LAWRENCE, EVANS & CO., LLC

Investment Banking | Healthcare Finance | Consulting

BIOASTRONAUTICS

The Future of Healthcare

August 2024

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WHAT IS BIOASTRONAUTICS?

Bioastronautics is the study of the biological and medical challenges associated with space travel and the human body's adaptation to space environments. It encompasses a wide range of disciplines, including physiology, medicine, psychology, and engineering, to ensure better health, safety, and performance of astronauts during space missions.

Physiological Effects of Microgravity

Understanding how the lack of gravity affects muscle and bone loss, cardiovascular function, and other bodily systems.

Radiation Exposure

Radiation exposure in space poses significant health risks, including increased cancer risk, DNA damage, and acute radiation syndrome.

Space Medicine

Developing medical protocols and technologies for diagnosing and treating illnesses and injuries in space.

Psychological and Behavioral Health

Addressing the mental health challenges of living in confined, isolated environments for extended periods.

Life Support Systems

Designing systems to provide air, water, food, and waste management in space.

Extended Shelf-life Pharmaceuticals for Space Missions

Long-duration space flights require pharmaceuticals with extended shelf lives due to resupply limitations.

BIOLOGICAL SPACE FLIGHT RISKS

Bone and Muscle Degeneration

Microgravity leads to a lack of mechanical stress on bones and muscles, causing significant bone density loss (osteopenia/osteoporosis) and muscle atrophy.

Radiation-Induced Health Risks

Cosmic radiation in the space heightens health risks, increasing cancer, cardiovascular disease, cataracts, and potential acute radiation sickness susceptibility for astronauts during extended missions.

Cardiovascular and Circulatory Issues

The redistribution of bodily fluids and exposure to microgravity affects cardiovascular function and blood circulation.

Psychological and Cognitive Challenges

Isolation and confinement in space missions can lead to anxiety, depression, cognitive decline, and behavioral issues.

Spaceflight-Associated Neuro-ocular Syndrome (SANS)

Microgravity-induced fluid shifts increase intracranial pressure, impacting the optic nerve and eye shape.

Sleep Disruption and Circadian Rhythm Disturbances

Lack of natural light cycles and constant artificial lighting in space disrupt sleep patterns and circadian rhythms.

Immune System Dysregulation and Microbiome Alterations

The space environment, including microgravity and radiation, disrupts immune function and alters the human microbiome.

Metabolic and Endocrine Changes

Spaceflight impacts the body's metabolic processes and endocrine system due to altered physical activity, diet, and microgravity.

Source: www.nature.com/articles/s41526-024-00354-y

MARKET OVERVIEW – Space Medicine Market

The global space medicine market was valued at **$770M** in 2023 and is projected to reach **$1.6B** by 2030, growing at a CAGR of 11%.

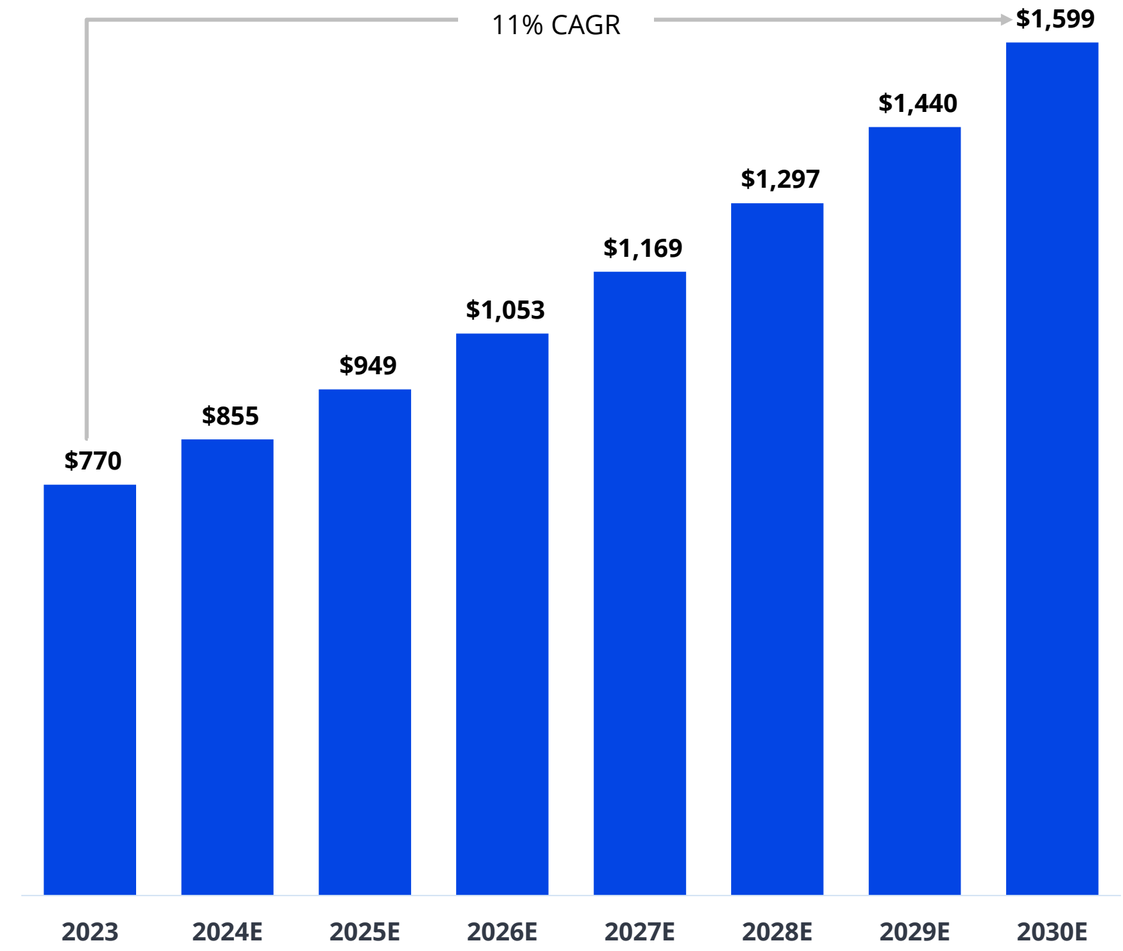
North America leads the market with NASA and strong healthcare, while **Europe** follows with space tourism and satellite communication advancements .

The **growth in space exploration and commercialization**, along with **technological advancements**, is driving demand and opportunities for space medicine solutions.

It requires **substantial investment** in R&D for zero-gravity applications, while navigating **complex international safety standards and regulatory hurdles**.

Developing countries' expanding space programs and **increased global funding in private space exploration** provide huge opportunities in space medicine technologies.

Global Space Medicine Market Size ($M)



Source: Coherent Market Insights

MARKET OVERVIEW – HISTORICAL SPACE LAUNCHES

Phase 1: The Space Race and Early Exploration (1950s-1970s)

Cold War Competition and Human Spaceflight Milestones: The 1950s launched the Space Race between the U.S. and the Soviet Union, driven by Cold War tensions and the quest for technological dominance. In 1961, Yuri Gagarin became the first human to orbit Earth, with the U.S. responding through its Apollo program.

Phase 2: Expansion of Scientific and Robotic Missions (1970s-1990s)

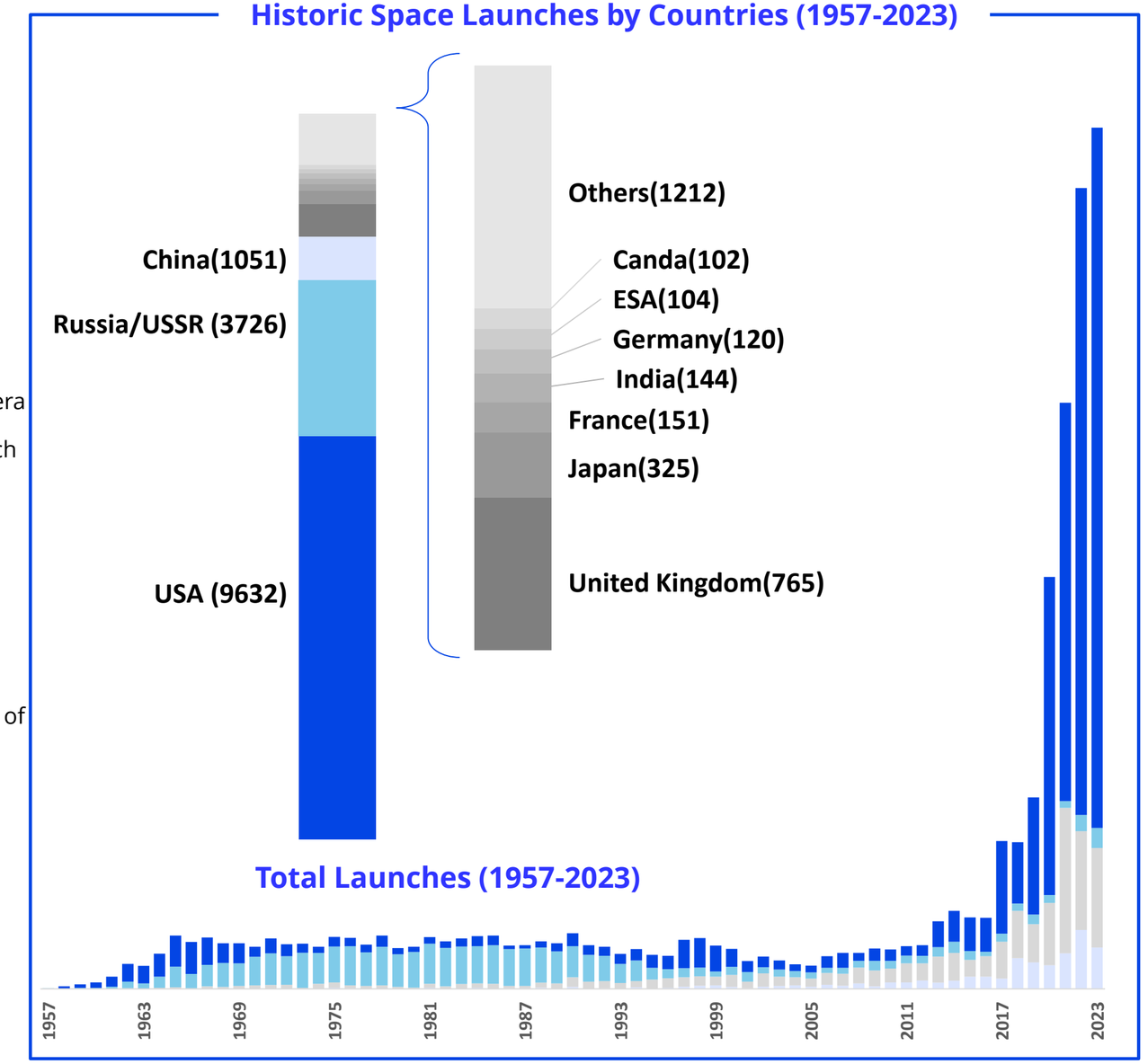
Robotic Exploration and Long-Term Human Presence: NASA's focus shifted to robotic exploration after initial manned missions, including the Viking missions to Mars, Voyager probes, and Soviet Venera missions in the 1970s. These efforts expanded knowledge of the solar system and included the launch of space stations during the same period.

Phase 3: International Collaboration and the ISS (1990s-2010s)

International Space Station (ISS) and Rise of New Space Nations: In the 1990s and early 2000s, international collaboration in space peaked with the ISS, while nations like China, India, and Japan advanced their space programs, launching satellites and planning missions, marking a significant era of global space exploration and technological development.

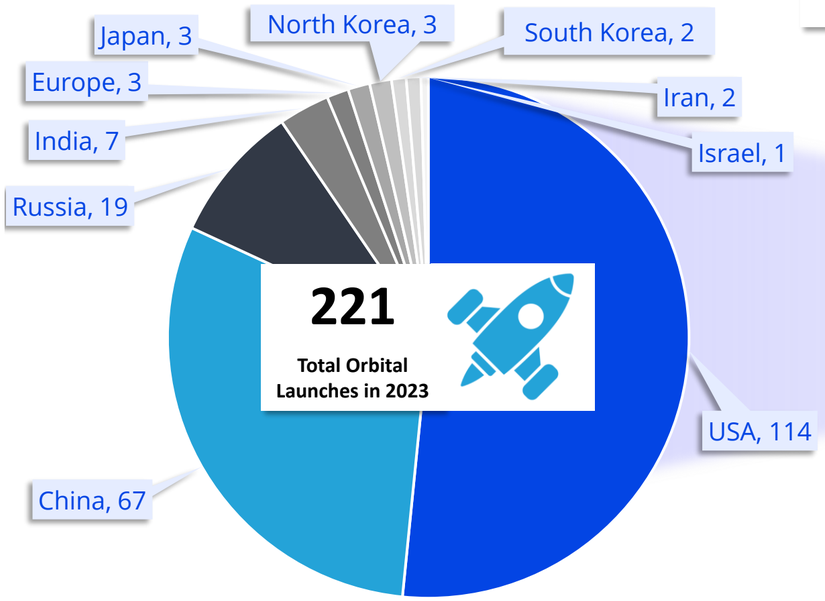
Phase 4: Commercialization and Deep Space Ambitions (2010s-2024)

Private Sector Involvement and Deep Space Exploration: After 2010s, private companies like SpaceX and Blue Origin advanced space exploration by developing reusable rockets, lowering launch costs, and pioneering missions to Mars, lunar bases, and asteroid mining, marking their rise as key players in space exploration.

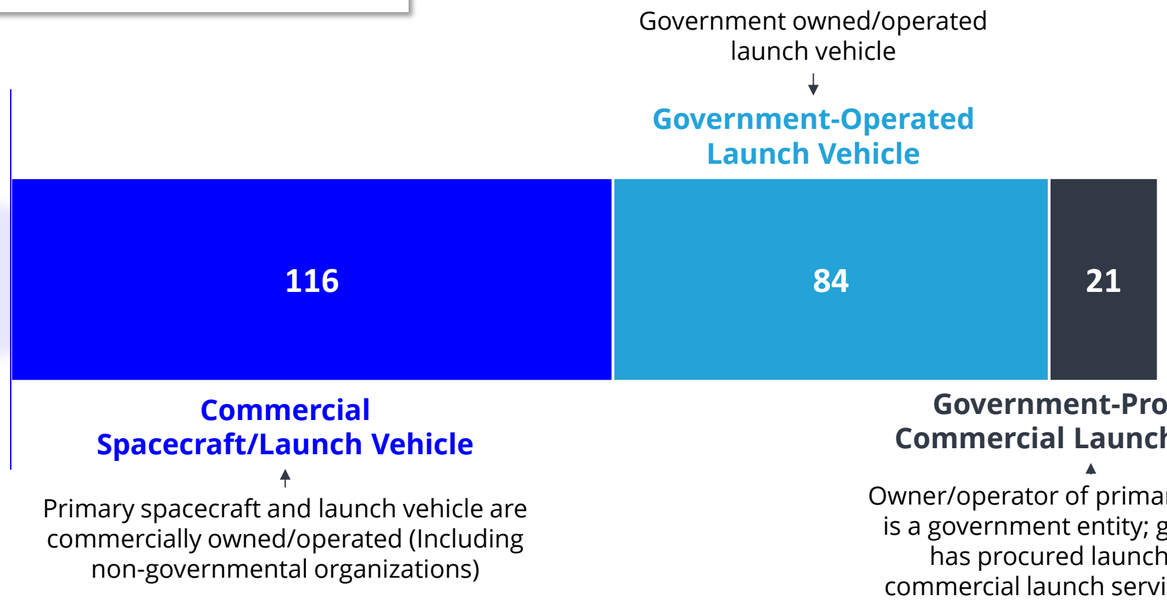


MARKET OVERVIEW: 2023 ORBITAL LAUNCHES - PUBLIC VS. PRIVATE

2023 Orbital Launches Year in Review



Total Orbital Launches Breakdown by Government/ Commercial



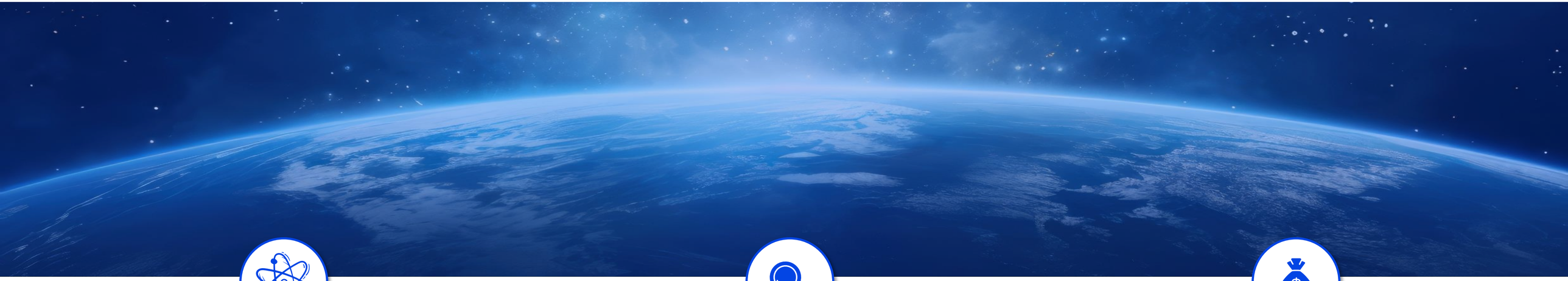
Surge in Demand for Orbital Launches

Expanding Satellite Applications: The demand for orbital launches has surged due to the rapid growth in satellite-based services, including global communication, Earth observation, and navigation systems. **End-of-life satellite disposal** - 219 total satellites became inactive in 2023; 508 GEO satellites in a graveyard orbit, including 25 added in 2023

It's about the Destination, not the Journey: Low Earth Orbit (LEO) remains the hottest destination with over 80% of successful launches deploying payloads there. Many companies and agencies are deploying constellations like SpaceX's **Starlink (>4,000 Starlink satellites now in orbit)** and SDA's Proliferated **Warfighter Satellite Architecture**.

SpaceX's Record-Breaking Year: SpaceX closed 2023 with a record-breaking **98 launches**, marking the company's busiest year yet. This achievement underscores SpaceX's dominance in the commercial space sector, driven by its highly reliable Falcon 9 rocket, which has become the workhorse for both government and private missions.

MARKET DRIVERS



Scientific Innovation

Innovations in medical devices, telemedicine, and diagnostics are enhancing the capability to monitor and manage astronauts' health in space. This ensures timely medical intervention and improved well-being of astronauts during space missions. These innovations drive the success and safety of human space exploration.

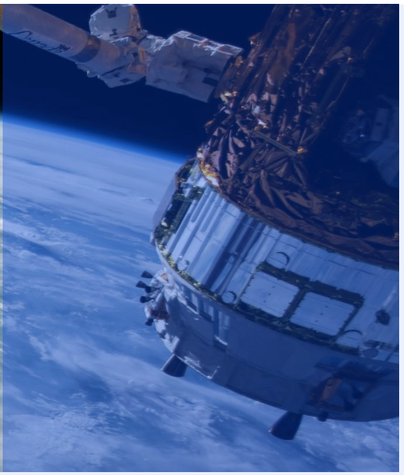
Space Exploration

The increasing number of space missions by government agencies (such as NASA, ESA, and CNSA) and private companies (such as SpaceX, Blue Origin, and Virgin Galactic) is driving the need for advancements in space medicine to ensure the health and safety of astronauts and space tourists.

Commercialization of Space

Private companies are working commercial flights such as suborbital and orbital flights to make space travel accessible to individuals. The microgravity environment in space allows for production of materials and products that are impossible or less efficient to create on Earth. This includes high-precision materials such as fiber optics, pharmaceuticals, and advanced alloys.

NASA’S BIOLOGICAL AND PHYSICAL SCIENCES (BPS)



NASA's BPS Harnesses Spaceflight for Unique Research

In 2020, NASA moved biological and physical sciences research under the Science Mission Directorate to leverage spaceflight for studying phenomena unachievable on the Earth.

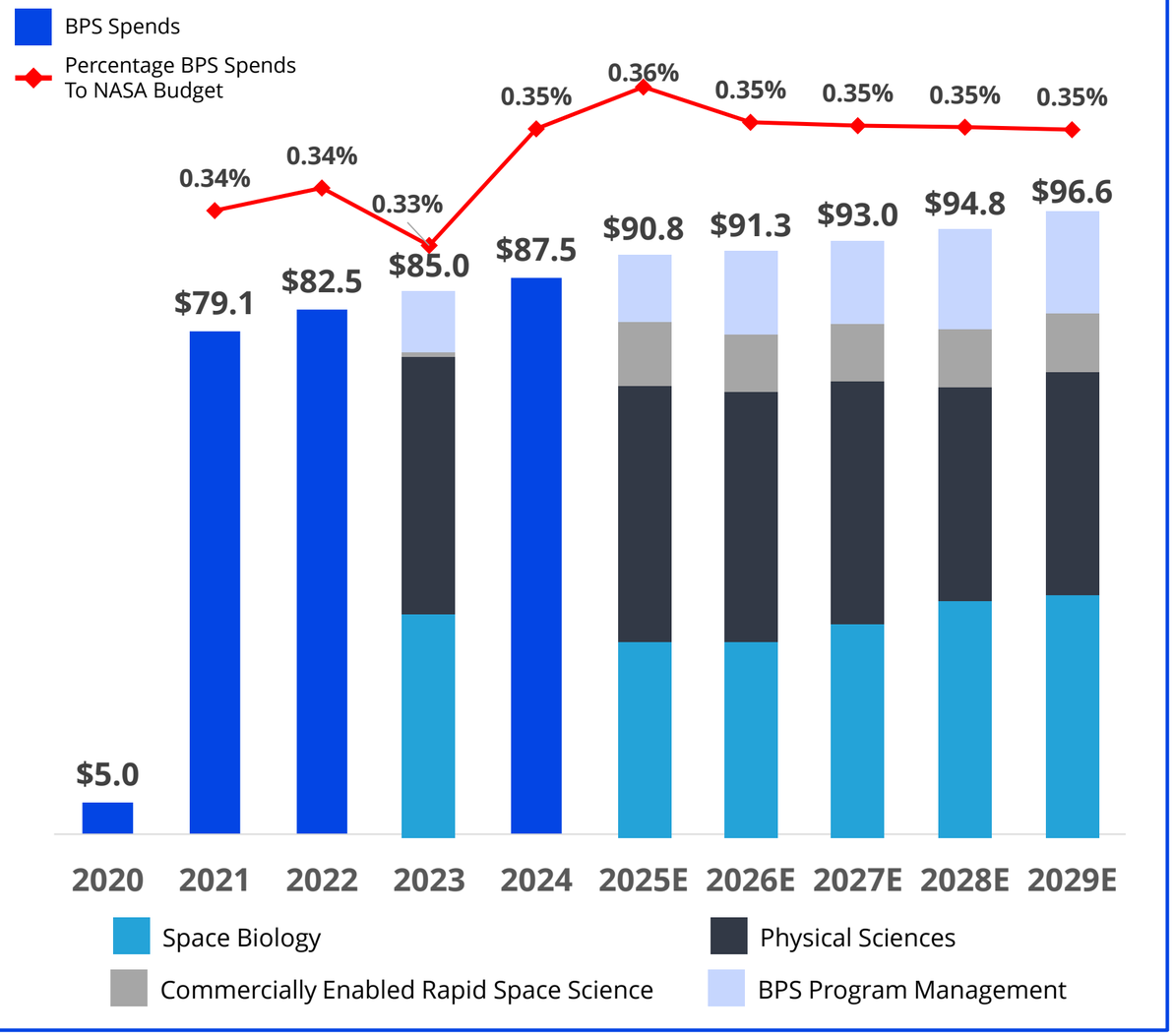
After years of research, $5M was allocated to the BPS program in 2020, followed by a commitment of approximately 0.35% of NASA's budget each year to further boost research grants, enhance the use of the ISS, and support human spaceflight as well as the commercialization of Low Earth Orbit.

BPS has four division of focus:

1. **Space Biology**: This explores how living organisms adapt and evolve in space, focusing on microbes such as viruses, bacteria, and fungi. The goal is to develop new treatments, tools, and countermeasures to address microbial behavior in the spaceflight environment.
2. **Physical Sciences:** The research aims to understand the fundamental laws of the universe and how physical systems behave in spaceflight environments. For instance, BPS researchers study space combustion to enhance fuel efficiency and reduce pollutant emissions.
3. **Commercially Enabled Rapid Space Science Initiative:** This aims to accelerate research by partnering with the commercial space industry, enabling scientist astronaut missions on the ISS and LEO destinations, and developing automated hardware for experiments beyond Low Earth orbit.
4. **BPS Program Management:** This project supports BPS's institutional activities, including peer reviews, National Academies studies, NASA Postdoctoral Fellowships, IT, communications, and administrative tasks, alongside research and educational support services.

Source: NASA Update and Initial Decadal Survey Response

NASA Biological and Physical Sciences (BPS) Spends ($M)



TELEMEDICINE: DELIVERING CARE

Communication Systems

Spacecrafts are equipped with high-speed communication systems that enable real-time or near real-time transmission of data and video between astronauts and Earth-based medical teams.

Medical Protocols

Detailed medical protocols are developed for common issues and astronauts are trained to follow these procedures while waiting for remote guidance.

Challenges

Depending on the distance from the Earth, there may be communication delays ranging from a few seconds to several minutes, which can affect the timeliness of responses.

IN-SPACE PHARMACEUTICALS

The in-space pharmaceuticals market is an emerging sector that focuses on drug development and manufacturing in microgravity environments.

01
Enhanced Drug Efficacy
Microgravity allows for more efficient crystallization, improving drug stability and effectiveness.

02
Novel Drug Development
Space conditions can lead to the discovery of new molecular structures, enabling breakthrough therapies.

03
Reduced Contamination
The sterile environment of space minimizes contamination risks.

04
Biomanufacturing
Space-based biomanufacturing offers new opportunities for producing complex biologics.

05
Strategic Collaboration
Partnerships between space agencies and pharmaceutical companies are driving innovation in this market.

Major startups and companies are exploring advancements in space pharmaceuticals.

VARDA SPACE INDUSTRIES

A California-based startup focused on manufacturing pharmaceuticals in microgravity. It has launched test missions to develop drug ingredients in space.

REDWIRE

A space infrastructure company that collaborates with pharmaceutical companies such as Eli Lilly to explore in-space drug manufacturing.

AXIOM SPACE

South Korea's Boryung has invested $50M in Axiom Space's Series C funding, unlocking new opportunities for pharmaceutical discovery in space.

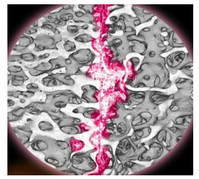
BioOrbit

BioOrbit Space is a research & development facility focused on biotechnology in space, advancing life sciences through microgravity experiments and space-based innovations.

TECHNOLOGICAL ADVANCEMENTS

Medical Concern	Hazards to Health in Space	Technical Solutions
Early detection and treatment of mental health and cognitive issues	Stress, fatigue, radiation-induced changes in mental health, and cognitive functions such as processing speed and performance	Wearable brain imaging monitors such as NINscan, which is a portable device for noninvasive monitoring of cerebral oxygenation
Early detection and treatment of non-emergent medical conditions	Loading injuries, pain syndromes, and vascular flow alterations	Portable imaging and blood analysis devices such as OCT-A that noninvasively detects blood flow and noninvasive inertial measurement unit (IMU) arrays to collect data for movements and postures
Treatment of medical emergencies	Bone fractures, cardiac arrest, hemorrhage, and sepsis	Using extended reality for medical guidance and real time clinical and operational support
Radiation exposure	Cosmic radiation is a catalyst for diseases and malignancy	Personal protective equipment such as AstroRad, which is a vest that protects astronauts beyond Low Earth Orbit from radiation

COMPANIES INVESTING IN SPACE

Company		Product
PlenOptika		PlenOptika QuickSee is a portable binocular autorefractor to measure refractive errors and changes over time.
1Drop Diagnostics		The portable 1Drop Health Reader analyzes biomarkers and the data is accessible by smartphones, tablets, or computers.
Virtual Incision		Miniaturized surgical robot.
Redwire Space		The BioFabrication Facility is a 3D bioprinter to print human tissues in space.
RevBio		Tetranite, a bone adhesive, can hold bones together to start the repairing process.

COMPANIES INVESTING IN SPACE CONT.

Starlab is a Low Earth Orbit commercial space station that will replace the ISS and is scheduled to launch in late 2028/early 2029.

Voyager has been awarded with over $217M through the Space Act Agreement and tasked with continuing human presence and American leader in Low Earth Orbit.

Airbus delivers engineering and design services for the Starlab space station.

MDA Space supplies a wide variety of external robotics, robotic interfaces and robotic mission operations to the station.

Hilton is developing the space hospitality crew quarters on Starlab, which includes communal areas, hospitality suites, and sleeping arrangements for astronauts.

Mitsubishi Corporation is using space research to advance terrestrial product development.

Palantir provides enterprise-wide software data management solutions for the Starlab Space Station.

Northrop Grumman is developing autonomous docking technology for the Cygnus spacecraft to provide cargo resupply services for Starlab.

Ohio State hosts the terrestrial analog of the George Washington Carver Science Park. This will be a replica of the Starlab Space Station science park.

FUNDING OPPORTUNITIES

Funding Source	Description
NASA • **ROSES** https://solicitation.nasaprs.com/ROSES2024	Through the ROSES program, NASA will award different sized monetary amounts from about $5K to multi year contributions of millions of dollars.
NASA • **Human Research Program** https://www.nasa.gov/hrp/	HRP uses research to develop methods to protect the health and performance of astronauts in space. With the goal of traveling to Mars and beyond, HRP is using ground research facilities, the International Space Station, and analog environments to enable cutting-edge science. $154 M NASA budget in 2024
Translational Research Institute for Space Health Research https://spacehealth.bcm.edu/prog/catalyst_2024_program	The Catalyst Grants program offers funding for research in the space health field. Tier 1 projects receive a maximum amount of less than $150k with limitations of 1 year. Tier 2 projects can receive a total amount of more than $150k with limitations up to 2 years.
National Institutes of Health https://commonfund.nih.gov/funding-opportunities	The NIH grants money for health-related research through the Common Fund Programs. Distributions are given every year for research in areas outlined in the programs.

SPACE POLICY AND REGULATION

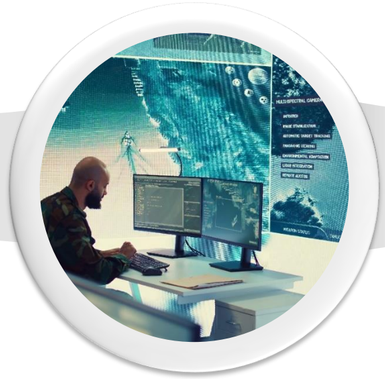
In the U.S., as it pertains to astronaut health, mission safety, and other operational aspects, NASA is responsible for policy implementation. For policies related to military space operations and national security, the Department of Defense is in charge of enforcement. The Department of Commerce oversees commercial space activities to ensure commercial space operation compliance.

NPR 8900.1B - NASA Health and Medical Requirements for Human Exploration

This directive defines standards for physiological and cognitive requirements for human space flight and applies to all NASA human space flight programs and NASA-contracted human space flight programs.

NPD 8900.3 - NASA Astronaut Medical and Dental Observation Study and Care Program

This NASA policy states that it is the responsibility of NASA to provide medical care, dental care, and occupational monitoring to astronauts, payload specialists, and other space flight participants when they are on active duty with NASA.



SPD - 5: Cybersecurity Principles for Space Systems

SPD - 5 provides key guidance on the security of space assets and supporting infrastructure from potential cyber attacks.

SPD-41a - Open science policy for NASA-funded research

SPD-41a is NASA's policy mandating open access to SMD-funded research publications, data, and software, ensuring immediate public availability without embargo. It enhances transparency, encourages collaboration, and aligns with federal guidelines for open science practices

CONCLUSION

Medical and Scientific Discoveries

Breakthroughs and inventions are the driving force for innovation.

Nex-Gen systems will be able to facilitate life not only on space transportation vehicles but on other planets as well.

Next-Generation Technology

Space Exploration

Overcoming biological and environmental obstacles allows for missions deeper into space.

Humanity has an insatiable desire for knowledge. The universe holds answers to the fundamental principles that govern existence.

Satisfy the Human Need for More Knowledge

Market Opportunities

Strong space market dynamics will drive over 11% CAGR, propelled by increasing commercialization in the sector.

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- Space Flight Risk - https://www.nature.com/articles/s41526-022-00193-9
- Voyager Space https://voyagerspace.com/starlab/
- BRAX Space – JV w/ Axiom Space and Boryung - https://www.axiomspace.com/news/boryung-brax

NASA

- NASA Human Research Program https://www.nasa.gov/hrp/
- NASA Budget 2025 - https://www.nasa.gov/fy-2025-budget-request/
- NASA Budget 2024 - https://www.nasa.gov/nasa-fiscal-year-2024-budget-request/
- NASA Budger 2023 - https://www.nasa.gov/wp-content/uploads/2023/07/nasa-fy-2023-budget-request-summary.pdf
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- NASA Budget 2020 - https://www.nasa.gov/organizations/budget-annual-reports/fy-2020-budget-request/
- BPS Info - https://nap.nationalacademies.org/catalog/26750/thriving-in-space-ensuring-the-future-of-biological-and-physical
- BPS Divison - https://science.nasa.gov/wp-content/uploads/2024/03/final-2024-03-20-cbpss-carnell.pdf
- NASA Research Opportunities in Space and Earth Sciences (ROSES) - https://solicitation.nasaprs.com/ROSES2024

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- The International Space Station ISS is the result of a partnership between five space agencies: NASA (United States), Roscosmos (Russia), JAXA (Japan), ESA (Europe) and CSA (Canada). The ISS has been continuously occupied by humans since 2000, making it the longest-occupied space station in history. On any given day, an average of seven astronauts are living and working in space. https://www.nasa.gov/international-space-station/
- Space Omics and Medical Atlas (SOMA) across orbits https://www.nature.com/immersive/d42859-024-00009-8/index.html
- Second Space Age spanning omics, platforms and medicine across orbits https://www.nature.com/articles/s41586-024-07586-8
- Bio Orbit - https://www.ukri.org/news/uk-start-up-to-develop-tech-for-pharma-factory-in-space/
- Redwire Eli lilly- https://redwirespace.com/newsroom/redwire-announces-first-spaceflight-mission-for-new-cutting-edge-pharmaceutical-drug-development-lab-partnering-with-eli-lilly-and-company-to-expand-space-research-to-study-heart-disease-and-diabetes/
- BioAstra – nonprofit for research & scientific standards for the future of off-planet healthcare https://www.bioastra.org/
- Mohammad Bin Rashid Space Centre (MBRSC) https://www.mbrsc.ae/
- Varda - https://www.foxweather.com/earth-space/pharmaceuticals-made-in-space-varda

SELECT RESEARCH UNIVERSITIES

- The Ohio State University involvement Starlab –https://convergence.osu.edu/gwcsp/about
- Baylor College of Medicine Center for Space Medicine –https://www.bcm.edu/academic-centers/space-medicine
- Berkeley Space Center at NASA Research Park https://berkeleyspacecenter.com/
- Weill Cornell Medicine https://news.weill.cornell.edu/news/2024/06/commercial-astronauts-shed-light-on-flights%E2%80%99-health-impacts-and-create-spaceflight

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- Turnaround Management
- Debt Restructuring/ Refinancing
- Orderly Liquidations
- Chief Restructuring Officer (CRO)
- Bankruptcy Planning/ 363 Sales
- Receivership/ Trustee

Special Contribution by:

Anthony Mandravellos (Analyst)

Andrew Moulas (Analyst)

Shivam Nag (Associate)

Contact Us

Neil Johnson
Managing Partner

Email
njohnson@lawrenceevans.com

Phone
(614) 448-1304

Address
88 E Broad St, Suite 1750
Columbus, OH 43215