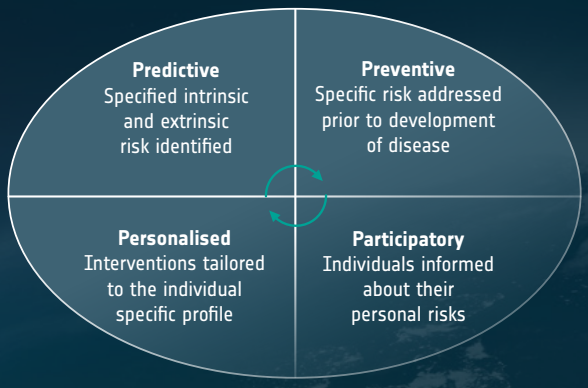
Health innovation trends and opportunities for space businesses

Critical healthcare challenges in Europe

Europe has made huge strides in health outcomes with life expectancy increasing[1] and many serious diseases becoming manageable, allowing patients to live a normal life. At the same time, huge challenges for Europe must still be addressed, including an **ageing population** and a **greater prevalence of chronic diseases** which are intensifying demand for services and threatening the sustainability of European healthcare systems[2]. The COVID-19 crisis has laid bare the need to tackle **workforce shortages** and strengthen the resilience of the healthcare system, (including products and chemicals sourcing), as well as highlighting the **growing pace of digitalisation**.

Moreover, an analysis of EU health systems highlights the need for a shift towards **prevention, primary care and integrated care**[3]. The 2019 Companion Report reaffirmed the need to prioritise health promotion as a prerequisite to achieving effective and resilient health systems[4]. However, as a share of total health spending, prevention represents just over 3% on average and less than 2% in France, Portugal, Romania, Malta, Greece, Cyprus and Slovakia.



In its 2019 report, the Companion report reaffirmed the priority of health promotion as the precondition for effective and resilient health systems[5]. However, overall, the share of total spending dedicated to health, prevention is just over 3% on average and below 2% in France, Portugal, Romania, Malta, Greece, Cyprus and Slovakia.

Issues linked to an **ageing workforce, recruitment and employee retention** as well as an **uneven geographical distribution** between and within in EU regions also need to be addressed. Problems also exist with **timely access** to certain services, leaving people with mental health problems, disabled persons, older persons, and people in need of palliative care particularly disadvantaged.

Finally, the digitalisation of the European healthcare sector is extremely patchy. Research carried out by the Bertelsmann Stiftung compared 14 EU member states and 3 OECD countries, showing that countries are digitalising their healthcare systems at very different speeds[6]. Estonia and Denmark, where all citizens can view their test results, medication plans or vaccination data online, rank at the top of the index, whereas France, Germany and Poland are trailing behind. Moreover, while myriad innovative solutions are being developed, it is their integration in digital platforms, the user experience they offer, and above all, the associated reimbursement scheme that will determine their potential for commercialisation[7]. In other words, health innovation, if it is to take hold, is dependent on being integrated with regulatory ecosystems at national and supra-national level.

An overview of the regulatory health ecosystem in the European Union

Healthcare is currently governed by national regulations with no unified legal framework established for its provision in the EU. Regulatory fragmentation has led to legal complexity in areas such as GDPR, reimbursement rules, medical guidelines and clinical trials. At EU level, **DG SANTE, DG CONNECT** and **DG RTD** are directly and indirectly responsible for health-related topics. Recently, EU agencies also stepped in, with the **European Centre for Disease Prevention and Control (ECDC)** and the European Medicines Agency (EMA) playing a key supportive role in the response to the COVID-19 pandemic[8].

The new **EU4Health 2021-2027** programme[9] aims to counter the negative impacts of COVID-19 by investing in prevention, crisis preparedness, the procurement of medicines and equipment, and improving long-term health outcomes. The Commission also proposed the creation of a **European Health Data Space**[10] in 2021 to strengthen the EU's crisis preparedness and response, taking the first steps towards a European Health Union.

This report highlights some of the numerous examples of healthcare use-cases in which space technologies can be leveraged.

1. MORTALITY AND LIFE EXPECTANCY STATISTICS...
2. STRENGTHENING EUROPEAN HEALTH SYSTEMS (EFPIA.EU)...
3. POLICY_BRIEF_A4 (EHMA.ORG)...
4. 2019_COMPANION_EN_0.PDF (EUROPA.EU)...
5. 2019_COMPANION_EN_0.PDF (EUROPA.EU)...
6. BERTELSMANN COMPARES DIGITAL STRATEGIES...
7. THE EUROPEAN PATH TO REIMBURSEMENT FOR DIGITAL...
8. EMA'S GOVERNANCE DURING COVID-19 PANDEMIC...
9. PROGRAMME L'UE POUR LA SANTÉ 2021-2027...
10. EUROPEAN HEALTH DATA SPACE (EUROPA.EU)...

Space-added value

Emerging technologies and new business models are creating a market pull for new solutions in areas where space can add significant value. These areas include:

- **Medical and biomedical research** including tissue engineering, personalised medicine, drug development and disease modelling;
- **Telemedicine and digital health** for healthcare prevention, remote diagnosis, patient treatment and monitoring, digital health applications and connectivity;
- **Public health management** for environmental health, health at individual, group, population or ecosystem level and hospital delivery care operations.

The European Space Agency (ESA), through numerous projects[11] and the **Business Incubation Network**[12], has already supported over 70 start-ups located at the intersection of space and health in a variety of areas such as cancer treatment, sustainable food or personalised nutrition for space travel. The ESA Business Applications and Space Solutions programme (ESA BASS) has notably successfully implemented a number of projects and build partnerships with key actors such as the National Health Service (NHS). Moreover, the ESA **Technology Transfer Office**[13] supports technological exchange between the space and health sectors with spin-ins, as well as spin-offs. In addition, the **Business in Space Growth Network**[14] (BSGN), notably through its Life Sciences Industry Accelerator[15], offers opportunities for **pharmaceuticals** and **biomanufacturing** industrial research by facilitating access to commercial space-based platforms in Low Earth Orbit.

Medical and Biomedical Research

The space industry can be leveraged by the healthcare industry as a platform for testing and manufacturing.

The effects of microgravity on biological, chemical and physical processes which can be observed in space-based laboratories enhance our understanding of a broad range of diseases, making it possible for the public and private sectors to improve existing treatments as well as develop new medicines for humans on Earth. The possibilities include, but are not limited to, protein crystallisation, 3D tissue cultures, tissue regeneration, DNA regulation, drug and vaccine development, stem cells, bone physiology and pathology, and treatments for diseases such as cancer and other life-threatening and debilitating conditions. In particular, the formation of protein crystals is key to the pharmaceutical industry which uses crystal dissolution to deliver medications in the fight against a broad range of protein aggregation-related diseases[16] (Alzheimer's, diabetes, Parkinson's, etc.). Moreover, microgravity-induced osteoporotic modelling (accelerated bone loss in microgravity) can be of great assistance in the testing of bone-like structures: ESA is for example supporting Greenbone Ortho[17], an Italian SME with the in-orbit validation of an innovative bone substitute which will be used to treat osteoporosis. Taking Greenbone to space is considered faster and cheaper than conducting animal testing on Earth. Further revenue-generating applications can be found in drug design, structural biology and bioseparation. The effects on human physiology of microgravity combined with isolation and harsh environments can also improve our understanding of changes in metabolism and nutrition, cardiovascular regulation and respiration, immunology, psychological fitness and ageing[18].

Added value of space for healthcare testing and manufacturing

ORBITAL & SUBORBITAL COMMERCIAL RESEARCH

Orbital and suborbital testing aboard the ISS or other orbital facilities can advance medical research

GROUND-BASED COMMERCIAL RESEARCH

The space industry has developed ground-based facilities for research that can simulate space conditions (e.g. Yuri Gravity Clinostat) and serve to de-risk the hardware or fine-tune experiment protocols

IN-ORBIT MANUFACTURING

The space environment is of interest for biomanufacturing of life sciences products and technologies (tissue engineering, organ on a chip) and the manufacturing of materials (thin film technology) which may be of interest for med tech in the long term

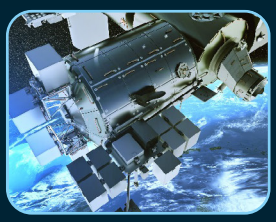
11. ESA - PAST FUNDED PROJECTS (HEALTH, MEDICINE & PHARMA)...
12. ESA BUSINESS INCUBATION CENTRES...
13. ESA - ESA'S TECHNOLOGY TRANSFER AND PATENT OFFICE...
14. THE BUSINESS IN SPACE GROWTH NETWORK (ESA.INT)...
15. LIFE SCIENCES INDUSTRY ACCELERATOR - BSGN (ESA.INT)...
16. SPACE AND HEALTH: A LONG SUCCESS STORY OF SYNERGIES...
17. HOME | GREENBONE ORTHO...
18. (PDF) SPACE MEDICINE PROPELLING EARTH-BASED MEDICINE...

In Europe, commercial services like the ICE Cubes Service and Bioreactor Express Service are facilitating access to the European Columbus Laboratory aboard the International Space Station (ISS) where commercial microgravity research can be carried out by paying customers. Several start-ups and SMEs that focus on the development of related experiment hard- and software are specialized in and working for pharmaceutical and biomedical industry, for example Space Pharma and Yuri Microgravity. ESA's BSGN has signed a Memorandum of Understanding with the ESA's BSGN has signed a Memorandum of Understanding with the Exploration Company to assess the potential of the Nyx capsule to deliver payloads to Low Earth Orbit[19]. ESA's Boost Programme[20] is supporting Space Forge with the development of a satellite-based microgravity research and production facility[21]. Furthermore, through the Commercial Applications enabled by Space Environments (CASE) Open Call for Proposals, ESA supports the development of commercial services that benefit from microgravity and space environments.

ESA's Space Rider[22] will further increase European capabilities in this market by providing access to regular uncrewed deliver of payloads to Low Earth Orbit.

Various biotech start-ups have already had the chance to carry out research in microgravity conditions[23]. In March 2023, the fourth commercial Kirara project was for example launched to space. It is currently hosted inside the Facility of the ICE Cubes Service[24] on the International Space Station (ISS) by Space Applications Services[25]. However, low awareness among further potential clients remains a barrier, as are misconceptions in terms of the time, cost and value proposition of space-based research. What is needed is a holistic approach, with collaboration stimulated further among institutions, research organisations and private players, including investors, within the health sciences industry, as well as with space service providers.

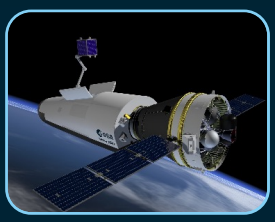
BSGN partners (source: BSGN)



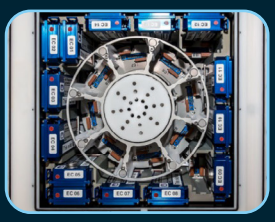
BARTOLOMEO

ICE CUBES SERVICE

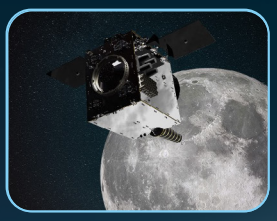
YURI MICROGRAVITY



SPACE RIDER

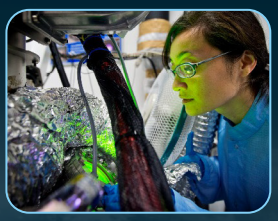


BIOREACTOR EXPRESS SERVICE



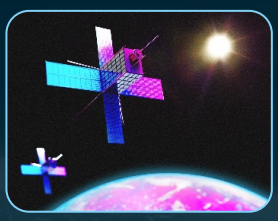
LUNAR PATHFINDER

GOONHILLY DEEP SPACE COMMUNICATION



ESA MATERIALS & ELECTRIAL COMPONENTS LABORATORY

SPACE PHARMA



SPACE FORGE

NYX | THE EXPLORATION COMPANY

LSAS - LUNAR SURFACE ACCESS SERVICE BY OHB

LUNAR TRANSPORTATION AND EXPLORATION SERVICES BY ISPACE

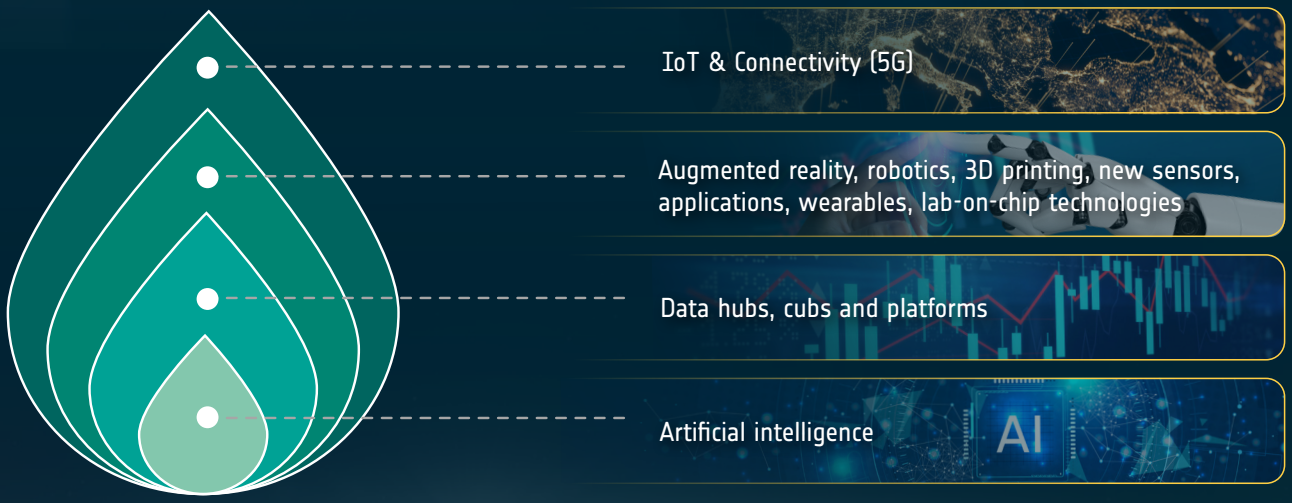
19. HTTPS://BSGN.ESA.INT/2022/12/12/PRIVATE...
20. ESA - BOOST!...
21. HTTPS://WWW.ESA.INT/ENABLING_SUPPORT/SPACE...
22. SPACE RIDER - BSGN (ESA.INT)...
23. HTTPS://BSGN.ESA.INT/2022/09/21/95933-REVISION-V1/...
24. ICE CUBES SERVICE - BSGN (ESA.INT)...
25. SPACE APPLICATIONS...

Telemedicine and Digital health

The digital transformation is playing an increasingly vital role in the healthcare sector: by 2025, Rolland Berger estimates that the share of digital products and services in the total healthcare market will grow to 12%, or nearly €1tn, with Europe alone accounting for around €232bn. Much of this surge in digitalisation results from the tremendous progress made in a variety of fields including robotics, **augmented reality** and **3D printing**, and the **connected devices** such as sensors, applications, wearables and other mobile gadgets that use these enabling technologies to deliver e-health services. The health-related data collected by these devices can then be saved in platform-connected **data hubs** for analysis by **artificial intelligence** (AI) or machine learning (ML) algorithms.

The telemedicine market in Europe is estimated to grow from $11.32bn in 2022 to $21.80bn by 2027[28]. A study by Accenture has indicated that, globally, 40% of patient visits could be performed remotely by 2030[29]. Possibilities for the development of telemedicine solutions targeting low- and middle-income countries are particularly vast[30] as telehealth projects have been undertaken for decades as a means of improving access to healthcare. In those countries, it is clearly understood that digital health innovations could directly strengthen healthcare, in terms of both patient management and disease surveillance and prevention.

Healthcare digitalisation technological layers



Innovation in the health sector is to a large extent driven by start-ups specialising in clinical intelligence, real-world evidence, virtual care delivery, drug discovery, disease management, the pharma supply chain, and more. Drug companies have established venture capital funds and incubators to invest in promising start-ups working on new drug technologies and are hence outsourcing development risks[26]. But innovation it is also being fostered by tech giants as digital pioneers breaking into the healthcare market, with, for example, Amazon's diversification into the health insurance and online pharmacy[27] segments.

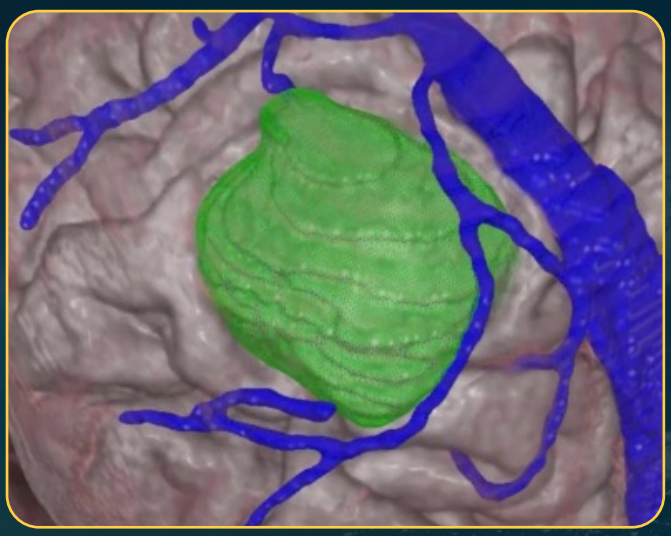
In addition to telemedicine becoming more widely accessible, another main driving force behind the uptake of innovative healthcare solutions is the growing volume of healthcare data. The use of digital technologies in the form of mobile phones, fitness trackers, heart rate monitors, online health coaches, wearables and sensors has become commonplace, and more than 300,000 health-related applications are available for use on mobile phones. Leading companies such as Phillips Healthcare and Medtronic, as well as newly arrived start-ups and SMEs, offer a wide portfolio of **remote patient monitoring** (RPM) services. ESA, through its incubation programme[31], has supported companies such as Portabiles HealthCare Technologies[32] , which has developed a wearable sensor system that analyses gait and transfers data wirelessly to a data hub.

26. BIG PHARMA IS USING ITS VENTURE CASH...
27. AMAZON LAUNCHES $5-A-MONTH UNLIMITED...
28. EUROPE TELEMEDICINE MARKET WORTH...
29. HEALTHCARE AND THE ENVIRONMENT...
30. INNOVATION MAPS – Briter (briterbridges.com)...
31. ESA BUSINESS INCUBATION CENTRES...
32. PORTABILES HEALTHCARE TECHNOLOGIES GMBHON...

This growth in the volume of healthcare data collected is not only attracting interest from insurance companies wishing to tap into it for a closer understanding of their clients' behaviour, it is also propelling the rise of **healthcare digital platforms**. Precedence Research predicts 17.8% annual growth in healthcare cloud computing by 2027[33]. To date, the largest platforms have emerged in China and the United States, but new players are now emerging in Europe providing personal, patient-doctor, pharmacy and even national platforms. These data platforms are paving the way for a wider adoption of AI in the global healthcare industry with increasing needs for automated evidence-based decision-making.

By 2025, 20% of medical services could be replaced by AI, especially in diagnosis, prevention and monitoring[34]. **Computer vision**, used extensively in space remote sensing, has become key in reducing the burden on healthcare professionals in image analytics. Technology transfer can therefore benefit both sectors.

Moreover, the use of **digital twins of patients, patient groups or even populations** to test therapies before they are applied is becoming increasingly widespread. These are being used by start-ups driving pharma innovation, most notably, accounting for 63% of all new prescription drug approvals over the last five years[35]. Furthermore, the healthcare industry is also leveraging **augmented reality** (AR) and **virtual reality** (VR) for much the same reasons as the space industry, opening the door to synergies, between the two sectors. Technology that can help train or otherwise prepare surgeons prior to surgery are currently in high demand in the sector. Surgical Theatre software[36] sets a compelling precedent for AR technology in aerospace training (Israeli Air Force) being redeveloped to train surgeons.



Surgical Theater's 360°-3D XR Visualization (source: Surgical Theater)

COVID-19, for its part, further accelerated the digitalisation of the industry and became a major driver for a number of digital applications:

COVID-19 SHORT- AND MID-TERM EFFECTS

- Widespread use of **telemedicine** as well as virtual and innovative health management tools
- Leverage of **interoperability** and **analytics** in clinical decision support
- Use of **robots** and **virtual assistants** to treat highly contagious patients
- Augmented demand for **tele-radiology** infrastructure and services

The value added by the space sector to digital healthcare services is highlighted by several activities that ESA is currently undertaking. In collaboration with the UK National Health Service (NHS) and the UK Space Agency, ESA is for example promoting innovative solutions exploiting space technologies for the benefit of the NHS ecosystem[37].

ESA is also supporting the role of satellite in **5G/6G** development, key enabler for future digital applications.

EXAMPLES OF AREAS WHERE SPACE ADDS VALUE

- Real-time monitoring (e.g. IoT, wearables, sensors) to monitor the patient's condition for preventative care
- Applications bringing people together during isolation periods to reduce social exclusion and improve mental health
- Timely diagnoses, second opinions, treatment adjustments, etc. made possible by the faster sharing of patient data among doctors, ambulances and hospitals
- Remote diagnosis by enabling patients to engage with doctors through real-time telepresence systems (e.g. videoconferencing, immersive reality)
- Doctors in remote locations to receive support or training using telepresence systems (e.g. immersive reality) or the use of haptic feedback / robotics
- Monitoring of patient recovery and condition management in rural areas (e.g. through their activity levels)

33. HEALTHCARE AND THE ENVIRONMENT...
34. FUTURE OF HEALTH (ROLANDBERGER.COM)...
35. BIG PHARMA'S SCRAMBLE TO INVEST IN START-UPS...
36. VIRTUAL REALITY FOR SURGERY | PRECISON XR...
37. HTTPS://BUSINESS.ESA.INT/FUNDING/NHS-FUTURE...

Public Health Management

Digital technologies can support health infrastructure and logistics by integrating care, helping identify and reduce risks, helping manage the health needs of the population and improving the quality of data flow to deliver timely, efficient and safe care. Emerging features include continuous clinical monitoring, 3D printing for surgery, and the use of smaller and portable devices. **Centralised digital hubs** to enable decision-making are also becoming critical. Health Data Research UK, and the German Medical Informatics Initiative are just some of the national schemes in Europe aiming to pool big health data (BHD) for exploitation by researchers, institutions, citizens, start-ups, etc. The European Commission, under its EU4Health programme[38], has also committed to creating a common Health Data Space[39] (eHDSI) over the period 2019–2025.

Technologies will also play a key role in providing enhanced planning, synchronisation and collaboration in the supply chain.

The use of **radio-frequency identification (RFID)** and **real-time locating systems (RLTS) for asset-tracking** by healthcare organisations is on the rise to help streamline the supply chain and improve visibility on inventory. In terms of last mile delivery, drones have great potential as a critical source of cost efficiency. Apollo and Fortis own and run private hospital chains across India that invest heavily in digitalising their value chain[40]. As a leader in express delivery, DHL offers solutions (e.g. temperature-controlled delivery) tailored to the medical and pharmaceutical industry.

The digital transformation of health infrastructure will provide opportunities for satellite-enabled solutions. ESA has experience and expertise in the field of environmental monitoring, track and trace, IoT/M2M and enabling last-mile delivery through drones. The areas where space adds value include:

HEALTH INFRASTRUCTURE

Provide connectivity, security and robustness to IT infrastructure for:

- Data sharing/storing of electronic health records
- Hospital operations
- Disease / pandemic tracking (tracing and warning apps)

Environmental/EO data to support national data hubs in:

- Clinical decision making
- Pandemic and disease surveillance
- Population and health management
- Environmental risks including air pollution

SUPPLY CHAIN

Provide real time tracking capabilities for:

- A clearer picture of where medication doses sit in the hospital's supply chain during the planning phase
- Improved visibility on consignment inventory and redirecting inventories in real time to areas experiencing shortages

Connectivity in remote areas to enable:

- IoT and M2M solutions for supply chain monitoring
- Drones to carry out BLOS deliveries of vaccines, medication etc.

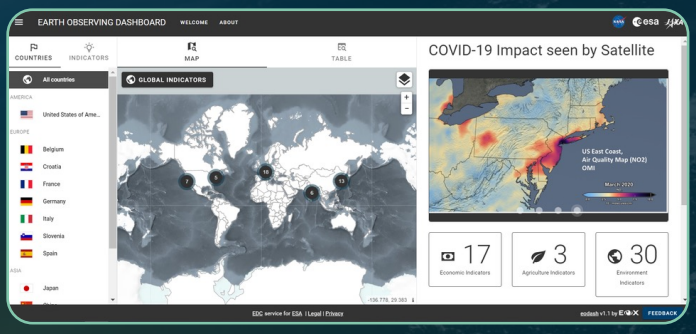
38. EU4HEALTH (EUROPA.EU)...
39. EUROPEAN HEALTH DATA SPACE (EUROPA.EU)...
40. LIFE LINE: APOLLO'S DIGITAL DISRUPTION TO DELIVERY...

Moreover, space can help tackle issues associated with One Health and the environment.

What is One Health?

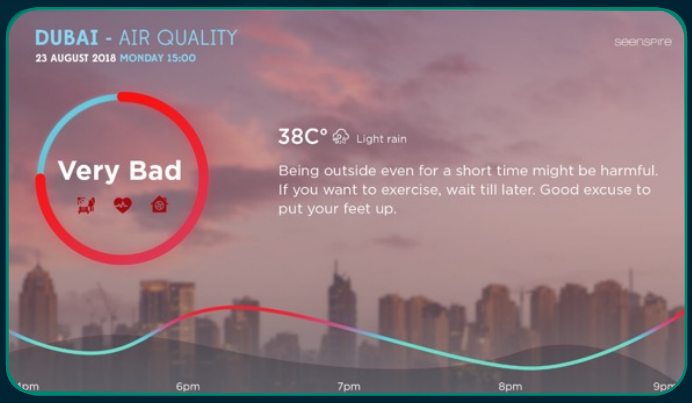
One Health analyses the impact of climate change on human as well as animal health, vector-borne diseases, particularly zoonotic diseases (shared between animals and humans), and water-borne diseases[1]. Experts see a link between pandemics and the biodiversity and climate crisis caused by humans: increasing environmental devastation, habitat degradation and the accelerating effects of global warming are leading to increased wildlife-human interaction. More than 75% of emerging infectious diseases in humans are zoonotic. In the IPBES #PandemicsReport Escaping the *'Era of Pandemics'*[41], it is estimated that the cost of reducing the risk of pandemics with a view to preventing them is 100 times less than the cost of responding to such pandemics. Transformational changes in the global approach of dealing with infectious diseases should

In this context, remote sensing can help forecast and model the spatio-temporal evolution of diseases. Only through satellites can vast territories or whole regions be scanned, analysed and correlated with ground data. Space therefore supports early warning systems through risk modelling and mapping, as well as through the identification and visualisation of hotspots to manage epidemics. ECDC has set up a web portal called the **E3 Geoportal**[42] to collect and make available a wide range of information on infectious disease epidemiology in Europe, using among others EO data. For its part, ESA is supporting initiatives such as the AIDEO project[43] that explores the use of AI applied to a pool of EO datasets in the context of the West Nile Disease, a widespread zoonosis caused by a vector-borne virus. During the COVID-19 crisis, NASA, JAXA and ESA set up, in an unprecedented collaboration, **the COVID-19 Earth Observation Dashboard**[44] to gauge the effects of the pandemic on social, economic and environmental variables. At the same time, ESA and the European Commission have developed the twin **Rapid Action Coronavirus and Earth observation (RACE)**[45] platform for user-friendly, free access to data.



COVID-19 Earth observation dashboard

Satellites can also be used to detect the emergence of **water-borne diseases** as parameters such as turbidity, suspended matter, chlorophyll-a, harmful algae bloom and trophic state classification can be derived from EO imagery. For example, the ECDC uses EO data to monitor Vibrio bacteria in the Baltic Sea[46]. Moreover, satellites are key to monitoring **heat exposure** that can place significant strain on the cardiovascular system[47] and **air pollution,** which results in multiple adverse health outcomes such as lung dysfunction, cardiovascular diseases or coronary artery diseases. Sentinel-5P for example monitors methane, formaldehyde, aerosol, carbon monoxide, nitrogen dioxide and sulphur dioxide in the atmosphere. ESA has also supported the demonstration of projects such as the Aircheckr app[48] that leverages two space assets, Earth observation and satellite navigation, to provide **air quality indicators and personal recommendations.**



Aircheckr app

Throughout all 3 domains, **Medical and Biomedical Research**, **Telemedicine and digital health** and **Public Health Management**, the analysis has shown that building blocks and critical benefits can be leverage through space technologies and services, providing valuable infrastructure and assets for future Healthcare and Medicine.

41. IPBES #PANDEMICSREPORT: ESCAPING THE 'ERA OF PANDEMICS'...
42. ECDC GEOPORTAL | E3 NETWORK (EUROPA.EU)...
43. VECTOR-BORNE DISEASE CIRCULATION PREDICTED WITH EO...
44. ESA - SPACE AGENCIES JOIN FORCES TO PRODUCE GLOBAL...
45. RAPID ACTION FOR CITIZENS WITH EARTH OBSERVATION...
46. WATER-BORNE DISEASES: EO SYSTEM FOR THE COASTAL...
47. HEAT EXPOSURE AND CARDIOVASCULAR HEALTH: A SUMMARY...
48. HTTPS://BUSINESS.ESA.INT/PROJECTS/AIRCHECKR...