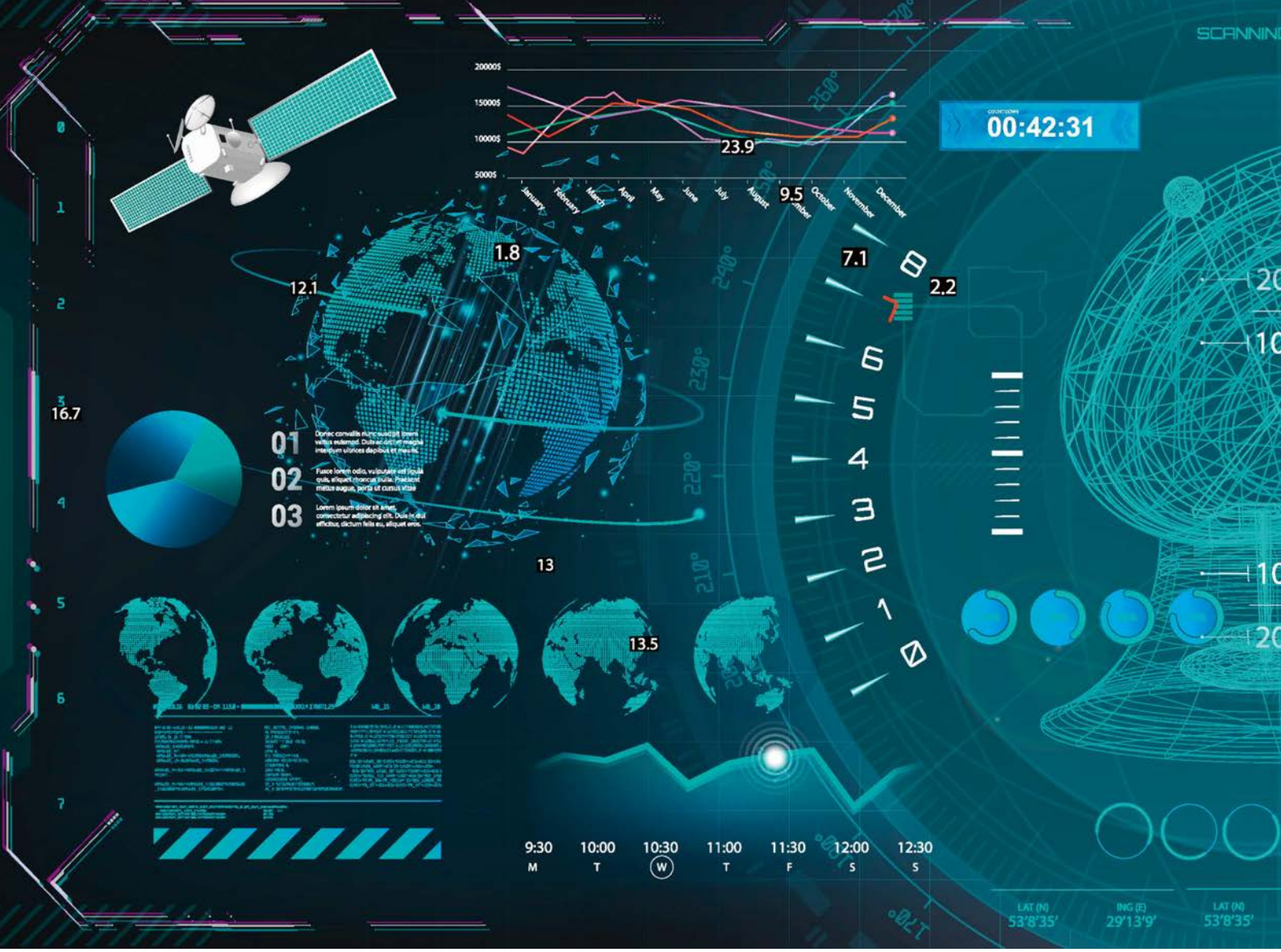


Space Domain: A Global Vision

By Dr Massimo Claudio Comparini, Chief Executive Officer, Thales Alenia Space Italy

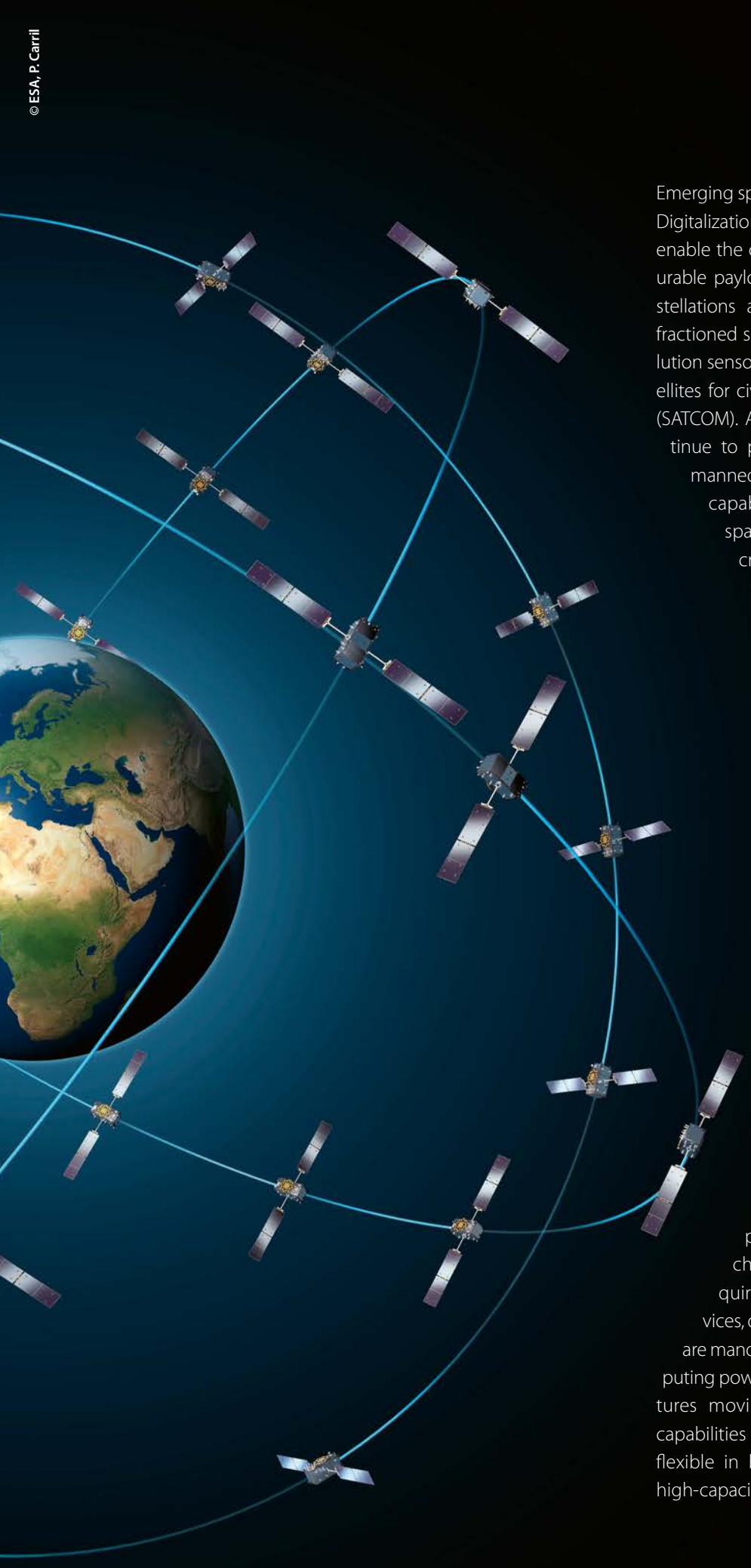
Space technologies moved fast in the last decade. Enhanced and new technologies combined with a business-model evolution enabled the conception and realization of a new class of space assets, which addressed new challenges and more sophisticated needs of the global user community. If the technology evolution transverses civil and military domains, the construction of specific assets for the Ministries of Defence and military users remains very important; at the same time we cannot ignore the new wave of commercial systems. Global surveillance with its persistent or quasi-persistent capabilities, global space connectivity with next-generation broadband hybrid networks, protection to counter cyber threats, the capability to protect assets in orbit and accomplish orbital maintenance combined with the ability to operate following military doctrine in the space domain, all require effective technological and architectural solutions, potentially derived from commercial markets.

This challenge is particularly relevant considering that, in the past few years, space and cyberspace have moved from 'key enablers' to a recognized position as domains, alongside the 'traditional' domains. An extraordinary revolution. For more than a century, there were three domains of operations: land, mari-

time, and air. Now, in less than three years, NATO has added two new domains, Cyber in 2016 and Space at the end of 2019. This will radically change the whole concept of military operations and warfare. The impact of space and cyberspace must be considered in the framing of the definition of multi-domain operations, capturing the ability to use information-enabled command structures and combat capabilities to build information security across the full array of domains.

Without a doubt, a day without space will severely degrade not only NATO, but also every country's capability to operate and defend. Space is essential to supporting modern military operations in a complex, multidimensional, highly dynamic and disruptive environment. It is essential to a coherent Alliance deterrence and defence posture. The information gathered and delivered through satellites is critical to all NATO activities, operations, and missions. The role of space to conduct Intelligence, Surveillance and Reconnaissance (ISR), support missile defence, provide Position, Navigation and Timing (PNT), and facilitate tactical operations in the other domains is essential. Space is crucial to providing commanders with situational awareness, accurate assessments, and maintaining real-time or near-real-time information superiority to support fast decision-making.

Similar to the missions in the air domain, the space domain will see the emergence of new missions and operational concepts from space superiority to space dominance, defensive and offensive counter-space, space surveillance and tracking, or debris removal. Even though NATO has pledged not to 'weaponize' space, this pledge does not guarantee that other players will apply similar self-restraint. NATO needs to be ready.



Emerging space technologies offer vast opportunities. Digitalization and miniaturization of onboard systems enable the construction of next-generation reconfigurable payloads and satellites, including global constellations and mega-constellations, federated and fractioned space infrastructures, extremely high-resolution sensors and tremendously high-bandwidth satellites for civil and military Satellite Communications (SATCOM). Additionally, spacefaring nations will continue to promulgate reusable and manoeuvrable manned and unmanned spacecraft and vehicles capable of operating in lower sub-orbital space. Concurrently, space is becoming more crowded and competitive with some countries having developed and tested a wide range of counter-space technologies requiring NATO countries to maintain the state-of-the-art in this domain.

SATCOM

The space segment of SATCOM is a major contributor to secure end-to-end connectivity and is a key requirement for any in-the-field operation and for future combat air systems, as part of a much larger System of Systems (SoS). Concepts such as the United States Air Force's Advanced Battle Management System (ABMS) are indicative of the future of these SoS, including a robust space element. The amount of protected or classified information to be shared among forces is exponentially increasing and the data accessing and processing capabilities become true game-changers. To cope with the flexibility requirements and to offer advanced new services, digital and reconfigurable in-orbit solutions are mandatory. The improvement in on-board computing power makes it possible to conceive architectures moving from the standard reconfiguration capabilities to fully software-defined payloads, ultra-flexible in both frequency and coverage, for very high-capacity geostationary satellites.

At the same time, global coverage necessitates new Low Earth Orbit (LEO) constellations based on low-latency solutions. For the past few years, the commercial market has aggressively explored these solutions and now NATO must consider the advantages offered to military users. The end-goal for military and NATO requirements combines the expected evolution of requirements with the need to share in multinational/coalition operations and networks resulting in a multi-layered constellation architecture.

ISR

The evolution of Earth Observation (EO) capabilities from space and the geospatial information domain is a central part of a global digital transformation process to secure information superiority. NATO has increasingly delivered more information through geospatial data and services. The combination of EO data and data coming from a wide array of platforms, including media streams (i.e. open-source intelligence), is a fundamental part in this digitalization revolution.

NATO must anticipate the exponential growth of the impact of Information Technology (IT), advanced algorithms, machine and deep learning, and Artificial Intelligence (AI) to generate information streams for a range of user communities. These changes will certainly affect military users, with requirements to specifically address change detection, near-continuous monitoring, and persistent or quasi-persistent surveillance. In conjunction with cloud-based large computational capabilities, space and digital technologies are the fuel for the engine driving the transformation in the geospatial sector and represent a real game changer in the geospatial sector for military exploitation.

Even if large or mega-constellations of small/micro-satellites are limited in resolution, they offer the advantage of high-revisit rates and high resiliency of the whole architecture, providing continuous flow of data in optical, radar, multi-spectral, electromagnetic radiation sensing and Signals Intelligence (SIGINT) data. These systems are essential to build true patterns of life, to quickly identify what is changing on earth, both globally and locally.

Missile Defence

To defend against new threats such as hypersonic missiles and to detect and track manoeuvring high-speed missiles, space-based capabilities can undertake missions currently carried out by manned and unmanned aircraft. As an example, space constellations offer accurate Moving Target Indicator (MTI) capabilities against different categories of targets. In combination with navigation and positioning data and data generated by aerial platforms (drones, High Altitude Pseudo Satellites (HAPS), low suborbital vehicles, etc.), these constellations provide true dynamic analytic capabilities through multi-sensor and multi-platform real-time data fusion.

Data-Driven Decision-Making

Data-driven decision-making, which means AI-based learning techniques combined with big data analytics, provides warfighters at each level with the actionable information that helps them make data-informed critical decisions in real time. The ability to analyse, coordinate, and fuse massive amounts of raw data depends heavily on the available computing power, data storage capability, and power constraints. The key to success will be to synchronize operations and intelligence by continuous exploitation of analysed data in the Processing, Exploitation and Dissemination (PED) cycle.

These brief highlights already give the idea of how space domain and its convergence with cyberspace and the digital world is relevant for the Alliance. The Internet of Things (IoT) or, in this case, the Internet of 'Military' Things will produce a huge amount of data generated by space systems, sensors, and device nodes. To address the need for decisions at the speed of relevance, exponential computing power, cloud platforms, edge-computing nodes, and the big data dimension requires NATO to explore and exploit the concept of Digital Continuum[1] into the multi-level structured space domain to deliver a fast and continuous flow of information.

Until now, NATO has kept a traditional distinction between space companies, space technologies, and IT companies. In the future, NATO needs a combination of all those industries to implement effectively those space capabilities required to generate and assure information superiority of all Alliance countries and to gain advantage, in terms of both speed and capability, and to evolve the business paradigm.

How to Protect Space Assets?

Today, space systems are essential for our economies, the security of our countries, our information superiority, and subsequently for effective command and control, missile defence, early warning, and ISR. These space systems represent critical infrastructure requiring protection, especially given the exponential growth and congestion of LEO. From the more than 4,000 active satellites today, we will reach an estimated 50,000 by the end of this decade, for an entire space economy of more than one trillion USD.

In this setting, Space Traffic Management (STM) rapidly becomes a priority topic in space policy, protecting space infrastructure and guaranteeing the safe and sustainable use of outer space in the long term. Military stakeholders must consider challenges and opportunities associated with STM and become engaged in the debate to assess and influence how a changing environment may affect military space operations and space support to operations. Space Situational Awareness (SSA) is essential to manage the increased traffic and to avoid and prevent disruptive collisions in orbit.

The Role of In-Orbit Services (IOS)

Despite the difficulty in developing a comprehensive definition, IOS provide a number of actions including, but not limited to, maintenance, tugging, and inspection. Relevant examples of IOS are the reconfiguration of spacecraft payload or modules, station-keeping docking of the service spacecraft with a target satellite, orbit correction to include relocating space systems to the required orbit, creation of large infrastructure in orbit that cannot be assembled before launch due to their weight, volume, size, etc. In any case, IOS require rendezvous and close proximity operations, which could be defined as *orbital manoeuvres in which two spacecraft arrive at the same orbit and approach at a close distance.* Close proximity operations usually imply two space systems within a few kilometres or less from each other. IOS provides capabilities that will enable a range of activities to include space safety, space security, and certainly military operations, both defensive and offensive.

IOS will also require better SSA to be operational, most likely resulting in enhanced debris management and active debris removal. These elements are ideal for cooperation across borders, between national Space Commands, and for a possible specific analysis from NATO.

Conclusion

Having superficially highlighted a few relevant elements, it is useful to debate how space assets and space technologies may contribute to respond to the capability needs of NATO today and in the future. We need to increase resiliency and survivability of our space assets, including 'hardened' ground and launch capabilities, with a combination of passive and active solutions maintaining the ability to manoeuvre in the space domain to assure our missions.

Resiliency of space support, defined as 'the ability of a space system architecture to ensure a persistent support to mission success in spite of hostile actions',[2] *is the priority*. Firstly, we must deter the enemy from detecting and targeting space services or assets. Then, we must assure the ability to reconstitute, either by launching new assets or activating spare capabilities, in-orbit or ground-based. NATO requires the architectural and technological capabilities to conceive and support higher resiliency in space missions through disaggregation, distribution, diversification, protection, proliferation, and deception of space assets.

A number of enabling technologies are essential to provide a new dimension of information superiority from quantum communication to persistent surveillance and from AI-based advanced information algorithms to space robotics. A systemic and holistic approach will be essential to utilize the benefits of the technology evolution and to rapidly incorporate new integrated architectures while simultaneously building proper technology planning capacity road maps. The Alliance must protect the entire value and supply chain at governmental/institutional/industrial levels during the process to grow technological readiness levels. A multinational coordinated and cooperative effort in this respect can be very effective and NATO may play a large role in this regard.

In conclusion, to be effective in the new space domain, our countries must share a principle of cooperation at the political and technological levels in conjunction with an evolution of the standard paradigms in the public-private partnership. The role of transnational organizations, industries, and, of course, NATO, together with the capability to build up cross-border partnerships are fundamental to responding to the challenges facing our Alliance. ●

1. Digital Continuum framework: a conceptual model anchored at one end by Digital Products and at the other by Digital Services.
2. Space Domain Mission Assurance: A Resilience Taxonomy, A White Paper, Office of the Assistant Secretary of Defense for Homeland Defense & Global Security, September 2015.

Massimo Claudio Comparini

holds a Master Degree in Electrical Engineering, Remote Sensing and Radar Systems, University of Rome La Sapienza (Italy), and a Degree in Strategy from Graduate School of Business, Stanford University, CA (USA). He is currently Deputy Chief Executive Officer of Thales Alenia Space Joint Venture, SEVP Observation, Exploration and Navigation and Chief Executive Officer of Thales Alenia Space Italy. He started his career in 1983 at Selenia Spazio (later Alenia Spazio), holding various management positions, up to the role of Chief Technology Officer. In 2013 he was appointed Chief Technical Officer of Telespazio. In 2016 he became the CEO of e-Geos, a JV company between Italian Space Agency and Telespazio, established global leader in the Earth Observation and Geo-Spatial Information and Director Line of Business Geo Information at Telespazio. He was Chairman of the Board of GAF (Germany) and EarthLab Luxembourg, still in the geospatial business domain. In his long career he held a number of academic chairs in technical, economics and innovation management disciplines, while also a member of various academic and scientific boards.