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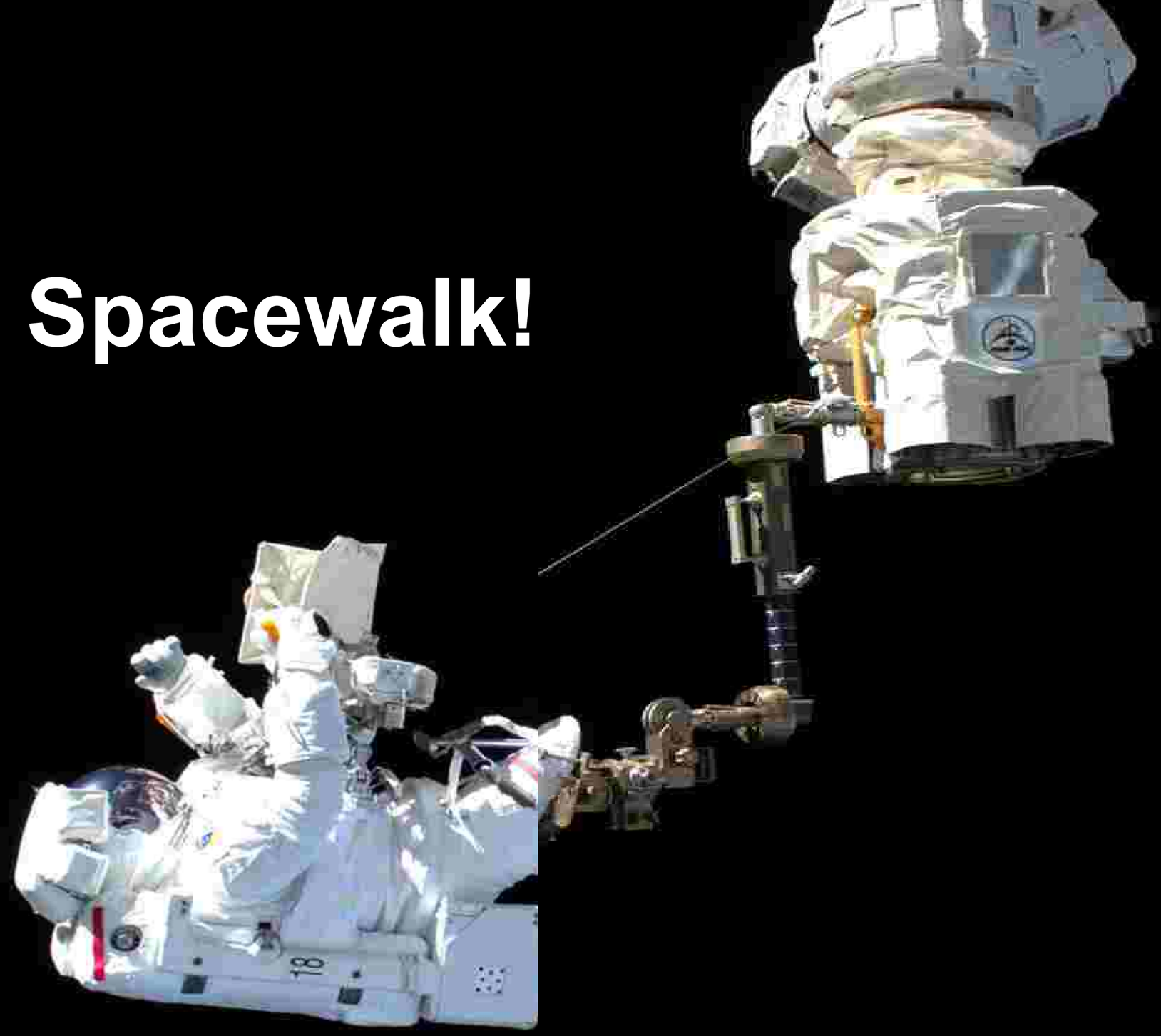
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Where is commercial satellite market really going?

Spacewalk!

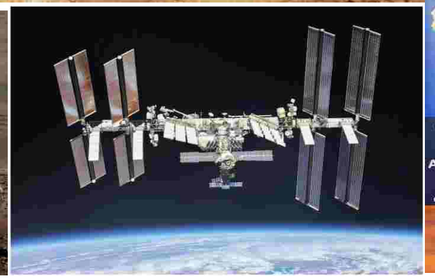


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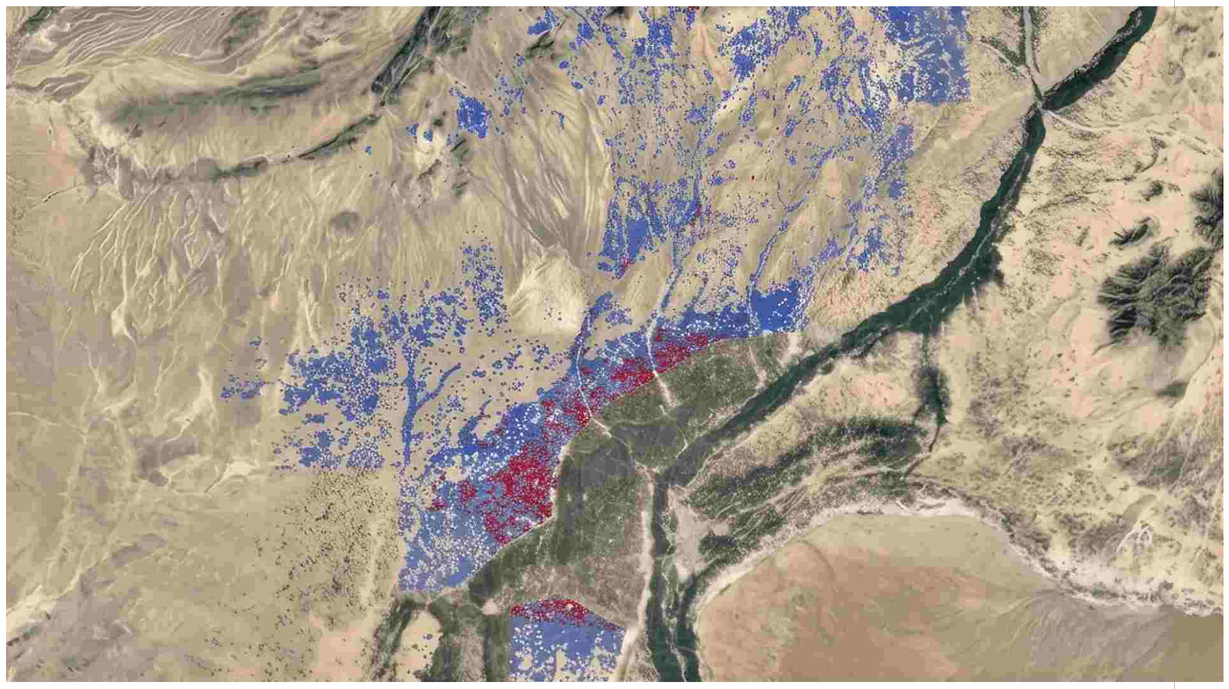
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Can satellites spot illicit crops from space?



From hundreds of kilometres up in space, large patch of land is being photographed by a satellite, pinpointing individual trees and animals. Satellites have already been in use for several years, and drones are currently undergoing trials.

In UK, scanning a farm with a satellite costs about one third as much as sending an inspector on a field visit - £115 about $180; 150 euros rather than £310 ($490; 400 euros), says the UK's Rural Payments Agency (RPA), which is responsible for disbursing the subsidies in the UK and checking for irregularities. Satellites can rapidly cover a huge area in detail and quickly return to photograph it again if necessary.

In 2010, about 70% of the total required controls on farm payments in the EU were done by satellites, which photographed more than 210,000 sq km 81,000 sq miles of land in all. But farmers these days have to keep their land in "good agricultural and environmental condition" to qualify for subsidies, so images also reveal whether the farmer is complying with the rules on hedges and ponds, say, or buffer strips around arable fields.

The monitoring is not always to spot infringements or illegal activities. Satellite images can help identify problems such as erosion. Farmers can then be asked to change their methods to prevent further damage. In the above images, overproduction and deep ploughing in clay earth meant rain washed soil away.
In South America, Colombia has become the world's largest producer of coca leaf and the main producer of opium poppies in the Americas; these plants are the basic raw materials used to produce cocaine and heroin. The nineties were characterised by an expansion of coca growing in the order of 286 percent as cultivated hectares increased from 37,500 in 1992 to 144,807 in 2001. This expansion was accompanied by reduced cultivation in Peru and Bolivia.

Coca is native to the Andean Region of Bolivia, Peru and Colombia. Its cultivation and consumption as leaf has long been part of the traditions and customs of Andean peasant farmers, above all in Bolivia and Peru. In recent decades, specifically since international demand for drugs began to increase, this region has become the world's leading producer of coca: 200,000 hectares of coca are under cultivation in this part of the world. The cultivated area in these three countries was stable throughout the nineties. But in recent years the proportion of the total grown in each country has changed substantially. Colombia went from being an importer of coca base to being a net producer of coca leaf from 19 percent of total regional cultivation in 1990 to 72 percent in 2001.

Over the same period Peru's share fell from 57 percent to 17 percent, and Bolivia's from 25 percent to 10 percent This relocation of coca production in the region was the result of successful eradication and interdiction efforts in Bolivia and Peru. Although these policies enjoyed domestic success, they did not have the same results at regional level. Reduced production in these two countries was compensated for by new crops in Colombia. Colombia's increased participation in the global drug market led to the strengthening of drug trafficking and the consolidation of the industry still using imported coca base from Peru and Bolivia.

However, erythroxylum coca is an evergreen shrub with a dense, glossy canopy and high chlorophyll content. In near-infrared wavelengths roughly 750 to 900 nm, it reflects strongly, producing a normalised difference vegetation index NDVI that is consistently higher than the surrounding secondary forest or pasture it often displaces. That contrast is the spectral handle every classification algorithm grabs first.

Cannabis is more seasonal and more variable in canopy structure, but outdoor plots in Colombia's Sierra Nevada or Afghanistan's Helmand province still show elevated red-edge reflectance during the vegetative growth phase. The challenge is separating it from other broadleaf crops at the same phenological stage. That is where time-series analysis earns its keep: the planting and harvest cadence of illicit crops rarely matches the calendar of legal agriculture in the same landscape.

Many of the new satellites currently in Earth's orbit are equipped to provide revolutionary tools and data to improve global food security and strengthen agrifood systems. A new report from the Food and Agriculture Organization of the United Nations FAO and the United Nations Office for Outer Space Affairs UNOOSA aims to inform and guide an array of experts and policy makers on the various intersections of space technology and farming, forestry and land-use management as well as climate and environmental trends.

“Space technology has emerged as a game changer. Satellite imagery, global navigation satellite systems data and their integrated applications are now critical tools for agriculture, enabling stakeholders, ranging from local farmers to international policymakers, to monitor crop health, manage water resources, detect and control pests, and plan for weather uncertainties, among various other applications,” according to Lifeng LI, Director of FAO's Land and Water Division, and UNOOSA Director Aarti Holla.

The use of geospatial technologies is far from new, having begun in 1957. Since then, more than 17,000 satellites have been launched, with the rate now reaching nearly 3,000 each year. But its potential has been magnified by the increasing precision and diverse capacities of satellites, as well as a host of cloud-based applications that make granular Earth data increasingly accessible all the way to smartphones.
There is a growing need to bridge the gap between space and agriculture from technical interoperability and data harmonization to capacity development initiatives, and the need for international collaboration to ensure small-scale farmers and developing countries can access and benefit from satellite data.

Kuva space

Finnish satellite Earth observation company Kuva Space has released the results of a pilot project exploring the detection of illicit crops at a regional scale over 648,450 km² and almost 250,000 fields. This was done through its Hyperfield-1 satellite, observing agricultural areas of Afghanistan to investigate opium production.

“Satellite monitoring has traditionally forced a trade-off between covering very large areas and seeing enough detail to identify what is actually growing there,” said Jarkko Antila, CEO of Kuva Space, in a statement.
“Hyperfield data and in-house AI powered models start to close that gap. By detecting differences in vegetation that conventional imagery misses, we can screen entire regions and focus the most expensive analysis on a much smaller set of high-probability areas. That changes both the economics and the scalability of illicit crop monitoring.”

The approach combined satellite monitoring with Kuva's Sentinal-2 data and AI classification to analyse almost 248,889 fields identifying 8,835 as likely poppy fields that warranted examination.
The company reported a 75% overall accuracy for its combined approach, using an average geolocation accuracy of 21.75 meters, which is less than one Hyperfield pixel.

The method distinguished legal crops from poppy fields by measuring reflected light across narrow spectral bands, detecting differentiation in chlorophyll, water content, and pigmentation to draw conclusions, creating a partly automated screening layer.

Since 1974 an initial illicit crop identification programme was carried out through an advanced aerial photography system which located the poppy cultivation more accurately. The Mexican government efforts implemented strategies to monitor the drug-producing areas in a better way and in 1983 the territory was divided into operative bases with the aim of carrying out activities such as reconnaissance aerial operations, eradication and verification of illicit crops with plans and special operations in the historical periods identified as high incidence to sow and harvest drug narcotics as well as police investigation operations, among others.

In 2003 the Mexican government implemented the first works to detect illicit crops over its territory with new technologies and an avantgarde vision through the institutions in charge of the national security. This launched the “Mexican Receiving Station of the SPOT Constellation” that allowed to receive satellite imagery of a 20, 10 and 2.5-meter spatial resolution. This station was located and operated in government premises.

“To confirm whether the field is a poppy field, a centimeter-level accuracy aerial or on-site view is required, but that is not currently possible in a safe manner in Afghanistan,” Ollie Eliranta, Data Scientist at Kuva Space told Advance. “The safety issue is one of the major reasons why we have done the study using spaceborne instruments.”
Between January and June 2026, Kuva Space's Hyperfield-1 satellites collected 363 hyperspectral images representing 648,450 km² of total image coverage across the Helmand region in Afghanistan.

The data was combined with Copernicus Sentinel-2 imagery and AI-based classification. Because precise field boundaries were not available for Afghanistan, Kuva Space used a separate parcel delineation model based on filed of the world, fine-tuned on Sentinel-2 data to adapt to Afghanistan's small, desert-mixed fields. The resulting model achieved 75% overall accuracy, compared with 71% using Sentinel-2 alone, while reducing false positives.

Across the analyzed area, the system identified 248,889 agricultural fields and classified 8,835 as likely poppy fields, corresponding to approximately 3.6% of the identified cultivated area. The aim is not to replace verification, but to narrow the search: helping analysts identify where costly high-resolution imagery and further investigation are most likely to be worthwhile.

Seeing what conventional satellite imagery misses

Multispectral satellites such as Sentinel-2 are widely used to monitor agriculture and land cover. But distinguishing one crop from another can be considerably harder. Hyperspectral sensors measure reflected light across many narrow spectral bands, revealing subtle differences in vegetation linked to characteristics such as chlorophyll, water content and pigmentation.

This creates a richer spectral signature than conventional satellite imagery alone cannot provide.
For illicit crop monitoring, that matters because poppy can be grown in small or heterogeneous fields and can resemble legal crops at different stages of the growing season. Cloud contamination, terrain shadows, and rapid changes in vegetation over time can make reliable identification more difficult still. In the pilot, combining Kuva Space's hyperspectral Hyperfield-1 data with Sentinel-2 reduced false positives compared with either source alone.

That has a direct operational benefit. Every false positive can result in additional imagery acquisition and analyst time. A more selective screening layer allows those resources to be concentrated on a smaller number of higher-probability areas.

Satellite monitoring has traditionally forced a trade-off between covering very large areas and seeing enough detail to identify what is actually growing there. Hyperspectral data starts to close that gap, according to Jarkko Antila, CEO of Kuva Space.

Building the model without relying on field access

Reliable reference data is essential to train and validate any crop-detection model. For the Afghanistan pilot, poppy reference fields were identified using a combination of very-high-resolution (VHR) satellite imagery and Sentinel-2 observations over time, using a workflow similar to that reported by UNODC for poppy monitoring in Afghanistan.
Rather than relying on a single image, analysts examined how candidate fields changed during the growing season, including differences in harvest timing. Poppy in the target regions is typically harvested earlier than several visually similar crops, providing an additional clue for classification.
Accurate field boundaries were also unavailable across much of the study area. Kuva Space therefore generated its own parcel map using a deep-learning field-delineation model adapted to Afghanistan's small and heterogeneous agricultural plots.

The result was a parcel-level system designed to identify likely poppy fields rather than simply flagging individual pixels. The Kuva Space model is fine-tuned for small and desert-mixed fields in Afghanistan, providing more precise field delineation than publicly available parcel data.

Combining hyperspectral data and AI

Kuva Space built the hyperspectral classifier on its HF-1 foundation model, pre-trained on more than 1.2 million Hyperfield image patches. The model learns spectral and spatial patterns from satellite imagery, then applies them to downstream tasks such as vegetation classification. For the pilot, Kuva Space tested separate Hyperfield and Sentinel-2 classifiers before combining their predictions. The strongest-performing model classified a parcel as poppy when both sources agreed.

The combined model reached 75% overall accuracy, outperforming Sentinel-2 alone at 71% and reducing false positives from the individual models. In a geolocation test using three Hyperfield images overlapping the Pléiades VHR imagery used for poppy identification, Kuva Space achieved an average CE90 of 21.75 meters, equivalent to 0.87 Hyperfield pixels. This was sufficient to align detections with the correct field locations even in the small, fragmented agricultural parcels typical of Afghanistan.
All agreed pilot KPIs were met, including targets for classification, geolocation, processing speed, and memory consumption.

A shifting global opium map

The need for scalable monitoring is also changing geographically. According to the ‘Uns 2026 World Drug Report, Afghanistan’s opium production remains dramatically below pre-ban levels, while poppy cultivation in Myanmar increased 17 per cent in 2025, making it the ‘worlds largest opium producer.

As cultivation shifts between regions, monitoring systems need to be able to cover large territories and adapt quickly, particularly where physical access is limited. Kuva Space's approach is designed for that type of problem: using hyperspectral satellites and AI to screen large areas first, then directing more detailed analysis to the locations most likely to warrant further investigation. By detecting differences in vegetation that conventional imagery can miss, we can screen entire regions and focus the most expensive analysis on a much smaller set of high-probability areas. That changes both the economics and the scalability of illicit crop monitoring, according to Jarkko Antila, CEO of Kuva Space.

The next space race



IWe're in a space race" with China, NASA Administrator Bill Nelson warned in December. The nature of that race is different from the Cold War contest with the Soviet Union that America fought and won. The national security components of the space race today include not just weapons systems but also the security of critical infrastructure much of which relies on global positioning satellites, remote imagery, and advanced communication. The economic aspect is just as striking. The Space Foundation, a nonprofit advocacy group, has determined that the global space industry generated $469 billion in revenue in 2021. This number will only increase with technological and manufacturing innovation.

More than a decade ago, the U.S. National Security Space Strategy warned that space will become more "congested, contested, and competitive." This warning proved prescient, but the U.S. government has not done enough to adapt to that reality. Major portions of American space systems are still not designated as critical infrastructure and do not receive the attention or resources such a designation would entail. The majority of today's space systems were developed under the premise that space was a sanctuary from conflict, but this is no longer the case.

The threat from Russia and China is growing. Both those authoritarian powers have placed American and partner space systems in their crosshairs, as demonstrated by their testing of anti-satellite (ASAT) capabilities. The United States needs a more concerted and coherent approach to risk management and public-private collaboration regarding space systems infrastructure. After interviewing more than 30 industry and government experts, the authors have concluded that designating space systems as a U.S. critical infrastructure sector would close current gaps and signal both at home and abroad that space security and resilience is a top priority.

In 2013, Presidential Policy Directive-21 designated 16 critical infrastructure sectors "so vital to the United States that the incapacity or destruction of such systems and assets would have a debilitating impact on security, national economic security, national public health or safety, or any combination of those matters." Space systems clearly meet this threshold.

Currently, space systems serve as the foundation for military operations, mission assurance, and intelligence, surveillance, and reconnaissance. Critical infrastructure sectors energy and water, for example rely heavily on satellites for positioning, navigation, and timing for industrial control systems that power pipelines and transmission lines. Within the financial services sector, trading and transactions, ATMs, and credit cards all rely on space systems as do the telecommunications, maritime transportation, and agricultural sectors. And in daily life, Americans rely on the global positioning system (GPS).

Meanwhile, the economic impact of space systems is growing rapidly, prompting at least one expert to suggest the economic dimension may soon equal and surpass the national security impact. Estimates project that within 10 to 15 years, the value of the space industry could approach $1 trillion worldwide. The Department of Commerce estimates that in 2019, the U.S. space economy generated $194.4 billion in real gross output, an increase of 20 percent from earlier in the decade,

translating to 0.6 percent of U.S. gross domestic product. During fiscal year 2021, NASA alone "generated a total economic output of more than $71.2 billion," according to the agency's October 2022 economic impact report. The interplay between space and commerce will only expand as off-Earth manufacturing and mining mature and construction of commercial space stations begins. Alongside these developments, soon-to-be-operational, fully reusable space launch systems made by SpaceX, Blue Origin, and others will have a transformative impact on space logistics and national defense. America's adversaries recognize the importance of space systems to U.S. national and economic security and have tested capabilities to destroy them. In 2007 and 2021, respectively, China and Russia tested direct-ascent ASAT missiles.

The Russian test alone created more than 1,500 pieces of debris big enough to track. Calling the test "dangerous and irresponsible," Secretary of State Antony Blinken warned the debris would "significantly" heighten the risk to the International Space Station.

In February 2022, Moscow hacked U.S.-based satellite internet provider Viasat to disrupt Ukraine's military communications just an hour before Russia invaded the country. The attack also disrupted internet service across Europe. Russia subsequently mounted electronic attacks, attempting to jam the Starlink constellation. At a UN forum in October 2022, Russia asserted that commercial space systems "may become a legitimate target for retaliation." A month later, U.S. government analysts revealed that they had discovered Russian state-backed hackers inside U.S. satellite communications networks, apparently operating undetected for months prior to discovery.

China, for its part, has for years been honing the ability to strike enemy satellites using cyber operations, electronic warfare, and other means as part of the country's larger warfighting strategy and doctrine, designed to deny adversaries access to space-based systems. A November 2022 Department of Defense DoD report on China's military capabilities warned that Beijing's civilian and military capabilities in space are rapidly maturing. The report notes that the Chinese military is developing "kinetic-kill missiles, ground-based lasers, and orbiting space robots" as well as "satellite jammers; offensive cyberspace capabilities; and directed-energy weapons," which can not only monitor but also disrupt or destroy satellites.

The Pentagon further highlighted that Chinese military academics argue that attacks on satellites could "blind and deafen the enemy." China is also copying SpaceX as fast as it can. Space systems are vulnerable to adversarial attacks for many of the same reasons as other critical systems. Adoption of cybersecurity best practices in the commercial space sector has been uneven, as satellites are typically designed for longevity, not security. Networks and technologies for controlling space assets may connect to corporate networks and the internet.

Adversaries may compromise increasingly complicated hardware and software supply chains. Communications between ground stations and satellites known as uplinks and downlinks are often transmitted through unencrypted or open networks and are thus susceptible to hostile intervention that could disrupt, degrade, or destroy data and operations and compromise vital missions.

Moreover, like all other critical infrastructure sectors, space systems use legacy technologies and protocols. Satellites may use old software that cannot be updated. They may not have the onboard processing required to update software. They may, due to construction constraints, lack redundancies that have become a standard best practice for resilience. While the situation regarding legacy technology in critical infrastructure is improving generally and within space systems in particular, space systems face the added difficulty that they must be repaired or replaced in orbit. The introduction of next-generation hardware and software only adds to the complexity.

As commercial space organizations have begun to drive more low-earth orbit activities up to 2,000 km from earth, NASA has had to shift its efforts toward exploring deep space, accomplishing further manned missions, and setting up permanent facilities on the moon as a gateway for missions to Mars and beyond. Cases in point are NASA's launch activities. While in the past NASA was the sole developer of launchers in the U.S., today it has outsourced most of its launch activities to companies such as SpaceX or ULA and is actively supporting these commercial actors (as stipulated in the Commercial Space Launch Act). NASA's focus in developing launchers in-house is on its Space Launch System SLS, a heavy-launch system that is required for deep-space missions; NASA has no explicit plans to commercialize SLS.

An identity crisis for space agencies?

As the space industry evolves, so do space agencies' roles in it. When the first space agencies were established at the start of Space 2.0 in the 1950s, they were the single champions and main actors and investors of their national space sectors. Today, a space agency is one of many space participants and needs to redefine its place in the national space sector. The NASA example illustrates well the dramatic changes that space agencies are exposed to.

At the peak of the space race, NASA's budget was 4.5 percent of the US federal budget. Nowadays, it is below 0.5 percent, which implies that NASA has undergone a transformation. Broadly speaking, NASA has had to reinvent itself three times since its inception, in line with the evolvement of the space industry, according to a NASA veterans in a recent article in the Harvard Business Review.

The global space industry is undergoing a paradigm shift. It is at the cusp of a new era, moving from Space 3.0, which was characterized by large government investments and public-public relationships, to Space 4.0, a more democratized and accessible field with public-private and private-private relationships. To operate under such a paradigm, the success of national space programs hinges on transforming their space agencies towards future-proof entities that act as key enablers of Space 4.0 or on establishing space agencies in the first place as well as assuring that all enablers for Space 4.0 are in place. We have identified key questions that decision-makers should ask themselves to understand whether the national space sector is ready for Space 4.0.

During the traditional NASA period, space was both a frontier market and a competitive endeavor between superpowers (the space race). NASA, building on its military heritage, developed and used technology internally and maintained high control over a select number of contractors. NASA, a centralized, hierarchical entity, was the space sector's prime contractor and exclusive customer.

With the Cold War coming to an end, the US's space ambitions changed towards exploration of deep space. As these missions became more expensive and complex, it was no longer possible for a space agency to conduct them on its own. While NASA was still the main actor in the national space sector, the need for collaboration with other space programs increased.

The prime example of this is the collaboration on the ISS2, in which NASA partners with the European Space Agency, JAXA, the Canadian Space Agency and Roscosmos. During this transitional phase, NASA learned how to function within a cluster of partners, as opposed to being the dominant party in a supplier/buyer relationship. This demanded shifts in cultural values, relational approaches, and technology strategy, which helped to prepare NASA for Space 4.0.

NASA's latest transformation, in line with the space industry's movement towards Space 4.0, started with the Commercial Resupply Services program, launched in 2006, to carry cargo to the ISS after the space shuttle was retired. The shuttle's retirement, budget pressures, government interest in promoting commercial space, and rapidly growing commercial expertise in space led NASA to seek suitable commercial partners. NASA is now a more outwardlooking agency that recognizes the innovative capacity of the market and has learned to work effectively with the commercial sector.
For the most part, NASA successfully completed the transformation into a key enabler of Space 4.0. However, in light of the ongoing paradigm shift in the space sector, with the private sector increasingly performing activities that used to be in the traditional domain of space agencies, most agencies are still rethinking their roles. The possible roles of the future agency are manifold and need to be adapted to its local context.

Despite their variety, the future agency's roles will build upon the traditional mandate and assure that the agency is a key enabler of Space 4.0. We believe the future agency should assume the following roles, enabling the national space sector, foster private sector growth and attract foreign business, define and communicate a clear vision and strategy, establish a conducive and strategic regulatory framework, be the national space sector's international face, and drive strategic space activities.

The future agency should define and pursue initiatives to enable private and public space sector participants. This includes providing access to infrastructure, creating human-capital development programs, providing targeted funding and promoting the space sector.
A key characteristic of Space 4.0 is the increased participation of private space actors. More and more of these are international and are looking for the best national space ecosystems in which to thrive. Therefore, the future agency should introduce initiatives to attract foreign investment and foster private sector participation in the national space sector.

Since Space 3.0, space exploration has been a truly international endeavor. The future agency should continue to forge international collaborations (e.g., leading space agencies, governments, aerospace companies, academic institutions) to be fully integrated in the international space ecosystem, participate in major projects and build local know-how.

In line with the space agency's traditional role, the future agency can be involved in driving strategic space activities such as science missions. The activities assigned to the agency should not put it in competition with other actors of the sector. Therefore, they should be limited to strategic space activities that are not fully pursued by other actors of the national space sector due to their scope, economic viability or other reasons.

Together with the executive power, the future agency should continue to set long-term strategic objectives to provide clear direction to all participants of the national space sector – both public and private. In addition, each participant's roles and responsibilities in the national space sector need to be defined. This is typically achieved by defining a comprehensive national strategy and communicating it to all actors of the sector through a space policy.\

MaiaSpace: A closer look at its history

MaiaSpace is a French launch company building Maia, a two-stage rocket whose first stage is meant to land on a barge at sea and fly again. Before we continue you should know: MaiaSpace belongs entirely to ArianeGroup, the company that builds Ariane 6.
ArianeGroup set it up at the end of 2021 in a dormant shelf company and presented it as a startup ever since, with agile methods, a young team and a promise of private money. Almost five years later the shareholder register holds one name, the losses have used up all of the capital, and the cash comes from customer advances and public contracts. Maia runs on Prometheus, an engine ESA has paid ArianeGroup to develop since 2017, and its first stage builds on Themis, a test vehicle that was meant to hop in 2023 and has not. Over the same years SpaceX made booster landings routine and China put a methane rocket of Maia's size in orbit.

“We are today a 100% subsidiary of Ariane and our objective is the objective of our parent company. The opening of our capital to third-party investors is the best guarantee of maintaining the autonomy we have today. So, I'm not going to lie about the fact that being a subsidiary of a large group also potentially has disadvantages. But I'm convinced the advantages this gives us are greater than these disadvantages, says MaiaSpace CEO Yohann Leroy.

MaiaSpace works from Building A37 on ArianeGroup's site in the forest of Vernon, Normandy, where ArianeGroup also fires the Prometheus engine on its test stands. The company has an office in Courbevoie near Paris and, since October 2025, a registered site at the former Soyuz pad in Sinnamary, French Guiana, which CNES assigned to MaiaSpace in 2024. A rocket factory of about 12,000 square metres, the MaiaFactory, is being built in Vernon, and Prime Minister Sébastien Lecornu laid its foundation stone on 4 September 2026.

Satellites now play an essential role in telecommunications, navigation, Earth observation, and defense capabilities. Having European launch solutions therefore helps limit dependence on external actors and provides greater control over the conditions for accessing orbit. The French government has, in fact, included MaiaSpace among the strategic industrial projects contributing to national industrial sovereignty. For European industry, the challenge is thus twofold: to develop competitive technology while building an industrial ecosystem capable of producing it on a large scale.

Maia rocket was developed by MaiaSpace, an ArianeGroup subsidiary. It is Europe's first reusable mini-launcher which incorporates first-stage vertical landing on an offshore barge. With it, MaiaSpace will be able to offer highly competitive, reactive space mobility options, and at the same time help to speed up acquisition and extension of reuse technologies in Europe.
“By developing a reusable launcher we have two launchers for the price of one or in other words we have a launcher with two optimized operating points. The operating point of the launcher when we recover the first stage and the operating point of the launcher when we consume the first stage and that changes everything. With this double launcher, we can attack a segment of the market that is wider than if we had a single consumable launcher optimized for a single operating point. That changes everything because all other things being equal no one will be able to address a wider market, have a higher rate, and therefore lower costs more quickly because we will cover the experience curve more quickly and ultimately have a business plan much more attractive for investors, says MaiaSpace CEO Yohann Leroy.”

Maia is a two-stage rocket burning methane and liquid oxygen. The first stage has three Prometheus engines and is meant to land on a barge at sea, the second stage has one, and an optional kick stage called Colibri can carry payloads further. The company gives a height of about 50 m and a diameter of 3.5 m, while press reports from January 2026 gave 55 m and 300 tonnes.

MaiaSpace is expected to operate as an autonomous entity. According to Leroy not only will the company build the launch vehicle but it will not rely on ArianeSpace to operate and market the vehicle and will instead do that itself.
“Not only are we in charge of the development of our launcher, we are going to operate it. But we are also going to market it and that seems to me the best option if I may say so because that is our objective. It is not just to develop technologies, not just to develop a launcher even if it is part of our role to provide Europe with technologies that are key for its independence in terms of access to space. But we also want to build a company and to build a profitable company we must listen to our customers and therefore market our services ourselves,” explained Leroy.

The core rocket has stayed at 1.5 tonnes to sun-synchronous orbit, expended, since 2023. The



4 tonne figure needs the Colibri stage and a lower, inclined orbit. In April 2026 the CEO said the first rocket would have “a bit less performance” than the target, and that the first landing attempt would come around the eighth or ninth flight, in 2028 or 2029.
AFP quoted a price of about EUR 6,000 per kg in December 2025, and the company compared it to SpaceX's list price. SpaceX sells rideshare places to sun-synchronous orbit at USD 7,000 per kg in 2026, on Falcon 9, which had flown 690 times and landed 643 boosters by early October 2026.

ArianeGroup set up MaiaSpace in 2022 with the goal of rapidly developing a competitive, reusable, eco-responsible mini-launcher. To do this, MaiaSpace combines the best of two worlds: the flexibility and reactivity of a start-up working in “test & learn” mode using an Agile® approach, allied with the technological launch systems expertise and experience of ArianeGroup and its European industrial partners. MaiaSpace is particularly concerned with sustainability, with a focus on reuse and an eco-design approach implemented right from the very first day. It is the first European start-up which has opted to power its launcher with the Prometheus® reusable engine running on MethaLox, developed by ArianeGroup for the European Space Agency.

The Maia rocket exists in both a reusable version, capable of placing payloads of up to 500 kg in sun-synchronous orbit, and an expendable version, capable of delivering of up to 1.5 tonnes to sun-synchronous orbit. MaiaSpace will offer access to space for all types of satellites: nano-satellites of 50 kg and under, microsatellites, smallsats from 250 to 500 kg, up to satellites of more than 1.5 tonnes.

With its optional Colibri kick-stage integrated into a 3.5 metre diameter fairing which will enable it to deliver a performance boost of at least one tonne to low Earth orbit LEO for each version, Maia is ideal for a wide variety of missions, notably for reactive deployment of constellations with precise orbital positioning, and for the in-orbit services market.
Eutelsat, Europe's only Low Earth Orbit satellite operator, has entrusted MaiaSpace, a pioneering European launch services provider, to secure access to space for part of its OneWeb LEO constellation. The Parties have entered into an agreement for multiple launches spanning several years from 2027.

This agreement opens the prospect of securing the majority of Maia launch manifest during the first three years of operation. This agreement with an experienced launch service customer validates the relevance of the Maia launcher's design. With its large 3.5-meter diameter fairing, a launch mass capability of up to 4 tons in inclined orbits, and the addition as an option of the Colibri kick-stage increasing mission flexibility, MaiaSpace offers compelling solution for various missions, in particular for the deployment or replenishment of broadband satellite constellations.

Eutelsat's OneWeb low Earth orbit (LEO) satellite network delivers high-speed, low-latency connectivity on a global basis. With 650 satellites flying in 12 synchronised orbital planes 1,200km above the Earth, the constellation brings high-speed internet to every corner of the planet. Fully focused on the professional B2B market, Eutelsat's OneWeb is one of only two fully operational LEO networks globally and the sole European operator. The access to space provided by MaiaSpace will contribute to assuring full operational continuity for customers of the constellation, by progressively launching replacement satellites for early batches coming to end of operational life.

In 2015, ArianeGroup and the French space agency CNES started work on Prometheus, a low-cost reusable methane engine. ESA funded it from December 2017 with a EUR 75 million contract and announced a full-scale ground test for November 2020. The first ignition took place at Vernon in November 2022, two years later.

In December 2020 ESA added Themis, a reusable first-stage demonstrator meant to rise, hover and land, with a EUR 33 million contract and test hops planned from 2023. A second Prometheus contract worth EUR 135 million followed in May 2021, and ArianeGroup then expected a version of the engine to fly on an upgraded Ariane 6 as early as 2025.

On 6 December 2021 economy minister Bruno Le Maire visited Vernon to present the EUR 1.5 billion space part of France 2030, the state's investment plan. His ministry welcomed ArianeGroup's new reusable mini-launcher, whose first commercial launch “could take place as early as 2026”. Two weeks later ArianeGroup moved the project into ASL PROJ 1, a dormant shelf company it had registered in Paris in December 2016, renamed it MaiaSpace and moved its seat to Vernon.

MaiaSpace was registered in Evreux on 4 January 2022 with EUR 500,000 of capital. Its first président was André-Hubert Roussel, then chief executive of ArianeGroup, and Yohann Leroy took over in May 2022. The registered purpose was a semi-reusable rocket able to carry 700 kg to a 700 km sun-synchronous orbit with its first stage recovered.

In June 2022 Leroy said MaiaSpace would raise “several hundred million euros” from private investors over three years, starting in the last quarter of 2022. He added that the company would not seek research money from ESA or France 2030. The first launch was planned for 2026, with three Prometheus engines on the first stage, one on the second, and a first stage derived from Themis.
No outside investor came. ArianeGroup put in EUR 6 million in January 2023 and EUR 27 million in June 2023, and the team grew from about 20 people in 2022 to about 40 in early 2023. In June 2023 the company moved its target forward to a first orbital flight “before the end of 2025”, and Prometheus fired for 12 seconds on the Themis test stage at Vernon the same month. The 2023 accounts show EUR 21.3 million of operating costs against EUR 9,470 of revenue.

ArianeGroup's money

In January 2024 ArianeGroup raised its planned investment in MaiaSpace to EUR 125 million, and in March 2024 it paid in EUR 45 million and took warrants for up to EUR 40 million more. On 26 March 2024 President Emmanuel Macron named MaiaSpace one of four winners of a France 2030 contest, run by CNES, to buy demonstration launches, next to HyPrSpace,Latitude and Sirius Space Service. MaiaSpace promised a demonstration flight before the end of 2027 with 1,500 kg to a 600 km sun-synchronous orbit, and the state did not publish the amount.
In September 2024 CNES gave MaiaSpace the former Soyuz pad at the Guiana Space Centre, and the company put its first launch at the end of 2025. Two months later ESA signed about EUR 230 million of new work on Prometheus and Themis with ArianeGroup and planned a first Themis hop for 2025. CNES also chose ArianeGroup, with MaiaSpace as launch operator, for SkyHopper, a France 2030 project to land a Maia first stage on a barge and fly it again.

The 2024 accounts show EUR 180 million of advances from customers, EUR 176.6 million of cash and a net loss of EUR 24.0 million. In March 2025 MaiaSpace announced its first commercial customer, the French in-space transport company Exotrail. In June 2025 four ministers visited Vernon, and the company called its technical and financial roadmap “in line with expectations” and moved the first flight to the second half of 2026.

In July 2025 ESA picked MaiaSpace as one of five candidates for its European Launcher Challenge, which buys launches from companies that reach orbit by the end of 2027. At ESA's ministerial council in November 2025 France put EUR 179 million into that programme for MaiaSpace alone. Themis had arrived at Esrange in Sweden in June 2025 and did not hop that year. MaiaSpace closed 2025 with a net loss of EUR 37.5 million and negative equity.

MaiaSpace has one shareholder, ArianeGroup Holding, the joint venture of Airbus and Safran that also builds Ariane 6. By the end of 2025 it had paid in EUR 83.4 million of capital and share premium, and it holds warrants for up to EUR 40 million more that were not used by the end of 2025. No outside investor has been announced, and the share capital has not changed since March 2024. The company's website lists “125 M€ funding secured”, the amount ArianeGroup committed in January 2024.

Net losses from 2022 to 2025 add up to EUR 85.1 million, slightly more than everything ArianeGroup paid in. Operating costs grew from EUR 21.3 million in 2023 to EUR 60.8 million in 2025, of which EUR 20.1 million went on wages and social charges and EUR 32.2 million on outside purchases and services. Research tax credits brought in EUR 5.7 million over the three years.
Ernst & Young audits MaiaSpace and signed clean opinions on the 2021, 2023, 2024 and 2025 accounts. The 2025 report adds a note on a change of accounting method and no warning on going concern. The notes to the 2025 accounts state that a decision on the company's future would be needed, and ArianeGroup took it in June 2026 by keeping the company alive.

The 2024 balance sheet shows EUR 180 million of advances received from customers, and the 2025 balance sheet EUR 96 million, plus EUR 59.2 million booked as income received in advance. The accounts do not name who paid. MaiaSpace told European Spaceflight the money covers its France 2030 contract and private contracts it did not name. The advances sat in an interest-bearing account and earned EUR 5.1 million in 2024, more than that year's revenue of EUR 4.8 million, and EUR 3.7 million in 2025. In 2025, EUR 15.5 million of the EUR 15.9 million revenue came from customers in France and was partly booked as work on contracts progressed.

In January 2026 Eutelsat signed a launch agreement for its OneWeb satellites, ten launches from the second half of 2027 according to AFP. In February the first flight moved to 2027, with a suborbital test first and a first launch “less than five years after the company's creation i.e., April 2027”. On 25 June 2026 ArianeGroup, as sole shareholder, recorded that equity had fallen below half of the share capital and decided not to dissolve the company, a decision French company law requires in that case.

In July 2026 MaiaSpace dropped the suborbital flight. The first flight is now an orbital attempt in the second half of 2027, and the first stage will not be recovered on it. Loft Orbital (July), the rideshare broker RIDE! (August) and the Japanese radar satellite operator iQPS (September) signed agreements, none with a published value. On 27 August ESA signed launcher challenge contracts with Isar Aerospace, Rocket Factory Augsburg, and PLD Space, said MaiaSpace's contract was “nearing completion”. In October it was still under negotiation.

On 4 September 2026 Prime Minister Sébastien Lecornu laid the foundation stone of the MaiaFactory in Vernon and said “On joue gros” (“we are playing for high stakes”). At the end of September Themis completed a second fuelling rehearsal at Esrange, again without a hop, and the EU has moved the deadline of its Themis grant to 31 December 2026.

MaiaSpace steps up the pace in the race for reusable launch vehicles

Named MaiaFactory, the future facility is set to gradually expand to **12,000 m²** at the Plateau de l'Espace in Vernon. It will take over from the Maia Proto-Factory, where the launcher's prototypes and first flight models are currently being produced and tested. The goal is to gradually transition from a prototyping approach to repeatable and scalable production capable of supporting the program's ramp-up. The various components produced in Vernon will be shipped to Le Havre before being transported by ship to French Guiana. Final assembly of the launch vehicle will take place at the Guiana Space Center, on the former Soyuz launch pad allocated to MaiaSpace.

This organizational structure thus creates an industrial supply chain linking **Normandy, the Port of Le Havre, and French Guiana**, with significant challenges in terms of coordination, logistics, and flow management.

MaiaSpace aims to eventually reach a launch rate of approximately **20 launches per year** by the early 2030s. The MaiaFactory is intended to help make this industrial scale possible. At full capacity, the factory is expected to produce approximately twenty upper stages each year, which are used up during each mission, as well as a variable number of main stages depending on the recovery rate. This ramp-up is based on a key principle: designing, from the outset, an industrial facility that is flexible and scalable, capable of gradually increasing its production volumes rather than relying on a fixed infrastructure.
This approach is particularly important in the space industry, where development costs are high and the ability to repeat production operations can be critical to achieving a competitive business model.

The MaiaSpace project also relies on the **reusability of the launcher's first stage**. After its return, the first stage must be recoverable on a barge at sea and reusable for new missions. The company estimates that this recovery could significantly reduce launch-related costs. The Maia launch vehicle can achieve a payload capacity of **up to 4** metric tons, depending on the mission configuration, while SpaceX's Falcon 9 can carry more, illustrating the difference between the two models.
MaiaSpace is therefore not necessarily seeking to replicate SpaceX's model exactly. Rather, its ambition is to develop a European solution tailored to specific launch needs, particularly those related to satellite constellations. The company has already signed an agreement with Eutelsat for several launches, notably for its OneWeb constellation starting in 2027, which helps secure part of its future business.

Leveraging geospatial technology to combat smuggling



The current pace of global trade is unrelenting. As digitalization, automation, and data-driven risk management transform the nature of commerce, legitimate trade continues to innovate, achieving new levels of speed and efficiency. At the same time, illicit trade adapts just as quickly, exploiting loopholes, targeting weak links, and undermining trust in global supply chains.

In an era where technology is redefining national security, and trade enforcement, the Nigeria Customs service is charting a bold course into the digital frontier. By deploying advanced geospatial technologies, including satellite imagery, drones and Artificial Intelligence driven geospatial tools, the service is transforming how Nigeria monitors its borders, combats smuggling and protect national revenue.
At the center of this modernization drive is the Comptroller General of Customs, Bashir Adewale Adeniyi, whose administration has prioritize intelligence led enforcement and technology innovations as key pillars of Customs reforms. The integration of Geographical Information Systems GIS, remote sensing predictive analysis marks a significant shift from traditional border monitoring methods to a highly automated intelligent driven surveillance ecosystem.

The adoption of these cutting-edge tools reflects Nigeria Customs commitment to strengthening border security while aligning with global best practices in customs administrations. Recently, the service commences a capacity building programme on Artificial Intelligence AI driven revenue generation, remittance and reconciliation as part of efforts to enhance transparency, and efficiency in public finance management

Technological innovations

Geospatial mapping can be understood as the use of Geographic Information System (GIS) capabilities to collect, manage, analyse and visualize geographically referenced data into operational map products. Building on this, geospatial intelligence concepts exploit and analyse imagery and geospatial information to produce decision-support outputs depicting geographically referenced activities. Through technologies such as GPS, GIS and remote sensing, Geospatial Mapping enables the visualization and analysis of spatial data to generate insights that support decision-making. For Customs, this can support operational planning, transit control and enforcement activities, including at porous borders and in maritime contexts.

Geographical visualization of Customs units to support collaboration and supervision; deployment of resources and intervention units; tracing goods and controlling transit (including electronic seals and GPS-based monitoring); combating trafficking drugs, illicit minerals, human trafficking and strengthening capacity at porous borders; maritime risk analysis (tracking vessel movements and cross-referencing location data); improved intelligence and data-driven decisions through enhanced visualization.
Drones are unmanned aircraft or ships guided by remote control or onboard computers. Unmanned aerial vehicles (UAVs) form part of an unmanned aircraft system (UAS) that includes a UAV, a ground-based controller and communications between the two. UAVs may operate under remote control or autonomously. Their use has expanded rapidly beyond military applications to a wide range of civil contexts. For Customs, drones are used for surveillance and monitoring, including in port areas and coastal regions, and can provide remote and rapid situational awareness in environments that are large, complex or difficult to access.

Surveillance and monitoring of port areas and coastal regions; supporting anti-smuggling and anti-trafficking operations (intelligence gathering, evidence collection and tactical surveillance); monitoring vulnerable coastal and inland areas and uncharted routes; maritime support especially, seaport terminal surveillance and cruise ship inspection support); improving officer safety and operational response.

Artificial Intelligence (AI) refers to systems that change behaviour without being explicitly programmed, based upon data that is observed, collected and analysed, including Machine Learning (ML), deep learning, computer vision and natural language processing. ML is a branch of AI that enables computers to learn from data, identify patterns and make decisions or predictions without being explicitly programmed for every task, improving performance as they are exposed to more data.

Data Analytics is the application of computer systems to analyse large data sets to support decision-making, drawing on disciplines such as statistics, ML, pattern recognition, operations research and artificial intelligence. In Customs, it is used primarily for risk management, including fraudulent trade detection and HS code recommendation, with scope to expand toward a more holistic, data-driven approach across Customs and border management, including trade facilitation. Together, these technologies enable Customs to make sense of growing volumes of data generated by cross-border movements and to detect and predict patterns more accurately.

The Comptroller of Nigeria Customs, Bashir Adeniyi said, “The Customs is united in its resolve to ensue transparency in public accounting. Technology continues to evolve and play an important role in strengthening our operations. It has also helped us better understand patterns in international trade”, he said.

He expresses optimism about opportunities Artificial Intelligence AI offers to improve Customs operations, while noting that the service operates within a broader national and international trade value chain. We want to reap the benefits of Artificial Intelligence collectively.

In addition, Blockchain is a decentralized and distributed ledger architecture that enables secure peer-to-peer movement of data among participants while making a record of the transaction instantly available to all participants in a trusted and immutable manner. Transactions are linked and time-stamped, making the technology resistant to retroactive modification. For Customs, blockchain can facilitate processes ranging from clearance to compliance by enabling multiple parties to rely on a shared, trusted record rather than maintaining separate ledgers.

Similarly, Cloud Computing is a paradigm for enabling network access to a scalable and elastic pool of shareable physical or virtual resources, with self-service provisioning and on-demand administration. Cloud Computing deployment models generally include private, public, community and hybrid clouds. A private cloud is provisioned for the exclusive use of a single organization and may be operated on or off premises by the organization itself or a third party. A public cloud is provisioned for open use by the general public and is operated by a cloud service provider. A community cloud serves a specific group of organizations with shared concerns. A hybrid cloud integrates two or more distinct cloud infrastructures while maintaining their separation to enable data and application portability.

Business continuity, disaster recovery and system resilience; risk management, targeting and intelligence; inter-agency data sharing; trade facilitation and clearance systems; pilot and proof-of-concept environments.
The Internet of Things (IoT) is the internetworking of physical devices connected/smart devices, vehicles, buildings and other items embedded with electronics, software, sensors, actuators and network connectivity, enabling these objects to collect and exchange data. In practical terms, the IoT transforms physical objects into smart devices that can communicate and interpret information from their surroundings. For Customs, IoT-enabled devices and systems can support real-time monitoring and improved visibility across movements of goods and related control processes.

Real-time shipment tracking; monitoring cargo conditions particularly, temperature and humidity); regional electronic cargo tracking systems; electronic seals and RFID in transit and bonded warehouse management; automation of border posts and agile processing via handheld devices; connected scanning and detection technologies supporting remote/centralized analysis; connecting inspection systems (container and baggage scanners) and detection systems (e.g. radiation/ explosives) to support coordinated analysis.

Border management and control

Today, Nigeria shares thousands of kilometers of land borders with neighboring countries, including vast stretches of terrains that are remote, porous, and difficult to monitor using conventional patrol methods. Historically, smugglers have exploited these unapproved routes to transport prohibited goods, evade duties and undermine economic stability.

Recognizing the limitation of manual surveillance, the service has embraced geospatial technology to gain a strategic advantage. Using GIS enabled platform, Customs officers are now able to monitor remote border through digital mapping systems that provide detail geographic data. These systems identified and track unapproved routes commonly used for smuggling activities.
Through advanced techniques such as buffer analysis and geofencing, officers can establish virtual boundaries around sensitive locations. When movements occur within these digital zones, they generate alerts, enabling real time monitoring of physical border points without requiring constant physical presence.

This approaches significantly enhances surveillance coverage, allowing authorities to monitor multiple locations simultaneously while optimizing manpower deployment. The integration of drones further strengthens these capabilities. Equipped with high resolution cameras and sensors, drone provides aerial surveillance over difficult terrains such as forest, rivers and mountainous regions. These devices capture real time imagery that can be transmitted directly to the command centres, enabling swift response to suspicious movement.

Satellite imagery complement these efforts by offering a broader overview of the landscapes. By analysing satellite date over time, Customs officers can detect patterns, identify emerging smuggling routes, and assess terrain changes that could influence border security operations. One of the most significant milestone in the Customs modernization agenda is the development and pilot implementation of the Geoportal platform, alongside the innovative Ceen system. Launched as a pilot operation in 2025, the Geoportal platform serves as a centralized digital hub that integrates geospatial data from multiple sources. These include satellite feeds drone footage, border patrol reports, and intelligence inputs from collaborating agencies.

Through this unified interface, Customs officers can monitor aircrafts and vessels movements in real time, improving situational awareness across land, sea and air borders. This n-Ceen platform enhances intelligence sharing by connecting operational units across various border commands. This ensure that information gathered in one region can be rapidly disseminated to other units, fostering coordinated responses to emerging threats.

The adoption of these platforms represents a paradigm shift from a fragmented intelligent system to an interconnected digital framework that promote efficiency and accuracy. In operational terms, this technology allows Customs to predict potential smuggling attempts rather than merely reacting to them. By analysing historical movement data and identifying anomalies, the systems support proactive enforcement strategies that reduce the likelihood of successful smuggling operations.

Capacity building

Technology alone cannot drive transformation without skilled personnel to manage and interprete data. Recognizing this reality, the Nigeria Customs Service has placed strong emphasis on capacity building and workforce development. Training workshops have been organized across Customs formations to equip officers with specialized skills in spatial data analysis, remote sensing and geospatial mapping.
During these sessions, officers learn how to interpret satellite imagery, operate drone systems and utilise GIS tools to map landscapes and identify high risk zones. These programmes are designed to ensure that personnel at all operational levels, from field officers to command supervisors are proficient in using digital tools to enhance enforcement activities.

Capacity building also fosters a culture of innovation within the Service, encouraging officers to adopt data-driven decision-making processes. By investing in human capital, the Nigeria Customs Service is ensuring that technological adoption translates into measurable operational gains. The transformation of Nigeria Customs into a technology driven enforcement agency has been strengthened through strategic partnership with international organisations. Notably, the Service collaborates with the World Customs Organisations WCO and the Japan International Cooperation Agency JICA to develop advanced mapping systems and intelligence frameworks.

These partnerships provide technical expertise, funding support, and access to global best practices in Customs operations. Through these collaborations, Nigeria Customs has been able to map smuggling hotspots across border regions and deploy predictive analytics tools that identify potential illegal trade patterns. International cooperation also ensures interoperability between Nigeria's customs systems and those of neighboring countries, promoting regional security and trade transparency. Such alliances position Nigeria as a leader in adopting innovative customs enforcement technologies within the West Africa regions.

Predictive enforcement

Perhaps, the most transformative aspect of the geospatial initiative is its shift toward predictive enforcement. Traditional customs operations relied heavily on physical patrols and reactive responses to intelligence reports. However, the new system leverages Artificial Intelligence AI and data analytics to identify threats before they occur.
By analysing trends in border movements, seasonal patterns, and historical smuggling incidents, the system can identify high-risk periods and locations. This predictive capability enables Customs to deploy personnel strategically, focusing resources on areas with the highest likelihood of illicit activity. the result is not only improved efficiency but also reduced operational costs, as fewer personnel are required to achieve border coverage surveillance coverage. Moreover, predictive analytics enhances revenue protection by minimizing duty evasion and ensuring legitimate trade flow remain uninterrupted.

Smuggling remains a significant a challenge to Nigeria's economic stability, illicit trade undermines domestic industries, reduces government revenues and exposes consumers to substandard goods. By strengthening border surveillance through geospatial technology, the Nigeria Customs Service is addressing these risks at their source.

The improve ability to detect illegal routes and monitor suspicious movements directly support revenue collection efforts. When goods enter the country through revenue collection efforts. When goods enter a country through approved channels, duties are paid, boosting government income and supporting national government. Furthermore, enhanced border security protects local manufacturers from unfair competition caused by smuggled products. This in turn, supports job creation and economic growth across various sectors.;;

Conclusion

Despite the promising results, the adoption of geospatial technology is not without challenges. Infrastructure limitations, including inconsistence internet connectivity in remote areas, can affect data transmission and system reliability. Additionally, maintaining advanced technological systems requires sustained funding and technical expertise. Cybersecurity also remains a critical concern, as digital platforms handling sensitive data must be protected against unauthorized access and cyber threats. However, ongoing investments in infrastructure, training and partnerships are expected to address these challenges over time.

The integration of geospatial technology into Nigeria Customs operations represents more than just a technological upgrade. It signals a fundamental transformation in how border security is managed. By embracing digital tools and predictive intelligence, the Service is setting new standards for Customs administration in Africa.

This modernization effort align with Nigeria's broader national security objectives and supports the government commitment to improving trade efficiency and economic resilience. As global trade becomes increasingly complex, the ability to monitor borders using advanced technologies will remain essential. For Nigeria, the beginning of a new era, one in which intelligence, innovation and technology converge to safeguard national interests and strengthen the integrity of borders.

Data driven analytics identify energy drilling sites



'Earth Science Analytics were selected by the Norwegian Petroleum Directorate and the British Oil & Gas Authority and Oil and Gas Technology Centre, to deliver the first ever cross-border machine learning project on missed pay. The objective was to predict oil or gas missed pay intervals amongst thousands of wells on a basin scale, leveraging cloud-native big data analytics and machine learning technologies. \

Operators from the UK and Norway donated over 30,000 km of wireline data that Earth Science Analytics used to predict missing CPI curves and identify over 400 exploration opportunities.
A typical exploration team can deal with 20% of their available data before they must make a drill or drop decision on a prospect. At Earth Science Analytics, we leverage all the available data and enhance them with analogues and or synthetic data, to reveal new insights and uncover viable drilling prospects that may have been overlooked.

A collaborative cloud environment brings new insights to old concepts, captures expertise and allows data to be explored with more agility. Thanks to the "on demand" access to computers via the cloud, our work meant we were able to generate rock-and fluid-property curves, bad-hole and QC flags in moments. Using semi-automated tools to edit wells at both single-well and multi-well scales, the result was a data bank of 70 different types of data, spanning 90 million depth indexes.

Identifying close-in drilling sites

From here, we used our wells tool to predict missing logs and then had proven oil finders review the results to ensure we had realistic predictions. By giving our exploration team the tools and data they required, we provided them with the opportunity to take a second look at the subsurface. Using EarthNET for identifying and ranking pay zones, we found over 400 well candidates, located near existing infrastructure, that we believe are worth a second look.
These included misreported wells that were tagged as dry, that have potential to trigger new exploration activity in mature areas and provide much-needed new barrels into existing infrastructure.
Essentially every company operating in the oil and gas industry is aware that digital transformation and digitalization are a high priority at all levels, from boardrooms to rig platforms. In my role, I work directly in support of industry professionals using digital technologies to improve efficiency and efficacy in upstream environments, most notably within exploration and production (E&P). In our data-driven world, the rate of change is accelerating, as companies, individuals and teams see that machine learning and digitalization can replace time-consuming and monotonous tasks with data-driven systems that enable both cost reduction and new opportunities to add value.

Digital transformation, particularly within a geoscience context, has the power to make less biased volume estimates and more data-driven decisions in E&P. While there's a real and tangible buy-in relating to the concept of digital transformation in general, most operators now understand adoption is an integral part of their future success. However, when viewed from the perspective of the technology being deployed, its full adoption is still comparatively low. This article will outline the reasons for this, but as a software vendor, we are rapidly working to implement a meaningful change.

Artificial intelligence is changing the energy sector.

The digital advancements witnessed by those operating within the sector over the last five years have been nothing short of phenomenal. From beneath the surface, decades of data have been collected, and this knowledge is now at the fingertips of domain experts and decision-makers. The data are being paired with artificial intelligence (AI), cloud computing and modern data analytics technology. Today, operators can undertake geoscience studies to support E&P activity at a pace not previously possible. The next generation of geoscience tools has made significant strides, combining first-hand domain experience with the monumental advancements in data science.

Operators now have a much clearer picture available on critical geological factors. These include factors such as reservoir architecture, rock and fluid property distribution, which have vast potential to reduce exploration uncertainty using insights from AI assisted methods. This innovative technological insight is now available for companies to use and exploit, and it's a matter of when, not if, they do so. During the last several years, alongside other service providers, Earth Science Analytics has made significant progress in providing operators the tools to use machine learning for their geoscience tasks. From petrophysics to seismic inversion and seismic structural interpretation, digital transformation within geoscience is advancing what can be done at an extremely high level and pace.

The biggest disruption has been the technological progress in the field of AI. Simply put, AI is changing the manner in which the upstream energy sector operates. It is directly altering the landscape of geoscience, leading to numerous benefits for those involved with E&P activities. Not only is it changing what can be seen and done, it is changing how geoscientists interact with data.

The potential is there for organizations to make more informed decisions that are faster, better and more accurate than ever before. AI technology can be used to reduce the number of non-commercial well bores and to increase the recovery from producing fields. Once these automated AI-assisted workflows are in place across the industry, it will lead to reduced first oil delivery times and enable projects on a larger scale than ever before. This is, by nature, paired with reduced human bias, leads to better-informed decisions and increased E&P success.

Earthnet

Traditional seismic inversion methods are time-consuming, resource-intensive and limited by the requirement for highly trained practitioners. Earth Science Analytics understood the challenge and developed EarthNET, an AI-based software for geoscientists that uses deep learning to help geoscientists overcome the time and learning-curve barriers.

The introduction of EarthNET software provides a solution that delivers faster, cheaper and more accurate predictions, using AI to identify rock and fluid properties in the search and recovery of oil and gas resources, **Fig. 1.** Machine learning combines new methods with algorithms that gain intelligence from all available data, supporting and enhancing data-driven decisions. Ultimately, this helps to increase the efficiency and accuracy of quantitative seismic interpretation activity of those operating in the oil and gas industry, as the real, true value of data can now be fully extracted.
Those using the software can easily leverage advanced no-code AI and data-science technology to maximize the value of their data, while also building strong foundations to support any future decisions.
The software helps to connect energy company users with their internal and external data assets via high-performance computing resources and AI-powered geoscience software applications. This connectivity and the integrated applications allow EarthNET users to break out of the data and discipline silos and embrace truly integrated, cross-disciplinary data analytics workflows. The integrated system allows users to seamlessly access and use all the relevant data to gain new insights, produce 3D property models, and compute data-driven probabilistic volumes for prospects and fields.

Geoscientists now have the tools available to predict reservoir properties directly from seismic data. The models are trained on a combination of well and seismic data, augmented with synthetic seismic responses of nearby or analogue wells, and are used for direct prediction of rock and fluid properties in 3D, including quantification of prediction uncertainty. Access to wide-ranging contextualized data from multiple sources, all in one place, is the key to ensuring that we have the fullest possible picture of what lies beneath, Fig. 2. The days of lacking a first-hand visual perception of rock and fluid-property distribution are over, meaning that operators are no longer approaching their E&P operations blindly or using best-guess estimations to drive decisions.

Automatic seismic interpretation

The interpretation of faults, horizons and geobodies from seismic data has always been intriguing, yet time-consuming and complex tasks for practitioners. Its success, or failure, has the potential to impact license rounds and exploration target evaluations, reservoir analysis, and potential drilling hazards and regional studies. Because of this, its importance should never be overlooked.

Depending on the size of the survey, previous manual seismic interpretation would have taken weeks at best, or sometimes even months at worst. However, over the last few years, we have worked hard to deliver what we refer to as automatic seismic interpretation. With automatic seismic interpretation now available to operators, the tools are there for faster, higher-quality, data-driven seismic interpretation, providing turnaround time of a few hours, with a cost-effective intuitive software platform that also quantifies interpretation uncertainty, This digital transformation technology directly uplifts the accuracy and efficiency of workflows, supporting future E&P activity as a result.

Barriers to entry

While ongoing digital transformation continues to take place at pace, barriers to entry remain, most notably in relation to geoscience's software requirements. In terms of sector challenges hindering full adoption, there remain several hurdles to overcome. The most glaring is perhaps what is an ongoing transitional phase in terms of legacy software and the need for this to be transitioned to cloud-native solutions. This in turn leads to several connectivity challenges, but one which those in the industry are attempting to address.

Most E&P operators are using legacy software designed for desktop deployment. By their very design, these have traditionally been built with their own data storage systems in place. They are not open for third parties to access and manipulate the data, meaning that the information remains controlled by the original software company. To get around this challenge, any future digital solution must be based upon using data platforms that are fully open, and paired with cloud-native solutions.

The introduction of the OSDU Data Platform will go a long way in supporting this requirement, not only for E&P operators, but for software vendors as well. An open data platform will enable any software provider to deploy its products with full connectivity to the platform and to all the data, via application programming interfaces. Its full adoption will be a significant step-change for the energy sector.
However, this change will take time, as operators large and small will have to completely overhaul how they have previously undertaken IT activities. However, we have first-hand knowledge that several operators are working hard to implement this as fast as they can, a move that can only be viewed as a positive. The digital opportunities available are plentiful. Once operators have systems in place to take full advantage, this could lead to increased success for future E&P activity.

Identifying missed pay zones. One of the most notable aspects of recent digital transformation, particularly in relation to geosciences, centers around the so-called missed pay prediction. Missed pay opportunities can be attributed to several factors, including insufficient data quality and coverage, poor logging runs, lack of evaluation when the initial discovery was made, or a reduction in the knowledge available following company mergers or takeovers. By identifying missed hydrocarbon pay zones among drilled wells in mature basins, operators can be given a second chance to find additional oil or gas accumulations, in a streamlined and efficient way.

Most of the easy-to-access hydrocarbons within existing fields are already being produced, and a significant amount of aging infrastructure is nearing the end of its operational life. Therefore, it's urgent to find new barrels that can postpone decommissioning. We published our own missed pay findings, based upon our own machine learning technology. The workflow activity was performed within the EarthNET software, using AI and cloud-native technology.

With EarthNET's well-data analytics module, geoscientists can now rapidly predict high-quality rock and fluid property curves and predict missing logs within wells. Geoscientists can apply machine-learning models to predict reservoir properties directly from wireline logs, core data, fluid data and CPI's. Machine-learning methods for property prediction in wells will support geoscientists to carry out projects efficiently, and at large scales.

By identifying missed pay within exploration wells or assets that are already producing oil or gas, the potential is there to increase reserves, locate and produce cost-effective hydrocarbons, and even deliver new exploration targets to operators.

Looking to the future

Earth Science Analytics' mission is to provide high-quality data-driven petroleum-geoscience solutions to those operating within the E&P industry. The next-generation E&P software is cloud-native and also deployable on premise or as hybrid solutions. These solutions are real collaborative environments that put data and insights at the fingertips of domain experts and decision makers. These storage and computing resources are available on demand, enabling organizations to rapidly scale up or down, relative to business needs.

We strongly believe that our solutions enable petroleum geoscience teams to work more efficiently, with greater precision and at lower cost, compared to what could have previously been achieved through traditional methods.

Our solution ensures that more data-driven decisions can be made, ultimately leading to more profitable decisions. It's an exciting time to be operating in the sector, as companies become increasingly aware of the availability and potential of new enabling technologies.

The ongoing digital transformation taking place in the energy sector is advancing at an accelerated pace. New opportunities are being identified. However, while barriers to full entry remain, companies that recognize the potential and move rapidly in their adoption of the latest technology will reap the greatest benefits.

By fully embracing machine learning, AI and data-driven decisions, operators have the potential to positively impact their company's profitability. As a service provider, we are excited about what the coming years hold, as digital transformation continues to take root and flourish. It's a future that we are immensely proud to be a part of and look forward to continuing our role in driving and facilitating ongoing digitalization to help shape the energy sector of the future.

SPECIAL REPORT

For most of human history, space has occupied a unique place in our imagination!

When President John F. Kennedy told the audience at Rice University that NASA's budget had tripled7 in a single year, there were just 45 satellites in space. By 1980, there were 1,685 launched objects8 orbiting Earth; today, there are more than 18,000. Although President Ronald Reagan famously quipped "The nine most terrifying words in the English language are 'I'm from the government, and I'm here to help,'" the government has played an irrefutable role in funding nascent technologies.

There is perhaps no better illustration of the government's ability to back transformative technological innovation than the original space race. Spurred on by intense rivalry with the Soviet Union, the US government invested $26 billion above $318 billion today on the Apollo Program through 1973 and ultimately fulfilled President Kennedy's objective in 1969 when Neil Armstrong made that giant leap for mankind. In the process, an entire industry was formed around reaching this singular goal of putting a man on the moon: over 400,000 people and above 20,000 companies were involved in the Apollo Program.

This enormous moonshot effort also helped seed a budding US semiconductor industry. NASA's decision in 1962 to use integrated circuits for the guidance systems on Apollo missions, along with the Air Force's adoption of integrated circuits for its Minuteman II missiles, yielded massive federal contracts for Texas Instruments and Fairchild Semiconductor, two major domestic players. Massive government orders unlocked economies of scale, and long-term revenues helped fund further R&D breakthroughs. The cost per microchip fell from $32 to $1.25. Today, microchips are fundamental building blocks of advanced defense technologies, including modern spacecraft.

Although government-led spending and innovation defined this era, it gave rise to many of the commercial space-based technologies and services that have revolutionized life on Earth for the past several decades. Today, these innovations support diverse sectors spanning telecommunications, logistics, agriculture, defense, and finance.

The night sky has served as a canvas for myth, navigation, and wonder, a domain whose scale defies ordinary understanding. And yet, much of our modern economy depends on the orbital infrastructure operating hundreds of miles above Earth. From global logistics and modern defense architectures to AI, strategically important industries all rest in part on technologies that circle the planet every 90 minutes.

For most of the 20th century, these systems were built almost entirely by governments, fueled by geopolitical rivalry during the Cold War.
Space exploration served national prestige, scientific ambition, and military competition. The institutions that shaped early space activity were designed for this environment, when exploration was the domain of nation states and the number of actors was limited.

In the last few decades, that model has given way to something entirely different as the economics of reaching space have fundamentally shifted reusable launch systems, smaller satellites, advances in computing, and modern manufacturing techniques have reduced the cost of sending payloads into orbit. In turn, private-sector companies now build the infrastructure once exclusive to government programs, and capital markets provide the critical funding for space exploration and commercialization.

Space is becoming a new pillar of the industrial economy, one that is increasingly important to life on Earth. As the economic frontier of space extends, so will competition for orbital access, launch capacity, and space-based services. As with other industrial systems, the space economy will develop supply chains, infrastructure nodes, and points of concentration where economic power accumulates.

Similarly, the space economy will face the same technology, financial, and regulatory bottlenecks that impact traditional industrial supply chains. The firms and countries that control launch capacity, manufacturing capability, orbital infrastructure, and space-derived data will shape how value is created in the emerging space sector. As space becomes more economically central, it also becomes more strategically important to national security. And with corporates preparing to build and operate much of this critical space infrastructure, the line between public- and private-sector interests is blurred.

These converging forces are fueling a new space age defined not only by exploration but also by economic competition, a domain where capital markets, industrial capacity, and national strategy collide. Control of infrastructure, access to scarce resources, and mastery of emerging technologies will shape the orbital ecosystem.

The modern space economy

The modern space economy is structured into upstream and downstream. The upstream segment encompasses the manufacturing and deployment of space assets, including satellite production, launch services, and ground infrastructure. Conversely, the downstream segment focuses on the operational utility of these assets, delivering space-enabled services that support a vast range of terrestrial activities. These capabilities spanning Earth observation, global communications, object tracking, and precision PNTserve a diverse array of end users from nearly every global industry.

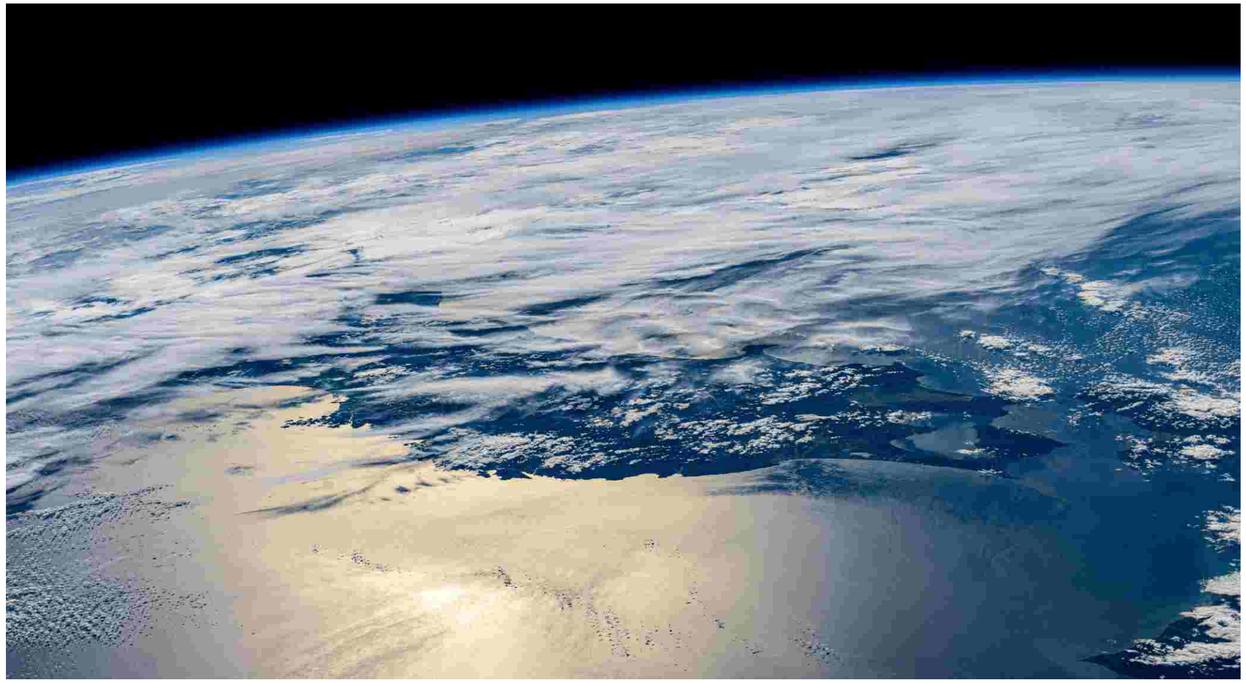
Since the early 2000s, the modern space economy has been revolutionized by three interconnected innovations: the advent of reusable rockets, the phenomenon known as the "SmallSat revolution," and the growing use of LEO.
Because of the limited number of launch service providers globally, launch acts as the upstream chokepoint for every aspect of the space economy and defines the cost structure for all other segments of the industry. In 1981, getting a kilogram of mass into LEO cost $65,400/kg on the US Space Shuttle. Today, SpaceX Falcon Heavy has brought costs down to $1,500 per kg. This massive decline in costs has been enabled by the advent of partially reusable rocket boosters, an innovation that transformed the massive fixed costs of building rockets into an asset that can be recycled for multiple launches. As a growing number of companies seek to replicate and improve upon this innovation, launch costs could continue to decline, democratizing space access even further.

At the same time, technical innovations and cheaper manufacturing techniques have led to a decline in the size and manufacturing cost of most functional satellites, creating new form factors and dramatically decreasing the complexity of reaching orbit with SmallSats. Until the mid-2000s, the industry had been dominated by large, school-bus-sized satellites in geostationary equatorial orbit (GEO) about 35,786 km above Earth's equator that cost $100 million to $200 million to build, with launch costs on the order of $50 million. These custom-built satellites were designed to remain in orbit for decades, making them prohibitively expensive for most actors except governments and telecommunications giants.

Concurrently, more satellites began to move into LEO above 550 km from Earth from higher orbits, taking advantage of lower latency and cheaper costs. While the LEO constellations of the 1990s including, Iridium, Globalstar, and Teledesic failed spectacularly, by the 2010s a new class of space startups were launching commercially viable, large-scale LEO constellations. Operating closer to Earth offered several advantages. First, lower radiation makes it viable to use commercial-grade electronics. Second, LEO satellites require less intense receiving infrastructure and user terminals on Earth, enabling devices as small as a satellite phone to communicate with a satellite and further reducing infrastructure costs. Finally, with reduced latency, the LEO revolution expanded the types of activities that could be conducted, such as video calls and online gaming.
LEO infrastructure is one of the clearest commercial beachheads of the modern space economy, extending, supplementing, and even competing with terrestrial networks.

In the four years since launch, Starlink, SpaceX's fully operational global broadband LEO constellation provides high-speed low-latency internet, serving more than 10 million customers, generating more than $11 billion in revenue in 2025.2 The Starlink network currently has almost 10,000 satellites in LEO, with thousands more approved for deployment in the next few years. Amazon, too, is investing significantly to build up its LEO satellite network, known as Amazon Leo, that can serve broadband internet and DTC most notably through its announced agreement to acquire Globalstar, which includes radio spectrum rights for DTC communications. DTC, normally considered a low-data operation for edge-processing use cases in remote environments, is likely to expand to high-data operations in the future and complement regular LTE service.

Although the markets for DTC and broadband services are converging and are being pursued by many of the same players, the competitive dynamics of these markets differ. The physical terminal required for broadband services means that the switching costs in this market are higher, providing an advantage to first movers. For instance, Starlink terminals generally cost between $200 and $600, depending on product and geography, and the upfront cost deters customers from switching easily to other providers. On the other hand, companies pursuing DTC can partner with existing cell carriers to add space-based coverage, instantly granting them access to large existing customer bases without selling any hardware. This also means DTC users will face lower switching costs compared to broadband, which could make competition in this sector stronger as it develops
.
Regardless of how these competitive dynamics resolve, a trend line is forming: As LEO networks become denser and latency improves, satellite communications are likely to become an embedded feature of the broader digital economy, supporting direct-to-device mobile connectivity, aviation and maritime broadband, emergency response, autonomous vehicles, electric vertical takeoff and landing eVTOL crafts, mixed reality, telemedicine, smart cities, and machine-to-machine communications.
Over time, the most important commercial shift may be that LEO makes connectivity ambient—available across geographies, modes of transport, and industrial settings where terrestrial networks are intermittent or uneconomic. That creates a platform for second-order applications: autonomous systems that require continuous data links, cross-border enterprise networks that avoid terrestrial chokepoints, resilient backup communications during disasters, and eventually space-to-space



communications that support a more complex orbital economy. In that sense, LEO is not merely a substitute for fiber, 5G, or submarine cables; it is becoming a new connectivity layer that expands the addressable market for communications, enables new categories of digital services, and reinforces the report's broader argument that space infrastructure is moving from a specialized frontier to an essential pillar of the industrial economy.

New frontiers spurring new industries

Space innovation is also accelerating beyond the services and sectors that exist today. The next phase of development may be defined by advancements in in-space servicing, assembling, and manufacturing (ISAM), which could prove to be a gateway to a host of new space-based technologies by allowing objects larger than current payload capacity to be manufactured in orbit, as well as enabling lighter satellites through mid-flight refueling. It could also give way to in-orbit manufacturing of goods that benefit from microgravity, such as biomanufacturing. In turn, resource extraction, solar energy production, and large-scale lunar activities could all become commercially viable. As these activities scale and enabling capabilities mature, they could justify a continuous lunar presence, which in turn could support a wider lunar economy spanning transport, communications, energy, construction, and space tourism.
Orbital compute has emerged as a particularly dynamic vector for development. Compute already exists in space, largely for edge-processing use cases, but companies are now exploring what it would take to develop more wide-scale capabilities, given the exponential growth in token demand and the challenges facing terrestrial data center development namely, limited power availability, long grid interconnection queues, and permitting delays. With solar panels in sun-synchronous orbit, space could potentially offer almost limitless power and fewer regulatory hurdles. However, challenges remain. Although space is cold, the environment is a near vacuum, creating engineering difficulties for the radiators designed to dissipate heat from the GPUs. Uplink and downlink capacity currently limit bandwidth and latency capacity, and the ability to maintain or repair parts in orbit particularly chips remains constrained. The GPUs themselves may also require engineering modifications for radiation hardening.
However, progressing toward the commercial era of space will require governments and companies to confront new challenges. The proliferation of satellites in LEO has led to an increase in orbital congestion: While a single satellite in GEO can cover a large section of Earth from just one position, at their low altitude, LEO constellations require many more satellites to reach full coverage. Both countries and companies are competing to obtain satellite slots, which the International Telecommunication Union allocates on a first-come, first-served basis. As a result, early movers like SpaceX have a significant advantage, but the competition for orbital slots will only grow more acute as launch activity continues to accelerate.
And congestion is only one dimension of a broader governance gap. Many of these novel space capabilities also fall within a legal gray zone. Clarifying regulatory frameworks for these emerging capabilities will be a critical part of spurring the investments needed to reach commercialization.

SPECIAL REPORT

Extreme space weather: impacts on engineered systems and infrastructure

Electricity: imagine our world without it. Society depends on electricity for everything from communication, banking and business transactions to basic necessities like food and water. Terrestrial weather and human errors account for $75-180bn annually in economic costs from power outages. One serious threat to the reliability of electric power is geomagnetic storms, the severe disturbances caused by solar storms in the upper layers of our atmosphere that induce currents in long conductors on the Earth's surface, such as power lines. These additional currents can overload the electric grid system to trigger voltage collapse, or worse, damage a significant number of expensive extra-high voltage transformers. The economic costs of such an event would be catastrophic. Large transformer repairs and replacements occur on the timescale of weeks to months, and could result in long-term widespread blackouts.

Coronal mass ejections CMEs are one manifestation of the latter and stream interaction regions, formed when fast streams in the solar wind overtake and compress slow streams, also occur. Directly or indirectly the ionising radiation, the ionised particles and the plasma interact with the magnetosphere and the ionosphere below it to cause a variety of effects on engineered systems.

“Space weather” isn't the next blockbuster movie franchise; it refers to conditions created by the sun, solar wind, magnetosphere, ionosphere and thermosphere near Earth's space environment that impact our planet. The effects of space weather can interrupt and damage critical technologies, such as electric power grids, airlines, trains, pipelines and global navigation satellite systems GNSS, but the scope of these threats was unknown.

Minor (G1) and moderate (G2) storms are relatively common, occurring on about 1,200 days out of every 11-year cycle, but are barely perceptible. Most cause only small voltage fluctuations in power grids and faded signals on high-frequency radio networks. For a lucky few, the northern lights aurora borealis may be visible as far south as Idaho and New York.
Severe (G4) and extreme (G5) storms are less frequent, occurring on just 60 and four days, respectively, in every 11 years but do much worse damage.

The surface of our Sun is a froth of plasma and magnetic fields, always active and ever changing. The sun follows a cycle of magnetic activity reflected by the number of sunspots and the average sunspot area, which waxes and wanes on a time scale of 9-14 years. Historical sunspot data dates back to 1775, which marks the beginning of the first solar cycle
A sunspot appears as a dark area where magnetic field lines enter and exit the Sun's visible surface. The field lines create an area of slightly reduced thermal temperature, which causes the dark appearance. The actual measure of the 'sunspot number' is a weighting between individual spots and sunspot groups, or complex areas with several merged sunspots. For extreme geomagnetic storm risk, it is the largest sunspot groups, or 'superactive regions', that pose a significant threat to the Earth.

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Human society depends on electricity for everything from communication, banking and business transactions to basic necessities like food and water.

Electricity transmission infrastructure is vital for functioning of modern economies and is, thus, regarded as a “critical” infrastructure. As industry, communication systems, transportation, and several other sectors depend on the secure and reliable supply of electricity, failures in electricity delivery can result in significant economic costs and the collapse of modern economic and social life. To protect electricity transmission and distribution grids from multiple risks, the functionality, continuity, and integrity of electricity transmission networks must be ensured; this includes assessment, mitigation, and effective management of blackout risks.

Today, the task of protecting electricity transmission systems has become a greater challenge than ever before: during the last decade the number of blackouts has grown steadily, as have their respective impacts, affecting an increasingly large number of people in developing, transition, and developed countries. The number of major blackout events classified as disasters when 1000 people or more people are affected for at least 1000 hours or 1 million people are affected for at least one hour – has increased, according to Organization for Security and Cooperation in Europe.
In an extreme storm, power systems experience widespread voltage control problems, with the risk of blackouts or complete collapse. Electric currents reaching hundreds of amperes surge through pipelines. Satellite navigation may degrade or be unavailable for days at a time, and the aurora is visible in Florida and Texas, according to NOAA.
In March 1989, an extreme geomagnetic storm blacked out the whole of Hydro-Quebec's power network in less than 90 seconds, wiping out power to 6 million people for up to nine hours.

The biggest storm of all occurred in 1859. Known as the Carrington Event, it was really two massive blasts on Aug. 28 and Sept. 2. The northern lights were visible as far south as Panama, so strong that they lit up the night sky as if it were day in the Rockies and New York.

Currently, four space satellites SOHO, Solar and Heliospheric Observatory, ACE, the Advanced Composition Explorer, and STEREO Solar Terrestrial Relations Observatory monitor the Sun. Situated between the Sun and Earth or along Earth's orbit, these satellites can provide warnings of incoming Corona Mass Ehections on a timescale of a few days to hours. These warnings allow electric grid operators to take protective measures especially by decreasing the electric load in the grid and increase reactive power production before the storm hits.

Africa is vulnerable to the impacts of space weather which can affect High Frequency radio communication, power distribution networks, satellites, avionics, navigational aids, and communication systems. Internationally, space weather is being considered a significant risk to the stability of national assets, safety, and security, and in this regard is being considered at a high level in national governments. The economic impact of a space weather event can be catastrophic, and should not be taken lightly. The main recommendation from this policy brief is that South Africa should identify space weather storms as a potential risk that could impact the economy negatively, and therefore appropriate recognition, understanding and capability development is required in order to ensure adequate preparedness.

Operation and delivery of electric power

The electric grid comprises three distinct functions: generation, transmission, and distribution. Electric power is generated at power plants; can be transported over long distances using electric power transmission systems; and is sent to residential, commercial, and industrial consumers of electric power through distribution systems.
Operation of the electric grid is managed by system operators. Because electric energy is not typically stored in large quantities, system operators must constantly balance the generation and consumption of electric power to maintain system reliability. To do this, system operators utilize a system of sensors and controls to monitor power consumption and generation from a centralized location and manage adjustments in the output from power plants to match changes in consumption.

On Generation, power plants generate electric power by converting energy from other forms using different types of fuels or energy sources into electric power. The initial form of energy can be chemical petroleum, natural gas, coal, mechanical (hydroelectric or wind, thermal geothermal or solar, or nuclear. Power plants use generators to transform these initial energy forms into rotational mechanical energy and then into electrical power. Alternatively, radiant energy (solar) power stations use photovoltaic cells and power electronics to transform solar energy into electrical power.

However, the power transmission system connects geographically distant power plants with areas where electric power is consumed. According to report, the system includes approximately 240,000 miles of high-voltage, alternating current AC transmission lines between 230 and 765 kilovolts.9 When electric power was first used in the 19th century, electric power needed to be used near generators. However, with the development of high-voltage, AC power transmission, power lines could transmit power over longer distances compared to the original direct current DC system. To transport electric power over long distances with minimal power losses, suppliers continued to increase the voltage of transmission lines.
The installation of high-voltage transmission lines contributed to the expansion of the electric grid and encouraged the construction of higher-power generators to serve the growing electric power demands of the nation.

A new network of dedicated antennas in Africa will lend insight into the havoc that storms of charged particles from the sun wreak on satellite and radio communications. Zambia set up its first such sensor in March—one of eight multifrequency receivers being deployed around the continent, in addition to four already operating in South Africa. Kenya and Nigeria will install their receivers by the end of the year.
Feeding into an upgraded space weather center scheduled to open in South Africa in 2022, the network will provide real-time data on how solar storms distort the ionosphere, the charged outer layer of Earth's atmosphere. This distortion can have dangerous consequences, says Mpho Tshisaphungo, a space weather researcher at the South African National Space Agency (SANSA). Signals between crucial satellites and the ground pass through this region, where charged particles can cause interference. Also, high-frequency radio signals (often used in defense and emergency services communications) have to bounce off the ionosphere; Tshisaphungo notes that when solar storms alter the layer, “the radio signal may either be attenuated, delayed or absorbed by the ionosphere.”
South Africa has already been providing global networks with information about the ionosphere above the country in periodic batches, relying on satellite and ground data from international space weather programs. The new network will give Africa its first access to 24/7 local details on how the sun's behavior is affecting the atmosphere overhead, researchers say.

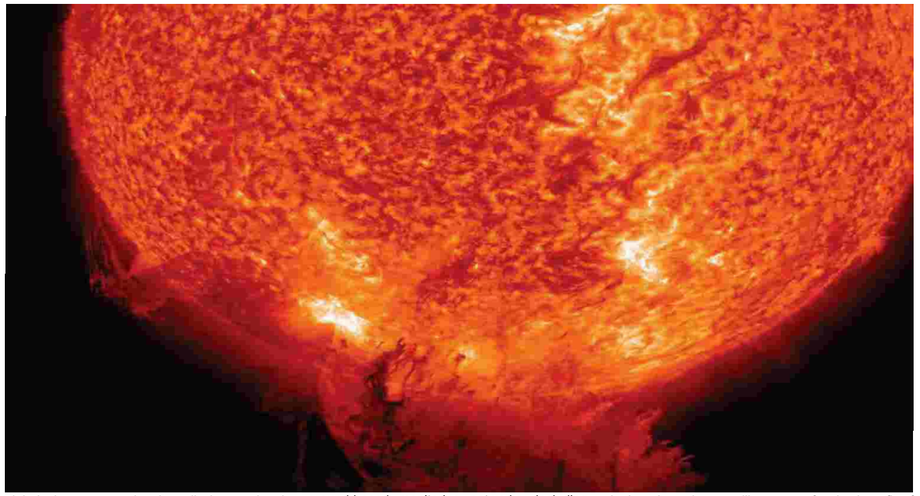
South Africa Beefing Up Space Weather Expertise

Space weather is a suite of phenomena caused by highly charged plasma that's spewed out by the sun and flung across the solar system, interacting with Earth's atmosphere and magnetic field as it passes. Such events can interfere with satellites in orbit and even interfere with power grids on Earth's surface, and scientists are still developing techniques to monitor and predict space weather trends. South Africa wants to be sure it and its neighbors aren't left out of the process.
“We could see that space weather was growing in the world and it was becoming a natural risk to technological systems,” Lee-Anne McKinnell, managing director for space science at the South African National Space Agency (SANSA), told Space.com recently at the International Astronomical Congress. "In many ways, many African countries leapfrog into technology, so they miss all the little steps in between and they go straight there.”

So far, South Africa hasn't suffered too much from the impacts of space weather, she said. Two incidents, a satellite falling silent and a burnt-out power transformer, may have been caused by space weather. But right now, the sun is relatively quiet, at a low in its 11-year activity cycle. By the next peak in that activity, South Africa will be at higher risk than it was at the most recent peak.
"In the last 10 years, the growth in technological systems and our uptake of technological systems has increased dramatically in Africa.”

Space weather projects often focus on orbiting instruments, but South Africa's key strength for the issue lies in its ground-based monitoring networks, including those that detect how satellite signals change as they travel through the atmosphere and those that measure changes in the geomagnetic field. "South Africa is very good at measuring space from the ground, through a distributed network of instruments, so we want to expand that through Africa,” McKinnell said. "That's what we bring to the party.”

It's also important for South Africa and its neighbors to develop their own monitoring capacity, rather than rely on other countries' satellites, McKinnell said. "Space weather is a global phenomenon, but it really has regional impact," she said. "The space environment as you go across the globe is very different, so the impact that you're going to feel from space weather is very different." Local monitoring is particularly important for Africa, she said, because the magnetic equator dips through the continent, affecting its space weather.



South Africa got its start in space weather work because of its previous expertise in magnetic observations, she said, but so far, the country has been stronger in space weather science than in applications. SANSA is now working to change that with a new facility to monitor space weather around the clock and process data faster.
“When you do research, real-time data is not really your priority. When you do operations, real-time data is your priority," McKinnell said. "We will move from a research-and-development, limited-focus, working-hours-only center to a fully operational, 24/7 center in three years.”

That transition will put South Africa in charge of a regional center focused particularly on the ways space weather impacts aviation. The country hopes that, in turn, will make its continuing reliance on technology less vulnerable and of more benefit to its residents. Space weather projects often focus on orbiting instruments, but South Africa's key strength for the issue lies in its ground-based monitoring networks, including those that detect how satellite signals change as they travel through the atmosphere and those that measure changes in the geomagnetic field. "South Africa is very good at measuring space from the ground, through a distributed network of instruments, so we want to expand that through Africa," McKinnell said. "That's what we bring to the party.”

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According to the South Africa National Agency, SANSA is in a position to work together with all the affected sectors, and government, to make provision for a space weather capability that addresses the nation's requirements, and leads the country towards mitigation measures against this risk. In conclusion, it should be noted that further work will need to be undertaken to assess the likely impacts of space weather that would affect the South African economy.

India's shift towards space economy



India has a long and proud history of space exploration. The country's first satellite, Aryabhatta, was launched in 1975, and India has since become a major player in the global space community. In recent years, the Indian government has taken steps to further develop the space sector.
In 2023, the government unveils new Indian Space Policy 2023, which outlines the government's vision for the Indian space sector in the coming years. The 2023 space policy is a significant departure from previous policies. It is more liberal in its approach to private sector participation, and it gives greater emphasis to the use of space technology for social and economic development. The policy is also more ambitious in its goals, and it sets out a vision for India to become a leading spacefaring nation.

India's history of space exploration is extensive and illustrious. Since the beginning of the Indian space programme in 1969, five space policies have served as its guiding principles. These regulations have played a role in shaping the growth of the Indian space industry and ensuring that the nation's overarching objectives for economic and social development are met by the space programme in India. Indian National Space Policy, 1969, was the country's first space policy. In this strategy, the government established its goals for the Indian space programme, which included the creation of space technology for the benefit of the nation. Additionally, the policy emphasized the necessity of international collaboration in space exploration.

The space ecosystem in India today consists of stakeholders within government, private companies, start-ups and universities. Space research in India commenced in 1962 with the founding of the Indian National Committee for Space Research, which resulted in the establishment of ISRO in 1969. Today, ISRO anchors the core of India's space research and exploration. As the national space agency, ISRO operates under the Indian Government's Department of Space (DOS), whose primary objective is to promote the development and application of space science and technology of the country's space programme.
ISRO has several specialised centres like the Space Applications Center (SAC), which develop instruments and payloads and their applications for national technology development and societal benefits. Alongside these operate several autonomous bodies, chief of which is the Physical Research Laboratory (PRL), a major driver of India's planetary exploration program conducting fundamental research in astronomy, astrophysics, solar physics, planetary science, atmospheric sciences and geosciences.
To spur private sector development in India, the government established the Indian National Space Promotion and Authorization Centre (IN-SPACe) in 2020, a Department of Space entity created to “promote, hand-hold, guide and authorise space activities” of private players in the country. This move followed the establishment of New Space India Limited NSIL in 2019, which is a Department of Space company tasked with commercialising Indian space technologies, especially those developed by ISRO.

In large planetary exploration missions, ISRO acts as the primary agency responsible for mission planning, development, execution, and management. It collaborates with various governmental and educational institutions for research and development. In the ISRO-led Chandrayaan and Mangalyaan missions, various national and international institutions had collaborated for payloads and research. In domains like astrophysics, the Indian scientific community recommended the use of AstroSat, India's first dedicated multi wavelength space telescope, and XPoSat, a polarimetry mission to carry out research.

ISRO has partnerships agreements with NASA and ESA and significant bilateral collaboration with France, the Netherlands and the United Kingdom. The agency has signed 283 Cooperative Documents with 61 partner countries with the aim of enhancing knowledge sharing and capacity building in the space domain.

According to Chairman of ISRO Dr. SP Somnath, ISRO has interest in the Danish space strategy and is especially interested in collaborating with Denmark at a corporate level. As for India's academic progress in space, leading institutions like the Indian Institution of Science (IISc) and Indian Institutes of Technology have significant space orientation. Dr. SP Somnath is an aerospace engineer and the Chairman of ISRO.
Private companies are increasingly involved in ISRO's EO missions, initially as component and technology suppliers and eventually as key development partners. However, there is no plan yet to carry instrumentation from private companies on India's national space science missions.

The Indian aerospace sector is linked to the outer space sector through development, manufacturing, and deployment of technologies and systems that support space exploration and satellite communication. Key players in the Indian aerospace industry, including public sector giants like ISRO and private enterprises like L&T, Godrej Aerospace, and HAL, contribute significantly to space missions by providing expertise, infrastructure, and manufacturing capabilities including production of launch vehicles, satellites, and ground systems. This collaboration not only enhances India's capabilities in space but also in international aerospace and defence markets.

The vendor and supplier network in the Indian space ecosystem is vital for the successful execution of space missions and has multiple levels. At the primary level are large companies and research institutions that provide major components and technologies for spacecraft and develop structures for launch vehicles. These entities often work closely with ISRO to develop mission-critical technology.

The secondary level includes smaller companies that supply specialised components, software and services. These entities are crucial in providing innovative solutions and niche products that contribute to the efficiency and effectiveness of space missions. Start-ups are also expected to start contributing to national missions at this level.

Finally, there are numerous tertiary suppliers that provide generic components and services. While their products may not be specific to the space industry, they are essential for the overall functioning of space missions. From a strategic standpoint, this expansion of India's space capabilities to the private sector is expected to aid India's journey towards self-reliance in space.

Regulatory landscape

The Indian space sector's regulatory landscape has undergone significant changes, with an increased focus on facilitating and managing the participation of non-Indian entities. These changes are a part of India's broader initiative to integrate its space sector with global markets and encourage international collaboration. This strategic approach seeks to foster private capital infusion and harness global proficiency. Every proposition undergoes meticulous scrutiny, evaluated individually with regard to factors such as national security and technological intricacy.

India's policy on foreign investment in the space domain encompasses satellite establishment and operations, contingent upon governmental sanction. In February 2024, the government announced that it had amended its Foreign Direct Investment policy allowing 100 per cent investment in the space sector. The liberalised entry routes under the amended policy are aimed at attracting potential investors to invest in Indian space companies. This move is anticipated to spur job creation, facilitate the assimilation of cutting-edge technologies, and foster self-sufficiency within the sector. Companies will have the opportunity to establish manufacturing units domestically, thereby bolstering the 'Make in India' and 'Atmanirbhar Bharat' initiatives endorsed by the Indian Government..
The recent Indian Space Policy 2023 has contributed largely in guiding India's space economy by presenting a multifaceted terrain of both opportunities and hurdles for international enterprises and research bodies. India's space ambitions are also reflected in the increase in government spending in the space domain.
While the policy advocates for increased involvement of non-governmental entities in space endeavours, thereby fostering international collaboration, it also demands cautious manoeuvring within a novel and potentially uncertain market landscape.
Following the touchdown on the Moon by Chandrayaan-3, ISRO plans to expand its human spaceflight program by creating an Indian Space Station in Earth orbit by 2035. This would be followed by sending the first Indian to the Moon by 2040. To realise these ambitions, the DOS and ISRO are developing a roadmap for lunar exploration, which will comprise a series of Chandrayaan missions, the development of a partially reusable Next Generation Launch Vehicle (NGLV), a new launch pad, and more. “With ISRO's human spaceflight program Gaganyaan, there's a strong focus on growing and extending indigenous capabilities, which includes sourcing components and manufactured modules from Indian private entities, “according to Lt. General (Retired) Anil Bhatt, Director-General of the consortium Indian Space Association.

Next Moon mission

For its next Moon mission launch before the end of decade, India is partnering with Japan to have the LUPEX rover directly study the nature, abundance, and accessibility of water ice on the Moon's south pole. This will provide critical information for the ongoing global rush to the Moon, which has sustainable crewed missions and habitats as the end goal, and towards which the European Space Agency is also working via the US-led Artemis missions. India is also planning to launch Chandrayaan-4 before the end of decade. It's a sample return mission, expected to provide a bounty of lunar science. At the same time, Chandrayaan-4 will demonstrate several technologies needed for a future crewed mission to the Moon and back. Like previous Chandrayaan missions, ISRO-affiliated institutions will provide key scientific instruments for LUPEX and Chandrayaan-4.

Data from all of ISRO's space science missions is available freely on the dedicated website for the purpose: www.issdc.gov.in. In December 2023, ISRO opened up access to 5-metre resolution remote sensing data from 44 of its satellites, making it among the highest resolution datasets of its kind in the world available to the public.

There are promising areas for collaboration, such as sustainability, which aligns with the existing Green Strategic Partnership between Denmark and India, as well as research and development (R&D), which is a cornerstone of the Danish space sector and a key focus area for India.

The downstream space technology value chain in India covers sectors such as Earth Observation EO and analytics, Positioning, Navigation and Timing PNT, and Satellite Communication SATCOM. Opportunities entail adapting to a market distinct from Europe in terms of regulatory frameworks, business practices, and consumer demands. Danish firms specializing in satellite components, manufacturing, and communication systems could discover openings here, but achieving success will likely demand substantial market analysis and establishment of local partnerships to navigate the distinctive features of the Indian market. India's emphasis on incorporating AI and machine learning into space technology dovetails with Denmark's expertise in these domains. Companies such as SkyServe and SatSure are pioneering edge computing for satellites and already have established European collaborators.

Regarding privately developed launch vehicles like those by Skyroot Aerospace and Agnikul Cosmos, inherent technical complexities suggest that achieving the extensive track record and stability typically sought by Danish companies in international partnerships might be several years away. Upstream solutions satellites, rockets, rocket fuel, propulsion systems from the private sector require substantial capital, which has not been a primary source in India's Department of Space thus far. The transition from operational viability to commercial viability also entails a lengthy timeline. Consequently, in the short term, downstream solution providers with quicker maturity timelines will likely serve as more suitable partners.

India's space start-up ecosystem

In recent years, there has been a notable rise in the number of private players in the Indian space ecosystem, a clear sign that they are increasingly complementing the efforts of the government in diversifying the indigenous space sector's capabilities. A wide array of companies, specifically start-ups and SMEs aim at providing endto-end solutions in areas ranging from hyperspectral imaging to launch capabilities.
The policy frameworks that enable their role in the space ecosystem, however, are new or still under development. In 2023, there were registered 190 Indian start-ups operating in the space sector, a figure approximately the double of the previous year. Additionally, various tangential companies, including Amazon Web Services, are venturing into space with specialized offerings. With the booming start-up and SME ecosystem, coupled with the liberalisation of FDI, a surge in investments and international partnerships is anticipated.
Most space start-ups in India primarily concentrate on satellites, particularly the advancement of nano- and microsatellites. An important characteristic among satellite-oriented start-ups in the country is their adeptness in recognizingmarket voids, distinguishing themselves based on critical factors like measured light spectrum and pioneering inventive products. As the Indian space program expands, numerous entities are becoming more open to leveraging third-party platforms, thereby creating avenues for start-ups and SMEs to adopt a more significant role.

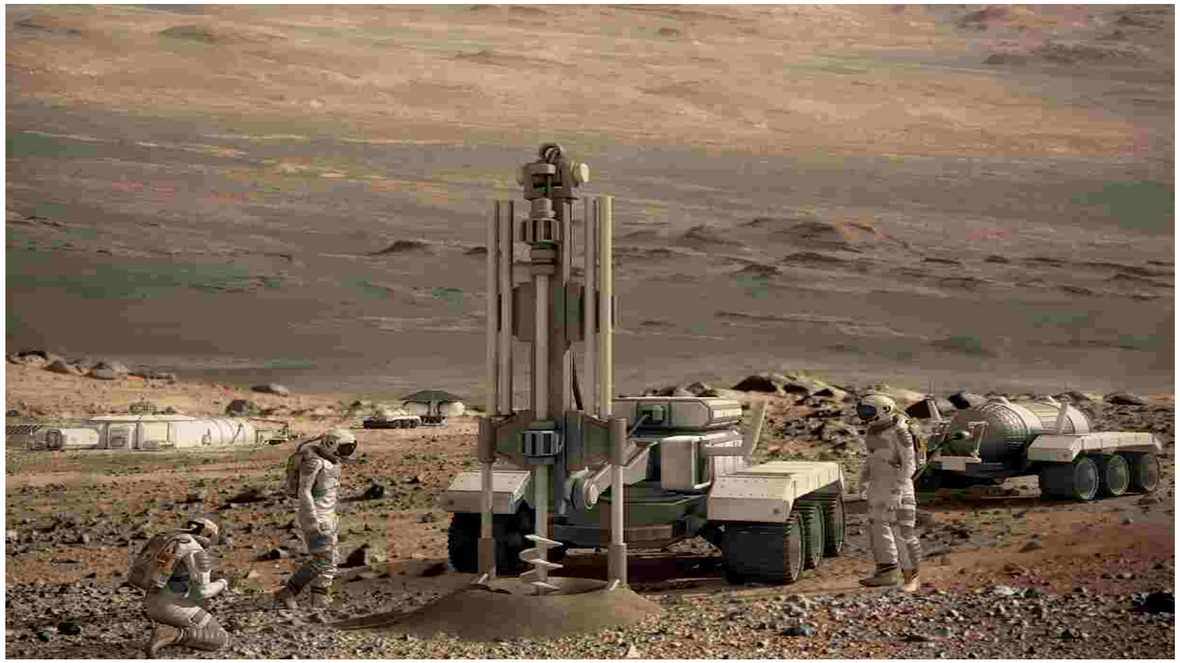
Other than enabling the private space sector via policy and regulations, the Indian government extends some support to start-ups chiefly via IN-SPACe. The organisation provides up to 120.000 USD in seed funding to start-ups with innovative ideas. IN-SPACe also offers a Design Lab for new space start-ups to access comprehensive, high-performance space simulation suites without having to invest in their own. ISRO and IN-SPACe struck a deal with Amazon Web Services to offer free cloud computing services to start-ups and research institutes. Notably, IN-SPACe also conducts technology transfers from ISRO to start-ups and companies, presenting a good vector for international companies seeking to collaborate on specific areas of mutual interest. With large traditional contractors like Larsen & Toubro (L&T) moving into satellite manufacturing, opportunities are growing for European and other foreign start-ups to enter the supply chain via specialised components.” Says Narayan Prasad, COO of the global space-based marketplace Satsearch.

India's space start-ups have seen a significant increase in investment by multinational companies. Notably in 2023, Microsoft announced its collaboration with ISRO to empower space tech start-ups with the apt technology tools and platforms, support towards market entry and mentoring to facilitate their growth and readiness for enterprise-level operations. Similarly, Google has invested USD 36 million in a Series B funding round in Pixxel Space.

The Indian space start-up ecosystem actively pursues international collaborations and leans on its successful trackrecord for cost-effective innovation. Consortiums like the Indian Space Association ISpA have teamed up with the French Aerospace Industries Association to catalyse business ties between the respective swarms of Indian and French space companies. Other foreign space agencies have also shown a keen interest in working with Indian space start-ups, notably the Australian Space Agency, which provided USD 20,7 million in funding to Australian businesses and research organisations for conducting joint technology projects with Indian space entities.
However, there are large gaps in the Indian space sector that require a reliance on imports. Furthermore, a large number of Indian companies involved in the commercial development of parts for ISRO operate at tier-2 and tier-3 levels, meaning that they are in the lower end of the supply chain. As start-ups/SMEs fill out some gaps within the sector, providing innovative solutions, they are arguably a positive element for the sector to stay up-to-date with global tech trends. However, as the ecosystem is still nascent, this potential is still to be fully realised and policy frameworks are yet to be fully developed. Table 5 shows a SWOT analysis of the Indian start-up space ecosystem.

For Danish SMEs and startups looking to enter the Indian space market, there are several avenues to consider, depending on their sector focus: Work directly with ISRO: Companies can engage with ISRO by responding to tenders, known as 'Announcement of Opportunities,' either independently or in collaboration with an Indian partner such as a company or university. Partnering with an Indian entity often streamlines the process.

Will SpaceX Send Humans to Mars in 2028?



Nearly seven months after launching from Cape Canaveral Air Force Station, NASA's Perseverance rover landed safely on the surface of Mars, becoming the largest and most sophisticated robot ever launched into space had successfully reached its destination.

The Perseverance landing is a remarkable feat given what's come before. Despite thousands of calculations, data points, and predictive models, space has a way of throwing in the unexpected. Historically, only around fifty percent of surface missions have touched down as planned on the Red Planet. Success can never be taken for granted. This particular mission faced additional complications. Assembly, testing, and mission control at NASA's Jet Propulsion Laboratory were all disrupted due to the Coronavirus pandemic.
So far, Perseverance has lived up to the name. After making it through the Entry, Descent, and Landing phase - dubbed by NASA as “7 minutes of terror” the rover is now preparing to explore Mars' Jezero crater.

Back in 2012, NASA dispatched a similar rover, Curiosity in an effort to discover whether Mars could sustain life. The purpose of the Mars 2020 mission is for Perseverance to take the next step and search for biosignatures of ancient life on the Red Planet.
The images beamed back by Perseverance have raised interest in Mars across the globe. But in truth, we've been fascinated by the Red Planet for decades.

In the 1960s, the US and the USSR raced to launch several flyby missions in an attempt to get a closer look at Mars. All of them failed, until NASA's Mariner 4 made it to the Red Planet on July 14, 1965, and sent 21 grainy photos home.
The next significant step was taken in 1976, when Viking 1touched down and captured the first ground photos of Mars.
Twenty years later, NASA's Pathfinder lander and Sojourner rover arrived in the summer of 1997. The lander used a set of airbags to ensure a soft landing, Sojourner was the first rover to wheel around on the Red Planet.
In 2001, NASA's Mars Odyssey satellite arrived in Mars' orbit and to this day relays images and data from rovers on the ground. Soon after, NASA's Spirit and Opportunity rovers landed on the Red Planet and discovered evidence that Mars was once home to large bodies of water.
In 2012, the Curiosity rover arrived in the Gale Crater. A matter of days after landing, it discovered perfectly rounded pebbles that are thought to have been formed by ancient rivers: physical proof that surface water on Mars was present at one point during its history.

But that attention is grounded in data. Mars is a promising target for exploration for all sorts of reasons. For starters, it's relatively easy to get to. During the window of alignment between Earth and Mars, it can be reached in under seven months.
As a result, we've been able to study the Red Planet for decades with various landings and satellites. And several exciting discoveries have encouraged further research.

In terms of atmosphere and geology, Mars is the most similar planet to Earth in our solar system. It has seasons, volcanoes, polar ice caps, and weather. There's evidence that its surface was once covered with liquid water. Billions of years ago, Mars was warmer and wetter than it is today and conditions would have been suitable for life as we know it.

Mars is a very hostile place for humans, which means any colony would require constant, costly support. Mars has almost no breathable air, very little atmospheric pressure, and intense radiation from the Sun. The average temperature is around –80 °F, far below freezing.
To live there, humans need airtight habitats, heating, oxygen supplies, water recycling, and protection from radiation and dust storms all of which are expensive to build and maintain. Additionally, everything on Mars would have to be shipped from Earth at a massive cost at least until the colony might produce its own goods, which could take decades. One estimate says just to ship things to Mars might cost about $300,000 per kilogram of cargo. Imagine the tons of food, equipment, and building materials a colony needs the transportation costs alone would be enormous. Opponents argue that Mars colonization is not a one-time expense; it would be a never-ending money drain to keep the colony going.

Mars is the most Earth-like planet in our solar system and could hold answers about the origin of life or how planets change. Colonizing Mars would allow scientists to do much more detailed research than robots can. The money spent could lead to discovering useful resources. For instance, Mars has water ice that could be turned into drinking water or rocket fuel, and minerals that might be mined in the future. Some supporters argue that a colony could eventually pay for itself if we find valuable materials or develop new technologies through living on Mars. While immediate economic returns are uncertain, the knowledge gained is valuable. Every mission to Mars has taught us more about Earth's climate and geology too, helping us understand our own planet.

Establishing a permanent human installation on Mars

One major reason to settle Mars is to secure a “backup planet” for humanity. Famous scientists like Stephen Hawking and entrepreneurs like Elon Musk believe that living on other planets will protect us if something terrible happens on Earth. For example, if an asteroid hit Earth or climate change got really bad, humans on Mars would survive. Buzz Aldrin, the Apollo 11 astronaut, said that humanity's goal should be to settle Mars for “permanence,” uniting people with a common goal of survival.
However, establishing a permanent human installation on Mars sounds exciting, but critics say it comes with an astronomical price tag that is hard to justify. They ask: Should we spend hundreds of billions or even trillions of dollars to send humans to a freezing, airless desert, when we have so many problems on Earth? Those against the idea believe the money required for a Mars colony would be better used solving issues here at home. and that Mars is not worth the huge cost right now.

President G. W. Bush announced the Vision for Space Exploration in 2004 but it was partially cancelled in 2010. The Vision for Space Exploration, like the earlier Space Exploration Initiative, included robotic, moon, and Mars missions. NASA's 2004 budget projections, “based on long-term affordability,” increased year by year from 3 billion to 5, 10, and finally to 15 or 18 billion dollars per year from 2004 to 2020. The total cost to 2020 amounted to roughly 130 billion dollars. Extending this annual cost rate for another 20 years to 2040 would add another 300 or 350 billion dollars. The overall total for Vision for Space Exploration would then be 450 or 500 billion dollars.

Investing in Mars exploration spurs new inventions and technologies that can help people on Earth. Over the decades, money spent on space programs has led to everyday products called “spinoffs.” For example, NASA's research gave us memory foam used in mattresses, cordless power tools, and water purifiers to make dirty water clean. It even helped improve medical devices like MRI scanners and develop better solar panels. These innovations show that a dollar spent on space isn't wasted, it creates new industries and jobs. In fact, studies have found that every $1 the U.S. put into NASA returned many times that amount in economic growth and technological progress. The pursuit of Mars will push scientists and engineers to solve hard problems, and those solutions can make life better on Earth, for instance, developing efficient life-support systems or new energy sources.
NASA Administrator Jared Isaacman, speaking at the agency's 'Ignition' event earlier this week, said: "If we concentrate NASA's extraordinary resources on the objectives of the National Space Policy, clear away needless obstacles that impede progress, and unleash the workforce and industrial might of our nation and partners, then returning to the Moon and building a base will seem pale in comparison to what we will be capable of accomplishing in the years ahead.
“
The announcements included "a major step forward in bringing nuclear power and propulsion from the lab to space. NASA will launch the Space Reactor-1 Freedom, the first nuclear-powered interplanetary spacecraft, to Mars before the end of 2028, demonstrating advanced nuclear electric propulsion in deep space. Nuclear electric propulsion provides an extraordinary capability for efficient mass transport in deep space and enables high-power missions beyond Jupiter where solar arrays are not effective".

The announced plan is that when the spacecraft reaches Mars "it will deploy the Skyfall payload of Ingenuity-class helicopters to continue exploring the Red Planet". NASA said the mission "will establish flight heritage nuclear hardware, set regulatory and launch precedent, and activate the industrial base for future fission power systems across propulsion, surface, and long-duration missions. NASA and its US Department of Energy partner will unlock the capabilities required for sustained exploration beyond the Moon and eventual journeys to Mars and the outer solar system".

Enormous financial cost

Sending people to Mars and keeping them alive there would be one of the most expensive projects in human history. Various estimates show just how extreme the price could be. NASA analysts have estimated that the cost of establishing a livable outpost on Mars could be around half a trillion dollars, while Elon Musk has suggested that building a self-sustaining city on Mars could cost anywhere from $100 billion to $10 trillion.

For perspective, $10 trillion is roughly half of the United States' annual the value of all goods and services the U.S. produces in a year. Even the lower estimate of $100 billion is huge: that amount could fund over four years of NASA or build thousands of new schools and hospitals.

“When the International Space Station design was adopted, NASA estimated that about 75 percent of the previously prepared design work could be incorporated into the new configuration.” The ISS was to be developed from 1994 to 2002, when assembly was expected to be complete. During this time, the prime and other contracts would require 12.6 billion and operations, payloads, reserves and other activities 17.11 billion.

“The ISS is arguably the most expensive single item ever constructed. In 2010 the cost was expected to be $150 billion, which includes NASA's budget of $58.7 billion for the station from 1985 to 2015, Russia's $12 billion, Europe's $5 billion, Japan's $5 billion, Canada's $2 billion, and the cost of 36 shuttle flights to build the station; estimated at $1.4 billion each, or $50.4 billion total.” These numbers add up to 146.8 billion 2010 dollars or 160 billion 2015 dollars.

NASA spent $2.9 billion on the ISS program in 2013. $1.23 billion was spent on system operations and maintenance costs, such as hardware including Orbital Replacement Units and extra-vehicular activities. 660 million was spent on research, labor and travel, and cargo and crew projects. The total is 1.89 billion per year, very close to the 2.02 billion per year implied by the 20.22 billion over ten years in Table 2. The remaining 970 million spent in 2013 went for all crew and cargo transportation costs to ISS, with 370 million for crew. This is roughly 10 billion over ten years, much lower than the 50.85 billion for shuttle transportation. The shuttle is no longer flying and probably less mass at lower cost is being lifted to LEO than was expected in 1995.

The cost of the Mars life support system could easily be the same or even more than that of the ISS system The ISS life support can provide for more than the three or four US crew on ISS, so it could be easily scaled down to one half the ISS size. On the other hand, a Mars mission will require two life support systems both able to support the full crew. One system will be for Mars transit, the trip from Earth to Mars and back in zero gravity. The other system will be for the surface of Mars. The Mars surface system may be a different design to take advantage of gravity, atmosphere, or surface materials. Having different transit and surface life support designs would increase the hardware development cost.

Another important difference between ISS and Mars is that Mars life support should have much higher reliability and maintainability than ISS life support. The ISS crew can receive oxygen and water from Earth or return to Earth if life support fails, but the Mars crew cannot. Higher reliability suggests that the number of spares should be larger. Another important difference between ISS and Mars is that a Mars mission cannot receive spare parts from Earth as needed. All the spare parts must be launched to Mars and then either descend with the surface system or be sent back toward Earth with the transit system. The mass to be launched will be higher for Mars, especially if more spares are used for higher reliability. And the cost to send mass to the surface of Mars or on the round trip is much greater than the cost to launch mass to LEO.

SpaceX mission overview

Since about 2016, SpaceX released a series of various press releases, “tweets” and glossy websites making various claims that tax our credulity regarding sending humans to Mars. Most recently, it is widely reported on the Internet that on September 7, 2024, Elon Musk claimed via a “tweet” that humans could be on Mars in four years. Because of Musk's fame and achievements, this claim was taken seriously in some quarters. We can state fairly certainly that humans will not reach the surface of Mars in four years. More likely at least thirty years from now.

The SpaceX Mars mission is an ambitious enterprise involving many tens of heavy lift launches, several massive landers on Mars, a crew of twelve, and a very large in situ The SpaceX mission introduced an innovative concept for a human mission to Mars.
The various announcements made by SpaceX since 2016 reveal some aspects of the SpaceX approach to a human mission to Mars. The mission is built around the “Starship” which is a 100 MT vehicle that can haul 100 MT of payload.

Several Starships would deliver cargo to the Mars surface. Two Starships would each be fitted to carry a crew of six from LEO to Mars and back to LEO. All the Starships would be fueled in LEO by a dozen tankers, each delivering propellants, totaling 1,200 MT of propellants in LEO. The crewed Starships would refuel on Mars with propellants produced by ISRU utilizing supposed water resources on Mars. All told, there might be 72 heavy lift launches at one launch opportunity.

SpaceX proposes to land a 200 MT vehicle on Mars. The mission to Mars introduces innovative ideas for a future human mission to Mars that might provide a very good approach for a human mission to Mars some thirty or more years in the future. The idea of SpaceX landing humans on Mars in 2028 seems overly optimistic.
SpaceX uses the same propellants and the same engines for all phases of the mission, including transport to Mars, descent and ascent, and return from Mars. The propellants are cryogenic, but are far more easily storable than LH2, and are compatible with Mars ISRU. There is no need for different propulsion systems for different phases of the mission.

The assertion that a human Mars mission will cost about 500 billion dollars is well established and widely known. It was recomputed using very simple cost estimating. The point is that, if we work as we have in the past, the expected cost is “on the order of half a trillion dollars.” It seems strange to estimate the extraordinary first human trip to Mars by assuming we will follow traditional development methods, but thinking that we can do much better could produce very over-optimistic cost estimates. We can hope but not plan that new ideas or new approaches can get humans to Mars for less than half a trillion dollars.

Spatial analysis of deforestation



The Amazon rainforest serves as a home to some of the most isolated Indigenous communities across South America, including the Yuri and Passe communities in Colombia's Rio Pure region. They have chosen for centuries to avoid broader society, and the isolation is essential to their survival, protecting them from disease, violence, and outside disruption.

Forests are a lifeblood of our economies and our health from the air we breathe to the wood we use. Covering nearly one-third of the Earth's land area, forests are home to more than half of the world's land-based species and are the source of 75% of the world's freshwater. More than a billion people live in and around forests, and they are the physical and spiritual home to many indigenous peoples and local communities.

Forests are key carbon sinks – tropical forests alone store seven times more carbon than humanity emits every year and draw down up to 1.8 gigatonnes of carbon annually. Yet forests today are in crisis, devastated by fires, converted and degraded for agriculture, for fuel and for timber. The mismanagement of the world's forests is ramping up carbon emissions, ravaging biodiversity, destroying vital ecosystems, and affecting the livelihoods and wellbeing of local communities as well as societies globally. And the situation is getting worse. The world's current unsustainable food systems mean that instead of repurposing degraded land for sustainable agricultural use, forests, savannahs and grasslands continue to be destroyed.

Deforestation and forest degradation are major drivers of zoonotic diseases. When healthy, forests are a buffer against diseases like Covid-19. But when forests are under attack, their safeguards are weakened, leading to a spillover of diseases. It's time to value what nature provides to us, and a key focus for that action has to be our forests. As this report shows, we need collective action to implement tailored and integrated solutions that work for people and nature. And this shift needs to happen across the chain from the countries that are home to forests to countries where consumption patterns and lifestyles are contributing to deforestation.

All this lends further weight to the need for a New Deal for Nature and People that puts nature on a path to recovery by 2030 and sets us on course to achieve real sustainable development, and a carbon-neutral, nature positive, equitable society. Among other goals, we're calling for an end to the loss of natural spaces like forests, and measures to halve the negative impacts of production and consumption.

But illegal gold mining is threatening that way of life. Mining operations physically destroy riverbanks and forests while releasing mercury and other toxic chemicals into waterways. These illegal miners are increasingly entering the ancestral territories of isolated communities, placing both their environment and their existence at risk.

The Amazon Conservation Team is an organization that has partnered with indigenous communities for nearly 30 years, including working to protect the territories of isolated Indigenous communities. As a Vantor Purpose Partner, ACT has access to Vantor's spatial intelligence to protect these communities and the rainforest they call home, in collaboration with the Amazonian Alliance for the Reduction of Gold Mining Impacts AARIMO. AARIMO is a network of local civil social organizations that work to reduce the impacts of gold mining in the Colombian Amazon. Protecting these communities also means protecting the remote forests and waterways that sustain them.

Using insights from Vantor's current satellite imagery and a historical baseline from Vantor's archive that spans more than 20 years, the team has helped document hundreds of illegal mining barges across the region.

Through collaborative information-sharing processes involving AARIMO and other stakeholders, these findings have informed actions by relevant authorities and partner institutions in Colombia and Brazil, contributing to the destruction of more than 115 illegal mining barges and the protection of territories inhabited by isolated Indigenous peoples.

Monitoring a remote and threatened terrtory

Río Puré National Natural Park is one of the most remote areas in the Colombian Amazon, and it's increasingly becoming a target of illegal miners. Monitoring illegal activities from the ground is dangerous, difficult, and time-consuming. Insights from Vantor's high-resolution satellite imagery provide ACT and its local partners with a safer way to observe changes across vast, inaccessible areas.

AARIMO team members work together within Vantour Hub to identify illegal mining activity, monitor the movement of dredges, and provide actionable intelligence to enforcement agencies. Vantor Hub's tasking capabilities have allowed the team to obtain a complete view of the full length of the Puré River. With 15 cm HD resolution imagery, the team can make distinctions between different kinds of illegal activity on the ground and support timely responses while reducing the need for potentially invasive overflights by planes or drones.

In November 2025, a binational military operation traveled for days by boat and helicopter into Río Puré National Natural Park. Guided in part by spatial intelligence from Vantor, the police navigated the river to locate illegal dredges and destroy mining equipment with explosives.

“The resolution and accuracy of Vantor's imagery helps monitor and map mining activity with unprecedented detail,” said Brian Hettler, ACT Director of Mapping. “Because these regions are so vast and remote, consistent ground-based monitoring is impossible. Vantor's insights and persistent monitoring provide critical information that supports local coalitions and public agencies working to address threats to isolated Indigenous territories and surrounding ecosystems.”

Photojournalist Federico Rios accompanied the operation and documented its efforts. His images illustrate the extraordinary challenges of enforcing environmental protections in the region. Officers faced difficult terrain, hidden waterways, and armed resistance from miners who fired sporadically from the riverbanks before disappearing into the jungle.

The work also revealed the human and environmental consequences of illegal mining. During the operation, officers rescued a dog abandoned on a dredge and brought him out of the forest. While one rescued dog is only a small moment in a much larger crisis, the operation reflects what is at stake: the safety of people, wildlife, and ecosystems that have few other advocates.

Protecting the Amazon

The Amazon faces immense and growing pressure from illegal mining, deforestation, and criminal networks. Addressing those threats requires strong partnerships, local knowledge, and the ability to see what is happening across places that are otherwise nearly impossible to reach. Together with ACT and its partners, Vantor is helping transform satellite imagery into insight and insight into action to protect the Amazon and the people who have cared for it for generations.

Spatial analysis of deforestation from biofuels

Plans to expand biofuel production have sparked debates concerning whether biofuel feedstock production threatens food security and reduces land-based income generation, and whether it is resulting, or will result, in a growth in deforestation rates. This to a large extent related to the additional carbon emissions that result from forest clearing with impacts on climate change, and also has to do with broader concerns linked to sustainability in the sense of loss of natural heritage and biodiversity, and decrease in the environmental services and goods that forests provide to local populations. This article shares these latter concerns and seeks to explore the spatial interactions between biofuel feedstock production and deforestation

Brazil, the largest producer of biofuels worldwide, has been at the centre of the biofuel-deforestation debate. In a simplified perspective, some argue that sugarcane expansion in the south of the country is pushing the expansion of soybean in the center west which in turn is displacing cattle further into the Amazon region, thus inducing increased deforestation.
With over 800,000 square kilometers of deforested native vegetation, Brazil has already lost a fifth of the original extent of its Amazon Forest. Protecting this vegetation is a formidable challenge, accentuated by the vast forest and its rich diversity, as well as the complex legal framework governing land use in Brazil. But it is a challenge worth facing.
According to report on commodity crop mapping in South America, the soy cultivation area in the Amazon biome was approximately 1.5 million hectares in 2008. By the year 2023, it had expanded to a staggering 7.2 million hectares. This represents an increase of 5.7 million hectares over a period of 15 years, equivalent to about 384,000 hectares per year. In other words, in 15 years, the soy-growing area of the Amazon increased by more than 150,000 hectares per year, which is equivalent to more than twice the size of the city of São Paulo or more than three times the size of Los Angeles.

Similarly, the Amazon Soy Moratorium has become a private and voluntary sectoral agreement, signed between traders and non-governmental organizations, and supported by the Brazilian government. This pact stipulates that traders will not purchase soybeans from areas that were once forested in the Amazon biome, even if such deforestation is legal. The Amazon Soy Moratorium cutoff date is August 2008. It is a zero-deforestation agreement that aims to eliminate both legal and illegal deforestation from the soy-exporting supply chain in the Brazilian part of the Amazon biome. In 2023, the EU approved the European Union Deforestation Regulation, which aims to remove deforestation-risk commodities from the European market, including soy, along with six other groups of commodities (beef, leather, wood, palm oil, coffee, cocoa and rubber). In essence, the European Union Deforestation Regulation has implemented due diligence requirements for European companies, known as operators, who introduce products onto the European market for the first time. These operators must submit various information, including that the imported product was not produced in areas deforested after December 30, 2020.

Sale of timber rights increases sanctuary's vulnerability

Prey Lang Wildlife Sanctuary is southeast Asia's largest lowland evergreen forest. The sanctuary spans approximately 500,000 hectares across four provinces of Cambodia, as highlighted in dark green below. Designated as a wildlife sanctuary in 2016, Prey Lang is government-protected land.
Prey Lang contains diverse flora and fauna and plays a vital role in the traditions, local customs, and beliefs of indigenous people and local communities. Yet, recent events have weakened the sanctuary's natural defenses and degraded its borders. The sale of timber rights on land just outside the sanctuary's eastern border has negatively impacted Prey Lang. Amnesty International began monitoring illegal logging in Prey Lang. Micah Farfour, a Special Advisor in Remote Sensing for the Crisis Response Program, has a long history of working with GIS and satellite imagery to monitor change globally. She and her team have effectively used Planet's satellite data to identify and track illegal activity within the sanctuary's borders. After the government sold the timber rights to the land bordering Prey Lang, the winning company actively and legally clear-cut and harvested its concession, but with unintended consequences for Prey Lang. The disappearance of trees bordering the sanctuary eased access for people and vehicles. Easier access and high timber prices contributed to the illegal logging of the sanctuary's old resin and other trees.

Given the vast size of the sanctuary, monitoring the area is difficult for Farfour and her team. The indigenous population and local community are not allowed to patrol the area. The high level of cloud coverage over the region hinders remote sensing. And degradation happens at the individual tree level, which requires a high level of detail for effective monitoring. Amnesty relies heavily on the University of Maryland to produce an annual dataset over Cambodia. Every year they assess the dataset and see the deforestation of the past. Although valuable, this data, Farfoiur says, “is not stopping trees from being cut. It's just showing that the tree has been cut and obviously getting ahead of the problem is our goal.” To counter these challenges, Amnesty International has adopted Planet's satellite imagery. Using Planet data and a “tip and cue” strategy, Amnesty can now identify and address areas of rapid deforestation within the sanctuary in real-time and work to prevent further harm.

According to the United Nations Food and Agriculture Organization, deforestation is "the conversion of forest to other land use, independently of whether human-induced or not," and constitutes a significant environmental challenge. Since 1990, more than 420 million hectares of forest have been lost. Furthermore, since 2000, approximately 47 million hectares of ecologically invaluable primary forests have been lost. Deforestation in Sudan . This loss figure excludes tree cover gains over the same period and therefore does not represent net change. From 2021 to 2025, 100% of tree cover loss in Sudan occurred in natural forests.

Planet helps Farfour's team monitor Prey Lang Wildlife Sanctuary for environmental abuse by remotely monitoring, capturing, and inspecting the entire sanctuary expanse using the PlanetScope satellites. Along with this data, Farfour effectively employs a “tip and cue” strategy, which uses medium resolution, high-frequency PlanetScope images to identify areas of concern in order to task a high-resolution SkySat satellite for more detail. Amnesty relies on PlanetScope to objectively monitor Prey Lang. Image details are scrutinized, and Farfour's team is alerted to potential areas of deforestation. The daily frequency improves the chances of getting a cloud-free picture. Spatial resolution of approximately 3 meters per pixel can quickly pick up deforestation over a large area. A high-resolution satellite is then tasked to focus on those targeted areas for a closer look at the forest, individual trees, and even machinery.

Farfour shares, “High-resolution imagery is actually quite rare over these wildlife sanctuaries in Cambodia, so we've had to be resourceful with the lower resolution imagery and develop areas of interest to task with high resolution since the protected areas are very large.”
In addition to deforestation, PlanetScope images help detect land clearing for road development or agriculture. For example, Farfour used Planet satellite imagery to identify a new road on the other side of the sanctuary's eastern boundary. She says, “a lot of the access comes from the edges, the boundaries, where there are roads already established, but sometimes potentially from the villages. The new road not only increased access to the area, it provided an easy route for the illegal logging and transport of timber outside of the sanctuary.” Today, Amnesty and Planet are working together to refine their data analysis further. Farfour comments, “We're doing things like testing radar imagery to be able to detect through cloud cover and testing road detection algorithms with Planet.” As these capabilities expand, satellite images will help Farfour and her team better protect Prey Lang on the ground.

In Sudan, the Acacia Forest, one of Khartoum State's oldest and largest reserves, was added to the national reserve system in 1939. It mainly features acacia trees that withstand autumn floodwaters. The forest hosts a variety of bird species, including resident and migratory birds such as geese, egrets, terns, ibises, ducks, gulls, herons, sparrows, and other savanna birds. It covers 1,500 hectares on the White Nile's eastern bank near the Nile's confluence. War in Sudan and indiscriminate logging for cooking and other uses are among the main causes of deforestation and forest damage. The Acacia Forest was not the only forest in Khartoum to be destroyed; according to official statistics, Khartoum has 19 forests, most of which are located along the banks of the Nile. These forests were also damaged by human activity during the armed conflict

This forest has major educational value. The Forestry Experts School was established there in 1946 to train forestry personnel in techniques, management, and cultivation, reflecting the growing need for formal forestry education in Sudan. It produced the first generation of forestry technicians, who played a major role in forestry across Sudan. The forest also abounds with reptiles, insects, and small wild animals, enriching the natural environment and enhancing its vitality. All this has made the Acacia Forest a natural retreat for Khartoum residents and visitors. It is a vital link in the region's ecological balance, helping moderate the climate and absorbing gases and toxins from vehicle emissions and factory waste

Worldwide, forest types vary with climate, geography, and dominant species, including tropical rainforests, boreal forests, and temperate deciduous forests. Furthermore, forests can be classified based on administrative boundaries, land cover (including trees and ground vegetation), or land use, such as timber production, conservation efforts, or recreational activities. Sudan, the largest Arab country by forest area, with about 183,595 sq km, has diverse forests, including dense Nilotic forests along the Nile, Dahra forests in arid regions, and limited irrigated forests. The acacia forest at the Nile's confluence faces encroachment and development plans, some of which have been blocked by local opposition. UN and FAO data show that deforestation in Sudan causes over 9.3 million tons of CO2 emissions annually, with forest degradation adding 1.6 million tons. Protecting forests is vital to fight climate change and sustain environmental health.

A Kenyan's Path into the Space Industry

Growing up in Kenya, space was something that happened to other people. It was rockets on the international news channels, or the kind of thing you studied for an exam and then forgot. Nobody I knew grew up saying "I want to work in space." We wanted to be doctors, engineers, pilots - careers you could point to and explain in one sentence at a family gathering. "Space" was not on that list. It still isn't, for most people back home.

My perspective began to shift during university, where I gradually realized that tremendous practical problem-solving potential lay not in rockets themselves, but in space-derived data. As AI and automation reshaped the workflow of data analysis, I became deeply fascinated by spatial deep learning, a field that still occupies most of my thinking today. Therefore, when a competition calling for remote sensing AI algorithms for space was announced, I did not hesitate to sign up. It struck me as exactly the opportunity to practice the theories I had only read about in textbooks.

A life-changing competition

In 2024, as a member of the Remote Sensing Research Group at DEDAN KIMATHI UNIVERSITY OF TECHNOLOGY (DeKUT) under the supervision of Dr. Kuria B. Thiong'o, our team developed an AI algorithm for vegetation health monitoring for the Spaceborne AI Rideshare Algorithm program. This joint initiative was co-launched by the Kenya Space Agency and STAR.VISION, a Chinese aerospace enterprise that I barely knew about at that time. Our team claimed second place, and for a long time, this achievement alone felt like the biggest milestone.

What I didn't know then was that second place would open a door I hadn't even seen. It earned our team a spot at the Space Summer Camp 2025, and from there, an invitation followed that I genuinely did not see coming: a three-month Global Space Winter Internship at STAR.VISION's headquarters in Hangzhou, China.

From student researcher to solutions manager

During those three months of internship, I shifted from an onlooker to an active technical contributor. I participated in diverse projects, each teaching me practical experience unavailable in classrooms. What followed still surprises me whenever I mention it aloud: my internship performance secured a full-time offer, and I now serve STAR.VISION as a Business & Solutions Manager. My daily work involves communicating with clients and translating satellite technological capabilities into targeted solutions for their real-world challenges. This journey has brought me valuable humility. I quickly learned that even the most sophisticated AI model is meaningless if you cannot concisely explain its practical value to paying clients.

I share my story not to polish my experience into a neat, perfect narrative. I hope young people in my home country understand that the leap from university research labs to international AI and aerospace companies is far less unattainable than it seems from the outside. START.VISION is a pioneering space-tech enterprise focusing on AI satellite technology, space computing and deep-space exploration. After more than one year witnessing the company's development, I confirm this positioning is far more than marketing slogans; it is a promising mission worth devoting myself to.

The next frontier: In-orbit AI

If I had to bet on where this industry goes next, it isn't just more satellites going up - it's smarter ones. The real shift I see coming is in-orbit AI: algorithms that process imagery directly in-orbit. Space computing, in that sense, is what cloud computing did for the internet - infrastructure that becomes invisible precisely because it works, until people simply expect answers in real time rather than after a long download. For an industry that used to measure turnaround in weeks, that's not a small shift. It's the difference between a satellite that only observes and one that can actually decide. And it's exactly where STAR.VISION has placed its bet as a manufacturer of AI-powered satellites.

What satellite intelligence means for Africa

This leads me to the issue I care most about: how space technology will benefit Africa. I have witnessed firsthand how AI and satellite technology resolve practical regional challenges when applied properly. STAR.VISION is preparing to launch two OSE hyperspectral AI satellites (HS01/02). Regular, affordable monitoring, once only achievable through costly, occasional aerial surveys, will become accessible across Africa. The continent rarely lacks ambition; what it lacks is stable, low-cost geospatial data. I am eager to witness the launch of these twin hyperspectral satellites in person during Space Summer Camp 2026, and I firmly believe the data collected will reshape the agricultural economy of Kenya and the entire African continent.

A call to the next generation

That's the case I'd make to any young space enthusiast, African engineer, data scientist, or geographer weighing whether this space industry is "for them": it is, and increasingly, it needs you specifically. Back at home, Kenya Space Agency e Agency has set out a strategic plan through 2027 that leans hard on exactly this kind of human capital, and programmes like the one that brought me here are one of the more direct ways of building it. I came in as a researcher with a second-place finish. I'm writing this as someone who now helps decide how satellite intelligence gets pitched to the people who might use it to fix something real.

In conclusion, there's a lot of work still ahead-for us young space professionals, and for Africa's place in this global space industry. I'm very glad to be part of building it rather than watching it from the outside and thankful to the entire STAR.VISION family for the opportunity to work and grow together.

Cubic Appoints Elliot “Lee” Sander President and Chief Executive Officer of Cubic Transportation Systems

Cubic Corporation announced that Elliot “Lee” Sander has been appointed President and Chief Executive Officer of Cubic Transportation Systems (CTS), effective immediately. He will report to Stevan Slijepcevic, Chairman, President and Chief Executive Officer of Cubic Corporation. The appointment follows a multi-month search for a leader with deep industry expertise, a strong understanding of the customer experience and the ability to guide organizations through significant change. Sander will lead CTS as it continues to strengthen the business, execute its strategy and deliver critical programs for customers around the world. He succeeds Slijepcevic, who has served as interim President of CTS.

Sander has worked with CTS as an advisor since August 2025 and has served as Executive Chairman since June 2026. During that time, he has worked closely with CTS leaders, employees and customers, giving him a firsthand understanding of the business, its priorities and the opportunities ahead.

“Lee is the right leader for CTS at this moment,” said Slijepcevic. “Few people know the transportation industry from as many perspectives. He has led major public agencies, built global transportation businesses and helped shape national transportation policy. Over the past year, I have watched him work closely with our teams and customers, and my confidence in his ability to lead this business has only grown.”

Sander previously served as Executive Director and Chief Executive Officer of New York's Metropolitan Transportation Authority and as Commissioner of the New York City Department of Transportation. In the private sector, he led Bombardier Transportation Americas and built AECOM's global transportation division.

Sander also founded the National Association of City Transportation Officials and served as Chairman of the Regional Plan Association, helping shape transportation policy nationally. He has played a central role in major infrastructure initiatives across the United States and has developed deep relationships with agencies, officials, operators and partners throughout the industry.

“CTS has extraordinary people, deep customer relationships and a long history of solving complex transportation challenges,” said Sander. “Having worked with the business for the past year, I understand both the progress CTS has made and the work ahead. I am honored to lead this team.”

At the heartland of STAR.VISION

Last month, a delegation from Kenya Space Agency (KSA) led by the Director General, Maj Gen Hillary Kipkosgey, made an industrial tour of space industry and infrastructure facilities in Shangdon Province, China. During the tour, the delegation visited STAR.VISION's Ground Station, Data Center and Assembly, Integration and Test (AIT) facilities to familiarize themselves with the facilities' satellite system manufacturing processes.

They also toured the Orienspace rocket factory, where they were taken through the rocket assembly processes. The team later toured Haiyang Oriental's land-based, maritime and ship-based spaceport platforms. The tour enabled the KSA team to appreciate satellite manufacturing, data operations and the interconnectedness of the satellite and rocket manufacturing ecosystems.

In china, the Director General Kenya Space Agency (KSA), Maj Gen Hillary Kipkosgey, visited Beihang University the Beijing University of Aeronautics and Astronautics, his alma mater, in Beijing.
The DG met and held discussions with senior leadership of the institution led by Vice President Prof Zhao Weisheng. Also in attendance were accompanying staff from the KSA and three Kenyan postgraduate students at the University.

In his remarks, Prof Weisheng briefed the delegation on their collaboration initiatives with Chinese Aerospace Industry as well as with international partners including Kenyan public Universities and other institutions in human capital development and in research and development. He pointed out that the institution currently has a total of nine(9) Kenyan students enrolled in various undergraduate and postgraduate Programmes including Aerospace Engineering.

Prof Weisheng added that the University has established a Center for Space Studies accredited by the United Nations Office of Outer Space Affairs (UNOOSA) for the Asia Pacific Region. The institution also plans to establish the Sino Africa school in Morocco to serve as Beihang's African HQ. Prof Weisheng also expressed the University's plans to support the launch of an alumni association for African students.
Maj Gen Kipkosgey acknowledged that Kenya and China enjoy excellent bilateral relations and ties across many spheres including trade, economic, military, cultural, tourism and infrastructure development, among others. He expressed the Kenya government's appreciation for the many scholarships awarded to Kenyan students to study in prestigious institutions such as Beihang and many other institutions of higher learning.

He called for enhanced collaboration between Beihang and the Kenya Space Agency towards human capital development through the Centres for Aerospace studies. He committed to support the proposed establishment of an alumni association for African students. Thereafter KSA delegation conducted a tour of the University's Aerospace Museum.

The Director General, Maj Gen Hillary Kipkosgey, also led a delegation from KSA on the visit to MinoSpace, a commercial Chinese aerospace company headquartered in Beijing, China MinoSpace is an end-to-end small-to-large scale satellite design and manufacturing company focusing on AI-ready optical and synthetic aperture radar satellites among other satellite products.
The DG met and held discussions with the senior leadership of MinoSpace led by co-founder, Mr Huan Yiheng. The discussions focused on collaboration opportunities for enhancement of Kenya's National space capability, including capacity building, access to satellite data and development of upstream and downstream capabilities, among others. The KSA delegation was taken on an extensive tour of the MinoSpace Assembly, Integration, and Test facility in Haidian District, Beijing.

As part of the Kenya Space Agency's ongoing engagements in China, the Director General, Maj Gen Hillary Kipkosgey, led a delegation from the Agency on a tour of the facilities of Emposat Co.



Ltd, a commercial NewSpace company headquartered in Beijing.
Emposat Co. Ltd primarily focuses on provision of telemetry, tracking and command services, development of ground stations and provision of integrated space-ground communications solutions. The DG met and held discussions with the senior leadership of Emposat, led by the Chairman and co-founder, Mr Zhao Lei. The discussions centred around exploration of opportunities for collaboration between the two organizations focusing on enhancement of Kenya's National space capability.

AfDevSat

A dedicated team of engineers from the Kenya Space Agency (KSA) announced they have successfully designed, developed, and tested the Electrical Power Subsystem (EPS) for the African Development Satellite (AfDevSat) mission. The work was carried out at the Egyptian Space Agency (EgSA) facilities in Cairo, Egypt.
The project is designed to facilitate the launch of a pan-African satellite project named the African Development Satellite Initiative (AfDev-Sat) and the participants took courses in space project management, space sub-system design, CAD tools and design software orientation, satellite testing, among others at EgSA.

The primary focus of this project is hands-on training. The first phase covers the theoretical aspects, including lectures on satellites and their composition and the second part covers the hands-on training. The engineers were trained at the EgSA facility- with state of the art laboratories, equipment and devices needed to develop mechanical parts, electrical boards, software for the satellite and carry out various simulations. They would also build and assemble a cubesat.

AfDevSat is a collaborative initiative bringing together six African countries, including Egypt, Ghana, Kenya, Nigeria, Sudan, and Uganda to design, develop, and launch a hyperspectral-imaging CubeSat. As part of this mission, KSA was entrusted with the responsibility of developing the EPS—the “heartbeat” of the satellite—ensuring reliable power generation, safe storage, and efficient distribution across the entire platform.
The EPS consists of three core components: a Power Generation Board that harvests and regulates solar energy, a Power Distribution Board that ensures regulated supply and switching, and a Battery Management System that monitors, protects, and controls the thermal performance of an 8-cell lithium-ion pack configured in 4S2P.

The Kenya Space Agency team, led by Capt. Jackson Koll together with engineers Mr. Brian Oure Omollo and Mr. Evans Yomu Kidada, worked tirelessly to deliver this critical subsystem. Beyond technical development, the program fostered collaboration, knowledge-sharing, and resource pooling among African space professionals, ensuring successful subsystem assembly, integration, and qualification within the set timeframe.

This milestone marks a defining moment in Africa's space journey, showing what is possible when nations unite around a shared vision. The success of AfDevSat not only strengthens Africa's space capabilities but also serves as an inspiration to the next generation of scientists, engineers, and innovators across the continent.

The trainees participated in many technical sessions, particularly related to simulations of satellite systems [such as orbital simulation], mission analysis and mission designs for satellites. The knowledge gained from this programme is to be applied to their home countries and be able to build dedicated satellite subsystems that can ultimately be integrated into each other to engineer a complete satellite.



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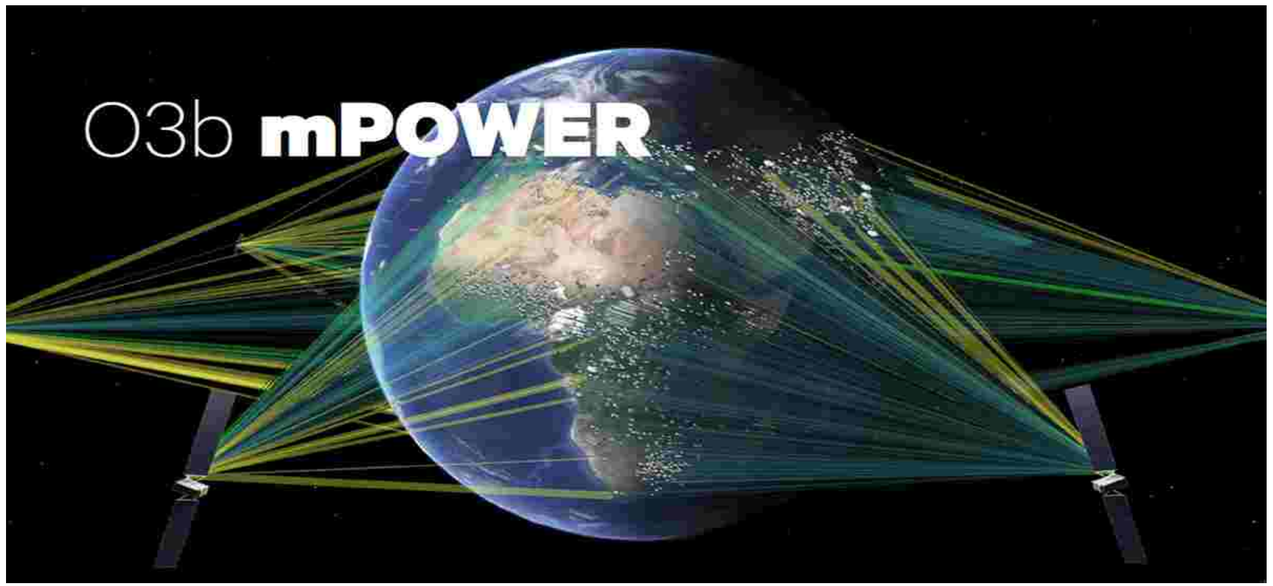
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Cover source: GGPEN



The geopolitics of satellite connectivity



With around 33% internet penetration, Africa is the least connected continent on earth. Naturally, connectivity varies by country, but universally, the greatest gap is between urban and rural areas. Whilst 50% of urban dwellers are connected, this figure drops to 15% in rural areas. This is the lowest percentage of any region in the world.

Compounding this discrepancy, Africa, like the rest of the world has been impacted by Covid-19. As in the rest of the world, demand for bandwidth skyrocketed, driven by cloud computing, social media, video meetings, distance learning and video streaming. Governments recognised the importance of keeping businesses running and have started to invest more in digital infrastructure, including in some cases in expanding Universal Service Obligations (USO) to extend broadband access to rural areas.
Extending fibre to rural areas is challenging anywhere in the world. The economics are just not there. Costing US$30,000 a mile, it's expensive to lay. Even in developed economies in areas with low population density and therefore usage, revenue often isn't high enough to justify the investment. Affordability of broadband services is also a challenge in the region.

More than two thirds of the population (>700m) in Sub-Saharan Africa remain unconnected and almost 575m people out of 700m remain unconnected not because of lack of coverage but because of other reasons including lack of affordability.

The Global System for Mobile Communications, GSMA estimates that the average cost of mobile coverage in rural areas is 18% higher than in urban areas, and 35% higher in more remote areas. In Africa, this situation is magnified. There is no lack of undersea fibre surrounding the continent, taking that fibre, further inland than the immediate coastal cities, is where the challenge really begins. The terrain can be particularly inhospitable, making it difficult to lay. Only 59% of population reside within reach of terrestrial backbone infrastructure in Africa however this varies sharply by country. For example, in DRC only 27% of the population lives within a 25km range of an operational fiber node and in the case of South Sudan, only 4% of the population lives within fiber reach. On top of this, poor quality installation and maintenance, leave the fibre particularly vulnerable to backhoe accidents, and water and rodent damage. Sabotage is not uncommon in some areas. The household fixed broadband penetration is only at 9% with no expectations to rise anytime soon.

The African Union, supported by the World Bank Group, has set the ambitious goal of universal connectivity by 2030. A challenging, but necessary goal to help lift rural areas out of poverty. According to World Bank data, a 10% increase in broadband penetration in Africa could increase GDP per capita by around 2.5%. Further research on 12 African countries also shows that those individuals with access to high-speed internet are almost 14% more likely to be employed than those without. Increased employment leads to a large impact on household consumption and reduction in the number of households below the poverty line. This was exemplified in Senegal where the introduction of 3G led to a 14% increase in consumption and a 10% reduction in extreme poverty.

No single organization or technology can achieve the ambitious goal of universal connectivity. Collaborative approaches involving international players working closely with local and government players are needed. It also requires a mixture of government and public-private partnerships, and a variety of technologies.

Fibre, satellite and mobile networks all have a role to play. In rural areas, most end-users will connect to the internet, via mobile broadband, and Africa still has a long way to go in this aspect. In March 2021, the majority of mobile connectivity was 2G or 3G, with low bandwidth; 4G represented only 15% of mobile connections in total. The challenge for Mobile Network Operators (MNOs) is to expand and upgrade their networks to 4G and 5G at a time when revenue is not growing in sync with demand and data traffic. Lowering the total cost of ownership (TCO) is essential to enabling this expansion to take place.

Whilst historically satellite has been considered an expensive solution for backhaul, much has changed in recent years. Standardisation, reusable launch vehicles, digital processing, beam forming and software defined wide-area networks (SDWANs) have combined to reduce the costs associated with high throughput satellites (HTS) and non-geostationary satellites (NGSO) such as SES's O3b constellation launched in 2013. Satellite solutions complement terrestrial solutions, as demonstrated by our customers operating across Africa in both urban and semi-urban environments. For example, InterSAT, a state-of-the-art Service Provider, has partnered with SES to enhance connectivity in both rural and urban areas in no less than 32 African countries. SES was also asked by Tigo Tchad to upgrade 40 cell sites and build a new teleport as well as manage the integrated cellular/satellite network.

Based on the proven success of the O3b constellation, SES decided to launch O3b Mpower, the second generation low-latency, high throughput medium earth orbit (MEO) constellation that will launch in few months. The capability of this constellation is already being recognised by top world companies such as Microsoft, Virgin Voyages, Orange and many others.

Orange, one of the world's leading multi-service telecommunications groups with a presence in 18 African countries and a user of O3b, will now along with its subsidiary Sonatel, the leader in Senegalese telecommunications, be early adopters of the ground-breaking communications system. As part of the partnership, SES and Orange/Sonatel deployed the first African O3b mPOWER gateway in the village of Gandoul in Senegal which will be used by Sonatel and Orange to deliver high-performance, low-latency, and cloud-optimised connectivity services throughout Africa.

These are just three examples of the way that satellite can work seamlessly alongside terrestrial networks, and international players can work with local entities to reach the goal of universal connectivity for Africa.

Next Generation Satellite Communication

Just about everyone acknowledges the importance of Internet connectivity to foster economic growth, drive social inclusion and meet consumer demand. It is also widely understood that satellite communication can significantly assist by delivering bandwidth to regions that lack terrestrial connectivity and to moving platforms such as airplanes, cruise ships, and other commercial vessels

However, to meet the exponential demand for bandwidth, the satellite communication industry is going through a fundamental transformation. Next-generation satellite technology is evolving to multi-orbit constellations that include Non-Geostationary Orbit (NGSO) constellations and Very High Throughput Satellites (VHTS) in Geosynchronous Earth Orbit (GEO). Like on the ground, the new generation of satellites, regardless of orbit, will be software-defined enabling on-the-fly in-orbit programmability of thousands of beams in terms of coverage, bandwidth and power. Additional functionality is the ability to configure specific beams to track airplanes and ships and thereby to deliver fixed SLA to moving platforms globally.
These new-generation satellite capabilities will enable ubiquitous connectivity for fixed and mobility sites, 5G and IoT, and will also require innovation of the ground segment to provide the needed software-defined platform to deliver on-the-fly configuration of carriers, higher throughput data processing, and network orchestration capabilities to allow tight coordination between ground and space.

The Elastic Era, the next generation of satellite communication, will more accurately and efficiently focus the satellite and ground segment resources on where there is actual demand at minimal costs. This transformation will address the major satellite industry challenges of delivering affordable higher throughput services, with ensured availability and lower latency

Orbital politics

Africa's challenges with orbital slot allocation stretch back nearly five decades to the establishment of the original satellite broadcasting plan in 1977. Since then, the continent has struggled to maintain access to allocated resources as the geostationary orbit has become increasingly congested. To make matters even worse, many of the resources became obsolete due to interference from other satellite networks and natural degradation.

This scenario has left Africa working to secure its position in an increasingly competitive geostationary orbit, where technical requirements and financial capabilities determine success.

The challenge runs deeper than mere bureaucratic inefficiency. While Africa was once heavily dependent on satellites for international communications, the rapid expansion of submarine and terrestrial fibre-optic networks now carries the vast majority of traffic. Satellite connectivity remains crucial for remote areas, redundancy, and specialised applications. Yet the very system designed to ensure equitable access has become a barrier to African participation, creating a cycle where nations lose valuable spectrum resources before they can mobilise the financial and technical capacity to utilise them.

The geostationary orbit presents a finite resource that belies its vast appearance from Earth's surface. At 35,786 kilometres above the equator, advances in satellite technology have allowed operators to position satellites at two degree spacing, providing approximately 180 slots per frequency band, a significant improvement from the three-degree separation required in the 1960s and 1970s, which limited capacity to just 120 slots per band. Each orbital position can accommodate a maximum of eight satellites. When combined with the limited radio frequency spectrum available for satellite communications, the constraints become even more pronounced.

“The orbital positions are limited, and the maximum that an operator is allowed to place into any one particular slot is about eight spacecraft,” explains Mr Timothy Ashong. “It is not just physical space that is limited. Radio frequencies are also limited. You have to share the radio spectrum with other users.”
The most developed countries of the world, including those in North America, Europe, and Asia, have launched several thousand satellites that have congested the geostationary orbit, leaving few or no slots for new entrants into the market. This congestion forces operators to seek higher frequency bands when traditional C-band and Ku-band allocations become saturated, pushing them into Ka-band and beyond, where equipment costs rise substantially, and technical challenges multiply.

The scarcity has created a particular burden for African nations, which often require C-band frequencies due to the continent's heavy rainfall patterns in most areas. These lower frequencies can penetrate cloudy and rainy weather more effectively but require larger, more expensive ground equipment that strains already limited budgets.
The International Telecommunication Union's framework aims to strike a balance between equitable access and practical deployment requirements through a system that grants filing rights based on detailed technical submissions. Once a country files for an orbital position, it must coordinate with other countries to prevent interference, then bring a satellite into service within seven years or risk losing the slot.

“A country that files for a slot but fails to bring a satellite into service within the required timeframe risks losing that slot,” explains Eng Kezias. “This often affects developing nations that lack the resources to move quickly, leaving them vulnerable to forfeiting valuable orbital rights.”

The coordination process itself presents significant challenges. Countries may object to filings if they anticipate interference with their own operations, creating negotiations that can stretch for years. Smaller nations frequently find themselves disadvantaged, unable to match the legal and engineering resources that larger, more experienced players can deploy. Furthermore, the economic burden compounds these technical challenges. Although the ITU does not charge for filing orbital slots for some filings, the costs of preparation, legal support, and eventual satellite deployment can reach hundreds of millions of dollars. This reality has prompted some African governments to seek partnerships with private operators who can shoulder the financial burden in exchange for long-term usage rights. “This is where consultants and intermediary companies come in,” notes Mr Timothy Ashong. “They help governments navigate the process, but the arrangement can sometimes favour the private partner more than the host country.”

The silence trap

“Imagine being given a plot of land but having to constantly prove you deserve to keep it,” Mr Timothy Ashong explains. “That's essentially what's happening with orbital slots. The ITU gives you a slot, but it's up to you to defend it through constant technical and bureaucratic engagement.”

Perhaps the most pernicious aspect is what industry insiders call “the silence trap.” When commercial satellite operators file for nearby orbital positions, the ITU sends coordination notices to potentially affected nations.

“If you don't respond, whether due to lack of expertise, bureaucratic delays, or simple oversight, your silence is interpreted as consent,” Ashong explains. “Suddenly, your pristine orbital slot is degraded by neighbouring satellites, often from wealthy nations or corporations with teams of lawyers and engineers.”

In fact, several African administrations have already seen early filings lapse in silence. Kenya, for instance, lost access to a C-band filing from the early 2000s after failing to respond to multiple coordination requests. Ghana, by contrast, adopted a policy of replying to every ITU notice, even before launching its first CubeSat. Ghana's experience provides both a warning and a model. The West African nation successfully protected its orbital rights by making it policy to respond to every ITU notice, even before having its satellite programme. “But most African countries don't have that capacity,” laments Mr Ashong. “We're talking about understaffed agencies trying to monitor hundreds of technical notices annually, often without proper software or training.” As Mr Ashong puts it, “Right now, the system doesn't need villains to fail Africa. It just needs good intentions without follow-through. And that's exactly what we're seeing.” This pattern of theoretical equality masking practical disadvantage recurs throughout the orbital allocation process, as the next section will explore and examine Africa's growing slot leasing crisis.

The battle for orbital slots is a broader theme in international governance: showing how global frameworks can either perpetuate or challenge existing inequalities, and whether collective action by developing nations can reshape systems designed in an earlier era. Africa's experience in satellite governance may well serve as a template for addressing similar challenges in other domains where technological advancement outpaces institutional adaptation. However, telecommunications is only part of the story. As satellite applications expand into earth observation, navigation, and emerging technologies, orbital access becomes increasingly central to economic competitiveness and national security. Africa's success in managing its orbital heritage will determine whether the continent participates as a full partner in the global space economy or remains dependent on services controlled by others.
The continent continues preparing for future regulatory battles, with WRC-27 representing the next critical milestone where African interests must be defended and advanced through coordinated advocacy. The regulatory changes achieved through Resolutions 559 and 170 provide a foundation, but ongoing vigilance and technical capacity building remain essential for protecting these gains.

Is ground station ready for the new era of satcom?



Despite it being a complex operation, ERMIS-3, an 8U CubeSat developed by the National and Kapodistrian University of Athens, has established a link with an optical ground station marking an important step in validating optical communications on small satellites. The demonstration, supported by the European Space Agency (ESA) and achieved using optical terminals developed by Lithuanian company Astrolight, happened only weeks after the satellite's commissioning. This milestone represents Greece's first optical link with a low Earth orbit (LEO) satellite.

Unlike conventional radio-frequency communications, optical links use narrow laser beams to transmit data. This enables high data rates, but it also makes establishing and maintaining a connection technically demanding. The beam must be directed precisely towards a receiver while the satellite moves through orbit at several kilometres per second. Both terminals must acquire the signal and continuously track one another during a limited communication window. Not only that; atmospheric conditions add more complexity as clouds can block the link entirely and turbulence can degrade signal quality.

Launched on 30 March 2026 alonside ERMIS-1 and ERTMIS-2, ERMIS-3, is part of an in-orbit demonstration programme testing communications technologies for small satellites. Optical links could help address the growing volume of data generated by missions such as Earth observation, where high-resolution and hyperspectral imagery must be transferred to the ground.

ESA contributed technical expertise to ERMIS-3, including through environmental testing and optical alignment at ESA European Space Research and Technology Centre (ESTEC) in the Netherlands, supporting the successful demonstration of its optical communication link.

The mission is part of Greece's National Space Programme, implemented by ESA on behalf of the Greek government. “This achievement demonstrates that Europe can deliver world-class innovation through close cooperation between industry, academia and institutions. For the first time, an 8U CubeSat developed by the University of Athens has established a laser communication link directly to Earth using a miniaturized optical terminal developed by Astrolight under the Greek National Space Programme.

ESA is proud to have provided programme management, technical supervision and engineering support throughout this journey, helping transform an ambitious concept into a pioneering in-orbit resilient demonstration,” said Frederic Rouesnel, Head of the Resilience Initiatives Implementation Management Office at ESA.
“The ERMIS-3 nanosatellite is among the most advanced CubeSats developed in Europe. Using ATLAS-1 as a laser communications terminal has led to a unique collaboration and the first operations of a laser optical link on the CubeSat. This achievement is opening new capabilities and opportunities for secure communications for small satellites within the European ecosystem,” said Professor Vaios Lappas and Antonis Paschalis, Principal Investigators of ERMIS.

The rapid expansion of low earth orbit satellites (LEO) is motivating a shift in how terrestrial networks scale to support space-based connectivity. As constellation sizes grow to 10's of thousands of satellites, the need for efficient ground station interconnects will intensify. This application note demonstrates how deployment of an entirely pluggable optical line system can enable high density, power efficient and cost-effective ground station interconnects.

The space industry is undergoing one of the most profound transformations in its history. Private capital is driving rapid commercialisation, while geopolitical shifts are turning space into a new strategic battleground. Hundreds of next-generation satellite programs are being designed and launched, with far greater complexity and higher stakes than ever before.
Yet, while spacecraft technology has advanced becoming more software-defined, flexible, and autonomous the ground segment remains stuck in traditional, hardware-based approaches. This mismatch has created a bottleneck that threatens the efficiency, scalability, and security of modern space operations.

As of January 2026, there are nearly 10,000 satellites operating in low Earth orbit (LEO), with many thousands more approved for launch. Goldman Sachs estimates that as many as 70,000 LEO satellites could be deployed by 2030 [1]. This rapid expansion of LEO satellite constellations, combined with the increasing adoption of inter-satellite links (ISLs), is expected to drive significant growth in traffic between ground stations and Points of Presence (POPs), as data from a larger number of satellites is aggregated and concentrated at fewer, higher-capacity gateway locations.
As gateway sites begin to serve larger satellite populations, ground stations will require greater rack density and power capacity, leaving less available space and power for the optical transport infrastructure needed to carry tens of terabits per second of traffic to remote POPs. Coherent pluggable optics have emerged as an attractive solution for delivering DWDM capacity directly from routing and switching platforms between ground stations and POPs. Early deployments centered on 400G ZR interfaces, which supported a limited number of wavelengths and enabled simplified IP-over-DWDM architectures.

Era of NewSpace

NewSpace innovations are shaking up the entire space value chain, and that includes the satellite ground segment. An increasing number of satellites are being developed, launched, and operated to provide cutting-edge services, such as satellite communication (SatCom) and Earth observation (EO). These satellite operations are supported by a growing sector of ground segment providers. Consisting of antennas, connectivity and often data centers to control satellites and download data, the ground segment is a critical enabler of satellite applications and cannot be an afterthought for any mission design.

Technological advancements, such as on-board processing and the introduction of inter-satellite links, reduce the need for data downlink to some extent, and thus decrease the demand for ground segment. However, this decrease is being outpaced by an increase in demand due to NewSpace trends. The democratization of space, with lower barriers to entry, shorter development cycles, and increased private investment, has enabled innovative, small and agile players to enter the market.

Traditional deployments of a small number of large and powerful satellites in geostationary orbit (GEO) are now being complemented by large constellations with hundreds or even thousands of small satellites in low-Earth orbit (LEO) to offer low-latency broadband connectivity on a global scale. Further driving additional constellations into LEO is the growing appetite for different types of EO data and geointelligence and applications, partly fueled by the shifting geopolitical context.

A stronger focus on sustainability, both in space and on Earth, has also seen an uptake in satellite missions dedicated to Space Situational Awareness and Space Traffic Management, in-orbit servicing and debris removal, space-based power, and other new use cases, all of which result in growing demand for ground segment infrastructure and service provision.

These solutions eliminated the need for dedicated transponders but still relied on traditional line card-based optical transport equipment for functions such as amplification, protection, and performance monitoring.

As the emergence of NewSpace is fueling growth across the entire industry, traditional business models within the ground segment market are coming up short. Increasing competition and the high cost of ground infrastructure requires companies to remain agile and look for new ways to optimize resources.

A new demand for Ground-Segment-as-a-Service (GSaaS) is emerging, especially driven by EO constellation operators. These constellations typically need a global network of ground infrastructure with relatively low contact time per satellite. Additionally, the service model is increasingly also finding adoption in SatCom, as evidenced, for example, by ground segment carve outs from satellite operators.

GSaaS offers ground station services to both legacy and NewSpace operators that are either unwilling or lacking the resources to develop a dedicated ground segment. This model is similar to a “shared economy” approach, with by-the-minute or per-pass pricing. Additionally, subscription or flat rate models comparable to the traditional dedicated antenna model exist.

As ground station traffic continues to grow alongside the expanding LEO satellite population, networks are expected to evolve toward higher capacity technologies, delivering more than 25 Tbps of fiber capacity in the C-band. In this environment, optical transport platforms that minimize footprint and power consumption become increasingly important. This is true not only at ground stations, where rack space and power are at a premium, but also at POP locations, which are often hosted in co-location facilities where recurring costs are directly tied to the space and power consumed by deployed transport equipment.

The space environment is no longer static. Legacy ground systems, however, are rigid. They require slow, costly updates and involve too many manual processes to keep up with dynamic operational needs. This rigidity creates “operational paralysis,” making it impossible to manage frequent changes at scale.

Greg Quiggle, Senior VP of Product Management at Kratos, summed it up: *“Dynamic orchestration is what allows you to really be able to tune a network in literally minute-by-minute increments to get peak performance out of all of the infrastructure… When you do this fully virtualized and fully orchestrated, it really opens the door to a whole new era of business models and scale.”* Without agility, operators risk falling behind in competitive markets or being unable to respond to real-time challenges effectively.

As satellites become critical infrastructure for communications, navigation, security, and daily services, resilience is no longer optional. Legacy ground systems, anchored to fixed physical locations, are especially vulnerable. Securing them often means heavy investments in physical protections fences, guards, and hardened facilities that do little to address modern cyber or hybrid threats.

Mike Dean, Director of Command, Control, and Communications at the US Department of Defense, put it as: *“We think about the space segment, we think about the terminals, but we always forget the ground. Building a true satellite internet requires not just satellites and terminals, but a complete reimagining of the ground infrastructure.”*

GSaaS is experiencing strong market pull from NewSpace operators looking to convert CAPEX into OPEX, especially for LEO applications. By outsourcing the ground segment operating expenditure, satellite operators can lower the upfront investment as well as the inherent risk of commercial failure.

Changing requirements can quickly and easily be accommodated, and even complete pivots in technical requirements or business models aren't hindered by ownership of ground assets. In turn, ground segment providers with expertise and enough customer aggregation can offer a multitude of capabilities and accommodate changing requirements, all while benefiting from the increase in demand for services.

Big Tech companies not traditionally active in the space industry (such as Amazon Web Services and Microsoft1) have also entered the ground segment market. This is in part due to the parallels of including an as-a-Service component in their portfolios, and the leveraging of their big data centers assets and data analytics capabilities.

Together with technological developments such as AI for ground segment operations, ground segment virtualization and flat panel antennas, these new forces may provide a further boost to GSaaS as well as the entirety of the ground segment market.

Players in the ground segment and GSaaS market include legacy technology companies, ground station and satellite operators with decades of experience such as GMV, Indra, KSAT, SSC. Agile NewSpace entrants such as Atlas Space Operations, LeafSpace, Infostellar, and Contec, as well as Big Tech companies looking to diversify their cloud offering especially AWS also play an important role. There might also be opportunities for infrastructure-as-a-service players with technical expertise or facilities in favorable geographic locations. While inevitably some will fail over time, current developments suggest that small NewSpace players as well as legacy operators and big tech all have a place in the market. \

The new era of satcom

Spectrum is one of the satellite industry's most valuable resources. But securing access to spectrum is only part of the challenge.
As demand grows for higher-capacity connectivity, resilient communications and more dynamic satellite services, operators also need to ask whether their ground infrastructure is ready to make effective use of that spectrum.

High-throughput satellites, expanding LEO constellations, earth observation missions, sovereign communications programmes and emerging multi-orbit services are all placing new demands on the ground segment. Networks must handle wider bandwidths, more complex RF environments and greater operational pressures, while remaining reliable, secure and adaptable.
This is creating a growing gap between spectrum ambition and ground segment reality.

An organisation may have access to the satellite capacity, services or frequency bands it needs. But its ability to exploit them fully will depend on the maturity of its architecture, operations and internal capability. Spectrum readiness is therefore not simply a question of technology. It is a system-level challenge.

In the coming years, The industry is witnessing more collaboration between the ground segment and space segment in the satellite sector. This represents an exciting new future for the industry. LEO has set the challenge, and now ground segment stakeholders need to rise to the occasion and deliver on a key part of the chain. The recent expansion of video streaming and High Throughput Satellite (HTS) capacity and has put satellite capacity pricing under strain, but as long as the satellite market continues to offer a competitive price per bandwidth it remains valuable. Working collaboratively with LEO operators will help to support this.

LEO constellations will focus on selling megabits rather than megahertz, and in some instances, will reduce uplinks and downlinks through intersatellite links using onboard lasers. As an RF equipment manufacturer, ETL Systems has the capability to manage the bandwidth and multiple links as required. As connectivity increases there will be an explosion in the number of links, which is where ETL System's equipment and experience will be invaluable. All development teams must position themselves to respond to that need.

The emergence of LEO offers an opportunity for GEO ground system manufacturers to develop new products for a lucrative market, capitalising on years of GEO experience. We haven't seen significant change within the ground segment of the satellite industry for a long time, and LEO is really driving innovation. It's a truly exciting time to be working within this sector.

The future of global communication networks is being reshaped by the rapid growth of Low Earth Orbit (LEO) satellite constellations, and ongoing research and technology advancement suggest even more integration, performance, and service diversity in the decades to come. Next-generation LEO systems are predicted to go beyond their present functionality as broadband providers and take on an important role within an integrated terrestrial and non-terrestrial communication ecosystem as a demand for high-capacity connectivity globally grows.

Additionally, factors like network management, connection technologies, Artificial Intelligence (AI), regulatory evolution, satellite hardware and cross-domain integration contribute significantly impact this progression. When considered collectively, these developments indicate that LEO constellations will not only enhance the improvement of current communication infrastructures but also open completely new categories of applications in automation, mobility, sensing, and international data sharing. Optical and hybrid inter-satellite links (ISLs), present another key area of innovation that is becoming the foundation for resilient, high-throughput networking in space.

Enabling High-Speed Connectivity across Africa

There is no continent on Earth that is in more desperate need of space science and technology than Africa. Dramatically raising the standard of living of Africa's peoples requires a brute-force, great-project approach, a leap-frog over 20th-Century methods, to directly employ the most advanced technologies that are available, and those that are on the cusp of development.

Transforming the continent, through projects of the scope of Transaqua, requires mapping resources, comprehensive water management, geographic and geologic analysis, land use planning, the tracking of disease, and agricultural monitoring, all of which are done most efficiently using space-based technologies. Land remote-sensing satellites have long been recognized by numerous African nations as a necessary tool for scientifically informed economic development. Communication satellites, which can connect rural and remote communities to educational programs, and health and other government services, also help to knit together a coherent national culture. Such satellites also connect African nations with each other, enabling international development projects with a continental impact.

But more than any specific economic benefit from space technology applications, such national programs create a cadre of scientists, engineers, technicians, and highly-skilled machine-tool and manufacturing operatives, who can then take the lead in creating quantum jumps in productivity throughout the economy, and lay the basis for the breakthroughs by the next generation of Africans.

At the Rio20 Conference held in June 2012, Austria, Brasil and the United Nations Office for Outer Space Affairs (UN-OOSA) sponsored a side-event on “Space for Sustainable Development” to highlight the role of space as an indispensable tool in this endeavour. Subsequent to the 1959 establishment by the UN of its Committee on the Peaceful Uses of Outer Space COPUOS, OOSA has become one of several UN agencies to promote and use space acquired data, especially in developing countries. Yet, in today's Space Age, UN meetings on sustainable development have consistently failed to give any recognition to space tools as a means of achieving sustainable development goals on Earth.

According to the United Nations, more than two billion people suffer from water-borne diseases with more than 2.2 million people dying every year. In 2015, three billion people, nearly 40% of the world population are expected to live in countries that find it difficult or impossible to mobilize enough water to satisfy the food, industrial and domestic needs of their citizens. Projections indicate that, by 2026, two out of every three persons on Earth will live in water-stressed conditions. To achieve sustainability of water resources on Earth, there must be shared management based on a shared system of information, data and analysis.

Because of its reliability and consistency, space acquired data offers the right solution. With the aid of Jason-2 and Envisat satellites, satellite enabled river gauges are in use to monitor water flows along international rivers; similar devices are also in use world-wide to monitor the levels of lakes and reservoirs. Another challenge is the trans-national dimension of water, which reaches beyond the limits of national sovereignty in terms of surface, ground, and atmospheric water resources. Forty percent of the world's population in almost 50% of the Earth's land surface live within basins whose water resources are shared by two or more sovereign states; the Amazon, the Brahmaputra, the Nile, the Niger, and the St. Lawrence Rivers come to mind. Similarly, the tremendous spatial extension of territorial waters and related exclusive economic zones poses a fundamental challenge, not only of monitoring the resource systems but also of maintaining an effective legal regime in coastal waters, particularly in the interest of the local population. The type of data needed to exercise such control cannot depend on the use of conventional and manual techniques. Because of the unequal natural distribution of water resources in the world, advanced modes of water management would be the answer. Space is an indispensable component of the needed management tools.

Marine ecosystems

Many of the 64 coastal and marine ecosystems of the world are today suffering from environmental degradation, including the mismanagement of their fisheries resources because of stock depletion, mariculture extinction, industrial and municipal pollution, contamination by ballast water, coastal erosion and the destruction of upstream spawning areas. The exploration and exploitation of petroleum and gas resources, particularly in the mangroves, has led to a situation where these ecosystems suffer an average of more than 1000 oil spills and related fires every year. Many of these problems are easily captured by Earth observation satellites, using instruments such as MER on ESA's Envisat satellite, MODIS on the Aqua and Terra satellites and the IMAGER on board INSAT. Marine and coastal ecosystems also need recovery and sustenance of their depleted fisheries, the restoration of degraded habitats, the reduction of land- and ship-based pollution and a reversal of coastal area degradation and living resources depletion.
These and other related problems can be resolved, among often competing interests and institutions, through cooperation in a regional and international setting, with the aid of copious satellite data. What is needed are shared objectives, a degree of coordination of the different governmental, intergovernmental and non-governmental responsibilities, and the willingness to work with shared information and data.

Enormous potential

At present, only a handful of nations in Africa participate in the application of space technology, such as the use of remote-sensing and satellite communications capabilities. But the need, and the potential, are enormous. South Africa, which has developed the most extensive space capability in Africa, announced the establishment of its South Africa National Space Agency on December of the year. It will bring together disparate space related efforts in the country, and will also aim to revive space facilities that have been mothballed since the 1990s.

The new agency plans to create a satellite-design and building capacity, using local expertise, building on its successful Sumbandila micro satellite, circumventing its reliance on satellites from abroad. This year, it will begin a feasibility study to assess the state of the facilities left over



from its medium-range ballistic missile program, with the view toward creating a satellite launch vehicle, and will extend its participation in international astronomy projects.

Nigeria established its National Space Research and Development Agency in 1999. The nation's first satellite, Nigeriasat-1, was part of an international microsatellite Disaster Monitoring Constellation, and was built by Surrey Satellite in England. It was launched by Russia in 2003, and produces high-quality remote-sensing images. Nigeria's first communications satellite, the Chinese-built NigComSat-1, was launched by China in 2007. But the satellite failed on orbit a year later, and will be replaced later this year. Nigeria's NigeriaSat-2 is also scheduled for launch later this year, along with a training model, which was undertaken by Nigerian scientists and engineers. The Algerian Space Agency was created in 2002, and soon after, saw the launch of its Alsat-1 remote-sensing satellite, also part of Surrey Satellite's five-satellite Disaster Monitoring Constellation. In July 2010, the European- built Alsat-2 was launched by India, which included an intensive training program for Algerian engineers and scientists.

Egypt has operated its own European-built communications satellite since 1998. A follow-on, Nilesat-2, of similar design, was launched two years later. A next generation communications satellite, Nilesat-201, was launched in August of last year. For Earth remote-sensing capabilities, Egypt has teamed up with Ukraine's Yuzhnoy Design Bureau, and EgyptSat-1 was launched in 2007. The contract with Ukraine included the train ing of Egyptian satellite operators, and Egypt's ground receiving stations capture the satellite images.

Egyptian scientists, both at home and abroad, have participated with NASA and other international scientists in studies of the North African desert, the location of ancient subterranean water channels, and existing underground water resources. In 2004, an international team took deep radar sounding measurements at the Bakareza Oasis, testing instruments that could be used to find subsurface water on Mars.

Going regional

Various regional African space organizations have been proposed, and some have been created, to pool Africa's limited resources devoted to space applications. Nairobi, Kenya hosts the Regional Center for Mapping of Resources for Development, which has the participation of 15 African member-states.

Satellite data are used to predict floods, as an early warning tool for disasters, to track water-borne diseases, and for infrastructure planning, continent-wide. In 2009, former director of the space program of Egypt, Dr. Mohamed Argoun, proposed, at the Global Space Technology Forum in Abu Dhabi, that there be a Pan-Arab space agency in the future, when there is a concrete, multilateral program in place, with industrial and university participation. Middle Eastern and African Arab nations, he suggested, should develop a space technology industry, to contribute to a new, high-resolution Earth regional observation satellite.

Another regional initiative came in August 2010, when the Ministers of Communication and Information Technologies of the African Union agreed to conduct a feasibility study on the formation of an African Space Agency. Its focus would be on telecommunications capabilities.

More recently, Dr. Argoun has proposed an Africasat, to bring together, and enhance, the technical and industrial capabilities of Africa. Following his presentation at the 61st International Astronautical Congress, held in Prague, the Czech Republic, in September 2010, he was interviewed by EIR's William Jones about this proposal, and the importance of bringing water to the African deserts. Science can still save Africa. This must start with a global financial and economic reorganization that begins in the United States, with the replacement of the bankrupt financial system through a Glass-Steagall policy, the return to a credit-based economic growth policy, and international agreements to make that policy global. In this way, Africa can finally be free of hundreds of years of colonial rule, and decades of international financial strangulation, and ready to truly enter the Space Age.

Growth of Africa's space industry

Africa's space industry has expanded considerably over the past two decades, reflecting growing recognition of the strategic importance of space science and technology for sustainable socioeconomic development. According to UNOOSA, more than twenty African countries now operate space-related programmes, while over fifteen have successfully launched satellites for Earth observation, communications, scientific research, navigation, and technology demonstration. The establishment of national space agencies has been a major driver of this growth.

Nigeria created the National Space Research and Development Agency (NASRDA) in 1999 to coordinate national space activities. Since then, the country has launched several satellites, including NigeriaSat-1, NigeriaSat-2, NigeriaSat-X, NigComSat-1R, and EduSat-1, supporting disaster management, environmental monitoring, telecommunications, agricultural planning, and national security. South Africa has developed one of Africa's most advanced space programmes through the South African National Space Agency SANSA. The country has invested heavily in Earth observation, satellite engineering, space weather monitoring, and astronomy, including its participation in the Square Kilometre Array (SKA), one of the world's largest radio astronomy projects.

Egypt has emerged as another continental leader through the establishment of the Egyptian Space Agency and its role as host of the African Space Agency. The country has invested in satellite manufacturing, remote sensing, and regional capacity-building initiatives, positioning itself as an important hub for space science and technology in Africa. Other countries, including Algeria, Kenya, Rwanda, Ghana, Ethiopia, Angola, Morocco, Tunisia, and Mauritius, have also expanded their space programmes through satellite launches, international partnerships, and investments in Earth observation and telecommunications.

Kenya's space programme has supported environmental monitoring and scientific research, while Rwanda has promoted satellite applications for digital transformation and precision agriculture. Ghana has strengthened national capacity through the Ghana Space Science and Technology Institute and university-led satellite projects. In addition to government programmes, African universities have become increasingly involved in satellite engineering, CubeSat development, and space research. Therefore, collaborative projects with international institutions have enabled students and researchers to acquire practical skills in spacecraft design, satellite operations, remote sensing, and geospatial analysis.

These initiatives contribute to the development of indigenous expertise and reduce long-term dependence on external technical support overall, the expansion of national space agencies, increased satellite launches, greater investment in research and development, and the establishment of the African Space Agency demonstrate that Africa's space industry is entering a new phase of institutional maturity and technological advancement.

Prospect of African space industry

The African space industry is a rapidly growing sector valued at over $22 billion that focuses heavily on utilizing space-for-earth applications like telecommunications, remote sensing, and agriculture. About 59 satellites have been launched by African nations, with an estimate of 110 African satellites launched by 2030. South Africa and Egypt are the leading African countries with satellites in space driven by their historic satellite capabilities and strategic applications in the telecommunications industry. South Africa is the largest player in Sub-Saharan Africa, having launched 12 satellites, displaying its capacity for satellite deployment and signifying its leadership in African space technology.

According to current plans, 24 countries in Africa will have launched a satellite by the end of the decade. The African space sector has experienced rapid expansion due to the establishment of national space agencies such as the National Space Research and Development Agency NASRDA in Nigeria, the South African National Space Agency (SANSA), and the Egyptian Space Agency EgSA. The launch of satellites for communication, navigation, and Earth observation has strengthened socioeconomic development across the continent.

Furthermore, the establishment of the African Space Agency AfSA reflects the African Union's commitment to fostering regional cooperation in space science and technology. The future of Africa's space industry is promising. Increasing demand for satellite-based communication, Navigation, earth observation, and climate services are expected to drive further investment.

The expansion of commercial space activities, stronger regional cooperation through the African Space Agency, and advances in artificial intelligence, data analytics, and satellite technologies provide new opportunities for innovation. Space technology will continue to play a critical role in disaster risk reduction, climate change adaptation, precision agriculture, environmental monitoring, and digital connectivity across Africa.

Where is commercial satellite market really going?



Africa is experiencing a pivotal moment. Long perceived as a distant domain reserved for established powers, space is today at the heart of the concrete realities of our societies. It underpins food security, strengthens climate resilience, improves the management of our natural resources, connects our territories, secures our maritime and terrestrial domains, and modernises governance.

In the face of this transformation, African continent cannot remain merely a user of solutions designed elsewhere. Africa must structure its capabilities, organise its priorities, and participate fully in the space value chains that are reshaping the global economy.
In the last few years, Africa has witnessed an unprecedented acceleration in tech products and services hinged on the outer space resource. As of August 2022, the African space industry is worth USD 19.49 billion, and is expected to grow to USD 22.64 billion by 2026. As of April, 53 satellites have been launched by 15 African counties, and of these satellites, nine were launched by commercial entities. Africa's satellite program began in 1999, with the launch of SUNSAT-1 by South Africa, and the latest launch was that of the Kenyan educational satellite, Taifa-1, launched on 11 April 2023. Africa has a legacy in across up and downstream, covering remote sensing; telecommunications and navigations; as well as space manufacturing, and the establishment of critical infrastructure, which are all expanding. Lately, there has been a boom in critical investment plans in Africa specifically, such as the recent plans to establish a commercial spaceport in Djibouti, which is one of multiple prospects geared towards critical investments for space infrastructure in Africa.

Space is no longer a projection; it has become a critical infrastructure. It is in this spirit that the African Space Agency (AfSA) is co-organised, alongside the Government of the Republic of Côte d'Ivoire, the Africa Space Expo ASPEX 2026, to be held in Abidjan from 24 to 26 September 2026. ASPEX is not just another event. It represents a continental execution platform through which applied space activities in Africa are organised, structured, and deployed. Its architecture is designed around a clear objective: delivering tangible results.

Africa's space economy is no longer a futuristic ambition discussed only in research institutions or government policy rooms. It is rapidly becoming a practical tool for solving some of the continent's most urgent ground-level problems.
Low Earth orbit (LEO), medium Earth orbit (MEO), geostationary Earth orbit (GEO) and high Earth orbit (HEO) satellites are all helping African businesses, governments and communities make better decisions down here on Earth. However, the difficulty is connecting this information to the people and institutions who need it. The connectivity gap continues to affect the gains Africa can realise from existing satellite infrastructure and advancements in emerging satellite and space technology

The space economy is emerging as a major growth sector, propelled by advancements in satellite technology, government initiatives, and private sector innovation. As the industry evolves, a variety of players compete to harness opportunities across satellite deployment, launch capabilities, and space-based services. This overview explores the current market size, key drivers, leading companies, and future trends reshaping the space economy landscape.

The global space economy market is projected to reach $645.42 billion by 2030, growing at a steady compound annual growth rate of 8%. This robust expansion is largely driven by increased commercial satellite launches, heightened government and defense expenditures in space programs, and accelerating private sector commercialization. Key participants such as aerospace manufacturers, satellite operators, launch service providers, and new space companies are competing fiercely in areas including satellite constellations, reusable launch vehicles, space communications, Earth observation, and in-orbit servicing. Meanwhile, exploration missions, the commercial use of low Earth orbit (LEO), data-driven applications, and AI integration are continuing to influence strategic shifts across the market.

The increasing role of private companies is also transforming the space economy. Private firms are spearheading advancements in satellite manufacturing, reusable launch vehicles, in-orbit servicing, space tourism, and commercial infrastructure. Aerospace companies, startups, and venture capitalists are driving down launch costs and broadening access to space. Public-private partnerships are facilitating commercialization in telecommunications, research, manufacturing, and resource exploration, fostering heightened competition and operational efficiency. This factor is forecasted to contribute roughly 0.5% annual growth to the overall market.'

By 2030, the space economy market is expected to surpass $645 billion in value. Within the broader Aerospace & Defense sector, which is projected to reach $1,166 billion by the same year, the space economy will represent nearly 55% of the total market size. The anticipated growth rate for the space economy is a CAGR of 8% through 2030, highlighting its increasing significance within the overall aerospace landscape.

Africa's space economy was valued at more than $19 billion in 2021 and is projected to grow another 16.16% to exceed $22.64 billion in 2026. The industry employs more than 19,000 people across the continent. So far, African nations have committed a total of about $534 million to their space programs in 2022, a 2.24% increase over 2021. Africa's space economy continues to grow at a pace that exceeds Africa's GDP growth rate. It is also becoming a strategic tool for stimulating national economies and achieving sustainable development goals on the continent. As of 2022, 13 African nations have produced 48 satellites. Basically, work is being done on small satellites, because they make it possible to launch a full-fledged service and "educate" the necessary personnel in the country at a sufficiently low investment.
Recent report estimates that, 272 NewSpace companies located in 31 African countries are developing and promoting new uses for space technology, offering applications in several fields, including industry, medicine, transportation and logistics, among others.
Satellite communications are expected to play an important role in bridging the communication services consumption gap in Africa, while global positioning and satellite TV services will become the most significant sectors of the space economy on the continent.
The market of satellite communications – both fixed (FSS) and mobile (MSS) – and satellite television accounted for the bulk of the African space and satellite industry in 2021. A significant share of revenue came from the major direct satellite broadcasters: DSTV, Canal+ Afrique, and StarTimes.

Within the space economy market, the satellite industry segment is projected to be the largest in 2030, accounting for 39% of the total market or $253 billion. This segment will benefit from demand for high-throughput satellite connectivity, next-generation satellite constellations, commercialization of satellite-derived data and analytics, and the application of satellite technologies in sectors such as agriculture, transportation, and energy. Advances in miniaturization, onboard processing capabilities, and international collaboration on satellite deployment will also support this growth.

A recent report by the World Economic Forum and McKinsey predicts that the global space economy will expand from $630 billion in 2023 to $1.8 trillion by 2035. This growth includes vital services like satellites and launchers, as well as applications where space technology aids businesses across various industries. Key growth drivers highlighted in the report include the need for better satellite connectivity, increased demand for positioning and navigation services on mobile phones, and a rising demand for AI and machine learning-powered insights.

Similarly, a recent report by Deloitte offers a compelling look at the space economy. Recently, the challenges of manufacturing, launching, and operating satellites and other space-based assets have significantly decreased. Satellites are now smaller and cheaper to produce and operate. Reusable rockets have drastically reduced launch costs. Digital and advanced technologies are opening up satellite data access and new business opportunities to more players than ever before. The report, however, notes remaining uncertainties and challenges, emphasising the need for a pragmatic and collaborative approach to achieve steady growth toward a self sustaining space sector.

Roles of African Space Agency AfSA

As the continent embraces digital transformation and innovation, the emergence of the African Space Agency (AfSA) signals a new era in which Africa is positioning itself as both a creator and consumer within the global space economy. This provides an opportunity to restructure the African space ecosystem and the decisions made in the next two to three years about the AfSA's role, whether as a grant administrator, a regulatory body or a market maker, which will shape the long-term outlook of Africa's space economy.

A new global space player, AfSA is being set up under the umbrella of the African Union (AU), the international organisation based in Addis Ababa, the capital of Ethiopia, which is the forum for dialogue between 55 of the 59 states on the black continent. It is set up, according to article 2 of its constitutive text, to "promote, advise and coordinate the development and use of science, space technologies and associated regulations for the benefit of Africa, the world and inter-African and international cooperation".

Its creation responds to the conviction of most African leaders that space-based applications are key to accelerating the development and prosperity of their respective countries and, step by step, they have brought the African Space Agency into being**.** The aim is to acquire technologies and build infrastructure to improve, for example, the management of water, marine and terrestrial natural resources, agriculture and the environment.

Among the objectives is the interest in "strengthening space missions on the continent to ensure optimal access to space data, information, services and products"**.** It should be noted that, in practice, all African nations are consumers of products derived from satellite communications, meteorology, observation and navigation technologies. Only a few are major players and have satellites of their own: Algeria, Egypt, Morocco, Nigeria and South Africa, joined in recent years by Angola and Kenya.

With the aim of "fostering cooperation and avoiding duplication of efforts**"**, article 5 of the AfSA assigns it the role of "promoting strategic intercontinental partnerships, fostering regional coordination and collaboration, and engaging member states in space-related activities and research in Africa".

ASPEX 2026

Africa Space Expo is the African Union's flagship continental space exhibition and conference, designed to accelerate the commercialization and application of space technologies for Africa's development. This year's edition held on the 24–26 September 2026 at the Abidjan Exhibition Park and Radisson Blu Hotel in Abidjan, Côte d'Ivoire, was co-organized by the African Space Agency (AfSA), the Côte d'Ivoire Space Agency (ASCI), and the Eburnie Space Foundation. ASPEX serves as the continental execution hub where space ambitions become markets, and where space solutions translate into real impact for Africa. The 2026 edition expects more than 10,000 participants, 300+ exhibition stands, and hundreds of strategic partnerships across Africa's growing space ecosystem.

The high-level ceremony brought together senior government officials, policymakers, and industry stakeholders, signalling growing political and institutional backing for the continent's space ambitions. Among those in attendance were Dr Tidiane Ouattara, President of the Council of the African Space Agency (AfSA); Djibril Ouattara, Côte d'Ivoire's Minister of Digital Transition and Technological Innovation; and Prof. Adama Diawara, Minister of Higher Education and Scientific Research. Speakers emphasized the strategic importance of developing a coordinated African space ecosystem to address pressing socio-economic and environmental challenges.

The Africa Space Expo is scheduled to take place from September 24 to 26, 2026, at the Abidjan Exhibition Centre. Organizers say the event will bring together governments, private sector actors, start-ups, researchers, and international partners to promote collaboration and investment in space-based technologies. Officials highlighted the role of satellite data and related innovations in areas such as environmental monitoring, disaster risk management, territorial planning, and economic development.

The event was positioned to serve as a leading platform for Africa's emerging space economy, with a focus on fostering partnerships, showcasing local capabilities, and structuring the continent's participation in the global space industry.

ASPEX was initiated by the African Union as a platform to showcase the continent's space capabilities, attract investment, accelerate startups, and connect African space initiatives with global industry partners. AfSA, the African Space Agency, established in 2023 and headquartered in Cairo, Egypt and the Government of Côte d'Ivoire co-organize the 2026 event. Abidjan, one of West Africa's most dynamic economic hubs, provides a fitting venue for this continental gathering of space industry leaders, entrepreneurs, and governments.

During the event, the Business Arena constitutes its strategic core. It brings together public decision-makers, industry leaders, investors, and financial institutions in a setting designed to facilitate high-level exchanges, structured negotiations, and contractual engagement. The Solutions Showcase makes space tangible.

It directly connects innovation with the continent's economic and institutional priorities by offering a concrete view of the transition from technological development to operational deployment. The Project Labs transform intention into engineering. They promote the co-development of pilot projects, the structuring of partnerships, and the emergence of cooperation mechanisms between Africa and international partners. With Pitch & Acceleration, the event identify and support initiatives capable of entering a deployment trajectory. With Talent & Future, we invest in what remains our greatest asset: human capital. Training, inclusion, and knowledge transfer are essential because no sustainable ambition can take root without strong skills and an engaged generation of young Africans.

Representatives of Heads of State and Government, ministers, leaders of space agencies, international financial institutions, development banks, sovereign funds, and major technological partners participated within a confidential and structured framework oriented toward decision-making. These was not a protocol meetings, but rather a space for operational diplomacy, aimed at formalising cooperation agreements, structuring joint

investment mechanisms, aligning national and continental strategies, and positioning Africa within the international architectures of space governance.

This sequence extends ASPEX's momentum by ensuring institutional execution. While the three public days structure the market and showcase capabilities, the following three days transform convergence into lasting commitments and concrete strategic trajectories. Through ASPEX, participants affirm a vision of structured sovereignty and responsible cooperation. Africa must strengthen its capabilities, but it will do so in openness, through responsible cooperation, co-development, and shared value creation. Our ambition is not isolation, but balance and maturity. African space is entering a new phase, the phase of responsibility. Responsibility toward our populations. Responsibility toward our youth. Responsibility toward our partners. ASPEX 2026 marks the beginning of this decisive stage. It provides a structured framework to transform intentions into projects, and projects into concrete solutions.

At the event, the African Space Agency (ASA) has called for stronger collaboration among governments, investors, businesses, researchers and innovators to transform Africa's growing space capabilities into sustainable enterprises and practical solutions for development. Addressing the official opening of the inaugural African Space Expo (ASPEX 2026) in Abidjan on Thursday, the vice-president of the agency, Thandekile Mbvundula, said the continent must move beyond demonstrating its potential in space and focus on creating businesses, partnerships and investments capable of generating lasting economic and social value.

“We gather here today with a shared purpose: to transform Africa's space potential into successful enterprises, lasting strategic partnerships and tangible benefits for our people,” Mbvundula said. The three-day expo brings together businesses, entrepreneurs, investors, researchers, public institutions and policymakers, with the agency positioning the event as a platform for connecting the different parts of the continent's emerging space economy.

Mbvundula stressed that ASPEX is designed to be more than a traditional exhibition. “ASPEX is more than just an expo. It is a unique business platform anchored in private sector engagement,” she said. The platform is intended to bring companies, entrepreneurs and innovators into direct engagement with public institutions, policymakers, investors and potential customers. According to the vice president, the objective is to create a pathway from ideas to solutions, from solutions to sustainable enterprises and ultimately from those enterprises to broader economic and social development.

She said ASPEX reflects collaboration between the African Union and its member states to strengthen national space economies and advance Africa's space agenda and Agenda 2063. “Our ambition is clear: to build Africa's space economy together, across the full value chain, from skills and research to technology, infrastructure and services that deliver and improve lives,” Mbvundula said. The vice president emphasised that Africa's space ambitions will require partnerships that bring together complementary capabilities across sectors and countries.

Referencing a statement frequently made by Côte d'Ivoire's President, Dr. Alassane Ouattara, Mbvundula said space activities require substantial resources and therefore cannot be pursued effectively by a single institution, sector or country acting alone. She said the purpose of bringing strategic stakeholders together in Abidjan is to create an environment in which governments, businesses, investors and researchers can combine their respective strengths.

“Our progress is dependent on our ability to find synergies, collaborate and establish partnerships that leverage complementarities,” she said. She identified these partnerships as essential to turning African capabilities into solutions that can have a lasting development impact. A significant part of Mbvundula's address focused on the role of academia and research institutions in Africa's emerging space economy. She called on universities and research institutions to work more closely with industry to develop technologies, test solutions, train skilled professionals and create pathways for research to move from laboratories into practical applications. “Academia has to come to the table,” she said.

The African Space Agency, she added, intends to facilitate stronger connections between academia and industry as part of efforts to develop the continent's space economy. ASPEX provides opportunities for these relationships through potential joint research initiatives, technology transfer, licensing arrangements and research-based startups. Such partnerships could also help companies gain access to specialised knowledge while enabling researchers to better understand the needs and requirements of the market.

Mbvundula also highlighted the importance of ensuring that ASPEX develops into a sustainable platform rather than remaining a one-off event. She announced that the expo will be co-supported over the next two years by the Africa-EU Space Partnership Program (AESPP). Following that period, the government of Côte d'Ivoire is expected to assume full responsibility for carrying the platform forward. “We are basically setting a sustainability model to ensure it's not just a flash in the pan,” she said. Mbvundula thanked AESPP and its partners for their contribution and expressed appreciation to Côte d'Ivoire for supporting both the inaugural expo and the longer-term future of the platform. The arrangement is intended to give ASPEX continuity while establishing Abidjan as a platform for sustained engagement among African and international space sector stakeholders.

UAE Space Agency at the Africa Space Expo in Abidjan

The UAE Space Agency, led by Eng. Salem Butti Al Qubaisi, Director General of the UAE Space Agency, participated in the first edition of the Africa Space Expo (ASPEX 2026), held in Abidjan, Côte d'Ivoire. During the visit, the Agency signed two agreements. The first was a Memorandum of Understanding (MoU) on cooperation in peaceful space activities with the African Space Agency (AfSA). The second was a Letter of Intent (LoI) with Angola's National Space Program Management Office (GGPEN). Al Qubaisi also held bilateral meetings with leaders of African space agencies and senior government representatives.

Organized by AfSA and the Government of Côte d'Ivoire through the Côte d'Ivoire Space Agency, ASPEX 2026 brought together governments, space agencies, industry, investors and researchers with a shared focus: turning space technologies into practical solutions for Africa's development priorities.

Eng. Salem Butti Al Qubaisi, Director General of the UAE Space Agency, said: "Across Africa, space is increasingly being used to answer practical questions: how to protect harvests, manage water, respond faster to disasters and plan growing cities. The UAE intends to be a long-term partner in that work. The agreements we signed in Abidjan are designed to move from dialogue to delivery."

"As we implement the National Space Strategy 2031, partnerships like these matter to the UAE as well. They connect our institutions, companies and talent with new partners and markets. They also reflect our belief that space capabilities create the greatest value when they are shared and applied to real challenges on Earth," Eng. Al Qubaisi added.

The MoU was signed by Al Qubaisi and Dr. Tidiane Ouattara, President of the Council of the African Space Agency, in the presence of Mamadou Touré, Minister for Youth Promotion, Professional Integration and Civic Service, Republic of Côte d'Ivoire and Ali Yousef Al Nuaimi, UAE Ambassador to the Republic of Côte d'Ivoire.

Priority areas include space science and applications, Earth observation and satellite data for climate, disaster management and food security, policy and regulation, talent development, and collaboration between African and UAE startups.

The two agencies will develop a joint action plan to translate these priorities into specific activities.

The LoI was signed by Eng. Al Qubaisi and Dr. Zolana Rui João, General Director of GGPEN, in the presence of Mário Oliveira, Minister of Telecommunications, Information Technologies and Social Communication (MINTTICS), Angola. It sets out a shared intent to cooperate in Earth observation, satellite data sharing and applications, satellite development, research and innovation, and space policy, supported by training, technical exchanges and internships for specialists in both countries.

The visit supports the Strategy's pillar on expanding space partnerships and global market access. This pillar prioritizes international alliances and applying space technologies to challenges such as food security, climate change, and disaster management. The Strategy aims to place the UAE among the world's top 10 space economies by 2031. Its targets include increasing the sector's value added by 60%, doubling revenues and investment in space infrastructure, and expanding the number of national companies and startups.

On the sidelines of ASPEX 2026, Al Qubaisi held a series of bilateral meetings with senior government officials and leaders of African space institutions, including Dr. Tidiane Ouattara, President of the Council of the African Space Agency and Director General of the Côte d'Ivoire Space Agency; Prof. Matthew Olumide Adepoju, Director General/Chief Executive of Nigeria National Space Research and Development Agency (NASRDA); Maram Kairé, Director General of the Senegalese Agency for Space Studies (ASES); and Odete Semião, Director General of Mozambique's National Agency for Geospatial Development .

The discussions explored opportunities to deepen cooperation in Earth observation and satellite applications, disaster response, satellite data and AI, small-satellite development, capacity building and knowledge exchange, and stronger links between the UAE and African space ecosystems. The meetings also addressed opportunities for cooperation through the International Charter: Space and Major Disasters and the development of potential joint initiatives.



Human capacity building

African countries have been urged to expedite concerted efforts in developing the continent's human capital in space science and technology to harness its vast opportunities.

Speaking to the media on the sidelines of the ongoing 38th African Union (AU) summit at its headquarters in Addis Ababa, Ethiopia's capital, President of the African Space Council of the African Space Agency Tidiane Ouattara said the African continent lacks the critical mass of expertise needed to fully leverage space science and technology.

Rwanda has fairly made progress in the last few years towards laying a foundation for the space industry, preparing the country to tap into the economic potential the sector holds.

The country is one among the many that are increasingly leveraging commercial use of space which is essentially the provision of goods and services of commercial value by using equipment such as spacecraft and satellites with hope to derive greater value from the industry. While the space has long been utilized by governments and large telecommunication companies, multiple private companies have ventured into the industry to drive innovation.

Ouattara said the African Space Agency, a newly established independent organ of the AU, is tasked by African leaders with promoting the use of space science and technology by fostering continental collaboration and advancing relevant knowledge and skills.

"Creating local capacity is one of our strategic objectives. Since space science is relatively new in Africa, we have realized that we need to create a critical mass and increase the number of young people who are knowledgeable about space science," Ouattara said.

Noting the crucial need to coordinate space programs, Ouattara said African countries can be classified into three groups based on their experience and engagement in the sector.

He said countries such as Nigeria, Algeria, Egypt, South Africa, and Morocco are the pioneers in Africa's space sector, while a number of newcomers are exerting efforts in the sector, including Ethiopia, Gabon, Rwanda, and Kenya. He, however, said the majority of African countries do not even have dedicated space policies and institutions.

“More than 60 percent of Africa's population is young, and they are our opportunities. If we train them well, we have the opportunity to use their capabilities for many kinds of space science applications, such as disaster risk reductions, climate change adaptation and mitigation, rural development, urban development, and others," Ouattara said.

Acknowledging the absence of robust data-sharing practices and policy frameworks in Africa's space sector, he stressed the need for enhanced coordination and cooperation to enable countries to benefit from data exchange mechanisms.

"We cannot develop the space without the partnership, both intra-African partnerships and partnerships with abroad," he said.

International technology cooperation

In 2025, Lusaka became a hub of agricultural innovation as technicians from Southern African countries gathered for a unique three-day training session.

Unlike typical workshops, this one provided a customized experience. Participants brought data from their own countries and practiced on the satellite remote sensing agricultural monitoring platform developed by Chinese scientists, tailoring their learning to fit local needs.

The platform they learned is CropWatch, a cloud-based tool developed by the Aerospace Information Research Institute (AIR) under the Chinese Academy of Sciences.

It analyzes agroclimatic conditions, assesses crop growth status, tracks the dynamics of cropland use, estimates crop areas, predicts yields, and evaluates global food supply prospects.

"Food security is increasingly a global priority, but establishing satellite-based platforms for agriculture monitoring requires significant investment, which most developing countries simply cannot afford," said Zhang Miao, a workshop trainer from the AIR. He had just flown back from Lusaka when interviewed by Xinhua.

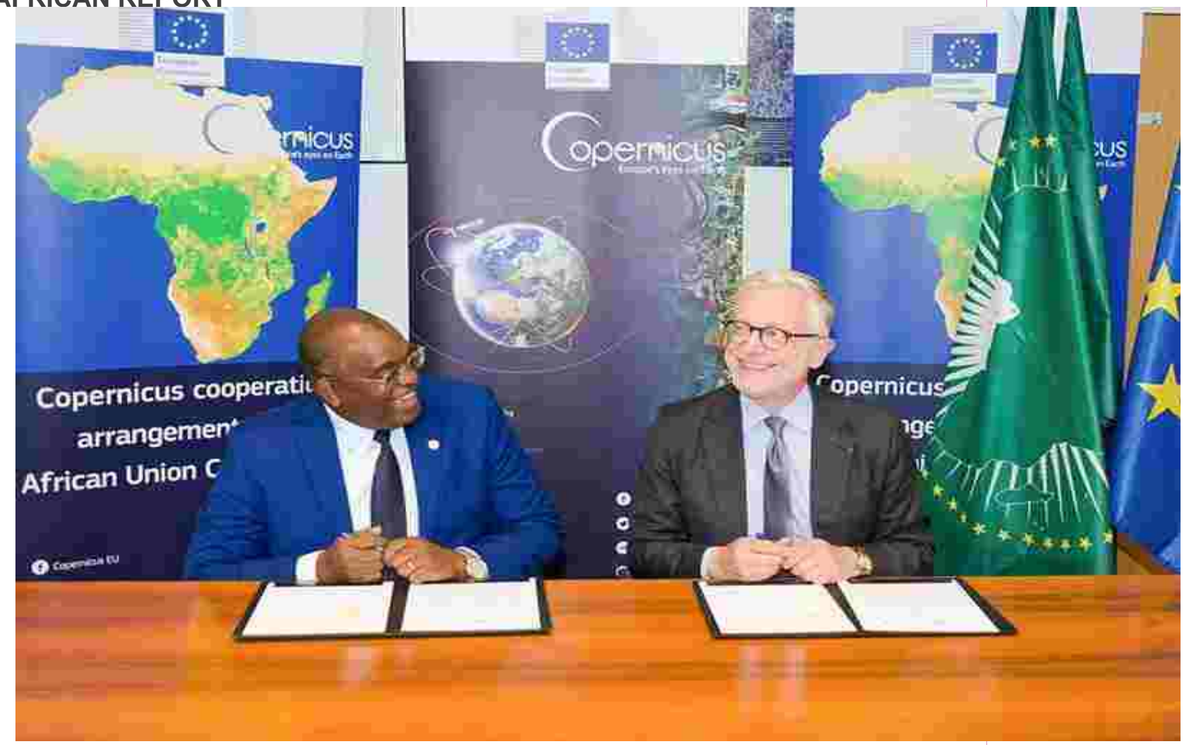
Unlike the traditional Western approach of delivering ready-made crop-related information and reports, the Chinese team has embraced a collaborative model with Global South countries -- "teaching a man to fish" by empowering them through knowledge transfer and platform self-customization.

Over 30 participants from Mozambique, Zimbabwe, Botswana, Mauritius and South Africa received one-on-one guidance in the training.

"A customized approach acknowledges the specific context and challenges faced by Mozambicans," said Hiten Jantilal, an officer of the Crops and Early Warning Department in Mozambique. "This method can lead to more effective learning and better outcomes."

"Africa's cropping system is quite different from China, especially the small-holder farming, with issues like widespread weeds and common mixed cropping," said Zhang. "Our platform has proven effective in addressing these challenges."

The AIR team has incorporated advanced AI models, including DeepSeek and ChatGPT, into the mobile APPs and a CropWatch Analysis component. This upgrade enables more intelligent interpretation of in situ crop



photos and remote sensing maps and products, significantly enhancing the precision and efficiency of satellite data analysis.
According to Zhang, these field-collected data, numbering in the millions, not only support the crop monitoring in CropWatch but also contribute to partner countries for internal applications.

CropWatch is now used in over 20 Global South countries, including Mozambique, Mongolia, Thailand, Vietnam, Cambodia, Myanmar, Zambia, Zimbabwe and Kyrgyzstan. In a heartwarming video taken last June, an elderly woman at a Rayong care home in Thailand sat in bed, chatting via real-time video with a local rehab specialist via a test terminal at Mahanakorn University of Technology in Bangkok, which was linked to the eight-satellite experimental constellation built by the Chinese space firm GalaxySpace.
The seamless high-speed video stream showcased the power of real-time mobile-to-satellite communication in Thailand's remote areas, where traditional networks are unreliable.
"It will further enhance Thailand's capacity building in aerospace technology and applications," said Suphongsa Khetkeeree, a scientist from the satellite research lab at the University.

In February 2025, GalaxySpace signed a Memorandum of Understanding with True Corporation, a major Thai telecommunications operator, to collaborate in areas such as the Starlink-like low-orbit satellite communication technology. "We are thrilled that this collaboration will bring cutting-edge innovative technologies to Thai consumers," said Manat Manavutiveth, CEO of True Corporation.
The Beijing-based satellite manufacturer is now actively forging partnerships across Africa and Southeast Asia to deploy cutting-edge satellite internet technology to empower underserved local communities.
Moreover, China's commercial satellite constellation, Spacesail, is set to provide satellite communication services to Brazil and broadband internet access to the country's remote and underserved regions.
Spacesail is a low-Earth orbit constellation with full frequency bands and a multi-layer and multi-orbit design. Its commercial network construction was officially launched last August. The constellation is expected to bring its commercial services to Brazil in 2026.
At a space city in Egypt, the ground station for MISRSAT-2 featured a prominent white dome with a red emblem of Chinese aid. Launched from China's Jiuquan Satellite Launch Center on December 4, 2023, MISRSAT-2 made Egypt the first African nation with full satellite assembly and testing capabilities.
Haitham Medhat Akah, a program manager from the Egyptian Space Agency, said that the MISRSAT-2 project helped Egypt become a leader in the field of space satellites in Africa and the Middle East. The satellite is now playing an important role in areas such as agriculture, mineral exploration, urban planning, and monitoring changes along the coastline.

For much of Africa, terrestrial networks are clustered around urban centres, leaving thousands of rural and remote citizens and businesses without voice, let alone data, connectivity. Studies show that in some areas, more than 100 million people in Africa don't have access to communications. In Nigeria alone it is estimated that more than 20 million people are not covered by any kind of network.

Yet one satellite can provide ubiquitous communications over one third of the earth's surface - so connecting multiple continents! Today all of Africa is covered with satellite communications, operating mainly in C, Ku and Ka frequency bands, delivering affordable, reliable and robust services across the entire territory. Through satellite services, the continent has immediate access to some of the world's most advanced technologies such as broadband connectivity and 3G communications which are taken for granted in developed countries.

Satellite operator Rascomstar has independently brought mobile telephony to remote villages in the DRC. Such villages often have populations of up to 20 000 people, no stable electricity supply and no GSM coverage as the population density is too low to make commercial sense for mobile network operators. The satellite operator therefore bears the cost of securing the installation of a tower, solar panels, BTS and GSM antennas and satellite antennas to backhaul the traffic. The result is an immediate social impact calls can be made from the village to any fixed or mobile phone in the world. First users are doctors, teachers and local businessmen, with higher traffic than expected even though the average calls are less than 2 minutes long. Despite the lack of electricity, people are able to recharge their batteries through local vendors.
As High-Throughput-Satellites come to Africa, isolated villages can also have access to mobile broadband services noting, once again, the important lack of interest of mobile network operators to connect areas with low population densities.

Financial Services

Over the last decade, Africa's interest in space has been growing fast, offering opportunities for existing and new players from within and outside the continent. However, Africa needs to develop a far larger pool of local space experts, according to a report on the sector. "Capability gaps benefit foreign space powers, such as China and Europe," according to a 2022 EU Global Action on Space Market Report Africa. Media, analytics and consulting firm Space in Africa projects that the continent's space market will exceed $10-billion in value by 2024, on the back of rising investment. Over the last few years, Africa's space industry has been working with a number of countries paying to send satellites into orbit – including those designed and developed on the continent.

Access to financial, banking and money transfer services is a prerequisite for economic growth in Africa but the lack of reliable and affordable telecommunications prevents the ubiquitous roll-out of financial outlets. Banks cannot count on traditional fixed or wireless telecommunication services which either are present with poor quality or are simply non-existent in remote regions in Africa. In these remote areas, satellite communications are enabling affordable, high quality solutions to connect money transfer, micro finance or bank agencies or even ATMs.

Satellite communications are used in West Africa by several micro finance, money transfer and banking institutions to connect their remote agencies and ATMs to their headquarters and to the Internet backbone. Connecting remote points of presence is key to ensure services across the continent and provide equal access to all citizens. Modern, easy to install and maintain satellite communications terminals are now connecting small remote agencies or ATMs so they can benefit from affordable communications services to check and clear transactions.

Satellite companies have been working in partnership with banks to help deliver reliable access to banking services. In 2015 Inmarsat, working in partnership with the Equity Bank Group helped to deliver financial services to 200 sites across Kenya using portable terminals, including some of the most remote places in the region, and extend financial inclusion to the unbanked and unconnected. Local agents can also use this connectivity to offer other data-based services, which increases business opportunities both for them and the wider community. Each of the satellite terminals were provided with smart devices preloaded with information on banking and finance subjects, addressing local knowledge gaps and helping to drive economic growth.

Satellite technology played a key role in the last Burkinabe Presidential Election's process. Together with Commission Electorale Nationale Independante (CENI) and a number of key partners, SES provided a satellite broadband solution that enabled secure digital transmission of the electoral results. The main 368 electoral offices were equipped with satellite services and served as hubs for the collection and transmission of the votes from over 18,000 polling offices across the country to the central CENI centre in the capital, Ouagadougou.

The SES platform was at the core of the set-up to connect the electoral district offices, even in the most isolated regions. Each site was equipped with a VSAT station, allowing a rapid transmission of data towards the collection server at the central CENI office. The raw data was automatically sent to a specialized server for its process. Via a satellite terminal, the Public TV of Burkina Faso (RTB) could then collect the obtained graphs, showing the evolution of the results in near real-time, and broadcasted them live. On top of the IP connectivity, the system also provided a Voice over IP (VoIP) service allowing each site to establish voice calls with the CENI headquarters. This voice service was also used for the technical support related to the processing of the election results. Thanks to satellite technology, voters' voices, even from isolated or remote regions, could be heard.

The role of the private sector

Importantly, the AfSA recognises that Africa's space future cannot be built by governments alone. The private sector must play a central role in driving innovation, investment and commercialisation. This aligns with a growing recognition that the 'NewSpace' economy characterised by startups, commercial innovation and private sector participation is likely to shape Africa's long-term competitiveness. The market has long been marked by promise and frustration in equal measure. On one hand, it is sustained by a growing pool of private firms, academia and strong regional and international partnerships. On the other, as evidenced by a 2019 survey of the African Earth Observation (EO) private sector, commissioned by the African Union, the market has to navigate prohibitive data pricing, scarce infrastructure and fragmented regulations.

Private African space companies are already providing solutions in the form of satellite data analytics, drone technology, geospatial mapping, satellite manufacturing, connectivity services and climate intelligence.

Governments, the key stakeholders for satellite-based services in agriculture, disaster response and natural resource management, simultaneously regulate the sector, provide competing services in-house and route procurement to established foreign suppliers often through donor-tied contracts that exclude local firms by design. Many African space startups still face major barriers, including limited access to capital, weak investment ecosystems, inadequate regulatory frameworks, limited technical infrastructure and high operational costs.

Unlike traditional government-led programmes, private-sector-led projects (or public private partnerships) tend to advance, innovate more rapidly and create jobs more directly. Industry experts increasingly argue that governments should focus on creating enabling environments rather than overregulating emerging innovators and becoming commercial competitors with private sector actors. The future of Africa's space economy may, therefore, depend less on state ownership and more on strong public–private collaboration.

Eutelsat and SES focus on broadband

Among global operators, Eutelsat and SES are the most active on the African market. Both operators have long worked in the DTH market and today point to Africa as one of the priority areas for the development of satellite broadband services. Eutelsat's main activity at the moment is centered around the ultra-high-capacity Eutelsat Konnect satellite whose commercial operation began at the end of 2020. The operator has signed agreements with several providers and renders services in a number of African countries, expanding its footprint: the company now operates in a total of 27 countries.

Among the latest contracts, there is an agreement with Liquid Intelligent Technologies who will not only provide Konnect services in Uganda, South Sudan and the eastern regions of the DRC but will also build the first Eutelsat Konnect gateway in Africa, allowing the provider to count on a leading role in the distribution of Konnect services in that market. Liquid is already a longtime partner of Eutelsat: the company uses the bandwidth of the Eutelsat 7B satellite to organize VSAT networks in sub-Saharan Africa. The provider notes high demand for bandwidth from existing customers who are ready to switch to higher-speed Ka-band service.

SES, too, has long been cultivating the African market through partnerships with local operators. The largest of them, InterSat, cooperates with SES to build communications networks in remote regions of 32 African countries. The operator plans to reach a new level of service for the African connectivity market with the commissioning of the medium-altitude O3b mPower constellation, the launch of which is scheduled for the end of 2022. Here SES builds its strategy based on cooperation with mobile operators. One of the main partners is Orange: this operator operates in 18 African states and has already launched services in several countries via the first-generation O3b constellation. One of the first users of O3b mPower will be Sonatel, the company's subsidiary in Senegal, and Orange has already deployed the first African O3b mPower gateway with Sonatel.

First SBAS open service

NigComSat-1R, the Nigerian Communication Satellite, is successfully utilising its L-band/ SBAS payload as the backbone in a partnership between NIGCOMSAT Ltd, Thales Alenia Space and the Agency for Air Navigation Safety in Africa, and Madagascar, ASCENA to provide a Satellite-Based Augmentation System (SBAS) that broadcasts signals over the Africa and the Indian Ocean (AFI) region

This aims to provide the first SBAS open service in this part of the world on NigComSat-1R satellite, a communications satellite managed and operated by NIGCOMSAT Ltd under the Federal Ministry of Communications and Digital Economy of Nigeria.
The open service was provided as part of the "SBAS for Africa and Indian Ocean" programme, which pursues the autonomous provision over the continent of SBAS services to augment the performances of the satellite navigation constellations GPS and Galileo.
The system prototype uses a reference stations network, the SAGAIE network, deployed by CNES (National Centre for Space Studies, France) and ASCENA with the support of Thale Alenia Space.
The signal is broadcast via the SBAS payload on NigComSat-1R and uplink station in Abuja (Nigeria). It is compliant with the standards and recommended practices of the International Civil Aviation Organisation and the Minimum Operational Performance Standard developed by the Radio Technical Commission for Aeronautics (RTCA) organisation. It will be visible in the whole of Africa and the Indian Ocean up to the West Australia coast and also in Europe.

SBAS Project Manager, Dr Lasisi Salami Lawal, said that the development would improve GPS accuracy to within a metre and boost integrity, availability, and continuity of safety-related applications.

According to Dr. Lawal, the SBAS services would improve flight safety and efficiency in Africa, as well as support safety and commercial applications related to land, sea, and rail transportation which are beneficial to the economy.

The project manager further noted that the open service is essentially aimed at carrying out technical trials as well as partnering with airlines, field demonstrations for aircraft and rotorcraft, to demonstrate the benefits of the future operational safety-of-life SBAS services expected from 2024. It is expected to include Precise Point Positioning (PPP) and emergency warning service to populations, which performance will be proven through demonstrations.

"The signal-in-space is generated by a dedicated system tested and developed as part of the SBAS for Africa and Indian Ocean preliminary design phase, which is financed by the European Union and awarded to Thales Alenia Space, a joint venture between Thales (67%) and Leonardo (33%). The SBAS for Africa and Indian Ocean is based on the European EGNOS developed by the European Space Agency (ESA) acting under the delegation of the European Commission and operated by the European GNSS Agency GSA," he added.

The development, according to the satellite company, will leverage on the Nigeria digital policy as led by Minister of Communications and Digital Economy, Dr. Isa Ali Ibrahim, which among other things emphasised the implementation of the regional satellite-based augmentation system.

The SBAS service, which is one of the several socio-economic derivatives of NigComSat-1R, is expected to grow the GDP and value proposition not only in the communications sector but also in aviation, maritime, rail transport, precision agriculture, survey, oil and gas, security of strategic national infrastructure and mass-market applications for sustainable development within and beyond Nigerian shores.

APPOINTMENTS

Victoria Strand appointed EVP and Head of Business Area OLRT

Victoria Strand has been appointed EVP and Head of Business Area OLRT of SSC Space. Victoria Strand has served as Interim Head of OLRT since December 1, 2025. She takes office today and will be part of the Executive Committee.
Victoria brings extensive leadership experience from large industrial companies, most recently serving as CEO of Stora Enso Forest Sweden. She holds a Master of Science in Mechanical Engineering and Business Administration from Linköping University.

“I would like to congratulate Victoria on this well-deserved appointment as EVP and Head of Business Area OLRT. Victoria brings solid leadership and industry experience and a strong customer focus. I look forward to continuing our journey together as we advance Europe's access to space,” says Charlotta Sund, President and CEO of SSC Space.

“I am excited to lead Business Area Orbital Launch & Rocket Test as we continue developing Esrange Space Center as a key European spaceport and creating new opportunities for customers seeking to launch satellites into orbit. Demand for reliable launch services is growing rapidly across the commercial, institutional, and defense sectors,” says Victoria Strand.

Bright Ascension welcomes John Bone as Chief Commercial Officer

Bright Ascension has appointed John Bone to Bright Ascension as itsnew Chief Commercial Officer (CCO), strengthening our leadership team as we continue to grow and support an increasing number of spacecraft programmes worldwide. Prior to joining Bright Ascension, John held senior commercial leadership roles with leading UK and European space organisations, including Orbex, Rhea Group, Telespazio and CGI.

With more than 20 years' experience across the space and software industries, he brings a deep understanding of the commercial and institutional space sectors and a proven ability to help organisations grow, scale and deliver value to customers. As the space industry continues to evolve, we're seeing increasing demand for software that enables organisations to develop, integrate and operate spacecraft with greater confidence and efficiency.

John's appointment reflects our continued investment in ensuring Bright Ascension is well positioned to support that growth. As Chief Commercial Officer, he will lead our commercial strategy, bringing together our sales and marketing teams to strengthen customer engagement, expand our global reach and ensure we continue delivering value to organisations building the next generation of space missions.

Bright Ascension has built a strong reputation for delivering mission-proven software that supports satellite missions from concept through to operations. As more organisations enter the space sector, we're committed to making that experience and expertise even more accessible.

Arqiva appoints Simon Duffy as Chair

Arqiva announces the appointment of Simon Duffy as Chair of the Board, effective 01 October 2026. Simon Duffy is an experienced business leader who has held executive and non-executive roles across public and private companies in the UK and internationally. He brings extensive board-level experience spanning the media, telecommunications, technology and entertainment sectors, having served with organisations including Oger Telecom, Wizz Air and Millicom. He also has a strong executive track record in corporate transformation, finance and governance, having held senior leadership positions including Chief Executive Officer of NTL and Chief Financial Officer of Orange.

He currently serves as Non-Executive Chair of Modern Times Group AB, Viaplay Group AB and LW Theatres Limited, and as a Non-Executive Director of LW Entertainment Holdings Limited. Shuja Khan, Chief Executive Officer, said: "Following a comprehensive search process, Simon emerged as the outstanding candidate to lead Arqiva's Board. On behalf of everyone at Arqiva, I am delighted to welcome him as our new Chair. His deep experience across telecommunications, media and technology, combined with his strategic insight and operational and financial expertise, will bring a valuable perspective to the Board as we continue to deliver our strategy and create long-term value.

"I would also like to sincerely thank Scott Longhurst for his leadership and stewardship as Interim Chair." Simon Duffy, incoming Chair, said, "I am thrilled to be joining Arqiva as Chair. Arqiva plays a vital role in the UK's communications infrastructure, providing services that millions of people and organisations rely on every day. "The company has distinctive capabilities, long-standing customer relationships and a critical role to play as the markets it serves continue to evolve. I am excited to work alongside the Board, Shuja Khan, his leadership team and colleagues across the business as we build on Arqiva's strong foundations, deliver its strategy and create opportunities for future growth.”

Myriota Appoints Richard Leon as Chief Financial Officer

Myriota, a global leader in Satellite IoT technology, has announced the appointment of Richard Leon as Chief Financial Officer as the company prepares for its next phase of global growth and an upcoming capital raise. A highly accomplished public markets CFO, Richard joins Myriota following a career leading technology companies through major growth milestones, including global expansion, strategic acquisitions and successful capital raises. Most recently, he served as Chief Financial Officer at Altium Limited, returning to the company after serving as its CFO from 2008 to 2016. He played a central role in Altium's landmark A$9.1 billion acquisition by Renesas Electronics and led a capital raise totalling A$45 million.

Between those appointments, Richard was Chief Financial Officer at Infomedia Ltd from 2016 to 2021, where he led an A$85 million raise and delivered a fourfold increase in Infomedia's share price during his tenure. His appointment comes at a pivotal stage in Myriota's growth. The company is advancing its position as the global platform for physical world intelligence, enabling organisations to connect remote assets at scale and transform field data into operational insight. Richard's experience helping technology companies navigate defining periods of growth will be instrumental as Myriota prepares for its next phase of expansion.

Vantor Appoints Will Cocos to Lead U.S. Government Business

Vantor, the leader in unified spatial intelligence, announced that Will Cocos has been appointed Executive Vice President and General Manager of its U.S. Government business. Cocos will lead Vantor's work across the U.S. defense, intelligence and civil government communities, with a focus on accelerating the delivery of mission-ready capabilities to warfighters and other operators.
Cocos has served as Vantor's Chief Transformation Officer since 2023, helping shape the company's strategy and expand its spatial intelligence capabilities. Over the past year, he has helped drive growth in Vantor's international business, including supporting the company's partners in conflict zones. That work has given him firsthand insight into how rapidly evolving battlefields are changing customer needs and what it takes to move technology into operational use quickly.

Cocos brings that perspective to Vantor's U.S. Government business as missions grow more complex and decision timelines shrink. Warfighters, commanders, analysts and civil government users need more than just data; they need trusted intelligence delivered fast enough to act. They also require technology that works where the mission happens — from contested tactical environments to disaster response and humanitarian operations.

“My priority is getting the right capabilities into the hands of U.S. warfighters, analysts and other mission users faster,” said Cocos. “Vantor has an incredible team with deep technical expertise and dedication to the mission. We need to stay relentlessly focused on what our customers need, including sustaining what they rely on today, removing friction and moving new technology into operational use. That means building for real-world conditions: under time pressure, at the edge and in environments where connectivity or GPS cannot be assumed.”

Kinéis appointment of Thomas Hiriart as General Manager

Against this backdrop of strong growth, Kinéis announces the appointment of Thomas Hiriart as General Manager. With experience in high-value-added industrial and technology sectors, he will be responsible for accelerating international commercial deployment, structuring the company's offerings and services, strengthening strategic partnerships with major European customers, and preparing the next IoT/AIS constellation planned for 2030.

A graduate of ISAE-Supaero and the Georgia Institute of Technology, and holder of an INSEAD MBA, **Thomas Hiriart** has built his career across space agencies, industrial players in the sector and strategy consulting at BCG. He subsequently led the development of ION-X, supporting the deeptech from its early stages through its first technological, industrial and commercial successes.

"With 25 satellites launched in 2025 and a fully operational constellation since last summer, Kinéis is Europe's first operator of its kind, offering global and fully sovereign connectivity. I am honoured to join the company and put my energy and experience at the service of this outstanding project, whose applications in civil protection, energy, logistics, the environment and defence are of paramount importance."

HawkEye 360 Appoints Christina Hoggatt Senior Vice President of Global Communications

HawkEye 360, Inc.,, a global leader in signals intelligence data and analytics, announced the appointment of Christina Hoggatt as Senior Vice President, Global Communications. She brings more than 27 years of marketing and communications experience across aerospace, defense and national security, with expertise spanning brand strategy, strategic communications, executive engagement and global stakeholder outreach.

In her new role, Christina will lead HawkEye 360's global strategic communications and marketing strategy, helping strengthen the company's market position, deepen customer and partner engagement, and support continued growth as demand for commercially available signals intelligence expands worldwide.

“Christina brings deep national security experience and a strong understanding of how to connect innovative capabilities with customer missions and business priorities,” said John Serafini, Chief Executive Officer of HawkEye 360. “Her leadership will bring an even greater strategic focus to our marketing and communications efforts, aligning how we position our capabilities, engage key markets and support the company's growth priorities. As HawkEye 360 expands its global presence and role in critical customer missions, that integrated approach will be increasingly important.”

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Europe's NewSpace startup NewOrbit Space announces Joel Krajewski as Technical Advisor

Europe's NewSpace startup NewOrbit Space announces the appointment of Joel Krajewski as a Technical Advisor to NewOrbit.
Joel Krajewski is an accomplished planetary mission leader and systems engineer, formerly Deputy Chief Engineer for Planetary Science at NASA's Jet Propulsion Laboratory.
He led Mars Cube One (MarCO), the first interplanetary CubeSats, proving that small, low-cost spacecraft could operate in deep space while relaying data during the InSight landing.

MarCO was developed under unusually tight constraints for a NASA mission: a team of around 20 people, which went from concept to launch in 2 years. It proved that a small, focused team could deliver an ambitious spacecraft mission quickly and cost-effectively.
His leadership across MarCO, Mars Science Laboratory, Phoenix and the Mars Exploration Rovers has been recognised with four NASA medals, including two Outstanding Leadership Medals.

Mark Peller named United Launch Alliance President and Chief executive officer

United Launch Alliance (ULA) named veteran aerospace industry executive Mark Peller as its next president and chief executive officer effectively immediately. Prior to being named to the top position at ULA, he served as the chief operating officer responsible for the operations of the Atlas and Vulcan launch vehicle programs, including engineering, supply chain, production, launch, quality assurance, information systems, and overall program management and integration.
“This is an exciting time in the launch industry where there is unprecedented demand for access to space,” said Robert Lightfoot, president of Lockheed Martin Space and ULA board chair. “We see a strong future with continued growth for ULA and have tremendous confidence in Mark's ability to lead this company.”

Peller has been at ULA since its formation in 2006 and led the development of the Vulcan rocket from the inception of the program through its successful entry into service and certification for US government missions.

“We completed a thorough, months-long process where both internal and external candidates were interviewed,” said Kay Sears, vice president and general manager of Space, Intelligence & Weapon Systems for Boeing as well as ULA board member. “Mark's background coupled with his extensive knowledge of both ULA's business and technical offerings, make him the best candidate to fill the CEO position.”



Voyager Appoints Patrick Yarborough to Lead Investor Relations

Voyager Technologies appointed Patrick Yarborough as vice president, Investor Relations, effective immediately, bringing more than a decade of capital markets, investor communications and corporate development experience to the company.
“Growing a public company requires growing the market's trust in it,” said Phil De Sousa, chief financial officer, Voyager. “As we scale our capital base and investor footprint, having someone who has sat on both sides of the table advising companies and allocating capital will be critical to earning long-term confidence from the market.”

Yarborough most recently served as the strategic transactions lead at Lockheed Martin Space, where he focused on the evolving space and defense technology landscape, translating corporate strategy into actionable inorganic growth opportunities and transaction execution through financial and market analyses. Previously, he was an investment strategist at Obermeyer Wood Investment Counsel, serving on the Investment Committee for a multi-billion-dollar investment platform and engaging directly with management teams and investors on business outlooks and portfolio positioning. Yarborough also spent nearly a decade at UBS Investment Bank, where he advised founders, executives and boards on IPOs, follow-on offerings, PIPEs and private financings and led investor-facing preparation for roadshows and equity transactions.

Kymeta Appoints Former Senior Intelligence Official Elizabeth Kimber to Drive Growth with National Security Partners

World-leading flat-panel satellite terminal manufacturer, Kymeta, today announces former senior intelligence official, Elizabeth Kimber, as its new Chief Growth Officer. The strategic appointment will continue Kymeta's expansion across the U.S. Department of War, the Intelligence Community, and other key national security customers.
In her new role, Kimber will bring together Kymeta's innovative technology, products, capabilities, and domain expertise to solve some of the most critical communications and mission challenges faced by the company's customer base. Kimber joins the team officially after sitting on Kymeta's Board of Advisors since 2024.

“Beth's appointment as Chief Growth Officer marks an important step in Kymeta's strategy to accelerate growth across defense and government markets,” said Manny Mora, CEO of Kymeta. “Beth brings an exceptional depth of experience across the national security and intelligence communities, with a first-hand understanding of the complex operational challenges facing today's operatives. Her insight into evolving mission requirements, and the critical role of advanced communications in delivering operational advantage, will be invaluable as we continue to expand our presence within the U.S. Department of War.”

“With demand for secure, resilient multi-orbit, multi-band connectivity accelerating, Beth will play a pivotal role in strengthening our strategic partnerships, deepening engagement with national security customers and ensuring Kymeta's technology delivers mission-critical capabilities where they are needed most.”

Kimber joins Kymeta following a distinguished 37-year career at the Central Intelligence Agency (CIA), culminating in her role as Deputy Director for Operations (DDO) where she oversaw CIA's worldwide foreign human intelligence (HUMINT) operations and covert action missions.
She also served as Acting Deputy Director of CIA; Assistant Director of CIA for Europe and Eurasia; Deputy Director of the National Clandestine Service, and Chief, Special Operations Department, Counterterrorism Center.
She spent 18 years in the field including assignments as Chief of Station and Director of National Intelligence (DNI) Representative. Following an illustrious career in the Intelligence Community, Kimber joined Two Six Technologies as Vice President of Intelligence Community Strategy.
“Having worked closely with Kymeta over the past two years, I have seen first-hand the potential of its metamaterials technology to address some of the most pressing, modern communications and RF challenges facing our defense and intel communities today,” said Kimber. “In national security operations, secure, resilient and reliable connectivity is a mission-critical necessity. Kymeta is redefining what's possible for mobile and resilient communications and is uniquely positioned to deliver the capabilities required to operate effectively in increasingly complex and contested environments.”

Planet Labs: How a satellite startup takes a flight to feed the world



As global food production struggles to meet rapidly growing demand, a nanosatellite startup dares to photograph the entire planet every day, providing unprecedented visibility and business tools to feed the world.

Intervening with nature, humanity triggered the chain of events from dangerously increasing global temperatures, greenhouse gasses, and sea levels which all recorded all-time highs as of 2023, according to World Meteorological Organisation, to raging extreme weather events such as wildfires in Hawaii, floods in Libya, droughts worsening in the Horn of Africa, the list goes on to every corner of our world. However, if we can stop deforestation there could be a chance to make things right.

Tropical forests store almost 50% of the global carbon which means the carbon goes back to the atmosphere when they are cut down. Even though we need the trees to clean the carbon dioxide more than ever, we lose 8.1 billion tons of trees every year, increased by 10% since last year (WRI s.d.), and create 4.8 billion tons more emissions because of it. The main causes of deforestation are agricultural production and increased land use for pasture, mainly happening in Brazil and Indonesia, taking approximately 50%.

Of the many organizations addressing this challenge, one of the most universal is the United Nations, which pledged to protect the lands with the Sustainable Development Goal 15: Life on Land yet, 75% of the targets under SDG 15 are off track (UN 2023) and remains to be a major challenge in all geographical regions. The struggle of insufficient comprehensive data, especially in lower-income countries, creates significant knowledge gaps, leading to ineffective policy-making and hindering the advancements toward achieving the goal.

Bringing easy-to-understand, affordable, transparent real-time information to the heart of local communities is needed to accelerate the change. By providing daily images of Earth's landmass from every point to local stakeholders, Marshall and his team are now closing the data gaps with their low-cost satellites in orbit

From a garage to the orbit

Marshall was deeply inspired by the UN conference themed 'Use of Space to Help Humanity' he attended. He started to fierily seek ways to use satellites for achieving what was then known as the Millennium Development Goals.

Schingler and Boshuizen with the same questions in their mind, crossed paths with Marshall at the conference. As the three started to discuss in excitement, their shared passion bonded the NASA engineers. Fueled by inspiration, the trio started to work in the garage of a community house in Cupertino with a simple yet profound mission, helping life on Earth by taking images of Earth every day. Determined to go beyond orbiting satellites, Marshall, Schingler, and Boshuizen identified three crucial areas that need to change in the space architecture including decreasing the cost of the mission to go to space, miniaturization of space technology, and transition to cloud computing.

The three didn't believe in big, multimillion-dollar traditional satellites and they realized to make this change possible, building and launching their fleet of low-cost, small satellites that could be produced in large quantities was necessary.

With their north star ahead to make Earth observation continuous, transformative, and accessible for all, Marshall, Schingler, and Boshuizen founded the startup, Planet, formerly known as Cosmogia in 2010. Development of their satellite and software involved countless iterations in design and testing since they were applying the rapid application development methodology to their earth observation technology. With this new approach in space science, Planet became the pioneer of what they called “agile aerospace”. After 14 iterations, Planet's first CubeSat satellite named “Dove” in the size of a shoebox and weighing approximately five kilograms, was completed. In April 2013, their first demonstration satellites, “Dove 1” and “Dove 2” were deployed into the orbit.

The following summer of 2013, Planet raised its initial funding at $13.1 million and closed its Series B funding at $52 million in December. By the beginning of 2014, Planet was able to deploy its first fleet "Flock 1" with 28 satellites, the largest earth observation constellation in the human record until that day.

Ally for Sustainable Development Goals

Planet's first mission was capturing daily images of the Earth and believed in the value of Earth data for tackling humanity's problems in a transformative way. Thereby, Planet didn't find it hard to align its capabilities with the objectives of the United Nation's Sustainable Development Goals. Not only that, but Marshall also received an invitation to the UN's summit took place in 2015, to advocate the possibilities of space technologies, satellite imagery, and the important role of collaboration between organizations to meet the SDGs. He was feeling privileged to be in the very position where once he stood, attentively listening and envisioning ways to aid humanity through space technology. In his speech, Marshall made it clear that his own company Planet will be dedicated to making their data available to initiatives that are in line with the SDGs. Marshall continued his words by emphasizing how relevant Planet's data is for 15 out of the 17 goals and how they can help monitor more than 70 of the objectives directly and indirectly. SDG 15 was the first one on his list.

As Marshall was explaining how Planet's daily imaging could be used to track changes in forests to identify and prevent deforestation activities, he was already envisioning Planet's potential to do much more. Their first action was to make $60 million worth of imagery available under the Global Partnership for Sustainable Development Data. Next, they didn't waste time in initiating cooperation with the Global Resilience Partnership, an organization focusing on sharing innovation and knowledge for accelerating sustainability policies.

Earth Data Solutions

Planet has two constellations of actively orbiting satellites: PlanetScope and SkySat which can capture images of the Earth in different resolutions, coverages, and frequencies. This way, they deliver geospatial data in different layers of information for diverse needs. Their products can be divided into three main categories: medium-resolution daily imagery, high resolution tasking imagery, and tools to leverage and analyze the Earth data. Planetscope constellation consists of Dove and SuperDove satellites which are used to provide global, daily imagery with pixel resolutions of 3 meters which costs around $300 thousand with 3 years of useful life.

SkySat constellation, on the other hand, has satellites with a higher pixel resolution of 0.5 meters that can also capture stereo imagery and 90-second videos, making them useful for tasks that can be alerted from the images. SkySat constellation is planned to be replaced with the next generation satellites called Pelican which will cost approximately $4 million with 5 years of useful life. Their RapidEye satellites due to the end of their useful life have retired in 2020, however, their archive of imagery going back until 2009 makes Planet the owner of one of the largest archives for 5-meter pixel resolution imagery.

In total, Planet has safely deployed 542 satellites with currently more than 200 active satellites orbiting the poles every 90 minutes capturing Earth's whole landmass in approximately 4 million images every day. Planet is also holding the record of managing to launch the largest fleet of earth observation satellites, Flock 3p, in human history still today with 88 Dove satellites. As an early mover, Planet was able to expand its imagery capabilities which can cover 40 times of landmass more than from its closest competitors daily with more than 10 years of historical archive. This irreplaceable historic geospatial data is one of the Planet's great “moats” which is used for timeline analysis solutions and training data for machine learning.

On top of the Earth data, Planet provides a cloud-based, machine-learning-powered analytics and monitoring platform, as well as application programming interfaces (API), allowing users to examine the images, acquire insights to analyze patterns and forecast change. The platform delivers daily measurements of land use, crop health, land surface temperature, forestry, and more by rendering complicated satellite images. Planet uses a fixed-price subscription model and usage-based contracts to sell its licensed data and analytics tools. By the nature of their business model, they generate a large recurring revenue base and lower costs to serve one more customer. This "land-and-expand" go-to-market strategy, allows Planet to generate more value from each customer over time through broadening their scope of services and products.

Planet collaborates attentively with its customers and partner organizations to make sure of their early success and provides support for account and technical management. Over the years, Planet was able to grow its customer portfolio to more than 700 customers, 200 partners, and 34,000 users by expanding its geographical coverage and enhancing its data and software capabilities. Planet operates across large commercial and governmental verticals, serving more than 10 industries including agriculture, defense and intelligence, forestry, energy, insurance, and disaster management. For commercial uses, global and high-frequency geospatial data have been used to measure the effectiveness of sustainable agriculture applications, to identify possible food security risks, and to monitor extreme weather events which include drought, threats to biodiversity, and wildfire.

On the side of nonprofit and non-governmental organizations that support humanitarian actions, Planet's data have been used for evacuation of civilians in disaster-stricken areas, damage assessment for infrastructure, measuring the impact of food supplies, as well as tracking human rights abuse cases and de-mining operations. Established partnerships with governmental bodies also demonstrate the importance of Planet's products in measuring and verifying sustainability performance which is crucial to understanding the progress of enforced policies.

Earth Observation Market

During the last decade, the new space industry has been growing at an accelerated speed, becoming the central source for digital transformation. One key driver of this transformation is the increasing number of private actors emerging with innovative approaches. Based on the Union of Concerned Scientists Database, 1168 EO satellites were orbiting in January 2023 and almost 50% were commercial satellites. The global earth observation market was worth around $17 billion in 2022 and the US is taking up the biggest piece with around 32%. The market is expected to grow at a CAGR of 7%, yet, it seems that earth observation technologies are still in the early phases of the adoption curve. Lack of awareness of the benefits or financing for these technologies especially in developing countries, and gaps between technology and user skills are the continuing bottlenecks. Although technologies such as spaceborne LIDAR which can measure vegetation and canopy height, EO data products, and synthetic EO data are expected to reach the "plateau of productivity" at least in 10 years, solutions powered by EO are proving its importance.

Let Them Eat… What?

According to the UN Food and Agriculture Organization, the world's farmers will need to produce 70% more food relative to 2006 levels to meet the demand of 9.2 billion people projected to inhabit the planet by 2050. Further intensifying this pressure is global climate change. Extreme weather events like droughts and flooding, and long-term changes such as rising sea levels are damaging crop yields and shortening growing cycles. Production levels are already flattening, with yield plateaus, or even abrupt drops in yield gain, among 31% of total global rice, wheat and maize production. As most of the land suitable for farming is already farmed, incremental food production globally must come from higher yields.

But fear not, the “it” technology of the day, namely Internet of Things, has come to the industry's aid. Smart farming aims to make existing arable land more “intelligent” through an amalgamation of connected technologies, such as sensors to collect information on productivity factors, including temperature, humidity, soil moisture and nutrient content, threat from weeds, pests and diseases, software to monitor input and remotely control connected harvesters and irrigation equipment; unmanned aerial vehicles to control crop picking; and geospatial technologies to monitor and optimize crop health and production and farm operations.

Forestry landscape

The United Nations has recognized that space technologies are essential for managing natural resources and particularly earth observation as an enabler for the Sustainable Development Goals. At the national and regional level, policies and developments to advance upstream such as infrastructure, and downstream such as platforms for geospatial data, are supported to achieve SDGs. On the global scale, the UN's Global Geospatial Information Management committee and Group on Earth Observations have been working towards the availability and use of geospatial data.

EO4SDG initiative of GEO and Copernicus program of the European Union have been the early initiatives with the mission of advancing the effective use of EO for SDGs. While several digital efforts centered on the environment and the sustainable use of natural resources are expanding, their coordination, guidance on effective use, and calls to action directed for the SDGs are needed particularly for regions with limited access to resources.

EO as the enabler, 16 out of 17 SDGs in different levels of coverage for their indicators
can be directly measured or indirectly supported. In fact, one of the most contributed goals is 15: Life on Land which is "primarily focused on sustainable forest management, slowing and reversing land and natural habitat deterioration, successfully battling
desertification, and reducing biodiversity loss".

From its set of 12 targets and 14 indicators (Exhibit 9), EO technologies can contribute to 8 targets and 5 indicators. The linkages weren't unexpected since forest mapping applications have been carried out since the first landmass monitoring satellite Landsat 1 launched in 1972. Nowadays forest stakeholders can access a wide range of data on forest management, temperature and soil, tree species spread, and

Artificial intelligence in Africa

As the storm clouds finally cleared, Esther stood at the edge of her shattered farm, her heart sinking into the muddy earth beneath her feet. The fields, once vibrant with the promise of harvest, lay in ruins crops uprooted, trees snapped, and the soil washed away by the merciless deluge. Her hands trembled as she thought of her children, huddled inside their modest hut, where the rain had leaked through the roof and hope seemed to drain away with every drop. They deserved more than this, she thought more than a life where their poorly resourced school was a 5km slog away, and where even basic healthcare was a distant, unreachable dream. She wiped away a tear, knowing that, despite her resilience, the odds were heavily stacked against her family, and many others like them.
Artificial intelligence (AI) is set to work as a catalytic force in the economic and social transformation of Africa. While the continent is not yet a major global centre of frontier AI model development, AI adoption is accelerating through applied use cases in agriculture, health, finance, logistics, and public services. According to the African Development Bank AFDB AI could add up to US$1 trillion to the African GDP and create 40 million jobs by 2035. Even on a less optimistic growth trajectory, the bank predicts, that AI will add at least US$250 billion to the African GDP by 2035. Although starting from a low base Africa is projected to experience the fastest growth in AI spending globally, reaching US$6.4 billion by 2026. Opportunities for business are greatest in Africa, where both the private and public sectors can come together to formulate AI solutions across all sectors.

In Africa, smallholder farmers often lack access to improved seeds and fertilisers due to underdeveloped distribution systems. Fertiliser use is extremely low, averaging 8-15 kg of nutrients per hectare compared to the global average of 100 kg/ha. High prices and poor availability contribute to this limited use, while weak infrastructure and high transaction costs make inputs expensive. Only 4% of cultivated land is irrigated, compared to 37% in South Asia, making agriculture highly dependent on unpredictable rainfall. This dependency exacerbates vulnerability to climate variability, as the region lacks sufficient investment in water storage and distribution.

Access to credit is restricted due to high risks associated with agriculture and the absence of tailored financial products. Smallholder farmers struggle to secure financing for essential inputs like seeds and fertilisers, which limits their ability to enhance productivity.
Agricultural research and extension services are underfunded, resulting in limited development and dissemination of technologies suited to diverse farming conditions. This gap hinders farmers' adoption of new practices that could improve yields and resilience.
Agriculture in sub-Saharan Africa is predominantly rainfed, making it highly sensitive to climatic changes such as erratic rainfall and higher temperatures. Additionally, land degradation from deforestation and unsustainable practices threatens agricultural productivity, potentially causing significant loss of arable land by 2050.

Smallholder farmers lack access to training and support needed to adopt new technologies, reducing their ability to improve productivity and resilience against climate impacts. Governance issues, including political instability and inconsistent policies, further complicate agricultural development.
Packaging is often expensive and of low quality, limiting farmers' ability to preserve their produce. A lack of investment in packaging systems and a shortage of expertise further constrains the agro-processing sector, making products less competitive.

Inadequate cold storage facilities and poor transport infrastructure lead to significant spoilage. Without proper refrigeration, even well-packaged goods can perish, exacerbating post-harvest losses.
Poor road networks and storage facilities contribute to high transportation costs and post-harvest losses, with some estimates suggesting up to 40% of food produced is lost before reaching consumers. Low levels of mechanisation and dependence on traditional practices also limit efficiency in managing harvested crops.

Addressing these challenges requires comprehensive strategies that include improving infrastructure, expanding credit access, enhancing agricultural education, and investing in climate-resilient practices. Developing robust policies and fostering public-private partnerships can help unlock the region's agricultural potential.

TThere have been AI innovations coming out of Africa in recent years. It should be noted that over US $500 million has been raised by African AI startups since 2021. In Nigeria, a chatbot called Kudi AI extends financial services to underserved communities. A similar chatbot in South Africa called MomConnect, connects 1.8 million expectant mothers with pre-and post-natal services. Google AI lab has worked with farmers in rural Tanzania to create a machine-learning application Nuru to diagnose early onset of cassava plant diseases. The app works directly on mobile phones even without internet connectivity and prompts them to take early intervention measures by quickly identifying the onset of the disease. In South Africa MySmartFarm, Aerobotics, Drone Clouds, and FarmDrive are using AI-enabled technologies to diagnosis plant disease, make price prediction, and access financial services. Ghanian engineering company Bace Group has developed AI facial recognition software that is good at identifying black African faces. By using a more diverse dataset, their software minimises bias that is common among Western developed AI models. Kenyan startup firm Amini collects and curates farm level environmental data. Zindi, a South African data science competition platform is exploring edge computing to enable AI model training and inference on devices at the edge, reducing reliance on cloud infrastructure. Edge computing can reduce latency and lower bandwidth costs in low connectivity areas, while maintaining the data privacy.

Ethiopian startup Gebeya has come up with AI-powered digital agents tailored for African businesses. The technology is designed to automate customer engagement, support operational decision-making and reduce costs for enterprises operating in fast-growing and often fragmented markets. By embedding AI-driven tools into day-to-day operations, Gebeya aims to help businesses transition from informal workflows to structured systems that can support regional expansion and participation in cross-border trade.

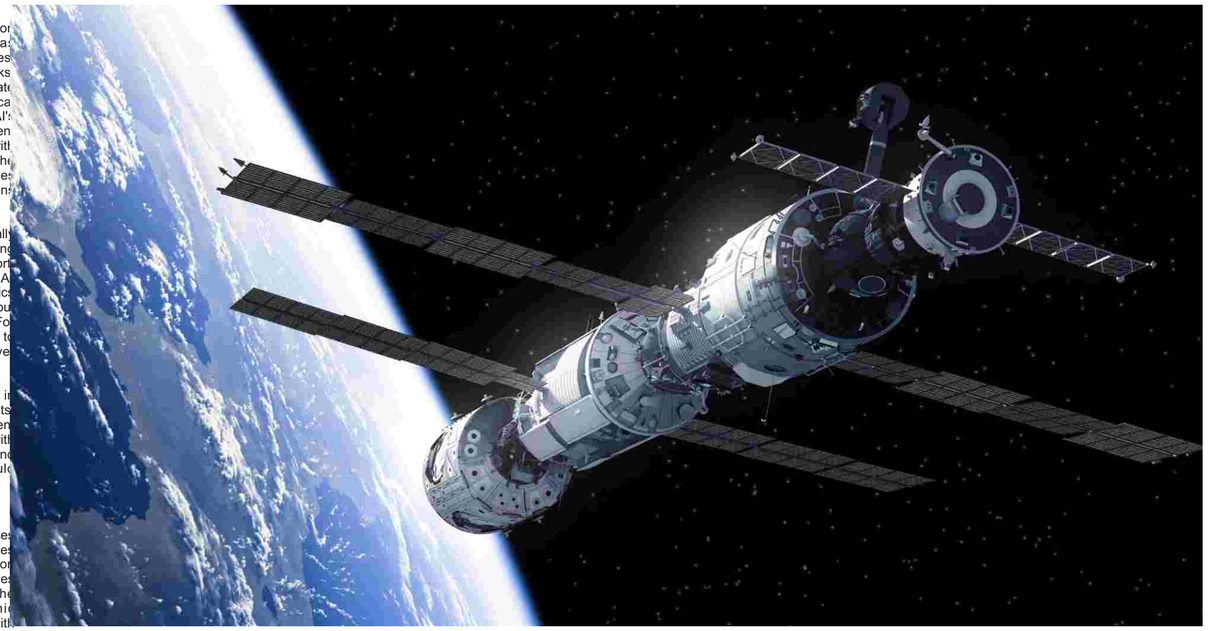
In 2018, Mauritius became the first African country to have formalised a national AI strategy. Egypt has established a National Council for Artificial Intelligence and an African Working Group on AI. South Africa has set up a Presidential Commission on the Fourth Industrial Revolution. Tunisia scored a remarkable success in 2023 when its homegrown AI startup Instadeep secured US$100m in series funding. AI labs and research centres are popping up across Africa. Morocco itself has set up AI Center of Excellence at the Mohammed VI Polytechnic University (UM6P) in Rabat and another one - the House of Artificial Intelligence in Oujda.

However, research indicates that there are significant levels of development taking place across these sectors, using the latest advances in Artificial Intelligence ("AI"). The tremendous advantages that this technology offers might just enable the region to overcome the many challenges that have historically held it back, and leapfrog it to levels of accessibility, service and productivity that have previously only been the preserve of the most developed countries in the world.

Despite the potential, challenges such as limited infrastructure and data availability remain. Collaborative efforts between local stakeholders and international partners are essential to tailor AI solutions to the diverse agricultural landscapes of the region. The transformative potential of AI across agriculture, education, healthcare, and SMEs in Sub-Saharan Africa is immense. However, realising this potential hinges on overcoming significant barriers such as infrastructure deficits, data accessibility issues, and the need for supportive policy frameworks. Collaborative efforts among governments, private sectors, educational institutions, and local communities will be vital in harnessing AI's capabilities to drive sustainable development across the region. As these sectors evolve with technological advancements, they hold the promise of not only improving economic outcomes but also enhancing the quality of life for millions across Sub-Saharan Africa.

Globally and in Africa, AI and ML are gradually reshaping education by enhancing learning experiences and providing personalised support. Machine learning, a key driver of AI advancements, allows for learning analytics, collecting, measuring, and using data about students to inform teaching strategies. For instance, Kenya's M-shule uses an AI system to assess students' competencies and deliver appropriate lessons.

However, the adoption of advanced AI in education faces challenges such as high costs, integration difficulties, and data management issues. African institutions also struggle with overcrowded classrooms, limited resources, and diverse language needs, which AI could potentially help address.



Downside of AI in Africa

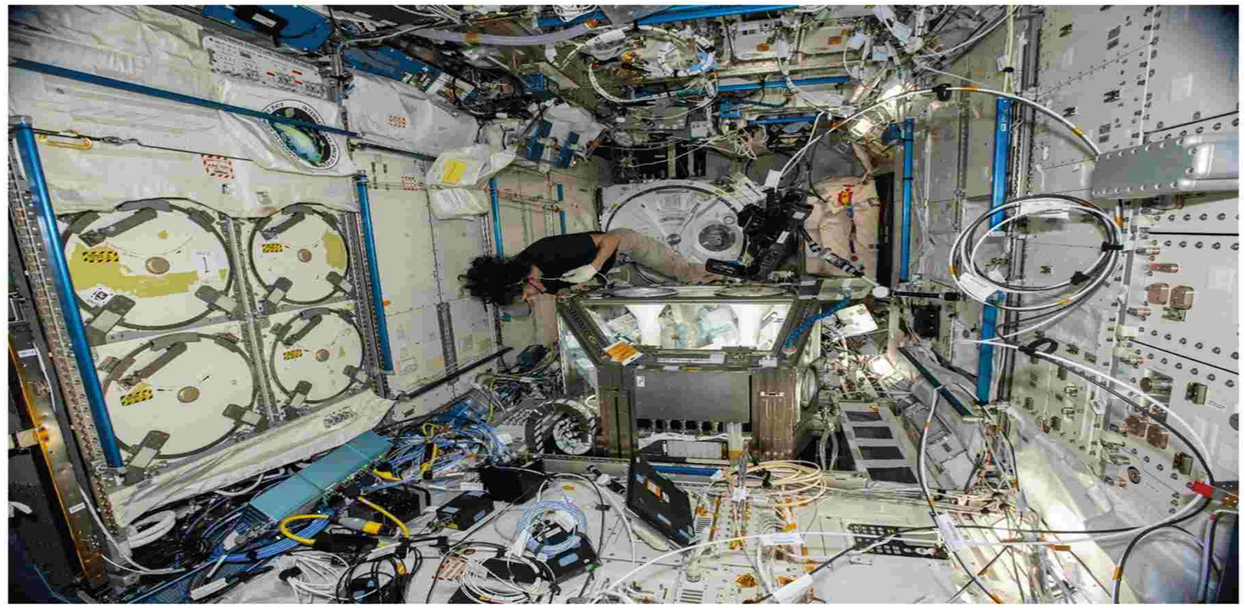
Despite AI in Africa ranking low on global indices and indicators for AI activities and formal policies — and still being in the early stages of adoption and use in business, a growing set of AI activities and communities is emerging across the continent. Coalesced around academic institutions, and usually in conjunction with industry and development partners, new interdisciplinary machine learning communities are providing opportunities to showcase skills, cascade opportunities for participation in projects, and gain a better understanding of developments in the field.
While AI presents an enormous opportunity to dramatically contribute to a broad range of sustainable development goals such as reducing poverty and hunger, quality of education for all, clean water and sanitation, affordable and clean energy, and peace justice and strong institutions , Africa is not able to take full advantage.
When measured on government AI readiness, the African continent is among the lowest-scoring regions on average, in part due to few countries in the region having set out their vision for the implementation of AI.A lack of preparedness to harness the tools that widespread adoption of AI would bring hampers the introduction of useful AI-based interventions that would solve many of Africa's most pressing social and economic problems. This reality could potentially entrench economic inequality and render obsolete already poor public services. Notwithstanding this bleak picture, an AI ecosystem exists in Africa, with evidence of pockets of activity that could be prioritized, coordinated, and funded to result in an energized and productive AI infrastructure.

While global technology companies such as IBM in Kenya and South Africa possess the essential elements for AI R&D, namely the financial, human, data, and computational resources to deploy sophisticated algorithms African governments and local start-ups face a deficit in these areas. Creating an efficient AI ecosystem that supports innovation requires successful collaboration, governance, investment, sound infrastructure, and skills. In African countries, this under-resourced ecosystem is attributable to governments' lack of vision and supporting policies to improve AI implementation, digital capacity, adaptability, technology sectors that are small and lacking in scale, human capital, and infrastructure and data availability .In addition, a lack of access to sufficient 16 computing power and unreliable internet limits access to cloud services.

Digital infrastructure is the foundation on which AI adoption rests, and Africa's infrastructure gaps are a major impediment to faster adoption. Only 36% of sub-Saharan Africa has access to broadband internet. Data affordability is another constraint. Even basic data plans can cost up to three times more than in regions with more advanced digital infrastructure. Africa possess only 1% of the total data centre capacity and most of that is in one country - South Africa. Data centres and the hardware needed to run AI algorithms, suck massive amounts of power. Reliable plentiful electricity is not something that Africa has in abundance. 77% of the firms in sub-Saharan Africa experience electrical outages. Cloud adoption in Africa is only 15% below 72% in Europe. This global power imbalance has elicited growing concerns about data sovereignty, as African governments and businesses are largely dependent on non-African big tech companies who host and now control much of the personal data of African citizens. AI systems learn from data. But quality up-to-date data in Africa is hard to come by, limiting datasets on which AI can be trained. Compounding this problem is the vast amount of prejudice-laced information and views about Africa in cyberspace. This is where Generative AI often derives its answers. The issue of Dataset bias has therefore become critical when it comes to the use of AI in Africa. Another major barrier is that many AI tools are built and trained primarily in English, Chinese, and European languages, while African languages have limited digital presence. If not checked the increased use of AI could leave millions marginalised. The adoption of AI in Africa faces multiple challenges not least lack of technical skills, infrastructure, lack of data, and lack of state capacity to protect their citizens' data privacy. But the most serious risk that AI brings to Africa is the prospect of further widening the existing inequalities that threaten to leave so many millions behind.

INDUSTRY REPORT

NASA Looks to Private Sector for Successor to the International Space Station



The walls would be plush, like a Las Vegas lounge, speckled with hundreds of small LED lights programmed to change color. The vibe would be cozy and modern, intended to “create a nest,” its designer says: “A comfortable and friendly egg, which would feature materials and colors stemmed from a fetal universe.”

The best features would, of course, be the windows, generously large for expansive views of the Earth below and the universe beyond because star gazing is at the center of Philippe Starck's latest creation. Instead of designing another avant-garde piece of furniture, or a luxury yacht or a gleaming hotel, the French architect and designer is working on the interior of a commercial space station that NASA hopes one day would replace the International Space Station.

For more than 20 years, the ISS has served as a continuously inhabited foothold in low Earth orbit, a way for space agencies around the world to study how humans live off the Earth for extended periods. A total of 19 countries have sent astronauts there, binding them into an international consortium that has transcended politics and the geopolitical tensions that have roiled relationships on Earth. To build the ISS, the United States and Russia combined forces with Canada, Japan and the European Union.

The program has been such a profound tool of diplomacy, as well as science and engineering, that many in the space community think it should be awarded the Nobel Peace Prize. At the very least, they think the life of the ISS should be extended. And late last year, the White House backed NASA's plan to keep the ISS operating to 2030.

But it's not clear that that the station will last that long. In recent years, it has sprung a series of leaks and has been rattled by errant thruster firings that have sent it spinning wildly. Despite its incredible durability, it cannot survive in the harsh vacuum of space forever. The extreme hot and cold temperatures take their toll. So do the bits of micrometeorite debris that the space station dodges a few times a year and occasionally gets hit. At some point, it will reach the end of its life, and NASA and its partners will be forced to coordinate its demise by deorbiting it to Earth and crashing it into the ocean.

Knowing that day may soon come, NASA is racing to find its successor. But the space agency won't be building it. After investing billions of dollars into the ISS, NASA cannot afford to build another space station in Earth orbit, especially as it is embarking on an effort to return humans to the moon, under a program called Artemis. Instead, it is looking to the private sector to develop next-generation habitats that would be owned and operated by the companies, not NASA.

The space agency has recently taken the first major steps in that direction, reaching an agreement with Axiom Space, a Houston-based company that has hired Starck, to send a module of its space station to attach to the ISS as a test bed as soon as 2024. Late last year, NASA awarded contracts to develop commercial space stations, worth $415.6 million combined, to Jeff Bezos' Blue Origin, Nanoracks, which helps companies fly science experiments and other payloads to the ISS, and Northrop Grumman, the longtime defense contractor.

The contracts are yet another sign that NASA is willing to place enormous bets on the growing commercial space industry, which has been eroding governments' long-held monopoly on space activity. Driven by the investments and ambitions of the so-called “space barons,” Elon Musk, Jeff Bezos and Richard Branson, who have invested heavily into their space ventures, the industry has taken off.

Musk's SpaceX in particular has demonstrated the commercial ventures can be successful and help bolster NASA. For years SpaceX has flown cargo and supplies for the space agency to the ISS. NASA has expanded that public-private partnership, allowing SpaceX to fly its most precious resources—its astronauts—to the space station as well. The company also recently won a $3 billion contract to develop the spacecraft that would ferry astronauts to and from the surface of the moon.

NASA is now extending this relatively new model to space stations, hoping the private sector can take on an even greater task—building destinations in space—that presents a host of even greater challenges. And it comes as some are warning that unless NASA and its partners can build the stations quickly, it could be faced with the ignominious prospect of the ISS retiring before its successor is ready. That would leave the United States with nowhere to send its astronauts, a problem exacerbated by the fact that China has started to build a station of its own.

“I think it would be a tragedy if, after all of this time and all of this effort, we were to abandon low Earth orbit and cede that territory,” former NASA Administrator Jim Bridenstine told a Senate panel in 2020.

The cost of a new space station is enormous. And so are the technical and engineering hurdles. Keeping people alive and healthy in space requires enormous vigilance: making sure they have enough to eat and drink; that they get along and don't kill each other; that they don't get hit by a micrometeorite; that they can communicate reliably to people on the ground; that they can handle sickness or injury on their own; or repair any number of problems for extended periods. It is such a daunting task that it's something of a miracle that after more than two decades there has not been any major incidents on the ISS.

Whether the private sector can build commercial stations and operate them safely, then, remains to be seen. And if it can't do that before the ISS finally reaches the end of its life, NASA would have a gap that would be even more severe than the period after the Space Shuttle was retired in 2011 with no alternative to launch its astronauts from United States soil. Instead, Russia flew NASA' astronauts to the ISS, and charged a hefty price for the service, nearly $90 million a seat, before SpaceX restored human spaceflight for NASA in 2020.

“ISS won't last forever & incentivizing the private sector to begin follow-on capabilities are needed now,” Lori Garver, who served as NASA deputy administrator in the Obama administration, warned on Twitter in 2020. “This concept isn't hard. Have we learned nothing in the last 10 years?”

On the outside, Axiom's station may look like the ISS, with solar arrays, docking ports, but the inside would be a world apart from the government-funded station. It would feature the “largest window observatory every constructed for space,” the company says. And unlike the at-times clunky and cluttered ISS, designed purely for function and astronaut survival, Axiom's station would have the attributes of a hotel, a touch of Starck's style and eye toward comfort mixed in.

“We want the customers to have this great, comfortable, luxurious feel,” Michael Suffredini, Axiom's co-founder, told The Washington Post. “We're even looking at how we cook food on orbit…to make the food a little more tasty.”

Blue Origin's station, called Orbital Reef, would also have large windows, and the initial configuration would be expansive, about 90 percent of the interior volume of the ISS, with room for nearly a dozen astronauts. And it would have the ability to grow over time, as more modules get added. The station “will provide anyone with the opportunity to establish their own address on orbit,” Blue Origin says. The company has teamed up with a host of aerospace giants—Sierra Space, Boeing, Redwire Space, Genesis Engineering and Arizona State University—that would have the station ready by the second half of the decade.

Bezos has moved slowly and steadily into the space business, his passion since he was five years old and watched Neil Armstrong and Buzz Aldrin walk on the moon. That, as he has said, was a “seminal moment” for him, that inspired him to found the company—“blue” for the “pale blue dot” that is Earth, “origin” for where humanity began—more than 20 years ago.

Bezos has said his space venture is “the most important work I'm doing.” Recently it has flown a series of people to the edge of space and back on suborbital tourist jaunts, allowing paying customers a few minutes of weightlessness and views from more than 60 miles high. The company is also building a massive rocket called New Glenn, that could reach orbit, and spacecraft that would land astronauts on the moon

But it has even more ambitious goals; Bezos says he wants “millions of people living and working in space.” In the long-term, hundreds of years from now, Bezos envisions massive space stations large enough to hold entire cities, even mountain ranges, plucked from the pages of science fiction. These stations would house thousands of people at once with climate conditions controlled by humans.

“These are really pleasant places to live,” Bezos said in 2019, during a speech in Washington. “This is Maui on its best day all year long. No rain. No storms. No earthquakes.”

That dream is a long way away and may never be realized. In the meantime, the company is partnering with Colorado-based Sierra Space to build the Orbital Reef space station. Calling it “a mixed use business park in space,” the companies say it would provide “a vibrant, growing business ecosystem in low Earth orbit that will generate new discoveries, new products, new forms of entertainment and global awareness of Earth's fragility and interconnectedness.”

One of the key components of the station are habitation modules that inflate like balloons once they reach orbit. Instead of fixed structures, these habitats can be packed into the nose cone of a rocket and then expand in space, allowing them to be transported to orbit in a single launch.

Nanoracks also plans to use inflatable modules on its station, called Starlab. Built in conjunction with Lockheed Martin, Starlab would feature a laboratory, named for George Washington Carver, the famous scientist, where companies and countries could conduct experiments.

NASA would be one of the key customers for the commercial stations. But the companies believe there will be a strong demand from others as well that would support multiple private space stations. Countries with growing space ambitions, like India and the United Arab Emirates, could be looking for a destination for their astronauts. There are companies that would want to do research in space. Entertainment could also become a revenue source. Last year, Yulia Peresild, a Russian actress and film producer, Klim Shipenko, flew to the ISS to film scenes for a movie called, “The Challenge.” Peresild plays a doctor hoping to save the life of a crew member in space. NASA has also said it is working with Tom Cruise to shoot scenes for a movie on the ISS.

Commercial space stations could change what it means to be an astronaut and who gets to become one. The companies think there would be a high demand for private citizens to go to space. Blue Origin and Virgin Galactic have already sold dozens of tickets on their suborbital spacecraft. Blue Origin even auctioned off one seat for $28 million to a crypto entrepreneur. SpaceX flew a crew of four private citizens in orbit around Earth for three days last year in its Dragon spacecraft.

While it's developing its space station, Axiom Space it working with a number of private citizens to go to the ISS on flights chartered by the company on a SpaceX rocket. The first flight, scheduled for February, would take three wealthy businessmen, who are paying $55 million each, for about a week on the station. They'd be accompanied by Michael Lopez-Alegria, a former NASA astronaut, who now serves as an Axiom vice president. The company is planning another private-astronaut mission, scheduled for later in the year, with Peggy Whitson, the decorated former NASA astronaut who was the first female commander of the ISS, to serve as the guide.

In the 200s, Russia flew a number of private citizens to the space station for the price of about $20 million each. Until recently, though, the practice was prohibited by NASA, which feared they would interfere with the astronauts. The policy was changed, though in 2019, in an effort to boost the commercialization of space.

“This is the very beginning,” Jeffrey Manber, CEO of Nanoracks, said. “We're going to enter the next decade, where you have multiple private space stations in a robust public-private partnership with NASA.”

Perhaps. But space is hard, and failure is as much a part of the history of exploration as triumph. Even behemoths such as Boeing have struggled. While SpaceX has successfully launched several astronaut crews to the ISS for NASA, Boeing has yet to have a successful flight of the capsule it is developing for the same purpose.

On its first flight, a test without any astronauts on board in December 2019, the autonomous Starliner capsule ran into trouble shortly after it reached orbit. Its on-board computer was 11 hours off, making it think it was in an entirely different point in the mission. Then another software problem could have caused a collision as the service module separated from the crew capsule. Boeing had to cut the mission short and bring the capsule back without docking with the ISS, one of its primary objectives.

The redo of the uncrewed test flight last year didn't even get off the ground. While it was preparing to launch, officials noticed that several valves in the service module were stuck. Now, that flight may not happen until at least May, and the first flight with astronauts onboard may not come until the end of the year at the earliest, which would be several years behind schedule.

Given that track record, it is not clear that the commercial space industry is up to the more daunting task of building and operating space stations. Space is rough. There are thousands of bits of debris whirling around in orbit at 17,500 m.p.h. so that even a small piece can cause catastrophic damage. From time to time, the ISS has to maneuver to avoid getting hit, and sometimes it does. In 2016, a piece of debris cracked a window. Then last year a piece hit the station's robotic arm, leaving a small puncture, like a bullet hole.

Russia last year added to the dangerous clutter in space when it fired a missile and blew up a dead satellite as target practice. It was seen as a warning to the United States and others that it could take out key satellites in orbit. But it caused a massive cloud of debris that threatened the ISS, and forced the astronauts, including two Russian cosmonauts, to seek shelter. The crew out on their spacesuits, boarded their spacecraft and waited for the worst. If debris hit the station, the astronauts were ready to abandon it for home.

Last summer, the ISS was taken on a wild ride when the thrusters of a newly installed Russian module started firing by mistake. It spun the ISS one and a half times, leaving it upside down before crews could get it back to its normal orientation. The astronauts were never in danger, NASA said, but a flight director in Houston said that he was thrilled that the solar arrays didn't snap off.

There are less dramatic mishaps as well. After more than 20 years in orbit, things break, even the toilet. The batteries need to be replaced. Every once in a while, the ISS springs a leak, like the one recently that was so small the astronauts had a hard time finding it. They were able to isolate it to the Russian segment of the station, where an enterprising astronaut opened a bag of tea and watched how the leaves floated to a barely perceptible hole.

While the partners on the ISS are working to keep it going, the Chinese are building a brand new station. Last year, it launched the first of three modules and intends to complete it by the end of 2022. Called Tiangong, or “Heavenly Palace,” the station would be home to three astronauts, and China plans to keep it in operation for a decade.

It is part of a broader space program that included the first landing of a robot on the far side of the moon in 2019. Last year, it became only the second nation, after the United States, to land and operate a rover on Mars. Viewing China as a threat, the Trump administration took a very hawkish tone when talking about its space ambitions. In a speech calling for NASA to send astronauts back to the moon, former Vice President Pence warned that China was trying “to seize the lunar strategic high ground and become the world's spacefaring nation.”

While it has sought to dismantle virtually every remnant of Trump's legacy, the Biden White House has embraced its tough stance against China. Bill Nelson, who serves as the NASA administrator for the Biden administration, has called China “a very aggressive competitor” that is challenging American leadership. And he recently warned: “Watch the Chinese.”

The intent of such talk may be political. Compared to other agencies, NASA's budget is tiny—less than one-half of 1 percent of the federal budget. Over the next few years, much of it will be tied up in its “Artemis” program to return astronauts to the moon, leaving little for space station development. So Nelson, the former Democratic Senator from Florida, knows he needs more money from his former colleagues in Congress.

His predecessor agrees. “We are not ready for what comes after the International Space Station,” Bridenstine, the NASA Administrator during the Trump administration, said during a Senate recently. “Building a space station takes a long time, especially when you're doing it in a way that's never been done before.”
NASA this year requested $101 million for the program that would develop private space stations, but Bridenstine and other have said that is not nearly enough. In his written testimony, he said Congress needed to appropriate $2 billion annually to the effort.

While NASA lobbies Congress for more money, and the companies work to develop their commercial stations, the ISS keeps humming along, orbiting the Earth every 90 minutes, as it has for years, a marvel of engineering that continues to set new records for human space exploration. Another one is set to fall shortly.

About two weeks before he returns to Earth in March, NASA astronaut Mark Vande Hei would break the America spaceflight duration record set in 2016 by Scott Kelly. In all, the former Army Colonel will have spent a total of 353 days on the station—just short of a full year but 13 more days than Kelly and any other American. During his time on the orbiting laboratory, he will have performed hundreds of experiments for scientists on the ground. But in some sense, the real experiment isn't anything in a test tube. Rather, it's him, his body—brain, bones and blood—that doctors and scientists will study to see what sort of effect space had on him, and what clues it might hold as NASA prepares to send humans on long-duration missions to the moon and Mars.

As it looks to reaching out further into the solar system, NASA hopes Vande Hei's record, too, will fall. If it does, it won't be on a station that built by NASA. From now on, it plans to be a tenant in low Earth orbit, not the landlord.

Turkey trains its first astronauts in the United States

Recep Tayyip Erdogan's victory in the second round of Turkey's recent presidential elections may be due to the political leader's determination to have a Turkkish citizen in orbit before the end of the year. In the run-up to the electoral campaign, it was Erdogan himself who, during an air festival held in Istanbul, presented the first two selected to become astronauts before the national television cameras.

In order to accomplish the outer project, the government has choosen a fighter pilot from its air force, Colonel Alper Gezeravci, 43, as the first Turk to reach outer space.
The colonel is an accomplished soldier, with 21 years of service, an accredited F-16 pilot, which has perfected his studies at the United States Air Force Institute of Technology and has excelled in all the medical, psychological, intellectual and motor tests to which has been subjected.

His deputy is a 30-year-old aeronautical engineer, Tuva Cihangir Atasever, who works at the Turkish defense company Roketsan, Turkey's main missile and rocket manufacturer. He is the colonel's back-up man, whom he would replace in the event of an incident that prevents him from taking part in the flight. \

A Turkish citizen will be sent to the International Space Station ISS in the second half of 2023 within the scope of the Turkish Space Traveler and Science Mission project, Industry and Technology Mustafa Varank has said.

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Turkiye began the Turkish Space Traveler and Science Mission project on May 23, aiming to send a Turkish citizen to space. The project will also enable the Turkish citizen, who will undergo training before leaving for space, to conduct scientific research in space. The government signed a deal with Axiom Space, a U.S. space infrastructure developer, for the training and flight service of the space traveler.

Recalling the “National Space Program Strategy Document” presented in the presidential circular last year, Varank said, “After completing the necessary training, the selected Turkish space traveler is planned to be sent to the ISS to conduct scientific research in the second half of 2023.”
Turkiye made a significant progressin her ambition to the outer space. As part of the manned space project, Turkiye signed an agreement with the Swedish Space Physics Institute (IRF) at the TUBITAK Space Technologies Research Institute for the scientific payload of the Lunar Neutral Telescope, which will collect data on neutral particles from the Moon's surface as part of Turkey's first Moon mission.

In the agreement, Swedish Institute will provide the lunar payload, and Turkish engineers will integrate the lunar payload into the spacecraft it has developed for the Moon mission and make the data available to scientists of the two countries. With this workload, it will be possible to conduct research on fundamental subjects such as celestial bodies such as the Moon, whose atmosphere and magnetic field are not strong, and plasma interaction with their surfaces, the contribution of solar winds to the formation of water on the Moon, the formation of mini-magnetospheres and the physics of dust plasmasWith each passing day it is becoming clearer that there is not only a space race between the United States and China to see which of the two superpowers manages to colonize and extract mineral resources from the Moon and control outer space.

The facts prove that another competition has also been unleashed in the space framework, which peacefully confronts the regional and oil powers of the Near and Middle East for being present in outer space and, especially, for sending women around around the Earth. The dispute was confirmed during the International Astronautical Congress held from September 19 to 22 in Paris.

In the French capital, senior managers of the space agencies of Saudi Arabia and Turkey have been able to take advantage of their presence at the world's largest event dedicated to space science and technology . In both cases, they have contracted the services of a private company that, upon payment, can transport their nationals to Earth orbit, keep them for a short time on board the International Space Station (ISS) and bring them back to our blue planet.

The only company that is authorized and certified by NASA to carry out the tasks described is Axiom Space, which on September 22 signed an agreement with the Saudi Space Commission. The terms of the contract are to arrange and materialize a man and a woman from the Gulf country to fly a SpaceX Dragon crewed capsule to the ISS in the second quarter of 2023 at the earliest, stay on board between one and two weeks and make the return trip.

The agreement was signed in the presence of the chairman of the aforementioned Commission, Abdullah bin Amer al-Swahha , and by the founder and CEO of Axiom, Michael Suffredini . The latter and his capitalist partner Kamal Ghaffarian created Axiom in 2016 with the intention of docking several commercial modules to the ISS starting in 2024 and, later, building the first space station for commercial purposes.
President Erdogan wants to see Turks in orbit as soon as possible.

But while the Axiom project becomes a reality, the liberalization of access to space decreed by the United States allows the companies to promote private round-trip flights to the international orbital complex to transport researchers and tourists who can pay between 55 and 60 million dollars . per occupied position .

The looming business is based on the experience of Suffredini , a prestigious retired NASA engineer, whose 35-year professional career at the Agency began in 1989 and ended at the end of 2015, after having been for a decade –since 2005 until his retirement– the ISS program manager, responsible for the design, assembly, operation and utilization of the largest orbital complex ever built.

Michael Suffredini and Axiom are trusted by the Saudi Space Commission, a government agency created on December 27, 2018 and directly reporting to the Prime Minister, Crown Prince Mohamed bin Salman al-Saud. Equivalent to a space agency, its main function is to plan and develop policies and programs related to the sector and execute the National Space Strategy .

But Saudi Arabia is not the only nation that has been inclined to travel to the ISS at the hands of Suffredini . On September 19 in Paris, a few dates before the agreement with Riyadh, Axiom had also reached a commitment with the Turkish Space Agency (TUA) –founded on December 13, 2018, 9 days before the Saudi one–, to embark a couple of Turkish astronauts in another future mission of the North American company. Its flight could be the Ax-3, which is not yet approved by NASA and which, at the earliest, would take off at the end of 2023.

The president of the TUA, Serdar Huseyin Yildirim, a 61-year-old aeronautical engineer, has declared that the contract is part of the "ambitious 10-year space roadmap" of the Ottoman country, which includes "low-Earth orbit missions of the Earth, to the Moon, as well as the development of dual-use civil and military communications and observation satellites" , he specified.

The astronaut pre-selection process begins.The services provided by Axiom also include the training of Saudi and Turkish astronauts selected by the authorities of both countries . At least, in each case there will be four people, since the main crew and the reserve crew of each country must be trained together.

The instructors from the training department of the North American company –former NASA astronauts– will be responsible for providing the training that, Saudis on the one hand and Turks on the other, should enable them to travel, live and carry out research and scientific work in conditions of microgravity.

The selection process for the Turkish astronauts is carried out by the Tübitak Space Technology Research Institute in Ankara, with the support of Axiom and under the direction of the Turkish Space Agency on behalf of the Turkish Government. In the case of Saudi Arabia, the responsibility for the selection falls on its Space Commission. It must be remembered that the Kingdom had its first astronaut 37 years ago. It was Prince Sultan bin Salman al-Saud, who flew on the STS-51G mission of the Discovery shuttle in June 1985 along with five American and one French astronauts.

Axiom has already carried out a first private mission to the ISS. It was the Ax-1, which took off on April 8 and was back on the 25th of the same month. Its commander was a retired NASA astronaut, the 64-year-old Spanish-American Michael López-Alegría. Three businessmen traveled with him, an Israeli, a Canadian and a third American.

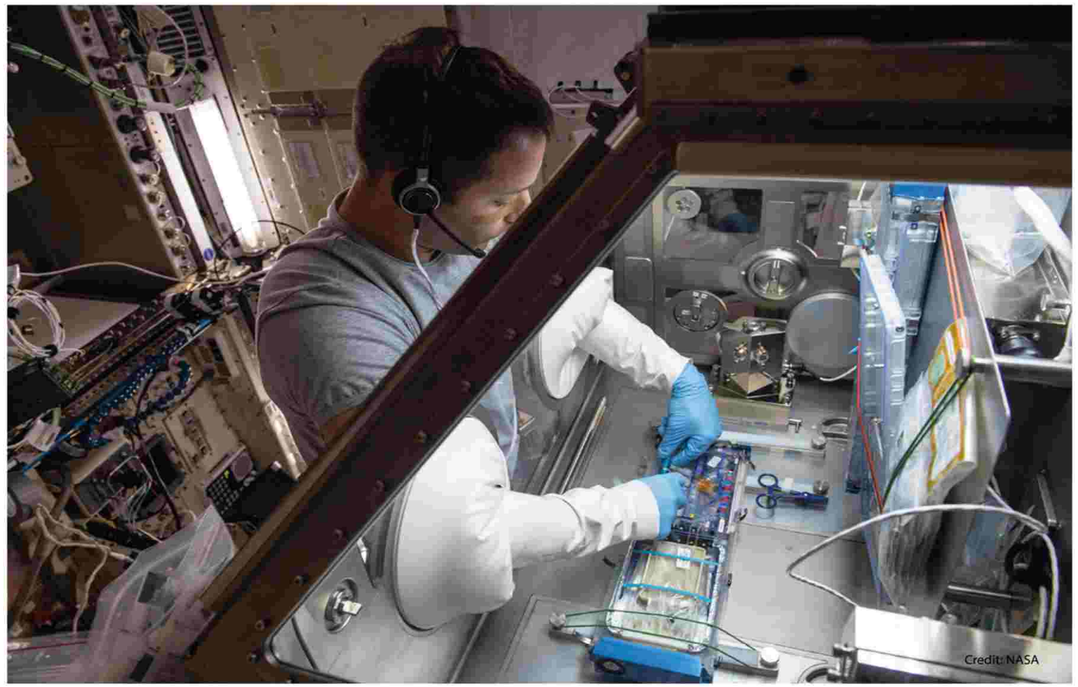
For the second Axiom mission, labeled Ax-2 but still pending final NASA approval and scheduling, the chosen commander is veteran astronaut Peggy Whitson , also a NASA retiree. She is a 62-year-old biochemist, she has been in space three times, holds the North American record for permanence in orbit (665 days and 22 hours) and was the first woman to be in command of the ISS
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Saudi Arabia focuses attention on the ISS

Saudi Arabia intends to diversify its economy and create a scientific, legislative and technical environment in view of the growing business opportunities offered by space. The Saudi Space Agency is already a reality.

A Royal Order of King Salman bin Abdulaziz Al Saud dated December 27, 2018 establishes the creation of the Saudi Space Agency and appoints His Royal Highness Prince Sultan bin Salman bin Abdulaziz Al Saud –formerly head of the Tourism and National Heritage –as president of the Board of Directors with the rank of minister. The measure is part of a major reorganization of the different portfolios of the Saudi government.

Its wording, "ambitious but realistic", says Prince Sultan bin Salman, has been agreed with representatives of the Ministry of Defense, other government agencies and with KACST, an acronym in English for King Abdulaziz City of Science and Technology, the government scientific institution whose purpose is to promote applied scientific research and which until now has been the main engine of the nation's space activities.
Since he was appointed to lead the Kingdom's space affairs, the Prince Sultan has focused his efforts, meetings and negotiations both on the aspect of training young Saudis and on strengthening international cooperation with institutions and agencies. space from other countries.


Credit: NASA

Prince Sultan was not only the first astronaut from an Arab country and the first Muslim male to travel in space. He was also the youngest human to orbit the Eart. At just 28 years old, he blasted off on June 17, 1985 aboard NASA's space shuttle Discovery as a payload specialist, along with 6 other astronauts, five Americans - one of them a woman - and one French.

The seven astronauts had to complete NASA's STS-51-G mission, whose main raison d'être was to place three communications satellites in orbit, the Mexican Morelos, the Telstar 3D of the AT&T corporation, and the Arabsat-1B, the latter owned by of the Arab Satellite Communications Organization (Arabsat), in which Saudi Arabia is the main shareholder. The shuttle Discovery returned to land on June 24 with all of its crew safe and sound. The Prince Sultan is not only a former astronaut but also a retired colonel in the Royal Saudi Air Force, with more than 5,000 flight hours to his credit.

Saudi Arabia is not a newcomer to the space field and has repeatedly expressed its interest in accessing space in its different aspects. It is a member of the United Nations Commission on the Peaceful Uses of Outer Space and has signed the five UN treaties and principles on outer space to promote the use of space technologies in different fields in the country.

Cooperate with China, the United States, Russia and many more countries
Riyadh has signed or is about to close a significant number of international cooperation agreements related to space exploration and research, the manufacture of communications and observation satellites, ground infrastructures and launch vectors with Germany, Brazil, China, the United States , France, Greece, Russia and Ukraine.

For example, it participates in the Chinese Chang'e-4 lunar space mission, which was launched into orbit in May 2018 and where advanced photographic systems developed in Saudi Arabia travel.
Prince Sultan bin Salman bin Abdulaziz and his team have held numerous meetings throughout 2019 with senior officials of the main space powers to further strengthen their international ties.

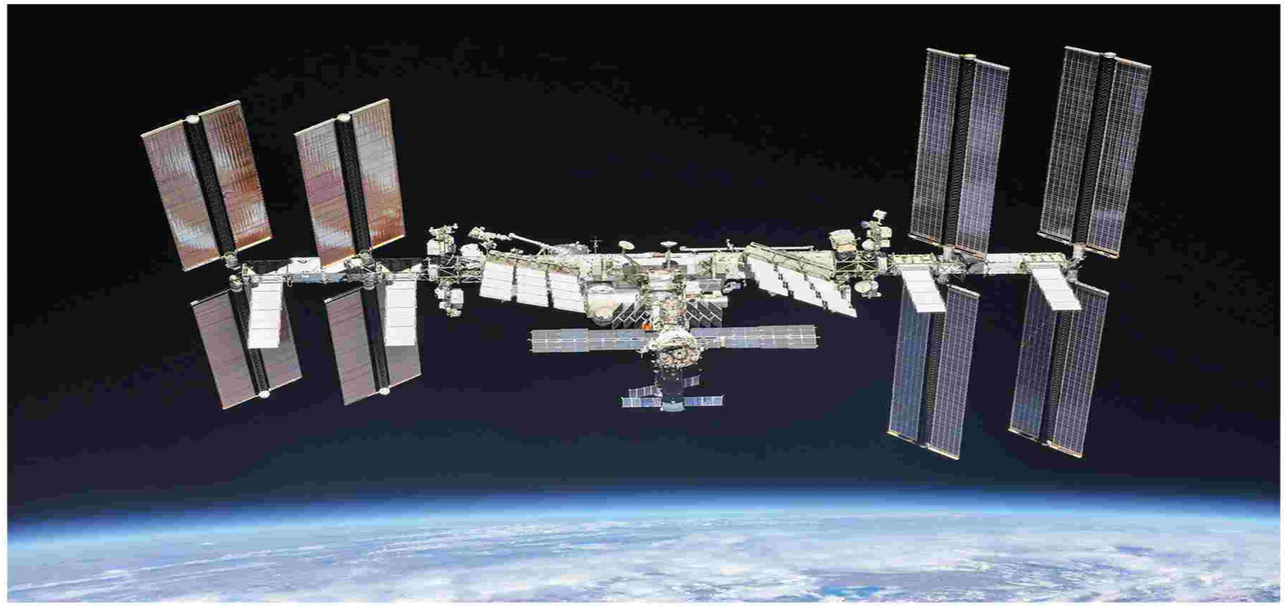
In Moscow and Riyadh, they have met with executives of the large Russian space companies and their authorities, for example, with the Minister of Industry and Trade and the General Director of the Russian Federal Space Agency (Roscosmos), Dimitry Rogozin to try to define the content of a cooperation program between both nations in the fields of exploration, industry and space sciences.

In December 2018, a Chinese Long March 2D rocket lifted off from the Jiuquan space base and launched the 425-kilogram SaudiSat 5A and SaudiSat 5B observation satellites into space. Its high-resolution images are processed and analyzed at the National Center for Remote Sensing Technology, an agency dependent on KACST, and are used for the fields of security, defense, and civil applications.

The Saudi kingdom has put into orbit more than twenty communications, observation and technological devices, either its own satellites or through operators of communications platforms in which it is the main shareholder.

SPECIAL REPORT

Leveraging space innovations for medical breakthroughs on Earth



The idea of using space as a research platform began with pioneering microorganisms research aboard early space stations like Skylab and Salyut in the 1970s and expanded significantly through NASA's Space Shuttle programme and its dedicated Spacelab modules in the 1980s. While largely exploratory, this groundwork culminated in today's International Space Station (ISS), a global laboratory supporting over 3,000 microgravity experiments from more than 100 countries to date, including extensive biopharmaceutical research in protein crystallisation, cell cultures, and disease models.

Recently, companies such as SpaceX and Blue Origin have dramatically increased commercial access to space, lowering entry costs and paving the way for biopharma to explore microgravity opportunities. Firms such as Axiom Space, Varda, or Voyager Space are planning to build commercial microgravity capability in low-Earth orbit LEO, with a direct focus on life sciences R&D. Despite these developments, a fully commercial microgravity ecosystem is yet to emerge.

Aboard the ISS astronaut-scientists observe 16 sunrises and sunsets every 24 hours. As the ISS nears its 2030 retirement and potential deorbiting, over 4,000 research investigations have been undertaken by numerous scientific organizations from 108 countries. Expeditions carrying experiments and scientists continue to be transported to the ISS sponsored by governmental, academic, medical, and commercial organizations all of whom utilize this celestial laboratory to better understand the effects of microgravity, radiation and a near continuous vacuum on human physiology, biology, material, and the physical sciences.

The microgravity research market is served by a small group of US commercial providers working alongside agency operators, rather than by a single dominant company. Redwire is the largest specialist, with Space segment revenue of $209.8 million in 2025 and a hardware line that includes PIL-BOX crystallization units, in-space manufacturing systems and payload services that NASA expanded in March 2025 and again in March 2026. Voyager Technologies, which absorbed Nanoracks and leads the Starlab station venture, reported 2025 net sales of $166.4 million, up 15%.

Axiom Space and Varda Space Industries represent the two newer commercial models. Axiom sells complete research missions, and its Ax-4 flight in June 2025 carried around 60 studies from 31 countries on a SpaceX Crew Dragon, while it builds station modules with Thales Alenia Space. Varda raised $187 million in July 2025 to scale autonomous capsules for pharmaceutical processing. Vast is preparing Haven-1 for early 2027, Sierra Space signed manufacturing agreements with Astral Materials and Space Forge in December 2024, and Space Tango serves smaller payload customers.

Agency contractors and platform operators form the third ring. Boeing remains the ISS prime contractor, Northrop Grumman's Cygnus and SpaceX's Dragon carry research cargo, and Blue Origin's New Shepard supplies suborbital flights. In Europe, Airbus Defence and Space operates the Bartolomeo platform on Columbus and Novespace runs the A310 ZERO-G for ESA, DLR and CNES campaigns, including DLR's 45th campaign in October 2025. China's Technology and Engineering Center for Space Utilization runs the Tiangong science program, and competition increasingly turns on who can offer the most frequent and reliable access after 2030.

The International Space Station hosted 54.0% of microgravity research spending in 2025 and contracts by 15.2% a year to 2034, the only platform that shrinks. Research on the station runs through the US Destiny laboratory, ESA's Columbus module, JAXA's Kibo and external commercial platforms such as Airbus's Bartolomeo. NASA's FY2026 request lowers the station line from $1,240.6 million in the 2024 operating plan to $920.1 million a year, and the agency expects to reduce research on the station because of fewer resupply missions and less crew time. Retirement planned around 2030 moves the remaining demand onto commercial stations in the second half of the forecast.

The China Space Station grows at 9.8% a year and is the second largest orbital platform. China's space application system carried out 31 new science and application projects in 2025, delivered about 867.5 kilograms of experiment modules and returned 83.92 kilograms of samples to Earth. The projects generated more than 150 terabytes of data and over 50 authorized patents. Its continued operation after the ISS retires makes it the longest-lived government laboratory in orbit through 2034.

Commercial space stations grow at 39.8% a year and free-flying capsules and satellites at 16.8%, the two fastest platforms. Starlab had collected 31 NASA milestones by March 2026, Vast targets a Haven-1 launch in the first quarter of 2027, and Axiom Space continues to build modules with Thales Alenia Space. Varda returned W-1 through W-3 and had W-4 in orbit by July 2025, proving a capsule model in which samples come home without a crewed station. Capsules also widen the market for microgravity experiment return services, since every flight ends with a recovery and hand-over of processed material.

Shorter-duration platforms serve as the entry point for most experiments. Suborbital and sounding rockets grow at 7.8% a year, with Blue Origin's New Shepard flying research payloads for agency and university customers. Ground-based simulators such as clinostats and random positioning machines grow at 6.8%, parabolic flights at 4.8% and drop towers at 3.8%. Novespace runs five to six scientific campaigns a year from Bordeaux, while the US lost its main commercial parabolic aircraft when the Zero Gravity Corporation's certificate access ended on 18 August 2025, pushing American teams toward European campaigns and suborbital rockets.

Microgravity research market outlook

The global microgravity research market stood at $3.5 billion in 2025 and reaches $5.25 billion by 2034, a compound annual growth rate of 4.6% that adds $1.75 billion of annual spending over the period. The market covers orbital laboratories such as the ISS and China's Tiangong station, free-flying capsules, suborbital rockets, parabolic flights, drop towers and ground simulators, plus the hardware, integration, operations, sample return and data services that research teams buy; launch contracts not tied to research sit outside the value.

Government budgets set the size of the market. NASA's FY2026 budget technical supplement shows the International Space Station program at $1,240.6 million in the 2024 operating plan, inside a Space Operations account of $4,220.0 million in FY2025 enacted funding. ESA member states committed EUR 2.976 billion to Human and Robotic Exploration at the November 2025 ministerial council, which funds Columbus utilization alongside lunar and Mars work. China's space application system ran 31 new science and application projects in orbit during 2025 and delivered about 867.5 kilograms of experiment modules, which makes Tiangong the second orbital laboratory of real scale.

Commercial revenue is smaller but rising faster. Redwire reported Space segment revenue of $209.8 million for 2025, a figure that includes its PIL-BOX pharmaceutical crystallization hardware, and launched 14 PIL-BOXes studying 18 unique molecules to the station during the year. Voyager Technologies, parent of Starlab and the former Nanoracks business, reported 2025 net sales of $166.4 million, up 15%, and collected $56.0 million of NASA milestone payments for Starlab in 2025. Axiom Space's Ax-4 mission in June 2025 carried around 60 studies from 31 countries, with national programs buying research access as a service.

The forecast balances two opposing forces. NASA's FY2026 request holds the station line at $920.1 million a year and proposes cutting Biological and Physical Sciences from $87.5 million to $25 million, a 72% reduction. Against that, Vast is preparing Haven-1 for a launch targeted in the first quarter of 2027, Starlab continues to clear NASA milestones and Varda has returned three capsules from orbit. Growth of 4.6% a year therefore reflects a government base that rises slowly through the station retirement window around 2030, with commercial platforms and pharmaceutical buyers carrying the second half of the period.

Redwire flew 14 PIL-BOXes carrying 18 unique molecules to the ISS in 2025, after NASA awarded it a contract in March 2025 to expand PIL-BOX pharmaceutical drug development, and NASA added another $4 million for PIL-BOX investigations in March 2026. Crystals grown without sedimentation and convection tend to form larger and more uniform lattices, which helps formulation scientists study hard-to-reproduce solid forms. Pharmaceutical and biotechnology companies grow at 8.3% a year as a result, and the microgravity protein crystallizer hardware that supports this work is moving from agency loan to commercial sale.

Varda Space Industries raised a $187 million Series C in July 2025, bringing total capital raised to $329 million, and has launched and returned its W-1, W-2 and W-3 capsules, with W-4 in orbit at the time of the round. The company holds an FAA Part 450 reentry license through 2029, which lets it schedule recurring capsule returns rather than seek approval flight by flight. Capital at this scale turns orbital processing into a product line and supports a capsule segment growing at 16.8% a year.

Axiom's Ax-4 mission, launched on 25 June 2025, carried around 60 scientific studies and activities representing 31 countries, with ISRO leading seven of them. China ran 31 new science projects on its own station in the same year, giving countries that are not ISS partners a second orbital laboratory to approach. This widens the buyer base beyond the five ISS partner agencies and lifts academic and research institutions to 4.3% growth a year even as NASA trims its science budget.

Voyager reported 31 Starlab milestones to date in its March 2026 results and collected $56.0 million of NASA milestone payments in 2025, while Vast advanced Haven-1 through its milestones toward a launch targeted for the first quarter of 2027. Sierra Space signed agreements with Astral Materials and Space Forge in December 2024 to develop manufacturing in microgravity on its future platforms. These programs give research buyers a path past the station retirement planned around 2030, and they make commercial space stations the fastest growing platform at 39.8% a year from a very small base.

In terms of research, life sciences and biotechnology is the largest research area with 30.0% of 2025 spending and grows at 5.6% a year. The segment spans pharmaceutical crystallization, cell and tissue research, plant and animal biology and microbiology. Redwire's 14 PIL-BOX flights in 2025 studied 18 molecules, and the Ax-4 portfolio in June 2025 was led by life and biological studies, including cardiovascular, microbiome and diabetes work. Tissue engineers and stem cell groups treat orbit as an extension of the microgravity cell culture pipeline, because cells grown without gravity form three-dimensional structures that flat laboratory cultures do not reproduce.

Materials science and in-space manufacturing grows at 6.0% a year, the fastest research area. Redwire describes in-space additive manufacturing and in-space advanced material manufacturing as core Space segment activities in its 2025 annual report, and Sierra Space signed agreements with Astral Materials and Space Forge in December 2024 to produce semiconductor and crystal materials in orbit. Programs in semiconductor research and development in microgravity target crystals with fewer defects than terrestrial furnaces can deliver. Metallurgists pursue similar goals in microgravity alloy development, where the absence of convection allows more even mixing of alloys and glasses.

Human research and space medicine grows at 3.6% a year and technology demonstration at 3.8%. Ax-4 in June 2025 included studies on cardiovascular adaptation to spaceflight, a field that also drives demand for exercise and countermeasure hardware such as the equipment covered in the microgravity treadmill segment. Technology demonstration covers exploration systems that must be qualified in weightlessness before deep-space use, and China's station tested lithium-ion battery behaviour among its 2025 projects. Work on propellant gauging in microgravity belongs to the same category, because fuel that floats freely in a tank cannot be measured by the level sensors used on Earth.

The physical sciences grow more slowly: fluid physics at 3.0%, combustion science at 2.6% and fundamental physics at 2.8% a year. These fields depend heavily on NASA's Biological and Physical Sciences Division, whose budget the FY2026 request would cut from $87.5 million to $25 million, and NASA said in May 2025 that it expected to significantly reduce such research on the station in FY2026. Industry interest keeps fluid physics alive, as the Ax-4 Microfluidic Drug Dosage Detection Development experiment showed by studying how liquids behave without gravity. Cold atom and complex plasma work runs mainly through agency facilities and tracks government funding closely.

Industry trends and commercial opportunities

What began as exploratory science has evolved into a strategic opportunity: today, startups and major companies are launching experiments to develop drugs, therapies, and biomedical products in orbit. Over the last two decades, the number of US patents mentioning “microgravity” has increased by 117% to 126 in 2024. This is primarily due to key market drivers such as reduced launch costs, the nascent convergence of space and life sciences sectors, the promise of commercial service providers, and compelling proof-of-concept results published by early adopters.

Several emerging players are now offering microgravity-as-a-service, effectively acting as space contract research organisations (CROs). For instance, SpacePharma aims to operate miniaturised automated orbital labs, similar to Frontier Space's SpaceLab, a scalable, modular, autonomous lab-in-a-box for in-orbit biomanufacturing. Another firm is BioOrbit, aiming to be the go-to pharmaceuticals factory in microgravity for protein drugs crystallisation, enabling subcutaneous injection at home. Both Space Forge, a UK startup, and Varda Space (USA) are developing reusable capsules for production in microgravity and return to Earth. In 2024, Varda's capsule successfully synthesised a batch of the drug ritonavir in orbit, crystallising a metastable form that is hard to produce on Earth and brought it back for analysis. Space Forge is set to launch Forgestar-1 in 2025, its first prototype factory satellite and the first UK ISAM satellite in orbit.

With the pharmaceutical industry spending over £300 billion each year on R&D, the opportunity is immense. Short to medium term collaboration with the space sector could generate £3-4 billion in revenue, higher than any other sectors benefitting from microgravity, such as semiconductors, according to report. Early investment signals include Varda's $90 million series B funding ahead of its in-orbit crystallisation experiment, or Axiom Space's $2.2 billion in customer contracts for their efforts to support life sciences experimentation in the ISS and its own future commercial space station. Axiom is particularly active in the UK, having signed MoUs with organisations with microgravity capabilities and Greater Manchester and Liverpool City Region Combined Authorities in the North West Space Cluster.

Despite these breakthroughs, high perceived costs, logistical and regulatory complexities, and unclear return on investment are preventing many biopharma firms from embracing microgravity R&D. Additionally, the link between microgravity-based studies and commercial products remains less well-defined than traditional lab-based pipelines. Nonetheless, growing numbers of universities and companies have begun piloting microgravity projects, often through public–private partnerships. As infrastructure and regulatory frameworks mature, these early investments and collaborations are paving the way for a robust and economically viable microgravity biopharma ecosystem.

Launch of Space provider “beyond gravity”



“On July 20, 1969 Apollo 11 mission commander Neil Armstrong and pilot Buzz Aldrin, both American, landed the lunar module Eagle on the Moon's surface. This exhibition celebrates the 50th anniversary of the Apollo Moon landing.
Humans have long dreamed of escaping the confines of Earth and traveling to the heavens. References to magic carpets, flying horses, flaming aerial chariots, and winged gods can be found in religion, mythology, and the arts from around the world. Early cultures honored the Sun and Moon and watched the sky for omens. Astronomers and astrologers observed the stars and wondered about Earth's place in the universe.

Although science fiction is a recent term, the idea of defying gravity is not new. In Greek mythology, Icarus and his father Daedalus escaped Crete by flying with wings made of feathers and wax. Icarus famously flew too close to the Sun and fell. Some have discerned an image of a hovering spaceship on a cylinder seal from Ancient Mesopotamia. Similarly, a 1350 painting of the Crucifixion from the Visoki Decani Monastery in Kosovo, Yugoslavia appears to show people in space ships. The artist and inventor Leonardo da Vinci was obsessed with flying machines and Nostradamus' predictions were tied to heavenly phenomena such as eclipses. Some say he predicted the 1969 Apollo moon landing. Jules Verne wrote From the Earth to the Moon in 1865. The first science fiction film, A Trip to the Moon, debuted in 1902. Today artists are inspired by images from the Hubble Space Telescope.”

Beyond Gravity, one of the world's leading suppliers of space products and the largest Swiss space company, opens an Innovation & Digital Hub in Portugal with a clear focus on capturing Space Engineering, Digital and Innovation talent. Beyond Gravity plans to immediately hire more than 50 new employees in Lisbon by the end of this year and reach 200 employees by 2025, becoming the largest space engineering company operating in Lisbon.

Beyond Gravity has been supplying products for hundreds of space missions for over 40 years. They all ultimately serve one goal: advancing humanity. We do this by working in the areas of satellite positioning and communications, providing instruments to collect satellite data that helps manage natural hazards, or working on satellites for better weather forecasting. We also help discover space, explore planets and countless other scientific missions. With our solutions we help our customers around the world make the impossible possible.
Headquartered in Zurich, Switzerland, Beyond Gravity is the first start-up to combine agility, speed and innovation with decades of experience and proven quality. Beyond Gravity is the preferred supplier of structures for all types of launch vehicles – including the European Ariane and Vega rockets. Beyond Gravity is also a leader in selected satellite products as well as satellite constellations. The company is also a longstanding supplier of the lithography market.
In 2022, the company changed its name from RUAG Space to Beyond Gravity. The new name and brand identity position the company more clearly in international markets and make our range of services even better known. In 2009, the former RUAG Space took over the space activities of Saab Space, Austrian Aerospace and Oerlikon Space AG, formerly Contraves Space. Beyond Gravity is part of RUAG International Holding AG. All shares in the company are held by the Swiss Confederation.

Beyond Gravity consists of three divisions. The Launchers division manufactures payload fairings for various European, American and Japanese launch vehicles, amongst other things. The Satellites division supplies almost all the core elements of a satellite – from the structure to the computer and the antenna. And the Lithography division manufactures special actuators and apertures which are used for the nanometre-precise exposure of wafers.
Beyond Gravity's new site in Lisbon will foster emerging technologies such as AI, enhancing the company's entire IT core and digital infrastructure. Lisbon will be working alongside Beyond Gravity's 12 existing international locations. This Innovation & Digital Hub will allow Beyond Gravity to take a leading role as an agile innovator in the space industry, drive growth and stay at the very top of engineering. With its 40-year history, Beyond Gravity is the preferred supplier of launch vehicles such as the new European Ariane 6 Launcher and is a leader in selected satellite products and constellations in the space sector. Moreover, the company is also an important supplier for the lithography industry.
200 professionals by 2025.

The expansion of the new site offers attractive employment opportunities to tap into Portugal's attractive talent pool in engineering and digital technology. Beyond Gravity plans to hire more than 50 new employees this year, mainly in the engineering, IT and financial areas, integrating 200 professionals by 2025, becoming the largest aerospace engineering company operating in Portugal.

At Beyond Gravity, the Launchers Division covers composite structures for rockets, which have been successfully used in over 400 launches to date. Our separation systems ensure that the satellite and rocket remain securely connected and that the payload is precisely placed in orbit. For decades,
our payload fairings, interstage adapters, dispensers, payload adapters and separation systems have been the first choice for launch service providers in the space industry.

Beyond Gravity is a world leader in the manufacture of satellite dispensers. The cylindrically shaped carbon fibre structures make it possible to attach numerous small satellites to them and then deploy them in space with pinpoint accuracy. The dispensers have been used successfully for many years, for example for the OneWeb satellite network. Beyond Gravity will also manufacture numerous dispensers for Amazon's new Kuiper satellite project, which will safely accompany the satellites into space and ensure fast, reliable Internet.
The H3 launch vehicle is Japan's new emblem for transport into space. Back in 2019, Beyond Gravity and Mitsubishi Heavy Industries signed a contract for payload fairings. Soon, the new rocket will be equipped with the rocket nose cones manufactured by Beyond Gravity in Emmen (CH), which will protect the precious cargo on its way into space. In terms of size and payload, the H3 is comparable to the Ariane 6.

With the Artemis missions still to come, ever larger loads will be transported into space and to the Moon, and with ever larger launch vehicles. For the largest American launch vehicle of all time – the SLS 1B – Beyond Gravity is building an important element together with its partner Dynamics: the Universal Stage Adapter. This connects the Orion spacecraft, in which the astronauts will be staying, with the upper stage of the SLS Block 1B rocket and at the same time protects the precious cargo. The adapter has a height of some 10 metres and measures just under 8.5 metres in diameter at its widest point.

The Satellites Division brings together all of Beyond Gravity's satellite activities and supplies mission-critical products for a wide range of satellite missions for commercial and institutional customers. With the exception of engines, all core elements of a satellite are offered: from the satellite structure, the computer and other electronics to thermal protection, a wide variety of mechanisms and slip rings.

For hundreds of small satellites, forming a satellite network, Beyond Gravity has developed the Constellation On Board Computer a computer based entirely on commercial components, offering high performance, short delivery times, competitive pricing and high reliability. After many years of development and investment, it is already used in over 50 models. Satellites are increasingly using electric ion engines. Beyond Gravity provides important control mechanisms for the ion engines of NASA's new Gateway space station. These mechanisms allow the thrust direction of the electric engines to be correctly aligned for both precise manoeuvres and long range orbit changes around the Moon during Gateway's lifetime. Beyond Gravity has more than 20 years' experience in building control mechanisms – including for the European satellite navigation system Galileo and for commercial satellites.

Slip rings are necessary to enable uninterrupted rotation and to continuously transmit data and electricity. Slip rings are used, for example, in mechanisms that continuously align satellites' solar panels with the sun in order to provide the greatest possible power supply for the satellites' systems. Beyond Gravity is the European leader in the field of space applications and can look back on many years of experience.

André Wall, CEO of Beyond Gravity is celebrating Beyond Gravity's commitment to innovation: “We are thrilled to announce the launch of our Innovation & Digital Hub in Lisbon.

This strategic move underscores our unwavering dedication to capturing top-tier talent in Space Engineering, Digital, and Innovation. By opening our doors to over 50 new team members this year and aiming to reach 200 by 2025, we are on a trajectory to become the premier space engineering company in Lisbon.” The Portuguese capital has been chosen as the 13 sites for Beyond Gravity after a careful analysis. Lisbon stood out with the concentration of technical universities, an attractive location, a dynamic start-up environment, a growing space ecosystem, among other equally important aspects. “In addition, Portugal has a pool of highly specialized professionals who are difficult to find elsewhere, and who will contribute to our company's growth in the coming years. It will put us in an even better position to respond to the needs and expectations of our clients around the world," André Wall adds.

Ricardo Conde, the President of the Portuguese Space Agency, considers that the establishment of Beyond Gravity's hub in Portugal will significantly contribute to the expansion of the national space ecosystem: “The Portuguese space ecosystem is steadily growing, and the inclusion of Beyond Gravity represents a significant leap forward. Not only is Beyond Gravity a well-established and renowned company, but it also offers a fantastic opportunity for our talented individuals. The Portuguese Space Agency anticipates the emergence of new synergies between Beyond Gravity and the national space ecosystem.”

“We are extremely pleased to welcome Beyond Gravity to Lisbon. Beyond Gravity new innovation & digital hub will be yet another major contribution to further strengthen the positioning of Portugal as a preferred location for Engineering and Tech-enabled operations and crucial for the growth and competitiveness of the space ecosystem in Portugal”, said João Noronha Leal, Executive Board Member of AICEP Portuguese Trade & Investment Agency.

Beyond Gravity is the preferred supplier of structures for all types of launch vehicles and is a leader in selected satellite products and constellations in the space sector. The company is organized into three divisions: The Launchers division manufactures payload fairings for various European, American, and Japanese launch vehicles, amongst other things. The Satellites division supplies almost all the core elements of a satellite from the structure to the computer and the antenna. And the Lithography division manufactures special actuators and apertures which are used for the nanometer-precise exposure of wafers semiconductor silicon substrate.

Beyond Gravity has supplied products for hundreds of different missions for more than 40 years and is currently working on 400 projects. The company's current customers include companies such as ESA, NASA, Maxar, Rocket Lab; Ball Aerospace, Airbus Defence & Space, Thales Alenia Space, Amazon, United Launch Alliance ULA, Ariane Group and Mitsubishi. The current 1600 employees are spread across 13 locations in seven countries (Switzerland, Sweden, Austria, Germany, USA, Finland and Portugal), develop and manufacture products for satellites, launch vehicles and the semiconductor industry. In 2022, the company generated revenues of around 356 million Swiss francs (365 million euros), and this figure is expected to grow.

Wide range of testing services for aerospace and industrial applications

Beyond Gravity offers extensive problem solving including, if necessary, model simulation, suggestions for improvement as well as crosschecking of the measures taken. Many methods and various types of equipment are available for non-destructive testing of materials, components and electronics: measurement of hardness, x-ray florescence, electrical conductivity, friction, optical microscopy, standard ultrasonic as well as phased array technique, an automatic air-coupled ultrasonic transmission test facility for large test articles, acoustic composite material testing as well as penetration tests using fluorescing class III fluids give us the possibility to not only characterize material under test, but also detect defects such as cracks, pores or delamination.

Beyond Gravity has a long-standing history in the management and execution of mechanical and structural testing. The extensive experience and expertise gained over many years of testing internal projects, combined with the specialized testing equipment developed during this time, ensures that a reliable partner is also available to external customers for all testing services.

The Beyond Gravity Test Centers are also able to perform environmental simulation testing, utilizing a variety of shakers, climatic chambers and thermal vacuum chambers as well as a centrifuge in order to test components and electronics under temperature, humidity and pressure conditions as well as vibration arising for example during space missions or other types of harsh environments. Our test facility for testing of components, printed circuit boards and electronics can handle the most relevant types of tests for evaluation and investigation including X-ray, PIND testing, Seal test, thermal dissipation tests as well as tests to determine solder bonding and PCB quality.

Space is the future

The global space industry is in the midst of a major change and transformation. The scientific exploration of space has recently celebrated great successes, most notably with the successful launch and commissioning of the James Webb Space Telescope. The Artemis missions are an equally exciting and comprehensive project, which, with the return to the Moon, will form the basis for a journey to Mars, but at the same time also include economic interests. In addition, large commercial satellite constellations by Amazon, SpaceX and OneWeb are shaping events in space. And, not least, space tourism is also gaining momentum, for instance with Virgin Galactic or Blue Origin.

The many governmental players and commercial providers are stimulating the space market to an unprecedented degree. A study by Citibank predicts that the space industry will generate an annual turnover of more than USD 1 trillion by 2040, up from around USD 370 billion in 2020 and an annual growth rate of five percent. The main driver of space industry growth is lower launch costs. The study predicts that launch costs could fall from USD 1,500 today to USD 100 per kilogram by 2040.

According to a study by Morgan Stanley (2022), important drivers for the growth of the space industry include, on the one hand, the climate crisis and the resulting increased demand for data especially satellite imagery, major private investments in the new space sector, the increasingly acute issue of space debris, but also the security needs of states, which are expanding into the space sector. And last but not least, there is the telecommunications industry and its needs for connectivity, navigation and communication. Beyond Gravity has won important contracts and prestigious customers in both the launch vehicle and satellite sectors, and is working with them at the forefront of further space exploration.

In 2022, for instance, Beyond Gravity received the largest order in the company's history and will supply products including dispensers and payload fairings for the launch of Amazon's Kuiper satellite network. Beyond Gravity also works with renowned organisations such as ESA and NASA in the institutional sector, for example on the James Webb Space Telescope, the Artemis missions and the latest generation of Galileo navigation satellites. For Beyond Gravity, “Realising what's next” also means that the company is working on innovative projects that are changing the space industry. Beyond Gravity's powerful and space-qualified computers will be used in the field of deorbiting (the collection of space debris) as well as in the small- and mini-rocket sector, where the company is delivering compact and innovative solutions in the field of rocket nose cones.

“Even though missions such as Artemis are working on getting to Mars in the near future, one thing is certain. For the time being, Earth will remain humanity's only home. We want to assume our responsibility and contribute to making sure that our planet is preserved for future generations by using resources wisely. At Beyond Gravity, we are convinced that it is important to combine economic success and growth with environmental and social responsibility.

We understand sustainability comprehensively, in the sense of ESG Environment, Social, Governance: our goal is to minimise negative impacts on our planet and to promote the well-being of our employees and the communities in which we operate. We are therefore committed to transparency and will communicate our ESG efforts through a comprehensive annual ESG report.

We will also continue to ensure seamless compliance and proactively integrate the increasing regulations and investor requirements regarding ESG into our thinking and actions. Not least, we see sustainability as an opportunity for new products and services, markets and revenue streams.”

Why is the Sultanate becoming a technology destination of choice?



Oman has embarked on a long-term, ambitious plan initiated by Vision 2040 founded on innovation, integration of roles and equal opportunities to build a productive and diversified economy. Under joint actions by the government, private sector and civil society, Oman is shaping its future building on its heritage, values and competitive advantages.

The global space sector is heading towards the inception of a new era that, under the impulsion of the newspace revolution, will be marked by democratized access to space-based solutions, a new ecosystem of stakeholders and renewed government ambitions to serve global agendas.
As emerging space nations expand globally, motivated by the variety of socio-economic returns that space activities can generate, it is crucial for Oman to begin its space journey, building on its national assets that makes it unique in the region and worldwide.
Several initiatives have taken place already paving the way for the development of Oman's space based capabilities. This is particularly true in the satellite communication and Earth observation domains where Omani organizations have built internatio

nally recognized expertise and excellence. Oman's government fully recognizes the vital importance of the space sector to stimulate national development as the Royal Decree 90/2020 mandated the formulation of the National Space Program. It is now time to act and pursue more ambitious goals for Oman's space sector, taking advantage of global opportunities and leveraging the full potential of our nation and its people.

As a commercially mature and rapidly evolving market, Satellite Communications (Satcom) contribute to a thriving digital economy. Offering multiple business opportunities, Oman's space sector can leverage its competitive ICT infrastructure and experience in Satcom services supply. Building sovereign Satcom capability will further contribute to achieving Oman's broadband strategy and support its national security.

Space, unique among human activities, has the power to propel human imagination and innovation. As a nation of pioneers and explorers in the pursuit of knowledge and prosperity, Oman has much to offer to and benefit from space. Oman's strategic location has contributed to the flourishing of maritime activity throughout the ages and now supports global connectivity across continents. Its culture is rich in customs and traditions borne by values of humanities, spirituality and tolerance, making Oman a unique partner to support open international dialogue and a launchpad for future opportunities in a domain humanity has just touched the surface, space. Oman has engaged an unparalleled transformation of our economy and society under the strategic direction of Oman's Vision 2040.

With significant progress made in laying the foundation for Oman's digital society and creating a modern ICT sector that is accessible to all and responsive to sustainable development needs, the Sultanate of Oman has been making huge strides towards becoming a technologically advanced country. Government, businesses, and individuals can access an integrated ICT infrastructure across the country, including rural and remote areas. Several major projects have been implemented nationwide, including the creation of a national broadband network, the unified government network, the National Center for Information Security, the Digital Certification Center, and many other infrastructure projects. In addition, the transformation into digital government contributed to accelerating the access to information technology by all segments of society and enabled the various economic sectors to develop and thrive.

The Sultanate's government is continuously working to unify national plans and strategies ensuring their alignment with the overall vision and national directions for sustainable development and all economic and social sectors. In this context, developing sustainable digital strategies have been given special attention making them a central pillar within Oman Vision 2040. The vision is centered around Several ICT strategic objectives so as to capture rapid technological advancements and facilitate adoption. There is a need to ensure a sophisticated IT infrastructure supportive for all sectors and capable of accommodating new developments as well as addressing the cybersecurity challenges.

The National Vision also aims to create vibrant sustainable smart cities and high quality dynamic urban communities for living, work and leisure. In addition, it seeks to develop a digitally-aware society with skills and capabilities that can preserve its identity, keep pace with the new developments, and provide the basis for high-efficiency government services and performance.

The Sultanate of Oman seeks to achieve several goals that contribute to building and developing a prosperous digital economy that responds to future requirements. The National Digital Economy Program was recently approved by the government containing a set of pillars, medium and long-term goals based on the national directions of Oman Vision 2040. These pillars are planned to be achieved through a set of executive programs.

The main three pillars highlighted by the National Digital Economy Program are digital government, digitizing businesses and digital society. Moreover, the most important executive programs that are encompassed by the National Digital Economy Program are Government Digital Transformation (2021- 2025), E-Commerce, Artificial Intelligence and Advanced Technologies, Space and Digital industry. The program focuses on utilizing the Fourth Industrial Revolution technologies in enabling the Economic Sectors, Motivating Digital Content development, developing a Cybersecurity Industry, Government Digital Transformation, Promotion of Data Centers and Cloud Services and Attracting foreign technology investments.

Artificial Intelligence (AI) and Advanced Technologies are seen as fundamentally important enablers that may facilitate global leadership in all future industries. Countries are racing to embrace AI technologies in numerous scenarios so that national security is bolstered and public services provided to society can be improved. The Sultanate of Oman is working to lay the essential pillars of AI applications in order to create a sustainable economy whilst also benefiting in its daily operations. These can be achieved through enhancing the productivity in sectors targeted for economic diversification through a coordinated application of smart technologies that develop the existing human talents and capabilities in this domain.
Successful adoption of AI in the most essential and strategic sectors must be supported by the right policies and regulations to ensure human-centricity in the AI arena.

Furthermore, the Government Digital Transformation Program outlines the plans and projects to simplify, re-engineer and automate government services to improve citizens digital experience when receiving government services. This will be achieved by ensuring system integration between different government entities and providing government services through in a unified e-Portal.
The vision of the programme starts from the principle of enabling the public sector to achieve outstanding innovative performance and provide smart services, proactive procedures, and a rewarding digital experience. It strives for excellence in Government performance, open-source data, and e-Community participation, all of which will contribute effectively to boost the business sector in Oman and attract an increased and wider spread of investments across different fields.

The digital transformation program is a stepping stone to enable Oman's rank in the UN eGovernment Development Index to jump from the top 40 countries in 2050 to the top 10 countries in 2040, as stipulated in Oman's Vision 2040. The Program is expected to empower startups and SMEs to provide innovative solutions to help develop a government work environment, enable agility, planning and predictability of future plans to enhance the performance of the state's administrative apparatus whilst ensuring transparency, accountability, and community engagement.

Oman's first communications satellite “OmanSat-1

The Sultanate of Oman signed a cooperation agreement with Airbus Defense and Space (ADS) to design, manufacture, and launch Oman's first communications satellite “OmanSat-1.” The project forms part of national efforts to enhance the telecommunications ecosystem, strengthen digital sovereignty, and build national capabilities in space and future technologies.

The agreement was signed by Eng. Said bin Hamoud Al Maawali, Minister of Transport, Communications and Information Technology while it was signed from the ADS by Alain Fauré, Head of Space Systems at Airbus
Airbus will design “OmanSat-1” with high capacity in the Ka-band frequency, covering the Sultanate of Oman including its economic waters as well as the Middle East, East Africa, and Asia. The satellite will be based on Airbus's OneSat platform, offering full digital reconfigurability while in orbit.

As part of the agreement, the Ministry of Transport, Communications and Information Technology has assigned the satellite's operation to the “Space Communications Technologies SCT,” a company fully owned by Oman Investment Authority (OIA), to serve as the national operator after launch and to be the executive arm during the design and manufacturing stages.
The Ministry has also established a Project Management Office within the SCT to oversee administrative and technical aspects of the project in collaboration with Airbus throughout the manufacturing process. The office will ensure infrastructure readiness for satellite operations and develop a fully integrated operational ecosystem in Oman for satellite management and service delivery to both government and private-sector entities after launch.
Eng. Said bin Hamoud Al Maawali, Minister of Transport, Communications and Information Technology, stated that “the project aims to strengthen Oman's digital sovereignty by establishing a national space-based infrastructure capable of providing independent and secure telecommunications and data services. This will enhance national cybersecurity, ensure continuity of critical services under all circumstances, extend coverage to rural areas, and improve the quality of telecommunications and internet services in alignment with Oman Vision 2040”.

He explained that this project represents a major step toward localizing technical knowledge. It includes intensive programs to train and qualify Omani talent across all project phases—from design to manufacturing, testing, and operation ensuring full Omani management capability after launch. It will also empower local companies, especially SMEs, to participate in the project's supply chain, supporting local value creation and strengthening the private sector's role in the national space economy. Additionally, the project will support scientific research through collaboration between local universities and Airbus Defense and Space.

Dr. Ali bin Amer Al Shidhani, Undersecretary for Communications and Information Technology and Head of Negotiation Committee for the project stated that “this project marks a transformational milestone in Oman's technological and space development journey. It reflects the government's commitment to building a sustainable digital economy anchored in knowledge and innovation. The satellite will significantly strengthen Oman's national telecommunications ecosystem, enabling vital sectors and supporting digital transformation and smart services. He also emphasized the national role of Space Communications Technologies as the project's operator and executive arm, ensuring knowledge transfer and national capacity-building in this strategic field.

He added that this milestone follows years of national effort involving extensive evaluation of various proposals for designing, manufacturing, and launching Oman's satellite. He confirmed that cooperation with ADS ensures effective institutional integration between government, investment entities, and the private sector to achieve national ambitions in space and communications.

Alain Fauré, Head of Space Systems at Airbus, expressed his pleasure at signing the contract to provide Oman with world-class, fully flexible satellite communications capabilities through its first geostationary satellite. He affirmed Airbus's commitment to working side-by-side with Space Communications Technologies to support the implementation of Oman's national satellite program and the development of sovereign capabilities to serve future customers.

Dr. Saud bin Humaid Al Shoaili, Head of the National Space Program and Head of the Project Management Office, stated that “the project is a key pillar in implementing the National Space Strategy (2023–2033), which aspires for Oman to become the regional gateway for space services and technologies that enable economic diversification and unlock future opportunities, enhancing the sector's contribution to GDP and expanding national space services”.

Dr. Saud added that the project complements national initiatives implemented by the Ministry of Transport, Communication and Information Technology in partnership with the local private sector, including satellite launch operations from Duqm Port under the “Itlaq” launch program, national space capacity-building programs, the Oman Space Accelerator Program, and geospatial data and Earth observation projects forming a fully integrated ecosystem to support Oman's space economy.

Eng. Salim bin Said Al Alawi, CEO of Space Communications Technologies, said: “We take pride in the trust placed in us by the Ministry of Transport, Communications and Information Technology and the Oman Investment Authority to operate and manage this national project. This marks a major turning point in the history of satellite communications in the Sultanate of Oman. We will work closely with Airbus to implement the project to the highest global standards.”

He added that the company aims to build a fully Omani-driven operational system managed by qualified national talent, enabling Oman to deliver advanced and secure satellite communication services. He clarified that the company will operate the latest software-defined satellite with high flexibility and Ka-band capacity, enabling the delivery of competitive services across targeted sectors.
Oman Lens Company, the Sultanate of Oman announced that it is ready to launch an efficient Omani satellite during the first half of next year. The satellite will be equipped with top capacity resolution imaging technology at a resolution of 50 cm panchromatic and multi-spectral imaging capabilities (RGB and NIR), in addition to an onboard artificial intelligence platform that will have a computing capacity exceeding 400 trillion operations per second.

The satellite will perform high-resolution Earth observation and remote sensing operations. Its uses also include the prediction and location of floods, street planning in cities and the reporting of vegetation, both beneficial and harmful.
The announcement was made during the signing ceremony of cooperation agreements inked by Oman Lens company with a number of parties, including Oman Chromite Company (OCC), Phoenix Space and Technology Company and other agents authorized to resell the company's products and services, such as Mustafa Sultan Enterprises, GIS HUB and Bedrock Mineral Resources Consulting Company (BMRC).

The signing of the agreements was in pursuance of efforts made by Oman Lens company to reshape the future of Earth observation by integrating artificial intelligence technologies with high-resolution satellite imaging, following the company's successful launch of OL1 one-meter capacity satellite.

Why Italian space startups are still underfunded?



The Italian economy relies heavily on small and medium-sized enterprises SMEs, given their widespread presence and their contribution to employment and value creation. According to the European Commission, SMEs in Italy account for over 99% of all businesses.

According to report, estimates indicate that these firms contribute to around 80% of private sector employment in the country. Italian SMEs are deeply rooted throughout the country and represent an important driving force for Italian industry. However, they have characteristics that distinguish them from SMEs in the rest of Europe.

Most of these small companies are family-owned and operate with informal governance structures. Control tends to be highly concentrated in the hands of a family or the founder, with little involvement from external managers. This ownership model provides stability and a long-term orientation, but it can also limit innovation and the implementation of more effective business strategies. \

This model also brings succession challenges, when the firm is transferred to the heirs who may be unprepared to manage it, the business faces risks of discontinuity and decline.

From a sectoral perspective, Italian SMEs have traditionally been concentrated in manufacturing and artisanal industries, sectors such as machinery, furniture, textiles, and agri-food. These activities benefit from a rich heritage of industrial skills and know-how, but they are also highly exposed to international competition and fast technological change. In recent times, there have been efforts to diversify into more knowledge-intensive fields like digital technologies, life sciences, and aerospace.

However, progress has been slow, and many high-tech SMEs still face structural obstacles in attracting the human and financial capital necessary for growth. Geographical distribution is another critical issue. SMEs are not evenly spread across Italy, they are primarily concentrated in the northern and central regions, particularly Lombardy, Veneto, and Emilia-Romagna.

However, undercapitalization is a chronic condition affecting a large share of Italian SMEs and represents one of the most serious structural weaknesses of the country's business system. The term refers to a lack of permanent capital, especially equity, within companies, which limits their ability to invest in growth, absorb external shocks, and compete over the long term. While this problem is not limited to Italy, it is much more prevalent here than in other advanced economies. This is due to specific factors related to the country's culture, institutions, and economy. According to Allianz Trade, the average equity-to-total assets ratio for small and medium-sized enterprises in Italy is less than 40%, which is much lower than in Germany or France.

Italian SMEs continue to face significant barriers in accessing external financing. According to ISTAT data for 2020-2022, the use of equity capital is extremely rare: only 1.7% of enterprises engaged in innovative activities obtained equity funding during that period. Similarly, just 20.6% of these innovative firms applied for and received bank loans to support innovation initiatives. Public support also reaches only a minority of companies. Only 29.7% of innovative enterprises benefited from fiscal incentives, and there is a clear difference by firm size: nearly half of large companies 48.1% made use of such tax incentives, compared to just 27.1% of small firms.

With regard to venture capital, Italy's market remains relatively small. The Venture Capital Monitor report for 2024 highlights that total investment in startups with an Italian nexus (including those based abroad but founded by Italians) reached about €1.9 billion across approximately 330 transactions. While this is a step forward, it is modest in the broader context of Europe's VC landscape.

Institutional barriers further complicate the picture. Italy still ranks below the European average in terms of business climate and ease of doing business, exacerbated by bureaucratic complexity, regulatory uncertainty, and slow judicial processes, according to European Commission report. These conditions lead to high compliance costs and a fragmented regulatory framework. As a result, smaller companies are often discouraged from using formal financing channels, and banks and investors face higher transaction costs, which reduces the appeal of smaller or higher-risk investments.

In 2022, Italy saw approximately €1.8 billion in VC investment, whereas France attracted about €12.9 billion. Adding to these structural problems is a cultural factor that keeps things the same: many Italian business owners want to keep full control of their companies and don't want to bring in outside partners or investors. This mindset limits the demand for venture capital even among high-potential firms. The outcome of these combined barriers is a fragmented, risk-averse financial ecosystem that struggles to support dynamic, high-growth SMEs. Overcoming these challenges will require a coordinated, systemic effort: improving entrepreneurs' financial knowledge, making administrative procedures easier, expanding and deepening capital markets, and fostering a culture more open to equity partnerships.

Only through such measures Italian SMEs can fully leverage external capital to enhance innovation, competitiveness, and long-term growth.
Capital needs in emerging high-tech sectors In emerging high-tech sectors, the financing needs and challenges of Italian SMEs are particularly relevant. The European Commission has identified fields such as artificial intelligence, advanced manufacturing, clean technologies, biotechnology, and the space economy as strategic priorities for Europe's competitiveness and resilience. T
hese sectors are characterized by fast innovation cycles, high upfront fixed costs, and ongoing R&D expenditures which make it difficult for SMEs to survive. Indeed, just a few sectors, information and communication technology (hardware and software), health and pharmaceuticals, and automotive, account for more than three-quarters of private R&D spending in Europe, highlighting that the required investments are capital-intensive.

In 2024, total VC investment in startups with an Italian origin (including Italy-based startups and those founded by Italians abroad) was near €1.9 billion across about 330 deals. While this is a dramatic increase from just a few years prior VC investment in Italy has risen more than twelve-fold since 2017, it still represented only around 4% of the European total in 2024. By comparison, Germany and France each attracted several times the Italian amount in that year, approximately €7.4 billion in Germany and €7.1 billion in France.

Across Europe, the space economy offers a clear example of the high-tech financing dynamic. Private investment in European space ventures rose by 56% year-on-year in 2024 to reach about €1.5 billion, with a large share of deals and capital concentrated in the UK and France, based on ESPI release. Many of the emerging opportunities in this sector involve downstream applications that combine aerospace engineering with software and AI. However, realizing these opportunities requires capital-intensive infrastructure and strict certification processes, which are challenging for early-stage Italian companies to afford given the limited domestic risk-capital markets. \

Although Italy has made significant progress, its Venture Capital ecosystem remains primitive if compared with international standards. Between 2017 and 2024, annual VC funding in Italy grew more than twelve-fold to approximately €1.9 billion in 2024, placing Italy at about 4% of the European total vs. only 1.5% in 2020. This is still a small share, by comparison, startups in Germany and France each attracted nearly €7 billion in 2024. Such numbers highlight the gap in scale. Italian startups are starting to attract capital, but overall levels remain far below those in larger European markets.

Venture capital funding works best for businesses that combine cutting-edge technology, strong founding teams, scalable business models, and large market potential. It is not intended for traditional small businesses seeking modest expansion, but rather to build high-growth companies capable of transforming their sectors. Moreover, VC provides more than just capital. Investors contribute so-called “smart money,” meaning they offer strategic guidance, governance support, and industry connections to help a company grow faster and more professionally.

According to the IMF, Venture capital -backed companies present up to 30% higher revenue growth and are far more likely to expand internationally than their non- Venture capital -backed counterparts. In an economy like Italy's, full of small and medium-sized enterprises, venture capital can be a game changer, particularly in deep-tech fields such as aerospace. By combining expertise and risk preference, VC funds can help SMEs address their structural weaknesses, enabling rapid growth even in international contexts.

Italian space economy

In the past, the term "space economy" made people think of government-funded moon landings, satellite launches during the Cold War, and other government-led projects. Today, it has grown to include a much bigger and more active ecosystem of business, government, and research activities related to using and exploring space. This ecosystem has the usual upstream parts, like making satellites, developing launch vehicles, and designing spacecraft.

Over the past two decades, the space economy has transformed significantly. In 2022, the global space economy's value reached approximately $546 billion. A substantial driver of this growth has been the contribution of private investment. For instance, venture capital funding for space-related companies around the world rose sharply. In 2015, global VC investment in space startups was about $1 billion, but by 2021 it had grown to almost $12 billion.

This increase in private capital and entrepreneurial activity is often characterized as the shift from “Old Space” to “New Space.” The New Space economy reflects a move away from the traditional government-led, slow-moving, and infrastructure-heavy model of space development and toward a more dynamic, cost-efficient, and commercially driven approach led by private companies. Notable New Space entrants like SpaceX, Rocket Lab, and Planet Labs have demonstrated how innovative business models and technologies can disrupt the legacy aerospace industry.

Italy has been an important player in the global space industry for a long time. It was one of the first countries to build and launch its own satellite, San Marco 1, in 1964. This made Italy a space-explorer nation early in the Space Age. In the 1970s, Italy was one of the first countries to join the European Space Agency. Italy is now the third-largest financial supporter of ESA's programs, after France and Germany.
For the 2025 ESA budget cycle, Italy is contributing with about €3.1 billion. Italy has been investing this much in space activities for a long time, and the amount has almost tripled in the past ten years, showing how important the sector is to the country.

Italy's domestic space economy ecosystem is characterized by a strong industrial base that contains both upstream and downstream activities. On the upstream side space infrastructure and manufacturing, Italy is home to major aerospace companies and system integrators. Key players include Leonardo, Thales Alenia Space Italia, Avio, and Telespazio. These firms and their subsidiaries cover a wide range of capabilities because they build satellites and spacecraft, develop and integrate space system components and provide launch services

and satellite operations. For example, Avio is the prime contractor for the Vega launch vehicle, one of the few operational small satellite launchers in Europe.
Thales Alenia Space's Italian division and Leonardo have been deeply involved in leading European projects like the Galileo global navigation satellite system and the Copernicus Earth observation program, supplying critical satellite hardware and services. Telespazio, a joint venture of Leonardo specializes in satellite operations and services, managing everything from mission control to geoinformation services.

In the downstream segment especially applications and services enabled by space data, Italy has experienced a wave of new ventures and innovative projects in recent years. A growing number of space-tech startups and research spin-offs are focusing on areas such as Earth observation data analytics, satellite-based Internet of Things (IoT) connectivity, satellite broadband services, precision navigation, and ground segment innovations. These startups aim to apply space originated data and technology to a variety of sectors, including agriculture such as crop monitoring, logistics and transportation, environmental protection and climate monitoring, urban planning, and defense and security. The downstream segment is seen as particularly appealing because it creates value by leveraging space infrastructure to solve problems on Earth, which makes it valuable and interesting to industries outside of space as well.

The space economy in Italy is diverse and innovative, as shown by several Italian companies and startups. D-Orbit is one of the most well-known space logistics companies. It is based in Como and specializes in deploying satellites in orbit and managing space debris. The ION Satellite Carrier is its most important product. It is an orbital transfer vehicle that can put small satellites into precise orbits and do technology demonstrations in space.

The company's fast growth has attracted considerable venture capital interest, and in 2024 it completed a €150 million Series C financing round led by United Ventures, with participation from CDP Venture Capital and the European Investment Bank. This funding is enabling D-Orbit to scale its operations globally and accelerate the development of advanced in-orbit services.

Wise Robotics is a startup born in 2015 made up of electronic and IT engineers, data scientists, economists and structural engineers with the mission of improving the quality and security of people's life, through the development of Iot monitoring solutions able to analyse the data to provide information and analysis in real-time. Wise possess expertise in Software Engineering, Artificial Intelligence, Big Data Analysis, Robotics, System Development and Cloud Computing. Among the projects developed by Wise, it is worth noting the Quakebots system, which is an innovative structural health monitoring platform based on Internet of Things, Machine Learning and Cloud Computing. The value of Wise Robotics has been demonstrated by relevant European awards such as SME Instrument Phase I and recognized by several key players such as the Enterprise Europe Network, Microsoft, LVenture and Forbes for the development and validation of the Quakebots System.

Quakebots is an innovative real-time vibrational monitoring system to analyze the dynamic response of buildings and infrastructures. The system is a micro-computer with a high sensitivity accelerometric sensor connected to the Quakebots Cloud platform via Wi-fi, Ethernet or LTE. Quakebots is a system that combines the latest technologies in AI, IoT and Cloud computing to offer high precision and high-quality services. Wise has worked to create a Cloud platform that is highly scalable and have the potential to handle millions of buildings with very low latency. The system enable a continuous monitoring of the structure over time, which in turn allows to discover deviations of the behaviour the structure from its normal state by means of AI and engineering algorithms, with the aim to help asset managers in the optimization of the maintenance operations.

The Quakebots system has achieved relevant national and international awards that have contributed to the development of the startup. Among them we can find the European Space Agency grant that allowed Wise developing the Quakebots SAT technology.

The new patented Quakebots SAT system combines the vibrational algorithmic component of measurements on buildings and infrastructures, with a positional component related to the use of GNSS. The Quakebots SAT allows to detect even the smallest displacement, landslides and for the early identification of any slippage of a structure over time.

The GNSS Quakebots SAT was installed on the Basilica of S. Francesco in Assisi, one of the test sites where it remained to perform acquisition and transfer of data. This allows to Wise to integrate these components with vibrational monitoring devices already present on the structure, through external prototypal connections, in order to obtain results and data based on the correlation between the movements registered by the vibrational algorithms and movements registered based on the component of GNSS. Quakebots is a patented technology and has been tested on ENEA (Italian National Agency for New Technologies, Energy and Sustainable Economic Development) vibrating table, together with DICA (University of Perugia), that certified Quakebots system and has already received an important market validation considering clients not only in Italy, but also in Belgium and Israel.

AIKO S.r.l. is an innovative deep-tech company with a unique mission: “Introducing Artificial Intelligence to space, to catalyze the evolution of space systems towards smarter, more autonomous and more efficient satellites” AIKO is a deep tech company, delivering state of the art Artificial Intelligence solutions for flight and ground software with the goal of enabling autonomous space missions. AIKO has active contracts, collaborations and partnerships with many european institutions and companies, including European Space Agency and the European Commission.

Leaf Space, founded in 2014 and headquartered in Lomazzo, Lombardy, provides Ground Segment as a Service (GSaaS) through a global network of ground station antennas. Its platform allows satellite operators to access on-demand communications infrastructure, eliminating the need to build proprietary antenna networks and in this way reducing operational complexity and costs (Leaf Space, 2023). The company's model has gained significant traction in the New Space market, supporting missions for a wide range of international clients.

AIKO has been the first European company to publicly announce the in-orbit demonstration of Deep Learning algorithms, in October 2019. Founded in 2017 in Torino and registered in the list of innovative Italian companies, since May 2017 is incubated in I3P (www.i3p.it), one of the most important public incubators in the world 15th worldwide in 2014, 1st worldwide in 2019. AIKO business focuses on the development of Artificial Intelligence software for space applications, targeting automation of operations, support to operators and advanced mission autonomy.

Key areas of expertise are Machine and Deep Learning, Knowledge-Based Systems and embedded software design applied to space missions, in the domains of autonomous decision-making, payload data information extraction, failure detection, and mission replanning. AIKO is composed of a team of highly skilled researchers and engineers, boosting years of experience in space programs, including two small satellites launched and operated, publications on international journals and congresses and collaborations with some of the most prominent research institutes, such as ESA, NASA JPL, and MIT. Since June 2018, AIKO is part of the NVIDIA Inception Program, a program reserved for startups that have Artificial Intelligence as the core competence and focus.
The program nurtures dedicated and exceptional startups who are revolutionizing industries with advances in AI and data science. AIKO has secured both private and public funding, including investment from VC involved in the field of Artificial Intelligence.
Argotec is another well-known example. It is an aerospace engineering company based in Turin that has become a leader in the development of microsatellites and satellite subsystems. Argotec made LICIACube, the cubesat that NASA used on its DART mission to document the asteroid impact, and ArgoMoon, a micro-satellite that flew on Artemis 1 to take pictures of the Moon and mission hardware. The company has also been very important to Italy's plan for observing the Earth. In 2022, Argotec signed a contract to make the first ten satellites for IRIDE, a high-resolution Earth observation constellation that is part of Italy's National Recovery and Resilience Plan and is run by ESA and ASI.

RIDE is set to be launched by 2026 and shows how Italian small and medium-sized businesses are providing cutting-edge hardware to government-funded programs.
Tyvak International, also based in Turin, shows the global integration of Italian space expertise. As the European branch of Tyvak, now part of Terran Orbital Corporation, the company specializes in nanosatellite and microsatellite design and manufacturing, serving both commercial and institutional customers. Its acquisition by Terran Orbital in 2021-2022 has positioned the Turin operations within a larger corporate structure, giving it access to global markets while leveraging Italy's strong engineering talent. Together, these companies showcase the width of capabilities and international relevance of Italy's emerging space economy.

From a policy point of view, Italy is still adjusting its national strategy to commercialize space technologies and services. A comprehensive strategy would include not just funding for R&D, but also measures to stimulate private investment, support technology transfer from research to industry and create a regulatory environment that attracts new space businesses.

While such an ambitious plan is still in progress, the Italian government's recent funding efforts signal that space is considered a national priority. Under the National Recovery and Resilience Plan , Italy's post-Covid recovery plan funded by the EU, approximately €2.3 billion has been allocated to space-related investments between 2021 and 2026. In addition, ASI's latest three-year plan as of 2022–2024 gives around €2 billion to national space programs. These funds are designated for projects such as satellite communications, Earth observation including the IRIDE program, space access launchers and spaceports, and in-orbit servicing technologies. The injection of public funding is expected to not only improve Italy's capabilities but also to attract private investment by reducing risk and creating new market opportunities.

Role of Venture capital in financing space-related companies

The globalization and commercialization of the space industry have opened the door for venture capital and private equity funds to play a more influential role. Historically, space initiatives were almost entirely funded and managed by governments and a few large aerospace contractors. Now, thanks to the rise of small satellites, reusable launch vehicles, and an increasing number of space-driven services, the space economy has become more accessible to private enterprises. This shift creates opportunities for external investors to provide capital and expertise to space companies, integrating traditional public funding.

Venture capital is particularly important during the early stages of a space company's lifecycle. This is because space startups often face substantial upfront research and development costs, highly technical challenges and a longer path to revenue than startups in many other industries. Moreover, space ventures must navigate regulatory issues especially licensing, ensure reliability in tough environments and attract specialized talent, all of which increase the complexity and risk of the business.

Venture capital funds, which are used to high-risk, high-reward scenarios, can deal with these long development timelines and capital-intensive investments by providing not just funding but also strategic guidance and networking. They often take board positions and actively mentor startups on product development, go-to-market strategies and fundraising.

Globally, the past decade has seen an increase in venture investment in space technology. Indeed, annual venture capital funding in the space sector grew from only around $1 billion in 2015 to well over $10 billion by the start of the 2020s. 2021 was a critical year because startups in the space sector raised an estimated $12–15 billion globally, a record high for the industry

In Italy, however, the integration of venture capital and private equity into the space sector is still in an embryonic stage. The landscape is improving, more space startups are being founded and seeking capital, but the amount of domestic



venture funding dedicated to space remains relatively modest. Italy lags behind some of its European peers in this topic. For instance, France and Germany have multiple specialized space funds or large funds that frequently invest in space and even smaller countries like Luxembourg or Spain have made strategic moves to finance space startups.

In Italy, many space companies historically relied on public funding or contracts from ASI, ESA, or the military and on collaborations with large companies, rather than on equity investment. As of the early 2020s, most of the significant investments in Italian space startups have involved either public-private partnership or funds from European programs.

This suggests that while Italy has technical know-how, it needs more risk-tolerant private capital to scale its space ventures. It is also important to recognize that many Italian companies active in the space economy are not early-stage startups but long-established firms that have evolved from precision manufacturing and advanced engineering sectors. Examples include Fabbrica Dallara and Eligio Re Fraschini, which have successfully expanded into space-related activities but whose ownership structures, maturity, and business models make them less suited to traditional venture capital investments.

These companies are often better positioned to benefit from private equity investors, who can provide strategic capital, professional governance and managerial expertise to help them scale operations and compete internationally.

A balanced financing strategy for Italy's space ecosystem should therefore combine venture capital to support innovative startups with private equity and other institutional investors to strengthen established firms and ensure the sector's sustainable growth.

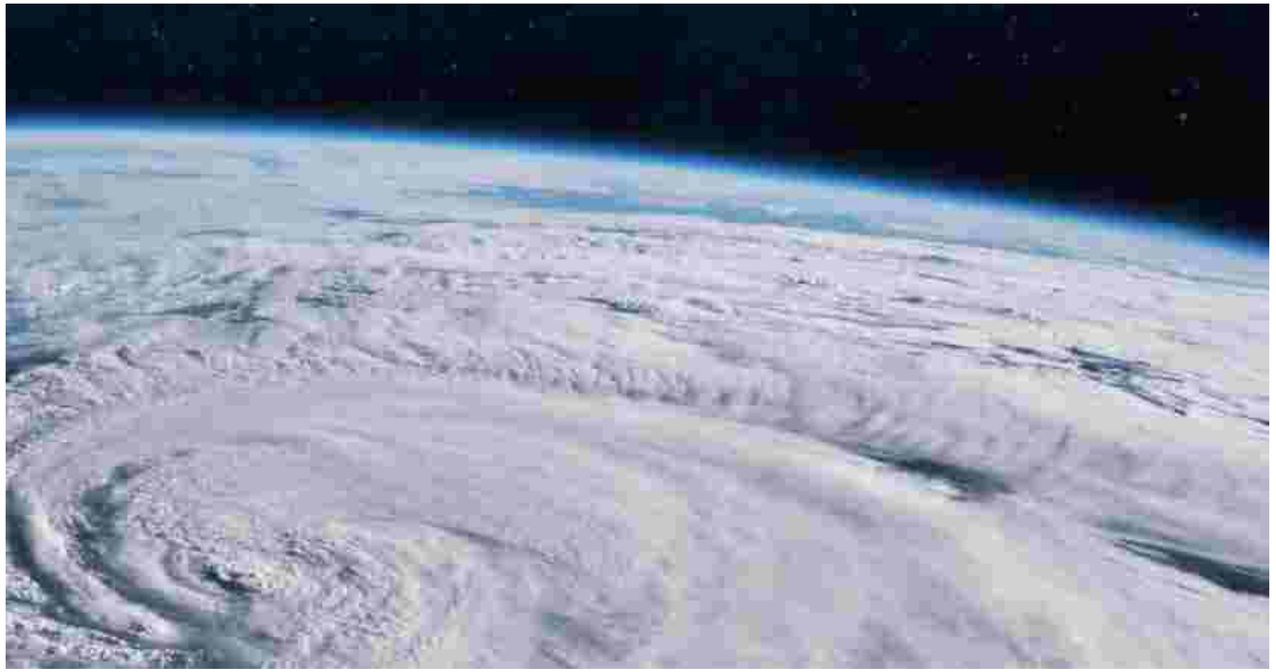
There are encouraging signs of change in Italy's venture capital landscape for the space sector. An important event was the launch of the Primo Space Fund in 2020, Italy's first VC fund dedicated exclusively to space technology. Backed by the European Investment Fund (EIF) and other institutional investors, Primo Space set an initial fundraising target of approximately €80 million and began investing in early-stage companies across both upstream and downstream segments of the space economy.

By 2021, it had already built a portfolio that included promising startups such as AIKO, a developer of autonomous satellite operations software, and provided financing to scale-ups like D-Orbit.
This initiative marked a turning point for the Italian space sector by introducing professional venture capital expertise and an international perspective which helps in filling the gap between Italy's deep technical talent and the broader investment community.
Another key player is CDP Venture Capital, the venture arm of Italy's state-owned investment bank Cassa Depositi e Prestiti.
Although its perspective is not limited to space, CDP manages multiple funds that have supported space-related startups, including Leaf Space and D-Orbit, often co-investing with private lenders and collaborating with university incubators. CDP's involvement provides validation that can help young companies attract further investment and expand internationally.

Beyond these examples, Italy still has relatively few dedicated space-focused funds, though several generalist venture capital firms and family offices have made selective investments in space or aerospace technologies. Interest from international investors, particularly from the United States, the United Kingdom, and France, is also growing, indicating that Italy's emerging space startup ecosystem is increasingly recognized within global capital markets.

SPECIAL REPORT

Data Centers in space



Over the past six decades, space has played a critical role in science, technology, and innovation. But recent disruptive trends are reshaping the sector. For instance, satellite launch costs have fallen by 95% over the last 30 years, and are expected to decrease further. Lower barriers to entry in the sector are creating opportunities for new entrants.

Traditional government agencies have been joined by a fast-growing group of private companies and investors, launching and managing satellites, exploring new economic opportunities, and more. Less traditionally spacefaring countries are also getting involved. Space is a critical sector for humanity and for governments, offering a wide range of economic, social, geopolitical, defense, and environmental benefits. And the influx of private players has revitalized the space sector as an engine of national innovation.

The space economy, encompassing all economic activities and value creation driven by space-related technologies and systems, is projected to grow from USD 596Bn in 2024 to USD 944Bn by 2033, primarily driven by the expansion of downstream services such as satellite communication services or value-added Earth observation services.

The space market, referring to the portion of this economy where the space industry operates directly, was valued at USD 224Bn in 2024, with satellite communication, Satcom and Earth observation accounting for around 80% of current revenues.

Space 4.0 is driving a new wave of advancements in manufacturing and engineering within the space sector. We see increasing adoption of agile spacecraft design with advanced systems and new engineering and production methods. Off-the-shelf components, agile production, and smaller satellites (smallsats) are further helping to reduce costs. Meanwhile, additive manufacturing and AI are driving down design and engineering costs and facilitating the use of advanced materials.

Increased use of minimum viable products and frequent iterations allow for rapid prototyping, faster error detection, shorter development periods, and quicker time-to-market.

These improvements in design and development are further enhanced by the emerging use of digital twins model based system engineering. Finally, we are observing the birth if in-space manufacturing especially the International Space Station's 3D printer, which over time will drive new business models, exploration priorities, and development of advanced materials.

The space sector has seen a dramatic increase in the number of national space agencies over the past two decades. Today, nearly 80 nations have established government space agencies, up from around 40 in the early 2000s. Sixteen of these agencies now have launch capabilities, including some newcomers such as the UAE , Bahrain, and Australia. The global investment in space reached approximately USD 117Bn in 2023, with the US alone contributing USD 73Bn.

Space is becoming increasingly congested as the number of satellites in orbit grows at an unprecedented rate. By 2033, over 30,000 satellites are expected to be launched, almost tripling the count from 2016 to 2024. LEO is particularly affected by this surge, driven by megaconstellations from companies like SpaceX, OneWeb, and Amazon, which aim to provide global broadband coverage.

This rapid expansion in LEO is leading to higher collision risks and escalating concerns about space debris, spurring calls for more effective space traffic management. Medium Earth Orbit (MEO), although less crowded than LEO, is also seeing an increase in deployments. Players like SES and Viasat are vying for MEO slots to enhance global communication systems, while traditional uses like navigation satellites (GPS, Galileo, Glonass) continue to occupy this orbit. Geostationary Earth Orbit (GEO) refers to stationary satellite positions. Only 10% of GEO's 1,800 slots offer optimal coverage, making the race for these positions highly competitive.

Meanwhile, diversification of launcher structures and capabilities is bringing down costs and creating niches in production and operation. We are seeing demand for different launch systems, with the emergence of small and micro-launchers for smallsats and super heavy-lift launchers for space exploration. Increasing reusability of components is driving down launch costs. New spaceports are opening around the world to house emerging launchers and provide sovereign access to space. New propellants and propulsion systems are also in development, like hybrid, electric, and methane engines. Ground infrastructure and operations are also being optimized with. More generally, we are witnessing a boom in space-related services driven by emerging technologies, ambitious exploration programs, privatization of space financing, and new public policies promoting private innovation. New Earth observation services are emerging, enabled by AI, big data analytics, and edge cloud computing capabilities.

New Global Navigation Satellite System (GNSS) Radio Navigation Satellite Service RNSS, Satellite-Based Augmentation System (SBAS) constellations and chipsets are expanding Positioning, Navigation, and Timing PNT services. IoT, broadband internet, and 5G backhaul are driving next generation Satcom demand with new applications. And new in-space service models are being explored, including spacecraft refueling, in-orbit satellite servicing, debris removal, and tourism.

These advancements are not only revolutionizing the space sector but are also driving technological innovation across the global economy. As the space sector evolves, its technological contributions will further accelerate global progress in fields ranging from communications to renewable energy and beyond. It is therefore important for countries to participate actively in space-related activities, to best position themselves for rapid learning and technological innovation.

Data center in space

As demand for AI infrastructure continues to outpace supply on earth, investors are beginning to focus on orbit as the next frontier to sustainably scale AI processing capacity. These facilities would place AI computing systems in sun-synchronous orbit, where they could access near-continuous solar power and connect with terrestrial networks. We believe the concept has real merit and should not be dismissed, though launch costs may need to fall by more than 90% before the economics become viable.

Even at this early stage, the investment implications are meaningful: the constraints motivating orbital data centers reinforce the value of scarce terrestrial capacity today, while efforts to overcome them could accelerate demand across launch services, satellite infrastructure, space-based power, and connectivity. In other words, orbital data centers could strengthen the case for both the infrastructure supporting AI now and the space economy that may support its next phase.

Why Is AI moving to space?

The case for orbital data centers rests on their ability to alleviate two constraints facing terrestrial AI infrastructure: power availability and cooling. Although orbital facilities are not currently cost competitive, their operating advantages could become increasingly relevant as power, grid access, land, water, and permitting constrain data center development on Earth.

AI's computing needs have risen sharply as models progress from reasoning toward agentic and, ultimately, autonomous capabilities. As a result, the primary infrastructure constraint is shifting from access to semiconductors and capital to access to reliable power. Global data center electricity consumption is expected to nearly double between 2025 and 2030 to around 945 TWh, growing nearly four times faster than overall electricity demand. In the U.S. alone, more than 100 GW of new data center capacity could come online between 2025 and 2035.The terrestrial grid is struggling to keep pace with that level of growth and energy intensity.

The challenge is compounded by permitting delays, slow transmission buildout, long interconnection queues, and increasing pushback from local communities. Roughly 20% of planned data center projects face significant delays, while interconnection wait times can reach a decade in key regions. Developers are responding by securing behind-the-meter generation, including nuclear power. The small-modular-reactor pipeline linked to data centers has nearly doubled, from approximately 25 GW at the end of 2024 to roughly 45 GW today. In our view, the AI infrastructure buildout is increasingly a competition for reliable energy, a constraint that orbital data centers could eventually help alleviate.

Space offers two operating advantages for power-intensive data centers: more consistent and abundant solar power, and reduced reliance on water-based cooling. In a dawn-to-dusk sun-synchronous orbit, a satellite can remain in near-continuous sunlight avoiding nighttime, cloud cover, weather, and atmospheric energy losses. As a result, solar panels could generate up to eight times more energy than comparable terrestrial systems. Orbital facilities would also eliminate the need for evaporative water cooling, instead rejecting heat through radiative cooling systems.

Together, these advantages could reduce orbital data center operating costs by nearly 67% relative to terrestrial facilities, where energy and cooling represent significant ongoing expenses. At the same time, a facility in orbit also sidesteps many constraints that delay development on Earth, including land acquisition, transmission siting, water-withdrawal permits, local zoning, and decades-long grid interconnection queues. If launch economics improve sufficiently, these structural advantages could support faster capacity deployment and expand the infrastructure available to meet rising AI demand.

Launch costs are the key economic hurdle

While space offers a meaningful operating cost advantage, the upfront infrastructure costs remain substantial. More specifically, the cost of delivering mass to orbit is the single largest barrier to economic viability. For instance, a representative orbital data-center node can require roughly 40 kilograms of hardware for every delivered kilowatt of compute capacity.7 Scaling that to a single gigawatt-class data center could mean lifting roughly 40,000 metric tons to orbit. At today's prices, that could imply well over $80 billion in launch cost alone.

By comparison, a one-gigawatt terrestrial AI data center may require roughly $40 billion in upfront capital. Spread over the equipment's useful life, that investment contributes to an annualized cost of roughly $9-10 billion, including operating expenses.8 Assuming the IT equipment costs are similar in space, orbital data centers would have only $7 to $10 billion of launch-cost headroom per gigawatt to remain competitive, even after accounting for operating costs that could be roughly 67% lower. That suggests launch costs may need to fall by more than 90% before orbital AI infrastructure becomes economically viable at scale.
Google estimates the economics could begin to shift at a launch cost of approximately $200 per kilogram.10 At that level, launch costs amortized over a spacecraft's life could become broadly comparable to terrestrial data-center energy costs on a per-kilowatt basis. Reaching that threshold remains a significant challenge but launch costs have already declined by approximately 90% over the past decade to roughly $2,700 per kilogram, with estimates that the $200-per-kilogram threshold could be reached by the mid-2030s. Further progress will likely depend on fully reusable and higher capacity launch vehicles, combined with a substantial increase in launch cadence.

Launch is not the only cost penalty. Orbital data centers also require hardware that terrestrial facilities do not need at comparable scale. Radiators and solar arrays can account for 65% to 70% of satellite mass, while space-rated photovoltaics remain far more expensive than terrestrial panels and depend on more specialized supply chains, including germanium substrates sourced largely from China.
Economic viability is not the only hurdle. Radiation remains a primary engineering challenge, as today's AI chips were not built for constant exposure to trapped particles, solar protons, and other space-based anomalies. Google's radiation testing of AI chips has shown encouraging data, but an orbital data center requires far more than processors alone. Testing, validating, and scaling production of the broader component stack including memory, networking, power, and other system components could take years.

Thermal management and connectivity present additional challenges. Without air or water to carry heat away, orbital facilities must reject waste heat through large radiator arrays, which can rival solar arrays in size and represent a significant portion of spacecraft mass. Orbital data centers would also require network links capable of transmitting tens of terabits per second across satellites flying in close formation to approximate the connectivity of terrestrial facilities. Current systems remain well below these requirements. '

Adoption is likely to begin with space-native computing

Gigawatt-scale orbital data centers remain a longer-term prospect, but smaller computing systems could become commercially relevant sooner. The most practical initial use case is processing data already generated in space.
Earth-observation satellites, defense assets, and disaster-monitoring platforms in space already generate substantial data in orbit. Transmitting all that data to Earth for processing is inefficient. Adding AI processing capacity in orbit would allow these systems to analyze data at the source and transmit only the relevant output, reducing bandwidth requirements and response times.

Defense applications could provide an early source of demand and funding. The U.S. Space Development Agency's Proliferated Warfighter Space Architecture already includes in-orbit processing requirements. The Department of War's proposed Golden Dome project could potentially leverage 7,800+ space-based interceptor missiles, adding trillions in funding tailwinds for space infrastructure and creating associated demand for in-orbit processing.

Today, SpaceX is the most credible infrastructure-scale player positioned to meet this cumulative emerging demand. The company could begin deploying its proposed constellation of up to one million satellites as early as 2028 but scaling that vision will depend heavily on reducing launch costs. Starship SpaceX's fully reusable heavy-lift platform – is the critical unlock, which could potentially bring launch costs closer to $200 per kilogram in our view, materially improving launch economics.

Private innovation is also advancing. Starcloud deployed the first data-center-class GPU in orbit in November 2025 and plans a laser-equipped follow-on mission in early 2027. Google's Project Suncatcher, developed in partnership with Planet Labs, is also targeting a prototype launch in 2027. These initial deployments would not compete directly with terrestrial hyperscale data centers. Instead, they could establish an early market for orbital computing, validate the underlying technology, and provide a pathway toward larger systems over time.
Lastly, the near-term monetization of the space economy will continue to come from where it comes from today: satellite connectivity, broadband, and Earth-observation data services, the profitable backbone of a market on track to grow from roughly $630 billion in 2024 toward $1 trillion by 2034.



In Europe, 2024 was somewhat of a paradox, but mixed feelings about 2026

At global level, 2024 was a great year for the space sector, with more records in satellite launches, satellites deployed, and total mass to orbit. Most of the growth was driven by SpaceX accelerating the deployment of its Starlink constellation, and the Chinese space programme lofting, for the 3rd time in its history, almost 180 tonnes to orbit. In the past 5 years, the Chinese deployed 726 tons in orbit on behalf of government sponsored programmes, for only 654 for their US equivalents and only 99 for Europe). China is solidly establishing itself as the largest player in all areas of space government programmes (and is also moving into Starlink territory, tackling commercial broadband services.

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Traditional government agencies have been joined by a fast-growing group of private companies and investors launching and managing satellites, exploring new economic opportunities, and more. Less traditionally spacefaring countries are also getting involved. Space is a critical sector for humanity and for governments, offering a wide range of economic, social, geopolitical, defense, and environmental benefits. And the influx of private players has revitalized the space sector as an engine of national innovation.

In the past two decades, at global level, the business opportunity provided to the space systems manufacturing sector has been much higher with government programmes than it was with commercial programmes. On average, over two decades, commercial programmes represented 10% of the total business opportunity for space systems manufacturing5, or about 3 to 10B$ per year for commercial systems against 20 to 50B$ per year for institutional missions.

When considering the launch services market presented below in value based on launcher supplier region we note a similar situation with the commercial launch demand represents a far lower business opportunity than institutional demand6 (18% of the total, in value, over the period). The launch market evolution exhibits a contrasted profile with the drop in 2005 due to both Ariane 5 and the Space Shuttle being unavailable, and an acceleration of the commercial demand driven exclusively by Starlink in recent years.

The global institutional demand for launch services, at almost 10B$ in 2024, is served by Chinese 36% and US 39% launchers this demand is basically captive. The commercial demand for launch services represented less than 2B$ in average in the past decades. It was primarily served by European and Russian launchers until 2017-2018. Starting in 2020 most of the commercial demand was absorbed by SpaceX, that also benefited from the captive internal demand for Starlink deployment that explains all the commercial launch market growth in 2021-2024.

It is worth noting that the institutional launch demand is traditionally well protected and usually served in priority by domestic launchers, while more competition is driving the commercial launch demand, as shown in the charts below (in mass launched). Note how the Starlink programme impacts the US Mission values in the commercial segment. Obviously, the Starlink programme launch demand is not available for competing launch suppliers. In recent years, with the woes that have befallen the Vega launcher series and the Ariane 6 development programme coupled with the retirement of Ariane 5, we witnessed European institutional players turning to SpaceX in order to launch their spacecraft.

In 2024, the main positive trend for the global space sector was the continued interest that governments worldwide expressed in space programmes, from the largest to the smallest. This interest was particularly strong for sovereign programmes, like military applications and exploration programmes, with the USA and China, leading by far, followed by Russia and, to a much lesser extent, Europe.

The year was also marked by the consolidation of SpaceX's market positions in key space business segments, particularly in launch services SpaceX performed more than half the total orbital launches in 2024 and with the market penetration of its Starlink service, crushing the competition on the fast-growing segment of broadband data connectivity in all segments. The very immediate consequence of SpaceX's competitive pressure was the contraction of the demand for the other commercial space systems (and the related launch services) accessible to legacy players, particularly ULA and Arianespace on the launch segment and MDA/Maxar, Boeing, Airbus and Thales Alenia Space on the satellite segment, with cascading consequences on lower tier players.

So, 2024 was somewhat of a paradox, with global business opportunities on the rise, in both the institutional and commercial segments, and with established players facing growing difficulties in front of the rise of SpaceX. And while the legacy industry is shaking, more emerging players feel they have an opportunity to seize.

The “newspace” crowd wants to walk in the steps of SpaceX, and a few larger new companies are starting to move the lines by securing growing shares of government business as they advance in maturity and grow their customer base. Regardless, the majority of financial information available on space start-ups indicates that even the more mature space of them are not yet in profit territory, and their survival is very contingent to the level of their cash reserves.

While global fundraising activity was still strong in 2024, with 6,7B$ of new equity, only a few tens of companies have achieved a critical funding mass to achieve (or approach operational status, and the majority of known equity tracked in the past decade has gone to just three companies: SpaceX, Blue Origin and Oneweb.

This creates a very unstable situation in the Western world's space supply chain, with most of the companies struggling to generate a sustainable profit, if any profit at all, while fiercely competing for a demand that remains insufficient to keep them all alive.

A sense of relief

In Europe, the space industry closed the year 2024 with a sense of relief. In July, the successful maiden flight of Ariane 6, eventually filling the gap after the retirement of Ariane 5 in 2023, felt like a deep breath of fresh air. In October, the European Union came to an agreement with all parties on the concession contract for IRIS2, “only” two years after the entry into force of the Regulation; this made for a happier end-of year for the supply chain, looking at the prospects of a hefty workload increment to develop, build and launch the 10B€ constellation.

To top the cake, the industry closed the year with increased final sales at 8,8B€ and workforce peaking at 66 thousand employees. Still, the European space industry may need to prepare for a long period of apnoea, because the majority of economic indicators are not on the brighter side.

A specialised strategic sector

The European space manufacturing industry is a strategic sector, essential for the implementation of many public policies, and supporting all economic sectors. It is embedded in the wider European AeroSpace and Defence industrial complex. The space manufacturing industry is an infrastructure supplier. The sector operates at the higher end of the space value chain, and supplies service providers and public institutions, spacecraft and launchers to meet their requirements.

The space industry designs, develops and manufactures spacecraft and launchers, along with the associated ground systems for satellite control and operations. The space manufacturing industry is organised vertically with large and medium system integrators (capable of delivering a complete launcher or spacecraft to the launch pad) providing business to a wide range of equipment and service suppliers (capable of delivering integration ready subsystem, equipment and components, or providing specialised services and tools supporting system design, integration and test). The industry is highly specialised and capital intensive. The sector is also rather concentrated; despite being distributed across all ESA member states.

Four large industrial groups Airbus, Thales, Safran and Leonardo are directly responsible for more than half of the total space industry employment via dedicated Business Units (BUs) and Joint Ventures. In 2024, the largest dedicated space business units and industrial capabilities are located mainly in Airbus Defence & Space, Thales Alenia Space and ArianeGroup. Smaller, but sizeable space players such as GMV, Beyond Gravity and OHB provide additional employment and capabilities to the European space industry.

SMEs represent only a small fraction (less than 10%) of the total space industry manufacturing employment. Notwithstanding, small space units are very common in the space sector, but they are often part of, or owned by, a larger company. These units often face the same issues as SMEs in the sector but cannot benefit from the dedicated support measures proposed by public institutions. Industry is distributed across all Europe, with the main industrial sites located in France, Germany, Italy, and, to a lesser extent, United Kingdom, Spain and Belgium. In 2024, the European space industry successfully delivered 89 spacecraft to the launch pad of which 50 large satellites and 39 pico and nano satellites. It also delivered 6 launchers for operations in Kourou.

But profits are receding

Organically, our industry is suffering from a massive profit situation. A systematic survey undertaken under the auspices of Eurospace Council unearthed a few worrying facts. The actual profit measured by EBIT of all companies in the sector has been constantly receding during the period surveyed 2019-2023, with the sector at large experiencing losses on its space business.

Of course, the major losses announced in the space segment by Airbus and Thales Alenia Space in 2024 weigh significantly in the European landscape. But generally speaking, and with very few exceptions, all available data points available indicate that the space systems business in Europe is trending towards decreasing profits; particularly for those players most affected by declining business in the commercial geostationary segment(with cascading consequences on both the launcher and the satellite supply chains, but not only, because the pressure on prices and performance is unusually high in all demand segments. The first visible consequence of declining profits are the workforce cuts, with the large 4 players Airbus, Thales, Leonardo and Safran cutting down their space workforce by 3% in 2024, and announcing wide ranging restructuring plans in the satellite segment.

Massive layoffs are looming

Notwithstanding, employment in the sector grew by 4% in 2024, under the positive impact of two different trends. First, the European industry has its order books filled to the brim, mostly with institutional orders thanks to the relentless investment of European states in space programmes, in constant growth in the past 5 years. This growth is registered in our annual statistics, where the share of revenues from European institutional programmes reached a new high in 2024 to 6,3B€ 72% of total industry revenues, with a Compound Annual Growth Rate of 3,4% through the decade.

And there is more! Considering the large spending backlog on ESA-managed programmes the ESA managed budget CAGR was 4,6% in the decade, but its procurement only grew by 3,6%, there is no medium-term uncertainty on workload. In order to absorb this work, many companies are hiring, particularly the midcaps, and those that are cutting on workforce are preserving critical resources to support these programmes; lacking these positive workload prospects, the workforce cuts in the large 4 would have been even more drastic.

Secondly, we note that the workforce employed in the bustling segment of space start-ups has spiked again in 2024, passing the 10000 mark after only 5 years. The segment now represents 16% of total industry employment. This growth was clearly fuelled by improved access to resources, mostly equity with 4,7B$ raised since 2000, of which 1B$ in 2024 alone (the biggest fundraising year for European space start-ups active in the upstream), but also the availability of government-sponsored grants and targeted development programmes that provided towards 250 M€ of revenues in 2024. While only a few share their revenue details with Eurospace, the data we have analysed indicates that many players in this segment are now also registering revenues from the sale of products and services, in the range of 300M€ in 2024. Still, the vast majority of European space start-ups are not yet economically or technically mature, and their bottom line is usually negative. Considering the estimated cash and employment history, it can be safely assumed that most players are underfunded, some severely. Only a few have some leeway ensured, and they are not necessarily the highest fundraisers.

Labour productivity still low

Eventually, with employment growing at a faster rate than the business, the apparent labour productivity is still very low in 2024 (132k€/FTE), an amount that does not sustain economically a capital-intensive industrial sector employing an expensive skilled workforce (more than half of industry employment has a high education.

With the receding trends in the commercial geostationary segment, where our industry has suffered from strongly declining demand minus 50% since the all-time high of 2017 calling for restructuring, the related supply chains, and the growing influx of new players in the sector, the sector exhibits a growing overcapacity.

The European industry is historically scattered, with many industrial capabilities having emerged at the whim of national policies of ESA member states, resulting in an extremely fragmented industrial base, despite the rather strong corporate concentration of most industrial capabilities within just 4 industry conglomerates - the combination of all space businesses of Airbus, Thales, Leonardo and Safran represents half of the total workforce.

The current trends of growing government support to European space programmes should provide additional business opportunities in the medium term for the growing industrial base, but the national obsession that drives this spending - enshrined in the ESA geo-return rule and exacerbated in national military programmes - combined with the lack of a coordinated industrial policy, strengthen the looming spectre of overcapacity, potentially clouding the future of the European space sector rather than enlightening it.

The diminishing profits and decreasing labour productivity are strong indicators that cannot be ignored in this context, and they are particularly troubling considering that global demand for space systems is growing. The problem, for Europe, is that the main forces behind this global growth are the two global space powers, China and the USA, pouring more of their tax-payer's money into sovereign programmes, not the mirage of a self-supported future Trillion dollar space economy.

European policies inspired by the "space economy" seem to want to prepare our industry for a future of growing commercial demand and satellite production of thousands every year, it is high time they acknowledge instead that all recent political statements in Europe consistently point, albeit without necessarily being precise in terms of time horizon, towards an increased demand in Europe to meet security and sovereignty needs.

The Falcon launcher is demonstrating the highest launch cadence ever witnessed for a single launcher in space history, it has consistently improved its market share on the commercial launch segment, but has not yet been able to create any significant additional launch demand on this segment. We note how the commercial market share of the Falcon launch system has improved significantly in 2024 with Ariane 5 retiring from the competition. Commercial launch customers represented more than 800M$ per year of launch revenues for SpaceX in 2023 and 2024.

Markets and customers

The European space industry has access to quite large, yet fragmented domestic markets, its core markets. It also exports its systems outside Europe. In both markets space systems are sold to a variety of customers, mostly public entities such as space agencies in Europe and worldwide, but also private customers such as satellite or launch service operators.

The first business area of the space manufacturing sector lies in the design, development and manufacturing of satellites for operational applications, such as telecommunications systems and parts, Earth observation systems and parts, and position/navigation/timing PNT systems and parts. The second area of business is launchers. Launcher activities include operational launch systems sales (mainly to Arianespace) and development and consolidation activities, mostly in support of the Ariane and Vega systems, but also for the development of brand new systems, especially micro-launchers.

Scientific activities include a wide variety of systems and leading edge technologies, with science systems and parts and human spaceflight (and related activities, such as crew and cargo systems for the ISS etc.) representing together the core of revenues in this area.

Ground systems and activities cover an array of diverse industrial activities, including engineering and consultancy services (provided to the manufacturing sector and in support to space agencies), the development and production of professional ground stations, and the industrial hardware required for the development, production and test activities European space industry sales exhibit contrasted evolutions over time, mostly influenced by the evolution of sales to commercial customers. Industry employment figures follow the variation of sales, with a similar pattern.

The output of the space industrial sector can be summarised every year with the measure of the mass of European spacecraft delivered for launch, and the measure of the mass launched by European-built launchers, Ariane and VEGA.

The output of the Space industry can also be measured every year with the number of spacecraft delivered for launch and the number of European launchers operated the same year. We note that since 2017 the number of spacecraft produced in Europe is growing, with numbers even exceeding 100, while in previous years the production would never peak above 50. This situation is due to the acceleration of very small satellites produced, with many being produced by students within university labs, and some by emerging European players specialising in very small satellite production. See the next chart for more details.

Regarding launcher deliveries the situation is quite different with peak years with more than 10 launchers and year corresponding to the years between 1996 and 2002 when Ariane 5 and Ariane 4 were operational at the same time. With the Ariane 4 phase out after 2002 the situation stabilised with less launchers produced. The introduction of the smaller VEGA launcher in 2012 did provide some additional launch opportunities, but limited to a very few launches per year. In 2023 Ariane 5 was phased out, and Ariane 6 eventually became operational only in 2024, resulting in very low launch numbers in these years.

Commercial programmes

There has been a lot of excitement in recent years about the development of commercial space, with very optimistic projections presenting a future of exponential growth for commercial space programmes, that would result in a massive growth of commercial demand for space systems and the related launch services, and major business opportunities arising for the space sector. The reality is a lot more sober, indeed while there has been a significant growth of spacecraft launched in numbers, 95% of the growth in mass in commercial programmes since 2019 is due to the Starlink programme. Other high numbers of spacecraft launched in 2017-2024 were mostly associated to constellations of hundreds of small satellites (like the 660 Oneweb satellites of 150kg each) or even extremely small satellites (like the Planet and Spire constellations of hundreds of 6U and 3U cubesats) that have had a negligible impact on the series.

Globally speaking, when isolating Starlink from the other commercial programmes, we note that the profile of commercial demand (in B$ see below) since 2015 for commercial launch and spacecraft exhibits a somewhat erratic profile with ups and downs. The past two years have seen commercial spacecraft demand peak at 5B$ (a level as high as 2017 or 2012), while the years 2019, 2020 and 2021 have been amongst the lowest in the decade with less than 3B$ worth of commercial demand. **In** average the commercial demand for spacecraft represented 3.8B$ per year in the decade and supported an average demand for commercial launch services of 1.4B$ per year.

During the same period Starlink has developed significantly, with potential effects on the future demand of commercial operators whose plan to roll out broadband services from geostationary orbit are being revised in light of Starlink capturing their market shares for residential broadband service and other B2G services such as maritime and aviation connectivity.

Public vs. Private customers

The sales of the European space industry are mostly associated to public customers (i.e. state-controlled/owned entities). They represent 75% of final industry sales. Private customers represent a significant, though lesser, share of European space industry sales, worth 25% of final industry sales. With current decreasing trends in the commercial market the share of sales to private operators is expected to further decrease.

Historically public entities have been the sole customers for space systems in Europe (and worldwide). Today, public governmental programmes are still the largest contributors to space industry activity worldwide, and Europe is no exception to this rule. Public customers particularly government controlled entities are mostly composed of space agencies in Europe and abroad, as well as public satellite operators (such as Eumetsat in Europe, or Arabsat, Chinasat, RSCC worldwide).

The gradual privatisation of a few specific areas of space activity has favoured the development of private customers for space systems. The first in line was Arianespace, the European private launch services operator. This development was accelerated at the turn of the millennium with the privatisation of all main telecommunications satellite operators including Eutelsat, Inmarsat, Intelsat.
As a consequence of the structure and nature of commercial markets in space, European space industry sales to private customers are concentrated upon two main product lines: large geostationary telecommunications satellite and operational launch systems for operations at Kourou.

Since the late nineties, two secondary commercial markets have emerged; the market for low Earth orbit mobile communications satellites in constellations and the market for commercial Earth observations systems. We now see an emerging commercial export market in the areas of Science and more importantly in the segment of human spaceflight.

European public and institutional customers

European public institutions, including ESA, national agencies, Eumetsat, and later the military and the European Comission, are the core historic customers of the European space industry. Today they represent 72% of space industry sales. Space agencies have been established in Europe progressively from the sixties to nowadays.

They have progressively acquired an extended technical competence that allows them to manage the complexity of space programmes, a unique competence that is put to the service of other institutions. Space agencies such as ESA and CNES in particular not only manage and procure programmes serving their own purpose, but also provide technical management and procurement services to other entities.

The most notable cases involve complete programme delegation, where full budgets are delegated to the space agency for implementation on behalf of a third party. This is the case of the Copernicus satellites, managed

and procured by ESA on behalf of the European Commission. This is also the case of the Galileo programme, where ESA ensures all procurement on behalf of the Commission. Similarly, ESA has consistently developed and procured the European meteorological satellites on behalf of Eumetsat. Thus, it is no surprise that ESA is now the single most important customer of the European space industry, worth 3,9 B€ of revenues.

In this total, the European Commission programmes delegated to ESA represent an estimated 687 M€ worth of revenues for the sector. Furthermore, programmes delegated by Eumetsat represented 180 M€ of revenues for industry. After ESA, national space agencies in Europe represent the most sizeable share of revenues from European institutional programmes, worth 1123 M€.

These are the revenues generated by national space programmes. Most of these are associated to the activities of CNES France, DLR Germany and ASI Italy. It must be noted however that these three civil space agencies also occasionally manage programmes on behalf of the military. This was the case of Essaim CNES, DGA, Satcom BW DLR/Bundeswehr, Sicral ASI, Forze Armate Italiane. In 2024 the estimated value of military systems procured by civil space agencies in Europe was 5M€.

With regard to the sales to military institutions in Europe, they represent revenues worth 966 M€. Since not all military systems are procured directly by military entities, the total value of military systems sales is higher than the value of sales to military customers in Europe, worth 995 M€.

This total includes the procurement of civil space agencies, worth 5 M€, the PPP approaches especially Airbus, Skynet worth 15 M€, and exports worth 63 M€ and a further 9 M€ worth of military systems whose customer could not be identified in the survey. In total, the sales of military systems represent 1057 M€ in 2024.
It is interesting to note that ESA and other institutional customers in Europe are not procuring the same types of systems. For Earth observation systems, the most important area of activity for institutional programmes, we note that ESA programmes including the delegated programmes from the EU and Eumetsat provide much larger revenue opportunities for the industry than national programmes in the same domain.

For telecommunications, we note an even more striking situation with industry revenues from ESA programmes being much lower than those of national programmes. Some domains of activity are mostly organised in the ESA frame, this is the case of launch system development, human spaceflight and ISS activities, and science.

by Pierre Lionnet



Disposing the International Space Station

As humanity moves into a new era of commercial space activity, defined by the emergence of commercial space stations in low Earth orbit LEO, the question of how to responsibly retire aging space infrastructure such as the International Space Station ISS and future large space objects is becoming increasingly urgent. More than a dozen new space stations are currently in planning or development, six of which are commercial space stations scheduled to launch before the end of this decade. These, too, will eventually require disposal just as the ISS is slated to be in 2031. The planned deorbiting of the ISS and future large space objects presents critical operational and policy challenges for the global space community.

The ISS is orbiting about 350 kilometers 220 miles above Earth. Previously operated by three international crew members, it is now continuously occupied by a multinational crew of six. It is the largest human-made object ever to orbit the Earth. Fifteen countries are involved in the project, and all of the partners are contributing components to be integrated in orbit. The operations and management centers involved in the program are located in eleven countries and staffed by international teams. In 2008, the laboratory space and research facilities were tripled with the addition of the European Space Agency's ESA's Columbus module and the Japan Aerospace Exploration Agency's Kibo module joining NASA's Destiny Laboratory, creating a research area about the size of three large buses.

Despite these accomplishments, the United States is currently planning to end its participation in the program in 2015, and the ISS is scheduled for a controlled de-orbit in 2016. International partners are interested in continuing the program but its fate is still uncertain. To understand why, it is useful to have an understanding of how the ISS program developed and how the current situation evolved. In 1985, memoranda of understanding MOU were signed with Japan, Canada, and the European Space Agency. By 1988, an intergovernmental agreement among participating countries was signed, and development of the station got under way. However, the program soon encountered difficulties.

As the world becomes increasingly interconnected, strong international partnerships are essential to the success of any nation, including the United States. The ISS allows the United States to maintain and continue to forge such partnerships and to explore ways of working successfully with other nations on technical projects. It provides a starting point for future collaboration beyond space programs, for projects of any kind. The utility of international partnerships was recognized early in NASA's history.

Global cooperation on large-scale technical projects is a growing phenomenon, and the International Space Station has been studied as a model for these types of partnerships. A great example is the 2008 integration of two international laboratories, the European Columbus lab and the Japanese Kibo lab, into the ISS. The Canadian Special Purpose Dexterous Manipulator has been added, and both the European Automated Transfer Vehicle and the Japanese H-II Transfer Vehicle have successfully performed servicing missions. These concrete steps forward provide strong evidence that the program is succeeding.19 International partners place a great deal of importance in the ISS.

The name of the Japan Aerospace Exploration Agency's laboratory Kibo means “hope” in Japanese. When the first module of the laboratory was delivered in March 2008, the Prime Minister of Japan hailed it as the beginning of Japan's new “home in space.”20 Each international partner mentions its participation in the ISS program as a major effort of its space program. The JAXA vision statement, written in 2005, notes that participation in the ISS program shows Japan's status as an “equal partner with the United States and European countries” and establishes its status in the international community.21 Russian, European, and Japanese space policy documents all mention the importance of research done on the ISS to successful future human spaceflight missions.

Paving the way for commercial space

An interesting benefit that results from the ISS program is a boost to the commercial space sector. Research done on the ISS concerning space systems and human safety will benefit any future space travel companies in addition to government spaceflight programs. As we learn more about how to protect humans in space and how to make systems that are more reliable for space travel, the commercial space sector is becoming increasingly robust. To date, seven “private spaceflight participants” have visited the ISS.

While small in scope, this effort has demonstrated that there is interest, even at very high prices, for commercial human spaceflight. Several companies are using this information to better understand the market for commercial space travel; one startup company, Virgin Galactic, has already begun taking deposits and wait listing passengers for its upcoming suborbital spaceflight operation.

The ISS is also acting as a catalyst for commercial development in another way. The Commercial Orbital Transportation Services COTS Program seeks to stimulate commercial space transportation services companies by creating a market for supply flights to the ISS. This has been likened to the government purchasing air-mail services during the early days of aviation to promote the growth of the airline industry. The COTS program may result in less expensive and less risky launch options for future NASA payloads, as well as for other customers. Companies involved in NASA's COTS effort may eventually provide commercial options for human space transportation, allowing NASA to focus on its goal of cutting-edge development and exploration rather than routine transportation.

The ISS is essential to this effort since it is the destination for which these vehicles have been designed. However, COTS vehicles are unlikely to be ready before 2010, and if the U.S. breaks away from the program in 2015 these technologies may not reach their full potential. The effect on COTS-D, the program aimed at supporting commercially-developed space systems to transport
humans to the ISS, may be even more pronounced, as these technologies are not scheduled to be ready until after the cargo vehicles have been developed and tested.

Even the infrastructure of the station is being opened to the commercial industry on some fronts. NASA has signed a service based contract with one company to provide water production services aboard the ISS. NASA does not need to purchase any hardware, just the water. The company will provide the equipment, and if the system does not work, NASA will not pay for it. The contractor is responsible for all system development and performance.

This is a fundamental change in the way NASA works with private companies and demonstrates the willingness of industry to invest in space systems. The designation of the ISS as a National Laboratory also opens new possibilities for the participation of commercial industry in the experiments and operation of the ISS. As with other forms of government research, the longer the ISS is available as a research facility, the more likely companies are to engage in research leading to break-through findings and innovations.

Deorbiting the ISS

The ISS has significantly advanced humanity's understanding and utilization of human presence in space since becoming fully operational in 2000. It has served as a home to more than 270 people from over 20 countries who have conducted over 4,000 scientific experiments in microgravity. However, its operational life is constrained by economic and engineering factors. Recently, after thoroughly evaluating various end-of-life options for the ISS, NASA awarded SpaceX a contract to develop a deorbit vehicle to safely guide the ISS, the largest human-made space object ever placed in orbit into a controlled re-entry over the Pacific Ocean. This decision has sparked concern among some space advocates, who view the planned decommissioning of the ISS as wasteful, and also among environmental advocates, who regard it as ecologically irresponsible.

In response, NASA issued a paper supporting its decision to deorbit the ISS. The agency argues that the ISS was not designed for autonomous operation; it requires a continuously active crew to stay operational. Additionally, boosting the ISS to a higher "graveyard" orbit presents substantial costs and risks. While there is an understandable desire to preserve this historic artifact, one of humanity's greatest achievements in science, engineering, and international cooperation comparisons to the Apollo landing sites, which we surely wish to preserve, are not entirely apt. The Moon is naturally suited to preserving history: its billion-year-old, pristine craters offer insights into our early solar system, and the Apollo sites, lacking atmospheric erosion or active geology, will endure for a very long time without expensive human intervention, provided we simply restrict access and operations nearby. The ISS, in contrast, will not.

The China's influence

In the past year, China conducted 66 orbital launches of which 64 were successful. With 12 launches, China's Chang Zheng 2D was the second most-flown orbital rocket in 2023, behind Falcon 9 which flew 92 times. China Landscape, a private company, launched the world's first methane-based rocket twice in 2023. And the Chinese company, i-space, completed two hop tests in preparation for its new reusable rocket, Hyperbola-3 rocket, planned for 2025.

This pace is breathtaking. None of these capabilities existed 5 years ago. Year by year the funding pouring into the space sector in China far eclipses that of the United States. The results are plain to see to anyone who is looking. And there is more to come: Just last week the Beijing municipal government released a commercial space industry plan intended to stimulate the sector over the next five years.

In low-Earth orbit, meanwhile, the Chinese have established Tiangong, an orbital space station that continues to grow in size and capability. China recognizes and exploits the power of utilizing low-Earth orbit to extend their influence, elevate national prestige and deploy soft power. China's plan to deploy over 1,000 payloads on Tiangong, and their partnership with the U.N. to select and operate international payloads has garnered worldwide attention. American companies preparing to operate commercial platforms in LEO are keenly aware of the threat posed by the Chinese station to their business models as China subsidizes flights, payload development, and science.

A gap in American presence in low-Earth orbit will enhance China's position globally, cement their “business case”, and place American orbital platforms in a position where they must fight to regain lost market share on an uneven playing field with an entrenched competitor. In the face of uncertainty and an absence of American capability, international industry and scientific institutions will be forced to partner with the Chinese in order to ensure their ability to continue to operate in low-Earth orbit.

The impact on the new economy being developed in space will be significant, causing a decline in the number of companies trying to utilize the microgravity environment. We have seen this pattern before, where the United States develops a capability and then China steps in to advance it and compete head-to-head. In low-Earth orbit, a gap will set up the same situation, with the U.S. falling behind China and once again importing rather than exporting technology and expertise to the rest of the world.



Disposition of large space objects in the future

An important issue lies behind this discussion how, generally, should we dispose of end-of-life objects in space, particularly as they grow in size? Simply dumping large low orbiting objects into the atmosphere carries significant risks and costs10 and prompts c

onsiderable concerns and opposition. The most sustainable long-term direction lies in re-using or recycling of structures, components, and materials that make up objects in space like the ISS rather than treating them as single-use. Currently such objects are not designed to be readily re-purposed or recycled, but now is the ideal time to begin prototyping these capabilities and establishing a new market sector for orbital recycling turning costly waste into valuable resources.

In this direction, NSS respectfully urges that the ISS partner agencies should formally publish a Request for Information for plans to re-use future large space objects, subject to the following conditions for reuse and recycling: The entity making the proposal must take possession of the subject object and its parts and relocate them within 24 months of approval. The objects and parts would be offered as-is, at no cost to the entity if there is no competition or to the best qualified bidder if there is competition.

To be accepted, the entity must provide a plan showing that their intended re-use or recycling is both safe, and within the capabilities of the entity. The entity must cover all the costs of removing the parts and materials from the object. In return for satisfying the above criteria, the entities will be provided a degree of liability insurance for a limited period of time.

Although early Space Station requirements envisioned an indefinite operational life through periodic maintenance, these specs were adjusted to a 10-year post-assembly lifespan. Nonetheless, the station was still designed for extended life via replacement of Orbital Replacement Units and in-situ repair.

During ISS assembly, modules were detached and repositioned, demonstrating modular adaptability, although support equipment and maintenance plans were not developed and one key support equipment item, the Space Shuttle Remote Manipulator Arm was retire). Development and validation of concepts for indefinite extension with repair and refurbishment are an absolutely vital step for long-term sustainability of outer space activities.

Therefore, the ISS partner space agencies should additionally, call on industry to submit proposals for the indefinite extension with repair for future in-space infrastructure, and consider demonstration of such techniques with the ISS prior to disposal, considering that it has an unprecedented time of exposure to the effects of aging in LEO, with humans in the loop, and would serve as a valuable “fleet leader” for future large space structures. These proposals may include any relevant engineering studies related to this topic.

This should cover the yet-to-be-constructed Lunar Orbital-Platform Gateway, but also any proposed or envisioned future infrastructure in space.
With such an effort, the ISS partner agencies could collectively jump-start an in-space repair/recycling industry, in much the same way commercial orbital transportation services were initiated by NASA in 2005. The results of this RFI should help to prevent future scenarios such as the ISS deorbit in which a large and expensive facility in space is designed for either a finite lifespan or in such a fashion that component reuse is impossible.

According to the Guidelines for the Long-term Sustainability of Outer Space Activities, “States and international intergovernmental organizations should encourage manufacturers and operators of space objects, regardless of their physical and operational characteristics, to design such objects to implement applicable international and national space debris mitigation standards and guidelines in order to limit the long-term presence of space objects in protected regions of outer space after the end of their mission.

States and international intergovernmental organizations are encouraged to share their experiences and information on the operation and end-of-life disposal of space objects, in furtherance of the long-term sustainability of space activities”. In line with this guideline, NSS encourages all states, not only those operating the ISS, to encourage their industries to actively share their ideas and proposals regarding the end-of-life disposal of the ISS and future large space objects. In this regard, NSS welcomes ESA's vision of a circular space economy by 2050 and ESA's recent campaign, “Large Space Structure Construction, Maintenance, and Recycling Technologies,”12 as valuable contributions toward establishing a new orbital recycling and reuse market for large space objects.

Key technologies and their policy implications

Sputnik 1 was the world's first artificial satellite, a technology demonstration placed into orbit by the Soviet Union in 1957. Sixty-nine years later, humankind operates many thousands of satellites to provide communications, navigation, and Earth observation imagery relied upon in many walks of life. A substantial amount of scientific discovery is also made possible with space-borne instrumentation. Additionally, space operations support military forces on Earth, and thus space itself is a domain in which international conflict and competition play out.

Today, the global space economy is growing at about 7 percent per annum.1 Valued at $600 billion in 2024, it is forecast to potentially reach $1.8 trillion by 2035.2 This growth is driven by space-based technologies and their impacts on various industries, including defense, transportation, and consumer goods. One distinctive feature of the space industry is the predominance of government investment, which totaled $135 billion globally in 2024, more than $75 billion of which came from the United States. While ownership of space assets is gradually shifting from governments to private providers, private-sector investment has declined for three consecutive years from its all-time high of $18 billion in 2021 to $5.9 billion in 2024 reflecting ongoing challenges in commercialization and intensifying global competition. The number of satellites launched per year has grown at a cumulative annual rate of over 50 percent from 2019 to 2024, supported by an increase in global rocket launches 271 in 2024. At its core, a space mission includes four components: The mission objectives, which can be scientific, commercial, military, or a combination thereof.

A user segment, which includes all the users and stakeholders of the space mission Space systems can be categorized in various ways. One such sorting factor is whether they are crewed or uncrewed. The International Space Station ISS is currently the nexus for spaceflight; since 2011, US-crewed access to the ISS has been via rockets operated by Russia and more recently through vehicles provided by SpaceX and Boeing. In the future, the NASA-operated Artemis program plans to launch its first crewed mission, a Moon flyby, in early 2026, followed by a Moon landing in 2027 or 2028.

Uncrewed systems include those for Earth and planetary remote sensing such as Planet Labs' Dove satellites; communication and navigation such as the United States' Global Positioning System, or GPS, satellites; astronomy and astrophysics such as the James Webb Space Telescope; space logistics and in-space assembly and manufacturing such as Northrop Grumman's Mission Extension Vehicles, or MEVs; and planetary exploration such as the Mars Perseverance rover Space systems can also be characterized by size.

Very large structures include the ISS, whose mass is 420 tons, and proposed future space stations that are part of the NASA-funded Commercial LEO Destinations CLD program, such as Orbital Reef Blue Origin, and Starlab (tarlab Space, a joint venture of Voyager Space and Airbus. Vastly smaller satellites, called smallsats, weigh under 500 kilograms. CubeSats are the most popular smallsat format, with each CubeSat unit measuring 10 by 10 by 10 centimeters and with a mass of 1.33 kg a couple of pounds. They can also be combined to build larger satellites. CubeSats support a growing commercial market, providing communications, Earth imagery, and other capabilities. Today, a large majority of functional satellites weigh between 100 and 1,000 kg.

Another classifcation of space systems reflects their trajectories. For instance, objects in orbit around Earth can be in low Earth orbit LEO, which is less than 1,000 kilometers (km) in altitude; medium Earth orbit MEO, which is between 1,000 and 35,000 km in altitude; high elliptical orbit; and geosynchronous orbit GEO, with an orbit period equivalent to one Earth day. The image in figure 10.1 was obtained by a Maxar Technologies commercial satellite in LEO.

A further categorization of space systems focuses on their composition. Distributed space systems, comprising multiple interacting spacecraft, can achieve objectives that are difficult or impossible for a single spacecraft. These systems take various architectural forms, defined by parameters like inter-spacecraft distances, required navigational accuracy, and number of satellites. They contrast with traditional single-spacecraft systems and offer expanded capabilities in space operations.

Impacts of space technologies

Space technologies have proven their value to the national interest. Some of the most important applications today include navigation. This includes positioning, navigation, and timing PNT services around the world and in space. GPS and similar services operated by other nations help people know their position and velocity, whether on land, on the ocean surface, in the air, or in space. Less well known is the timing information that GPS provides timing that is accurate to the nanosecond available anywhere in the world. This is a key tool for the financial sector, electric power grid, and transportation. Companies such as Xona Space Systems, a start-up founded by Stanford alumni, have begun developing GPS alternatives that aim to deliver even greater precision and robustness. More recently, driven by the explosion in the number of satellites and other spacecraft in orbit, interest has been growing quickly in characterizing and managing in-space objects.

Communications Satellites provide vital communications in remote areas and for mobile users, complementing the terrestrial networks that carry most long-haul communications. Companies like SpaceX's Starlink, Amazon's Project Kuiper, Eutelsat OneWeb, and Astranis aim to offer low-latency, wide-coverage satellite internet. Recent innovations include optical communication systems, which use light for higher bandwidth and security. Vertical integration across orbital, aerial, marine, and ground segments will be a key asset for future communication infrastructure. Several start-ups, such as Aalyria and SpiderOak, are also developing technologies for the orchestration of different networks to ensure robust and secure communications.

Remote sensing satellites, with their unique vantage point and sophisticated sensors, can rapidly gather extensive data about areas and objects of interest. These data are then integrated and used to train artifcial intelligence AI models to create a “digital twin” of Earth, enhancing prediction and simulation of terrestrial phenomena and responses to them. Applications include disaster response, environmental monitoring, topographical mapping, and geospatial intelligence tracking human, animal, and marine activity. Governments are expanding remote sensing programs, complemented by commercial companies like BlackSky, Maxar, Planet Labs, Spire Global, and ICEYE. Recent efforts have focused on increasing data resolution, reducing response times, and exploring other valuable information modes such as hyperspectral imaging, synthetic aperture radar, and radio-frequency sounding exploration of the environment through the use and exploitation of radio waves.

Space-based astronomy and exploration provide in-depth insights into the origins of planets, stars, galaxies, and life on Earth. The past few years have seen signifcant strides in solar system exploration, particularly involving asteroids. NASA's OSIRIS-REx mission successfully returned asteroid samples to Earth in September 2023, while the NASA Psyche mission was launched in October 2023 and is en route to examine at close range a metal-rich asteroid worth potentially quadrillions of dollars.

The space transportation industry has seen launch costs drop by more than an order of magnitude over a couple of decades to $1,500 per kilogram in 2021.10 Companies like SpaceX, Rocket Lab, Blue Origin, Stoke Space, and Virgin Galactic have made progress in providing reliable launches and developing new vehicles. SpaceX's Starship the most powerful rocket ever built could dramatically reduce the cost of achieving LEO, aspirationally making this between 10 and 100 times cheaper than today. Also, in January 2025, Blue Origin launched its reusable high-volume, heavy-lift New Glenn rocket, which successfully deployed a prototype of its Blue Ring platform in MEO.

Blue Ring can serve as a satellite support platform and a space tug that transfers cargo between different orbits. While SpaceX currently dominates the space launch sector, overreliance on a single company could prove risky for the US government, especially given the multiple failed test launches of Starship in 2025.

Meanwhile, Blue Origin, Voyager Space, Axiom Space, and Vast are developing commercial space stations to replace the ISS, which NASA plans to decommission in 2030. These new stations aim to ensure continued orbital research and expand human presence in space. Spacecraft constantly scan Earth for launches of ballistic and hypersonic missiles aimed at the United States or its allies, nuclear weapons tests anywhere in the world, radio traffic and radar signals from other countries, and the movements of allies and enemies in military contexts. A major focus of the Trump administration is the “Golden Dome,” a proposed multilayer system partly based in space used for threat monitoring and missile defense.

US government investment in space for national security purposes continues to grow, including new commercial partnerships focused on data sharing for tracking objects in space and on Earth, satellite internet for battlefield communications, and in-space logistics inspection and servicing to maintain space superiority and safety.

Trends in Space Technology

Privatization, miniaturization, and reusability. Today, the space sector is shifting from government-owned legacy systems and their long development timelines and mission lifetimes to a “NewSpace” economy driven by private companies. This privatization makes space technologies more accessible and less expensive. CubeSats and reusable rockets like SpaceX's Falcon 9 exemplify private-sector innovations enabling new opportunities. Governments are also embracing small spacecraft and on-demand launches to expand space capabilities cost-effectively. The combination of smallsats and distributed architecture like constellations offers advantages in reduced costs, faster development timelines, frequent technology updates, and improved resilience, flexibility, and performance.

However, the private sector's rapidly increasing role in space also presents new challenges. These include dealing with risks inherent in dual-use space technologies for instance, adversaries could use technology that was designed for removing space debris to attack other satellites; managing crises in a realm where lines separating individual private actors, the space sector as a whole, and government actors are increasingly blurred; differentiating between accidents and malevolent actions; and relying on companies whose interests may not be fully aligned with those of the US government.

The Moon rush Recent years have seen a renewed desire to maintain a permanent human presence in lunar orbit and on the lunar surface. The abundance of certain materials on the Moon provides opportunities for mining and manufacturing, known as in-situ resource utilization. Such activities would reduce the amounts of material that would otherwise have to be transported from Earth. Combined with the significantly lower amount of fuel needed to launch from the Moon rather than from Earth, moon mining and manufacturing facilitates the construction of moon bases, the conduct of space exploration missions, and even launches into LEO that could be undertaken with hardware manufactured with materials from the Moon.

There have been a number of successful lunar landings recently from both the commercial and the civil sectors, including the United States, China, India, and Japan. The NASA-led Artemis program is developing a new launch system, lunar-orbiting space station, lunar base camp, and lunar terrain vehicles, among other things, as steps needed for establishing a permanent human presence on the Moon.

Advances in small satellite technology

NASA has identified a list of issues that are restraining growth in usage of small spacecraft. They include limitations in launch capacity, autonomous capabilities, PNT capabilities, and propulsion systems. The past year has seen several mission failures due to these and other shortfalls. NASA is responding to these challenges via technology demonstration missions such as Starling, which, in 2024, became the first successful in-orbit example of several critical autonomous swarming technologies. Among Starling's payloads is an optical PNT system newly developed by Stanford's Space Rendezvous Laboratory.

This applies onboard cameras and advanced algorithms to not only navigate multiple satellites cooperatively, but also to characterize resident space objects RSO any human-made or natural object orbiting Earth using only visual data. In doing so, it addresses a key technological gap for small spacecraft, which must typically rely on jammable GPS or expensive ground-based resources for navigation. However, more work is needed to take full advantage of smallsat architectures and, by extension, distributed architectures featuring many smallsats working together.

New applications of space technologies

For certain types of manufacturing, such as specialized pharmaceuticals, optics, and semiconductors, space offers two major advantages over terrestrial manufacturing. Because the vacuum of space is very clean, minimizing contamination is much easier. Further, space's microgravity environment means that phenomena resulting from the effects of gravity, such as sedimentation, buoyancy, thermal convection, and hydrostatic pressure can be minimized. This enables, for example, the fabrication of more perfect crystals and more perfect shapes. Production processes for biological materials, medicines, metallizations, polymers, semiconductors, and electronics may benefit.

The Moon and asteroids may well have vast storehouses of useful minerals that are hard to fund or extract on Earth, such as rare-earth elements used in batteries and catalytic converters as well as in guidance systems and other defense applications. Helium-3 found on the Moon may be an important source of fuel for nuclear fusion reactors. Future space-mining operations could bring these resources back to Earth to meet growing demand in a sustainable way. Mining of regolith loose rock that sits atop bedrock and ice on the Moon is also critical for enabling a permanent human presence there and supporting subsequent expansion into the solar system.

Most orbits are exposed to a constant and intense sunlight, which can be a potential source of clean energy generation. Initial technology demonstrations have been performed in the past two years, and several companies are trying to unlock the potential in this area through two main approaches including solar panels in space that can capture solar energy, convert it to microwaves or laser light, and beam it down to Earth, where dedicated ground stations receive the transmitted energy and large mirrors in space that can directly reflect sunlight to existing solar farms on the ground.

Both approaches can be advantageous for areas on Earth that cannot easily receive power or fuel supplies or access these around the clock. While this technology is still at a very early stage, interest in it has been growing steadily.

The number of active satellites has increased from roughly 1,000 in 2014 to about 11,000 in 2025, a figure that will likely rise to several tens of thousands in the next decade. In addition, the European Space Agency estimates that about 1.2 million pieces of debris larger than 1 cm in size are in orbit, many of which are dangerous to satellites and space stations. Some potential methods of tracking this ultra-small debris by leveraging its electrical charge and the plasma environment of space have been proposed. Traditionally, military organizations such as the North American Aerospace Defense Command and the US Space Force USSF were responsible for tracking space objects. However, beginning in fall 2024, the US Department of Commerce's Traffic Coordination System for Space TraCSS program began taking over civil and commercial SSA responsibilities from the Department of Defense. TraCSS provides basic space situation awareness data and services to support the safety of civil and private spaceflight operations.
This transition was motivated by the fact that space situation awareness is important to both the civil and commercial sectors and to both national and international actors, not only to the US defense sector. Furthermore, this transition will alleviate the burden on the USSF, allowing it to focus on national security priorities in space. Commercial players will be heavily involved in providing a more accurate and responsive space-traffic management system by improving ground tracking capabilities using radars and telescopes, and deploying satellites and payloads for more timely and responsive on-orbit surveillance.

Leadership, security, and sustainability in space require ISAM capabilities to approach, inspect, repair, refuel, or remove space assets without jeopardizing the space environment. Spacecraft autonomy, in combination with rendezvous, proximity operations, and docking RPOD, is a critical technology for ISAM. RPOD refers to the ability of spacecraft to operate autonomously in combination with the ability to approach one another precisely and conduct close-up operations. Despite signifcant interest, only a handful of missions have demonstrated early RPOD capabilities in orbit; these include recent successes achieved by Astroscale using its ADRAS-J smallsat in LEO and Northrop Grumman via its larger MEV satellites in GEO.

A critical limitation for space exploration missions is travel time: Getting to the outer solar system can take ten years or more. As spacecraft is farther from the Sun, they will need novel forms of power, such as sources driven by nuclear reactions, for the propulsive energy needed to make their missions possible. Better propulsion systems that can be quickly deployed will also be needed to intercept interstellar objects so that samples can be collected from them. Today, it takes a very long time to prepare for exploration missions, which means that targets of opportunity that suddenly appear cannot be visited by such missions. An on-demand capability would enable the close-up investigation of suddenly appearing targets such as the Oumuamua interstellar object, which passed through the solar system in 2017. Undertaking such a mission requires that a spacecraft can be made ready for launch shortly after the target is identified. Because such targets are likely to originate outside our solar system, the scientific return from bringing back a sample would be enormous.

Shift in US executive branch priorities

The Trump administration has been reformulating national space priorities. While the current and proposed budgets for the domain aim to bolster human exploration to the Moon and Mars, they have also imposed significant cuts to numerous ongoing and planned scientific missions related to interplanetary exploration, aviation, and space science. These cuts have led to an outflow of talent from NASA, with the loss of four thousand employees a fifth of the workforce already. Similar budget cuts have been made to the National Science Foundation, Department of Energy, and other space-adjacent federal agencies. These cuts have a large impact not only on academic research and development, but also on private companies, which receive a large amount of federal funding to serve as contractors for government space programs. These policies may put the United States at a competitive disadvantage relative to China and other global powers.

International and national space governance has not developed at the same rapid pace as space technology. Existing legal frameworks many of which are products of the Cold War do not address wide swaths of current activities and are often contested in scope and interpretation. Attempts at improvement have often stagnated due to differing geopolitical aims. Even within the United States, space assets are not designated as critical infrastructure by the government despite their importance, and growth in space activity far outpaces the capabilities of current licensing processes run by the Federal Aviation Administration and the Federal Communications Commission.

Nonetheless, a number of developments in the past couple of years are notable. NASA released its strategy, including actionable objectives, for sustainability in space activities in Earth orbit. It also promised to release similar strategies in the future for activities on Earth; for the orbital area near and around the Moon known as cislunar space; and for deep space, including other celestial bodies. In addition, the Federal Communications Commission issued its first-ever fine for a satellite not properly disposed of from geostationary orbit. These short-term policy advances must be unified with a longer-term vision encompassing the next fifty to one hundred years to effectively address national security needs, support the space industry's continued development, and realize the responsible use of space as a global commons.

Finally, in the past couple of years, the rise of the private sector's importance in providing capabilities for rapid space launch and space-based communications has been dominated by SpaceX and Starlink, which are owned by the same person. In 2022, the CEO of Starlink, which Ukrainian military forces relied on for communications, denied its use to conduct military operations around Sevastopol, in Crimea, thus directly interfering with the execution of Ukrainian battle plans.



Why the Army need to integrates Blueforce in Operations



When soldiers' lives are on the line, detecting and locating the enemy or fellow soldiers on the battlefield is critical. Situational awareness is a crucial part of understanding current conditions in a Multi-Domain Battle environment to ensure the soldier can integrate Army, joint, interorganizational and multinational capabilities that allow him to visualize and create windows of multi-domain superiority through fire and maneuver to positions of relative advantage in decisive tactical and operational level operations for the mounted platform and dismounted user, leader, or commander. To do this, mission command uses a combination of hardware and software to enable centralized interaction while integrating Command, Control, Computers, Communications, Cyber, Intelligence, Surveillance and Reconnaissance (C5ISR). Also integrating Electronic Warfare (EW) platforms and weapons subsystems into one holistic capability can give the warfighters the ability to monitor, control, and interact with the entire system simultaneously.

As an example, in 2014 Leonardo DRS, in partnership with key industry partners, undertook a substantial C4I demonstration of a new tactical command & control system for a Middle Eastern customer. The experience Leonardo DRS had derived from delivering similar capabilities to the US Army on FBCB2 as well as the Mounted Family of Computer Systems (MFoCS) and with the British Army on Bowman was the basis upon which the Leonardo DRS communications and sensor integration capability has been designed and built. At the core of DRS' approach to this new C4I capability was a highly innovative piece of technology called the Data Distribution Unit (DDU) also referred to as the 'Magic Box,' which enables voice, data, sensor and video applications and vehicle services to be integrated via a common, highly compact line replaceable unit (LRU). This is ideal for a tactical vehicle & command post environment where space is tight and an effective approach to size, weight & power and cost (SWaP-C) is a key requirement.

On October 14, 2020 Leonardo DRS announced that it has been awarded a contract to provide advanced situational awareness hardware and software for an allied Middle Eastern customer. The total fixed-price contract is worth $44 million. Under the contract, the Leonardo DRS Land Electronics business unit will provide a significant number of tactical mission systems to be installed into a wide range of tactical vehicles and across a number of brigades.
At the core of the architecture is the latest version of the Leonardo DRS tactical voice, data and video tactical server, data distribution unit – block 4 (DDU-4), an upgraded digital vehicle intercom system and new rugged multi-touch commander's display.

At the heart of the system, the new Leonardo DRS DDU-4 provides classleading processing capability, an integrated router, LTE and GPS along with communications cross-banding together with video and voice management. These new products share much of their DNA with the Mounted Family of Computer Systems (MFoCS) II tactical computing products being delivered to the U.S. Army and other allies.

“We are honored to be selected to deliver a world-class tactical C4i capability to support our allies in the Middle East,” said Bill Guyan, senior vice president and general manager of the Leonardo DRS Land Electronics business. “Our solutions leverage many of the same technologies used in our products for the U.S. Army's Mounted Family of Computer Systems (MFOCS) II program. We are proud to be the world's leading supplier of missioncritical tactical computing and display solutions, a legacy that continues with this important contract award.” he said.

The tactical mission systems are designed to provide an ultra-reliable on-the-move computing capability with the latest cyber secure COTS technologies for mission-critical applications in harsh environments. In addition, the technology will deliver compatibility with other allied militaries using similar systems, including the United States.

Work on the systems will be completed in Melbourne, Florida. Delivery has commenced and will be completed during 2021. The DDU-3, the version of the DDU used for formative phases of this key project is where all of the primary systems functions meet and get integrated. It is open and agnostic and supports multiple Virtual Machines (VM), one of these supporting the Systematic SitaWare BMS and Mission Planning Application. It also interfaces with the tactical radios.

For this Middle Eastern customer as it is with many such systems, the ability to fully utilize the existing tactical communications infrastructure was vital. The DDU's ability to interface to up to four (4) concurrent tactical radios, potentially each from a different vendor and with disparate waveforms, was a key to providing the voice and data interoperability. An inbuilt Wave-engine provides the ability to securely crossband between say a Harris 7850M and Thales PR4G or even a 4G/LTE connected user interface (UI) device. This capability, coupled with the ability to interface the same DDU-3 to SatCom and LTE systems, was a game-changer and provided a degree of flexibility not possible before.

The DDU-3 also benefits from an embedded GPS (either commercial or Selective Availability Anti-spoofing Module (SAASM)) and as a backup to GPS, the option of interfacing enhanced longrange navigation (eLORAN) or L-Band for beyond line of sight Blue Force Tracking (BLOS BFT) services is also possible. The DDU-3 can also be interfaced to an INS/INU to provide system applications with a continuous dead reckoning of position and velocity. The DDU-3 was the foundation of delivering smart and cost-effective integration of the communications and sensor environment.

A highly effective Vehicle Intercom System (VIS) solution could also be integrated via the DDU-3, either to the network or standalone via its own Radio Interface Unit (RIU). The Leonardo DRS VIS is a digital-quality and resilient solution to providing cost-effective voice communication within tactical vehicles and command posts. The success of the live evaluation followed by implementation of an initial brigade of the new capability was the trigger for this
key customer to roll out the system across additional Brigades where Leonardo DRS will be providing an enhanced version of the DDU in the form of the DDU-4 with upgrades to the Vehicle Intercom System and a new multi-touch Commanders Display.

Technical Architecture of Blue Force Tracking

The technical backbone of Army Blueforce systems is a sophisticated network of space-based assets and tactical hardware. At the vehicle level, platforms are equipped with ruggedized transceivers that periodically burst-transmit their GPS coordinates, fuel levels, and current mission status to a constellation of military satellites. These satellites act as relay stations, beaming the data down to a Network Operations Center, which then disseminates the information to tablets and command-and-control displays across the theater. Data latency is a primary concern in the design of these systems. Military engineers work to balance the frequency of updates with the need for bandwidth conservation. In high-tempo operations, a vehicle might broadcast its position every few seconds, but in a stationary defensive posture, the system may switch to a "heartbeat" mode to save power and reduce electronic signature. This dynamic frequency modulation is critical to maintaining stealth while ensuring the commander always has an accurate picture of the battlefield.

Furthermore, the integration of data-link protocols such as Link 16 or the more modern Force XXI Battle Command Brigade-and-Below (FBCB2)—allows for the overlay of terrain data, weather reports, and enemy sightings. This turns the Blue Force tracking map from a simple "dot-on-a-map" display into a comprehensive Common Operational Picture (COP). By layering friendly locations over terrain analysis, planners can avoid hazardous routes or identify potential chokepoints where friendly forces might be vulnerable to ambush.

Modern military operations rely heavily on situational awareness, and the concept of "Blue Force Tracking" (BFT) stands as the cornerstone of this requirement. In military parlance, "Blue Force" represents friendly forces, while "Red Force" represents the enemy. The primary objective of an Army Blueforce tracking system is to provide commanders and soldiers with a real-time, digital map showing the exact location and status of friendly assets. This technology prevents fratricide, simply friendly fire, optimizes logistics, and provides the strategic oversight necessary for maneuver warfare in complex theaters of operation.
At its core, the system utilizes satellite communications SATCOM, GPS, and secure data networks to relay positioning data from vehicles, aircraft, and dismounted troops to a centralized command station. By integrating this data into systems like the Joint Battle Command-Platform, the military ensures that every unit knows exactly where its counterparts are, even in the most remote environments where traditional radio communication might be unreliable.

Addressing Alternate Intents: Blueforce Development and Software

While the military application is the dominant search intent, the term "Blueforce" also appears in the context of private sector security software, specifically "Blueforce Development." This company provides tactical collaboration and sensor integration software for first responders, law enforcement, and industrial security teams.
Their software allows organizations to create a "tactical mesh" network that connects body-worn cameras, heart rate monitors, and environmental sensors into a single dashboard. Unlike the military BFT system which focuses on geographic positioning for maneuver, Blueforce Development's solutions focus on human-centric data—monitoring the vitals of a firefighter inside a burning building or tracking the chemical levels in an industrial plant. While the terminology overlaps, it is essential to distinguish between the US Army's asset tracking infrastructure and private-sector incident response software. Users searching for "Blueforce" in a corporate or municipal context are typically looking for these unified communication platforms rather than military satellite hardware.

Implementing a comprehensive tracking system requires more than just hardware; it requires a disciplined operational process. The "Blueforce" workflow begins with vehicle and individual registration, where unique identifiers are assigned to every asset. In a large-scale deployment, this means coordinating thousands of entities across multiple branches of service, including Air Force air assets and Navy maritime vessels, to ensure the data is interoperable.

This procedural approach ensures that the system is not merely a tracking tool, but an active decision-making aid. By automating the reporting of fuel and ammunition levels, the system allows the S-4 (Logistics) staff to anticipate supply chain requirements before they become critical, thereby ensuring that front-line units maintain their combat effectiveness without constant manual status checks over radio.

Peter Hurst, vice president of International Projects & Strategy for the Leonardo DRS Land Electronics business said, “The success of our DDU based tactical systems architecture was that it provided a means to integrate and manage extant networks seamlessly while hosting a multitude of new capabilities such as Tactical LTE. The openness of the DDU to host many concurrent third-party applications and integrate with the vehicles real time systems was also a key enabler as it hands the end user effective control over how they want and need to develop their capability. The DDU does all of this while providing a new level of Cyber security assurance that is essential for today's modern tactical networked environments.”

As tactical vehicle environments have become more complex over the years, Leonardo DRS has been required to develop new hardware and software capabilities for the DDU. The Galileo Situational Awareness system being delivered to a South East Asian customer integrates several primary vehicles' systems into a capability that significantly reduces the reaction time taken to engage with this threat. The system also provides the means to share situational awareness both on the platform and with other networked vehicles in the same area of operations, as well as with high-echelon command posts and Headquarters (HQ).
An interface connects the DDU and the shot detection acoustic array, with the weapons system turret and the infrared radiation (IR)/day camera and the Battle Management System (BMS). The system integrates many C5ISR capabilities. A prime example of these capabilities, and one of the primary functions is to detect a gunshot and locate the source automatically. The system can then geolocate the source of the shot, pass a message to the overhead weapons system and automatically put its weapon and associated sensors, such as the camera and laser range finder, on the detected threat.

The commander of the vehicle is presented with this data, and the related imagery from the weapons system and other vehicle cameras through the high-resolution touch screen display and can, in conjunction with other vehicle crew, decide how to engage with the threat. This entire sequence
takes seconds and dramatically increases the ability to react rapidly to the threat. The DDU is also connected to the BMS and as a result, the tactical network.

The BMS application can be an application running on the DDU or could be an existing BMS system hosted by another processor. The DDU application has several critical pieces of data that are crucial to sharing any given event with other vehicles that it is deployed with and can assist in supressing the threat or would benefit from knowing about the threat. The DDU can pass this data to the BMS application, and in turn, the BMS application can plot the details of the detected shot on to a battle map that is shared across the network. Data including azimuth and inclination of the vehicle along with Laser Range Finder (LRF) data can also be shared, significantly increasing the level of situational awareness.

Leonardo DRS understands that enhanced situational awareness capabilities will be required to integrate with the military, civil and non-military land and sea platforms in a multi-domain battle environment. The integration includes hosting a variety of software applications on the DDU and interfacing with the various vehicle platforms, its subsystems, current military and commercial networks, and a variety of existing and new sensor technologies. This integration could potentially include platform sensor integration, leveraging additional military and commercial radios and networks for failover communications, weapons systems integration, video collection and distribution. Leonardo DRS has a portfolio of fielded proven capabilities that could enhance any military's position by providing a set of already developed mature technologies that together will provide enhanced situational awareness.

These features include but are not limited to the following: advanced IP routing and switching, sensor integration including weapons systems, commercial and military radio integration, voice cross banding, video integration, Battle Management System (BMS) integration and the ability to leverage commercial cellular networks.

The fact that Leonardo DRS have such established positions with the US Army and Marines via its MFoCS project and are delivering similar tactical mission systems to various other allied nations should have a direct correlation to the needs of UK MoD as they develop their approach to future phases of LE TacCIS projects such as Morpheus, Trinity and NIOBE. At the heart of the Leonardo DRS product offering is a range of proven, off the shelf and sustainable technologies that provide the open systems and scalable infrastructure necessary to build coherent and secure mission systems.

The DDU's functionality combines traditional computing, networking and distribution technologies into a small form factor, and embedded technologies allow the DDU to be deployed in a nonobtrusive manner without infringing on critical space or power requirements. The DDU provides an 'everything over Ethernet' backbone, allowing one or multiple users to access all electronics data within the vehicle. Numerous standard and non-proprietary interfaces are available on the DDU to allow connection to existing legacy mission equipment as well as support future integration requirements.

The greatest challenge facing current Blueforce systems is the shift toward "Multi-Domain Operations." As adversaries develop sophisticated electronic warfare (EW) capabilities, the reliance on GPS and satellite links becomes a liability. Future iterations of the system are moving toward "PNT" (Positioning, Navigation, and Timing) diversity, which incorporates quantum sensors and visual odometry to maintain location accuracy without relying on external signals.

Furthermore, the rise of AI-driven analytics is changing how Blueforce data is consumed. Instead of a human operator constantly staring at a screen, AI algorithms now monitor the data to identify anomalies—such as a vehicle stopping in an unauthorized zone and automatically alert the command team. This allows for a more "exception-based" monitoring approach, significantly reducing the cognitive load on staff officers during intense combat operations.

Additional report by Julian Nettlefold





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