The Earth seen from above

Artificial satellites history starts at the end of the 1960s, in the context of the Cold War. They have gradually covered several civil and military application sectors, such as telecommunications, Earth observation and navigation, to reach around 2,000 objects in orbit at the end of the 2010s. Over the past ten years, technological breakthroughs such as the digitization of payloads, the miniaturization of equipment and satellites as well as the use of commercial components, have accelerated the democratization of Space and the deployment of constellations, modifying the existing eco system and traditional economic models. The increase of Space occupation, following the multiplication of uses and services, in a context of increased commercialization of the orbit, as well as the strengthening of the militarization of the sector, raises the question of the sustainability of its use.

Recent technological progress makes it possible to envisage a new capacity based on airborne drones: HAPS (High Altitude Permanent System) such as the Stratobus. Stratobus is a stratospheric airship capable of operating during one year, at an altitude of 19 km, and carrying a payload of 250 kg with a power of 5 kW.

Earth observation applications are complementary to satellite applications, and allow to deploy independent and sovereign means of observation, offering permanent observation and unrivaled optical resolution. In addition, they can be moved above inaccessible areas, or ecologically fragile areas, or following a natural disaster.

The Stratobus project was selected in 2016 as part of the “Nouvelle France Industrielle”, which launched the design phase, then selected as part of the European Defense Fund to produce demonstrators which will fly from 2025 in the stratoport of Canarias.

In the last decade, the space transportation domain has been subject to a dramatic transformation, in all its dimensions: launch techniques, launchers technologies, industrial organizations, economic model, association and respective contribu-

Context, cross-cutting issues

43 The legal challenges of Earth observation from space in the context of the new space economy
Philippe CLERC

This article puts into perspective the public, private and legal issues that have shaped the construction of Earth observation from space, from its origins in the 1960s to the present day in the era of Big Data. It details the most salient features of its legal framework in order to clarify under what conditions such observation is lawful, how investors or operators can protect the results of their efforts, and how their data should be made available on a competitive market or to the general public.

This reflection takes into account the technical and political upheavals that have affected this activity, on a national, European and international scale, following the rise of the conquest of space, the development of computing, the Internet, mobile applications, the globalized digital economy, and then the advent of New Space. All of this has coincided with the emergence of legislation that, on the one hand, ensures intellectual protection, reservation, control and even exclusivity for the use of space-based data, and on the other, imposes free and unrestricted access (open data), while at the same time preserving certain restrictions.

51 Nanosat: a small-scale revolution
Imane EL KHANTOUTI & Didier DONSEZ

The advent of nanosatellites has transformed and democratized the access to space by offering a more economical and modular option compared to traditional satellites. These compact and standardized satellites are used in various fields, from Earth observation to telecommunications, thereby fueling the dynamics of New Space. The deployment of nanosatellites is carried out by private companies and academic institutions. This approach is characterized by lightweight technologies, short development cycles, project management agility, and increased tolerance for failure, distinguishing it from the more conventional approach of Old Space. The New Space ecosystem encompasses a variety of actors, from equipment manufacturers to carriers, launch providers, government agencies, and universities. Despite the opportunities presented by nanosatellites, challenges persist, including the management of space debris, radio interference in communications, and the threat of cyberattacks.

59 A breakthrough technology for detecting and geolocating ships at sea
Rachid NEDJAR & Maël TORCA

As human activities impact more and more our planet every year, our seas and oceans are more than ever at the center of critical challenges regarding biodiversity protection, global warming, disputes between nations or the multiplication of illegal activities that are difficult to contain.

Despite regulations, quotas and controls, legacy maritime safety systems are showing their limitations, and do not provide an exhaustive view of human activities at sea, and their harmful consequences.

Indeed, the maritime areas to be protected are vast, often far from coasts, and cooperative safety systems (AIS, VMS) can be deactivated or manipulated.

Unseenlabs has developed a space-based radiofrequency detection technology to detect, geolocate and track any vessel at sea, cooperative or not, anytime (night and day), anywhere around the globe, regardless weather conditions.

This capacity, fully operational for 5 years now, provides an innovative solution for oceans protection and global security, and opens new horizons for maritime surveillance from space. The aim of this article is to present the key benefits of space-based RF detection for maritime surveillance by illustrating them through multiple concrete use cases.

Applications of earth observation

agency, which operates Europe's operational meteorological satellites, is preparing to launch a new generation of space instruments that will enhance forecasting capabilities. At the same time, Météo-France is carrying out research to improve its models using in situ and space observations. Future advances in weather forecasting will rely on more frequent observations at higher spatial resolution with new generations of satellites, as well as the emergence of technologies such as AI.

100 Using altimetry satellites to measure sea level

Cyril GERMINEAUD, Claire DUFAU & Pierre PRANDI

Since the 1990s, satellite altimetry has revolutionized our understanding of ocean dynamics, providing over 30 years of continuous measurements. Altimeter satellites such as TOPEX/Poseidon, Jason-1, Jason-2, Jason-3, and Sentinel-6 MF have accurately monitored the evolution of the global mean sea level. The SWOT mission, launched in 2022, introduces innovative technology with a KaRIn interferometric radar, allowing spatial resolution ten times higher than classical altimeter satellites. This advance provides an unprecedented view of fine-scale structures in ocean circulation. An increase of about 10 cm has been observed since 1993, with a significant acceleration since the late 2000s. Two main factors contribute to this increase: the thermal expansion of the oceans, which absorb the excess energy (in the form of heat) generated by human activities in the Earth system, and the contribution of melting ice sheets and mountain glaciers. However, this elevation masks very significant regional variations, which can be observed using satellite altimetry. The risk of coastal flooding due to sea level rise is a major economic challenge. Coastal communities around the world face threats that require adaptive solutions. Initiatives such as LITTOSCOPE in France are using satellite data to assess flood risks, anticipate impacts and propose solutions to reduce the vulnerability of coastal areas. In summary, satellite altimetry has been instrumental in understanding ocean dynamics at different spatial and temporal scales, measuring sea level rise, and anticipating flood risks. Technological advances, such as SWOT's KaRIn radar, are opening new perspectives for even more detailed ocean observations, providing critical information to address the challenges posed by climate change.

108 Using satellite data to monitor improvements in farming practices

Antoine LEFEBVRE

Considered an imperative if we are to meet the challenges of the environment and climate change, the transition in agriculture is now being driven by ambitious political objectives and funding programmes. These require the use of measurement solutions that combine objectivity, geographical scope and responsiveness. The satellite analysis products developed by Kermap meet these challenges. They help to consolidate the environmental value chain in the agricultural sector by delivering reliable, enforceable indicators on sustainable agricultural practices: crop diversification, soil cover, grassland management, agro-ecological infrastructure and irrigation. This is a practical way of putting satellite imagery data to work, and echoes the objectives of the France 2030 plan, which aims to create innovative players to harness spatial data for the benefit of the ecological transition.

Defence and security

132 Military satellite communications (MilSatCom): a necessity for the connected soldier
Vincent SATGE & Grégoire CHAUCHAT

The growing need for connectivity for the armed forces is an ever-increasing reality. In addition to simply increasing connectivity, the SatCom offers incomparable advantages in terms of elongation, making it indispensable in certain use cases. Faced with the development of commercial constellations in low-Earth orbit, the military SatCom must now coexist with its civilian counterpart for the benefit of the military forces. The latter who will benefit from the advantages of the SatCom's diversity (civilian/military duality; geostationary/medium or low-Earth orbit complementarity).

Telecoms and setellite positioning

138 A tsunami in satellite telecommunications
Didier LE BOULC'H

The field of communication satellites does not escape from a tsunami of change. The successful arrival of new verticalized actors such as Starlink constellation from Space X, the evolutions in usage through the success of streaming platforms, the fast progress of digitization and virtualization, the convergence with terrestrial standards coming from Mobile World (3GPP standards), the increased interest from terrestrial telecom operators to expand their network through satellite, the change of financing scheme, and finally an increased sensitivity to sustainability and (Life Cycle Assessment reduction) are key factors that are deeply changing the satcom ecosystem. Ongoing heavy developments enable to face those challenges. The commercial space sector used to be somewhat conservative (no easy repair in orbit…) it is now heading a "never seen before" pace of innovation.

143 The use of Satcom systems for civil and government applications
Hervé POSTEC

Satellite communications systems are essential for both civil and government uses. They rely on satellites in geostationary, medium and low orbit, providing global connectivity. Civilian applications include global telecommunications, satellite television, and bridging the digital divide. Governments use Satcoms for strategic needs, taking advantage of their global reach.

The resilience of Satcoms is crucial in the event of major crises. Satellites provide robust connectivity, even if terrestrial infrastructure is destroyed.

Technological developments, including low-orbit constellations and flexible satellites, are shaping the future of Satcom. In conclusion, these systems play a key role in our technological landscape, requiring constant vigilance in the face of developments.

147 Convergence of the Telecommunication systems with 5G and 6G
Flavien RONTEIX, Mohamed EL JAAFARI, Dorin PANAITOPOL & Nicolas CHUBERRE

One observe a profound evolution in the communication networks towards the convergence of access technologies. The integration of satellite access with

terrestrial mobile networks is enabled by the 3GPP Non-Terrestrial Network (NTN). The satellite network component can contribute to the global service continuity and resiliency of mobile systems. Leveraging the terrestrial 5G access technology, a number of solutions mitigating the issues inherent from satellite communications specifics (e.g. Doppler, delay…) have been standardized in Rel-17 of 3GPP under the so called NTN (Non-Terrestrial Network) standard. In the 5G-Advanced (starting from Rel-18), further NTN added value will be unleashed by the usage of regenerative payload architecture and performance optimization enablers. In the ITU IMT-2030's vision, the 6G will bring new network capabilities to support the interactions between the human and its physical environment leveraging real time digital modelling. In particular 6G will see the unification of the TN and NTN into a multi-dimensional architecture enabled by a set of innovative technologies and concept at both radio and network levels.

157 The standardization of networking reaches space
Marc BLANCHET & Vinton G. CERF

Up to now, communications are largely direct between terrestrial infrastructures and devices in space. Parallel to space conquest, the Internet has conquered the Earth and the mobile networks have been deployed. Each of these domains have a standards body. With the major technology innovations and the significant cost reductions, the space conquest brings new providers offering various services in space, starting with Moon and around. A network is currently planned to be deployed insuring optimal utilisation of communications. The standardization of the network technologies is the key to provide interoperability between all future services. This article discusses the standards and provides an overview of the network technologies that will be used not only on Moon and around, but also for Mars and beyond.

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