Emerging trends on satellite-based applications in health: a synoptic view

Paravano A*[a], Viterbo M.[a], Trucco P.[a]

[a] *School of Management, Politecnico di Milano, Via Lambruschini 4, 20156, Milano, Italy,* alessandro.paravano@polimi.it.
[a] *School of Management, Politecnico di Milano, Via Lambruschini 4, 20156, Milano, Italy,* matteo.viterbo@mail.polimi.it,
[a] *School of Management, Politecnico di Milano, Via Lambruschini 4, 20156, Milano, Italy,* paolo.trucco@polimi.it
* Corresponding Author

This study examines the state of the art of satellite-based applications for human health. It deepens the main drivers and barriers to their diffusion and full-scale development.

Living in a more globalised, intertwined, and technologically advanced world has opened the door to a more digital health system able to connect many actors, reach remote locations, and provide coverage at a global level, whose exploitation has become even more urgent due to the Covid-19 pandemic. Space technologies may be a valid asset to tackle future health challenges. Despite the clear linkage of the two domains, the literature lacks a holistic view of the phenomenon of the current adoption of space assets in the health domain. Moreover, the factors that limit or foster the development of satellite-based applications in health management and healthcare delivery are still unclear and require a thorough investigation.

The framework on the relationship between space activities and global health applications elaborated by the United Nations Office for Outer Space Affairs has been adapted and populated with 86 business-cases gathered from a systematic literature review of the ESA public database. The findings were analysed to provide a comprehensive and in-depth view of the most relevant trends. The joint combination of satellite and digital technologies appears as the enabling factor to provide an effective service to professional end-users and improve the quality of health for patients. The importance of data integration from multiple satellite technologies and additional data is highlighted in many projects as the key success factor for developing effective applications. In addition, the technical, economic, organisational, socio-cultural, and political factors were explored in terms of barriers to or opportunities for the adoption of satellite-based applications for health. To this end, further information was gathered through a systematic literature review of 89 scientific articles and interviews with 8 internationally recognised experts. Results show how multiple factors could hamper the diffusion and success of the emerging applications, and how those factors should inform strategic decisions to foster the development of satellite-based applications in the future.

This study may benefit academics, practitioners and public institutions to grasp the benefits and challenges in adopting satellite and geospatial data in health. It provides a systematic overview of the existing practices, highlighting barriers and opportunities to their diffusion. The proposed synoptic might be taken as a point of departure for building a wider analysis on the role of satellite-based solutions to foster a One Health approach.

1. Introduction

Human beings have long been fascinated by outer space. Scientists, explorers, and more in general the humankind has always found space a source of imagination, curiosity, and inspiration. This perspective, combined with new technological disruptions, signed, from the second half of the 20th century, the start of the era of space exploration missions and activities. Space was considered, from the beginning, with a bidirectional view. It was intended both as external place with respect to the Earth to be explored through fascinating missions and as a source to bring concrete benefits back to our lives. The launch of satellite technologies and space stations foster the exploitation of space as a source of value for a plurality of Earth activities, creating a synergistic and virtuous cycle between outer space and our planet. The term "Space Economy" precisely summarises the concept expressed.

Before introducing the concept of "Space Economy", it is helpful to define the concept of Space Industry. The Space Industry is *"an example of industrial sector born on the basis of a capacity-driven development model, in which as a result of capability requirements, deriving from institutional needs of scientific research, space exploration, and national defense, technologies and applicative solutions to satisfy the given requirements were developed"* [1]. Accessibility to space (launchers), satellites, and the ground segment are the three pillars the space industry relies upon. The concept of "Space Economy" is an enlargement of the one of "Space industry".

1.1 The Space Economy

The Space Economy is *"the value chain that, starting from the research, development, and implementation of enabling space infrastructures, so called "Upstream", that are the pillars of the Space Industry, arrives till the production of "enabled" products and services, the so called "Downstream" (services for the environmental monitoring, meteorological forecasts, etc.)"* [1].

With an economic value of approximately USD 350 billion (2020), according to the Morgan Stanley investment bank, the space economy appears to be one of the most flourishing markets in the industrial panorama. *"The revenue generated by the global space industry may increase to more than USD 1 trillion by 2040"* [2]. Therefore, it has been explained that, on a worldwide scale, this flourishing market is inevitably accompanied by a trend of rapid growth of private players along its value chain, which brought to the introduction of the concept of "New Space Economy": *"A global trend encompassing an emerging investment philosophy and a series of* *technological advancements leading to the development of a private space industry largely driven by commercial motivations"* [3]. Nonetheless, this term of new space economy should not hide the intense effort of public institutions through investments in space programs. Public programs such as the European Copernicus (the European Union program for observing the Planet Earth with a bird's eye view), Galileo and EGNOS, centred on Satellite Navigation and geo-positioning systems, and others, certainly deserve to be cited [4].

1.1.1 The Upstream segment

The main component of the space infrastructure is the satellite asset, the true data generator. Earth Observation, Satellite Navigation (Global Navigation Satellite Systems and Geographic Information Systems), and Satellite Communication are the categories in which satellite technologies can be classified. Earth Observation satellites enable picturing the Earth from space with a "bird's eye" view. Global Navigation Satellite System (GNSS) is *"the infrastructure that allows users with a compatible device to determine their position, velocity, and time by processing signals from satellites. Those signals are provided by a variety of satellite positioning systems"* [5]. Geographic Information System (GIS) is "*a system designed to capture, store, manipulate, analyse, manage, and present all types of geographical data. The key information to do this is Geography, meaning that some portion of the data is spatial. This data is usually tabular, known as attribute data"* [6]. Last but not least, Satellite Communication enables the transmission of radio signals for multiple purposes, from satellite broadband Internet services and telephone calls to radio services and satellite TV [3]. Differently to terrestrial communication services, Satellite Communication systems appear to bring several benefits: higher availability of signals transmission, lower affectability by natural disasters, geographical barriers, and meteorological conditions, not to mention a reduction of costs from implementation (much lower wiring costs) to installation ones [7]. These conditions appear favourable, for example, to deliver telemedicine and general communication services in suburban areas with an ineffective, or even absent, terrestrial communication network.

1.1.2 The Downstream segment

For this reason, two more pillars need to be added to complement the concept of space economy: space services and non-space technologies and infrastructures that enable their realisation, such as Artificial Intelligence (AI), the Cloud, Internet of Things (IoT), and Big Data analysis and analytics instruments supporting the integration and analysis of data from heterogeneous platforms (for example, a joint combination of satellite data, data from the soil, data from aircraft, or even from social networks) [1]. Therefore, digital actors composing the downstream market are a must for providing services to final users. Those actors, even called "Intermediate users", acquire, process, and transform data into value-added services required by end users (public or private players from multiple industries) [8]. In a nutshell, they link the upstream side of the value chain to final users who need services built (also) on satellite data to create value in their businesses.

1.1.3 The End Users segment

End users are a fundamental driver in the value chain. *"Institutional end users play a key role because they express the requirements of the services for the production of common needs, identify gaps to close to make them fully satisfactory, and guarantee that the products developed are effectively used in the operative chains"* [1]. As stated, the institutional market has a role in expressing the demand for both innovative upstream technologies and new products and services, that *"creates the necessary conditions to foster the profitability of the private investments in the* *markets that are built around the processes of production of new common assets, enabled by spatial technologies"* [1].

1.1.4 Trends in the Upstream, Downstream and End users segments

Due to the urgent need for digital solutions to develop value-added applications for end users, a fast birth of digital startups and private companies occurred in recent years, attracted by the market in rapid expansion. Nonetheless, this privatisation trend has been observed along the whole value chain of the space economy ecosystem. An important presence of private players in the end users market has been ascertained (in which these players may see interesting solutions for their businesses by adopting services relying on the joint combination of satellite and non-satellite data). Not to mention the birth of innovative realities in the upstream segment, fostered by a trend of reduction of space access costs due to technological progress (development of new space technologies such as micro and nano satellites) and lower launching costs, and by a *"new entrepreneurial spirit"* [3]. The pioneering spirit of Elon Mask, founder of Space-X, could be certainly stated as an example.

1.2 Global Health Challenges

The World Health Organization (WHO), in March 2019, released a draft of the "Global Strategy on Digital Health 2020-2024". In the document, the organisation mentioned its strategic program: *"To promote healthy lives and wellbeing for everyone, everywhere, at all ages. The potential of Digital Health to advance the Sustainable Development Goals (SDGs) and to support health systems in all countries, in health promotion and disease prevention has been widely recognised"* [9]. To reinforce the importance of health in the next future at a worldwide level, the World Health Organization, in January 2020, presented the list of global health challenges for the decade 2020-2030 [10]. Elevating health in the climate debate, delivering health in conflict and crisis, making health care fairer, stopping infectious diseases, preparing for epidemics, investing in the people who defend our health, keeping adolescents safe, and harnessing new technologies figure out among the challenges [10]. The WHO General Director highlighted the importance of financial interventions to keep up with expectations, stressing how nations consistently invest in military campaigns but not against potential virus attacks, which would be far more dangerous socially and economically [10]. Therefore, delivering health in crises, facing pandemic scenarios, spreading health care to every individual despite age and social status, and relating health and climate represent primary health goals for the next decades.

In the final document, "Global Strategy on Digital Health 2020-2025", the urgency of "sharing of relevant information", "remote monitoring", and "virtual care" was highlighted to address the objectives [11]. As will be clarified later in the document, these primary needs would deeply benefit from adopting satellite and digital technologies. In tele-medicine, tele-health, tele-epidemiology and disaster management, as well as in the achievement of the SDGs (the primary societal, economic, and environmental issues countries should address in the coming years to improve the Earth's conditions), digital and space technologies would generate incredible opportunities [12]. More specifically, the United Nations declared thirteen (out of a total of seventeen) goals to be "highly impacted" by the use of Earth Observation and Satellite Navigation technologies (among the goals is present "Good health and wellbeing", but other domains are connected to the health thematic too) [12]. GNSS has been cited to be deeply impactful in fields such as tele-medicine, disease epidemiology, and disaster management [4]. The same could be argued about Satellite Communication, enabling (virtual) medical care in a remote geographical place (with a partial, absent, or damaged terrestrial communication network).

In a nutshell, the future societal, health, and economic challenges promoted by the United Nations and WHO appear profoundly related to digital and space technologies.

2. Research questions and methodology

The paper is centred on the adoption of space assets for the benefit of human health. Space Economy, on the one hand, showed a sharp economic rise in the last years, and the trend seems to be even sharper for the years to come. New programs and activities have been constantly launched to foster this wave of technological development. On the other hand, health management appeared to be a domain of primary concern. Also, in this case, initiatives and programs have been launched to raise global living standards. Living in a more globalised, intertwined, and technologically advanced world has opened the door to a more digital health system able to connect many actors, reach remote locations, and provide coverage at a global level, whose exploitation has become even more urgent due to the Covid-19 pandemic. Space technologies may be a valid asset to tackle future human health challenges.

Despite the strong linkage of the two domains, the literature lacks a holistic view of the use of space assets in the health domain. In addition, the factors that limit or foster the development of satellite-based applications in health management and healthcare delivery are still unclear and require a thorough investigation. Therefore, there are two main research questions the paper aims to answer.

RQ1) "What is the state-of-art and maturity of applications for developing space-based services in the health domain"?

RQ2) "Which factors explain the opportunities or challenges that the development of satellite technology-based projects face in the health domain"?

The United Nations Office for Outer Space Affairs (UNOOSA), knowing how relevant the use of satellite assets might be to improve health, computed the effort of relating those two domains, designing a matrix (Fig. 1) on the relationship between the "space activities" and "health activities" [13]. Inside each cell, several activities are listed. Nonetheless, no study in the literature tries to understand the maturity and trends of applications in this joint context. To answer this statement, the matrix has been adapted and populated with projects and applications to discover clusters of presence and analyse the main trends.

To answer the first question, two processes were conducted. The first research was conducted through the European Space Agency (ESA) database between October 2020 and January 2021, containing many interesting application projects. "Health", "Education and Training", and "Safety and Security" keywords have been included in the query. Both ongoing and concluded projects have been considered, be them "Kick-start Activities", "Feasibility Studies", or "Demonstration Projects". In this way, relevant information about factors hampering the successful outcome of projects from feasibility studies or kick-start activities could be extrapolated, which is useful to answer the second question. With the filters included, 256 applications have been selected (December 2020). After screening titles and abstracts, only relevant projects for our research have been considered. For example, maritime or border surveillance applications included under the domain of "Safety and Security" were not of interest to the study. In the end, 48 projects were selected. The second research has been performed through the Google platform. The following query has been used: (("Earth Observation" OR "Remote Sensing") AND "Health*"); (("Satellite Navigation" OR "GNSS" OR "GIS" OR "GPS") AND "Health*"); ("Satellite Communication" AND "Health*"). Also, in this research, projects have been screened, considering their alignment to the scope of the study. In the end, 38 additional projects have been added to the former ones, reaching 86 projects analysed and distributed in the matrix inside the specific cells they belonged.

		Individual Health	Individual and Communities		Population Health	
	Key Health Activities	Medical Practice	Health Services	Medical Research	Prevention and control of infectious and chronic diseases	Global Health Security
Key Space Activities		Tele-Medicine	Tele-Health	Health Sciences	Tele-Epidemiology	Disaster Management
Satellite Activities	Satellite Communication	• Specialist • Second opinion • Remote monitoring • Tele-diagnostic • Tele-consultation • Peer-to-peer • Tele-Robotic	• Professional training • Community health worker training • Community health education • Tele-education • Peer-to-peer training	• Knowledge transfer	• Data dissemination through centres of expertise • Water levels and water borne diseases • Emergencies communication for pandemic response	• Share maps from aircraft • Strategic planning, coordination and communication among relief workers, experts and individuals
Satellite Activities	Global Navigation Space Systems & GIS	• Routing medical emergencies • Tracking patients	• Contextual information on site • Health services optimization	• Causes of discomfort	• Geographic occurrences of diseases • Location of source of infection/pollution • Tracking animals and diseases sentinels	• Supply movement tracking • Detailed site information • Response worker location coordination and planning • Response aircraft location coordination
Satellite Activities	Remote Sensing of the Earth and Atmosphere	• Atmospheric conditions tracking	• Contextual information on site	• Causes of discomfort	• Tracking disease and risk factors • Vector-borne diseases • Air-boom diseases, including air pollution • Water-borne diseases • Food security	• Disaster mapping • Planning and response • Emergency tele-epidemiology • Detailed site information

Fig. 1. The UNOOSA matrix

The second research question focuses on factors, barriers or opportunities affecting satellite technology-based projects in the healthcare domain. Therefore, the question is: "Which are the factors explaining the opportunities or challenges that the development of satellite technology-based projects in the healthcare domain face"?

PubMed and Scopus databases have been analysed to answer the question. The research was performed in January and February 2021. The Scopus database was investigated through the following query, giving an output of 1228 documents: ("Space" OR "Satellite*" OR "GIS" OR "GNSS" OR "Satellite Navigation" OR "Remote sensing" OR "GPS" OR "Earth observation") AND ("Disaster management" OR "Tele-epidemiology" OR "Health sciences" OR "Telehealth" OR "Telemedicine") AND ("Case*" OR "Application*" OR "Stud*" OR "Project*") AND ("Achievement*" OR "Opportunit*" OR "Success" OR "Failure*" OR "Barrier*" OR

"Obstruction*" "Criticalit*" OR OR "Challenge*" OR "Obstacle*"). "Conference Paper, Article, and Book Chapter" were included in "Document type", "English" and "Italian" as "Language", skimming the documents to 1019. 1617 documents were identified using the same query in the PubMed database. After including the filters "Systematic Review", "Journal Article", "Books and Documents", "English" and "Italian"), 1591 documents resulted. Please note that the "Health sciences" keyword was deleted from the PubMed query, since too general for a medical database, and 336 documents remained. No year constraint was included, being the topic of healthcare and satellite present from the previous century. After collecting all the documents, the first step was to merge the databases to cancel duplicates. At the end of this first stage, 1126 documents were obtained (229 duplicates) and ready to be furtherly processed. After screening titles and abstracts, the most appropriate ones for the research were included (healthcare thematic of interest and explicitly or seemingly citing factors of barrier or opportunity). In this screening phase out of scope documents were excluded. This second step was performed before checking the journals' quality to verify if the documents, even if of not acceptable quality, might contain interesting factors of barrier or opportunity in the abstract to be further analysed. In the end, 164 documents remained. In the third step, the quality of the journals was checked to include only authoritative ones. "Scimago Journal and Country Rank" was used. Each journal is ranked on a four-mark scale (Q1 – Highest quality, Q4 – Lowest quality). This information is often provided by year and by sub-topic of the journal to have a more precise level of detail. Therefore, the journal's quality was checked per year the document was published and the sub-topic it referred to. Only high-quality Q1 and Q2 journals were considered, and 112 documents remained. Last, the 112 documents (if the pdf was present) were read. The exclusion criteria, to the final decision, if to consider them in the research was the effective presence of the factors of barrier or opportunity. Only 23 documents were irrelevant to our scope. Therefore, 89 documents were included. A request through the "Research Gate" network to the respective authors was sent to those whose pdf was unavailable. 63 documents could be entirely read (pdf available), while for the remaining 26 only the abstract was available. The PRISMA diagram in Fig. 2 summarises the literature review process.

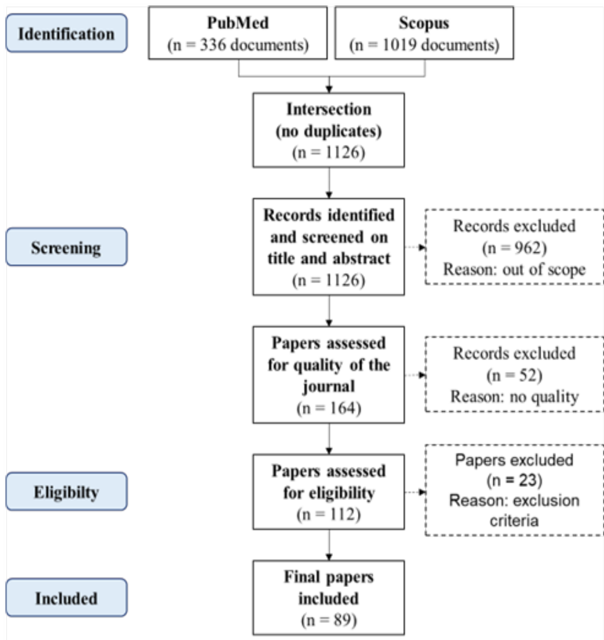

Fig. 2. The PRISMA diagram

In addition to the literature review, project analysis, and categorisation, a third relevant source of information was considered to have a complete view of the topic. We conducted eight interviews with first-class professionals in the joint domain of satellite technologies and healthcare, three of them being C-levels from top-class European Union space programs.

In conclusion, the discussion benefits from integrating all the different perspectives that emerged from the analysis of the systematic literature review, the projects review and the experts' interviews.

3. Findings

We present in Fig. 3 the findings from the analysis and categorisation of the 86 projects selected. Cells are coloured according to a Pareto analysis. The colour scale represent the frequency of collected projects: red=low; yellow=medium; green= high.

		Individual Health	Individual and Communities		Population Health	
	Key Health Activities	Medical Practice	Health Services	Medical Research	Prevention and control of infectious and chronic diseases	Global Health Security
	Key Space Activities	Tele-Medicine	Tele-Health	Health Sciences	Tele-Epidemiology	Disaster Management
Satellite Activities	Satellite Communication	• Specialist • Second opinion • Remote monitoring • Tele-diagnostic • Tele-consultation • Peer-to-peer • Tele-Robotic	• Professional training • Community health worker training • Community health education • Tele-education • Peer-to-peer training	• Knowledge transfer	• Data dissemination through centres of expertise • Water levels and water borne diseases • Emergencies communication for pandemic response	• Share maps from aircraft • Strategic planning, coordination and communication among relief workers, experts and individuals
	Global Navigation Space Systems & GIS	• Routing medical emergencies • Tracking patients	• Contextual information on site • Health services optimization	• Causes of discomfort	• Geographic occurrences of diseases • Location of source of infection/pollution • Tracking animals and diseases sentinels	• Supply movement tracking • Detailed site information • Response worker location coordination and planning • Response aircraft location coordination
	Remote Sensing of the Earth and Atmosphere	• Atmospheric conditions tracking	• Contextual information on site	• Causes of discomfort	• Tracking disease and risk factors • Vector-borne diseases • Air-boom diseases, including air pollution • Water-borne diseases • Food security	• Disaster mapping • Planning and response • Emergency tele-epidemiology • Detailed site information

Fig. 3. The UNOOSA matrix populated with the projects analysed

Most projects adopted Satellite Communication technologies in tele-medicine and disaster management domains, and GNSS/GIS and Earth Observation in tele-epidemiology and disaster management.

Tele-consultation, Tele-diagnostic, and Remote Monitoring appear as the most relevant activities in the Satellite Communication & Tele-Medicine cell projects. In-field operators (or directly the patients) were put in contact with back-office specialist personnel who supported them. In some of the projects, using digital devices to monitor patients' conditions highlighted the importance of Artificial Intelligence for data analysis and sending warnings. It is the case of the OURSES project, enabling the monitoring from remote of patients by tracking signals emitted from ECG sensors worn by them [14]. If the system algorithms scouted cardiac irregularities through out-of-limit data, alerts would be automatically sent to the physician's office [14]. The particularity of this project was the adoption of the satellite link to transmit the signal for complete coverage [14]. The projects have verified the growing use of Artificial Intelligence techniques to process Big Data and send alerts to back-office specialists in case of out-of-limit physical data.

The joint presence of Tele-consultation, Tele-diagnosis, Remote Monitoring, and Specialist was present in most of the projects belonging to the cell. The three services were together provided to end users. Technological devices, operated by patients or by first response operators, assured the remote monitoring of individuals' conditions, with satellite communication systems broadcasting information to back-office specialists. Satellite Communication, even as a mere backup system to ensure stable signals transmission, is a great advantage in healthcare. Here some citations from the projects. *"It was recognised that the use of satellite was the only effective way to bridge the digital divide in e-healthcare"* [15]. Satellite Communication enabled *"improve the usage of current medical systems offering higher speed, better coverage, and a continuous communication link"* [16]. *"Thanks to innovative satellite technologies, bringing the hospital to the patient is now proving to be a practical reality, to the benefit of the individual, the healthcare provider, and the national economy. As a result, satellite communications now form an essential part of an emerging model set to transform healthcare provision"* [14].

It also allowed remote training and education, covering the so-called "digital divide", as proved in the Satellite Communication & Tele-Health cell.

A couple of examples of projects adopting satellite communication services for tele-medicine benefits are worth to be cited. The EMERGENCY-112 project aimed at developing a system to transmit *"critical bio signals (ECG, BP, HR, SpO2, temperature) and still images of the patients, from the emergency site to an emergency call center, thus enabling physicians to direct pre-hospital care more efficiently, improving patients outcome and reducing mortality"* [17]. To work effectively in rural places, the system relied on Satellite Communication. A second and similar example is represented by the SatCare project, to foster immediate treatment by first responders to patients in ambulances [18]. First-line operators could consult remote doctors and specialists at the place of intervention or during the route to the hospital [18]. The importance of satellite technology in providing high-speed data transmission from the ambulance to the hospital and vice versa in areas where the terrestrial network was weak was remarked [18]. *"The emergency response vehicle will be equipped with a mobile broadband SatCom link that will improve the usage of current medical systems offering higher speed, better coverage, and a continuous communication link. The use of broadband will enable the deployment of diagnostic tools requiring the transfer of heavy data like ultrasound scans, videoconferencing between hospital and emergency response vehicle"* [18].

In emergencies (such as in the COVID-19 pandemic response), homogeneity of real-time information (through a stable and reliable signal), is mandatory [19]. While first-line operators spread all over the territory (even in isolated areas), the exchange of reliable two-ways information is required for an effective response. The role of Satellite Communications is once again fundamental in overcoming weather obstructions, geographical impediments, or damages affecting the operative infrastructures [19], as confirmed in the projects belonging to the cell Satellite Communication & Tele-Epidemiology. The React2 project summarised well the necessity of Satellite Communication: homogeneity of real-time information, with a stable and reliable communication signal, during emergencies (such as in the COVID-19 pandemic response) is a must [19]. Since front-line responders are spread geographically (also in remote places), a system that guarantees reliable two-way information exchange is necessary. Even if traditional communication infrastructures, such as Internet and mobile infrastructures, were adopted, the React2 system integrated Satellite Communications, fundamental in geographic issues, weather obstructions, or disaster situations that made the infrastructure inoperative [19].

In the cell Satellite Communication & Disaster Management, the core activity present in all the projects was the strategic planning, coordination, and communication among relief workers, experts, and individuals. For example, Satellite Communication also enabled to share maps from aircrafts, drones, or UAVs. In this way, a real time panoramic view of a place affected by a disaster is available to back- and front-line operators.

Different Satellite Communication technologies were adopted inside each cell. Most of the projects belonging to the cell Satellite Communication & Tele-Medicine adopted satellite-based broadband Internet. It indeed enables the transfer of data of patients and tele-consultation activities. Satellite Internet, satellite telephones, and TV broadcasting were used in the cell Satellite Communication & Tele-Health, with the first two also verified in the cells Satellite Communication & Tele-Epidemiology, and Satellite Communication & Disaster Management.

Tele-Epidemiology and Disaster Management domains were strongly impacted also by Global Navigation Satellite Systems (GNSS) & GIS. Routing of medical emergencies and tracking of patients were the main activities in the cell GNSS & GIS & Tele-Medicine. GNSS devices track and monitor individuals' positions in real-time. Through this information, a patient's daily activity can be defined (versus a medically prescribed amount), or its positioning can be tracked in an emergency. In the cell GNSS & GIS & Tele-Epidemiology, the location of the source of infection/pollution was the main reason the satellite technology was adopted. In some projects, the spot of a source of infection (or pollution) was complemented by a GIS representation of the distribution of the phenomenon visualised through dashboards. Pandemics such as the Covid-19 could be addressed with GNSS devices, for example, by adopting GNSS systems to track citizens' movements or pilot drones to picture the crowd level in public places. Also in the cell GNSS & Disaster Management many projects were found, enabling planning and control of response activities.

Earth Observation (Remote sensing of the Earth and Atmosphere) was strongly linked to Tele-Epidemiology and Disaster Management. In Tele-Epidemiology, EO enables the identification of areas possibly affected by disease and risk factors, vector-borne diseases, and water-borne diseases. Even though a picture from a satellite cannot scout the presence of mosquitoes or ticks in the soil, it can be used to gather data about environmental and climatic determinants (ECD) related to vectors' presence [20]. The satellite technology adopted is both the SAR (Synthetic Aperture Radar) and Optical one, often used together. For example, an optical satellite easily detects a pond, while a Radar one can perceive the moisture of a surface.

The cell Earth Observation & Disaster Management focused on using EO for disaster mapping, planning and control of the response. The majority of projects rely on the joint use of both SAR and Optical EO satellites, but some projects also relied on SAR satellites only. While in Tele-Epidemiology, SAR satellites enable the detection of natural proprieties of the soil (then associated with vectors' presence), in the field of Disaster Management, their use complements Optical satellite images, which are affected by cloud coverage or nighttime. In case of emergencies, there is the need to have a real-time scenario, whether it is night or stormy.

However, reviewing the projects, it was observed that great value for healthcare often depends on the joint combination of multiple satellite technologies for a common purpose. It is true in the Tele-Medicine, Tele-Epidemiology, and Disaster Management domains.

The joint combination of satellite and digital technologies appears as the enabling factor to provide an effective service to end-users and improve the quality of health for citizens.

In the Tele-Medicine domain, the joint adoption of satellite communication and satellite navigation enabled the effective realisation of some of the projects. It is the case of the Virtual Clinic Direct project, aiming to support patients in rehabilitation after suffering a fracture [21]. The patients could be monitored at their place, with sensors collecting data from the fractured area. Satellite Communication was used to have an optimal service with uninterrupted communication and complete coverage [21]. *"Between 10%-18% of users in the UK were estimated to require a SatCom connection to support remote measurement of this type"* [21]. In addition, GNSS allowed healthcare professionals to understand if the patient maintained their prescribed activity level [21].

In the Tele-Epidemiology domain, several projects used GNSS and Earth Observation. After picturing the site of potential infection through remote sensing images, GNSS allowed locating the place precisely. This way, first-line operators could reach the location to collect further data. Collecting additional in-situ data (from sensors, people, etc.) is fundamental in those projects to reach greater detail in the analysis of the problem. The use of Artificial Intelligence to combine and process data from various sources was then observed. An example of a project leveraging those two space assets is the RVF (Rift Valley Fever) project. The project was conducted in the Ferlo region in Senegal and addressed the Rift Valley Fever disease. Being caused by infected vector mosquitoes, the project aimed at identifying places in which mosquitoes were potentially present, such as ponds and vegetation factors [22]. GIS and Remote Sensing images were integrated. Fig. 4 summarises the main trends in space projects for health resulting from our analysis.

Fig. 4. Main trends in space projects for health

In Disaster Management, the combination of Satellite Communication, GNSS, and Earth Observation in the same project was often verified to have the most effective response to a disaster. Even combined with drones or UAVs, EO satellites allowed visual control over the disaster area. At the same time, GNSS allows the control of the movement of first responders, drones or UAVs. Since natural disasters might occur in remote areas (without or with partial terrestrial network coverage), or since the event might damage the terrestrial infrastructure, Satellite Communication plays a critical role. It would allow communication and sharing of visual information among relief operators and between them and the control tower (even from UAVs). In Disaster Management, the additional need for data sources proved pivotal. In-situ ground data, census data, and end users' inserted data were leveraged in many projects. Artificial Intelligence to combine and process data from heterogeneous sources was observed too. The SIS-SREM project could be stated as an example [23]. The goal was to guarantee improved search and rescue missions in ski resort areas [23]. Satellite Communication was used to have high-speed Internet access in remote areas without coverage, GNSS allowed the monitoring of the position of first responders and drones, Earth Observation satellite's and drone's imagery was combined to scout avalanches [23].

The last topic focuses on the implementation's geographic area and similarities among the projects. Most projects based on satellite technologies in the health domain were developed in the UK. In the domain of Tele-Epidemiology, most of the projects arose in the African continent. It is a direct consequence of the higher presence of disease vectors in those regions due to favourable climatic determinants. However, most of the prime contractors of these projects were from France, Belgium, and other European nations. This fact could be attributed to language similarity factors simplifying the collaboration between the nations involved. But more interestingly, African nations leaned intensively on developed countries' stakeholders. Another relevant trend is the collaboration of multiple stakeholders in realising the projects, often from a plurality of nations. Moreover, some of the joint presence of public and private actors has been verified, a topic that will be deepened later in the paper. Fig. 5 summarises the main factors of opportunity and barriers deriving from our analysis.

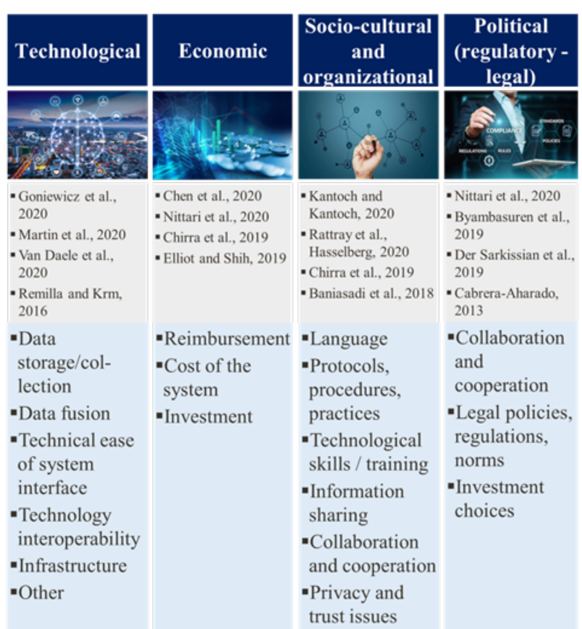

Fig. 5. List of the factors of opportunity and barrier (literature review and projects)

4. Discussion and Conclusions

As presented in Fig. 3, satellite technologies – Satellite Communication, Global Navigation Satellite System & GIS, and Earth Observation – proved to be a fundamental asset for the effectiveness of tele-medicine, tele-health, tele-epidemiology, and disaster management projects. These health activities received endless benefits from them. However, the literature reviewed, the projects listed, and the experts interviewed made immediately clear that several factors could hinder the development of projects in this joint domain, hampering their full potential.

After the systematic literature review analysis and the projects' information, a classification into categories of the factors of success or barrier to the development of satellite technology-based projects in the healthcare domain was computed. In particular, barriers were divided into four categories: technological, economic, socio-cultural, organisational, and political (regulatory and legal).

The same process was performed after the interviews were conducted with the experts. We present the factors of opportunity and barriers resulting from expert interviews in Fig. 6.

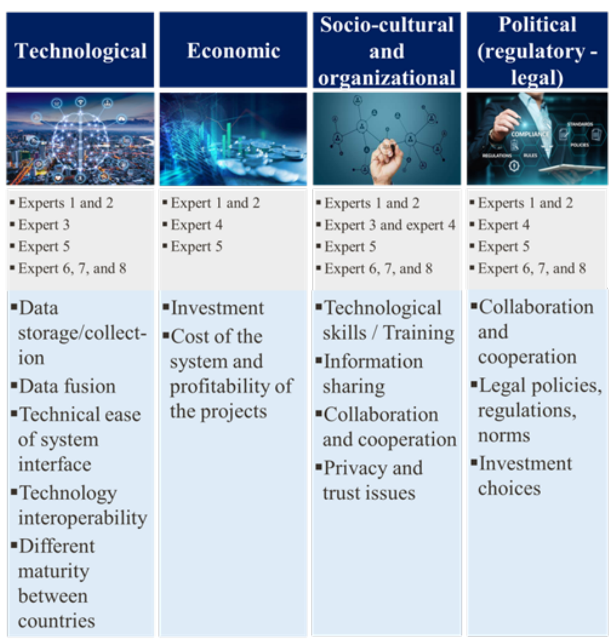

Fig. 6. List of factors of opportunity or barrier (experts' interviews)

Technological factors can be summarised in three key points: data storage and Accessibility, data fusion, and technological diversity within a single project and among nations.

The importance of data collection generates the need for proper data storage systems. All the three sources of information, projects, literature, and interviews stressed the point of tele-medicine, tele-epidemiology, and disaster management. Data is indeed the "conditio sine qua non" the systems could operate, whatever the healthcare domain. Since data is the enabling factor, a proper collection system is at the pyramid's base. Since data is often retrieved from multiple data sources, a system able to gather all the information in the same format is a strong requirement, as explained in the projects and by experts.

The data integration thematic was also highlighted by all the three sources of information for the tele-medicine, tele-epidemiology, and disaster management domains. Data from multiple sources shall be combined to provide a unique solution to health needs. Data collection and subsequent fusion were cited in many projects. For example, tele-epidemiology and disaster management projects stressed using Radar and Optical EO satellites to combine pictures of a location [20,22]. The need to merge the information gathered from the two satellite technologies is clear, as explained in the projects since each has some benefits. For example, a picture from a Radar satellite, even if less intuitive to read, can perceive the moisture of a surface and overcome cloud coverage or nighttime. In addition, many projects involved integrating other data (census data, data from in-field sensors, data from aircraft (drones and UAVs), health data, or end users data). In the tele-medicine domain, combined data sources were needed to monitor patients with multiple devices. Great technical and analytical skills are necessary to integrate and subsequently analyse data.

The technological difficulty in the interoperability of the systems is the third concept that emerged from the literature, projects, and interviews. Projects often derive from different technologies integrated into a single system. This problem is amplified when they are developed by multiple stakeholders (each providing its technology) from different nations (that might have different standards). The tele-medicine, tele-epidemiology, and disaster management domains revealed this aspect. Indeed, pandemics and disasters do not face geographical borders, and tele-medicine services are often shared across nations.

Moreover, at a technological level, every country has a different level of readiness (for both the healthcare and space sectors). In more digital-advanced nations, space technologies are clearly introduced much faster (space infrastructure availability, development of digital applications, and incentives). This situation is revealed empirically in the projects conducted on the African continent. There, it was seen how contractors were mainly Europeans, especially from France and Belgium.

Let's now switch to the economic domain. A major issue highlighted in the literature was the need for significant investments to start the projects and maintain the systems. Capital and operational expenses could be important, and the return on investment could be difficult to estimate.

Different issues could be reported for what concerns the socio-cultural and organisational factors. The first topic cited is the lack of technological skills. If, on one side, digitalisation has revolutionised the ecosystem, as verified in the technological domain, on the other side, experts and articles stressed a strong sentiment that data science capabilities are missing. Consequently, there is an urgent need to generate new skills. This aspect validates developers designing effective systems and end users handling them. As the space economy sector is growing sharply, technical skills for both digital and healthcare actors are fundamental. The need for training professionals in developing countries is even more urged, as underlined by experts.

Another aspect of the projects, literature and interviews was the lack of proper collaboration and cooperation among the stakeholders within a project. Difficulties in aligning to reach a common goal and developing long-term relationships were verified.

Last but not least, an issue of particular relevance was the need for security and confidentiality of information. It regarded the request of confidentiality by patients for their medical information or earth imagery information (the level of detail of the imagery taken may compromise privacy). In general, patients appeared to be quite sensitive to privacy. Data storage appeared to be a technical and even a socio-cultural topic. In the medical domain, the privacy of the information stored is fundamental. Patients' information shall not be used for issues other than the project or program intended. Security of information is therefore critical. The legal sphere is also connected, as later explained.

Regarding the political (regulatory and legal) factors, the literature highlighted the lack of proper collaboration and cooperation among institutional and non-institutional actors operating at the national and international levels. Limitations in this context regarding both the space sector (capacity building) and the healthcare thematic. An inorganic presence of constitutions, specific acts, laws, legislations, and regulations among nations was verified. This situation included multiple domains, from capacity-building initiatives to privacy, education, Liability, licensing, and data sharing issues across nations. Valachamy et al. [24], highlighted the difficulty in making geospatial data accessible and available for sharing purposes. Der Sarkissian et al. [25], confirmed the importance of agreements and laws to secure sharing of harmonised data. Petiteville [26]., suggested that to foster the use of EO remote sensing data, satellite data providers have to take appropriate measures to remove barriers related to data access. Cabrera-Aharado et al. [27] sustained national governments should cooperate with key international actors and domestic space agencies. According to them, "*International cooperation is the only way to* *get the most up to date satellite imagery for disaster relief and humanitarian efforts. An open data access policy is key to effectuate this objective, allowing for the free and timely sharing of data. International organisations and several nations have already acknowledged this necessity, instigating a trend of open data policies and guidelines. Challenges to achieving this purpose remain, mainly in the political and legal sectors"* [27]. Velterop et al. [28] sustained the need for greater collaboration and cooperation across countries (even those with their own satellite systems) since natural disasters are irrespective of political borders.

Van Daele et al. [29]., concluded that the lack of regulations in mental health care for digital practices across borders *"has already been identified for several years as an important factor hampering large-scale implementation and availability of tele-medicine"*. Therefore, also in tele-medicine, the creation of inter-state policies is urged.

In particular, literature highlighted licensing limitations requiring physicians to have different licenses to practice across nations. Even in disaster management, licensing limitations prevent private and commercial satellite providers from sharing data. It would hamper the opportunity to enrich data sets with helpful additional information from private players, a growing force in the space economy value chain. Another factor hampering the collaboration and cooperation among space actors is the liability issue. In disaster management, Cabrera-Aharado [27] stressed how that is a primary concern for both public and private entities: *"Liability for the accuracy of data is significant and can result in a reluctance of parties to share data internationally. Specifically, satellite imagery and data that are inadequate in part, or not as timely as may be required, run the risk of hindering relief efforts when relied upon. Potentially, this can result in lives lost, a waste of limited financial and other resources, and susceptibility to subsequent lawsuits as a result"* [27]. The parallel in the tele-medicine domain is the Liability for medical malpractice.

Finally, the last factor stated for the political domain is the investment decision by governments or inter-governmental organisations (ex. the European Commission, the United Nations, the International Monetary Fund, and the World Bank). Capital investments would be a success factor in expanding the infrastructure needed for connected health implementation and supporting research and pilot projects.

Now that a global panoramic on the factors of barriers to the spread of satellite-based applications in healthcare has been performed, a key message that could be immediately extracted by reviewing them is a pervasive need for harmonisation. A pervasive need for harmonisation in a plurality of aspects could be defined.

Firstly, harmonisation at the technical level would be required. Harmonisation in terms of data storage among data coming from multiple sources with different formats, and harmonisation in technological convergence are primary topics. Harmonisation in technological convergence would be even more important when players come from more nations. Then, harmonisation would also be required in the socio-cultural and organisational domains. Greater collaboration and cooperation among the actors involved in projects would be helpful to have more alignment in the medium-long term and reach the objectives. Finally, harmonisation in the political (regulatory and legal) sphere is a strong requirement. Harmonisation in terms of data dissemination and coordinated constitutions, acts, laws, legislations, and regulations among nations was a necessity.

Establishing Public-Private Partnerships appears to be very helpful in reaching a long-term collaborative environment to achieve harmonisation within a single project, inducing a higher level of cooperation and collaboration among the stakeholders. In this way, technological and organisational obstacles hampering the successful outcome of the projects could be overcome or at least better addressed among the players. PPPs would soften technical and organisational barriers, strengthening the collaboration and cooperation among stakeholders in the middle-long term. Contextualising the link between the public and private sectors is a direct consequence of the rise of private players in the space economy value chain, already explained in the introduction and verified by the projects. Along with PPPs, the issue of internal protocols, procedures, and practices among stakeholders would be needed for the organisational aspect.

Protocols shared with all the relevant stakeholders would define responsibilities. The establishment of PPPs, and the relative protocols, could also help in privacy and trust issues. In one of the projects, internal protocols were utilised to let the patients know the precise time and duration of data collection [30]. It enabled earning the trust of patients. Moreover, also the issue of generating the proper skills could be addressed. Specific training sessions for end users and sharing knowledge among the stakeholders could raise technical skills for developers and end users. The establishment of PPPs would even overcome problems related to legal concerns of liability and data sharing. Establishing partnerships in which actors collaborate and cooperate in the long term would create confidentiality and trust among the actors, fostering the willingness to collaborate. Finally, PPPs could create an environment of future collaboration, fostering actors to share economic resources to generate additional projects. Therefore, different stakeholders would share their resources in projects.

In the last paragraph, it has been seen how the establishment of partnerships among the stakeholders could overcome some technological, economic, socio-cultural, organisational, and political issues. However, other barriers remained outside of the potentiality of PPPs, and should be addressed at a higher level.

The fragmentation of constitutions, acts, laws, legislations, and regulations among nations highlight how harmonisation would be required even internationally. Collaboration and cooperation should be considered within single projects, but their need would be necessary, more widely, at the international level, among nations. The thematic of space economy for the healthcare sector needs cross-border collaboration to enforce capabilities to address global challenges. Since healthcare is a more and more inter-state and interdisciplinary domain, policies, regulations, and general actions fostering higher political and legal cooperation among nations appear urgent. Moreover, coordinated and global responses are requested since disasters and epidemiologic diseases do not know geographical frontiers. The concept of "One-Health" is now more evident than ever before. Therefore, capacity building should be enhanced worldwide in a pervasive way, with developed nations supporting developing ones through higher cooperation in the space sector. The result would be a generation of value from the use of space applications by developing nations, which would also increase worldwide capacity. Since, as the projects reveal, a strong presence of European contractors persists in the African continent, developing nations do not have enough assets and competencies yet.

For this reason, inter-state collaboration and cooperation are urged. The overall ecosystem would benefit from policies shared across nations to reach more international harmonisation. Since projects are often led across nations, space and digital assets do not face country borders, and healthcare problems are a worldwide issue, collaboration at the international level is the solution. Inter-state technological harmonisation should be considered along with political and legal harmonisation. The two domains are linked. It is seen how the key message of more harmonisation persists in the discussion. For example, licensing limitations could be overcome with inter-state agreements in the legal sphere. It would help share data among countries, benefiting the whole ecosystem. This way, international collaboration among actors would be fostered, and PPPs would be more easily set. Also, an alignment of security measures would soften the sharing of data. Shared global frameworks on security regulations and data protection issues would guarantee a harmonisation of the norms, overcoming barriers hampering the realisation of cross-border projects.

To conclude, as presented in Fig. 7, training practices should be set within specific projects and through institutional policies and regulations to be more pervasive in society. The technological, economic, socio-cultural, and political spheres are deeply intertwined in this domain. Generating technical skills would strengthen the ability to develop effective services by the downstream actors of the space economy, the "bridge" between space infrastructure and final users, and the ability of end users to operate the systems effectively.

Fig. 7. The need for training

The concept of harmonisation has been proved relevant among the actors in a project and different nations. A third domain in which harmonisation can be considered is the whole space economy value chain. It is an even wider picture. It means that, along the chain, the actors should be more aligned with each other. Analysing the literature and listening to the interviews, it was discovered that final healthcare users are not always aware of the potential benefits satellite technologies could offer to respond to their urgencies. Making end users aware would create economic value. Indeed, precise subgroups of end users could be targeted with appropriate solutions, benefiting the project's profitability (with precise clients) and the community of final users. A user-driven method of pulling the chain would benefit the whole sector. Since the benefits are often intangible or difficult to estimate, this ends in a lack of "information sharing" among healthcare actors. Providing evidence of cost-effectiveness is strongly urged to generate interest in the topic. Therefore, a bridge would be needed to merge the players. The solution can be found in "Translators" (see Fig. 8). Translators could be companies, consultants, or projects allowing the healthcare end users to comprehend the benefits of satellite technologies and vice versa, letting the upstream and downstream players understand the needs. Even if it is not easy to quantify the benefits of the projects in economic terms, they are not questionable. Indeed, there are plural benefits that can be stated. For example, tele-medicine would guarantee a reduction of hospitalisation costs, preventing the insurgence of diseases or helping in the recovery from an injury. In the tele-epidemiological context, satellite applications help in sensing the presence of disease sources and foreseeing a possible epidemic development. The potential of this solution in economic terms is important. Hospitalisation costs would be saved, and it could also be saved the global international economy. Everyone knows the economic disruption faced after the spread of the Covid-19 pandemic. Worldwide lockdowns occurred and world GDPs shrank. Satellite technologies could also be used to respond to a pandemic. Examples refer to identifying places to construct new hospitals or assigning vaccination teams to precise locations. In the disaster management scenario, satellite technologies could help prepare for or prevent catastrophes, minimising the related costs. They could help in sensing early signs of landslides or avalanches, which would dramatically hit the integrity of infrastructures, bringing recovery costs. They could also help in the process of recovery from earthquakes, floods, and hurricanes.

In conclusion, it can be affirmed that spreading information on the topic would foster understanding the positive contribution of satellite technologies among potential end users. But even satellite and digital actors should be more aware of the needs of healthcare actors. Therefore, creating the bridge along the space economy value chain is a priority. Generating awareness among end users should be viewed in parallel with increasing training on using those applications.

Another aspect relevant to be faced is the fact that technological readiness is different from country to country. There is a different level of readiness between developed and developing nations, with the last having the upstream and downstream segments not yet mature. Therefore, if for developed countries the main obstacle is not the technical one, it cannot be concluded the same for developing ones. Therefore, it is not yet clear why developed nations could not scale up despite being able to implement applications based on satellite technologies in pilot projects.

Fig. 8. The need for translators

As answered, part of this problem could be due to the lack of information sharing among the end users, who do not see the benefits of its adoption, limiting the possibility of converting pilot projects into widely adopted commercial applications. Another factor to be considered, along with the information sharing thematic, is political support. Apparently, in the last couple of years, no real appetite for investing much money into the space economy sector to respond to healthcare needs was perceived. The reasons for this situation were addressed mainly to the Coronavirus crisis. Experts argued that money was invested for other uses, such as studies and vaccination campaigns, but not in space. Investment choices and decisions should be considered at the political level to foster the issue. Of course, the lack of long-term-oriented PPPs and the lack of global international frameworks should also be considered.

The message of harmonisation (see Fig. 9), underlined for the technological, economic, and socio-cultural spheres, is also included in the political one. It was verified how important national policies are, supported by an international harmonisation among different countries. The integration of norms should consider all the actors in the ecosystem, public and private. If private actors are a source to leverage to expand the industry's capacities, on the other side, appropriate regulations shared among the public and private sectors would be welcome. Issues of liability and data sharing could be softened by establishing public-private partnerships, as already argued. Those partnerships would create a regime of trust and intimacy between actors. In this manner, more collaboration and capacity building would foster project development in the space for health. However, this approach should be complemented with a harmonised legal framework.

Tele-epidemiology and disaster management, highly impacted by EO and GNSS, strongly depend on data sharing. In those domains, it is a prior topic to solve legal issues negatively affecting its sharing. As argued by expects and literature, policies and institutional structures are urged to allow more Accessibility and availability of geospatial data for sharing purposes. Once again, the concept of harmonisation is remarked. The elimination of policies related to data access is supported by literature to overcome barriers to using EO data. Having a regime of more collaboration and cooperation at the international level would foster information sharing, which, together with an open data access policy, would enable free and timely sharing. In a nutshell, for disaster management, international collaboration reached through establishing policies and regulations on open data would guarantee the sharing of the most updated imageries, combining information from multiple actors.

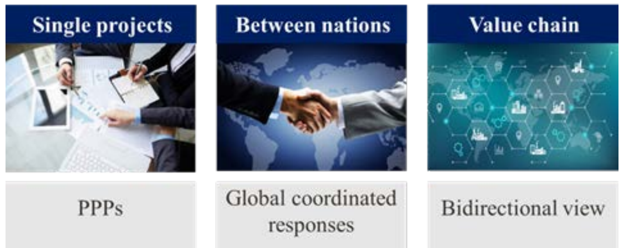

Fig. 9. The need for harmonisation

It is now possible to summarise the issues hampering the development of projects in developed and developing countries. Low information sharing among end users is a big portion of the pie, limiting the willingness to consider satellite technology-based solutions. For this reason, interesting pilot projects cannot scale up into commercial applications. If developing countries showed a lack of technological capabilities, hampering the development of pilot projects from the start, developed countries present the technological knowledge to initiate pilot projects. However, problems in scaling up pilot projects persist. Information sharing issues should be considered in parallel to other obstacles. Indeed, legal issues on data restriction, in addition to a lack of harmonised international legal frameworks, do not allow the transition from pilot projects to commercial services. Solutions fostering the sharing of data are needed. The establishment of long-term PPPs brought more confidence among the actors and willingness to cooperate, sharing information. Inter-state collaborative measures would help in this context. Overall, a harmonised framework of policies would soften international barriers, fostering cooperation in the ecosystem. This harmonisation would be necessary for the privacy and security of data, data sharing, Liability, and licensing. In this way, international PPPs would also be fostered among private and public actors from different countries answering global healthcare needs, trying to have a "One Health" approach.

5. References

[1] MISE, Il PIANO STRATEGICO SPACE ECONOMY 2016, 2016, May 2, https://www.mise.gov.it/images/stories/documenti/all_6_Piano_Strategico_Space_Economy_master_13052016_regioni_final.pdf

[2] Morgan Stanley, The Space Economy's Next Giant Leap – Morgan Stanley, 2016, https://www.morganstanley.com/Themes/global-space-economy

[3] European Investment Bank, The future of the European space sector. How to leverage Europe's technological leadership and boost investments for space ventures, 2019, https://www.eib.org/en/publications/the-future-of-the-european-space-sector-report

[4] United Nations, European Global Navigation Satellite System and Copernicus: Supporting the Sustainable Development Goals, 2018, January, https://www.unoosa.org/oosa/en/oosadoc/data/documents/2018/stspace/stspace71_0.html

[5] European Union, GSA GNSS market report 2019,https://www.euspa.europa.eu/market/market-report

[6] Research Guides, Definition of GIS, 1999 https://researchguides.library.wisc.edu/GIS

[7] G. Denis and X. Pasco, 'The Challenge of Future Space Systems and Services in Europe: Industrial Competitiveness Without a Level Playing Field', *New Sp.*, 2015, doi: 10.1089/space.2013.0034.

[8] European Union, Copernicus market report 2019, 2019, February, https://op.europa.eu/en/publication-detail/-/publication/693988e9-574c-11e9-a8ed-01aa75ed71a1

[9] World Health Organization, Global strategy on digital health 2020-2024, 2019, March 26, https://extranet.who.int/dataform/upload/surveys/183439/files/Draft%20Global%20Strategy%20on%20Digital%20Health.pdf

[10] World Health Organization, Urgent health challenges for the next decade, 2020, January 13, https://www.who.int/news-room/photo-story/photo-story-detail/urgent-health-challenges-for-the-next-decade

[11] World Health Organization, Global strategy on digital health 2020-2025, 2019, https://www.who.int/health-topics/digital-health/#tab=tab_1

[12] United Nations, The 17 goals, 2020, https://sdgs.un.org/goals

[13] Committee on the Peaceful Uses of Outer Space, Space technology for socioeconomic development in the context of the United Nations Conference on Sustainable Development and the post-2015 development agenda, 2015, February, Fifty-second session.

[14] Prieto-Guerrero, A., Mailhes, C., & Castanie, F., OURSES: a telemedicine project for rural areas in France. Telemonitoring of elderly people, 2008, August, In *2008 30th Annual International Conference of the IEEE Engineering in Medicine and Biology Society* (pp. 5855-5858), IEEE.

[15] IoTnow, Satellite Communications: Bringing the hospital to you, 2011, September 21, https://www.iot-now.com/2011/09/21/2658-satellite-communications-bringing-the-hospital-to-you/

[16] ESA, SmartSatCare – Smart Social and Healthcare Advanced Services with Smart TV and Satellite Communications, 2020, November 6, SmartSatCare - Smart Social and Healthcare Advanced Services with Smart TV and Satellite Communications | ESA Business Applications

[17] Pattichis, C. S., Kyriacou, E., Voskarides, S., Pattichis, M. S., Istepanian, R., & Schizas, C. N., Wireless telemedicine systems: an overview, 2002, *IEEE Antennas and Propagation Magazine*, *44*(2), 143-153.

[18] ESA, SatCare – Real-time remote diagnosis through in-ambulance telemedicine with broadband satellite connectivity, 2016, November 4, https://business.esa.int/projects/satcare

[19] ESA, REACT 2 – Resource for Emergency Services to Access Command and control data using satellites and hybrid Technologies, 2020, September 25, https://business.esa.int/projects/react-2

[20] ESA, Lyme-MAP feasibility study, a "rapid update" interactive, spatially accurate Lyme Borreliosis identification and risk management system, 2015, June 17, https://business.esa.int/projects/lymemap

[21] ESA, VIRTUAL CLINIC DIRECT – (VCD) – A new paradigm in remote rehabilitation – Virtual Clinic Direct Fracture Management, 2017, December,https://business.esa.int/projects/virtual-clinic-direct

[22] ProQuest, Satellite imaging and vector-borne diseases: the approach of the French National Space Agency (CNES), 2008, November, https://search.proquest.com/docview/2417269093?pq-origsite=gscholar&fromopenview=true

[23] ESA, SIS-SREM – Safety and information systems for ski resorts in emerging markets – demonstration project, 2016, May 12, https://business.esa.int/projects/sis-srem

[24] Valachamy, M., Sahibuddin, S., Ahmad, N. A., & Bakar, N. A. A., Geospatial Data Sharing: Preliminary Studies on Issues and Challenges in Natural Disaster Management, 2020, February, In *Proceedings of the 2020 9th International Conference on Software and Computer Applications* (pp. 51-56).

[25] Der Sarkissian, R., Zaninetti, J. M., & Abdallah, C., The use of geospatial information as support for Disaster Risk Reduction; contextualisation to Baalbek-Hermel Governorate/Lebanon, 2019, *Applied geography*, *111*, 102075.

[26] Petiteville, I., European space agency's strategic contribution to seismology, 2013, *Natural hazards*, *68*(1), 203-207.

[27] Cabrera, S., Langston, S. M., Antoniou, N., & Urquijo, E., The progressive use of satellite technology for disaster management relief: challenges to a legal and policy framework, 2013, September, In *64th International Astronautical Congress*.

[28] Velterop, E., Sirorattanakul, K., Novellino, A., Muhire, D., Amrutkar, R., Patial, S., Vargas-Sanabria, D., Ibitolu, H., Pyne, B., de Prados, A. V., Charles-Aimé, N. M., Towashiraporn, P, Current and near-future state of space technology for disaster situations, 2019, October, *Proceedings of the International Astronautical Congress, IAC*.

[29] Van Daele, T., Karekla, M., Kassianos, A. P., Compare, A., Haddouk, L., Salgado, J., ... & De Witte, N. A., Recommendations for policy and practice of telepsychotherapy and e-mental health in Europe and beyond, 2020, *Journal of Psychotherapy Integration, 30*(2), 160.

[30] Liddle, J., Ireland, D., McBride, S. J., Brauer, S. G., Hall, L. M, Ding, H., ... & Chenery, H. J., Measuring the lifespace of people with Parkinson's disease using smartphones: proof of principle, 2014, *JMIR mHealth and uHealth, 2*(1), e13.