Space Medicine and Human Longevity in Space

Q3 2021

Aging Analytics Agency

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Space Medicine and Human Longevity in Space Q3 2021 summarises key observations in the SpaceTech ecosystem, a rapidly evolving and exponentially growing industry. In it, we have assembled information about **key industry trends** and created a comprehensive database of more than **70 Space Medicine**-related private companies, **70 leading investors**, and **60 R&D Centers**.

This overview was compiled to give a detailed description of the **innovative approaches to control Human Longevity in Space and treat some systemic disorders,** highlighting their practitioner application for astronauts' recovery after extended periods of weightlessness. **The Age-related Targets and Biomarkers** in astronauts are selected by their **clinical efficacy** and create the most relevant modern precedent for safe and effective human experimentation and validation within the realm of SpaceTech and Space Medicine that the Longevity Industry can currently apply.

Against this background, a separate chapter provides an overview of several interesting scientific and technological **convergences between ageing and the harmful effects of spaceflight,** as well as showing how the **specific therapeutic approaches that are used to protect and preserve the health of astronauts** intersect with Practical Healthy Human Longevity. Modern unconventional approaches are further along in development and in many cases already available, in use, and ready for further research

To sum up, this analytical case study offers a one-stop expert evaluation of a novel and dynamic industry with high growth potential.

Approach of the Report

Database

Identification of relevant:

- Companies
- Investors
- Universities & Research Centres

Applied Research & Analytics Methods

- Descriptive Analysis
- Mixed Data Research
- Exploratory Data Analysis
- Comparative Analysis
- Qualitative Data Collection
- Data Filtering

Data Sources*

- Media Overview (Articles, Press Releases)
- Industry-Specialised Databases
- Publicly Available Sources (Websites)
- Industry Reports and Reviews
- Industry Leaders Interviews

Relying on various research methods and analytics techniques, this report provides a comprehensive overview of the longevity and space-health industries. This approach has certain limitations, especially when it comes to the leveraging of publicly available data sources and secondary research. Analytical agencies participating in this report are not responsible for the quality of the secondary data presented herein; however, we do our best to eliminate said risks by using different analytics techniques and cross-checking data. Please note that we did not deliberately exclude certain companies from our analysis. In fact, the main reason for their non-inclusion was incomplete or missing information in the available sources regarding the space medical research activity. The companies included in the database are those that are completely involved in the industry of space medicine and human longevity in space; partially belong to it through working with gravitational biology research and science on the ISS; or have been mentioned in appropriate space medical publications as collaborators.

Executive Summary

With the growing financial capabilities of the space industry, commercialization of space tourism is inevitable. But first, to prepare for long-term space flights, we have to get a better understanding of how the human body changes in weightlessness. In fact, **Space Medicine is a required core competence for space exploration, development, and settlement.**

The primary space-related medical issues include: **loss of bone and muscle mass, immune dysfunction, and heart and liver problems.** Numerous studies have shown that adaptation to the space environment differs between men and women. The difference lies in almost all organism systems: cardiovascular, immunological, sensorimotor, musculoskeletal, and behavioral alterations. Significant changes in **gene expression** responsible for tissue remodeling has been identified. Most of these genes are **pro-oncogenes** as well as genes that are involved in **bone metabolism** and the early stages of **muscle regeneration**.

Among traditional approaches in medical research in space and risk mitigation in astronauts, new ones are advancing in development: **organ engineering, 3D printing, artificial medical devices, etc.**

Bioregenerative Life Support Systems (BLSS) are considered the most advanced systems to provide space crew with oxygen, water, food, and air quality in a spacecraft.

Main Features of the Analytical Case Study

- Database of Key Market Players
- Overview of Men vs Women Adaptation to Spaceflight
- Comparison of Long-term vs Short-term Adaptation to Space
- In-Depth Assessment of Mitochondrial Biomarkers in Space
- Genomic Biomarkers are Warning Signs for Health in Space
- Key Physiological Changes of Women's Bodies in Space
- Biomanufacturing in Space - Main Research in the Market

Space Medicine Framework

1. HEALTH RISKS OF SPACEFLIGHT

Conducting genetic, biochemical, physiological psychological, and physical tests to select the fittest individuals capable of surviving extreme space flight conditions.

- RISK FACTORS
- ASTRONAUT'S HEALTH
- WOMEN IN SPACE

2. BIOMARKERS & TARGETS

Changes in expression level of protein and genes are noticeable after long-term influence of weightlessness in blood, urine and tissue samples.

- GENE EXPRESSION
- AGE-RELATED BIOMARKERS
- DRUG DISCOVERY

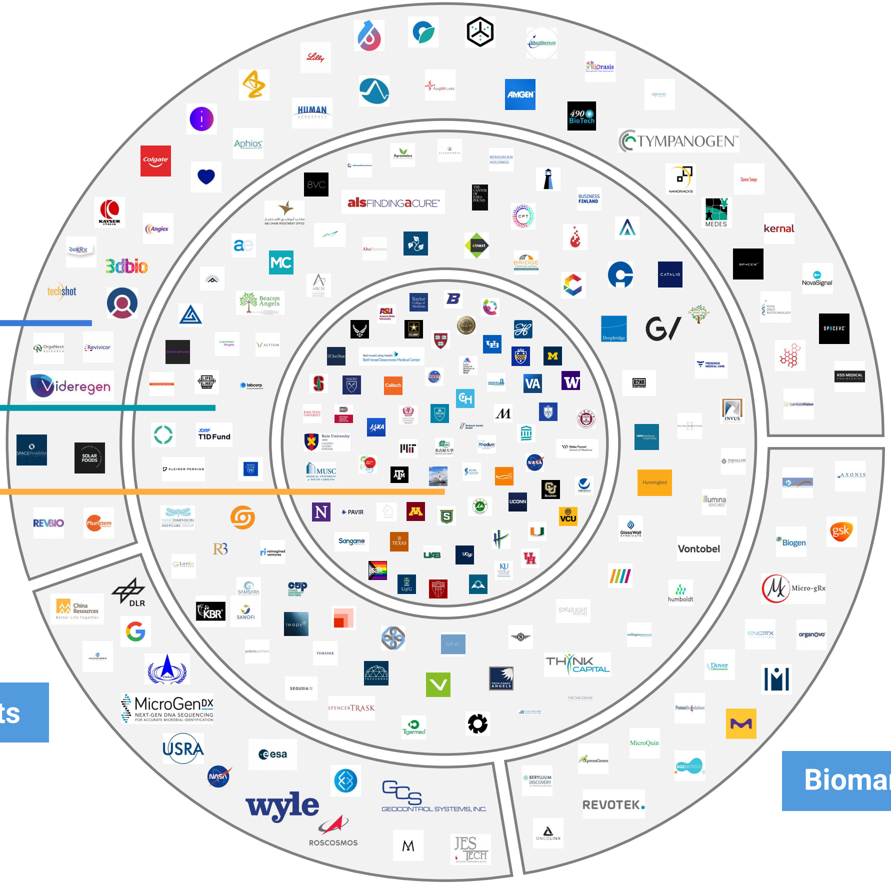
3. RISK MITIGATION

Biotechnologically enhancing radioresistance, tolerance to prolonged weightlessness and DNA-repairing mechanisms of the human body.

- PREVENTIVE MEDICINE & REHABILITATION
- ARTIFICIAL ORGANS & TISSUES
- RESEARCH & MEDICAL DEVICES

Space Medicine Landscape by Research Field Q3 2021

Companies – 70+
Investors – 70+
R&D Centers – 60+



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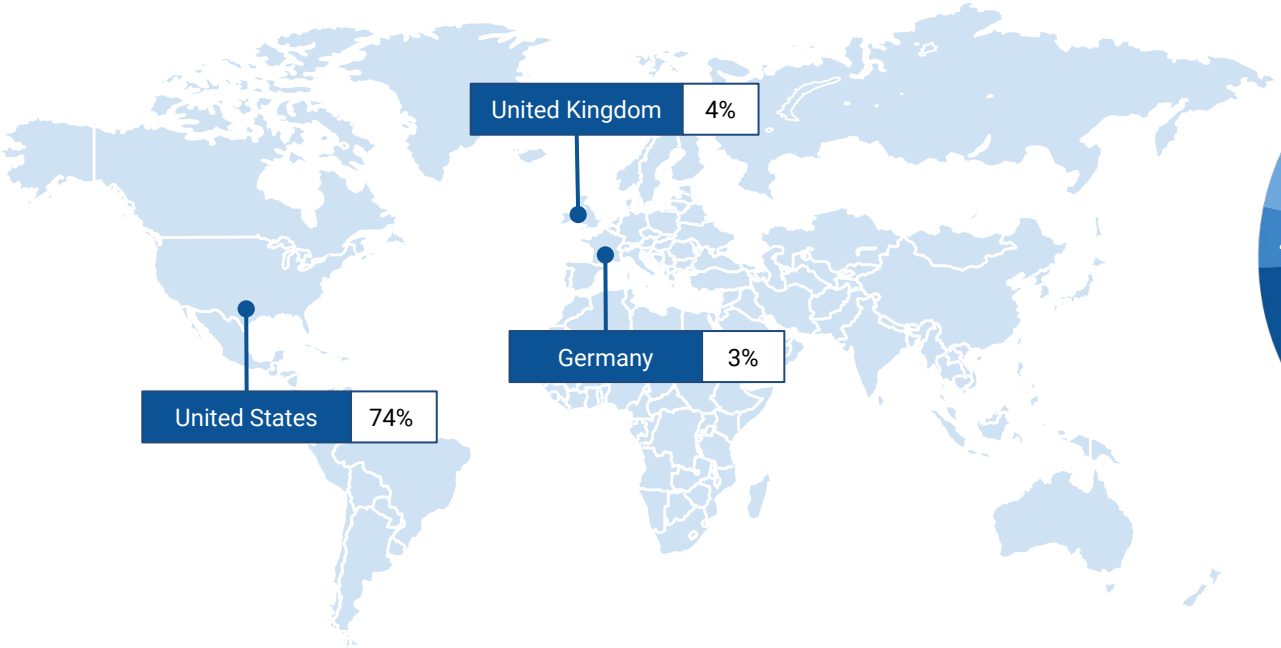
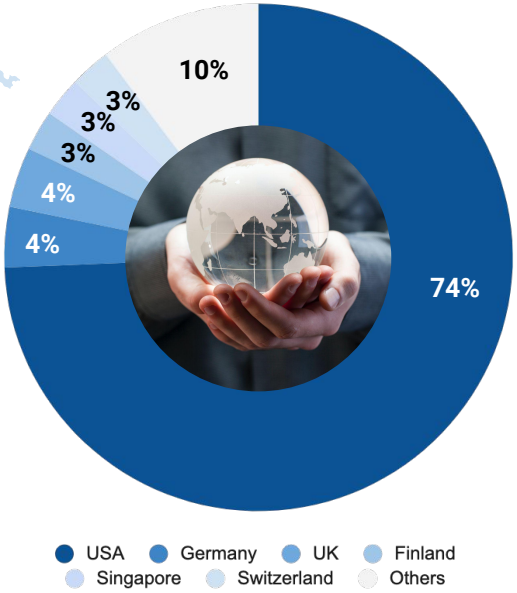
Investors in the Space Medicine Industry



Location of Investors



More than half (around **74%)** of investors in Space Medicine are in the **United States. An additional 14%** of investors are located in **Europe**, including 4% each in the UK and Germany, 3% each in Finland and Switzerland. Also 3% of investors are based in Singapore. Other investors are spread worldwide.

List of Therapeutic Clinical-Stage Companies that Target Mitochondria*

1	4SC AG
2	Abbott
3	Abbvie
4	Abliva AB
5	Amgene
6	Beijing Tide Pharmaceutical
7	BioAge
8	GenSight Biologics
9	Gilead
10	Ixchel Pharma
11	Khondrion
12	Longeveron
13	Minovia Therapeutics
14	Mitobridge
15	MitoQ
16	Mitotech
17	Navitor Pharmaceutical
18	Numeric Biotech
19	Poxel
20	Reata Pharmaceuticals
21	Reneo Pharmaceuticals
22	Stealth BioTherapeutics
23	Takeda
24	UNITY Biotechnology
25	Yiling Pharmaceutical Group

*in alphabetical order as for 2021

List of Therapeutic Clinical-Stage Companies that Target Inflammation*

1	AbbVie
2	Amgen
3	Bristol-Myers Squibb
4	CHRU de Tours
5	Daiichi Sankyo
6	Ethicare
7	Fournier Pharma
8	GlaxoSmithKline
9	Hanmi Pharmaceutical
10	Intas Pharmaceuticals
11	Jina Pharmaceuticals
12	Kos Pharmaceuticals
13	Millennium Pharmaceuticals
14	Novartis
15	Panacea Biotec
16	Pharmahungary Group
17	Proveca
18	Reliance Life Sciences
19	Renovo
20	Sanofi Aventis
21	Schering-Plough
22	Shiner Pharm
23	Strekin
24	Swedish Orphan Biovitrum
25	Veloxis Pharmaceuticals

*in alphabetical order as for 2021

Health Conditions Related to the Space Environment

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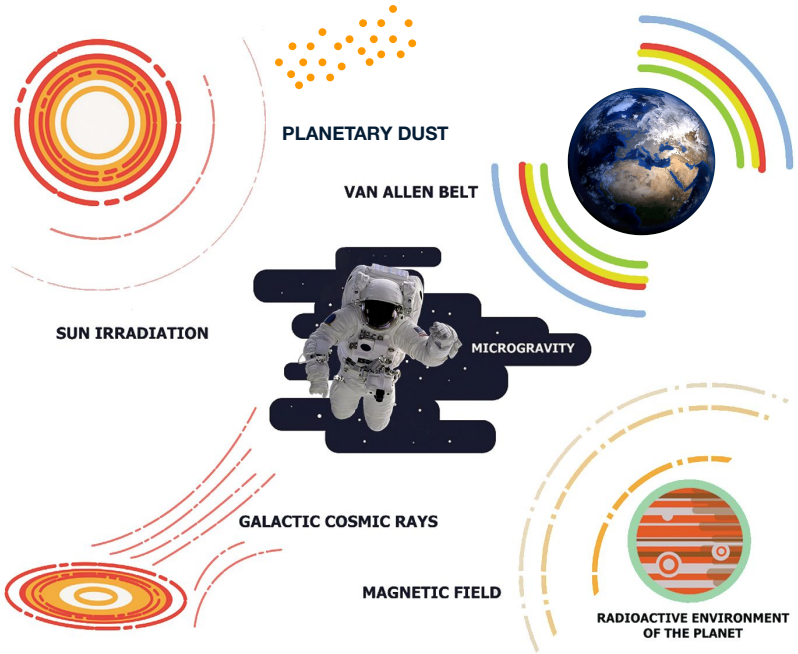
The Issue of Aging in Space



Spaceflight presents immensely difficult challenges. **Weightlessness, partial gravity, planetary dust, and space radiation** pose a significant threat to humans in both spaceflight and living in planetary habitats, which can result in the rapid development of life-threatening diseases in astronauts. In addition, the closed environments can create additional stress on a space crew's work performance and mental wellbeing.

The word "**weightlessness**" is used in this report to describe the condition that astronauts experience in different locations of altered gravity during the space flights. The term "microgravity" has it's limitations as it is basically means one millionth of the Earth gravity and it is incorrect to apply to the conditions that astronauts undergo during the space missions.

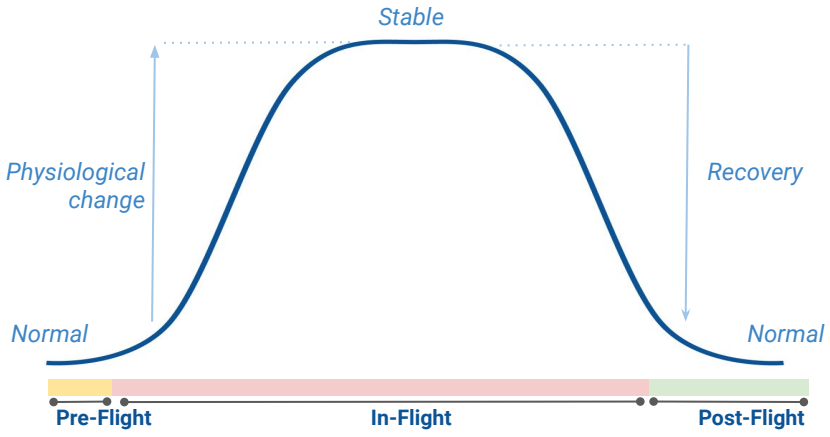
Advancements in Longevity are crucial for the future of space exploration. As more private companies continue to expand the space economy, the viability of space-Longevity research substantially increases. Space tourism is gaining popularity, and new heavy-lift low-cost launch vehicles are being developed at an unprecedented speed. However, life-support systems have not been advancing at a fast a pace. Humanity needs to develop new personalised medical approaches that can be applied in space to ensure the well-being of space travelers and settlers and become a multi-planetary civilisation.

Source: Encyclopedia Britannica

The Physiological Changes in Astronauts

Astronauts enter orbit in perfect health, but during spaceflight, their bodies undergo physiological changes. These changes stabilize during their stay in space, but a transformation occurs again when they return to Earth. The astronauts then need to undergo rehabilitation before recovering to their initial, stable condition. Space-medical researchers can observe and examine this entire process over short periods of time.

Changes of Biomarker Level during Spaceflight



Even with the rehabilitation process, some post-flight health conditions are still observed.

Sensorimotor deficits reported during and after spaceflight

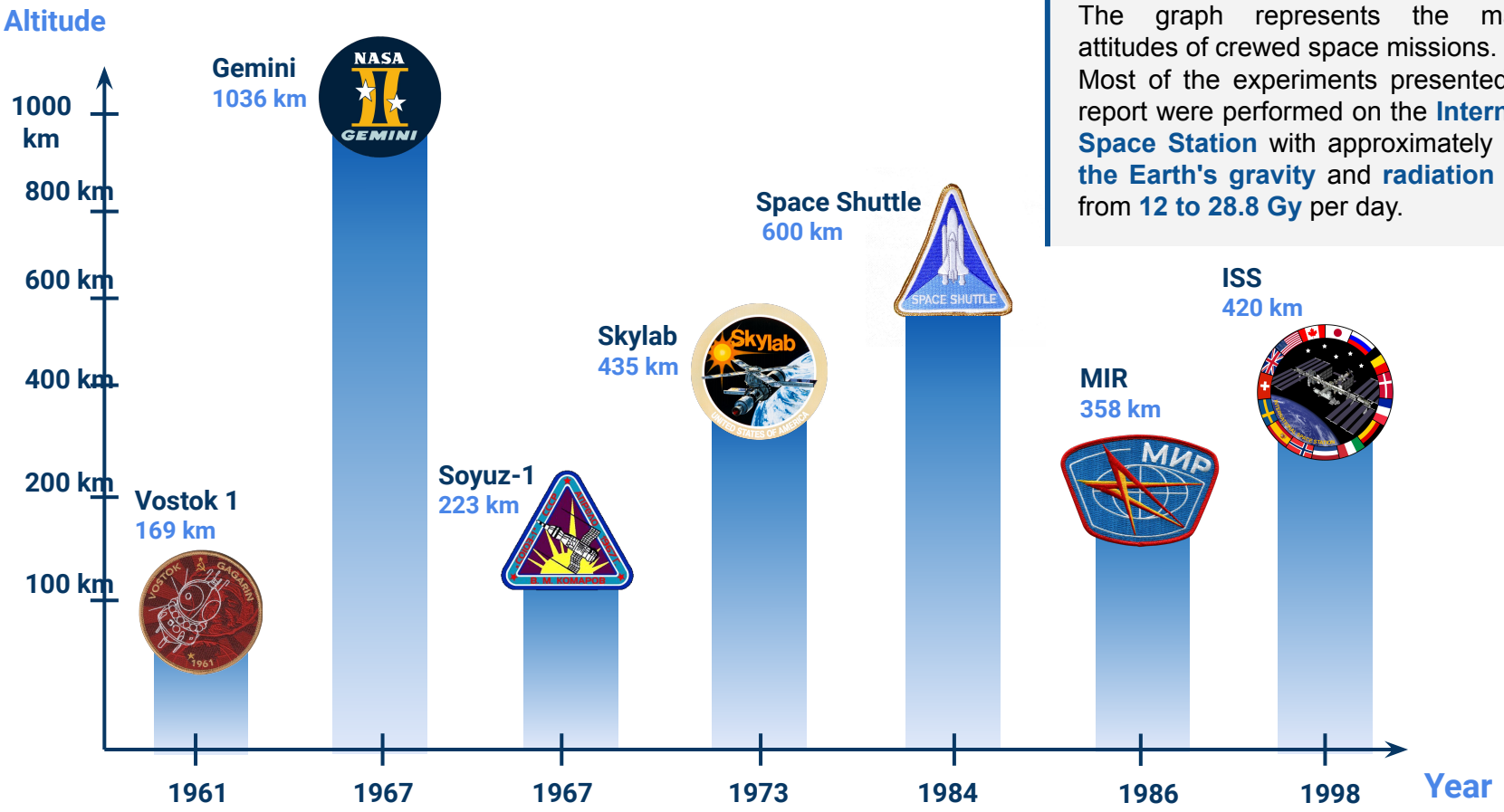
Loin and paraspinal muscle volume is 5% less after spaceflight

Astronauts' rate of lower limb bone loss is 0.8%.

Changes in microbiome taxa richness and antimicrobial resistance markers

Source: JAXA

Orbital Space Missions with Human Presence



The graph represents the maximum attitudes of crewed space missions.
Most of the experiments presented in this report were performed on the **International Space Station** with approximately **90% of the Earth's gravity** and **radiation** ranging from **12 to 28.8 Gy** per day.

Source: NASA

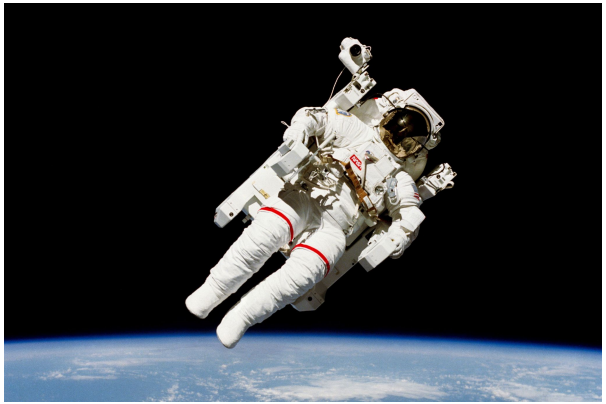
Tackling Weightlessness and Radiation Outcomes

Muscles and Bones

Researchers at the Jackson Laboratory for Genomic Medicine found that using pharmaceuticals to block certain signaling proteins in mice not only prevented the loss of bone and muscle mass that usually takes place in weightlessness but actually increased their density. This might become an effective solution to zero-gravity and weightlessness problems. Perhaps some in-utero treatment based on a cocktail of such proteins could help a space fetus grow bones and muscles in weightlessness, although much more research is needed before this could be determined.

The other more common alternative is to use bisphosphonate. It is a therapeutic agent that has been used to treat osteoporosis patients with a proven efficacy to increase bone mass and decrease the occurrence of bone fracture. Some research on Earth confirmed that this agent has a preventive effect on the loss of bone mass. Moreover, JAXA and NASA have collaborated to research this in more depth. Their crew members are participating in this study by taking this agent once a week while in space. The early results suggest that astronauts can significantly reduce the risk of bone loss and renal stones with the combination of resistive exercise and an antiresorptive such as a bisphosphonate.

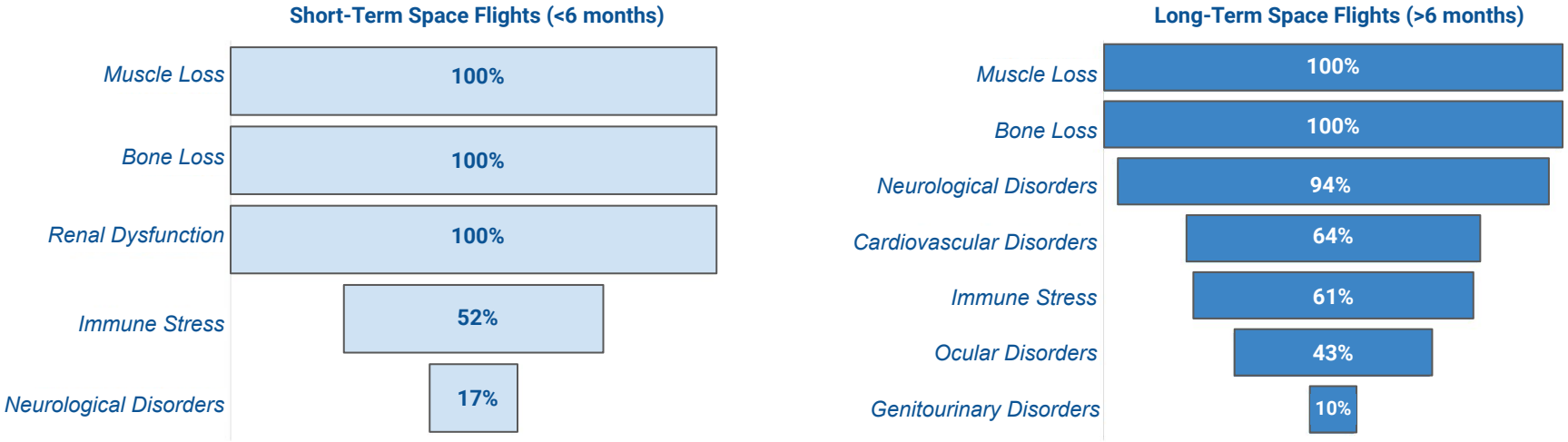
However, the common physical exercises that were discussed previously are still required for astronauts and settlers to be fit.



Source: NASA, The Jackson Lab

Health Risks for Astronauts: Long-Term vs Short-Term Spaceflight

Disorder Rates (% of cases) of Organ Systems among Astronauts

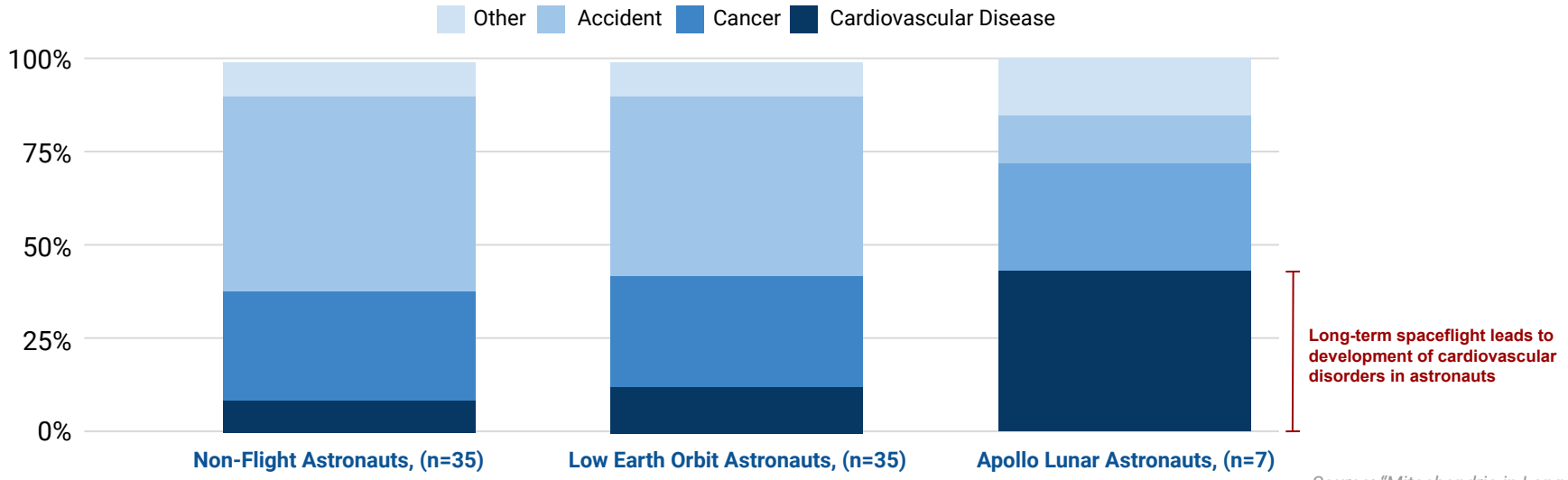


Astronauts are people with normal physiologies who live in an abnormal environment. Often in response to weightlessness, many complex physiologic changes can be identified. During spaceflight, blood and other fluids move from the lower limbs to the torso and head, so “puffy face, bird leg” syndrome will be observed. **Redistribution of body fluids is responsible for some of the early symptoms of space-motion sickness**. **Muscle and bone loss are constant.** An upward shift of the brain, increased intracranial pressure, narrowing of the central sulcus, and narrowing of CSF spaces at the vertex are present in both long-term and short-term spaceflight. Additionally, **cell-mediated immunity** and reactivation of latent herpes viruses are associated with spaceflight. **Genitourinary disorders and renal dysfunction are present with 10% in long-term spaceflight and 100% in short-term spaceflight,** respectively.

Source: NCBI

Causes of Mortality among Astronauts

Proportional Mortality Rates (%) among Astronauts

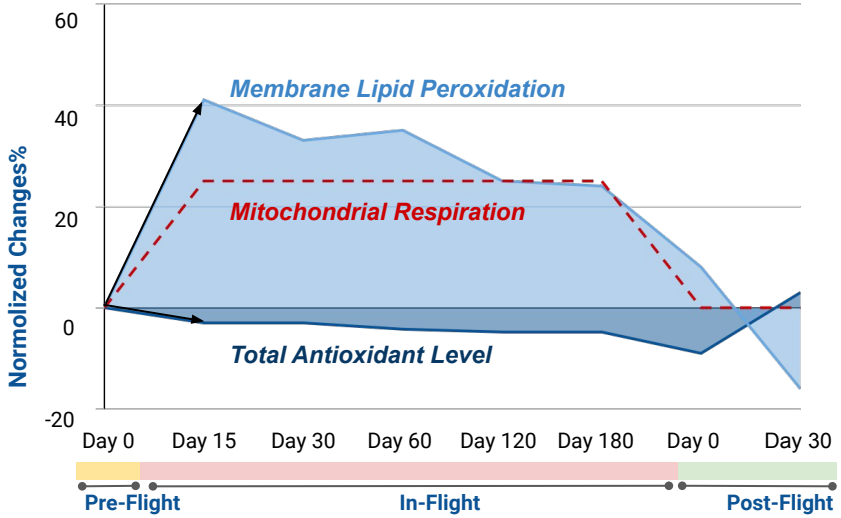


Source: "Mitochondria in Longevity and Space Medicine"report by AAA.

As multiple spacefaring nations contemplate extended crewed missions to Mars and the Moon, health risks could be elevated as travel goes beyond the Earth's protective magnetosphere and into the more intense deep-space radiation environment. There are **no differences in the CVD mortality rate between non-flight (9%) and LEO (11%) astronauts.** However, the CVD mortality rate among **Apollo lunar astronauts (43%) was 4–5 times higher than in non-flight and LEO astronauts**.

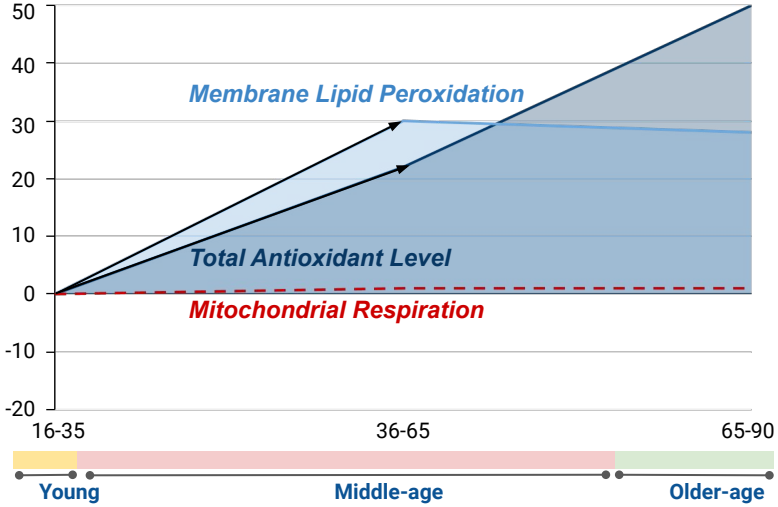
Mitochondrial Respiration and Redox Status in Astronauts vs. Aging

Astronauts: Alterations of Antioxidant Status



Source: da Silveira et al., 2020, Cell 183, 1185–1201

Healthy Aging: Alterations of Antioxidant Status



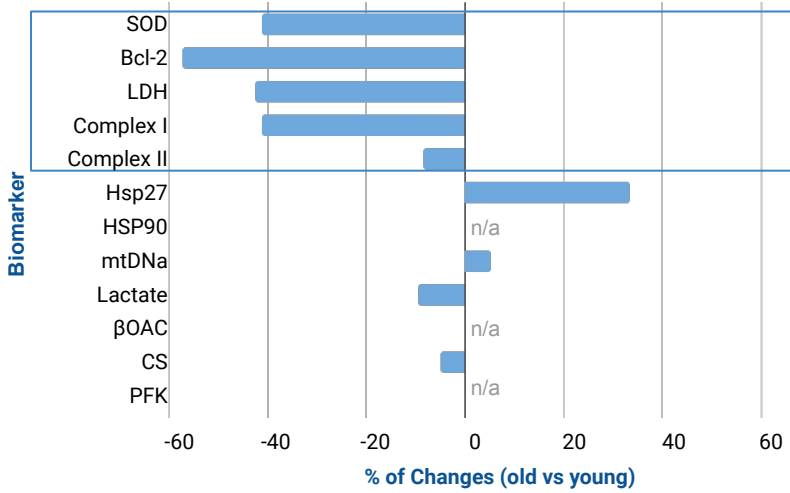
Source: M. Kasapoglu, T. Ozben, 2001, Experimental Gerontology 36, 209-220
E. Limberaki et al., 2012, Hippokratia, 16(2), 118-123
O. Miro et. al, 2000, Cardiovasc Res.. 18;47(3):624-31

Long spaceflight leads to **~25% activation of mitochondrial respiration** and **~30% growth of membrane lipid peroxidation** compared with peroxidation level before flight. The **antioxidant level in astronauts is 4-10% lower** in space flight than the antioxidant level before flight. Oxidative membrane damage was evaluated through the assessment of lipid peroxidation also is observed in oldery people vs young, but they have increased levels of antioxidants and there are no any changes in mitochondrial respiration.

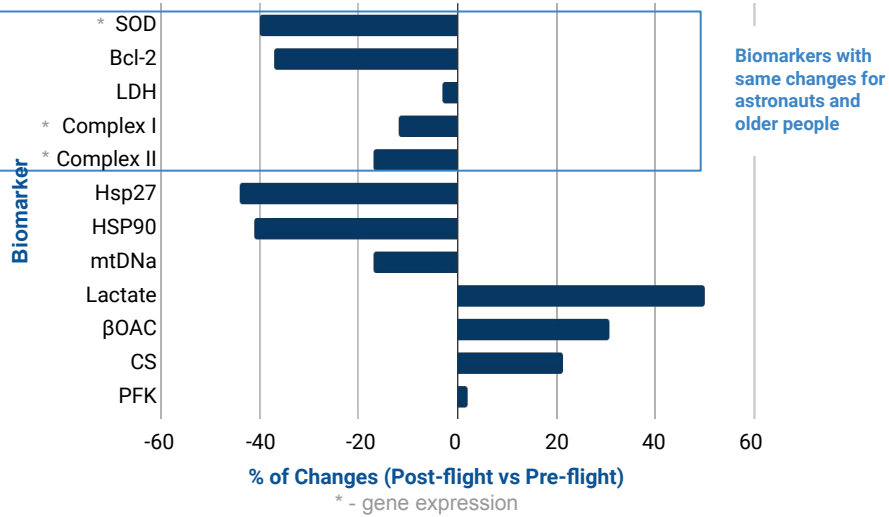
Source: Science Magazine

Mitochondrial Biomarkers Changes: Space Flights vs. Aging

Aging: Biomarker Level Changes in Older vs Young People, %



Astronauts: Biomarker Level Changes in Post-flight VS Pre-flight, %



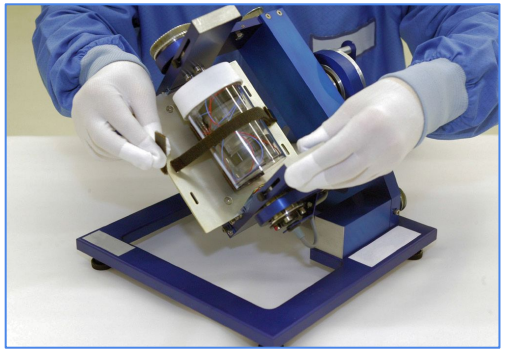
The NASA Twin Study provided excellent insight, looking at the same variables in an astronaut on a year-long mission with a control on the ground. A number of mitochondria-related changes at the genomic and functional levels related to the one-year mission have been identified.

Unfortunately, studies of space-related stress in the whole organism of astronauts are different than in isolated cells. **Only five mitochondrial biomarkers, as SOD, Bcl-2, LDH, Complex I and Complex II have the same changes** in astronauts after space flights (>6 months) and aging.

Source: Mitochondria in Longevity and Space Medicine

Simulated Reduced Gravity on Earth for *in vitro* Experiments

Is used to study the impact of **"simulated weightlessness"** on basic biological mechanisms.

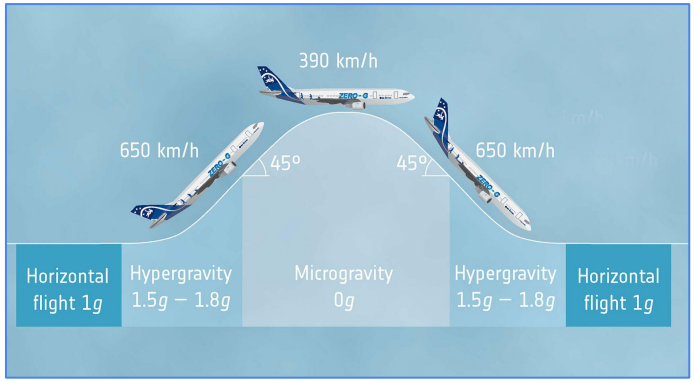


Clinostating (random positioning)

Provides **9.58 sec of weightlessness.**

Drop Tower

Offers **20 sec** of **weightlessness** - per parabola 31 parabolas **per flight = 10 min of weightlessness**



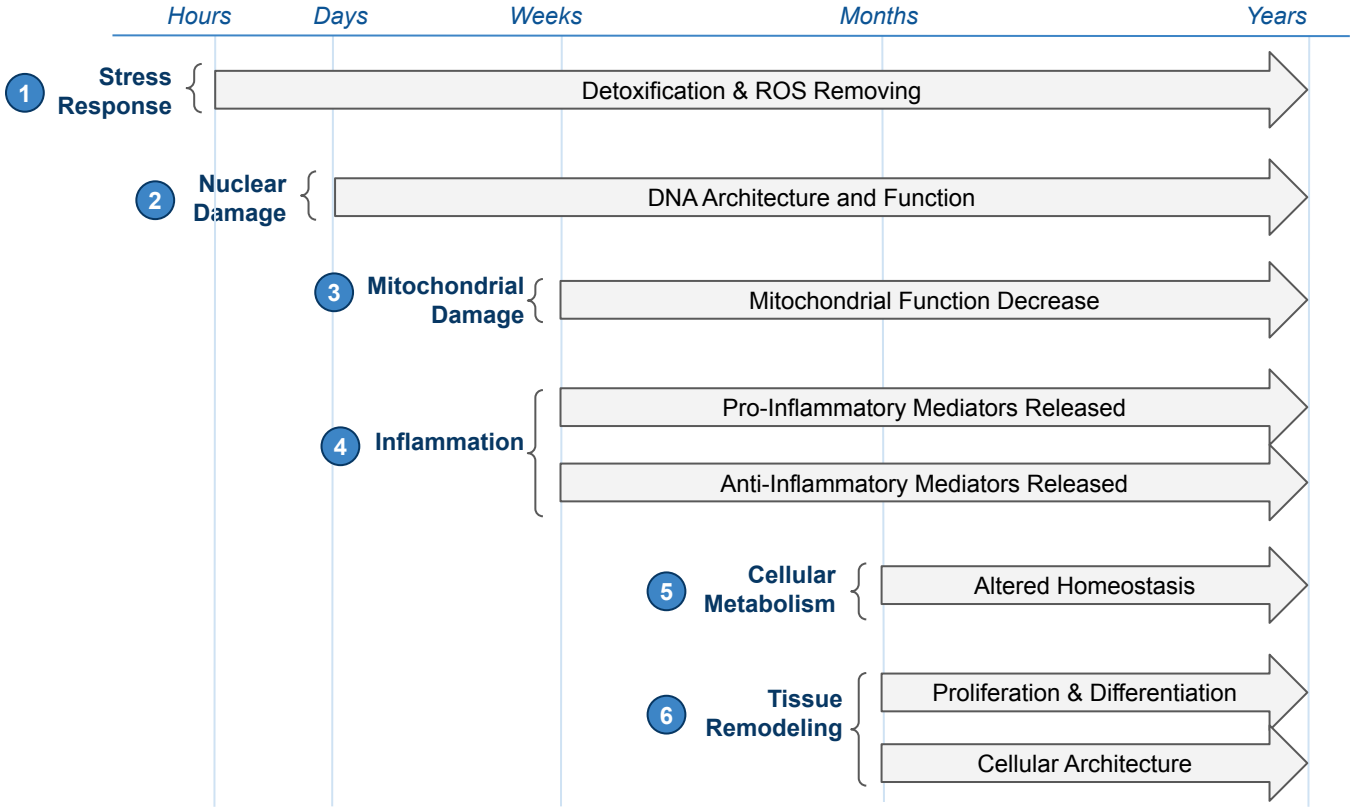
Parabolic flights

All of the following approaches allow the **validation of experiments before travelling to the International Space Station (ISS).** While clinostating is used for only mimicking the effects of weightlessness, drop-tower and parabolic flights create short-term weightlessness on Earth affordable for life sciences-experiments, especially *in vitro* cultures and research on mice. Suborbital flights will soon allow several minutes. Most experiments with humans are currently being done in parabolic flights and space medical research is carried out on the ISS specifically.

Source: ESA

Genomic Biomarkers are Warning Signs for Health in Space

Expression of Age-related Biomarkers during Spaceflight



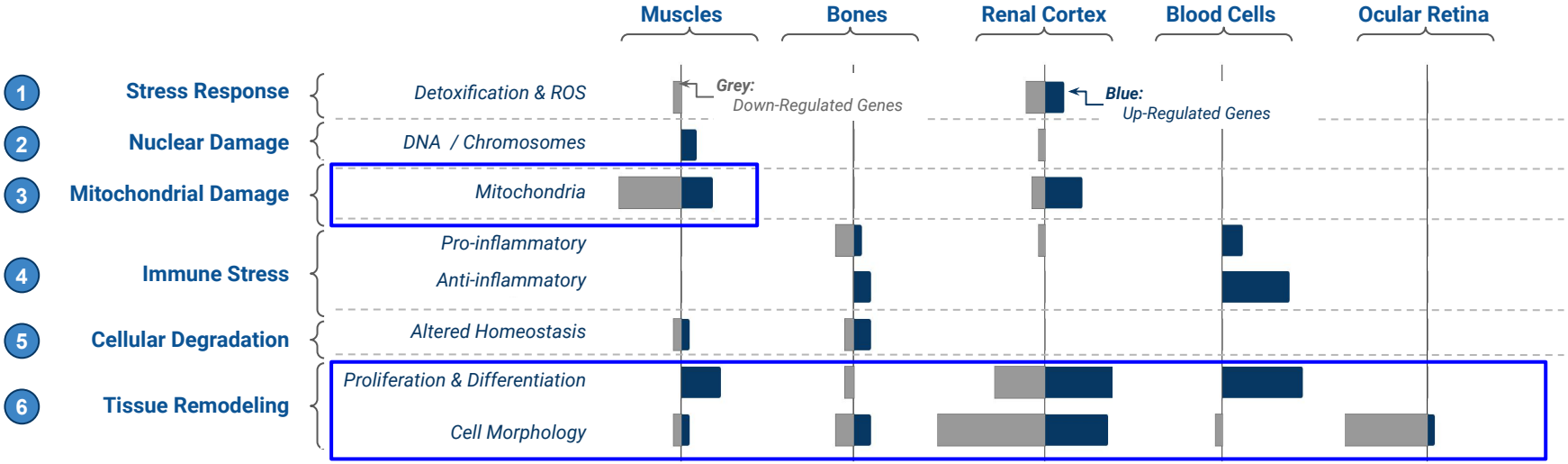
Source: Science Magazine

Several studies have been conducted for biomarker screening in astronauts during spaceflight. One is sponsored by the **JAXA-ISS Space Medicine Program**. The results of the combined data from Pre-flight, In-flight and Post-flight stages show significant changes in key gene expression that are related to mitochondrial function and aging. Space factors in flight result in the DNA and mitochondrial damage that is apparent post-flight, promoting cellular aging.

The data is partly taken from the "Mitochondria in Longevity and Space Medicine"report by AAA.

Single-Cell Gene Expression in Weightlessness (Human Cells)

Effect of Weightlessness on Gene Expression in Human Cells



Analysis of the results of different studies identified significant changes in gene expression responsible for **tissue remodeling** for all types of cells. Most of these genes are **pro-oncogenes: p53, c-Syn, Zip, WT33, Unph** etc. On the other hand, five markers: **IL-6, CRP, IL-10, CCL2/MCP 1, and IL-1Ra**, were elevated during space flight. These included tumor **TNF-α, IL-1α, and IL-1β**, which are normally associated with **immune dysregulation** but are also involved in **bone metabolism and the early stages of muscle regeneration**.

Annotation of genes upregulated in post-flight compared with the ground indicated that mitochondrial pathways were still enriched, demonstrating that a return to normal gravity does not completely restore normal mitochondrial gene expression. In muscles, the expression of genes from the mitochondrial electron chain were decreased more significantly than in other tissues: down-regulation of **complex I & II, LDH, SOD** led to altered mitochondrial respiration.

Source: PubMed

Key Players in Biomedical Research of Astronauts' Health in 2020-2021

The ISS is a unique laboratory for performing investigations that affect human health both in space and on Earth. Throughout the ISS operations, the space station has supported research that is providing a better understanding of certain aspects of human health, such as aging, trauma, disease and the environment.

Corporations

Google, KBR, GCS

Private Companies

wyle laboratories, MicroGen DX formerly Pathogenius Laboratory, JES TECH IGNITE OPPORTUNITY

Medical Centers

Translational Research Institute for Space Health, Aerospace Medical Association, Henry Ford Health System, CHRU Hôpitaux de Tours, Beth Israel Deaconess Medical Center

Governmental Services

Baylor College of Medicine, esa, JAXA, 名古屋大学 Nagoya University, University of the Health Sciences, University of Michigan, CNSA, Harvard Medical School, MUSC Health Medical University of South Carolina, UCSF University of California San Francisco, Denver CU in the City, SpaceX, NASA, ИМБП, DLR, ito Vasc, MIT Massachusetts Institute of Technology, University of Glasgow, USRA, РОСКОСМОС

Source: NASA

Women’s Bodies in Space

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Women's Health Indicators in Spaceflight are Different than Men's

G TOLERANCE

Several studies on female G tolerance compared to men are equivocal. It has been demonstrated that women have less tolerance to gravitational stress. It may be possible that hormones play a role in cardiac and vascular response under gravitational force conditions.

BONE & MUSCLE PHYSIOLOGY

It has been demonstrated that women have more slow-twitch muscle fibers, important for endurance, and men have more fast-twitch fibers, important for rapid bursts of energy.

CARDIAC PHYSIOLOGY

Terrestrially, women and men respond to cardiovascular stress with increased heart rates and increased peripheral vascular resistance. In space, it has been shown that women tend to have a reduced ability to maintain venous cardiac output, with an underlying mechanism potentially being hormonal.

CIRCADIAN DYSSYNCHRONY

The spaceflight environment may lead to poor sleep quality, thus resulting in increased chances of errors and mistakes, as well as decrements in performance and the inability to cope with adversity and other challenges. No evident difference between men and women in this regard.

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IMMUNOLOGY

Solar and cosmic radiation increases the risk of cancer among men and women because of the lack of protection from radiation, considering immune dysregulation in the context of the hostile environment of space.

NEUROVESTIBULAR ISSUES

Neurovestibular changes in spaceflight are the principle factors that affect posture control, locomotion, gaze stabilization, spatial orientation, and space motion sickness (SMS). Individual's capacity to function in the context of SMS symptoms is highly variable in men and women.

UROGYNECOLOGICAL & REPRODUCTIVE ISSUES

Long-duration missions pose a great risk for renal calculi. Concerning gynecological health, it was initially feared that female astronauts may be more predisposed to endometriosis due to the lack of gravity that can cause retrograde menstrual flow.

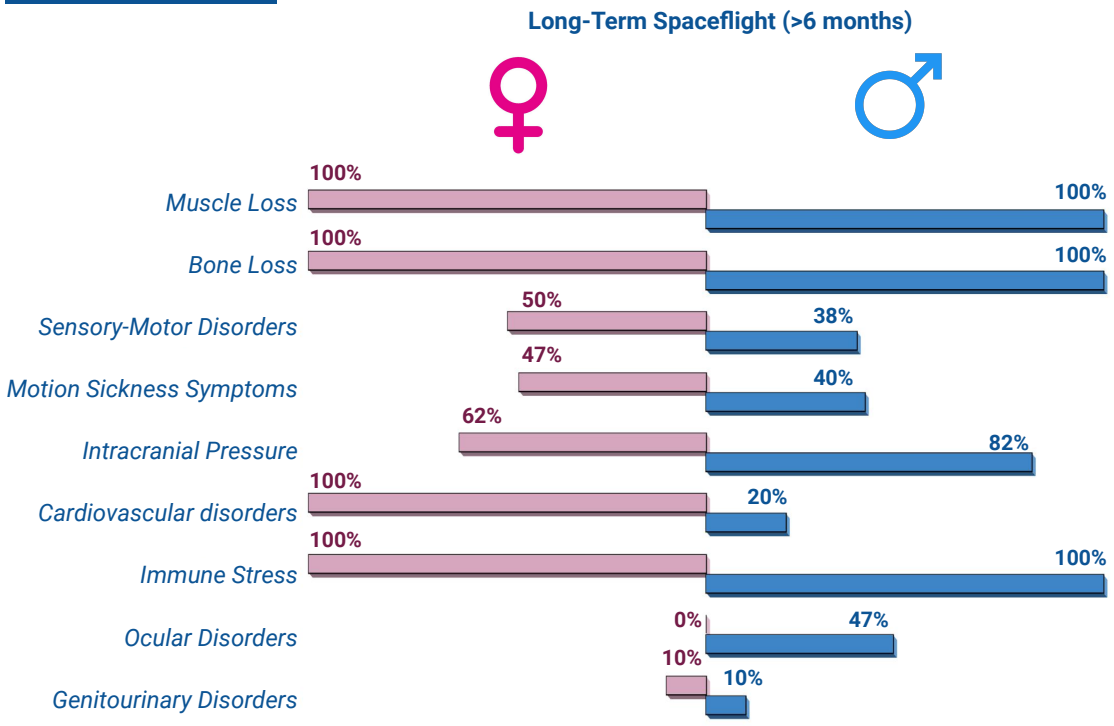
BEHAVIORAL CHANGES

On Earth, anxiety and major depressive disorders are about twice as common in women as they are in men. There is no evidence that female astronauts experience the same risk for depressive and anxiety disorders as their counterparts in the general population.

Source: "Women's Health in Spaceflight" by Laura Drudi and S. Marlene Grenon

Study Investigates How Men and Women Adapt Differently to Spaceflight

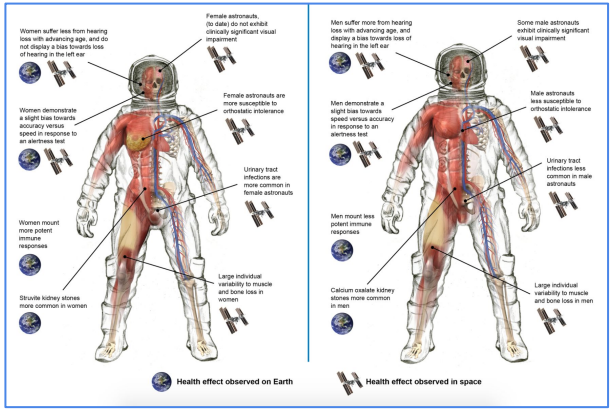
NASA & NSBRI



This diagram shows key **differences between men and womens** physiological **adaptation to the spaceflight** environment.

This includes:

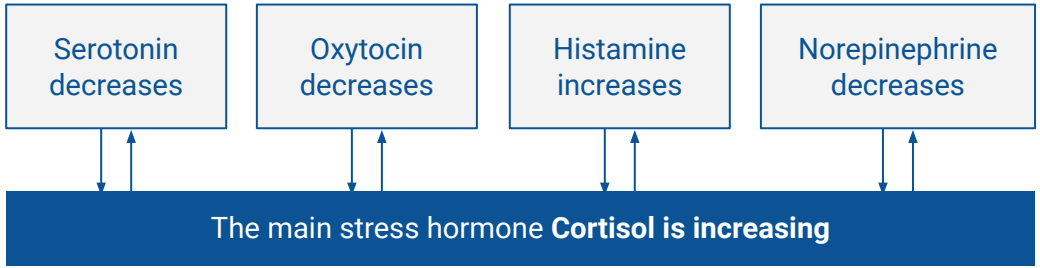
- **Cardiovascular,**
- **Immunological,**
- **Sensorimotor,**
- **Musculoskeletal,** and
- **Behavioral** alterations etc.



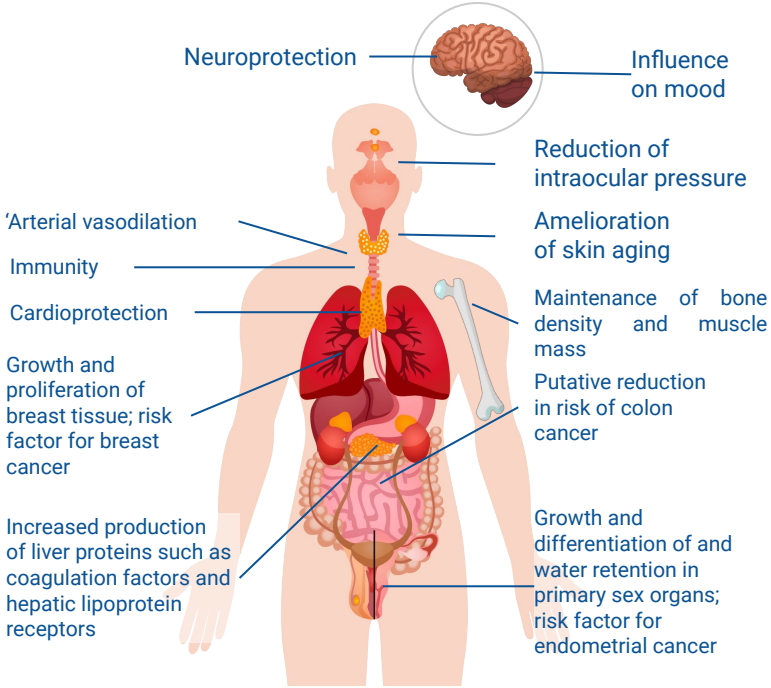
Source: NASA

Spaceflight Adversely Affects Hormonal Activity

Hormones. An astronaut's endocrine system usually gets altered during spaceflight. Hormones, that recover only by returning to Earth, may have a strong impact on healthy aging, and the reproductive system.



Oral contraceptives that female astronauts use on pre-mission training and during spaceflight **highly affect the reproductive system,** with impacts on a number of related hormones such as testosterone, dehydroepiandrosterone, corticosteroid-binding globulin, prolactin, and sex hormone-binding globin.



Studies have shown age-related changes in estrogen-receptor signaling to many vital organ systems, as is shown in the figure. Some of these systems had similar alterations in experiments on animals during spaceflight. **Decreasing the level of estrogen** as a result of hypo-gravitational and weightless environments **may lead to reducing gonadal function** in both men and women. However, estrogens recover in Earth's gravity.

Source: Effects of Sex and Gender on Adaptations to Space: Reproductive Health by April E. Ronca, PhD and others

Menstruation in Space Should Not Be an Issue

This physiological aspect of women's bodies may be a matter of particular importance when sending women into space. However, it should be noted that years of observation indicates that menstruating in space is no different from menstruating on Earth.

Menstrual difficulties in space:

- waste disposal systems were not designed to handle; menstrual blood;
- limited shower facilities and water supplies;
- zero-gravity environment that limits mobility.

SOLUTINS

Suspend menstruation:

- Combined oral contraceptive pill (the most common with a good track record in space);
- contraceptive implants;
- IUD (intrauterine device);
- contraceptive injection.

Duration of safe use

Oral Progesterone Pill	-
IUD	5 years
Contraceptive implants	3 years
Contraceptive Injection	3 years

"It's completely safe to suppress the menstrual cycle"
Varsha Jain (a gynecologist and visiting professor at King's College London)

3 years — The estimated duration of travel to Mars and back. Even if it was a one-way trip, it could take 1-3 years to arrange a safe and viable settlement.

1100 pills — The approximate number of contraceptive pills one woman can use for 3 years. Every pill has some weight, they should be stored and waste utilized afterward.

The IUD is considered to be the most suitable contraceptive for long-duration space travel. It does not take up much space, does not add excess weight, and does not create problems with waste disposal. The main advantage is that the allowed duration of its use is sufficient for a mission to Mars. Contraceptive implants could be used as well but with reservations, due to shorter-use duration.

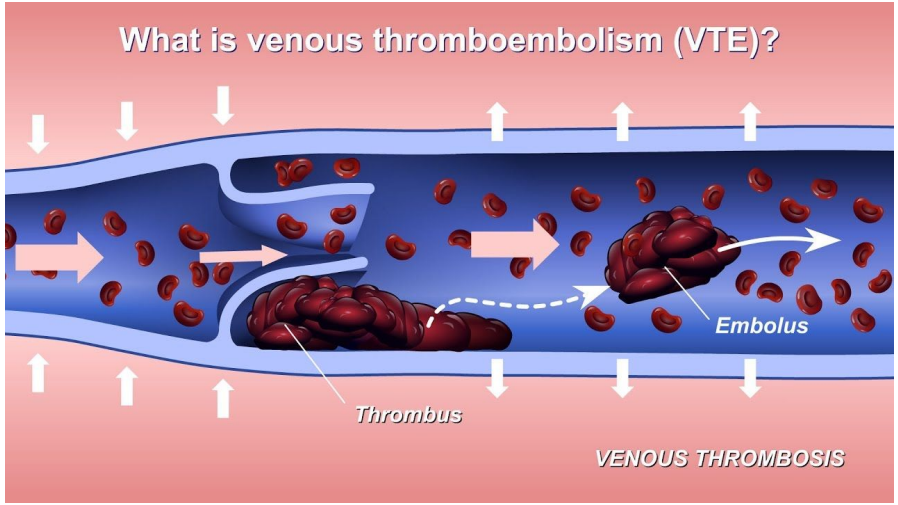
Sources: Nature.com

New Study Examines Women's Health During Spaceflight

ISU's Human Performance in Space Resident Faculty Dr. Virginia Wotring, along with women's health physician Dr. Varsha Jain and **NASA biomedical statisticians,** published a new study on the potential risk for developing a blood clot (venous thromboembolism) in space in the May issue of Aerospace Medicine and Human Performance. The study builds on previous work by Wotring and Jain and examined data from a large cohort of female astronauts from 2000 to 2014, in fact, more than half of the women who have ever flown to space.

"We see a need for continuing studies with female astronauts. Much of the previous biomedical research in space was conducted on males, simply because most of the astronauts were male. That has changed, and now we need a better understanding of how the spaceflight environment effects female astronauts" said Dr. Wotring.

The data shows that spaceflight and combined oral **contraceptive pill (COCP)** use does not increase the risk of **venous thromboembolism (VTE),** despite the fact that COCP use on Earth is known to double the risk. The authors suggest that the benefits from good fitness practices may outweigh certain other risks, a finding that could be meaningful for women on Earth.



Whether the unique environment of space affects astronaut risk of venous thromboembolism (VTE) is not known. On Earth, it is known that use of combined oral contraceptives (COCs) doubles the risk of VTE. Since some female astronauts choose to use COCs, this retrospective study examined known risk factors associated with VTE risk to determine whether the available data suggested elevated VTE risk in female astronauts. **The first case of VTE** on a space mission was reported in **January 2020**.

Source: Ingenta Connect

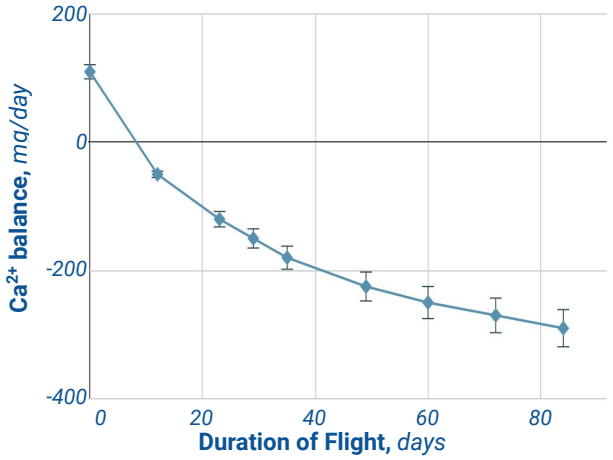
Weightlessness Effects are Deleterious for Both Men and Women

The human body evolved within the constant pull of the **Earth's gravity.** In the weightless environment aboard the orbiting International Space Station astronauts experience **physiological and biochemical changes** during their stay in space.

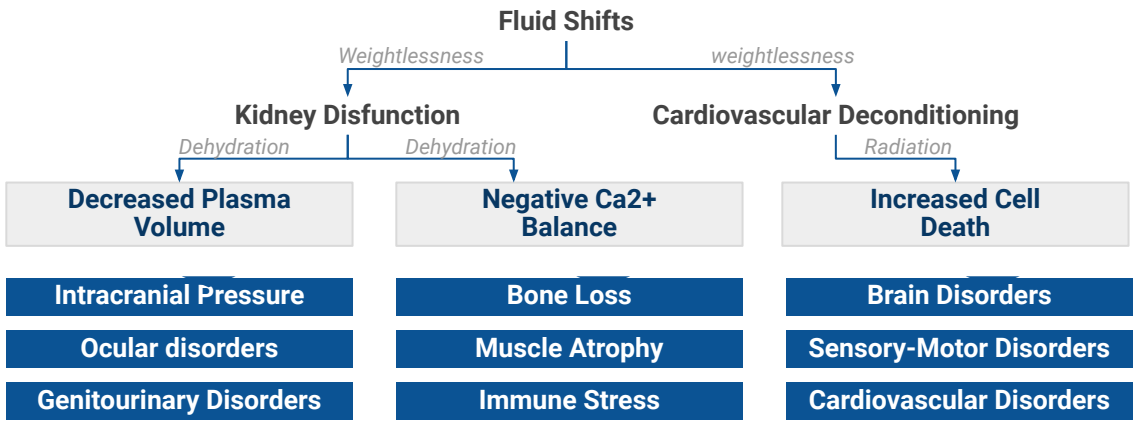
Russian Valeri Polyakov spent 437 consecutive days on a single space mission and American Christina Koch spent 328 days. Both of them set the records for the single longest space mission (in male and female categories respectively). Based on their experience, and the experience of other astronauts, researchers discovered a number of deleterious effects weightlessness has on the human body. However, some long-term effects probably remain unknown, and we can only hypothesize.

Generally, bones in the lower body atrophy, while the upper body skeletal parts grow in density. If long-term weightless effects don't ruin the body but it instead adapts, a new type of human might appear, but we currently lack the data to expect such an outcome.

Ca2+ Balance in Astronauts during Spaceflight



Biochemical and Physiological Changes in Astronauts



Source: NASA

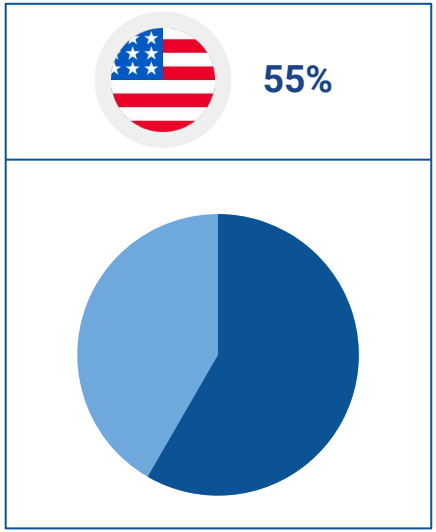
Private Medical Research in Space

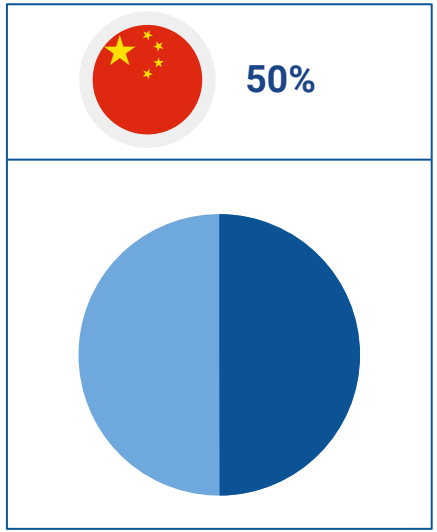
AGING ANALYTICS AGENCY

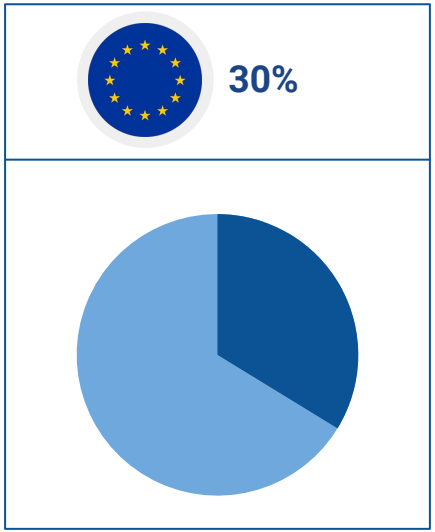
SpaceTech Analytics

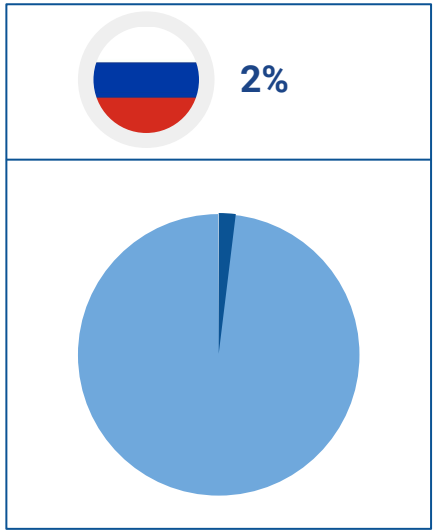
Growing Interest in Private Research in Space

Today, more and more space startups are arising and promoting private research in space. Giving the current rising interest, commercial research is increasingly taking over the market.









55% of the U.S. space market is coming from the **private sector.** The second country by the number of private space initiatives is **China** with **half of the market** dedicated to **commercial R&D. The European Union** holds third place with **30%** of the space projects initiated by **private companies**. Though historically Russia has the most experience in space research, space commercialization only began there in 2018. Since then **only one Russian company has carried out private research in space** - 3D Bioprinting Solutions.

Sources: NASA, Vedomosti, ESA

Top Companies Advancing Space Medicine

United States

Biogen Inc
Cambridge, Massachusetts, United States

Amgen
Thousand Oaks, California, United States

RevBio
Lowell, Massachusetts, United States

Angiex
Cambridge, Massachusetts, United States

Kernal Biologics
Cambridge, Massachusetts, United States

Merck
Kenilworth, New Jersey, United States

MicroQuin
Cambridge, Massachusetts, United States

490 BioTech
Knoxville, Tennessee, United States

Tympanogen, Inc.
Richmond, Virginia, United States

Eli Lilly
Indianapolis, Indiana, United States

SP8CEVC, Venture Capital
New York, New York, United States

60% of companies shown have their headquarters in the **U.S.**, with **Israel, France and Switzerland** sharing second place (**30%** of all private companies). Other companies are distributed equally among the **UK, Netherlands** and **Italy**.

Israel

SpacePharma
Herzliya Israel, Courgenay Switzerland

Pluristem Therapeutics Inc.
Haifa, Israel

France

Sanofi
Paris, Ile-de-France, France

Medes
Toulouse, Midi-Pyrenees, France

United Kingdom

AstraZeneca
Cambridge, Cambridgeshire, United Kingdom

Netherlands

OrgaNext Research
Arnhem, Gelderland, The Netherlands

Italy

Kayser Italia
Livorno, Toscana, Italy

Switzerland

Nova Space Biotechnology
Zürich, Zurich, Switzerland

Novartis
Basel, Basel-Stadt, Switzerland

Source: Mitochondria in Longevity and Space Medicine

Supporting Commercial Life Sciences Research - CASIS

Since 2011, when NASA engaged **the Center for the Advancement of Science in Space (CASIS)** to manage the ISS National Lab, CASIS has partnered with academic researchers, other government organizations, startups, and major commercial companies to take advantage of the **unique weightless lab**.

By 2025, CASIS plans to attain a profit approximately **equal to the current annual US costs of maintaining the ISS,** which is:

$4 Billion

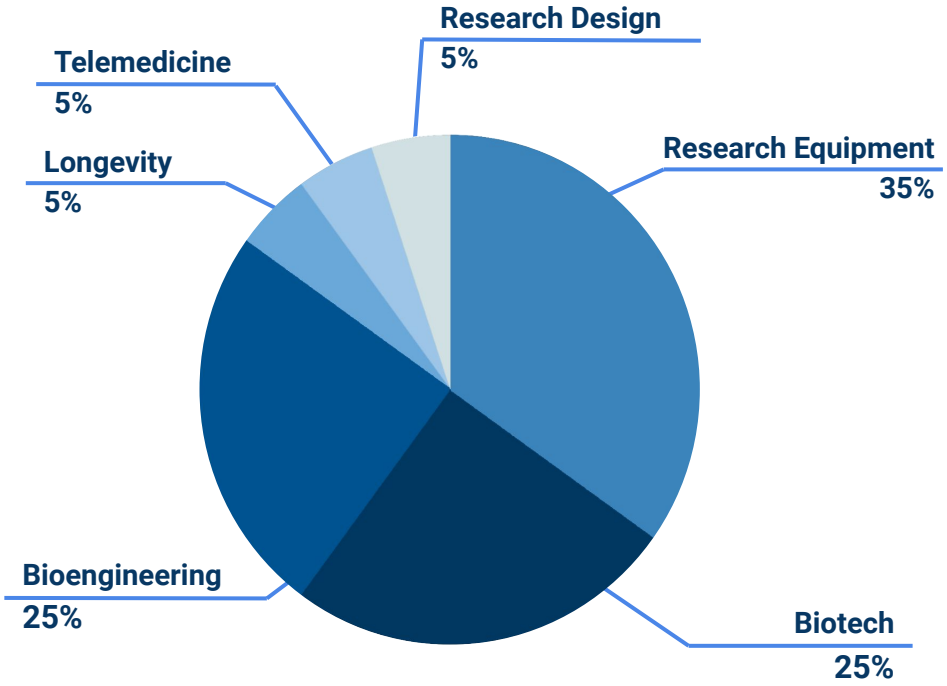
One of the main areas of focus for NASA is life sciences. Studying the effects of weightlessness on astronauts' physiology, microbiome, genetics, and life-support systems, including food-production systems, provides data for future space exploration and settlement.

From 2016 CASIS began a robust outreach to the pharmaceutical community, which takes advantage of the weightless environment on the ISS to develop and enhance therapies for patients on Earth. Companies such as **Merck, Eli Lilly & Company,** and **Novartis** have sent several payloads to the space station, including investigations aimed at studying diseases such as osteoporosis, and examining **ways to enhance drug tablets for increased potency** to help patients on Earth.

Source: CASIS

Services to Enhance Space Medicine Industry

Number of Companies in Each Sector



25% of the marketplace is dedicated to **bioengineering** solutions for astronauts to adverse age-related degenerative conditions: eye and bone implants, or medical hardware to analyse and support astronauts' health. Another **25%** of the space medical market is focused on **the biotechnology** industry dealing with space-related disorders and *in situ* amino-acid production.

More than **35%** of space-related companies **provide research equipment for the ISS.**

5% are dedicated directly to human longevity in space. In particular, a new venture-capital fund called **SP8CEVC** has been established to place a laser-tight focus on the intersection between space technology and human longevity.

Source: Mitochondria in Longevity and Space Medicine

Cost of Private Research on the ISS has Increased

In April 2021 after discussions with stakeholders about the current market growth, and in anticipation of future commercial entities capable of providing similar services, the new NASA commercial marketing pricing policy was formed and **prices went up significantly**.

	upmass	downmass	1h of crew member time	per person per day for life support, toilet and other supplies including food and air
2019	**$3,000**	**$6,000**	**$17,500**	**$33, 750**
2021	**$20,000**	**$40,000**	**$130,000**	**$88,000 - $164,000**

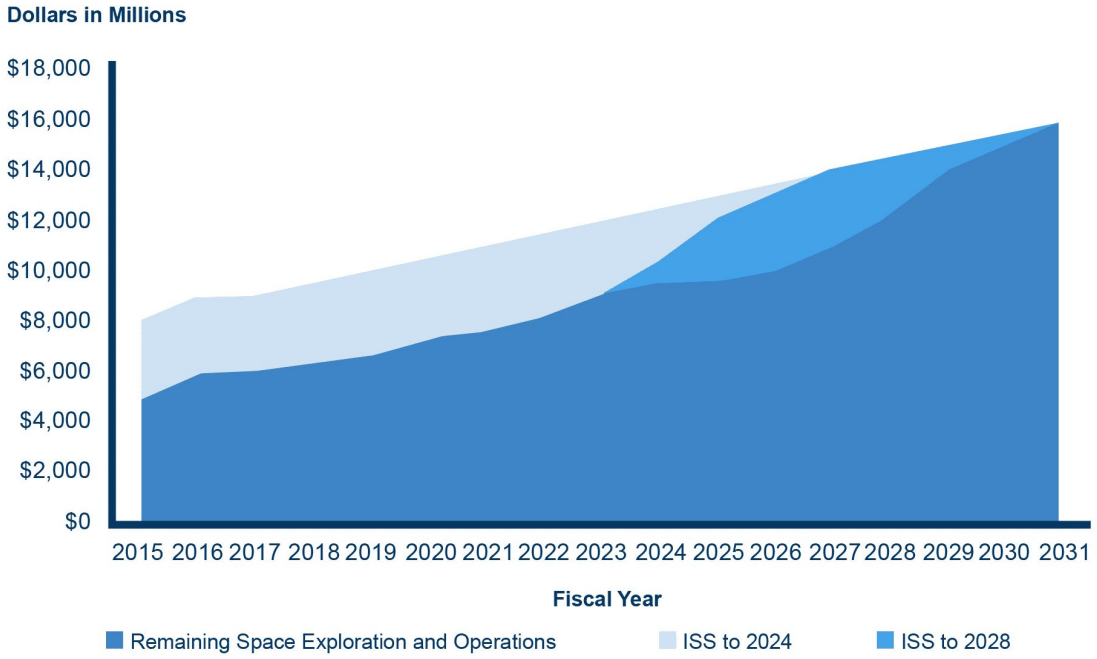
"The pricing policy from June 2019 **did not reflect full reimbursement for the value of NASA resources**; it was intended to stimulate the market and was planned to be adjusted"

- says Michael Johnson Chief Technologist of the Engineering and Technology Directorate at NASA

Source: SpaceNews, NASA

Supporting ISS for Weightless Research is Currently Very Costly

Supporting the ISS to 2028 will require additional funding **from other parts of the NASA budget**. Thus further cooperation with the private sector is urgently needed to ensure other NASA space activities, such as exploration beyond low-Earth orbit.



Assuming funding for NASA's human exploration program remains constant, a continuation of ISS funding through 2028 will require either **increased funding in the 2020s** to develop exploration systems needed for Moon and Mars missions or will require the Agency **to push out the timeline for its lunar/Mars exploration plans.**

NASA's CFO claims that a 4-year extension of the ISS to 2028 **could push out the schedule for NASA's Mars plans by at least 3 years.**

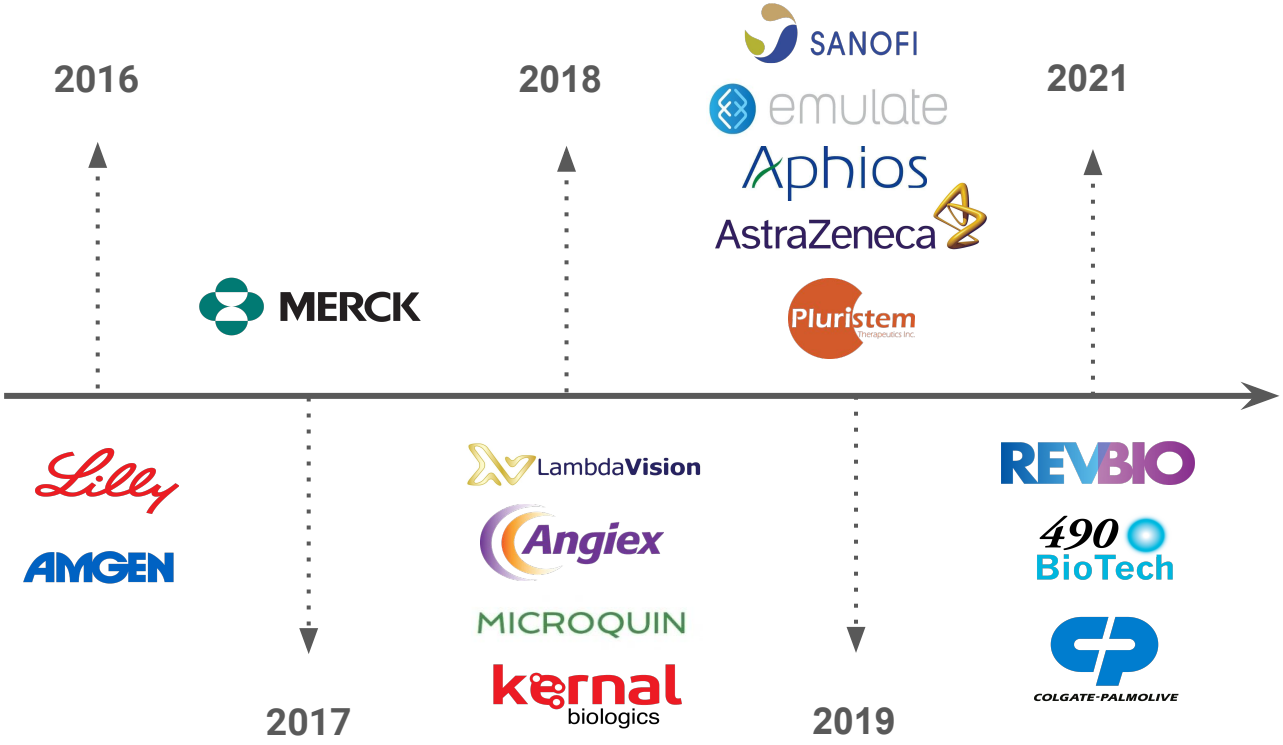
Source: NASA

Timeline of Private Biological Research on the International Space Station

ISS became available to private companies beginning in 2016.

Most of the investigations were carried out by pharmacological companies and studies were related to pharmacokinetics and drug delivery systems.

Due to the pandemic, no private research was carried out in 2020.



Source: The Scientist

Private Age-Related Research in Space

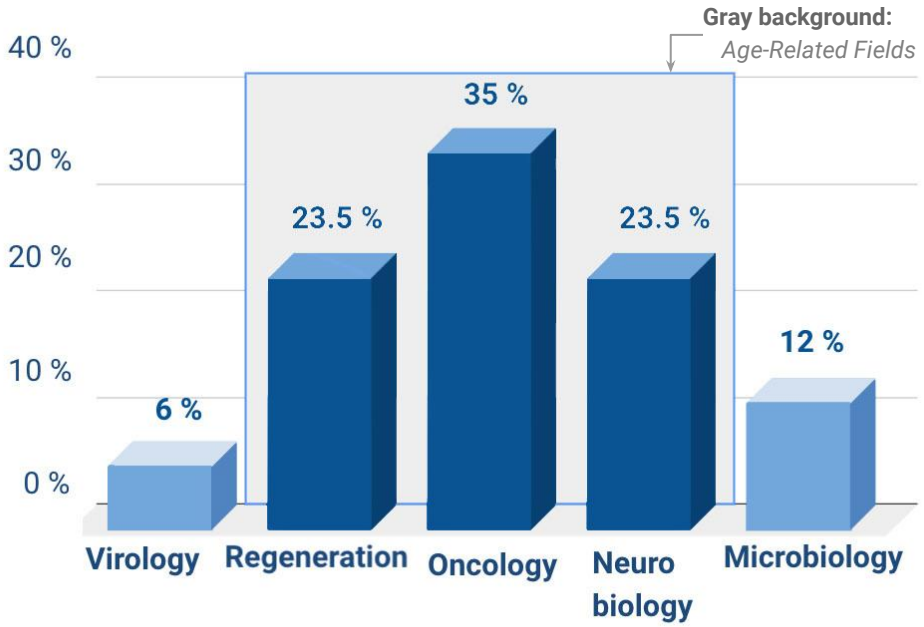
Low-Earth orbit (LEO) is a unique environment for investigation of novel approaches to mitigate age-related disorders.

35% of all private research on the ISS dedicated to drug-delivery systems to conquer **cancer.**

Another **47%** of applied sciences are equally focused on **neurodegenerative disorders therapy**, mainly Alzheimer's, and **regenerative medicine**: muscle and bone restoration, using human-cell culture.

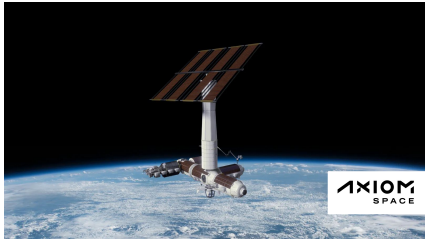
As microbes in space change their metabolism, and cause serious harm to astronauts, almost **12**% of private research is dedicated to microbiology and **6**% to viral replication and production studies, including the development of vaccines for space.

Main Research Fields

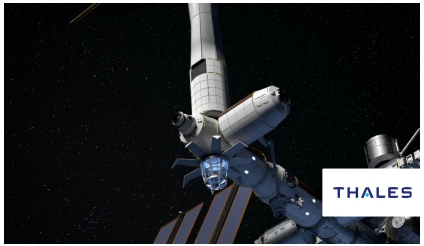


Source: Mitochondria in Longevity and Space Medicine

The Coming Era of Private Habitable Space Stations



NASA **awarded Axiom** the right to attach one of its own crew modules to a docking port on the ISS—and a **$140 million contract** to make it happen. The company's plan is to launch its first module to the space station by 2024 and expand from there. In addition to the crew-habitation module, CEO Suffredini says Axiom is planning for at least two others: One will be a laboratory and manufacturing facility, and the other will be a panoramic observatory similar to the ISS cupola.



Thales Alenia Space, a Joint Venture between **Thales** (67%) and **Leonardo** (33%), and **Axiom Space** of Houston, Texas (USA), have signed the final contract for the development of **two key pressurized elements of Axiom Space Station**. Scheduled for launch in **2024 and 2025** respectively, the two elements will originally be docked to the International Space Station (ISS), marking the birth of the new Axiom Station segment. The value of the contract is **110 Million euro**. Thales Alenia Space and the Italian Air Force have ratified a Memorandum of Collaboration, aiming to promote access to low earth orbit in favor of institutions, the scientific community, industry, and commercial operators.

The Large Integrated Flexible Environment (LIFE) habitat is under development by the engineers for **Sierra Nevada Corporation**, and a ground prototype is being used to evaluate how crew members could perform mission tasks in outer space. **The LIFE habitat** is meant to travel into space furled inside commercial launch vehicles and will then inflate on-orbit to its full size to house **four astronauts and their equipment. The three stories of space includes science labs, robotics work stations, medical and sick bays, sleep and hygiene quarters, exercise equipment, a plant growth system, and more.**

Sources: Axiom Space, Thales Group, Bigelow Aerospace

Biomanufacturing in Space

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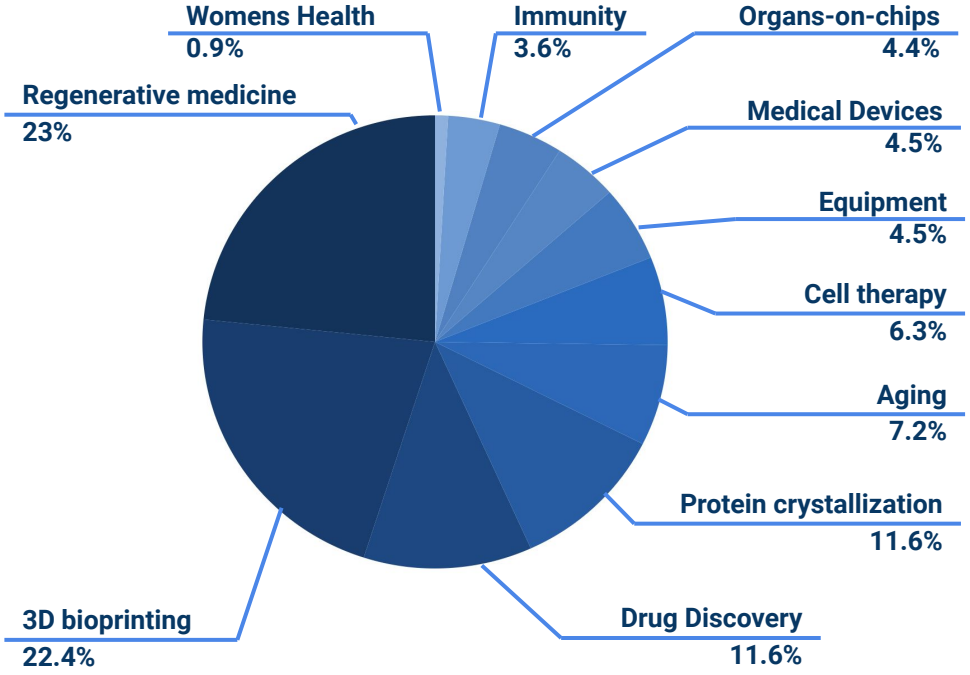
Biomanufacturing in Space - Main Sectors

Number of Companies in Each Field of Biomanufacturing



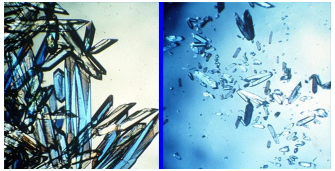
Leading positions in biomanufacturing are devoted to **regenerative medicine** which covers **23%** of the industry, and organ printing (**3D bioprinting**) with **22.4%** of the global market.

The third place is occupied by **drug discovery** and **drug development** using the **protein crystallization technique.** with **11.6** percent of the market in each sector. **7.2%** is focused on the aging process in bones, muscles, and brains under spaceflight conditions.

Cell therapy, including stem cells, has occupied **6.3**% of biomanufacturing research. **13%** is almost equally distributed among the **organs-on-chips** approach, **medical devices**, and **research equipment** for the ISS. Statistics include both private and governmental initiatives.

Protein Crystallization for Drug Discovery

> Crystals grown in weightlessness are often larger and more well-ordered than Earth-grown crystals, which can lead to improved datasets for structural determination. Many researchers, including several from commercial entities, are already using the unique crystallization environment onboard the ISS National Lab to advance their research and development.



The Dover Lifesciences research team is aiming to leverage weightless conditions on the ISS for crystallization of two protein complexes that are difficult to crystallize on Earth: the enzyme glycogenin in complex with glycogen synthase 1 (an enzyme in muscle) and glycogen synthase 2 (a critical enzyme for glycogen synthesis in the liver). This can lead to improved obesity and cancer treatment.

A Merck & Co. investigated how weightlessness can influence crystalline suspension of millions of tiny uniform crystals of **pembrolizumab** - the active pharmaceutical agent in the immuno-oncology drug Keytruda®

An investigation is underway by **The Michael J. Fox Foundation** to grow crystals of the **LRRK2 protein**, a key target in identifying the makeup of Parkinson's disease.

Eli Lilly launched protein crystallization research to study relevant molecules growth in weightlessness, using the LRL-CAT - the X-ray Synchrotron Beamline.

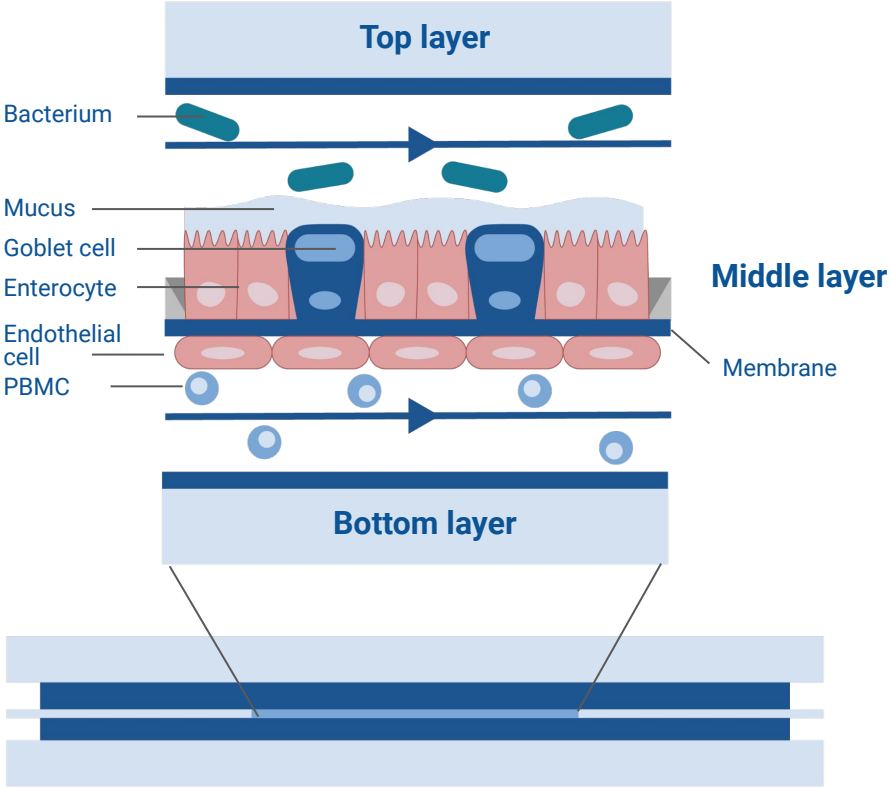
MicroQuin is aiming tat investigating a therapeutic drug to treat breast cancer. It is also involved in in the progression of Alzheimer's, Parkinson's, and Type 2 diabetes, and plays a role in bacterial infections, obesity, and ischemia-reperfusion injury (damage resulting from the return of blood supply to tissue after periods without oxygen).

Sources: ISS National Lab

Biomanufacturing in Space - Tissues and Organs on a Chip

A small device containing human cells in a 3D matrix represents a giant leap in the ability of scientists to test how those cells respond to stresses, drugs, and genetic changes. About the size of a thumb drive, the devices are known as **tissue chips or organs on chips.**

A series of investigations to test tissue chips in weightlessness aboard the International Space Station is planned through a collaboration between the National Center for Advancing Translational Sciences **(NCATS)** at the National Institutes for Health **(NIH)** and the Center for the Advancement of Science in Space **(CASIS)** in partnership with NASA. The Tissue Chips in Space initiative seeks to better understand the role of weightlessness on human health and disease and to translate that understanding to improved human health on Earth.



Human gut-on-a-chip as a model for bioavailability and biotransformation studies/WAGENINGEN university

Sources: NASA

Main Developers of Tissues and Organs on Chips

TRISH is a NASA-funded lean, virtual institute tasked with addressing the issues of human deep-space exploration, and persistently pursue and support high-impact science and technologies that will minimize the risk of humans exploring the solar system.

The University of Washington Institute for Stem Cell and Regenerative Medicine (ISCRM) is dedicated to doing ethical fundamental research in order to unlock the immense potential of stem cells and thereby produce treatments and cures.

The **ISS National Lab translational research** offers unique opportunities to explore the impact of the weightlessness environment on the human body and organs, utilising biochips.

MIMETAS strives to contribute to groundbreaking therapies with unique human-disease biology, revealed by robust, screenable assays in the most versatile technology platform. OrganoPlate® is the solution for all in-vitro tissue-culture applications.

Emulate is able to overcome limitations with living human studies by in-vitro models that empower researchers to explore the biological mechanisms of health and disease by producing microphysiological systems (MPS)

At **Columbia University, Vunjak-Novakovic Lab** is exploring biomedical engineering approaches to produce bone grafts and cardiac tissue use it for transplantation to patients.

The Center for the Advancement of Science in Space (CASIS) is looking for R&D concepts for flight investigations in applied research and development, translational medicine, technological-readiness-level maturation, and technology demonstrations to be undertaken aboard the space station.

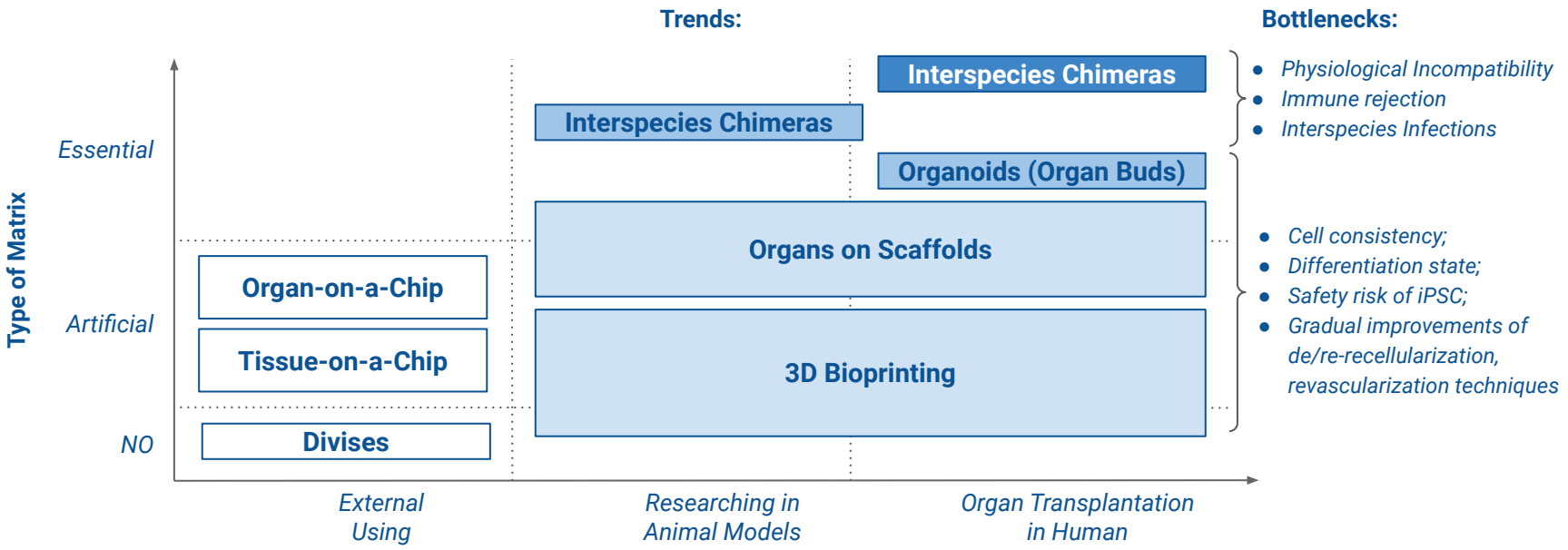
At the **University of Pittsburgh School of Medicine, Rocky S. Tuan Lab** is focused on developing novel approaches of stem-cell bioengineering in order to restore loss of functions in different organs.

MicroGrx design & manufacture custom microfluidic systems for human-biology research and evaluation on Earth and in space. Weightless experiments are conducted on the International Space Station.

The **J. Crayton Pruitt Family Department of Biomedical Engineering at the University of Florida's** primary purpose is to better the world and the human condition via the multidisciplinary and creative integration of engineering, biology, and medicine.

Sources: NASA

Biomanufacturing in Space: Trends and Bottlenecks of Organ Engineering



Organ engineering gives hope that this approach will become a commercial reality within the next decade. However, several barriers to commercialization are still major obstacles that need to be systematically addressed. Engineering whole-organ constructs with homogenous cell density and adequate cell populations is a significant technical barrier. To address this barrier, stem-cell research must be developed to improve cell invasion and adhesion of organ constructs. Though Organs on Scaffolds and cell bioprinting approaches have demonstrated the ability to incorporate multiple cell types into engineered organ constructs, this is often for the purpose of replicating just a single part of an organ's function, rather than replicating the entirety of the organ's functions. Regulatory pathways are an additional challenge facing the utilization of engineered whole organs as viable transplants and are principal among the non-technical barriers to commercial implementation.

Sources: MDPI

Key Clusters of Players in Organ Engineering (R&D, Companies, SpaceTech)

	Organs on Scaffolds	Organ Buds	3D Printing	Xenotransplant
R&D	Mayo Clinic NHS – Great Ormond Street Hospital for Children, NHS Foundation Trust Keio University Texas – The University of Texas at Austin Massachusetts General Hospital Sichuan University	Walter+Eliza Hall Institute of Medical Research – Discoveries for Humanity 東京大学 The University of Tokyo Salk Institute for Biological Studies YNU 横浜国立大学 Yokohama National University	uc3m Universidad Carlos III de Madrid Washington State University Wake Forest University HST Harvard–MIT Health Sciences & Technology Chalmers	Friedrich-Loeffler-Institut – Bundesforschungsinstitut für Tiergesundheit, Federal Research Institute for Animal Health Mayo Clinic Harvard Medical School The University of Melbourne SSPH+ Swiss School of Public Health – Inter-University Graduate Campus Duke 大阪大学 Osaka University LMU Ludwig-Maximilians-Universität München +10 more
Biotech Companies	Iviva Medical miromatrix Engitix Therapeutics Videregen	RIKEN	3DS 3Dynamic Systems Roche organovo	egenesis Sangamo Therapeutics Xeno Life Science Pvt. Ltd. Revivicor
SpaceTech	LambdaVision	UC San Diego Space Tango	3dbio – Creating Future Possibilities	Inserm

Sources: MDPI

Biomanufacturing in Space - Cancer Research

MAYO CLINIC	Chemotherapy Tumor Resistance
MERCK INVENTING FOR LIFE	Drug Delivery
Frederick National Laboratory for Cancer Research	Structure of RAS Proteins
490 BioTech	Drug Discovery
ONCOLINX	Drug Testing
Angiex	Therapy Development
MicroQuin	Tumor models and Protein Structure
kernal biologics	mRNA Therapy Development

- **ISS National Laboratory cancer research** consists of different studies, including: cultivation of clinical-grade stem cells for therapeutic applications, crystallization of proteins for improved drug discovery, and delivery of new therapies, with fewer side effects.
- In weightlessness, endothelial cells show a persistent state of **reduced cell growth**, which is more similar to cell behavior in the body than in cell cultures on Earth.
- Weightlessness promotes superior **3D cell-culture growth**, allowing drug evaluations that better mimic cellular response.
- A research performed by **Mayo Clinic** is focusing on a chemotherapy cancer resistance.
- A project from **Merck & Co**. is investigating growth of uniform crystalline particles of the therapeutic monoclonal antibody Keytruda® in order to improve drug delivery. Crystals grown in weightlessness show more uniform size and distribution.
- A project from **Frederick National Laboratory** for Cancer Research is focusing on the structure of RAS proteins by protein crystal growth.
- Research from **490 Biotech Inc.** is employing a new bioluminescent assay tool kit that may improve drug discovery.
- **Oncolinx Pharmaceuticals, LLC** is testing a new type of anti-cancer drug in 3D cell cultures.
- **Angiex Inc**. is developing a therapy that targets both tumor cells and tumor blood vessels.
- **Kernal Biologics** Inc. will screen oncoselective messenger RNAs for leukemia immunotherapy.
- **MicroQuin** investigates a way to crystallize a protein involved in tumor formation, and develops complex 3D models of human breast and prostate tumors.

Source: ISS National Lab

Biomanufacturing in Space - Neurodegenerative Research

NSCF	Stem Cell Research
SPACE TANGO	Microglia 3D Models
THE MICHAEL J. FOX FOUNDATION FOR PARKINSON'S RESEARCH	Parkinson's Disease Research
Aspen NEUROSCIENCE	Parkinson's Disease Research
NYSCF The New York Stem Cell Foundation Research Institute	Multiple Sclerosis Research

- The neurodegenerative disorders of Parkinson's Disease and Multiple Sclerosis are being investigated on the ISS.
- The ISS experiments are trying to explain what triggers those diseases, focusing on nerve and immune brain-cell interactions.
- Additionally, the experiments are investigating how space influences nerve and immune brain cells in healthy astronauts.
- Effects of weightlessness on Microglia 3-Dimensional Models of Parkinson's Disease and Multiple Sclerosis examine how microglial cells grow and move in 3D cultures and any changes in gene expression as a result of weightlessness exposure.
- iPSCs (induced pluripotent stem cells) from patients with Parkinson's Disease and Multiple Sclerosis, are used for evaluation of those cell-cell interactions and migration.
- Moreover, a mutation in the LRRK2 gene appears to be linked to Parkinson's Disease.
- The Michael J. Fox Foundation has partnered with ISS National Lab to determine the structure of LRRK2, by using protein crystals.

Sources: ISS National Lab

Universities and Organisations that Make Studies in the Following Directions

Biomarkers

- University of Alabama at Birmingham (USA)
- University of Michigan (USA)
- University of Washington (USA)
- Max Planck Institute for Biology of Ageing (Germany)
- University of Vienna (Austria)
- UCL (UK)
- Leiden University Medical Center (The Netherlands)
- Tsinghua University (People's Republic of China)
- University of Auckland (New Zealand)
  Institute of Nuclear Medicine & Allied Sciences (India)

Radioprotector

- University of Notre Dame (Australia)
- University of Sydney (Australia)
- Université de Lyon (France)
- Harwell (England)
- Philipps-University Marburg (Germany)
- Mittelhessen University of Applied Sciences (Germany)
- Belgian Nuclear Research Centre (Belgium)
- National Council on Radiation Protection and Measurements (USA)
- Southern Illinois University Carbondale (USA)
- University of New Mexico School of Medicine (USA)
- Memorial Sloan Kettering Cancer Center (USA)

Hibernation

- University of Tsukuba (Japan)
- RIKEN Center for Biosystems Dynamics Research (Japan)
- Niigata University (Japan)
- University of Bologna (Italy)
- Gifu University (Japan)
- Oregon State University (USA)
- University of British Columbia (Canada)
- Trento Institute for Fundamental Physics and Applications (Italy)
- National Institute of Nuclear Physics (Italy)
- University of New England (USA)

Gene Therapy

- University of London (England)
- GSK (England)
- Herlev Hospital (Denmark)
- University of Copenhagen (Denmark)
- The Icahn School of Medicine at Mount Sinai (USA)
- Universite Sorbonne Paris Cite (France)
- University of Pennsylvania (USA)
- The University of Tasmania (Australia)
- Baylor College of Medicine (USA)
- the University of Massachusetts Medical School (USA)

Source: PubMed

* Selected and categorized by the subject of their recent researches

Current Solutions to Support Human Health in Space

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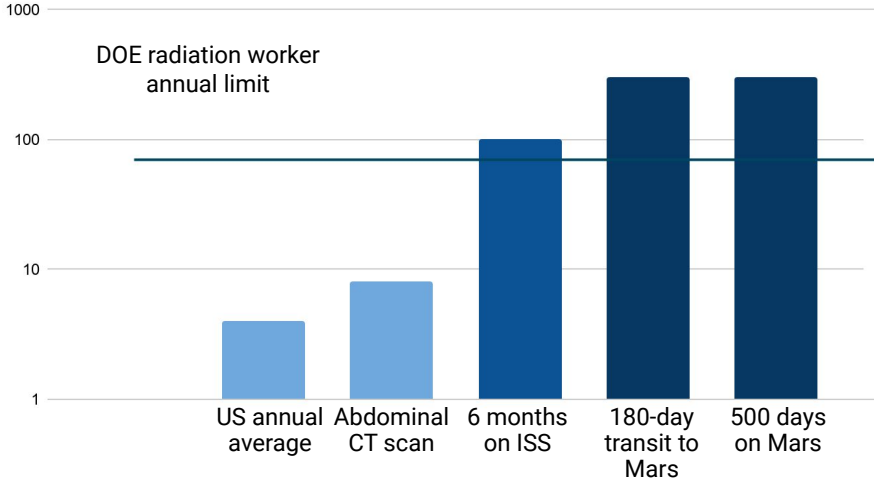
Radioprotectors

Outside the safe cocoon of Earth's atmosphere and magnetic field, subatomic particles zip around at close to the speed of light. **Space radiation** can penetrate habitats, spacecraft, equipment, spacesuits, and even astronauts themselves. The **interaction of ionizing radiation** with living organisms can lead to harmful health consequences, such as tissue damage, cancer, and cataracts, in space and on Earth. The underlying cause of many of these effects is damage to deoxyribonucleic acid (DNA).

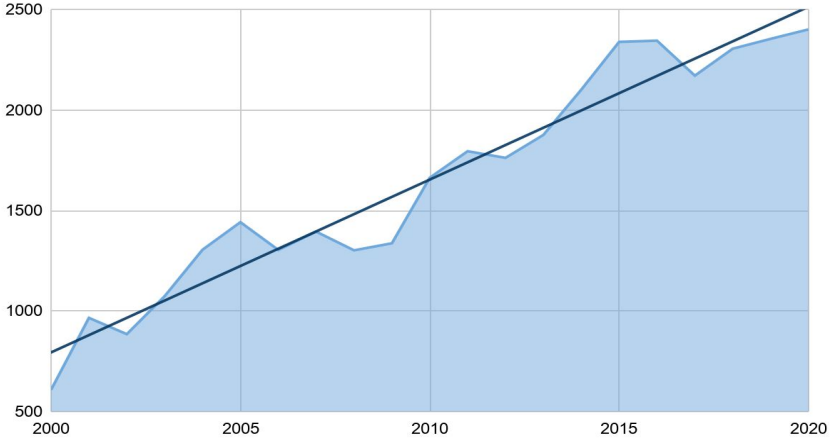
Drugs called **Radioprotectors** are capable of reducing damage caused by space radiation and increasing astronauts' resistance to radiation exposure. Having a formidable potential, they are extremely important in the era of space exploration, development, and settlement.

Radiation Dose (Millisieverts)



Source: PubMed

There is an Upward Trend in Research into Radioprotectors:



Countermeasure Protocols and Post-Flight Rehabilitation

Exercises

Active fitness is required to prevent the body from losing bone and muscle.

Exercise increases the amount of plasma in the body.

It also increases blood volume and circulation and prevents fainting.

"No other activity except eating and sleeping is given that much priority. Two and a half hours each day are devoted to fitness."

Don Hagan, director of exercise physiology at Johnson Space Center

1. **The Cycle Ergometer** is similar to a bicycle, so pedaling is the main activity. It also measures heart rate and the amount of work performed.

2. **The Treadmill** involves a regular walk or jog. Since this is not possible in space due to the lack of gravity, there are special harnesses that hold astronauts to the walking surface.

3. **The Resistance Exercise Device (RED)** is a comprehensive exerciser that allows one to train almost all parts of the body. Astronauts pull and twist stretchable cords attached to pulleys using their legs or arms.

These three exercises are common countermeasures to weightlessness outcomes. However, to take care of women's reproductive health, the protocol should be expanded with special exercises for the pelvic floor and other internal muscles of the abdomen, because they will play a major role in childbirth. Moreover, note that countermeasures remain an incomplete solution and bone loss will still occur. The existing effective countermeasure devices are too large to be delivered and incorporated.

Rehabilitation. Since post-flight injuries have sometimes occurred, NASA has created a rehabilitation program for astronauts returning from long-duration space flights. The program accelerates the recovery of functional capabilities to return crewmembers to baseline. For female astronauts, most of the risk is expected to be mitigated with oral contraceptives, hormone replacement therapy, doing impact exercise, and resistive exercise. All these approaches should be improved and adapted to Mars or Moon conditions.

Sources: Space.com

Medical Equipment Developed for Space is Implemented on Earth

Extraterrestrial Organs for Terrestrial Needs

Bioprinting of organs is another exciting technology. The weightless environment in the ISS is appropriate for 3D-printing tissues as it minimises the risk of collapsing under gravity.

Drug Development

The weightless environment on the ISS allows liquids that would not usually mix on Earth to combine and spontaneously form tiny spherical liquid-filled bubbles surrounded by a semipermeable outer membrane. Studying the samples upon return to Earth can help scientists to understand how to create the same microcapsules on Earth.

Next-generation Wearables

Astronauts need to monitor their physiological data. It usually means using several medical devices, which is bulky. The Bio-Monitor created a single “smart shirt” that measures pulse and electrical activity of the heart, breathing rate and volume, skin temperature, blood-oxygen saturation, etc.

However, this device can also be helpful for people with limited access to medical support or workers in dangerous environments such as mines, industrial sites, or factories.

Diagnosing the Remotest Patients

Astronauts live with limited access to medical facilities. VisualDX created a machine-learning algorithm that helps non-medical professionals to diagnose certain conditions. This platform uses pictures and answers for particular questions. On Earth, this tool can be used for emergencies and low-resource areas.

Downsizing Labs

Standard laboratory tools are unavailable in space. 1Drop Diagnostics created a portable device that measures a range of biomarkers to determine cardiovascular function and kidney and liver functions taken from small blood samples. On Earth, this tool can also be widely used because it detects the condition anywhere.

Sources: The Medical Futurist, Government of Canada, the Pharmaceutical Journal

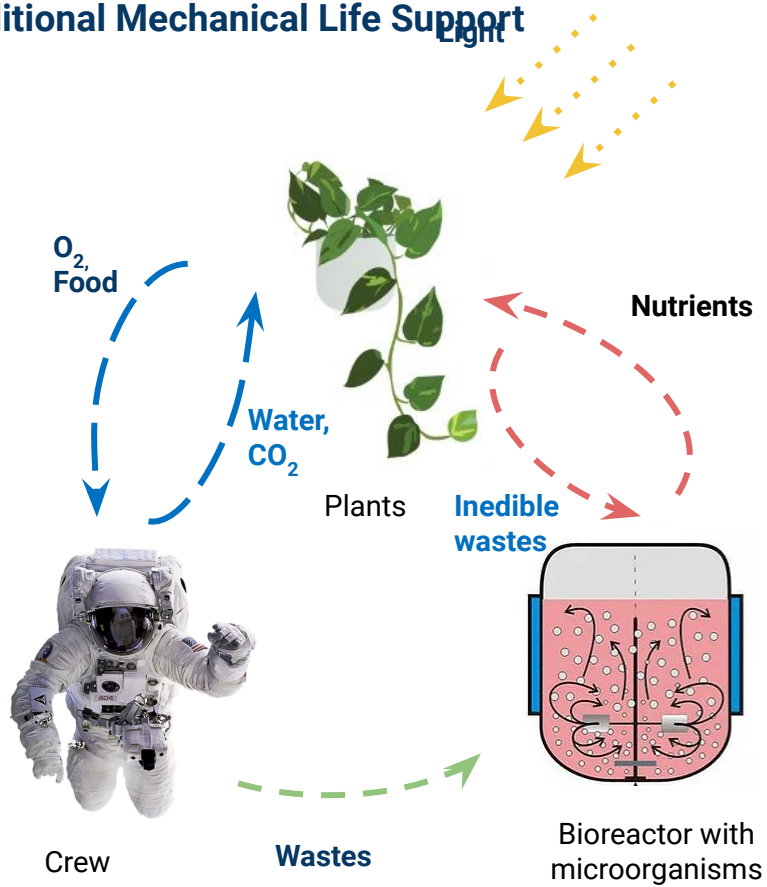
Bioregenerative Life Support Systems are an Advance Over Traditional Mechanical Life Support

Bioregenerative Life Support Systems (BLSS) are considered as the most advanced systems to provide space crew with oxygen, water, and food, and to supply clean air in a spacecraft.

This is achieved by sticking to the main principles of closed ecological systems, where waste products such as carbon dioxide, feces and urine must eventually be converted into oxygen, food, and water. To achieve maximum reusability, physico-chemical systems are often used, along with autotrophs such as algae, mushrooms, plants and microorganisms.

Previous BLSS were created exclusively as Earth-based experiments. The last attempt was carried out in China in 2017.

Yuegong-1 or "Lunar Palace" 2017



Source: Ecotechnics

Advances in Food Technology will be Crucial for Space Exploration and Settlement

The Vegetable Production System is a deployable plant-growth unit capable of producing salad-type crops in space. This technology will provide future space explorers with a sustainable food supplement during their long-duration missions, and ultimately allow space settlement.

Developed by NASA's Center of Excellence for Collaborative Innovation, ISS Fit app is designed for use aboard the International Space Station. The app provides astronauts with an option to track their food intake by making audio recordings, shooting videos, taking photos or scanning barcodes.

Being a health technology company, Mission: Space Food brings together a team of Michelin star chefs, aerospace engineers, doctors, astronauts and cognitive nutritionists. They are working together to define the future of space nutrition.

A company that develops space food which can also be used for mass human consumption on Earth.

The Space Foods Company Ltd. has the knowledge and ingredients to provide its services to the modern space traveller.

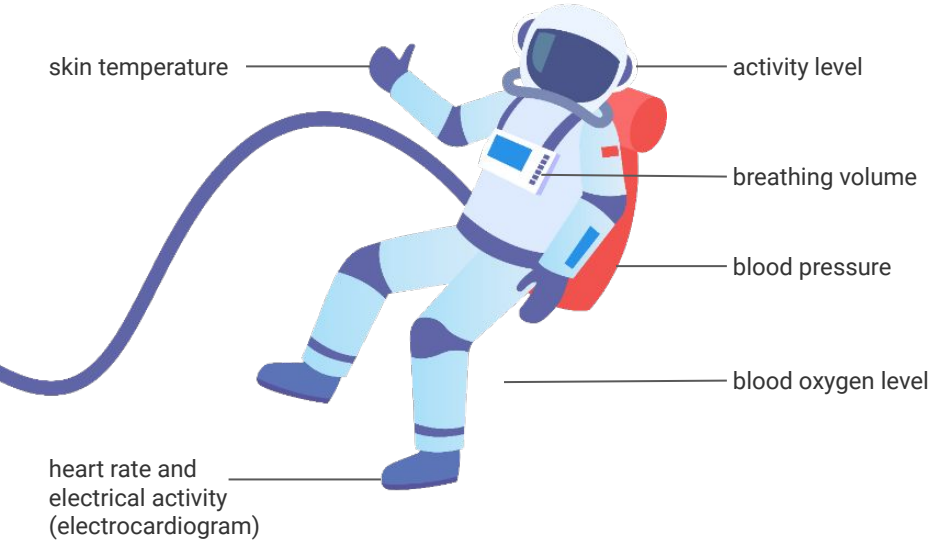
Source: NASA

Implementation of AI in Space Health - Non-Invasive Techniques

Wearable technologies for non-invasive health-monitoring systems have been in use for a long time. Today they incorporate Artificial Intelligence (AI) for real-time tracking of an astronauts health.

Wearable technologies

Bio-Monitor - technology developed by Canadian Space Agency aiming to carry out comprehensive analysis of astronaut conditions, including:



Electronic skin, motion sensors, smart shirt, etc.

Source: Nora M. Haney et al., 2020

Conclusions

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Key Takeaways

In order to explore deep space, health risks for astronauts during both long-term and short-term spaceflight have been investigated for years. In 1992 NASA designed the Longitudinal Study of Astronaut Health to investigate such health risks. Medical problems associated with **short-term space flights have been better investigated than long term, and countermeasures have been successfully established**.

On the other hand, long-duration spaceflight needs to be investigated more thoroughly. It is known that weightlessness influences **muscle loss, bone loss, renal dysfunction, cardiovascular system, immune system, as well different neurological disorders and behavioral health**. Usually, it is difficult to observe multi-systemic physiological changes, because the groups of subjects consist in a small number of astronauts, and there is much more data for men than women. This will likely change in the coming era of space tourism.

Although the data remains scarce, the development of countermeasures to minimize health and performance issues is continuing. Moreover, the focus of the research is shifting toward medical-prevention strategies, at least in the areas investigated to date. So one of the key strategies to address spaceflight-related conditions both in space and on Earth involves biomanufacturing research. The main areas of biomanufacturing include: **Regenerative Medicine, Organ Printing (3D bioprinting), and Drug Discovery.**

55% of U.S. space research is provided by **commercial** entities. This country is also the leading one in private space research. The current most effective way to establish private space initiatives is to use **CASIS** - the leading partner of NASA. But while there are a lot of upcoming commercial projects on the ISS, prices are going up significantly and have increased more than X10 since April 2021.

This creates a potential market for the emerging private sector and and has resulted in proposals to create commercial alternatives to the ISS. The current most likely companies to build private orbital facilities are **Axiom Space, Sierra Nevada Corporation, and Thales Alenia.** There is little doubt that as a result of a coming dramatic drop in the cost of getting to and operating in space, huge advancements in space health, for deep-space exploration, and even space settlements, will be advancing rapidly in the coming decade and decades.

About the Aging Analytics Agency

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The **Aging Analytics Agency** is primarily interested in strategic collaboration with international corporations, organizations, and governments in Longevity-related projects and initiatives.

The **Aging Analytics Agency** is open to cooperation with strategic clients via a variety of approaches, including:

- Conducting customized case studies, research, and analytics for internal (organizational) use, tailored to the precise needs of specific clients.
- Producing open-access analytical reports.
- Offering customised analysis using specialised interactive industry and technology databases and IT-Platforms.

In certain specific cases, if it meets our interests, the Aging Analytics Agency is open to co-sponsoring research and analytics for the production of internal and open-access industry reports, as well as special case studies for a variety of governmental, international, and corporate clients. Their topics of interest may include Longevity, the Longevity Financial Industry, Longevity Policy and Governance, and the development and execution of fully-integrated National Healthy Longevity Development Plans tailored to the specific needs of national governments and economies.

About SpaceTech Analytics

SpaceTech Analytics

SpaceTech Analytics is a strategic analytics agency focused on markets in the Space Exploration, Spaceflight, Space Medicine, and Satellite Tech industries.

Its range of activities includes conducting research and analysis on major areas of high potential in the SpaceTech industry; maintaining profiling of companies and government agencies based on their innovation potential and business activity; and providing consulting and analytical services to advance the Space Tech sector.

Our IT-Platform is designed to make key strategic recommendations and guidance regarding space-related technologies and techniques within reach of companies, other entities, and nations to assist them in optimising their action plans and strategies, providing specialized guidelines for business, and making core investment decisions.

About FemTech Analytics

FemTech Analytics

FemTech Analytics is a strategic analytical agency focused on relatively young yet already treated as the next big market disruptor FemTech market, which embraces the cornerstone sub sectors such as Longevity for women, Mental Health & Healthy Lifestyle, Reproductive Health, and General Healthcare. The range of activities includes research and in-depth analysis on major areas of high potential in the FemTech industry, maintaining profiling of companies and governmental agencies based on their innovation potential and business activity, and providing consulting and analytical services to advance the FemTech sector.

Our IT-Platform is designed to make key strategic recommendations and guidance regarding female-related technologies and techniques, within the reach of companies, other entities, and nations, in order to assist them in optimizing their action plans and strategies, providing specialized guidelines for business, and investment core decisions.

Introduction the new home for SpaceTech:

SpaceTech Analytics: Dashboard

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SpaceTech Analytics

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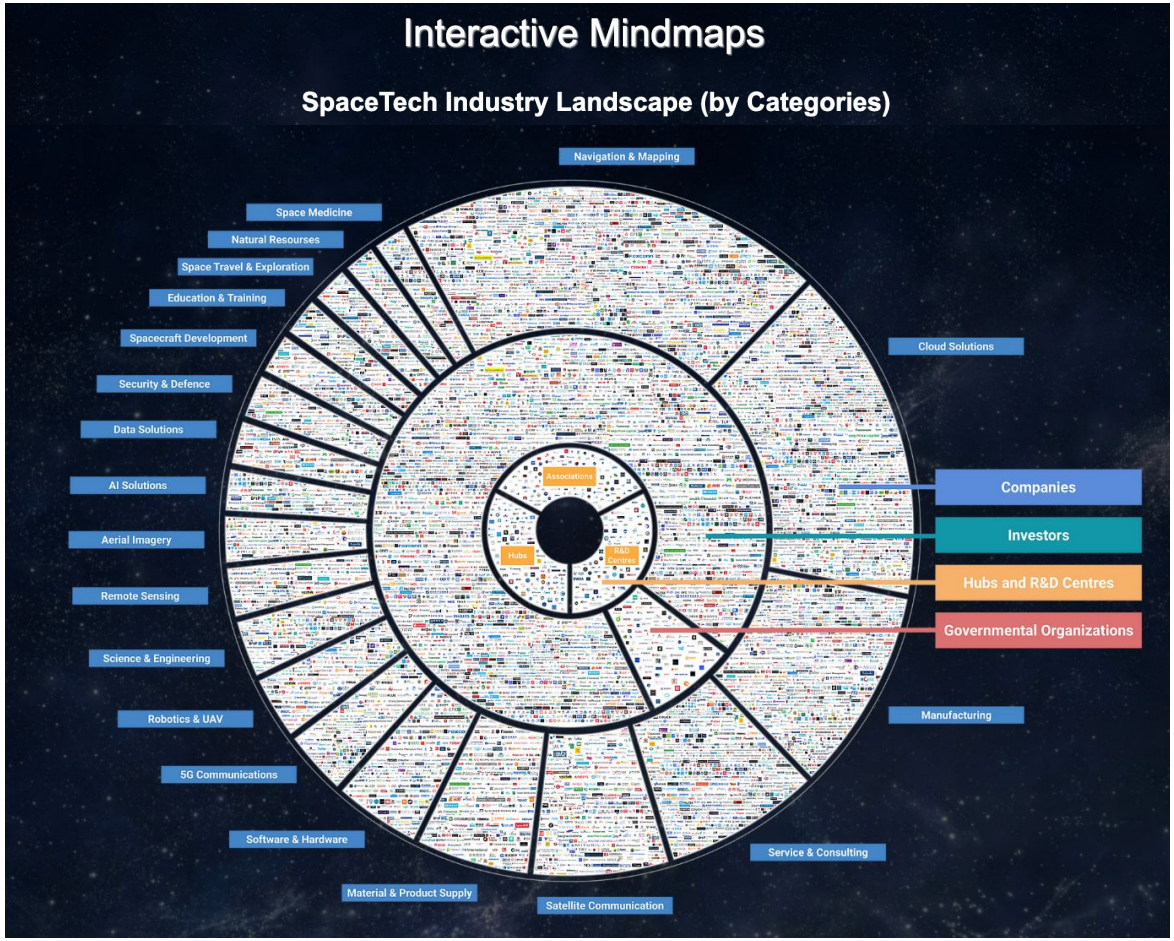
SpaceTech Interactive Mind Map



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Cloud Solutions
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5G Communications
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Science & Engineering

Remote Sensing
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SpaceTech Interactive Mind Map

SpaceTech Analytics: Report

SpaceTech Analytics

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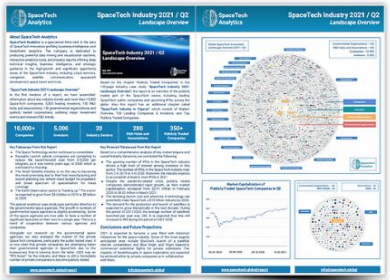

Teaser 30 Pages

This 165-page "SpaceTech Industry 2021 Landscape Overview" report marks the first installment in a series of reports on the topic of the space industry.

The main aim of this series of reports is to provide a comprehensive overview of the industry landscape. This overview highlights SpaceTech cooperation trends in a form of informative mindmaps and infographics as well as benchmarks the performance of key players that form the space and relations within the industry. This is an overview analysis to help the reader understand what is happening in the industry nowadays and possibly give an idea of what is waiting for it in the nearest future.

We assume the presence of minor inaccuracies in the first iteration of the project, which will be corrected in future releases.

See full report at SpaceTech Analytics: Dashboard

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