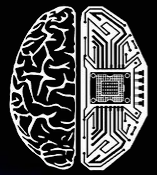
Giving Birth in Space Teaser

Q3 2021



SpaceTech Analytics

SPACEBORN UNITED

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SpaceTech Analytics and SpaceBorn United - Joint Report

SpaceBorn United is a bio-tech company that researches and enables the conditions for human reproduction in space.

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

"If humanity wants to become a multi-planetary species, we also need to learn how to reproduce in space."

- Dr. Egbert Edelbroek - CEO of SpaceBorn United

This report is a joint initiative of the SpaceBorn United - Netherlands based a biotech company that researches and enables the conditions for human reproduction in space.

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The first chapter covers the issue of **giving birth on Mars with women in the center of attention**. The first part of the chapter describes the past experience about female participation in space exploration and their adaptation to space. Predominantly, it is based on NASA experience and observations. However, the US has never had a serious policy to actually settle space. Consequently, very little research has been done on the ability of humans to procreate in altered gravity environments.

The second part outlines current advancements in the field of space settlement and birth on Mars. Starting with defining **the core risks related to space settlement and pregnancy**, it further provides a brief overview of **spaceflight, space medicine, and other technologies under development**. Likewise, the summary of birth-in-space animal experiments is included. Nevertheless, birth-in-space animal experiments results are too far from allowing us to make even approximate generalizations of human childbirth in space.

The third part acquaints with the **future projections of the different space settlement plans**. It involves a discussion about hypothetical ethical and physiological issues related to birth on Mars. Particularly, the Mars maternity hospital is discussed together with some notions of planet terraforming.

Our Approach

Database

Identification of relevant:

- Companies,
- Investors,
- Universities & Research Centers,
- Government Ministries, Departments & Agencies,
- Space Associations,

that operate, interact with or are somehow involved in the question of the human reproduction in space.

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	Industry Leaders Interviews

Relying on various research methods and analytics techniques, the report provides a comprehensive overview of the space industry.This approach has certain limitations, especially when it comes to the leveraging of publicly available data sources and secondary research. SpaceTech Analytics is not responsible for the quality of the secondary data presented herein; however, we do our best to eliminate the said risks by using different analytical 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. As for the Investors in the main database we include only institutional ones those who've invested in SpaceTech companies or SpaceTech-related companies. SpaceTech companies included in the database are those that are directly in the SpaceTech industry, or partially belong to it through working with clients from the SpaceTech industry, or there are separate departments in the company that work in this sector or cooperate with clients from it.

Reproduction in Space: Major Trends and Features

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
- Past Experience Overview
- Women's Adaptation to Space
- Current Advances: Space Medicine, Birth-in-Space, Spaceflight
- Startups and Collaborations to Solve the Challenges
- Future Projections and Developments
- Key Takeaways

We Lack Data about Effects of Spaceflight on Women

The groups observed that the disparity of spaceflight data available for men and women who have flown in space – **477 men vs. 57 women as of June 2013** – makes it difficult to derive concrete conclusions based on sex and gender alone. In the latest crew selection, NASA selected eight astronauts, comprising four women and four men.

The Sex & Gender work groups released five recommendations:

- Encourage and facilitate the participation of more female and male subjects in both ground and flight research studies.
- Focus on the responses of individual astronauts to spaceflight and return to Earth.
- Include sex and gender factors in the design of the experiments.
- Incorporate sex and gender and other individual risk factors into NASA-funded research programs

The 2013 astronaut candidate class, shown here in front of a Orion crew capsule mockup, comprises four women and four men

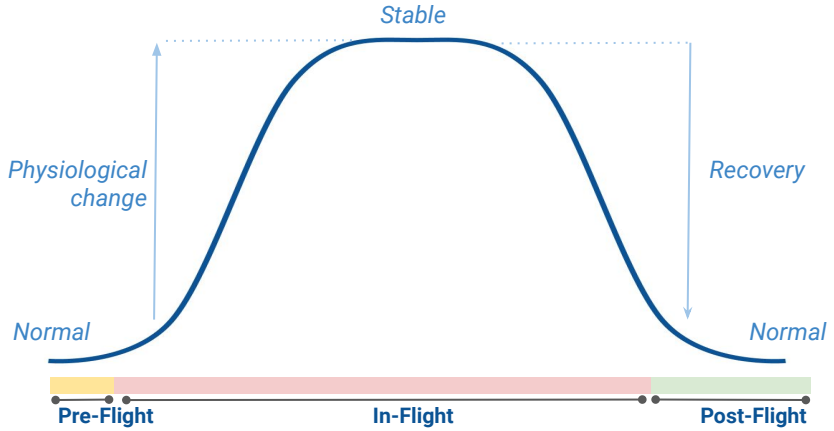
"This is the first major integrated examination of the issues of sex and gender in relationship to space exploration," said Dr. Mark Shelhamer, Chief Scientist for NASA's Human Research Program at Johnson Space Center.

Source: NASA

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 in 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

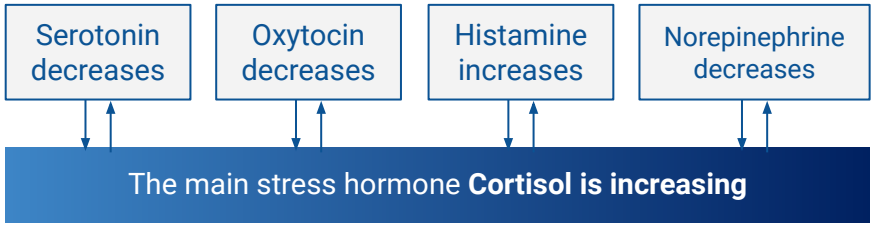
Astronauts' rate of lower limb bone loss is 0.8%.

Changes in microbiome taxa richness and antimicrobial resistance markers

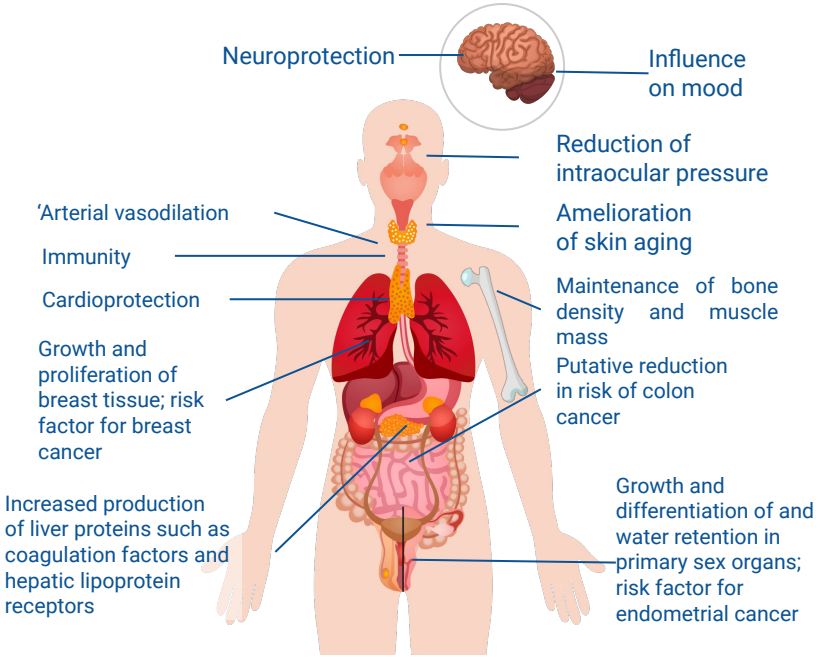
Source: JAXA

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.

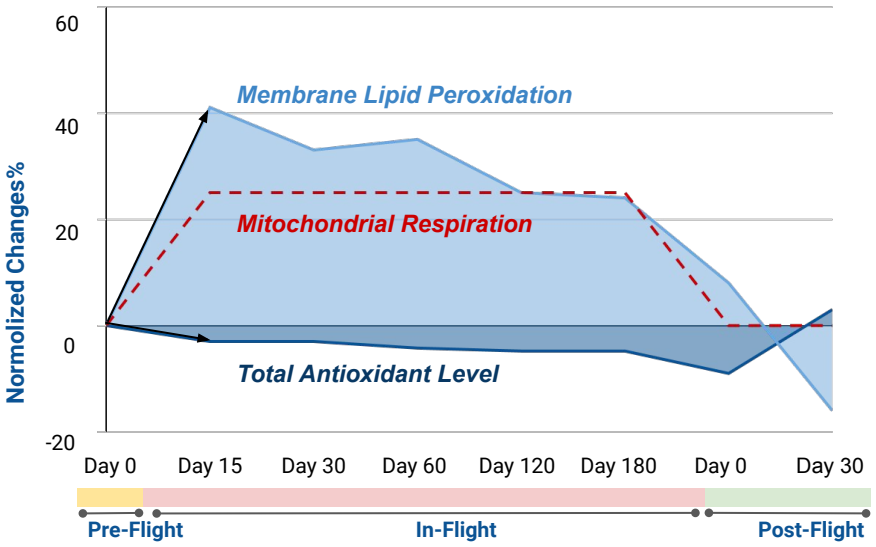


Studies have shown age-related changes in estrogen-receptor signaling to many vital organ systems, as is shown in the figure. Some of these systems had similar alterations in experiments on animals during spaceflight. **Decreasing the level of estrogen** as a result of hypo-gravitational and weightless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

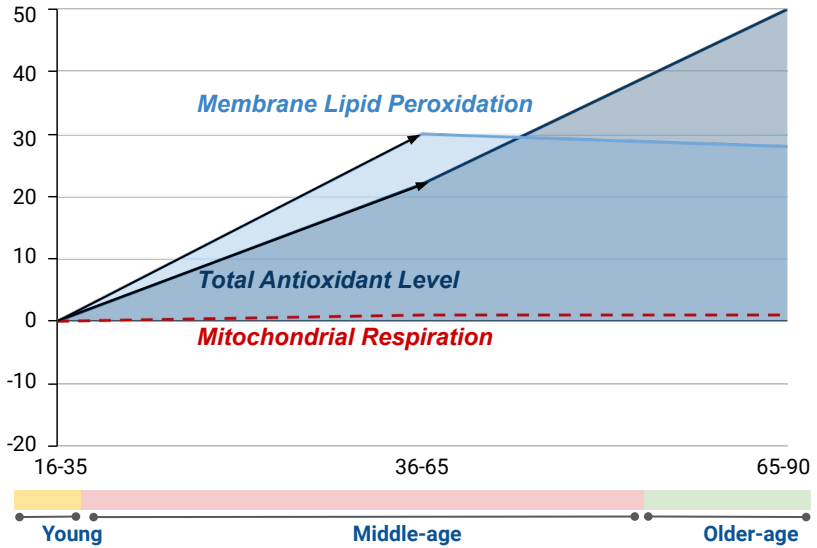
Source: Effects of Sex and Gender on Adaptations to Space: Reproductive Health by April E. Ronca, PhD and others

Mitochondrial Respiration and Redox Status in Astronauts vs. Aging

Astronauts: Alterations of Antioxidant Status



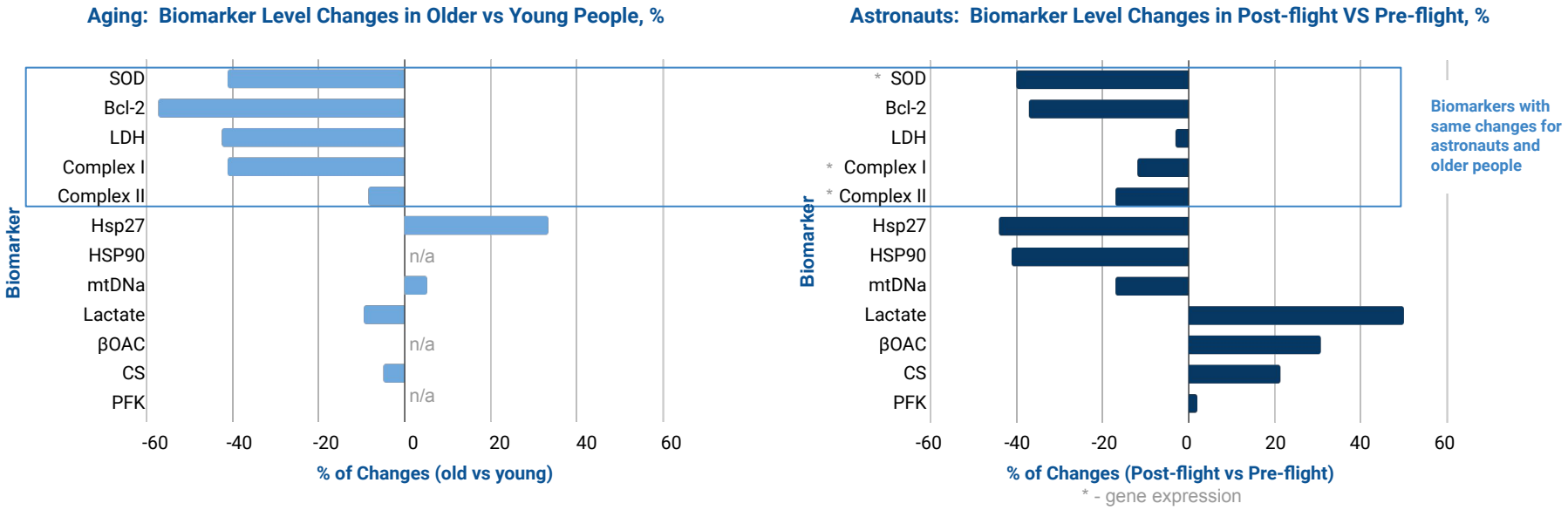
Healthy Aging: Alterations of Antioxidant Status



Long spaceflight leads to **~25% activation of mitochondrial respiration** and **~30% growth of membrane lipid peroxidation** in comparison with peroxidation level before flight. The **antioxidant level in astronauts is 4-10% lower** in space flight than 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 level of antioxidants and there are no any changes in mitochondrial respiration.

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

Mitochondrial Biomarkers Changes: Space Flights vs. Aging



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.

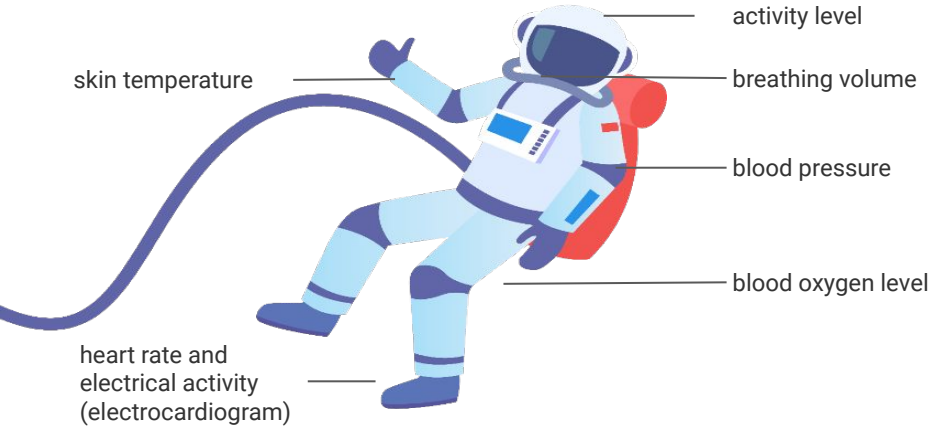
Source: Mitochondria in Longevity and Space Medicine

Implementation of AI in Space Health - Non-Invasive Techniques

Wearable technologies for non-invasive health-monitoring systems has been in use for a long time. Today, it incorporates Artificial Intelligence (AI) for real-time tracking of astronaut 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.

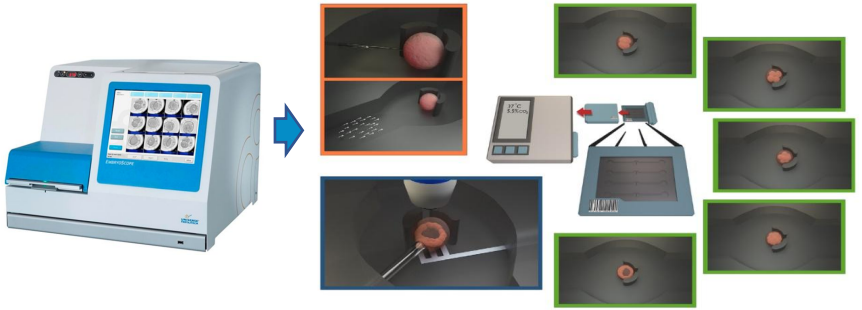
Source: Nora M. Haney et al., 2020

Biotech/ research company plans for conception in LEO

SpaceBorn United (SBU), a Dutch biotech/ research company researches the conditions for each stage of human reproduction in space. SBU translates the research outcomes into a missions program with execution partners and they develop the biomedical devices required for these missions.

Their first step is to enable conception and early embryo development in LEO. A recoverable biosatellite, provides artificial gravity (1G), during a 6 day mission. Follow up missions aim to study embryo development in partial gravity environments (e.g. Mars level).

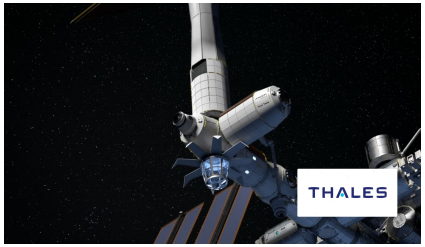
> "SBU is currently focused at developing ARTIS: assisted reproductive technology in space, by re-engineering existing IVF technology. We optimise and extend functionalities of existing embryo incubators to function as a life support system in space. We therefore apply microfluidic- and cryogenic technology and add adjustable artificial gravity" explained CEO Dr. Edelbroek.



Studying conception and embryo development in partial gravity is essential to understand the gravity requirements for this stage of reproduction. It fills crucial data gaps in existing research roadmaps enabling deep space exploration and becoming a multi-planetary species.

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 engineers for the **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

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 station 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 some conditions. This platform uses a picture 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 function from a small blood sample. On Earth, this tool can also be widely used because it detects the condition anywhere.

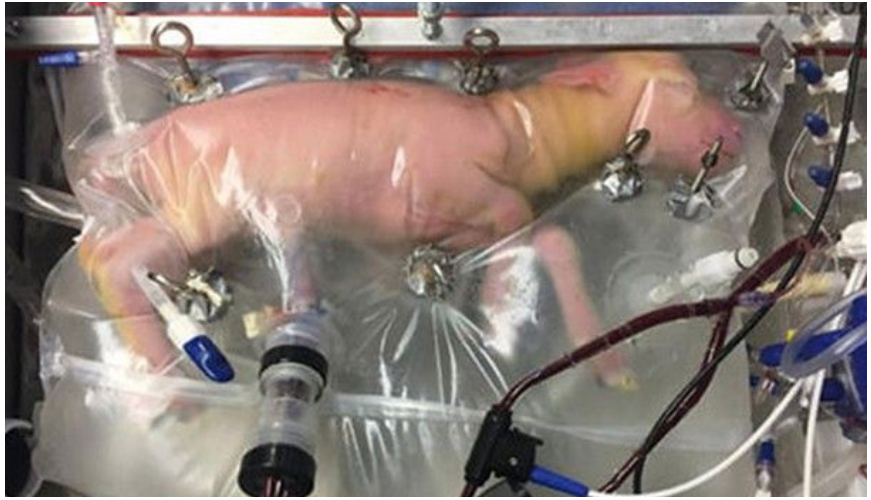
Sources: The Medical Futurist, Government of Canada, the Pharmaceutical Journal

The Coming Revolution in Postnatal Care

Since the Mars environment and spaceflight are fraught with infertility, recent advancements in postnatal care technologies can come to the rescue. These technologies are intended to solve fertility and birth issues on Earth but might be adapted to challenges of settling Mars.

Artificial wombs are designed to save babies born too soon, particularly to support preemies born as early as 21 weeks. The artificial-womb technology is moving to the point of development at which it will be possible to accept a fertilized egg and sustain it for an entire pregnancy.

A **“bio bag”** can mimic prenatal fluid to help give babies (born too early) extra weeks for their lungs to develop. It has been tested on fetal lambs. The next step in the development of artificial wombs is to provide the lambs with life support that doesn't require gas exchange through their lungs.



“We want to take the lung out of the equation.”

All these steps are on their way to total ectogenesis, but it is still at least decades away.

Sources: Neo.Life 1, Neo.Life 2

Academic Institutions Are Studying Space Medicine All Across The Globe

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)

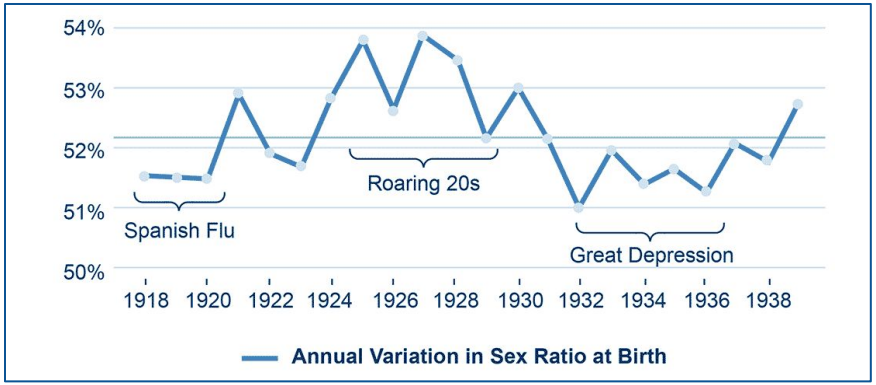
Source: PubMed

* Selected and categorized by the subject of their recent researches

There May Be Newborn Sex Biases off Planet

The space environment poses extreme challenges for humans. For example, **changes in the sleep cycle** can be counterproductive for astronauts, whose tasks range from a tight work schedule with hard cognitive tasks, to conducting experiments, or repairing satellites. This creates **additional pressure on an astronaut's mental health**. Settlers's lives will be difficult as well. Previous studies have shown that there are sex biases in environmentally challenging times.

For example, it is known, that **during such time periods** – the Spanish Flu (1918–20) and the Great Depression (1932–36) – relatively **fewer boys were born** relative to time periods of rapid economic and population growth and relative abundance of resources – such as the Roaring '20 s (1925–29). A similar situation might occur with the newborn sex ratio on Mars.



The likelihood of an **IVF** (in-vitro fertilization) birth resulting in a boy was between 53% and 56%, depending on how soon the fertilised egg was put back into the woman. In average, in every hundred births, **56 would be baby boys** and 44 would be girls. This compares with **49 boys** in every hundred births for **Intracytoplasmic sperm injection** and **51 boys** in every hundred births with **natural conception.** Due to the fact that Y chromosome-carrying sperm are lighter than X-carrying. This is an advantage for an *in-vitro* experiments, but not in the body.

Source:Nature Magazine

Key Takeaways

The report covered past experiences, current advancements, and future projections regarding giving birth in space. It appeared to be an extremely complicated topic requiring comprehensive analysis. The data gathered by NASA and other agencies for decades is not appropriate to make strong assumptions about the human ability to give birth on Mars.There are plenty of risks quite distinct from those professional astronauts are used to. Therefore, it requires completely new approaches to reach the goal of giving birth on Mars.

Nowadays, a lot of private companies and state space agencies worldwide are working on space settlement programs and cover a wide range of technologies from extracting oxygen and various metals in Martian and lunar surfaces to quantum telecommunication, artificial wombs, or new generation rockets. It reflects the paradigm turn from space exploration to space settlement. However, it is just the beginning with private companies ahead of the process.

Space radiation, weightlessness, Mars environment are hazardous factors for childbirth. Giving birth on Mars will become possible when all these factors are fully researched and resolved. Nevertheless, unexpected physiological, psychological, ethical challenges concerning birth on Mars will arise.Women are becoming more represented in the space industry (e.g. NASA space programs) and more data are collected on women health in space.

Mars settlement brings plenty of risks (radiation and weightlessness are the most serious among them) that can hazard women health, fertility, and embryo. Although experiments on animals show that birth beyond Earth is possible, pregnancy during spaceflight is fraught with harmful consequences.

The today's era of commercial space flights and habitable Low-Earth Orbit predisposes is accelerating the pace and necessity of experiments and related data concerning living and procreating in gravity environments. To reach Mars, the human body may need new and extra care: gene therapy, reproductive assistance, radioprotectors, advanced biomedical technologies and treatments, to increase chances of successful births and lives on Mars. Terraforming Mars may be required to create a safe child-friendly environment (e.g. artificial magnetosphere to provide an atmosphere providing radiation protection and oxygen).

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