

## Introduction

In the past decade, the world has faced growing concerns brought about by the need for continuously more resources, together with the need for acting against climate change. To deal with this challenge, new technologies and innovations are put in the equation, aiming at changing in depth our global economic system by making it sustainable and boosting the efficient management of resources. Space technologies can help support this objective as it enables innovative solutions which promote sustainable use of resources, as well as solutions that will help mitigate the environmental crisis through data collection and new satellite tools. Yet, space exploration has grown rapidly in recent years, with an increasing number of rocket launches and satellites exploitation. This paper will analyse how space technology can contribute to sustainable development, considering its impact both on space and earth environments.

### |- How space economy impacts our environment

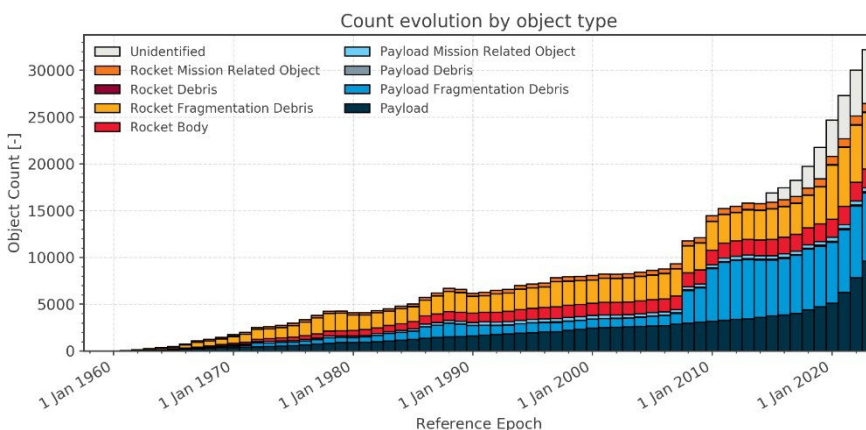
#### 1. In-space pollution

##### Space debris

Long-term sustainability of the space economy can be affected by some consequences of its activity, and space debris – or space “junk” – is one of them. Without taking care of them, space debris can become a threat to further expansion of the economy, especially regarding the exploitation of near- Earth orbital environment. Also, it has consequences on the night sky, which can in turn influence our own perception and vision of space. In this context, new boundaries for space pollution should start being implemented, as these debris depends on our activity in space and how we manage the objects that we put in orbit. This first consideration could help encourage sustainable actions in the space sector and would have consequences not only on the way we manage debris in space but also on how space exploration can impact our environment on earth.

##### Number of objects in orbit

The number of objects that we have put in orbit has almost doubled in the past 10 years, and debris is only one of the sources of space pollution. These objects are of different natures, and include mainly abandoned spacecrafts and fragments from collisions or explosions. One of the main problem of these objects is that the majority of them are not traceable, meaning that we are not capable of finding them



in space or defining the exact number. However, it has been estimated that there are about 128 million of them in outer space, and this number will inexorably continue to increase as space exploration will develop.

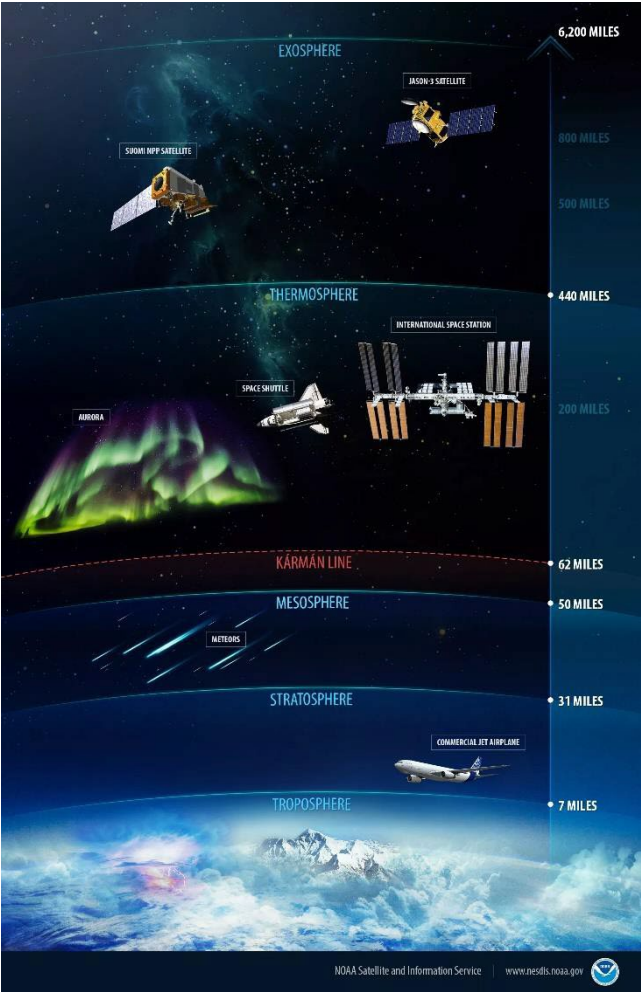
Among these space

objects we also find about 2,500 satellites sent since the beginning of space activity in the 1960s. Considering the increasing number of objects in space, this could represent a threat to space exploration and exploitation as it increases the risk of collision that could lead to degradations of the technical systems in satellites, endangering our space resources. As explained in a previous report by *Les Mines ParisTech*, “since the critical density of objects beyond which cascading debris collisions are self-sustaining has already been reached in some orbital regions, the number of objects in orbit will continue to increase even in the absence of additional launches over hundreds or thousands of years”. All in all this means that if we don’t act for conservation of orbital regions, we might soon lose some of them and will not be able to exploit them anymore, which could affect the whole world economy that relies on satellite data and communications.

2. Pollution on earth

Impact on atmosphere & environment

Every year, about 100 spacecrafts are launched in space and each rocket launch emits 200-300 tons of carbon dioxide. To give a better idea of what it represents, it takes 100 years for a car to emit this amount of CO2 into the atmosphere. In terms of volume this number is thus quite small compared to global car emissions, but as space missions are planned to increase a lot in the next few years, these CO2 emissions are not going to get lower.



Furthermore, as spacecrafts are going through all layers of the atmosphere, each of them is affected by these emissions. And the main concern is that in some of them, especially the stratosphere that contains the ozone layer, CO2 gets accumulated and space missions contribute to this saturation. This impact on ozone layer has been studied for a few decades, but what about the impact on the environment?

To get back to *Les Mines ParisTech* report, “available life cycle assessment studies of space missions are scarce and often do not account for emissions occurring during the launch event, or only partially, due to lack of data availability and modeling complexity”. Studies have still shown that in a year, rocket emissions contribute to warming the stratosphere by approximately 16 mW/m<sup>2</sup>, with direct impact on troposphere: it could lead to local sudden or accelerated climate changes such as warmings or natural disasters.

### 3. UN Sustainable Development Goals (SDGs) and Space exploration



In 2015, all United Nations member states have adopted seventeen SDGs as part of the 2030 Agenda. These objectives are giving a path for global partnerships to “end poverty, reduce inequality, protect the planet, and take more steps toward a better tomorrow for humankind” (UN report, 2015). In this 2030 Agenda are included some guidelines for space sector, mainly opportunities regarding the ways in which space sector can contribute to climate change mitigation. These goals are interdependent and when applied to the space sector, the main lever that can be used to achieve them is through the development of in space technologies. We can take as examples the following goals:

- *Zero Hunger (2<sup>nd</sup> Goal)*: spaceflight technologies and systems can be source of inspiration to help lower the hunger levels in the world, as they aim at lowering the use of water and pollute the least possible in the context of space missions which could also be applied on a larger scale.
- *Clean Water and Sanitation (6<sup>th</sup> Goal)*: in space technologies have been developed with the objective of consuming less water and reusing it when adapted systems can help to.
- *Affordable and clean Energy (7<sup>th</sup> Goal)*: spacecrafts have been built to be autonomous with a low-to-reasonable energy consumption. They rely mainly on power sources such as solar panels that have been thought to be more efficient, and these optimizations could directly be used in on-earth developments.
- *Sustainable cities and communities (11<sup>th</sup> Goal)*: companies such as SpaceX or BlueOrigin are working on the imagination of future possible cities in space, which will have to be auto sufficient in terms of energy, food, etc. This long-term planification could be helpful in the development of sustainable communities on earth.

These examples help understand that the space sector opens up a large panel of opportunities regarding the mitigation of climate change and environmental analysis and surveillance. However, do we know how is it done in practice, and what are the new innovations emerging in the space sector?

#### ||- Space Technology towards Sustainability

Sustainability has been climbing on the agenda in the business world, and the space sector has been no exception. Likely one of the most promising industries to bring innovation towards sustainable development of Earth and beyond, the space industry aims to solve both current environmental issues without hampering the prospects for future generations. Sustainability in the context of Space can be viewed from two perspectives.

Firstly, sustainability in relation to the development of space technology. The focus of this view is to highlight the environmental effects that the development of space technology has on Earth and Space in general. The current focus is on several key aspects of the developing space economy:

- *Orbital debris*: accumulation of unmanned, inoperative objects in Space that can increase the risk of collisions and population in the orbits
- *Space weather*: effects of weather conditions in Space on the progress and success of space missions and operations
- *Overcrowding*: due to the increasing number of launched objects in space, the accumulation of them increases the likelihood of collisions between each other and space debris
- *End of life protocol*: process of getting rid of space object after the completion of its purposes
- *Mega constellation and space debris*: the nature of these constellations greatly increases the likelihood of catastrophic collisions with space debris

Overall, this perspective focuses on ensuring that the environmental risk of space technology is reduced. The second view focuses on solving current environmental issues with the use of space technology. We take this view in the context of this article.

## 1. How space innovation can drive Sustainability Development Goals

### **Food security and agriculture**

One of the key features of space technology is a vast amount of geospatial and other data products. Farmers could benefit by getting information on weather changes and drought forecasting to increase their level of productivity and agility. Several current initiatives aim to make the data available such as Open Data Cube, WMO and Hassas-2, however, this technology is limited to developed countries due to high costs. In addition to local applications, satellite insights can help to track international food supply to better direct humanitarian aid.

### **Health applications**

Collaboration between space tech and healthcare is one of my exciting industries because of its huge potential. Earth-wide observation technology helps to tackle large-scale disease patterns and helps governments to better identify sources, risk areas and control planning. On the commercial, space tech is a key driver of telemedicine, telehealth and medical research. It can help to bring healthcare to remote locations as well as help advance disease and drug research in a microgravity environment.

### **Disaster risk reduction and humanitarian crisis prevention**

Satellite images and more high-tech instruments that track ocean currents, temperature and salinity, air quality etc., help to detect and monitor natural disaster risks. This is especially useful for vulnerable areas with a high risk of natural turbulence. Countries are heavily investing in modern meteorological services to mitigate these risks.

### **Natural resources and environment management**

The Earth observation industry is becoming an essential tool for managing natural resources on earth as well as the environment. Areas of application include agricultural production, fisheries, forestry and mining. To ease climate-related risks, space companies are working on developing a precipitation monitoring system that offers global rainfall maps using satellite data. Additionally, space tech could be used to prevent illegal activities related to mining or poaching. Finally, countries can utilize data to track relevant environmental conditions such as snowfall, ice and glaciers, and allow them to better manage weather conditions.

## Connecting the unconnected and other

A key service that Space technology offers to connect people is the delivery of broadband services. Rather than developing infrastructure-based connectivity, new broadband technology offers a more cost-effective option. Using telecommunications satellites, people could access the internet, which in turn gives access to many services.

To get a deeper insight of what we have seen so far, we will now dive into 5 examples of companies that are leveraging space technology to advance sustainability efforts on Earth.

### 2. What are the actual uses of space technology towards sustainability?

#### Space Forge



Founded in 2018, the startup aims to accelerate “the next industrial revolution” in Space. The core business is the manufacturing of new materials in electronics, pharmacy and

alloys for a new and more sustainable development. The founders recognized the limitations of manufacturing on earth:

- gravity - prevents perfect alloy in metals of different densities
- atmosphere - dense and ambient atmosphere of Earth contaminates clean processes
- temperature - limited ability to create temperature extremes

Thus, the startup aims to leverage the following key characteristics of space:

- *Vacuum*: a 10 trillion times lower pressure than Earth removes contamination and the need for multi-stage pumps
- *Weightlessness*: microgravity prevents buoyancy, allowing for larger and uniform alloy mixing
- *Near-Zero*: radiators facing cold space can freely produce temperatures close to absolute zero for superconductors and quantum devices

ForgeStar platform is the startup’s reusable satellite vehicle that is launched in space for clean industrial manufacturing and is returned to earth with the final products. The company also has a tool called Aether, which predicts landing locations of ForgeStar Platform, other satellites, and space bodies. Their first mission ForgeStar-0 mission is set to be executed by the end of 2022, and it will test the prototype satellite’s return capabilities. After several months in orbit, it would return to Earth where the products will be transported to customers. The satellite will then be refurbished ready to be reused and sent back into space.

Since 2018, the company raised \$10.8M over a total of 3 funding rounds. They have also partners with key UK and EU space players such as the UK Space Agency, ESA and EU Regional Development Fund.

#### WEO – Water Information from Earth Observation



WEO is a Luxembourg-based startup that enables earth environment management by analyzing earth observation (EO) data. The startup utilizes AI-powered radar along with optical and thermal imaging sensors aboard satellites to build an accurate

map of problem areas on earth. The startup provides insights into industrial and governmental concerns such as sustainable agriculture, climate change, water resource management, natural disasters, and urban forestry.

WEO focuses on major environmental challenges, such as water resource management, growing urban forests, preparing for natural disasters and adapting to climate change using Earth Observation data to provide frequently updated, affordable and actionable insights to our clients.

There are currently 3 core solutions that WEO offers:

**Urban Forestry** - As cities are increasing their urban forestation initiatives, the company developed a tree health monitoring system that would help cities to prevent the loss of existing trees and better manage the plantation of new ones. The system is based on data from the Copernicus Sentinel-2 satellite. The data from space provides new imagery every 5 days, which helps the company track tree growth. Moreover, WEO utilized AI to increase image quality and resolution.

**Resilient Cities** - The solution aims to provide a range of services to make cities more sustainable. Satellite-based imagery is used to identify where areas are being sealed to minimize flood risk, track the growth in green roofs to plan incentive programs, understand the impact of vegetation to reduce land surface temperature and more. Another two key application areas are land surface temperature monitoring and surface sealing tracking. WEO maps land temperatures so they can assess dangerous areas and intervene, by planting trees or vegetation which cools the air at night. And surface sealing is the process whereby natural surfaces such as grassland, forests or farmland are sealed either by roads, buildings or pavements as part of urban expansion.

**Managing Vegetation Near the Infrastructure** - WEO is developing with a European railway manager – an alternative method of mapping vegetation proximity to railways, utilizing satellite data. WEO can provide monthly maps to help identify areas at greatest risk from overgrown vegetation, helping prioritize interventions in the lead-up to the fire season. They track data on the proximity of vegetation to habitable areas, the structure of plants and tree and their flammability.

## Planet Labs



A leader in today's Earth mapping landscape, Planet was founded with a mission to image the Earth every day and make change visible, accessible and actionable. Today, the company provides a web-geo platform from the highest French satellite data available and foundational analytics to derive insights, empowering users

across the world to make impactful, timely decisions.

The company's services are used by businesses, governments and research intuitions to scale their operations, increase efficiency and mitigate risk, and develop novel solutions to address their most pressing challenges. This helps them stay ahead in ever-changing global contexts and ultimately capture unforeseen windows of opportunity.

Today, they have 34k users, 700 customers, and 200 partners and Planet operates in 65 countries. Notably, the company has built and developed 450 satellites, of which more than 200 operate in orbit.

The company offers a wide range of solutions for virtually every industry, including ample sustainability initiatives. Notably, they have sustainability-specific solutions aiming at mitigating climate risks. From

measuring climate risks and urban growth to monitoring biodiversity hotspots and global supply chains, Planet's data and products are a key component of data-driven, sustainable solutions. There are 3 areas of focus:

- **Agriculture:** Planet's global, high-frequency data can be instrumental in measuring the efficacy of sustainable agriculture practices as well as identifying potential food security risks across the globe.
- **Energy and Infrastructure:** Climate risks pose serious threats to aging energy grids and infrastructure. Planet's data can help monitor encroachment and manage vegetation in the context of more frequent extreme weather events.
- **Government:** Public-private partnerships are critical for building the technologies and designing policies that measure and verify sustainability efforts.

### Space4Good



Space4Good is an innovative social enterprise utilizing space technology for social and environmental good. Using remote sensing, GIS and artificial intelligence, they map, analyze and model complex ecosystems and support leading organizations and institutions on topics such as environmental crime detection, regenerative agriculture, tropical agroforestry management, humanitarian aid, air pollution and sustainable urban development. By doing so they help impact makers on the ground to make more informed decisions,

improve operational efficiency, create data-driven transparency and unlock new revenue sources such as carbon credits. The company provides 4 key services:

- Remote Sensing Data Analytics
- Geospatial Analytics
- Predicting & AI modeling
- Bespoke Development
- Reporting & Applications

### Open Cosmos

**OPEN COSMOS**

offers 3 key services to its customers:

They deliver satellite-based solutions designed to tackle Earth's biggest challenges. The company

- **Satellites:** scaled production of 3U, 6U, 12U and microsattellites
- **Mission Services:** design, satellite manufacturing, testing, launch, commissioning & operating, insurance & compliance for satellites
- **Development Tools:** OpenApp and OpenKit platforms allow customers to design and develop payloads

Another unique feature of Open Cosmos is its mission to democratize Space data for the betterment of Earth. DataCosmos is their new, multi-satellite data platform with advanced visualizations and applications.

## Conclusion

Overall, the innovative space sector has been playing an increasingly important role in advancing sustainability efforts on Earth with tremendous potential yet to be realized. However, the recent economic downturn and geopolitical tensions have been pulling the attention and funding away from the sector. For instance, \$3.4 billion was invested into space startups in the third quarter of 2022, which represents a 47% decline from the same period last year. Space being among the “emerging industries” is especially sensitive to market volatility as well as reliant on investment from VC firms, which tends to decrease during uncertain times. Despite the sector navigating difficult times, the added value of space technology, especially from a sustainability perspective cannot be overlooked.



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Source

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