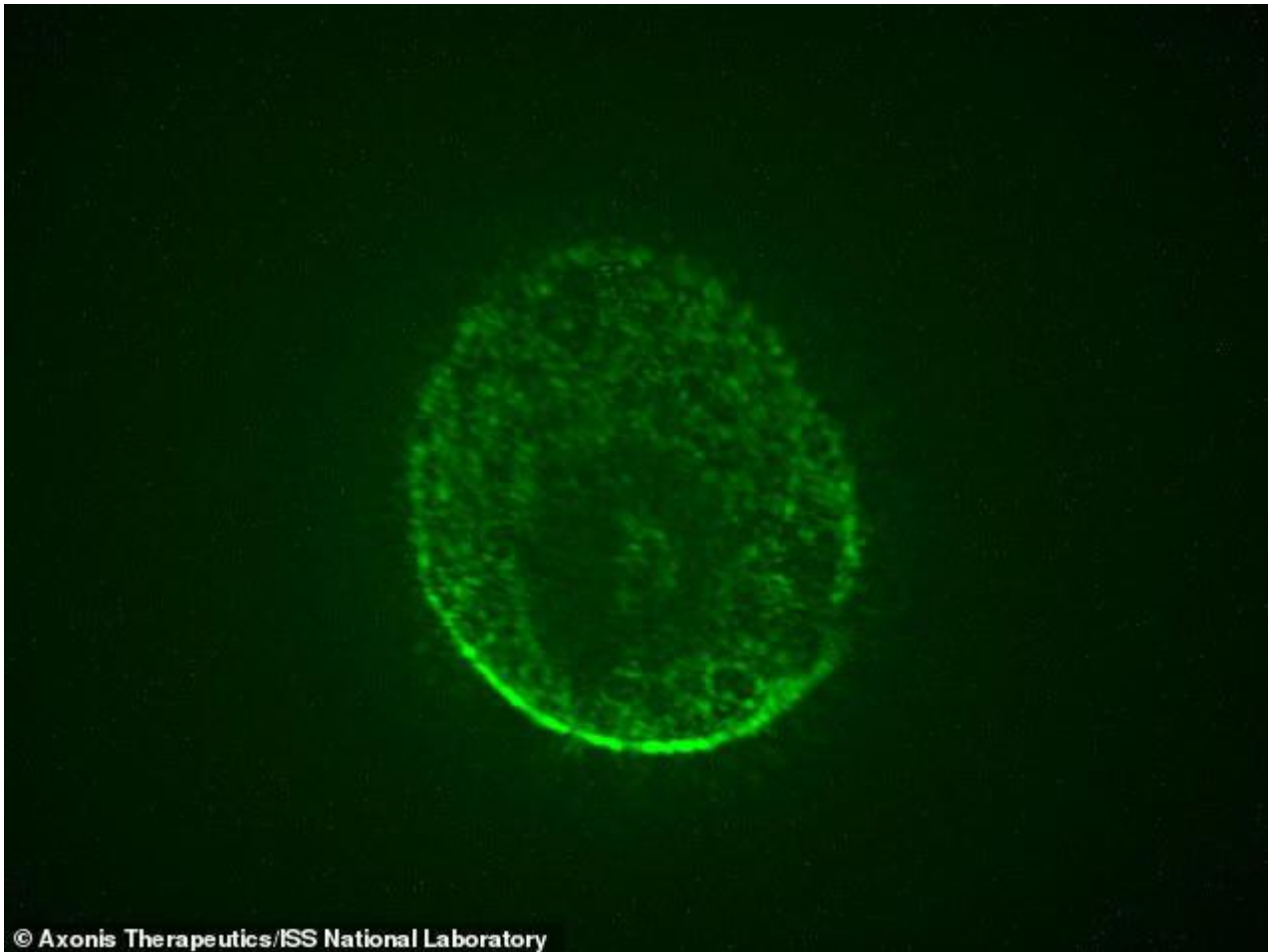
The promising new treatment, developed by biotechnology company Axonis Therapeutics, uses a reprogrammed virus to deliver beneficial gene therapy to central nervous system cells (CNS).

Such modified viruses are called viral vectors, and they could be particularly useful for treating Alzheimer's, Parkinson's and spinal cord injuries.

Nearly 600,000 Americans are diagnosed with either Alzheimer's or Parkinson's each year, and roughly 18,000 new spinal cord injuries occur in the US annually.

Testing revealed that the company's treatment worked in mice. But gene therapies that are effective in rodent models often fail in humans.

Axonis Therapeutics needed to perform tests using an accurate model of the human central nervous system, which is what prompted them to try and grow human brain organoids in space.



Scientists on the International Space Station (ISS) have grown brain-like organoids in space to research new treatments for Alzheimer's, Parkinson's and spinal injuries

Scientists can grow CNS cells on Earth, but gravity forces them to arrange themselves into two-dimensional single layers, which makes it difficult to culture the three-dimensional structure and complexity of brain cell functional groups.

These space-grown organoids quickly provided a highly accurate model of the human brain, allowing the ISS researchers to truly test the effectiveness of the new viral vector treatment.

'Doing research in space is not something you'd ever think about normally,' said Shane Hegarty, co-founder and chief scientific officer of Axonis Therapeutics.

'But the opportunity to leverage microgravity conditions can unlock a lot of untouched potential by pushing the boundaries of science in a unique environment,' he added in a [statement](#).

In August 2023, Axonis Therapeutics launched frozen vials of their viral vector, mature neurons and astrocytes - or cells that hold nerve cells in place and help them develop - toward the ISS aboard a cargo resupply mission.

A crew of researchers on the floating laboratory then injected these materials into a machine called BioCell, which is a specialized cell-culturing system.

They loaded the viral vector with a fluorescent protein gene. If it successfully infiltrated the neurons and implanted the gene inside them, they would glow neon green.

Within just 72 hours, the cells had not only organized themselves into three-dimensional human brain organoids, but were also glowing.



NASA astronaut Mike Barratt processes brain organoid samples aboard the ISS for a different research project conducted this year



ISS researchers used a specialized cell-culturing system called BioCell to grow the brain organelles and test the effectiveness of the viral vector

'The pivotal day was when the crew was doing the microscopy, and we saw big aggregates of green, glowing 3D tissue,' said researcher Sheila Nielsen of BioServe Space Technologies, the research organization that created BioCell.

'Shane and I were sending images of the organoids back and forth to each other, and we were pretty ecstatic because this is not something they had ever seen on the ground,' she added in the statement.

Viruses are very efficient at infecting cells and inserting genetic material into them.

This is how they sicken their hosts - the inserted genetic material damages cells and allows the virus to reproduce, eliciting an immune response.

But scientists can reprogram viruses to carry beneficial gene therapies to cells, providing a targeted treatment for disease or injury.

This study demonstrated that Axonis Therapeutics' viral vector would be able to deliver gene therapy to human neurons.

'It was very exciting - we were able to both validate the gene therapy targeting ability and show that we indeed rapidly formed 3D assembloid models of the human brain,' Hegarty said.

'The major breakthrough is that you can self-assemble mature neurons and astrocytes rapidly into a model of the brain in microgravity conditions, which you can't do on the ground.'

## Space-cultured stem cells show potential to cure cancer and heart disease

Space-cultured stem cells show potential for new therapies, from cancer to heart disease. Microgravity could revolutionize treatments.



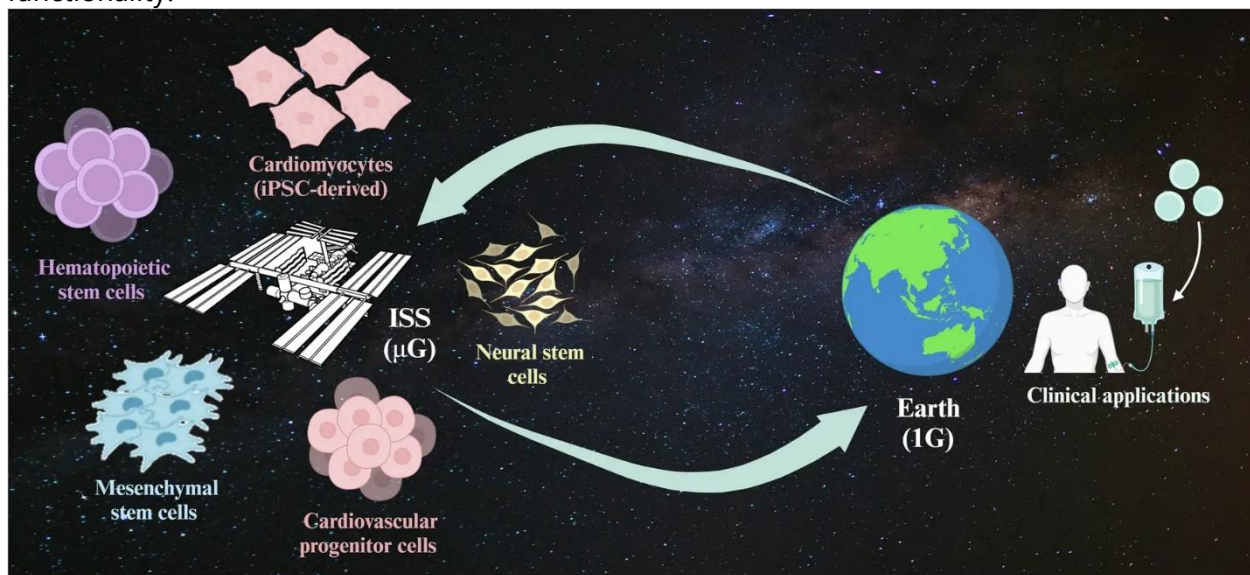
Microbiologist and astronaut Kate Rubins examines stem cell–derived heart muscle cells aboard the International Space Station. (CREDIT: NASA) Stem cells grown in microgravity aboard the International Space Station (ISS) are showing potential to transform treatments for complex diseases. This research, led by Fay Abdul Ghani and Dr. Abba Zubair from the [Mayo Clinic](#), explores how microgravity can enhance the regenerative abilities of stem cells.

Dr. Zubair, a regenerative medicine expert, notes that space offers a unique opportunity to observe cellular mechanisms that remain undetectable on Earth. This work, published in [NPJ Microgravity](#), aims to assess whether space is an ideal environment for producing high-quality clinical-grade stem cells, which are essential for developing cell-based therapies.

Conducting stem cell research in space reveals significant advantages. For instance, cells grow more naturally in a three-dimensional state under microgravity, closely resembling the way cells develop in the human body. This configuration differs from Earth-based,

two-dimensional cultures, which lack the depth needed to mimic human tissue effectively.

The findings from this research are exciting. Dr. Zubair explains, "Our hope is to study these space-grown cells to improve treatment for age-related conditions such as stroke, dementia, [neurodegenerative diseases](#), and cancer." However, the question remains: can these space-expanded cells survive and maintain their function upon return to Earth? Early results are promising, as space-grown stem cells display enhanced growth potential and retain their functionality.



Schematic diagram showing different types of stem cells grown in microgravity ( $\mu\text{G}$ ) on the International Space Station (ISS) and their return to Earth (1 G) for potential clinical applications. (CREDIT: NPJ Microgravity)

Space-cultured stem cells have shown specific advantages for disease modeling and testing new therapies. For instance, researchers can use space-grown cells to create lifelike models of diseases such as [cancer](#), providing opportunities to study disease progression and test novel treatments. Additionally, several specific stem cell lines have shown promising clinical potential:

- **Mesenchymal stem cells:** Known for their immunosuppressive properties, these cells show improved capabilities when grown in microgravity, which could benefit therapies for immune-related conditions.
- **Hematopoietic stem cells:** These blood-regenerating cells expanded in space have the potential to produce both [red and white blood cells](#), paving the way for managing blood cancers and other hematological disorders.
- **Cardiovascular progenitor cells:** Serving as the building blocks for heart muscle and blood vessels, these cells grown in microgravity might one day help repair tissue damaged by heart attacks.
- **Neural stem cells:** Crucial for brain development and repair, these cells also retain regenerative capabilities after being cultured in space, presenting a potential treatment path for neurological disorders.

Despite these benefits, challenges remain. Prolonged exposure to space radiation could damage cellular DNA, potentially impairing cell growth and function. Dr. Zubair's team has investigated the risk of cancerous transformation, finding no evidence that microgravity culture induces [chromosomal changes](#) in mesenchymal stem cells. However, scientists acknowledge the need for more data to fully understand the impact of space on stem cell properties.

Microgravity research is in its early stages, and the influence of space on cellular function is not yet fully understood. Researchers emphasize that continued support for these studies is essential for assessing the full potential of space-grown cells in regenerative medicine.

Since the inception of human spaceflight, scientific interest has focused on understanding how space affects the human body. This research initially sought to ensure astronauts' health but gradually expanded to explore the broader implications of microgravity on biological processes. [The ISS](#) now serves as a vital research platform for academic and commercial entities to conduct experiments that could benefit health on Earth. An emerging area of study involves induced pluripotent stem cells (iPSCs), which can develop into nearly any cell type in the body. Derived from a patient's own cells, iPSCs can be tailored for personalized treatments. However, producing the large quantities of cells required for therapies remains a challenge on Earth, partly due to gravity's effects. In microgravity, cells experience reduced stress and can replicate more efficiently, supporting efforts to produce high-quality stem cells for future treatments.



The ISS now serves as a vital research platform for academic and commercial entities to conduct experiments that could benefit health on Earth. (CREDIT: NASA)

Stem cell research in space holds promise for producing cells with therapeutic benefits for several critical health issues. For example, growing hematopoietic stem cells aboard the ISS has shown they can differentiate into [blood cells](#), offering a new potential treatment for patients with blood disorders.

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Cardiomyocytes derived from iPSCs have shown promise as well, especially in providing a cell-based therapy to replace damaged heart tissue. Experiments have revealed that these cells adapt to spaceflight by changing their gene expression, increasing their viability for therapeutic applications.

Neural stem cells, too, have shown potential for space-cultured cell therapies. Neural cells that expand in a weightless environment can maintain their regenerative potential when brought back to Earth. These cells could provide a foundation for treating neurodegenerative diseases, such as [Alzheimer's and Parkinson's](#), through cell replacement therapies.

In addition to these cell-based therapies, space-cultured stem cells are helping scientists better understand complex diseases. Researchers can use these cells to model disease mechanisms, creating accurate simulations that help track disease progression and test potential treatments. Stem cell research in space expands the scope of biomedical research, encouraging more precise investigations into disease behavior.



NASA astronaut Christina Koch works on the University of Washington kidney tissue chip investigation inside the Life Sciences Glovebox onboard the ISS. (CREDIT: ISS National Lab) Stem cells cultured in space could support not only health on Earth but also long-duration space missions. Understanding how these cells behave under microgravity aids in developing treatments for health issues that may arise during space travel. Stem cell therapies could help astronauts manage tissue damage or illness during extended missions, such as those [planned for Mars](#).

This work is drawing attention from commercial groups interested in biomanufacturing in low Earth orbit (LEO). As space access costs decrease, private companies may soon develop commercial applications for space-grown stem cells, expanding both scientific knowledge and commercial opportunities.

Microgravity could become an environment where cells and other biological products are produced for research and clinical use, encouraging advances in [regenerative medicine](#) and possibly benefiting the broader scientific community.

Growing cells in space pushes the boundaries of medical science, providing a unique platform for discoveries that could impact health care both on Earth and beyond. While significant challenges remain, the potential for space-cultured stem cells to improve regenerative treatments is clear.

This work reflects a collaborative effort, requiring input from scientists, governments, and private sectors to maximize the therapeutic benefits of this promising field.

# NASA Plans Spacecraft Assembly in Orbit Using Autonomous Robots

[NASA is developing a groundbreaking spacecraft concept designed to revolutionize Mars travel.](#) The ambitious plan involves assembling a football-field-sized spacecraft in orbit using advanced robotics. This innovation aims to overcome the challenges of transporting massive structures into space.

## Revolutionizing Space Travel with Nuclear Propulsion



NASA Plans Spacecraft Assembly in Orbit Using Autonomous Robots

NASA's new spacecraft concept incorporates a nuclear-electric propulsion system to accelerate journeys to Mars. At the core of this innovation is a nuclear reactor that generates electricity, powering an ion propulsion system. This method ionizes gaseous propellants to produce thrust, a more efficient alternative to chemical propulsion. Scientists at NASA's Langley Research Center in Virginia are spearheading efforts to make this technology viable for long-term missions.

## **A Cooling System the Size of a Football Field**

A critical component of this spacecraft is its extensive cooling system, designed to regulate the intense heat generated by the nuclear reactor. The system uses liquid metal coolant, such as a sodium-potassium alloy, circulated through massive radiator panels. These radiators, collectively spanning the size of a football field, present a logistical challenge. Transporting a structure of this magnitude in a single rocket is impractical, necessitating an innovative assembly approach.

## **Autonomous Robots to Assemble Components in Space**

To address the logistical challenges, NASA plans to divide the cooling system into smaller components, which will be autonomously assembled in space by robots. Amanda Stark, a lead engineer on the project, explains, "This approach eliminates the need to fit the entire system into a single rocket payload." Using robotic assembly, components can be delivered incrementally, significantly enhancing the feasibility of constructing large spacecraft in orbit. This modular approach is facilitated by the MARVL technology, enabling new spacecraft design possibilities.

## **The Future of Ion Propulsion and Mars Exploration**

Ion propulsion systems, which utilize electricity to accelerate ions and generate thrust, have already been used in various space missions. Traditionally powered by solar panels, these systems could also employ radionuclide batteries for deep-space exploration where sunlight is limited. NASA's prototype, expected to be tested on Earth within two years, could pave the way for round-trip Mars missions in the same timeframe. This technology promises faster travel and opens the door to more ambitious exploration goals.

NASA's orbital assembly strategy represents a paradigm shift in spacecraft design and construction. By leveraging robotics and modular assembly, space missions could become more efficient and scalable.

**How might these advancements redefine humanity's approach to interplanetary exploration? Share your thoughts in the comments.**

Based on content from [www.futurezone.at](http://www.futurezone.at) and own research.

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# Chinese astronauts make rocket fuel and oxygen in space using 1st-of-its kind 'artificial photosynthesis'

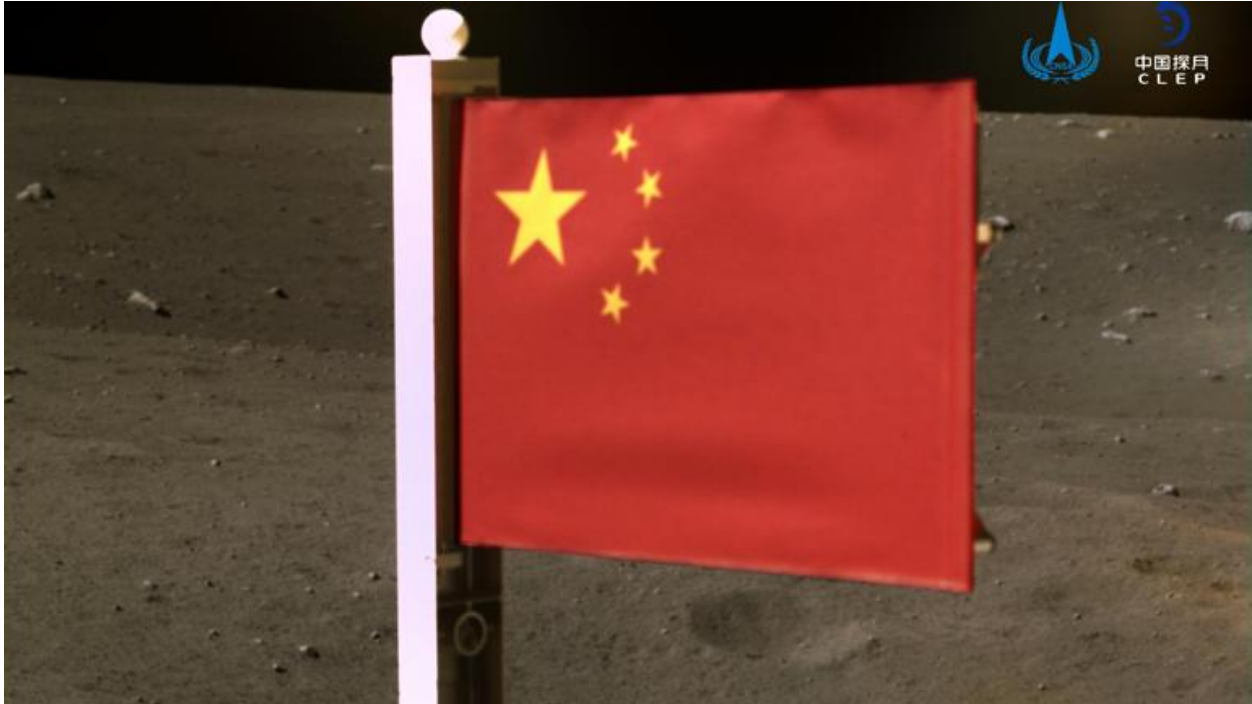
Chinese astronauts have just created rocket fuel and oxygen in space using a new type of "artificial photosynthesis." The breakthrough technology, which used fairly basic equipment and minimal energy, could one day be put to use on China's proposed moon base, which is scheduled to be completed within a decade.

The new experiments were carried out by members of the Shenzhou-19 crew living on board China's [Tiangong space station](#) (meaning "heavenly palace" in Chinese), which has been fully operational in low-Earth orbit since November 2022.

The artificial photosynthesis technology, which has been in development since 2015, converts [carbon dioxide](#) and [water](#) into oxygen and rocket fuel ingredients using a simple "drawer-like" apparatus and a "semiconductor catalyst," according to [Interesting Engineering](#). This is a similar reaction to [photosynthesis](#) in plants, which produces glucose instead of rocket fuel.

In this case, the astronauts created the hydrocarbon ethylene, which can be used as rocket fuel. But by using different catalysts in the reaction, the researchers believe they could instead produce methane, which could also be used for fuel; and formic acid, which can be used as a preservative, antibacterial agent or precursor to making sugars, Interesting Engineering reported.

"This technology mimics the natural photosynthesis process of green plants through engineered physical and chemical methods, utilizing carbon dioxide resources in confined spaces or extraterrestrial atmospheres to produce oxygen and carbon-based fuels," Chinese state television channel CCTV [reported Jan. 19](#). "The work is expected to provide critical technical support for human survival and exploration in outer space."



China aims to send humans to the moon by 2030 and build a lunar base by 2035. (The Chang'e 5 moon lander planted this Chinese flag on the moon's surface in 2020.) (Image credit: CNSA/CLEP)

The researchers have not revealed details about the technology. However, it supposedly requires much less energy than the electrolysis technology used to create oxygen from water on the International Space Station (ISS), the [South China Morning Post reported](#). Electrolysis uses up to a third of the ISS's power output, according to a [2023 study](#).

The new tests are the latest of several experiments carried out on board Tiangong. Previous experiments include [growing lettuce and tomatoes](#) and [lighting a match in space for the first time](#).

## China's moon base

The new technology could potentially be used by astronauts in China's proposed lunar base, which is due to be [built near the moon's south pole by 2035](#). It would enable the lunar colonizers to create breathable air and rocket fuel for return flights to Earth, potentially using [water that is already on the moon](#). This would save having to take these resources with them to the moon and could also make traveling to Mars and other worlds easier.

In March 2024, the China National Space Administration also announced that the agency would [use robots to build a mini nuclear reactor to power the base](#). This plan was put forward alongside Russia, which hopes to share part of the base with China and [help with its construction](#).

To build the base, China is planning to put astronauts on the lunar surface by 2030. This is after NASA's crewed Artemis missions are scheduled to return humans to the moon in 2026. However, the Artemis missions [keep getting delayed](#).

China has also developed a new type of giant reusable rocket to transport the necessary materials for the base, which is scheduled to [launch for the first time later this year](#).

FEBRUARY 27, 2025

# Metal made in space lands on Earth

by [European Space Agency](#)



Credit: ESA-R. Moorkens O'Reilly

The first metal 3D part ever created in orbit has landed on Earth.

The sample was produced in ESA's Metal 3D Printer on the International Space Station. Now, it's on Earth for the first time, at ESA's technical heart in the Netherlands (ESTEC).

The [printer](#), developed by Airbus and its partners, was installed in the Columbus module by ESA astronaut Andreas Mogensen during his Huginn mission in January 2024. In June, the facility succeeded in making its first print, a curvy line in the shape of an "S." In the summer, the printer produced its first full sample, and then a second sample in December.

This first sample will now be tested in the Materials and Electrical Components Laboratory at ESTEC and compared to samples printed on Earth to understand how microgravity affects the [printing process](#).

The second sample will be handed over to the Technical University of Denmark (DTU).

While astronauts have operated plastic 3D printers on the International Space Station before, this marks the first successful metal printing in orbit. As missions venture farther from Earth, in-space manufacturing will be crucial for self-sufficiency, allowing [astronauts](#) to

manufacture essential parts, repair equipment and create tools on demand, without relying on costly resupply missions.

Provided by [European Space Agency](#)

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