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A Study of the Applications of Space Science and Technology in Healthcare Development

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ABSTRACT

This study aimed to examine the applications of space science and technology in healthcare development in society. The study adopted a review research method by examining recent journal articles, conference papers, empirical studies, and technical reports. The review showed that some of the applications of space science and technology in healthcare development are telemedicine via satellite communication, satellite-based disease mapping, GNSS for emergency response and ambulance tracking, satellite monitoring of air quality and Ultraviolet (UV) radiation, water quality and sanitation monitoring from space, satellite weather forecasting for healthcare planning, and satellite communication for health education and public awareness. The study further revealed that integrating satellite communication, Earth observation, and navigation technologies into healthcare systems enhances decision-making, strengthens disaster preparedness, supports disease prevention, and promotes equitable access to quality healthcare. The study concludes that continued investment in space-based healthcare technologies and supportive policies is essential for sustainable healthcare development and improved health outcomes in society.

KEYWORDS: *Healthcare Development, Public Health, Space Science and Technology, Telemedicine, Satellite Communication, Nigeria.*

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1. INTRODUCTION

Space science and technology is the branch of science and engineering concerned with the exploration of space and the development and application of technologies such as satellites, spacecraft, remote sensing systems, and communication networks for scientific, commercial, and societal purposes. Space science and technology have many application areas, such as in agriculture, education, transportation, health, business, administration, oil exploration, water, environment, and many more (Asekhamen and Ayegba, 2017). Space technology applications for water quality have several advantages, including large area coverage, measurement frequency, and effective, up-to-date, cost-effective, and in-time manner. This paper reviews space technology's use in water quality assessment to achieve sustainable development. Examples of space technology spin-offs and use of online open data access on water quality monitoring are discussed. It also proposes satellite technology viewing a few millimeters of contaminants in water bodies in the near future (Oluwafemi and Olubiyi, 2019). Global coverage, broadcast/multicast capability, and the high capacity of satellites in Geostationary Earth Orbit (GEO) could potentially serve as a tool to extend quality healthcare to underserved remote rural areas (Anas et al., 2018). Earth-observing satellites produce an abundance of data that can be used in the study of human health. Measurements of reflected, emitted, and backscattered radiation track spatial and temporal

variation in the environment, including vegetation, surface water, soil moisture, temperature, and precipitation (Wimberly, 2022). Global environmental change has myriad influences on human health, and researchers are increasingly studying the connections between climate variation and health outcomes. Extreme heat events are becoming more frequent as the climate warms, leading to greater risk of heat-related illnesses and death (Franklinos, 2019). According to Sheffield (2018), the exponential growth of satellite-based information over the past decade provides unprecedented opportunities to support and improve water resources management. Furthermore, traditional barriers to the access and usage of satellite data are lowering as technological innovations provide opportunities to manage and deliver this wealth of information to a wider audience. Satellite remote sensing is increasingly being used as a complementary source of information to in situ monitoring networks and, in many cases, is the only feasible source, given that satellite-based sensors are now capable of making direct and indirect measurements of nearly all components of the hydrological cycle (Zhang et al., 2016), such as precipitation, evaporation, lake and river levels, surface water, soil moisture, snow, and total water storage. Satellites provide long-term, consistent, large-scale coverage that complements ground-based networks and offers significant advantages for air quality monitoring. Satellites enable observation of air pollutants across the globe, including in remote or under-monitored regions, ensuring no area is entirely data-scarce (Oluwafemi and Olubiyi, 2029). This work focuses on the use of space science and technology in the development of healthcare systems.

2. Methodology

This study adopted a review research method to examine the applications of space science and technology in healthcare development. To achieve this, relevant information was obtained from credible secondary sources, including peer-reviewed journal articles, conference proceedings, textbooks, and other scholarly publications published in recent years. The selected studies were critically analysed to identify their objectives, methodologies, major findings, and conclusions. The information obtained from these studies was synthesised and presented thematically to demonstrate how satellite communication, Earth observation, and navigation technologies have contributed to the improvement of healthcare accessibility, disease surveillance, emergency preparedness, environmental health monitoring, and public health planning. This approach provided a comprehensive understanding of the growing role of space science and technology in addressing healthcare challenges, particularly in developing countries such as Nigeria.

3. Results and Discussion

The following are some of the major applications of space science and technology in healthcare development.

1. Telemedicine via Satellite Communication

Telemedicine is the use of telecommunications and digital technologies to provide clinical healthcare services to patients when distance separates the patient and the healthcare provider. Telemedicine involves the use of satellite communication systems to deliver medical services over long distances, especially in areas where conventional communication infrastructure such as fibre-optic cables or reliable 4G/5G networks is unavailable. Geostationary Earth Orbit (GEO) and Low Earth Orbit (LEO) satellites provide broadband internet connectivity that enables hospitals and healthcare centres in remote locations to communicate with specialist doctors in urban medical facilities. Through satellite-enabled telemedicine, healthcare professionals can conduct real-time video consultations; exchange patients' medical records; transmit diagnostic images such as X-rays, CT scans, scans, and ultrasound results; and even provide remote guidance during complex surgical procedures. This technology significantly reduces the need for patients to travel long distances before receiving specialist medical attention, thereby saving both time and cost. Telemedicine also improves healthcare accessibility for rural populations, strengthens collaboration among healthcare professionals, and contributes to better patient outcomes through faster diagnosis and treatment.

Morris et al. (2025) investigated the optimisation of satellite-based telemedicine networks for improving healthcare delivery in rural Nigeria, using Igu Village in Abuja as a case study. The aim of the study was to develop a reliable satellite communication network capable of supporting telemedicine services in underserved communities. The researchers simulated a telemedicine network using the NigComSat-1R satellite and applied Particle Swarm Optimisation (PSO) to improve communication performance under varying weather conditions. It was observed that there were significant improvements in data throughput, reduced bit error rate, and low communication latency, enabling reliable video consultations and transmission of medical images. The authors concluded that satellite communication can significantly enhance telemedicine services and improve healthcare accessibility in rural areas.

Haroon et al. (2021) evaluated the effectiveness of telemedicine in satellite dialysis centres with the aim of assessing if telemedicine could provide specialist healthcare services while reducing unnecessary hospital visits. The findings showed that telemedicine improved access to specialist care, reduced patient travel, maintained quality healthcare delivery, and supported timely clinical decision-making. It was concluded that telemedicine is a safe and effective approach for delivering specialist healthcare services to patients in remote locations.

2. Satellite-Based Disease Mapping

Satellite-based disease mapping is the application of satellite imagery, remote sensing, and Geographic Information Systems (GIS) to detect, monitor, and map disease patterns and risk areas across geographic regions. Earth observation satellites, such as NigeriaSat-2 and Landsat, continuously monitor environmental conditions that influence the occurrence and spread of many infectious diseases. These satellites collect information on factors such as rainfall patterns, vegetation cover, land surface temperature, humidity, flooding, and the presence of water bodies, all of which affect the breeding and survival of disease vectors such as mosquitoes. In developing countries like Nigeria, satellite-based disease mapping strengthens disease surveillance systems by enabling faster identification of high-risk communities and supporting evidence-based decision-making. This technology enhances emergency preparedness, improves resource allocation, and ultimately reduces disease transmission and mortality by ensuring that healthcare interventions are directed to locations where they are needed most. To achieve this, the satellite-derived environmental data are integrated into predictive models that help health experts forecast the likelihood of outbreaks of diseases such as malaria, cholera, Lassa fever, meningitis, and other climate-sensitive diseases. By identifying areas with high disease risk before outbreaks occur, public health authorities can implement preventive measures such as mosquito control programmes, vaccination campaigns, environmental sanitation, public awareness initiatives, and the strategic distribution of medical supplies.

In the work by Wimberly et al. (2022), who investigated the use of satellite Earth observation data for malaria early warning systems, the results showed that satellite-derived environmental information accurately identified favourable conditions for mosquito breeding and enabled earlier prediction of malaria outbreaks. The researchers integrated satellite observations of rainfall, temperature, vegetation, and surface water with environmental datasets to identify areas at high risk of malaria transmission. They concluded that satellite-based disease mapping strengthens disease surveillance and supports timely public health interventions by enabling health authorities to implement preventive measures before outbreaks occur. Also, Ibeji et al. (2022) examined the spatial distribution of malaria and anaemia among children under five years in Nigeria, which was aimed at mapping disease distribution and identifying geographical hotspots to support healthcare planning. The work employed Bayesian spatio-temporal modeling using malaria survey data together with environmental and geographical variables to produce disease risk maps across Nigeria. It was observed that there were significant spatial variations in disease prevalence, with some regions consistently recording higher malaria risk than others. The authors concluded that disease mapping is an effective tool for supporting evidence-based decision-making and improving public health planning in Nigeria.

3. GNSS for Emergency Response and Ambulance Tracking

Emergency response and ambulance tracking are the application of space science and technology (communication networks, GPS, satellite systems, and monitoring technologies) to dispatch emergency services promptly and track ambulance locations in real time for effective medical response. Satellite navigation allows ambulance dispatch centres to identify the nearest available ambulance and direct it to patients using the fastest and safest route. Hospitals can also monitor the movement of ambulances and estimate their arrival times, allowing medical personnel to prepare appropriate treatment before patients reach the hospital. In addition, Global Navigation Satellite System (GNSS) supports the tracking of medical supplies, vaccines, blood products, and emergency medicines during transportation, reducing delays and ensuring that essential healthcare resources reach their intended destinations efficiently. In addition, satellite navigation supports drone-based delivery systems used to transport blood, vaccines, laboratory samples, and emergency medications to difficult-to-reach communities. By improving emergency response time, reducing logistical challenges, and enhancing coordination among healthcare providers, GNSS significantly contributes to better healthcare delivery and increased survival rates during medical emergencies.

Ganter et al. (2022) carried out research work on the application of Global Positioning System (GPS) technology for tracking first responders during medical emergencies, aimed at evaluating the

accuracy of GPS-based tracking in determining emergency response times. The researchers conducted an observational study by comparing GPS-recorded arrival times with manually recorded arrival times of first responders responding to cardiac arrest incidents. The results revealed GNSS-based tracking enhances emergency medical response by improving coordination and reducing delays in patient care. According to Højgaard et al. (2020), GNSS technology is a valuable tool for improving emergency response planning, reducing delays, and enhancing the efficiency of emergency medical services. This was the report in the work to examine the relationship between GPS-estimated and actual ambulance response times in a prehospital emergency care system.

4. Satellite Monitoring of Air Quality and UV Radiation

Satellite monitoring of air quality and UV radiation is the application of satellite-based sensors and remote sensing techniques to detect, monitor, and analyze concentrations of air pollutants and levels of ultraviolet radiation in the Earth's atmosphere. Space science has significantly improved environmental health monitoring through satellites equipped with advanced sensors that continuously observe the Earth's atmosphere. Satellites provide accurate and timely information on air pollution and ultraviolet (UV) radiation, enabling health authorities to monitor environmental conditions that directly affect human health. The information collected by these satellites helps governments and public health agencies monitor air quality, identify pollution hotspots, and issue early warnings when pollution levels become hazardous. In addition to monitoring air pollution, satellites provide valuable information on ultraviolet (UV) radiation reaching the Earth's surface. UV index data help health authorities educate the public on the dangers of excessive sun exposure, reducing the risk of skin cancer, eye damage, and heat-related illnesses.

Filonchyk et al. (2021) examined the application of the Sentinel-5P satellite for monitoring atmospheric air pollution in major urban areas. The aim of the study was to investigate the capability of satellite observations in monitoring nitrogen dioxide (NO_2), sulphur dioxide (SO_2), carbon monoxide (CO), and ozone concentrations for environmental and public health purposes. The researchers reported that satellite observations accurately identified pollution hotspots and temporal variations in air pollutant concentrations. It was concluded by the authors that satellite remote sensing is an effective tool for air quality monitoring and environmental health management. Also, Bauwens et al. (2020) examined changes in atmospheric nitrogen dioxide concentrations using Sentinel-5P satellite observations during COVID-19 lockdown in order to study the impact of reduced human activities on air quality using satellite remote sensing. The researchers analysed satellite observations of NO_2 over several countries before and during lockdown periods and compared the results with atmospheric model simulations. They reported that substantial reductions in NO_2 concentrations across major cities, showing the ability of satellite observations to monitor air pollution and evaluate environmental policies. The work concluded that satellite-based atmospheric monitoring provides valuable information for protecting public health and supporting evidence-based environmental decision-making.

5. Water Quality and Sanitation Monitoring from Space

Earth observation satellites equipped with multispectral and radar sensors continuously monitor rivers, lakes, reservoirs, wetlands, and coastal waters to detect environmental changes that may threaten water quality. These satellites provide accurate information on water pollution, sediment levels, algal blooms, flooding, and other environmental conditions that affect human health. Satellite imagery can identify harmful algal blooms, increased turbidity, oil spills, and other contaminants in water bodies before they become serious public health hazards. Also, Synthetic Aperture Radar (SAR) satellites can monitor flood extent even during cloudy weather or at night, providing valuable information for predicting outbreaks of waterborne diseases such as cholera, typhoid fever, and diarrhoeal infections that often occur after flooding.

The information generated from satellite observations enables governments, health agencies, and disaster management organisations to deploy water purification systems, drill boreholes, distribute clean drinking water, and implement sanitation interventions in communities most at risk. It also supports long-term planning for water resource management and environmental protection. Buma and Lee (2020) investigated the application of satellite remote sensing for monitoring water quality in inland water bodies. The aim of the work was to evaluate the effectiveness of satellite imagery in detecting changes in water quality that could threaten public health. The analysis of multispectral satellite images was done to monitor parameters such as turbidity, chlorophyll concentration, suspended sediments, and harmful algal blooms. The results revealed that satellite observations accurately detected water quality changes and enabled early identification of polluted

water bodies. The researchers concluded that satellite remote sensing provides an effective approach for supporting water quality monitoring, disease prevention, and sustainable water resource management. According to Page et al. (2022) in their work**,** which used Earth observation satellites for monitoring harmful algal blooms in freshwater ecosystems, satellite observations successfully identified algal bloom events and supported early warning systems for water resource managers and public health agencies. It was further stated that satellite-based water quality monitoring improves environmental surveillance, supports timely public health interventions, and enhances the management of safe drinking water resources.

6. Satellite Weather Forecasting for Healthcare Planning

Satellite weather forecasting for healthcare planning is the application of satellite meteorological data and forecasting technologies to anticipate weather-related health risks and support the planning, allocation, and delivery of healthcare services. Weather satellites continuously monitor atmospheric conditions such as temperature, rainfall, humidity, cloud cover, storms, and heatwaves. The data collected help meteorological agencies predict extreme weather events that may affect human health and healthcare services. The healthcare authorities, irrespective of the level, use weather forecasts to prepare for climate-related disease outbreaks and medical emergencies. In everyday life, weather forecasts obtained from satellites enable individuals to take preventive health measures by avoiding hazardous weather conditions, planning outdoor activities safely, and protecting vulnerable groups such as children, pregnant women, and the elderly. In Nigeria, satellite-based weather forecasting contributes to improved healthcare planning, disaster preparedness, and public safety by providing reliable information that supports timely medical interventions and reduces weather-related health risks. Wimberly et al. (2022) investigated the integration of meteorological forecasting and public health surveillance for predicting outbreaks of West Nile virus in North America. The aim of the study was to determine whether weather variables could improve the prediction of disease outbreaks and support healthcare preparedness. The results showed that weather variables such as temperature and precipitation significantly improved the accuracy of outbreak predictions, and they enabled health authorities to identify high-risk areas several weeks before disease transmission peaked. The work concluded that satellite-supported weather forecasting provides an effective decision-support tool for public health planning and disease prevention. Farooq et al. (2022) developed an artificial intelligence model to predict West Nile virus outbreaks using eco-climatic factors derived from satellite observations and environmental datasets. The researchers applied machine learning techniques to historical disease records together with satellite-derived temperature, vegetation, precipitation, and environmental variables to forecast disease occurrence across Europe. The results indicated that climatic variables obtained from satellite observations were among the strongest predictors of disease outbreaks and substantially improved forecasting accuracy compared with conventional surveillance approaches. It was concluded that satellite weather information combined with artificial intelligence can strengthen healthcare planning, improve disease surveillance, and support timely public health interventions.

7. Satellite Communication for Health Education and Public Awareness

Satellite communication is the process of sending and receiving electromagnetic signals through a satellite that acts as a relay station between transmitting and receiving Earth stations. Communication satellites transmit television, radio, and internet services over large geographical areas, enabling governments, healthcare organisations, and educational institutions to disseminate health information quickly and efficiently. Through satellite broadcasting, the public receives information on disease prevention, vaccination programmes, maternal and child healthcare, nutrition, family planning, sanitation, and healthy lifestyles. During disease outbreaks such as COVID-19, satellite communication enabled governments and health authorities to educate millions of people on preventive measures, vaccination campaigns, and public health guidelines, even in communities with limited terrestrial communication infrastructure. In everyday life, satellite-enabled communication helps people access health information through television programmes, radio broadcasts, online consultations, webinars, and mobile health platforms. It also supports the continuous training of healthcare professionals through distance learning and virtual medical conferences.

Doraiswamy et al. (2020) investigated the role of digital communication technologies in delivering healthcare services and health education globally. The authors analysed evidence from published empirical studies involving telemedicine, remote consultation, patient education, and digital health communication across different countries. It was highlighted that communication technologies supported by reliable broadband and satellite connectivity significantly

enhanced public access to health information, increased awareness of disease prevention, improved adherence to treatment, and expanded healthcare services to rural and underserved communities. The authors concluded that satellite-enabled communication infrastructure plays an important role in promoting health education, improving healthcare accessibility, and supporting effective public health interventions. Monaghesh and Hajizadeh (2020) investigated the effectiveness of telehealth during the COVID-19 pandemic. The aim of the study was to assess how telecommunication technologies contributed to healthcare delivery and public health education during a global health emergency. The researchers reviewed empirical studies that reported the application of telehealth for patient consultation, health education, disease surveillance, and healthcare communication. The results revealed that telehealth technologies enabled healthcare providers to educate the public on disease prevention, provide remote consultations, monitor patients, and reduce unnecessary hospital visits. The authors concluded that telehealth, supported by reliable communication infrastructure including satellite communication in underserved regions, is an effective tool for improving public awareness, promoting health education, and ensuring continuity of healthcare services during emergencies.

8. Satellite Navigation for Personal Health and Mobile Health Applications

Satellite navigation technology has become an important part of everyday healthcare through its integration into smartphones, wearable devices, and mobile health (mHealth) applications. Most modern smartphones use satellite positioning systems such as the Global Positioning System (GPS) to provide accurate location information that supports a wide range of health-related services. Mobile health applications allow users to locate nearby hospitals, pharmacies, blood donation centres, and emergency healthcare facilities using satellite navigation. During emergencies, users can share their precise location with ambulance services, reducing response time and improving access to medical care. In Nigeria, where smartphone use continues to increase, satellite navigation is making healthcare services more accessible, supporting healthier lifestyles, and enhancing emergency medical assistance in everyday life.

Alhasani et al. (2023) investigated the effectiveness of Global Positioning System (GPS)-enabled mobile health technologies in supporting healthcare delivery and personal health monitoring. The aim of the study was to evaluate how GPS-integrated smartphones and wearable devices improve healthcare accessibility, emergency response, and physical activity monitoring. The results showed that GPS-enabled mobile applications accurately tracked users' locations during emergencies, monitored physical activities such as walking and running, and enabled healthcare providers to remotely monitor patients with chronic diseases. The study further revealed that integrating satellite navigation with mobile health applications improved emergency response time, facilitated access to nearby healthcare facilities, and promoted healthier lifestyles. The authors concluded that satellite navigation technology has become an essential component of modern mobile healthcare systems by improving patient safety, healthcare accessibility, and health monitoring. In the work by Mishra et al. (2022), which examined the application of Global Navigation Satellite Systems (GNSS) and wearable technologies in healthcare monitoring and emergency medical services, it was revealed that the system successfully monitored patients' physiological conditions while simultaneously transmitting their geographical location to healthcare providers during emergencies. The authors concluded that satellite navigation technologies significantly enhance mobile healthcare applications, support independent living among elderly patients, and improve the efficiency of emergency medical services.

4. Conclusion

The research in the applications of space and technology in healthcare development has been carriedout using the review research method. Space science and technology have transformed healthcare delivery by providing innovative solutions to many challenges facing modern health systems. The review has shown that space science and technology (satellite communication, Earth observation satellites, GNSS, and other space-based technologies) play important roles in telemedicine, disease surveillance, emergency medical response, environmental health monitoring, vaccine distribution, health education, and mobile healthcare services. It was observed from the review that space science and technology improve access to quality healthcare, particularly in remote and underserved communities, as well as enhancing disaster control and public health planning. The results further showed that the integration of space technologies into healthcare systems contributes to improved disease prevention, efficient resource allocation, and better patient outcomes. It can be concluded that continued collaboration between the space, health, and information technology sectors will help in strengthening healthcare delivery and contribute to achieving sustainable public health and national development goals.

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