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AI Report

AI in Space: Is It Revolution or Evolution? And How Does It Help Climate Action?

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Space

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He holds a master's degree in Mechanical Engineering from the Massachusetts Institute of Technology (MIT) & Masdar Institute of Science and Technology Cooperative Program, and a bachelor's degree from RMIT Australia. He graduated with first-class honors, and in 2016 was recognized as one of the UAE's top graduates by H.H. Sheikh Mohammed Bin Rashid for his outstanding achievements. Alshehhi has also worked in global organizations including Airbus, Mitsubishi Heavy Industry, and Lockheed Martin.

Artificial intelligence (AI) has already had a dramatic influence on several sectors, including health, education, and sustainability. This paper will explore how AI can also play a crucial role in changing the dynamics of the space sector to tackle national and international challenges.

Over the past seven decades, human exploration of outer space has exceeded expectations. Humans are constantly striving to go further, pursue new challenges, and make new scientific discoveries. Outer space has always fascinated humans—it has been a source of inspiration as well as a cause for reflection on what makes us human, about what connects us across races and cultures.

Space: The next frontier

The space sector has already had a significant impact on all of our lives. It has driven technological advances and led to developments that we use in our daily lives and across various industries, most notably by enabling global connectivity and revolutionizing the way we communicate. International phone calls, global television broadcasts, and internet services were not widely available a few decades ago. Now they are widespread, and even possible in some of the world's most remote areas.

Space systems have also assisted in search and rescue missions by detecting distress signals from emergency beacons and helping locate people in need. In addition, Global Navigation Satellite Systems such as BeiDou, GLONASS, Galileo, and GPS have changed the way we get around. They are used not only by citizens in cars and on smartphones, but also in industries such as aviation, maritime, and logistics for accurate tracking and navigation.

The UAE's vision for space

The UAE's knowledge and investigations of outer space stretch back centuries, with its people having long used astronomy to aid navigation by land and sea, as well as to predict the weather. The UAE's far-sighted founder, the late Sheikh Zayed bin Sultan Al Nahyan, received Apollo Mission astronauts as early as 1976, sending a message to his people, the region, and the world that Emirati curiosity and ambitions had no bounds. He laid the path that has allowed the UAE to continue advancing his forefathers' knowledge of astronomy, navigation, and outer space.

The UAE's national space program began in 1997 with the establishment of the country's first homegrown satellite operator, Al Thuraya. The company made its first launch in 2000, enabling satellite communications. As of today, it has made more than **20 launches** toward several celestial bodies, orbiting Earth, Mars, and the Moon.

AI is rapidly increasing its influence space programs around the world. This paper illustrates the opportunities that the technology provides for the space sector.

The role of earth observation satellites

Earth observation space systems provide data needed for weather forecasting, helping to predict and monitor severe events such as hurricanes and storms. The ability to study Earth from space has provided invaluable information about our planet's climate and environment, helping shape our understanding of global warming and other environmental issues. Today, satellites are playing a crucial role in helping us better comprehend, inform, and support mitigation efforts related to climate change.

Emission control: Better understanding enables better solutions

Today, more than **50%** of essential climate variables are measurable only from space. Satellites measure atmospheric concentrations of greenhouse gases (GHGs), such as carbon dioxide and methane. This data allows scientists to track emissions sources and carbon sinks, and to measure how these gases are influencing our climate. Satellites are proven to be a highly effective way of monitoring GHGs at scale and speed.

They are also being used to monitor polar ice caps and glaciers, providing data on the rate of ice melt and on sea surface measurements. This is in turn generating critical insights into sea-level rise, a key metric of climate change. In addition, satellite imagery is helping monitor deforestation, urban growth, and changes in land use. These changes often contribute to increased carbon emissions because they can result in the destruction of natural carbon sinks, such as forests.
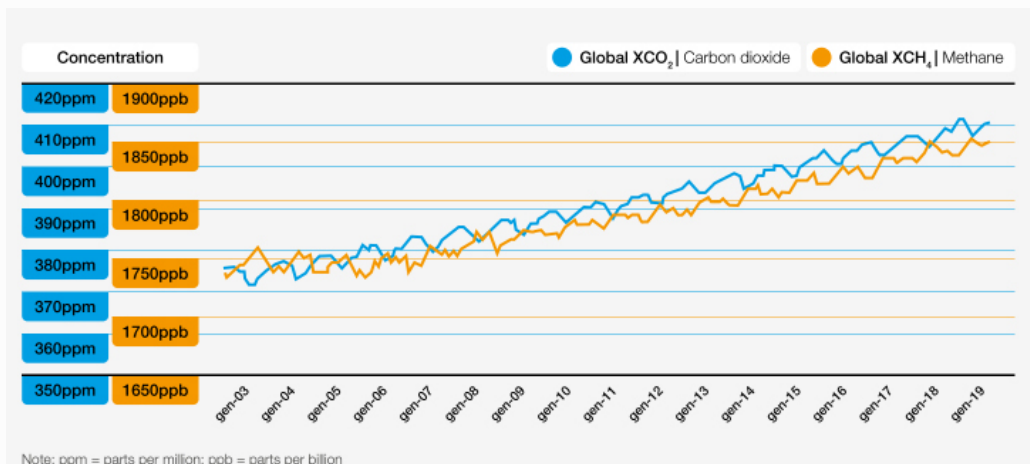
Figure 1: Global carbon dioxide and methane, 2003-2019

Source: World Economic Forum Report, Space for Net Zero.

Figure 1, shown above, displays global carbon dioxide and methane concentrations from 2003 to 2019. GHG emissions began rising dramatically in the 1800s due to the Industrial Revolution and changes in land use. GHGs stem from activities such as the combustion of fossil fuels, deforestation, fertilizer production and use, livestock farming, and landfill sites. According to the EU's Copernicus Programme, "of all the long-lived GHGs made by human activities, the ones that have the largest climate impact are carbon dioxide, methane and nitrous oxide."

Oceans also absorb a significant portion of atmospheric carbon dioxide and heat. Satellites monitor ocean temperature, salinity, and acidity, helping scientists understand the health of oceans and their role in climate change. Combining AI tools with the data that we receive from space systems and other sources offers huge potential in the field of climate science, including the prediction and tracking of GHGs from space and developing ways to tackle climate change.

AI is changing our relationship with data

In recent years, AI has played a crucial role in advances in the space sector with a particular focus on Earth observation applications, specifically those related to climate change. As space technology continues to evolve and expand, the incorporation of AI will become increasingly important, offering vast opportunities to improve, streamline, and innovate how we study our planet.

Several AI techniques are already used extensively in the space sector, including the below:

Machine learning is being deployed to analyze vast amounts of data collected by satellites. It helps to detect patterns and make predictions in a wide range of areas, such as weather forecasting, identifying geological features, detecting exoplanets, and predicting the trajectories of satellites or space debris.

Machine vision includes computer vision and image processing. It is crucial for autonomous spacecraft, which use machine vision to navigate and to dock with other spacecraft. It also facilitates space rover navigation, analysis the surfaces of planets and moons, and identification of features of interest, such as craters, volcanos, and signs of water or ice.

Natural language processing helps improve communication between astronauts and control centers. It can provide automated report generation and assist in data analysis by extracting relevant information from large textual datasets.

Automation and robotics are used extensively for deep space exploration. Robotic arms on the International Space Station assist in various tasks, from spacecraft docking and repairs to scientific experiments. Mars rovers such as Perseverance and Curiosity are examples of semiautonomous robots exploring other planets.

AI is also changing the way we process the data we get from space. Innovative ways of analyzing and displaying vast amounts of complex data in one simple platform will be vital to helping the global community tackle and adapt to climate change. This can only be achieved with big data gathered from various sensors and combined with AI.

Scientific research into climate change suggests the frequency and intensity of extreme weather events is increasing. Space systems can track these events and collect data to identify trends, thereby helping improve future climate models and

predictions by enhancing the datasets available for AI to work with.

A new tool created by IBM in collaboration with NASA, the watsonx.ai model, is designed to convert satellite data into maps of floods, fires, and other landscape changes to reveal our planet's past and derive insights into its future.

As part of a Space Act Agreement with NASA, IBM has built a foundation model for analyzing geospatial data. This is revolutionizing natural language processing by allowing developers to train one model on raw text, then use extra training to customize the model with for work on other natural language processing tasks. Users previously had to train a new model for each task, which required extensive data curation and computing. Rather than train a foundation model on words, IBM Research taught a model to understand satellite images, pre-training it on NASA's Harmonized Landsat Sentinel-2 data. Enabling all the data that satellites collect to be fed into computer models that predict future climate scenarios will be key to creating effective mitigation and adaptation strategies.

Observation and optimization: What AI can do

AI technologies and the space sector are increasingly intersecting, paving the way for novel applications and heightened operational efficiency. AI algorithms are optimizing spacecraft routing, automating data processing, enhancing satellite communications, and providing predictive satellite maintenance. In the context of Earth observation, AI algorithms are facilitating the interpretation and analysis of satellite imagery and accelerating the process of making meaningful inferences from complex and vast datasets.

Earth observation—particularly its application in climate change studies—is one of the most critical areas where AI has shown immense potential. The task of monitoring Earth's complex and ever-changing ecosystems is gargantuan, and traditional manual methods can be time-consuming and fraught with inaccuracies. AI, particularly machine learning, offers a compelling solution to these challenges.

The proliferation of satellite technology means we are now amassing even larger amounts of data about Earth's atmosphere, oceans, and land. The sheer volume of this data makes manual analysis impractical. However, machine learning algorithms can be trained to process and interpret this data, identifying patterns and anomalies far more efficiently than human analysts.

AI's predictive capabilities are particularly pertinent to climate change studies. Machine learning models can be trained on historical data to predict future climate trends, aiding in our understanding of climate change's potential impacts. This predictive capability is vital for decision-making processes related to climate mitigation and adaptation strategies.

AI has already proven to be highly effective in monitoring critical climate indicators. Machine learning algorithms can process satellite data to track changes in sea surface temperatures, polar ice coverage, deforestation rates, and atmospheric greenhouse gas concentrations, among other things. This real-time monitoring provides invaluable information for not just understanding climate change but, even more critically, for responding to it.

How space agencies are using AI to support climate action

NASA has been a pioneer in integrating AI into its operations. Its Earth Observing System Data and Information System uses AI to process and manage large amounts of Earth science data. It harnesses machine learning to analyze satellite data, allowing it to provide insights into various aspects of the Earth's climate system, including temperature, precipitation, and cloud movements.

The European Space Agency (ESA) is also heavily invested in the application of AI in observing Earth. Through its Climate Change Initiative, ESA is using machine learning to process satellite data and monitor key climate variables. This initiative has led to a better understanding of climate change and its impacts, informing policymaking and contributing to global climate initiatives.

The UAE Space Agency has set up a dedicated program for climate action that incorporates AI techniques. The Space Data Center is a digital platform that provides scientists, scholars, public and private entities, start-ups, and community members with access to space data that can be used to develop AI algorithms. It aims to provide an innovative ecosystem facilitating the sharing of space data and technologies to tackle global sustainability challenges. The agency hopes this will also boost the number of space industry companies and patents, with a focus on using AI alongside Earth observation satellites.

The UAE Space Agency recently announced a partnership with Planet Labs, a pioneer in Earth data and insights, as part of its efforts to bolster global resilience against the impacts of climate change. The establishment of a Loss and Damage Fund was the highlight of 2022's COP27 Climate Conference and the culmination of decades of pressure from climate-vulnerable developing countries. The fund aims to provide financial assistance to nations most vulnerable to the effects of climate change. The UAE's work with Planet Labs will focus on islands such as the Maldives, one of the nations most vulnerable to climate change.

80%   Around **80%** of its land area is less than one meter above sea level, and with sea levels projected to rise up to one meter by the end of the century, the entire country could be submerged.

Conclusion: AI is taking us further

AI is proving to be a critical tool in the space sector, particularly in Earth observation applications and understanding climate change. The transformative power of AI technology has not only increased operational efficiency, but also deepened our understanding of our planet.

As AI continues to evolve and improve, it promises a future where we can more comprehensively monitor and respond to climate change, helping us safeguard our planet for future generations. The ability of AI to process and interpret vast amounts of data, make predictions, and track critical climate indicators presents significant opportunities for even further advances in the space sector.