Synergies Between Space Tech and Healthcare

1. Medical and Biomedical Research

The features of the space environment can greatly accelerate medical research and impact enhance our understanding of the human body and conditions. Firstly, there are many medical applications in the microgravity environment. The weightlessness and zero-g help better understand the human anatomy in areas such as:

Bone loss:

Spaceflight-induced bone loss provides valuable insights into the mechanisms behind osteoporosis and other bone-related disorders. During their time in space, astronauts can lose up to 1-2% of their bone mass per month, especially in weight-bearing bones such as the spine and pelvis. This accelerated bone loss has led to research into the underlying cellular mechanisms and potential countermeasures.

For example, scientists have discovered that microgravity decreases the activity of osteoblasts (bone-forming cells) while increasing the activity of osteoclasts (bone-resorbing cells). This knowledge has helped to develop new drugs targeting these cells, such as denosumab, which is now used for the treatment of osteoporosis on Earth. Additionally, NASA's Advanced Resistive Exercise Device (ARED) has been developed for astronauts to maintain their bone and muscle health during space missions, and similar devices are now being used in physical therapy and rehabilitation programs on Earth.

Muscle atrophy:

Microgravity also causes muscle atrophy in astronauts, which has led to a deeper understanding of muscle-related disorders and the development of new therapeutic strategies. Astronauts can lose up to 20% of their muscle mass during a 5–11-month space mission, particularly in the muscles of the lower limbs and back.

The study of muscle atrophy in space has contributed to the development of new treatments for muscle wasting conditions, such as sarcopenia and muscular dystrophy. For instance, the research on myostatin, a protein that inhibits muscle growth, has led to the development of drugs that block its activity, promoting muscle growth in patients with muscle-wasting diseases. One such drug, ACE-031, is currently in clinical trials for the treatment of Duchenne muscular dystrophy.

Immune system:

Spaceflight has been shown to have an impact on the immune system, offering valuable insights into immune system functioning and the development of new treatments for immune-related diseases. Studies have shown that astronauts immune systems can be suppressed during and after spaceflight, increasing their susceptibility to infections.

One example of space research benefitting Earth's healthcare is the study of T-cell activation in microgravity. T-cells are an essential part of the immune system, and their impaired function in space can lead to a weakened immune response. Researchers have discovered that microgravity affects the way T-cells are activated, leading to the development of new drugs that can enhance T-cell activation and potentially treat immune system disorders, such as autoimmune diseases and cancer.

The space environment is also having positive effects in term of biomedical research and development. This section contains cutting-edge applications of microgravity environment to enhance development of medicine.

Drug development:

Microgravity research has been instrumental in studying the behavior of proteins, cells, and other biological components, improving our understanding of drug development processes and leading to the creation of new medications. In microgravity, protein crystals can grow larger and more uniformly, allowing for more accurate structural analysis, which is crucial for drug development.

One example is the crystallization of a key protein involved in the progression of previously mentioned Duchenne muscular dystrophy. This protein's crystal structure was determined aboard the International Space Station (ISS), paving the way for the development of new targeted drugs to treat this devastating disease.

Tissue engineering:

The microgravity environment in space has allowed for the growth of three-dimensional tissues and organs, advancing the field of tissue engineering and regenerative medicine. In space, cells can aggregate and form structures that are more similar to those found in the human body, compared to the two-dimensional cell cultures typically used in laboratories on Earth.

For instance, researchers have successfully grown functional human liver tissue in microgravity, which could be used for drug testing, disease modeling, and eventually transplantation.

Bioprinting:

The European Space Agency (ESA) has developed a "bioprinter" capable of 3D printing human tissue in microgravity. This technology has the potential to revolutionize the field of regenerative medicine by enabling the creation of complex, functional tissues and organs. Bioprinting in microgravity can overcome some of the limitations associated with Earth-based bioprinting, such as the need for scaffolds to support delicate structures.
An example of this technology's potential is a project called "3D BioFabrication Facility" on the International Space Station (ISS), which aims to print human tissues, including skin and bone, in space. The success of this project could lead to significant advancements in regenerative medicine and the development of innovative treatments for patients with severe injuries or diseases.

Finally, there is another unique feature of the space environment - space radiation. It refers to the high-energy particles and electromagnetic waves that exist in the space environment, originating from various sources such as the sun, cosmic rays from outside our solar system, and even the Earth's own radiation belts. Below are the ways humans have been able to utilize this concept to advance medicine.

Cancer research:

Space radiation poses a significant health risk to astronauts during long-duration missions, providing a unique environment for studying the effects of radiation on human health. Understanding how radiation affects cells and DNA is crucial for the development of effective countermeasures and therapies for cancer patients.

One example of space radiation research contributing to cancer treatment is the study of DNA repair mechanisms in microgravity. Researchers have found that space radiation can cause DNA damage in cells, which can lead to cancer. By studying how cells repair this damage in space, scientists can develop more effective radiation therapies for cancer patients on Earth.

Radioresistance:

Research on the International Space Station (ISS) has also contributed to understanding bacterial resistance to radiation. Studying the response of bacteria to space radiation has provided insights into their adaptation and survival mechanisms. This knowledge can be applied to the development of new strategies for controlling drug-resistant bacteria on Earth.
For instance, researchers have found that some bacteria, such as Deinococcus radiodurans, have the ability to withstand high levels of radiation. By understanding the molecular mechanisms underlying this radioresistance, scientists can develop novel antibacterial treatments targeting these mechanisms, potentially combating antibiotic resistance.

In conclusion, the synergies between the space industry and healthcare have led to significant advancements in medical and biomedical research. The unique environment of space has provided valuable insights into human physiology, drug development, tissue engineering, and radiation research, resulting in innovative therapies and treatments for various diseases and conditions. As our understanding of the effects of space on living organisms continues to grow, so too will the potential for new discoveries and applications in the field of healthcare.

2. Telemedicine

Telemedicine is the provision of healthcare services where traditional face-to-face patient – doctor interaction (or doctor – doctor) is replaced by over-distance interaction through the use of ICT.

Through its numerous applications, telemedicine is revolutionizing the healthcare industry in the fields of healthcare prevention, diagnosis, patient treatment and monitoring. The consistently growing cases of chronic diseases, heart failure, asthma, cardiopulmonary disorders are accelerating the development of advanced real-time patient monitoring. Some cutting-edge solutions include teleradiology, teledermatology, telestroke/teleneurology, and telemonitoring for various chronic diseases such as diabetes.

In addition to this, the field of mental health has seen rising demand caused by fear, isolation, beaverement, or loss of income, especially after the Covid-19 pandemic.
It is estimated that by 2025, 20% of medical services could be replaced by artificial intelligence, especially in diagnosis, prevention, and monitoring.

The benefits of expanding the use of telemedicine are threefold: it can improve the quality of healthcare services; permit the best use of often limited hospital resources such as beds, doctors, nurses and expensive medical equipment; and help to equalize the access to good health care.

Telehealth through communication satellites was often the only solution for the provision of connectivity in remote areas, but also during emergencies and disasters. Since decades satellites are a tried, tested and extremely reliable means of telecommunication. Strong collaboration among space agencies and international agreements and bodies ensures the application and dissemination of innovative space-based health solutions globally.
Satellite communications can bring to telemedicine several advantages include instant access to broadband services, particularly in remote areas where telecommunications are poor or nonexistent, and swift response in disaster situations where speed is vital. Satellites also provide a powerful and relatively inexpensive tool, particularly for video links between multiple users as costs are constantly decreasing.

ESA has a long-lasting history in the provision of connectivity in rural communities through satellite communication worldwide. The steady growth in use of digital technologies such form of mobile phones, social media, wearables and sensors, enables to advance health provision and education in low- and mid-income countries. The integration of 5G will further offer the needed bandwidth and therefore is expected to be the key enabler for these new solutions, offering real-time and high quality video capabilities to various telemedicine platforms. Applications such as Augmented Reality and Virtual Reality will further enhance the doctor's ability to deliver innovative and less invasive treatments but can also be used for own personal and skills development. IoT devices, such as wearables, will be able to deliver real time remote monitoring and increase patient engagement.

Since the 1970s, NASA has been involved in the research and demonstration of telemedicine for its potential in the care of astronauts in flight and Earth-bound applications. A combination of NASA funding, expertise and off-the-shelf computer and networking systems made telemedicine possible for a medically underserved hospital in Texas. Through two-way audio/video relay, the program links pediatric oncology specialists at the University of Texas Health Science Center in San Antonio to South Texas Hospital in Harlingen, providing easier access and better care to children with cancer. Additionally, the hospital is receiving teleclinics on pediatric oncology nursing, family counseling and tuberculosis treatment.

Despite its effectiveness, the expansion of telemedicine is still hindered by a lack of universal standards, legal and ethical concerns, security of data, funding, and a general lack of support to encourage doctors and hospitals to set up telemedicine services.

3. Health Infrastructure and Logistics

Another area in which digital technologies are increasingly being utilized is health infrastructure and logistics. The healthcare supply chain is a complex system that involves many stakeholders, from manufacturers to patients. The efficient management of this supply chain is essential to ensure that patients receive the care they need in a timely and cost-effective manner. Therefore, learnings from space operations can substantially enhance such supply chain management.

3.1 Satellites in Health Infrastructure and Logistics

Satellites have numerous applications in healthcare, including pandemic and disease surveillance and population and health management. On a national level, many countries are building up national digital health data hubs, where satellites can supply additional social and environmental data. This data can be used to identify areas of need, allocate resources more efficiently, and monitor health outcomes.

Consequently, the increasing use of satellites may enable a more timely resource allocation, right where they are needed. The potential to improve health care supply is huge, especially in remote areas and less wealthy countries.

3.2 Healthcare Delivery in the Hospital of the Future

The hospitals of the future will need to redefine healthcare delivery by optimizing inpatient and outpatient settings and integrating digital systems into traditional hospital services. One emerging feature of the hospital of the future is centralized digital centers, where all dataflows come together and that enable continuous clinical monitoring. This allows healthcare providers to access patient data in real-time, improving the quality of care and reducing the risk of medical errors. Besides, Virtual reality (VR), robotics, and 3D printing, originally developed for space applications, can also be used to improve surgeries, reducing the risk of complications and improving patient outcomes.

Also, the need for space equipment to be small may be useful in the Hospital of the Future, providing smaller and portable devices. Of course, such devices also strongly benefit the traveling of doctors to remote areas and enable them to provide better health care there.

3.3 Supply Chain Management

(Space) technologies will also play an important role in the medical supply chain: They can provide enhanced planning, synchronization, and collaboration. Radio-frequency identification (RFID) and real-time location systems (RTLS) for asset tracking enable a real-time overview of what will arrive when.

Another area in which new technologies might significantly improve the efficiency of the supply chain is last-mile delivery: Drones are an important source of opportunity for decreasing delivery costs. They can provide the healthcare supply versatility in delivering vaccines, medications and blood samples effectively and quickly, especially to remote areas. Furthermore, AI and predictive analytics tools are expected to support more accurate forecasting of demands and optimize inventory planning. This will reduce storage costs and decrease the number of medications/blood samples that need to be disposed of because they have turned bad.

3.4 Conclusion

As seen in the previous chapters and shown for the area of health infrastructure and logistics above, digital technologies are transforming healthcare, from patient care to disease management, and space technologies are playing an increasingly important role in this transformation.

In the area of health infrastructure and logistics, space technologies can provide valuable data that can be used to improve healthcare delivery and management. The hospitals of the future will need to optimize inpatient and outpatient settings and integrate digital systems into traditional hospital services, including the use of VR, robotics, and 3D printing. The use of AI and predictive analytics tools can also support more accurate forecasting of demands and optimize inventory planning, allowing for a more efficient management of the supply chain.

With the challenges facing the healthcare sector, the use of digital and space technologies represents a significant opportunity to improve patient outcomes and reduce costs.

4. One Health, Environmental Risks and Recovery

4.1 What is the One Health approach?

The One Health approach recognizes the interconnectedness of human, animal, and environmental health and the need for collaboration between different fields to address emerging and re-emerging diseases. With the increasing destruction of natural habitats and the loss of biodiversity, there has been an increase in human-animal interactions, which can lead to the transmission of zoonotic diseases.

Zoonotic diseases can be caused by viruses, bacteria, parasites, and fungi that are transmitted from animals to humans. Some of these diseases, such as the Ebola virus, can cause severe illness and even death in humans. The emergence of new infectious diseases, such as COVID-19, highlights the need for a One Health approach to address the complex relationships between humans, animals, and the environment.

Global climate change is expected to exacerbate the transmission of vector-borne diseases (transmitted through bites), such as malaria and dengue fever, as the range of disease-carrying insects expands. Warmer temperatures can also increase the growth and survival of disease-causing organisms in food and water sources. Additionally, changes in precipitation patterns can lead to the emergence of water-borne diseases, such as cholera.

4.2 How can satellites help mitigate these risks?

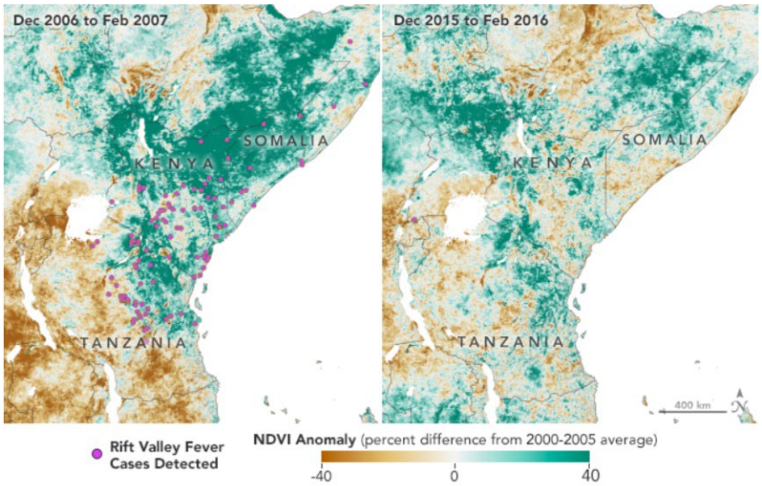
In order to identify these diseases early and implement warning mechanisms, new data sets and models are needed. With these, it will be possible to predict and understand the development and spreading patterns of such diseases.

Near-real-time data on flooding, irrigated areas, rainfall patterns, temperature, and other environmental factors can be collected by satellites and fed into models to generate risk maps and early warning systems. This data can also be integrated with socio-economic data, such as village, market, and road networks, to better understand the underlying drivers of disease transmission and inform targeted interventions.

Satellites can also monitor the spread of diseases through remote sensing, which involves the use of sensors to detect changes in the environment that may be indicative of disease outbreaks. For example, satellite images can detect changes in vegetation patterns that may be associated with the presence of carriers such as mosquitoes.

In addition to monitoring the spread of diseases, satellites can also be used to track the impact of disease outbreaks on vulnerable populations. For example, satellite imagery can be used to assess changes in crop production and food security that may result from disease outbreaks, as well as changes in human mobility and migration patterns.

Especially in combination with AI tools and innovative digital solutions, the analysis of such patterns and integration of satellite data has already been used to efficiently predict outbreaks.



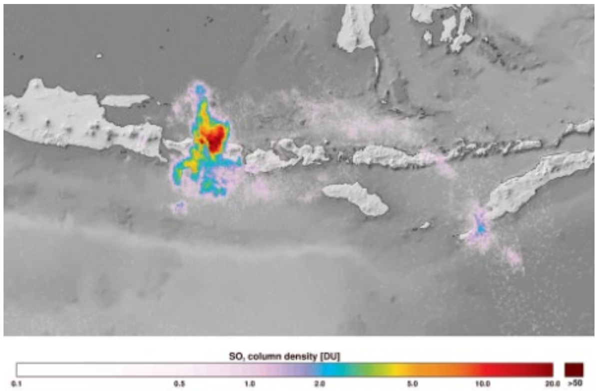
Satellite measurement of the "greeness" of vegetation, revealing a higher value than normal. Greener areas are usually wetter, suggesting better habitat for mosquitoes- conditions that lead to the outbreak of rift fever in 2006. The region greened again in 2015, but early warnings helped officials prevent the spread of the disease.

4.3 Impact of environmental pollution on human health

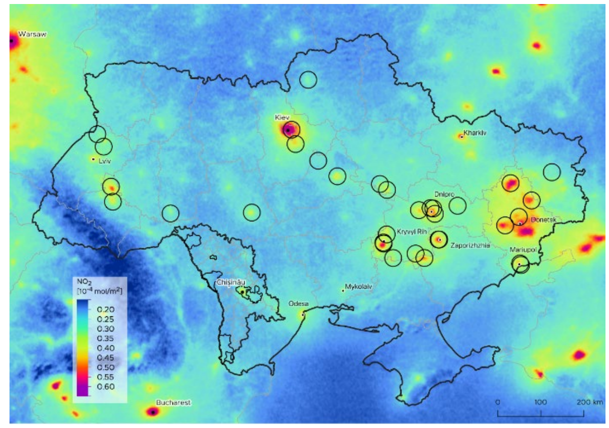
Air pollution can be harmful to human health because it contains particles and gases that can irritate the lungs and cause respiratory problems. Fine particulate matter, or PM2.5, is especially dangerous because it can penetrate deep into the lungs and even enter the bloodstream. Exposure to air pollution has been linked to a range of health problems, including asthma, chronic obstructive pulmonary disease (COPD), heart disease, and stroke. Children, the elderly, and people with pre-existing health conditions are particularly vulnerable to the effects of air pollution.

4.4 How can satellites help to track pollution?

Satellites can help monitor environmental pollution, including air pollution. This is important because air pollution can cause non-communicable diseases like asthma and heart disease. Sentinel-5P is a satellite that monitors different gases and particles in the atmosphere, like carbon monoxide and sulfur dioxide world wide. Satellites can also help detect harmful algae blooms, which can be a public health concern. They can also monitor water availability and access. By using satellite data, we can better understand and address environmental factors that affect human health.
In addition to Sentinel-4 over Europe, there are also GEMS, a geostationary satellite over Asia and TEMPO (North America), each of which reports hourly data.



Sentinel 5P capturing gases from a volcanic eruption in Bali



During COVID-19, the Moldovan government used satellite images of air pollution to make policy decisions on lockdowns. Especially in connection with the lung disease, conditions can worsen significantly when victims are also exposed to polluted air.

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