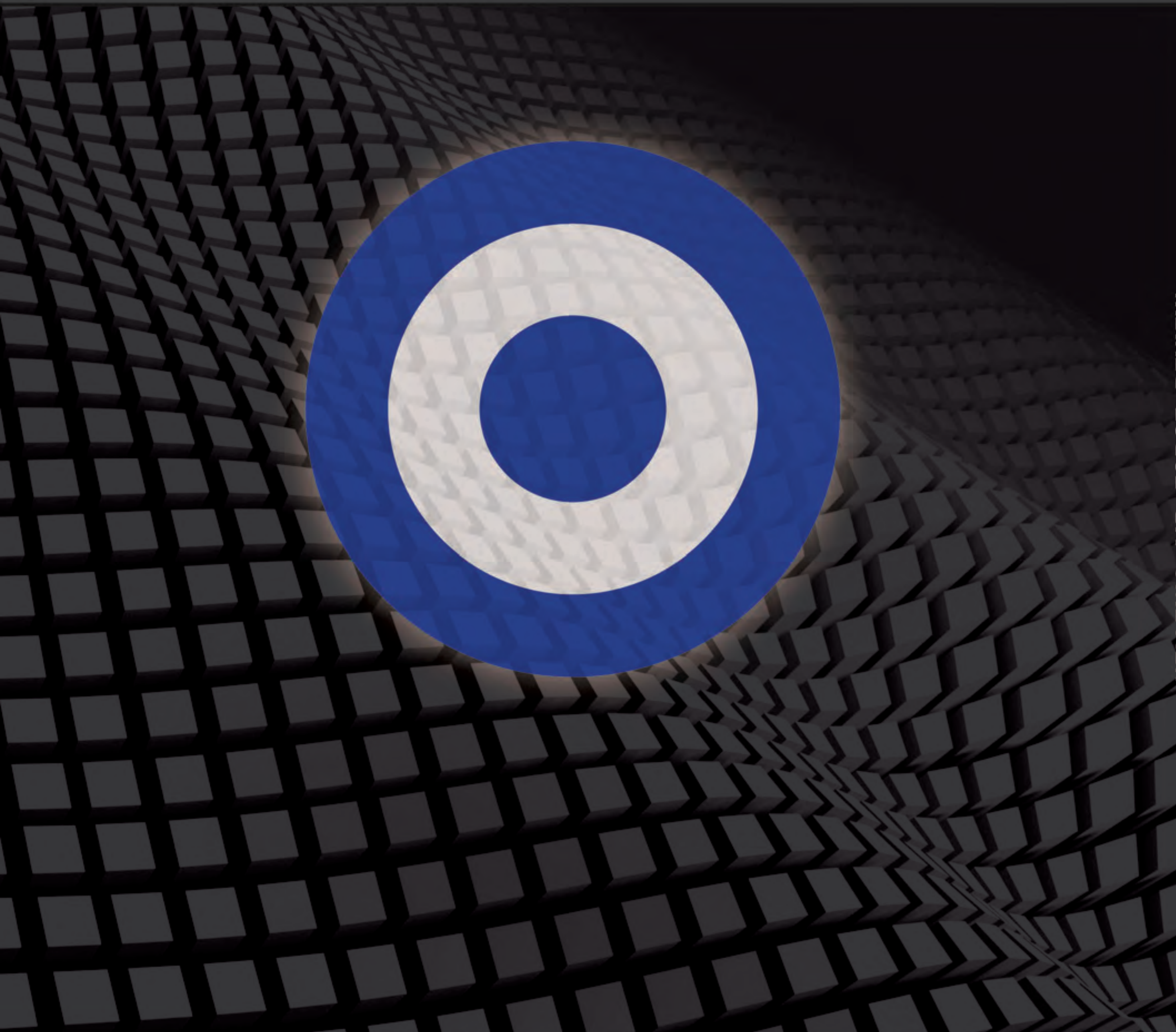
WEBSITE: https://www.haf.gr/news/publications/aeroporiki-epitheorisi

CITATION: Hellenic Air Force War College/Magazine Publication Department. (2025).
Hellenic Air Force Review (#134 - Apr 2025). Zenodo. https://doi.org/10.5281/zenodo.15206321



ISSN | 1105-5960

PRINTING: HELLENIC AIR FORCE PUBLICATION AGENCY

APRIL 2025

HELLENIC AIR FORCE REVIEW

ISSUE 134

HELLENIC AIR FORCE REVIEW

Space security

in a multipolar world

Academy of Athens Award

ISSUE 134
APRIL 2025

HELLENIC AIR FORCE WAR COLLEGE (HAFWC) EDITION

Emblem

“ΜΑΘΗ ΓΑΡ ΤΟΙ ΦΡΕΝΑΣ ΑΥΞΕΙ”

(Education enlarges the mind)
Empedocles

Empedocles, a presocratic philosopher, emphasizes the importance of learning, since education cultivates the mind and provides precious experience

CITATION: Hellenic Air Force War College/Magazine Publication Department. (2025). Hellenic Air Force Review (#134 - Apr 2025). Zenodo. https://doi.org/10.5281/zenodo.15206321

Hellenic Air Force War College

HELLENIC AIR FORCE REVIEW

RESPONSIBLE FOR ISSUING

Hellenic Air Force War College (HAFWC)
Colonel (Pilot) Dimitrios Zervos, Commander

EDITOR IN CHARGE

Dr. Gerasimos Karabelias Professor, Panteion University

SCIENTIFIC ADVISOR OF PUBLICATION

Brigadier General HAF (ret.) Alexander Kolovos
Professor, Hellenic Air Force Academy

TEXT EDITING

Major Michael Maravgakis

ARTISTIC EDITING

Major Michael Maravgakis

2nd Lieutenant Dominiki Spada

DIGITAL EDITING

2nd Lieutenant Dominiki Spada

Chief Master Sergeant Nikoletta Tsaousoglou

PRINTING

Hellenic Air Force Publication Agency

PACKAGING – DISTRIBUTION

Hellenic Air Force War College (HAFWC)/ Magazine Publication Department

WEBSITE

www.haf.gr/news/publications/aeroporiki-epitheorisi

CONTACT

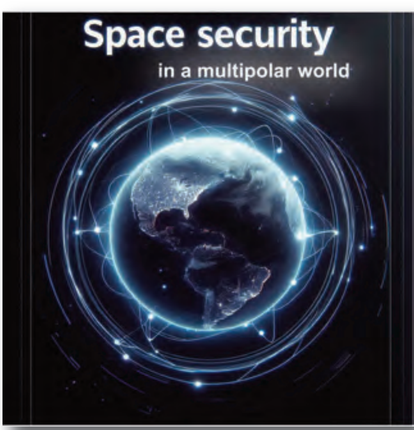
email: aero_epi@haf.gr
tel: +30 210 819 3964 - 16

EDITORIAL

In a world transformed by rapid technological progress and intricate geopolitical changes, space has become a pivotal factor in global security. It is no longer merely a frontier for exploration but a crucial arena where countries compete for strategic dominance, technological superiority, and operational resilience. The growing reliance on space-based technologies, spanning communication, navigation, intelligence, and surveillance has elevated space security to a pressing priority for nations worldwide.

This competitive, multipolar environment drives states to harness space, to strengthen their defense capabilities and safeguard their autonomy. For air forces, space is now a vital tool, sharpening precision, boosting situational awareness, and enabling seamless coordination over vast expanses. The Hellenic Air Force understands that these shifts are reshaping contemporary warfare, offering new possibilities to embrace and obstacles to address.

The Hellenic Air Force Review introduces the issue titled “Space Security in a Multipolar World” underscoring Hellenic Air-Force’s dedication to tackling the changing significance of space in both national and global security contexts. Featuring insights from experts, it delves into how space influences air power, global powers and Europe’s initiatives, as well as Greece’s aspirations. We all want to believe that this publication will enrich the ongoing conversation about safeguarding the space domain and highlight the Hellenic Air Force’s eager role in it.



Gerassimos Karabelias
Professor-Panteion University

Conceptual Overview and Structure of Issue No. 134 of the Hellenic Air Force Review

The concept for this English edition of the Air Force Review emerged following the conclusion of a specialised module, spanning five intensive days, entitled «Space Applications for Security and Defence». This course, now in its third consecutive year, was held at the Hellenic Air Force Academy in Athens (25-29 November 2024) under the aegis of the European Security and Defence College. The ESDC has also approved the syllabus of this course, proposed by the HAFA in 2017 and revised in 2024. The majority of the authors in this edition were speakers at this event. However, the rapidly evolving geopolitical landscape and its implications for European and space security prompted a broader examination of these matters.

The April 2025 edition of the Air Force Review, titled "Space Security in a Multipolar World," offers a comprehensive examination of space as a pivotal domain in contemporary security and defence. Structured into four distinct parts, this issue brings together leading voices from military, academic, and policy spheres to address the multifaceted opportunities and challenges that space presents.

Part I, "Space and Airpower Capabilities," explores the integration of space into modern air forces and defence. Professor and Brigadier General HAF (Ret.) Alexandros Kolovos' inquiry into the survival of air forces without space sets the stage. This is complemented by Colonel HAF (Ret.) Konstantinos Pilaftsis' discussion on the growing necessity of space-based intelligence, surveillance, and reconnaissance (ISR). Additionally, Georgios K. Kotlidas and Fotios Kotzakioulafis examine national and international challenges and opportunities in space law and security.

Part II, "The Space Superpower and Other National Space Powers," shifts focus to the strategies of key players in the global space race. Contributions include Professor Peter L. Hays' analysis of the United States' reconnaissance-strike complex. Professor Kostas Grivas, along with Anastasios Seferiadis, covers Russia's ambitions. Space experts like Dr. Dimitrios Stroikos examine the rise of China and India as space powers, while Dr. Deganit Paikowsky outlines Israel's approach to space security. Meanwhile, Lieutenant Colonel Panagiotis Katsaounis (HAGS) presents the space program of Türkiye. Collectively, these contributions offer a broad view of national priorities in this arena.

Part III, “European Space Security,” highlights Europe’s collective response to global space trends. Patrick Chatard Moulin from the European External Action Service and Dr. Christina Giannopapa detail the European Union’s space strategy and the evolving role of the EU Agency for the Space Programme, respectively. The EU Satellite Centre’s Director, Admiral Louis Tillier, explains the geospatial intelligence capabilities of the EU SatCen, while Dr. Nikolaos Tantouris and colleagues from ENISA address cybersecurity risks in space. Additionally, contributions from Dr. Pascal Legai, Senior Security Adviser to the European Space Agency Director General and Major General FASF (Ret), and Professor Kai-Uwe Schrogl, Special Adviser for Political Affairs at the ESA, further explore Europe’s strategic priorities and public engagement with space.

Finally, Part IV, “Greece and Space Security,” showcases contributions from Greece to this domain. Lieutenant Colonel (HAF) Fotios Giantsis discusses a possible option for next-generation military satellite communications, while Dr. Haris Kontoes details the National Observatory of Athens BEYOND Centre’s role in securing autonomy in Earth and space observation. Professors Vaios Lappas and Antonios Paschalis present the forthcoming ERMIS nanosatellite constellation’s defence applications, and Second Lieutenant (HAF) Georgios-Marios Margos considers the potential for a Hellenic Air Force pilot to become an astronaut.

Together, these articles hope to offer a comprehensive perspective on space security, connecting global developments with strategic interests relevant to Greece. This issue aims to enrich the global dialogue on space security by presenting diverse insights, encouraging collaboration and innovation among air forces, policymakers, and scholars from leading spacefaring nations.

Alexandros K. Kolovos,
Professor, Hellenic Air Force Academy,
Brig. General, Hellenic Air Force (Ret)

Table of Contents

Can Air Forces Survive Without Space?

Professor Alexandros Kolovos,
Hellenic Air Force Academy, Brigadier General HAF (ret)[1]

Citation: *Dr. Alexandros Kolovos, Professor Hellenic Air Force Academy, Brig. General HAF (ret.). (2025). Can Air Forces Survive Without Space? Hellenic Air Force Review, 134* https://doi.org/10.5281/zenodo.15170068

"We are now transitioning from an air force into an air and space force on an evolutionary path to a space and air force (Department of the U.S. Air Force, 1997)"[2]

Abstract

This article emphasizes the strategic importance of integrating space capabilities within air forces for national security. It reviews historical context and current trends among global players like the U.S., China, Russia, and Europe. The Hellenic Air Force pioneered this integration by creating a space center in 1977 and incorporating space into its ISR capabilities over 30 years. The analysis advocates for HAF to regain authority over ISR space-based assets, aligning with airpower theory and European trends. This approach enhances the precision and effectiveness of air and space operations, maintaining a competitive edge in modern military challenges.

Keywords

Air Power; Space Power, Hellenic Air Force; Space Integration; ISR Capabilities; National Security; Strategic Evolution

Prologue

President Donald Trump's selection of Dr. Troy Meink, Principal Deputy Director of the National Reconnaissance Office (NRO), as the next Secretary of the Air Force, underscores the strategic importance of integrating space and air capabilities within the United States Air Force (USAF). The NRO, part of the U.S. Intelligence Community and Department of Defence, manages reconnaissance satellites. Dr. Meink's experience with space-based collections is pivotal for this integration.

The nomination of Matthew Lohmeier, a former Space Force lieutenant colonel, as Under Secretary of the Air Force, further highlights the critical role of space in modern military operations and the need for cohesive space and air strategies within the Air Force.

The integration of space with air gained prominence after the First Gulf War (1991), often called 'the first space war,' which showcased the utility of space-based technologies like GPS for navigation and precision targeting. This success highlighted the strategic importance of space in warfare and spurred discussions on incorporating space capabilities into air forces.

In 1995, an article in Joint Force Quarterly argued that the Air Force needed to evolve into a space force to remain relevant.[3] This foresight was realised when President Trump signed the National Defense Authorization Act on 20 December 2019, creating the U.S. Space Force as the sixth branch of the

U.S. Armed Forces, tasked with ensuring American space superiority. This new branch was tasked with ensuring American space superiority through the organisation, training, and equipping of space personnel.[4]

The revival of U.S. Space Command in August 2019, after a 17-year hiatus, reflects a parallel commitment. SPACECOM's global space operations integrate with other combatant commands, reinforcing the centrality of space in military strategy."[5] It should be noted that the difference between the Space Command, and the Space Force (USSF), is that the first is the combatant command, while the latter is the military service (Table 1).[6]

The U.S. Air and Space Nexus

The USAF was established on 18 September 1947 with the National Security Act. It covered all U.S. photoreconnaissance needs until a U-2 crash in 1960 ended overflights over the USSR.[7] The first space image from Discoverer-14 on 19 August 1960 began the era of space imagery intelligence, convincing President Eisenhower there was no "missile gap", which meant that the USSR did not have missile superiority over the USA.[8] The National Reconnaissance Office (NRO) was founded on 25 August 1960. Both institutions have been crucial in U.S. defence and intelligence, focusing on air and space capabilities.

Entity	Role and Responsibilities	Relationship
Secretary of Defence	The principal defence policymaker and advisor to the U.S. President.	Oversees the entire Department of Defense, including the DAF and SPACECOM.
Department of the Air Force (DAF)	Oversees both the USAF and USSF. Provides overall administrative and policy framework. Reports to the Secretary of Defence.	The parent organization for both the USAF and USSF.
United States Air Force (USAF)	Organizes, trains, and equips air forces. Conducts air operations.	A branch under the DAF. Focuses on air domain operations.
United States Space Force (USSF)	Organizes, trains, and equips space forces. Develops space capabilities.	A branch under the DAF for administrative purposes. Operationally, it supports SPACECOM and other combatant commands.
United States Space Command (SPACECOM)	Conducts space operations. Integrates space capabilities into broader military strategy. Reports directly to the Secretary of Defense for operational control.	A unified combatant command that utilizes resources and personnel from the USSF.

Table 1: Roles, Responsibilities, and Relationships of U.S. Air Force and Space Entities

The Air Force has historically engaged with aerospace technologies like satellites and missile defence. The term 'aerospace' was introduced by General White in 1958 and widely adopted until the 1990s.[9] Initially focused on air superiority and reconnaissance, the Air Force's role expanded as space became a vital domain, requiring dedicated resources and strategic planning.

The USAF's extension to space operations made it well-suited to manage and develop space capabilities. Many space-based assets, such as satellites for ISR, communication, and navigation, are integrated with air operations. The Air Force's control of airspace and aerial missions logically extends to managing space assets. 'Outer space' is contiguous to 'air space,' with the lower limit of 'outer space' being the upper limit of 'air space.'[10]

Several individuals have transitioned from leading the NRO to serving as Secretaries of the Air Force, highlighting the integration of space and air expertise (Table 2). This pattern underscores the close relationship between the NRO and the Air Force, with NRO leadership experience being valuable for the strategic oversight required as Secretary of the Air Force.

Name	NRO Director Tenure	Secretary of the Air Force Tenure
Dr. John L. McLucas	March 17, 1969 - December 20, 1973	July 19, 1973 - November 23, 1975
Mr. Thomas C. Reed	August 9, 1976 - April 7, 1977	January 2, 1976 - April 6, 1977
Dr. Hans Mark	August 3, 1977 - October 8, 1979	July 26, 1979 - February 9, 1981
Mr. Edward C. Aldridge Jr.	August 3, 1981 - December 16, 1988	June 9, 1986 - December 16, 1988

Table 2: Transition of NRO Directors to Secretaries of the Air Force

In 1990, USAF Chief of Staff General McPeak renamed 'aerospace' to 'air and space' to reflect the distinct cultures and principles of these domains. This transition was driven by several factors, including the increasing reliance on space-based assets for communication, navigation, and ISR, making space crucial for national security.[11] The threat of space-based conflicts and the need to protect space assets highlighted the importance of space security. Integrating space capabilities into military operations required specialised knowledge and skills, making education in space security and defence vital. The global trend towards space militarisation also underscored the need for international cooperation. However, in 1997, General Ryan reinstated the term 'aerospace'. In 2002, the USAF replaced 'aerospace' with 'air and space power' to acknowledge the distinct culture and principles of space (Table 3).

Time Frame	Terminology Used	Description
1958 - 1990	Aerospace	The term "aerospace" was first introduced by Gen Thomas D. White in August 1958 and was used throughout the Air Force.
1990 - 1997	Air and Space	Gen Merrill A. McPeak became Chief of Staff in 1990 and renamed the term used by the Air Force to " air and space", to better reflect the distinct cultures and principles of air and space domains.
1997 - 2002	Aerospace	General Ryan took over in 1997 and the term USAF used was "aerospace ".
2002 - Present	Air and Space Power	From 2002, the Air Force uses the term "air and space power." This change was made to respect the fact that space is its own culture with its own principles. This shift was part of a broader effort to acknowledge the distinct nature of space operations within the Air Force.

Table 3. Evolution of Air Force Terminology over Time 12

Responses from Major Competitors and European Allies

This strategic shift is not unique to the United States. Other countries have also recognized the importance of this integration.

Major Competitors

Other major players, such as China and Russia, have also recognized the importance of integrating space capabilities into their military operations. However, while the U.S. has established a separate Space Force, and a Space Command, China and Russia have taken different approaches.

In 2015, the Chinese People's Liberation Army (PLA) established the Strategic Support Force (PLASSF) to oversee space, cyber, and electronic warfare efforts. This was part of broader reforms aimed at centralizing control over these crucial domains within the PLA. However, President Xi Jinping's vision for China to become a great space power by the early 2020s has driven aggressive investments and policies in space technology, aligning military and civilian efforts to ensure space superiority.[13] On April 19, 2024, the PLASSF was dissolved, and its functions were redistributed across the PLA's other branches. Concurrently, the PLA established the Aerospace Force, consolidating all space-based systems and assets under a unified command. This restructuring is seen as a move to integrate China's space capabilities more closely with its overall military goals. [14] The establishment of the Aerospace Force enhances China's ability to synchronize space operations with air and missile defence strategies, with an eye on regional and global military influence.

Similarly, Russia on August 1, 2015, has established the Russian Aerospace Forces (VKS), which combines the Air Force, Air Defence Forces, and Space Forces. This structure enables Russia to coordinate its air and space operations more effectively, ensuring a unified approach to national defence.

European Allies

In Europe, the trend is also gaining momentum. France and Spain have renamed their air forces to include the space domain. The French Air Force was renamed Armée de l'Air et de l'Espace (Air and Space Force) on September 10, 2020. The French Space Command (Commandement de l'Espace, CDE) was created on 3 September 2019 to enhance the operational effectiveness and governance of space within the French Ministry of Armed Forces. It is a French Air and Space Force command but also a joint forces organization, including members from the Air and Space Force, Army, Navy, Defence Procurement Agency, and joint forces logistics department. Functionally, the CDE is under the French Chief of Defence Staff for military operations and space policy, while organically it is

Country	Belongs To	Space Operations Managed By	Details
China	People's Liberation Army	Aerospace Force	Established on April 19, 2024. The Aerospace Force will focus on supporting and achieving China's space policy goals and will directly report to the CMC. It will develop military space capacities, ensuring China's access, use, and control of space, and enhancing Chinese space power.
Russia	Russian Armed Forces	Russian Aerospace Forces (VKS)	Established on August 1, 2015. Combines the Air Force, Air Defence Forces, and Space Forces. The VKS was created to improve efficiency and logistical support, and it plays a crucial role in aerial warfare, space warfare, and missile defence.

Table 4: Comparison of Aerospace Forces in China and Russia

under the Chief of Staff of the French Air and Space Force.

The Spanish Air Force was renamed Ejército del Aire y del Espacio (Air and Space Force) on June 27, 2022. It includes a Space Command consisting of personnel from the air force. Spain's investments in space are focused on developing its space capabilities and ensuring the security of its space assets.[15i] Both countries renamed also their Military Academies too.

in national defence.[16]

- The German Air Force (Luftwaffe) oversees the German Space Command (Weltraumkommando), which was established on July 13, 2021. It consists of personnel from the Luftwaffe and focuses on protecting Germany's space assets and enhancing its space situational awareness. Germany's investments in space are aimed at strengthening its defense and technological capabilities.[17]

Country	Original Name	Renamed Name	Renaming Date
France	Armée de l'Air	Armée de l'Air et de l'Espace	September 10, 2020
Spain	Ejército del Aire	Ejército del Aire y del Espacio	June 27, 2022

Table 5: Renamed European Air Forces to include Space in their names

Other countries preferred to establish only a space command, most under the auspices of their Air Force. These changes reflect the growing recognition of space as a critical domain for military operations and the need for air forces to incorporate space capabilities into their strategic frameworks.

- The United Kingdom Royal Air Force oversees the U.K. Space Command, which is a joint command established on April 1, 2021. It includes personnel from the Royal Navy, British Army, Royal Air Force, and the Civil Service. The U.K. has made significant investments in space capabilities, reflecting its strategic importance

- The Italian Defence General Staff, oversees the Italian Space Operations Command (Comando delle Operazioni Spaziali), a joint command that includes personnel from all branches of the military. It was established on June 30, 2020, to coordinate Italy's military space activities and enhance its space defence capabilities.[18]

Lessons Learned from the Organisational Structure Followed

Countries discussed above have structured their military organizations to

Country	Space Command Name	Belongs To	All Branches	Establishment Date
France	French Space Command (Commandement de l'Espace, CDE)	French Air and Space Force	Yes	September 3, 2019
Italy	Italian Space Operations Command (Comando delle Operazioni Spaziali)	Italian Defence General Staff	Yes	June 30, 2020
United Kingdom	United Kingdom Space Command.	Royal Air Force. UKSC headquarters is at RAF High Wycombe co-located with Air Command	Yes	April 1, 2021
Germany	German Space Command (Weltraumkommando)	German Air Force (Luftwaffe)	No	July 13, 2021
Spain	Mando del Espacio: MESPA	Spanish Air and Space Force	No	January 9, 2024

Table 6: European Countries with Space Commands

align with their strategic interests. Nations with global ambitions, such as the United States, have recognised the importance of space for achieving security and power projection. In contrast, countries with more regional or national interests have different options, which are analysed below.

Space as a Separate Domain: The US Approach

The United States, as currently the only space super-power, has invested heavily in both its Air Force and Space Force, with the latter now part of the Department of the Air Force (DAF). While the Air Force did not merge with the Space Force, the creation of the latter as it is documented by the 2020 Defense Space Strategy, underscores the growing complexity of space operations, necessitating dedicated focus and resources.[19] According to the Strategy, DAF will grow its spacepower capacity over the next 10 years to ensure space superiority and secure the Nation's vital interests.

The USAF continues to play a vital role in national defence, but the formation of the Space Force reflects the recognition that space has become too significant and intricate to remain a subordinate function within another branch. This separation allows both branches to specialise and excel in their respective domains, ensuring comprehensive coverage of both air and space operations.[20]

The Integrated Approach: Aerospace Forces of China and Russia

In contrast, nations with more regional strategic focuses, such as the great space-powers China and Russia, have adapted their space and aerospace structures to address national interests. China's recent military restructuring, particularly the creation of the PLA Aerospace Force in 2024, mirrors the Russian model. In 2015, Russia consolidated its Air Force, Anti-Missile Defence Forces, and Space Forces under the Russian Aerospace Forces (VKS), positioning itself for long-term strategic competition. This integrated structure enables Russia to coordinate air and space operations more effectively, strengthening its national defence and broader strategic objectives. China's recent Aerospace Force reflects a similar approach, aligning its space forces with its overarching defence strategy, which is influenced by the Russian example. Both nations aim to optimise their military structures by embedding space as a core component of their regional power projection.

These developments underscore the interconnectedness of air and space operations, where space is not simply an isolated domain but a crucial enabler of military objectives. Russia has integrated its space assets into the VKS to support strategic needs across Europe and Central Asia, while China's emphasis on the Indo-Pacific has driven substantial investments in space systems.

Space Command Within Existing Structures: The Medium - Power Approach

In nations with limited global ambitions and regional security interests, the establishment of a Space Command often depends on resource constraints, strategic priorities, and organisational efficiency. These countries typically lack the scale or necessity to create an independent space force. Instead, they incorporate their space operations within existing structures, such as the, the Ministry of Defence as a specific command or the Air Force.

Space Command under the Ministry of Defence: A Joint Command Approach

Some countries choose to place Space Commands directly under their Ministry of Defence as joint commands involving all branches. The Italian Space Operations Command provides a notable example. It operates under the Italian Defence General Staff, emphasizing a joint approach to space operations across all branches of the Italian military. This approach reflects a broader vision of space as a cross-domain enabler rather than a specialized domain linked solely to the air force. Joint commands, may facilitate integration across land, sea, air, and cyber domains, ensuring that space operations are aligned with the overall strategic objectives of the armed forces.

While this model promotes inter-service collaboration, it can also introduce complexity in decision-making and coordination, especially in nations with limited resources. The traditional hierarchical mindset can lead to delays in the dissemination of critical information, especially in wartime situations. A characteristic example is the Gulf War in 1991 when the CIA employs first informed their leadership in the U.S. about the findings and then sent the results to General Norman Schwarzkopf, who was the Allied Forces tactical commander and who needed those most.[21]

Space Command within the Air Force: Leveraging Existing Expertise

Alternative, embedding the space command within the air force is also a common choice, reflecting historical, operational, and technological synergies. The air force is often selected as the home for a space command because of its inherent expertise in domains that intersect with space operations.

The air force's long-standing experience in managing advanced technologies, such as radar systems, satellite communications, and aerial reconnaissance, provides a natural foundation for developing space capabilities. Another reason for situating a space command within the air force is the continuity of command structures and mission objectives. Air forces oversee high-altitude operations, including missile defence and aerial support systems, which serve as stepping stones to space-related missions. The Air Forces is the only branch that has the ability to quickly deploy and redeploy assets across long distances, which is essential for maintaining situational awareness of the area of interest and responding to threats. By integrating space command within the air force, nations can ensure a seamless transition between air and space domains, creating a unified chain of command that simplifies coordination and enhances operational readiness.

France and Spain provide strong examples of this trend. The creation of the 'Armée de l'Air et de l'Espace' in France and the renaming of the Spanish Air Force to include 'Space' (Table 5), demonstrate a clear commitment to integrating space operations within the existing Air Force structure. Furthermore, the establishment of the 'Commandement de l'Espace' within the French Air and Space Force and the creation of the 'Mando del Espacio' within the Spanish Air and Space Force (Table 6) further solidify this integration, leveraging existing expertise and infrastructure. The United Kingdom also exemplifies this approach. The UK

Space Command is co-located with Air Command within the Royal Air Force, while the German Space Command belongs to the German Air Force (Luftwaffe), highlighting the close operational relationship and utilisation of existing resources.

One critical issue for all Air Forces' missions is targeting. Targeting is at the heart of airpower theory. According to Giulio Douhet (1869-1930), a pioneering air power theorist often called the father of strategic air power due to his influential ideas on the use of aircraft in warfare, "the choice of enemy targets is the most delicate operation of aerial warfare." [22]

All Air Forces have the capability to strike targets with precision and effectiveness, utilizing Air Power. They can engage a wide range of deep targets, including strategic centers of gravity, critical infrastructure, and mobile targets, both in the air, at sea, and on the ground. To achieve this, all Air Forces require intelligence, especially for remote areas of interest. As Owens stated, "Air power is targeting, and targeting is intelligence." For these deep targets, intelligence is provided via space-based ISR systems. [23]

Also, Air Forces can strike a significantly larger number of targets than all other branches. The targeting by the Air Forces differs internationally from the targeting by other branches of the Armed Forces. The Air Force can strike targets at much greater distances due to the range and speed of aircraft, allowing for operations in geographically remote areas that other branches cannot reach.

The target development process, which involves creating and updating a list of entities of interest supported by intelligence, is crucial during crises or war. During such times, targets known from peacetime may relocate, or new mobile targets may emerge. Time, information transmission networks, and analysts' experience are critical factors. Challenges arise when image analysts from other branches, who may not fully understand the Air Force's specific needs and operational context, analyse its targets. Cultural differences and varying priorities can lead to misinterpretation, with analysts selecting and analysing data that is not relevant or critical for air operations. This lack of understanding can hinder the Air Force's ability to make timely and informed decisions. In urgent situations, this misalignment becomes even more critical, as the Air Force relies on rapid and accurate analysis to respond to threats and execute missions effectively. Any delay or error in target selection due to cultural misunderstandings or differing operational priorities can have serious consequences, impacting mission success and personnel safety.

Hellenic Air Force and Space

The unified Hellenic Air Force was established as an independent branch of the Armed Forces with Law 5121 «On the Organisation of the Air Force» on 10 July 1931. In 1952, Greece became a member of NATO, leading to the reorganisation and restructuring of the Hellenic Air Force in line with NATO standards, with support from the United States. Consequently, due to the close relationship between the two air forces, the HAF was able to stay informed about developments in the United States Air Force, including those related to space.

This is evident as the term «aerospace» was included as one of the topics of interest for which «Air Force Review,» the official magazine of the Air Force, accepted articles for publication. Notably, from the first issue of Air Force Review (January - June 1972), the term «aerospace» was mentioned and specialised in topics concerning the achievements of the two superpowers, the development of strategy and tactics of flying objects, and the future of aircraft in light of space achievements.

In 1977, the HAF established the National Space Research Center (NSRC). The mission of the NSRC was to support National Defence and the National Economy through space technology. This included informing the Air Force, Armed Forces, and Public Services about space science activities, processing satellite imagery, and representing these entities in space-related fields. By evolving into an «aerospace force,» HAF could leverage advanced technologies that operate seamlessly across both air and space domains.

The history of the HAF's involvement with Space has been detailed in the Air Force Review (Issue 127).[24] However, certain topics that are relevant to the content of the present article are reiterated or further specialised in this text.

In 1995, the Council of Chiefs of General Staff (SAGE) redefined the name and the mission of the NSRC to the National Center for Space Applications (NCSA). The NCSA was tasked for supporting the operational work of the General Staffs and other national entities in the collection and processing of satellite images and was subordinated to the A' Branch of the Hellenic Air Force General Staff (HAFGS).

While the HAF was instrumental in establishing the NCSA and proposed the Space Policy for the Ministry of Defence (1995), the Space Policy of the Western European Union (1998), and the EU Council decision 'ESDP and Space' (2004)[25], as well as the creation of a 'Space Office' within the Ministry of Defence in 2006, this progress was halted. In 2007, the HAF experienced a separation from the ISR space capabilities after proposing participation in the Helios II programme. Despite initial challenges, the political leadership's acceptance of the proposal brought the issue of control over Helios II to the forefront.

In November 2006, the Council of Chiefs of the General Staffs decided initially to transfer the NCSA to the Hellenic National Defence General Staff. Then, on 9 July 2007, the new Minister of National Defence decided to abolish the NCSA once the Helios II ISR 'Ground Satellite Station' became operational. The station was installed at the 114 Combat Wing (Tanagra Air Base) and became operational in 2010. Consequently, the NCSA closed after 30 years of successful work.

Currently, the Hellenic Ministry of Defence has two overarching space-related entities: the 'Space Office' at the General Directorate of National Defence Policy and International Relations of the Ministry of National Defence (proposed by HAF in 2006), and the 2021 'Space Directorate' at the Hellenic National Defence General Staff, which, among other responsibilities, oversees the Tanagra Air Base 'Ground Satellite Station'.

The abolishment of HAF's NCSA might explain why the 2014 HAF Doctrine made only a single reference to the term «space.» It stated that air power, utilising the third dimension with characteristics such as speed, flexibility, precision, rate, and effectiveness of its weapons, operates in both air and space.[26]

In contrast, 2023 HAF Doctrine, in a dedicated subsection on 'Air Power and Space,' integrates space as a crucial element of air power, recognizing it as a natural extension of the air domain.[27] It acknowledges that space exploitation provides new capabilities, adding Space Power as an additional dimension to Air Power. Space offers broad geographic coverage and long duration, enhancing military capabilities.

Given that the 2023 HAF Doctrine states, 'the unique characteristics of Air Power and Air Forces necessitate their command by a single Air Commander with the necessary knowledge and experience,' should the Air Force advocate for regaining authority over ISR space-based assets?

The emphasis on ISR systems arises from their distinct nature compared to other tactical decentralized systems (such as telecommunications, positioning, and navigation). ISR products require processing and analysis, which takes time to render them useful. The fact that the Air Force targets a greater number of locations of interest than the other two branches combined, due to the specific geographical configuration of the operational environment, was taken into account in 1995. For this reason, the responsibility for the relevant infrastructure was given to the Air Force, as it is directly related to the effectiveness of its mission. It is estimated that the same reasons still apply today."

This approach aligns with Douhet's emphasis on targeting and air superiority, mitigates delays and misinterpretations from hierarchical communication barriers, and ensures timely dissemination of critical information. Centralizing command under an experienced Air Commander would align with European trends and enhance the precision and effectiveness of air operations by optimally utilising ISR capabilities.

Epilogue

The integration of space and air capabilities is essential for national security and military effectiveness. This evolution is no longer a mere aspiration but a strategic imperative, as demonstrated by U.S., European, and global trends. Currently, the organization for space matters of the Hellenic Ministry of Defence is not yet on par with those of other countries, with Greece having been in the same space club in the past by entering into the Helios II programme.

The HAF's pioneering role in incorporating space into its targeting capabilities underscores the necessity of regaining authority over ISR space-based assets. This corroborates perfectly with airpower theory and European trends, enhancing the precision and effectiveness of air and space operations. The continued relevance of air forces without space integration appears increasingly tenuous. The HAF's return to an 'aerospace force' is a natural progression, necessitating organizational reforms. By addressing internal challenges, HAF can strengthen national security and maintain its operational relevance in an increasingly space-centric military landscape.

This aligns also with recent study of the U.S. Department of the Air Force, including both the USAF and Space Force, for 2050.[28] DAF envisions seamless integration of air and space operations to enhance mission effectiveness and maintain strategic superiority. By leveraging advanced technologies like AI, autonomous systems, and advanced propulsion, the DAF aims to ensure dominance in both domains. The HAF's historical ties with the U.S. and French Air Forces position it advantageously to adopt best practices and reinforce its air power capabilities through space integration.

Ultimately, embedding again space-based ISR infrastructure under HAF's command stems from pragmatic considerations. Smaller nations must balance their ambitions with their available resources, and the air force's existing infrastructure and expertise make it a logical and cost-effective choice. While alternative models offer their own advantages, the air force-centric approach remains particularly appealing for nations seeking to leverage their existing strengths while navigating the challenges of the increasingly critical space domain.

References

1 A. Kolovos, Professor at the Hellenic Air Force Academy, Brigadier-General, Hellenic Air Force

2 Department of the Air Force. (1997, January 1). *Global Engagement: A Vision for the 21st Century Air Force* (Accession No. ADA318235). Defense Technical Information Center. Retrieved from https://archive.org/details/DTIC_ADA318235

3 Szafranski, R. When Waves Collide: Future Conflict. *Joint Force Quarterly*, Spring 1995, 79. Retrieved from https://apps.dtic.mil/sti/pdfs/ADA528918.pdf

4 U.S. Department of Defense. Trump Signs Law Establishing U.S. Space Force. U.S. Department of Defense. December 20, 2019, Retrieved from https://www.defense.gov/News/News-Stories/Article/Article/2046035/trump-signs-law-establishing-us-space-force/

5 United States Code. 10 U.S.C. § 9081: The United States Space Force. In Title 10 - Armed Forces, Subtitle D - Air Force, Part I - Organization, Chapter 908 - The Space Force. 2019. U.S. Government Publishing Office. Retrieved from https://www.govinfo.gov/content/pkg/USCODE-2019-title10/html/USCODE-2019-title10-subtitleD-partI-chap908-sec9081.htm

6 United States Department of State, «The Space Force's Critical Role in National Security,» [Online]. Retrieved from: https://2021-2025. state. gov/briefings-foreign-press-centers/the-space-forces-critical-role-in-national-security. [Accessed: 25-Jan-2025]

7 F. G. Powers and C. Gentry, *Operation Overflight: The U-2 Spy Pilot Tells His Story for the First Time*. New York, NY, USA: Holt, Rinehart and Winston, 1970.

8 Central Intelligence Agency, «CORONA: America's First Imaging Satellite Program,» [Online]. Available: https://www.cia.gov/legacy/museum/exhibit/corona-americas-first-imaging-satellite-program/. [Accessed: 25-Jan-2025]

9 Air Force Magazine 41, no. 8 (August 1958): 36.

10 National Security Council: U.S. Policy on Outer Space, NSC 5814," June 20, 1958, document #345, declassified 1992 NSC, DDRS.

11 Agrawal, R., & Brooks, A. One Team, One Fight: The Department of the

Air and Space Forces. *Air & Space Operations Review*, 1(1), Spring 2022.

12 Jennings, F. W. New doctrine demands changes in the aerospace force. *Air Power Journal*, 13(1), AFRP 10-1. 1999.

13 Zhao, L. Xi: Build 'great space power'. *China Daily*. April 25, 2020. Retrieved from https://www.chinadaily.com.cn/a/202004/25/WS5ea23e86a3105d50a3d1884e.html

14 Pollpeter, K. L., Chase, M. S., & Heginbotham, E. *The creation of the PLA Strategic Support Force and its implications for Chinese military space operations* (RR-2058). RAND Corporation. 2017. Retrieved from https://www.rand.org/pubs/research_reports/RR2058.html

15 Aviacionline, "The Spanish Air Force is now a Space Force too," Aviacionline, June 27, 2022. [Online]. Available: https://www.aviacionline.com/2022/06/the-spanish-air-force-is-now-a-space-force-too. [Accessed: 01-Feb-2025].

16 Royal Air Force. (n.d.). UK Space Command. https://www.raf.mod.uk/what-we-do/uk-space-command/

17 Machi, V. Germany establishes new military space command. Defense News. July 13, 2021. Retrieved from https://www.defensenews.com/space/2021/07/13/germany-establishes-new-military-space-command/

18 Ministero della Difesa. (n.d.). Il Comando delle Operazioni Spaziali (COS). Retrieved January 23, 2025, from https://www.difesa.it/smd/covi/cos/index/25457.html

19 U.S. Department of Defense, 2020 Defense Space Strategy: Spacepower as a Force Multiplier, 2020. Retrieved from: https://media.defense.gov/2020/Jun/17/2002317391/-1/-1/1/2020_defense_space_strategy_summary.pdf [Accessed: Jan. 25, 2025]

20 United States Department of State, «The Space Force's Critical Role in National Security,» [Online]. Available: https://2021-2025.state.gov/briefings-foreign-press-centers/the-space-forces-critical-role-in-national-security. [Accessed: 25-Jan-2025].

21 A. Kolovos, "*Persian Gulf War: The First Space War. A Critical Assessment of Space Systems*," translated from the original 1992 publication, Aerospace Management and Control Laboratory, OCCASIONAL PAPER NO. 2, Automatic Control, Aerospace Technology, Defence Systems and Operations Di-

vision, Hellenic Air Force Academy, 2017.

22 G. Douhet, The Command of the Air. New York: Coward-McCann. 1942

23 G. Valentino. Using the space domain: An intelligence, surveillance and reconnaissance perspective. The Joint Air Power Competence Centre. NATO, 2020. Retrieved from The Joint Air Power Competence Centre.

24 A. Kolovos, K. Hellenic Air Force and Space: From the Past to the Future. *Air Force Review*, (127), April 2023.

25 Council of the European Union, *European space policy: ESDP and space,* 11616/3/04 REV 3. Brussels.Available at: http://register.consilium.europa.eu/pdf/en/04/st11/st11616-re03.en04.pdf. November 16, 2004

26 Hellenic Air Force. *Basic Doctrine of the Hellenic Air Force*. General Staff of the Air Force, Branch A - Directorate A1, Section 1, January 2014. Retrieved from https://www.haf.gr/wp-content/uploads/2015/01/basiko_dogma_pa_2014.pdf

27 Hellenic Air Force. *Basic Doctrine of the Hellenic Air Force*. General Staff of the Air Force, Branch A - Directorate A1, Section 1, March 2023. Retrieved from https://www.haf.gr/wp-content/uploads/2023//05/ΒΑΣΙΚΟ-ΔΟΓΜΑ-ΠΑ.pdf

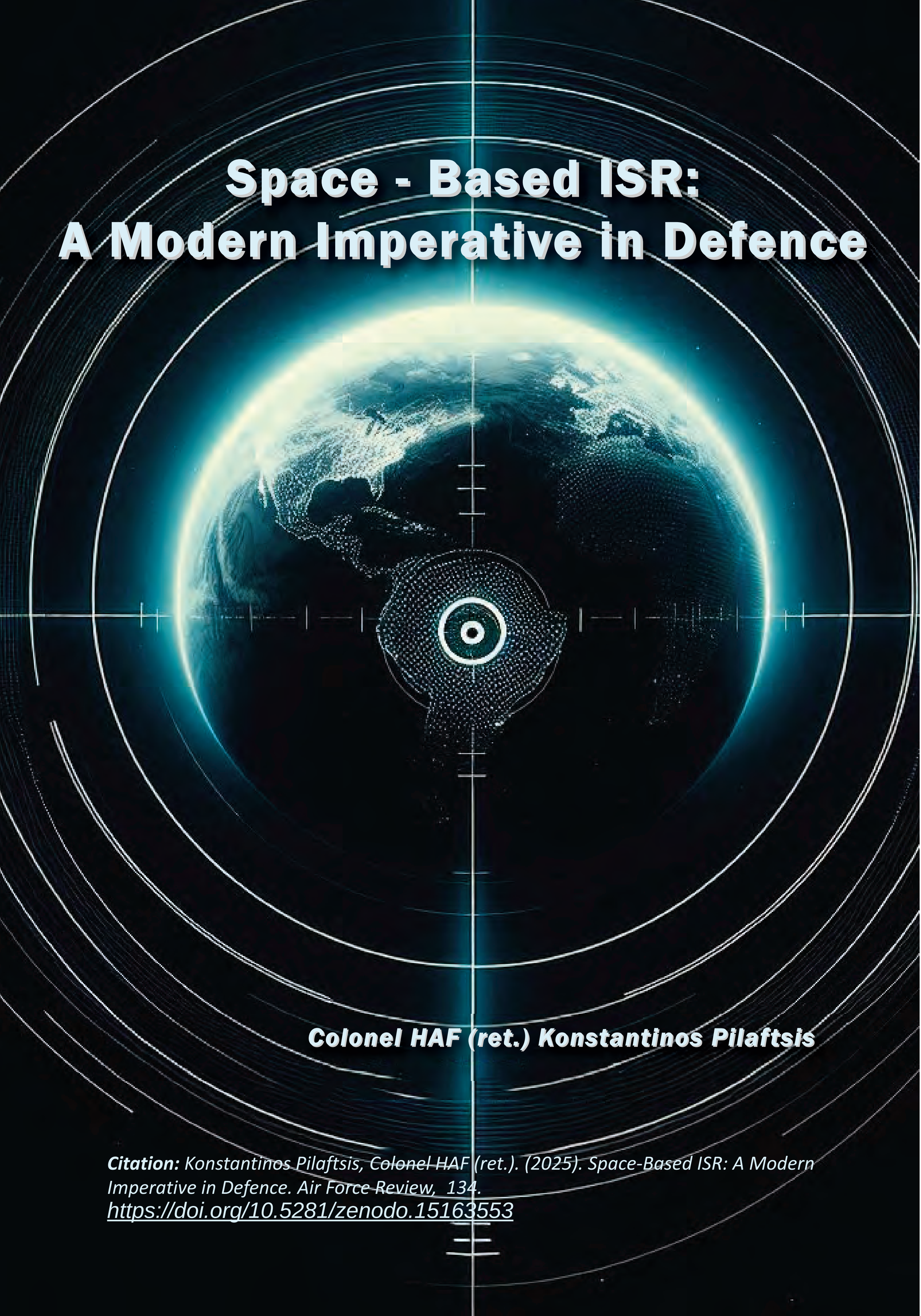
28 Department of the Air Force, "Report to Congressional Committees: The Department of the Air Force in 2050," December 2024. [Online]. Retrieved from: www.af.mil/Portals/1/AirForcePriorities/DAF_2050_Final_30_Dec.pdf. [Accessed: 01-Feb-2025].

Short Biography

Dr. Alexandros Kolovos, Professor of Space Technology at the Hellenic Air Force Academy (HAFA), graduated in 1980 and has been active in the Hellenic Air Force (HAF) for 49 continuous years.

He resigned as a Brigadier General in 2008 and then became a professor at HAFA, a part of HAF. He holds a Law degree from the University of Athens (1987) and a PhD in space-related international relations from Panteion University (2002). He led the National Centre for Space Applications (1991-2006) under HAF's Intelligence Directorate. Apart from his operational work, he proposed inter alia the 1995 Space Policy, the participation to Helios II and MUSIS Earth Observation programmes, and the establishment of the Space Office (2006) for the Ministry of Defence.

During two Hellenic Presidencies, he proposed the WEU's Space Policy (1998) and EU's ESDP and Space (2002-03), both adopted by their respective Councils. He represented Greece at the EU Satellite Centre (1995-2006) and served in UN, NATO, WEU and EU space committees. Prof. Kolovos authored 4 books, 5 monographs, 9 book chapters, and numerous articles on space.



Space - Based ISR: A Modern Imperative in Defence

Colonel HAF (ret.) Konstantinos Pilaftsis

Citation: *Konstantinos Pilaftsis, Colonel HAF (ret.). (2025). Space-Based ISR: A Modern Imperative in Defence. Air Force Review, 134.*
https://doi.org/10.5281/zenodo.15163553

Abstract

Space-based Intelligence Surveillance & Reconnaissance (ISR) plays a crucial role in modern military operations, providing unique capabilities that enhance situational awareness across strategic, operational, and tactical levels. This paper explores the significance of space ISR, emphasizing its operational value and technological advancements. By leveraging the distinct properties of the space domain, ISR systems enable comprehensive monitoring and intelligence gathering, which are essential for effective decision-making in complex environments. The integration of advanced technologies and the collaboration between government and commercial entities further enhance the effectiveness and efficiency of space ISR. As military operations increasingly rely on information dominance, the role of space ISR becomes indispensable in addressing contemporary security challenges and ensuring national defense.

Keywords

Space ISR, situational awareness, remote sensing, OODA loop, geospatial intelligence, information dominance

Introduction

Space ISR stands here for the military function of Intelligence Surveillance & Reconnaissance (ISR), as performed through space-based systems. Such space systems offer, multi-potent, remote sensing platforms that operate from near Earth orbits to empower the distinct capacity of space ISR.

The space domain has introduced unique operational qualities into ISR that support critically the strategic, operational and, lately also, the tactical level of military activities, both in peacetime and warfare.

By now, space has been acknowledged as a domain of military operations, next to the ones of land; sea; air; and cyber. Foremost, space is a physical domain that presents particular properties and challenges but also enables a breadth and depth of defence applications that constitute today indispensable military capabilities. As encapsulated in the words of a former defence minister of France “if space was the new frontier of the 1960s, there is no doubt that today it is a new front on the battlefield.»[1] . If this stands, armed forces should not have any high expectations of winning the next war if they are not capable to be present and active on this front.

In this context, Space ISR deserves the special attention of the defence community and will be presented here by understanding its staging domain; core function; emphasizing its operational value; and by examining the current advancements in technology & applications to acknowledge its competitive edge in today's military affairs.

Space-based Intelligence Surveillance & Reconnaissance

Although the purpose, objectives and functions of space-based ISR remain mostly the same, with its conventional application -as historically proven- in the land; maritime; and air domains, there are also unique advantages and specific limitations while operating from space. The space ISR framework inherits the native properties that come with the particular physics of the near-earth orbital environment; is bound by the maturity level of space technologies; serves the same military objectives on the ground; but is also subject to functional performance characteristics that prescribe its effectiveness at the strategic, operational and tactical level.[2]

Above all, space offers the highest ground possible for attaining a good observation point. A primeval operational expediency in any conflict, still holding its military value in the era of network-centric, full-digital, all domain warfare. Space ISR allows military actors to see farther, better and more. It reinforces a nation's defence posture through enhanced situational awareness. This leads to increased deterrence since, friends and opponents alike, understand that there are technical means of verification in place which can see beyond the perceived horizon and detect activities, no matter how deep they are in the strategic hinterland.[3] Capacity in space ISR directly correlates with the level of understanding of the geopolitical landscape and ultimately promotes national security and upholds the prosperity of a country.

ISR is a key enabler for freedom of action and autonomous decision-making while space is a new operational domain for military activities. Together they form an effective framework for comprehensive defence & security at national and collective level.

With space being inherently of global reach; penetrative manner; and of dual-use; space-based ISR is covering drastically the strategic level and recently closing up on lending support to the tactical level. Space ISR comprises a stand-off operational capability, still largely out of harm's way regarding its assets and operators. Space offers ISR the basis for a capability of truly global coverage, without geopolitical restrictions and geographical or regulatory constrains that other domains impose.

In parallel, systems' heritage, battle-proven applications and technological advancements have established today an all-weather and any-light operational capability. Altogether, resilient; cost-effective; scalable; permanently fielded; and always watchful from the best -unobstructed- vantage point one can get;

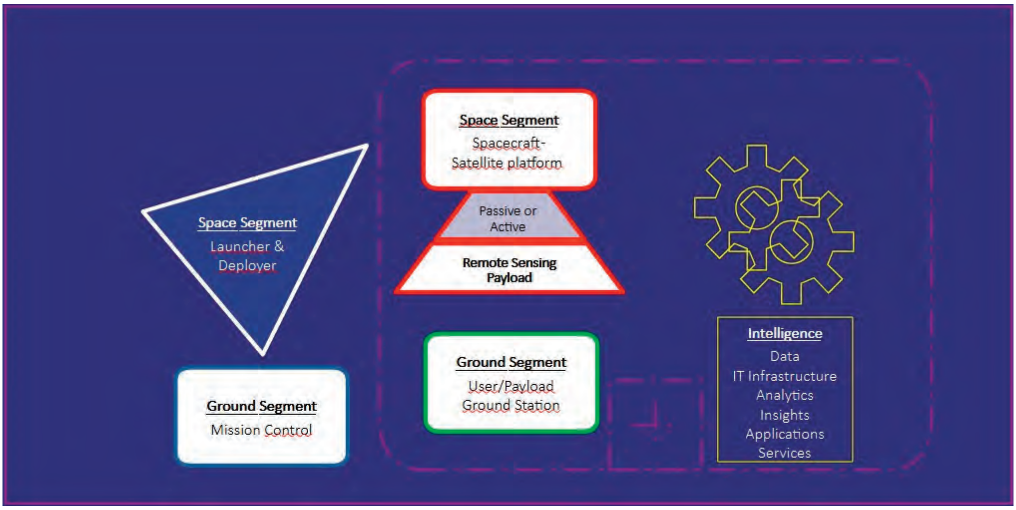


Figure 1: Anatomy of Space ISR: space mission building blocks

Space is not fundamentally changing the tradecraft but it has been proven instrumental in enabling consistent and persistent -global wide- ISR, both in reach and effect.

The scope of ISR

The purpose of ISR is to improve situational awareness.[4] A systematic and coordinated effort to obtain and maintain a current and credible perception of what is the situation at hand. This involves recording, registration, correlation, re-presentation and sense-making of a particular situation.

Conventionally and primarily, ISR is exercised to reveal and apprehend features and activities of military interest that are manifested within the land and maritime domains. This covers the prevailing environmental conditions; presence or absence of anthropogenic objects; actors involved; respective timelines; and monitoring of the evolution of activities;

ISR tries to piece together the most complete picture possible. An iterative, incremental, feedback loop process, entailing multi-view, multi-spectra, multi-time sampling and elaborated knowledge-building all along.

Towards the ultimate goal of delivering gleaned intelligence to planners; decision-makers; & actors; alike. Served through continuous feeds of validated information, on areas of interest and over activities of adversaries. Aimed to understand the dynamics of a particular situation, the interplay of forces in the field, their assumed intentions, and wielded to evaluate the potential and options of all involved actors.

Practically seeking all the answers to the major questions of what is happening when & where; Who does what; and, by deduction and inference, the how and why of actors and effects;

These are the broad objectives of ISR and they lead a perpetual race to detect, identify and track, anything that comes under the scope.

This need for continuous updates and appraisal of our environment and the activities therein has been captured in the concept of the Observe-Orient-Decide-Act (OODA) loop. A widely acknowledged and diversely applicable decision-making and dynamic adaption framework. Conceptualized by a fighter pilot, for all fighters & kinds of fights, it pivots around the survival skill of swiftly adapting and decisively prevailing in contested environments and over highly dynamic situations. The ability to go through the OODA process consistently and keep up with the tempo of operations, effectively determines victory over defeat.[5] Essentially, the OODA loop describes the way we actually fight, especially after the first bullet flies.[6]

With direct analogy, ISR forms the first half of the Observe-Orient-Decide-Act (OODA) loop by providing dedicated reconnaissance & persistent surveillance (Observation segment) and producing reliable intelligence (Orient segment). Most importantly ISR drives the vector of the whole OODA loop forward, on the basis of factual information and through feedback, which support critically both decision-making and required actions.

In the OODA framework the emphasis is placed on the first two steps of observation and orientation. Respectively, reconnaissance and surveillance have a vigilant role to detect and make out the disposition and dynamics of adversaries. Closing in, from the strategic to the tactical level of operations, the OODA loop gets accelerated as sensor-to-shooter timelines are compressed. While seeking to identify and exploit the opponent's half-beat, speed and timing become complementary and relate with the tempo and fluidity of activities.[7]

Likewise, ISR looks out for the openings that might be exploited as vulnerabilities through the choice of when, where and with what to disrupt the adversary's planning and actions. Ultimately, ISR empowers us to act, with speed, at the right moment, to the exact location and for the maximum effect.

The function of ISR

ISR encompasses a set of coordinated and integrated processes that are organized into relevant Concepts Of Operations (CONOPS), according to the level of command and the assets employed. Although ISR applications differentiate across these levels -and depending on the role and capacity of land, maritime, air and space platforms-still, the operational logic is universal and the functionality quite the same.

Expert personnel; dedicated assets;

advanced technologies; distributed infrastructure; and orchestrating concepts; all organized into competent ISR frameworks that reliably support military missions.[8]

In this context, the function of ISR:

- Allows to observe a situation systematically (e.g. revisit time of satellites in Low Earth Orbit)
- Deploys, regularly, remote sensing and data acquisition assets to gather raw information (e.g. Optical and SAR satellite imagery)
- Brings back a first-look (e.g. spot/detect a previously unknown object of interest).
- Provides continuous orientation by monitoring the situation at hand (e.g. capture of enemy Order-of-Battle)
- Employs persistent surveillance to reveal patterns and timelines of activity (e.g. over the threshold spikes or absence of activity)
- Keeps up with developments (e.g. Battle-Damage Assessment)
  Produces credible intelligence to sup port operational command and control (e.g. threat assessment analysis)
- Introduces added value in operations by progressing from raw data to factual information, and from there to actionable intelligence
- Applies analytical processes including Processing; Resolving; Correlating; Fusing; Extrapolating; Modeling; Projecting; Assessing; to make sense
- Installs confidence through informed decisions and by taking knowledgeable action
- Contributes to an assertive defence & security posture
- Reduces the Sensor-to-Shooter timeline

Anatomy of Space ISR

At system level, space ISR is based on the operation of dedicated space missions and the exploitation of their image & data output. Space missions are the protagonists here, since they field ISR satellites as orbital platforms for operational use. Like aircraft in the Air Force, ships in the Navy and battle tanks in the Army, satellites in Space Force departments attract all the glory and are the stars of the show. Although space ISR cannot be constructed without the integrating elements of communications networks; payload data ground stations (PDGS); information technology infrastructure; and expert knowledge systems; satellite missions are the pivotal technical means, around which the operational capability is established.

The building blocks of a typical space ISR mission (Figure 1) follow the conventional dichotomy of the space and ground segment sides. The space segment provides the satellite bus, as a platform for fielding the remote sensing payload(s) and includes the launch and communications elements to enable its operations. The corresponding ground segment installs typically the mission control center, with the necessary communications ground network, and -especially for ISR missions- a dedicated PDGS for producing the Analysis Ready Data (ARD) from the satellite raw data acquisitions.

Using a different approach, more along a narrative that observes the cadence of operations, space ISR starts with the last letter of the acronym. Reconnaissance is responsible for providing the space assets as operational capabilities, organic within the military command structure. The U.S. National Reconnaissance Office (NRO) , is the norm setting example of this organizational approach, mandated since the 1960's to develop & operate space missions and to conduct reconnaissance operations from space.[9]

Under the same approach, Surveillance installs the particular regime that applies the operational imperatives to the ISR framework. The dimensions of this framework, like range, resolution, depth and tempo of Surveillance is prescribed by the very own operations' and missions' realities. The framework connects military users with the operational assets through direct tasking or indirect access to the ISR satellites. Surveillance entails persistent information collection activities that require a proliferated space systems architecture to issue, capable of handling joint tasking orders that execute a carefully detailed observation plan.[10] The full set of systemic image tasking orders, uploaded through mission plan update cycles or ad-hoc events, practically enable operators to task the spacecrafts where to fly and what to record.

In parallel, the function of Intelligence formulates the Requests for Information (RFI), on a need-to-know basis of its actors and according to the objectives of the military and security operations. Intelligence is reactive but also proactive. It responds to users' emerging needs with dynamic tasking of the satellites. It also anticipates informational needs beforehand and plans routine imaging campaigns to keep the space assets effectively busy. On the other hand, Intelligence receives the reconnaissance combined output, fuses this with collateral information and disseminates the final surveillance results through intelligence products & services. By expertly registering & processing, analysing & deducting, and managing data & information, Intelligence is able to generate and disseminate actionable intelligence that seamlessly support almost all military operations & applications.

Technology drivers

Space ISR is by name and condition a technologically challenging affair. It re-sides in the harsh environment of space; it needs to cater for the operational complexity of military doctrines & missions; and it is required to persistently capture the actual situation and its ensuing evolution, no matter how obscured or hard to reach is the object of interest and despite the change dynamics or divergence from initial assessments & plans.

First of all technology enables ISR to be performed from space. By making possible and available the necessary space and ground systems that can constitute the operational capability in the first place. The anatomy of a space ISR mission has revealed the prerequisite building blocks that correspond directly with high-tech space systems.

In this context, space ISR is enabled by technologies for space systems (i.e. launchers; satellite platforms; power; communications; avionics; propulsion; etc) and for remote sensing payloads (i.e. electro-optical cameras; IR, Hyperspectral, Thermal instruments; SAR imagers; laser & microwave spectroscopy; etc). On the other side, space ISR is made meaningful by systems on the ground that employ Information and Communication Technologies (ICT) (i.e. infrastructure & equipment; data and imagery processing & exploitation; geospatial knowledge information management; visualization; modeling & simulation; security mechanisms; etc) to bring down to Earth the output of the space systems and transform it into strategic value and operational application.[11]

Once enabled from space and organized on the ground, advanced technology can further push the range, depth, performances and effect of space ISR through innovation and deeptech industrial applications.

Contemporary technological trends shape the form and function of space ISR beyond its conventional applications and capacities. In general, the most influential of such technological developments are deemed to be the ones that are now driving advanced materials; extreme miniaturization; AI integration; responsive space concepts; autonomous platforms; optical communications; and quantum applications.

More particular to the ISR operations technologies that lead to low SWaP-C systems (i.e. reduced in Size, Weight and Power & Cost); ubiquitous computing, where all becomes digital and everything is connected with each other; edge-computing and on-board processing (e.g. compression, redaction, fast/first-look reporting); software defined functions (e.g. payload mode switching, processing configuration choice, etc); and Artificial Intelligence for payload operations (e.g. image plan yield optimization), automation (e.g. tip-and-cue tasking) and analytics generation (e.g. unsupervised image data feature extraction);

In this setting and for the near future, technology altogether pushes ISR satellites to fly in constellations & multi-orbits; cover more ground & more often; converge & correlate with differently revealing spectral signatures and signals; respond with agility & operational purpose; and sort out data & filter information at the edge; In parallel and by the same agents, geospatial intelligence work is undergoing a fast paced transformation trough technological innovation and paradigm shifts in data & cognitive sciences; big data repositories & cloud computing frameworks; machine learning & AI algorithms on the analysis side; content management & knowledge information platforms; and visualization, modelling & simulation environments.[12]

The competitive edge

The competitive edge of space ISR lies within its primary mission objective, the persistent gathering of data & information and the gleaning of comprehensive intelligence & insights.

Warfare follows the technological, political, economic and societal conditions of its era. While considering that humanity is already in the age of information technology, warfare would need to be effective also in the same setting. The historical shift of the center of gravity in warfare represents this close association. This center of gravity has progressed, along human civilization's transitional steps, from manpower to firepower, onto manoeuvrer and by today, definitely into information.[13]

Information is also central in the military discourse about space and ISR, already codified in operational directives and doctrines since the last century.[14], [15] Space ISR is recognized to contribute drastically in information dominance capability development. The ability to collect data anywhere & anytime; increase information sharing; enable comprehensive cross-domain intelligence; accelerate decision-making & operational tempo; ultimately enhances national and collective defence & resilience postures. Because, a picture is always needed to inform political-decision making and enact military operations.

This becomes the fundamental tenet of ISR, as distilled in the principle of "the right picture at the right time and in the right hands".[16] Although captured within this, appearing to be simple, mandate the actual practice of attaining the right intelligence is an intrinsically complex effort, that involves people; organization; & knowledge; and above all requires significant resources, both in space and on the ground. Space ISR can be improved, in terms of capacity, operational value and -most importantly- cost, through a coordinated approach of wielding, in conjunction, government-owned and commercial space-based systems, applications and data.

Especially if considering that the new space era is here and the agile business models it brings along. Leveraging private funds and public investments it can uptake high-risk projects and fast-track systems, products and services to the markets. Employing advanced technologies to generate innovative applications; and fielding, any, Capability with as-a-Service mechanism;

ISR can significantly benefit from new space actors since Earth Observation (i.e. the civilian practice of ISR) is an established market with a lot of traction under the boost of new space. The commercially available EO capacity is already exploited the most by defence & security users in ISR since they can easily access technologically advanced space assets; seamlessly integrate credible services of proven operational added value; and acquire, gap-filling, all-spectra, passive & active remote sensing;

ISR can benefit from industrial capacity combined with user-centric business models. The proposition of everything as-a-Service holds promise in the era of big data and all digital frameworks. This has established sustainable industrial activities that develop, field, and operate the high-end EO & ISR satellite systems of today and provision, with credibility, the future generation of advanced ISR space systems.

The technological, industrial and operational proximity & similarity, between Earth Observation and ISR military satellite assets, allows for out-of-the-box synergies and cross-fertilization at the level of systems and applications. All major space applications (i.e. SatCom; EO; & PNT;) are dual-use by design and function. Earth Observation in particular proves this to be true with its established market verticals that are one-to-one corresponding with major defence & security applications in the field of ISR.

By joining forces with EO, ISR can additionally benefit from market investments, leveraging institutional & private funds; and by Private-Public-Initiatives, for pilot & demonstration missions in space that could make operational potentially disruptive capabilities and innovative services.

Ultimately, space is the overarching domain and therein, ISR is one of the primary operational applications. Regarding the state of regional and worldwide geopolitical security and the technological maturity of space systems and applications, military power is severely constrained without space power attributes integrated effectively within the defence & security apparatus at national and collective level.

Space ISR is needed more than ever into the future, to cater for a recognized and consolidated picture that take into account perplexed & combined threats; dense & wide theaters of operations; and force asymmetries & hybrid warfare; In this setting the value of ISR remains in it core function since, recording something is information, visualizing it is perception and making sense out of it is knowledge. Here, space makes ISR a persistent & global; penetrative & unobstructive; and multi-potent & high-performance; stand-off operational capability for maintaining situational awareness in modern warfare.

References

1 F. Parly, "French defense minister: Shifting from a new frontier to a new front," Defense News. Accessed: Mar. 03, 2025. [Online]. Available: https://www.defensenews.com/outlook/2021/12/06/french-defense-minister-shifting-from-a-new-frontier-to-a-new-front/

2 "Military Implications of Space Technology for Global Security - Total Military Insight." Accessed: Mar. 09, 2025. [Online]. Available: https://totalmilitaryinsight.com/military-implications-of-space-technology/

3 'National Technical Means' Leaves the Lexicon," Federation of American Scientists. Accessed: Mar. 09, 2025. [Online]. Available: https://fas.org/publication/ntm-obe/[4] NATO, "Joint Intelligence, Surveillance and Reconnaissance," NATO. Accessed: Mar. 08, 2025. [Online]. Available: https://www.nato.int/cps/uk/natohq/topics_111830.htm

5 D. Youvan, *Navigating the OODA Loop: Multidisciplinary Perspectives and Strategies*. 2024. doi: 10.13140/RG.2.2.22185.57448.

6 "Helmuth von Moltke," Oxford Reference. Accessed: Mar. 03, 2025. [Online]. Available: https://www.oxfordreference.com/display/10.1093/acref/9780191826719.001.0001/q-oro-ed4-00007547

7 "The OODA Loop and the Half-Beat," The Strategy Bridge. Accessed: Mar. 03, 2025. [Online]. Available: https://thestrategybridge.org/the-bridge/2020/3/17/the-ooda-loop-and-the-half-beat

8 R. A. McDonald, "Looking Closer and Looking Broader: Gambit and Hexagon — The Peak of Film-Return Space Reconnaissance After Corona".

9 "National Reconnaissance Office," *Wikipedia*. Feb. 28, 2025. Accessed: Mar. 09, 2025. [Online]. Available: https://en.wikipedia.org/w/index.php?title=National_Reconnaissance_Office&oldid=1278159433

10 B. Meidt, "A New Era in National Security: The NRO's Proliferated Satellite Constellation," Sycamore

Institute. Accessed: Mar. 09, 2025. [Online]. Available: https://www.sycamoreinstitute.org/post/a-new-era-in-national-security-the-nro-s-proliferated-satellite-constellation

11 "The Evolution of Space-Based ISR," Air & Space Forces Magazine. Accessed: Mar. 10, 2025. [Online]. Available:https://www.airandspaceforces.com/article/the-evolution-of-space-based-isr/

12 J. Bayley, "Transforming ISR capabilities through AI, Machine Learning and Big Data," Defence IQ. Accessed: Mar. 10, 2025. [Online]. Available: https://www.defenceiq.com/defence-technology/news/transforming-isr-capabilities-through-ai-machine-learning-and-big-data

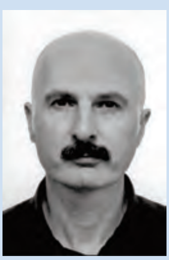
13 "The Evolution of War: The Fourth Generation." Accessed: Mar. 10, 2025. [Online]. Available: https://d-n-i.net/FCS_Folder/hammes.htm

14 M. R. A. Ramey, "Armed Conflict on the Final Frontier: The Law of War," *AIR FORCE LAW Rev.*, vol. 48, p. 142, 2000.

15 Secretary Of The Air Force Washington Dc, "Information Operations Air Force Doctrine Document 2-5:," Defense Technical Information Center, Fort Belvoir, VA, Jan. 2002. doi: 10.21236/ADA404833

16 M. Operational Working Group (OWG), "MUSIS Operational Requirements Document (ORD)." MUSIS TAMG, 2009.

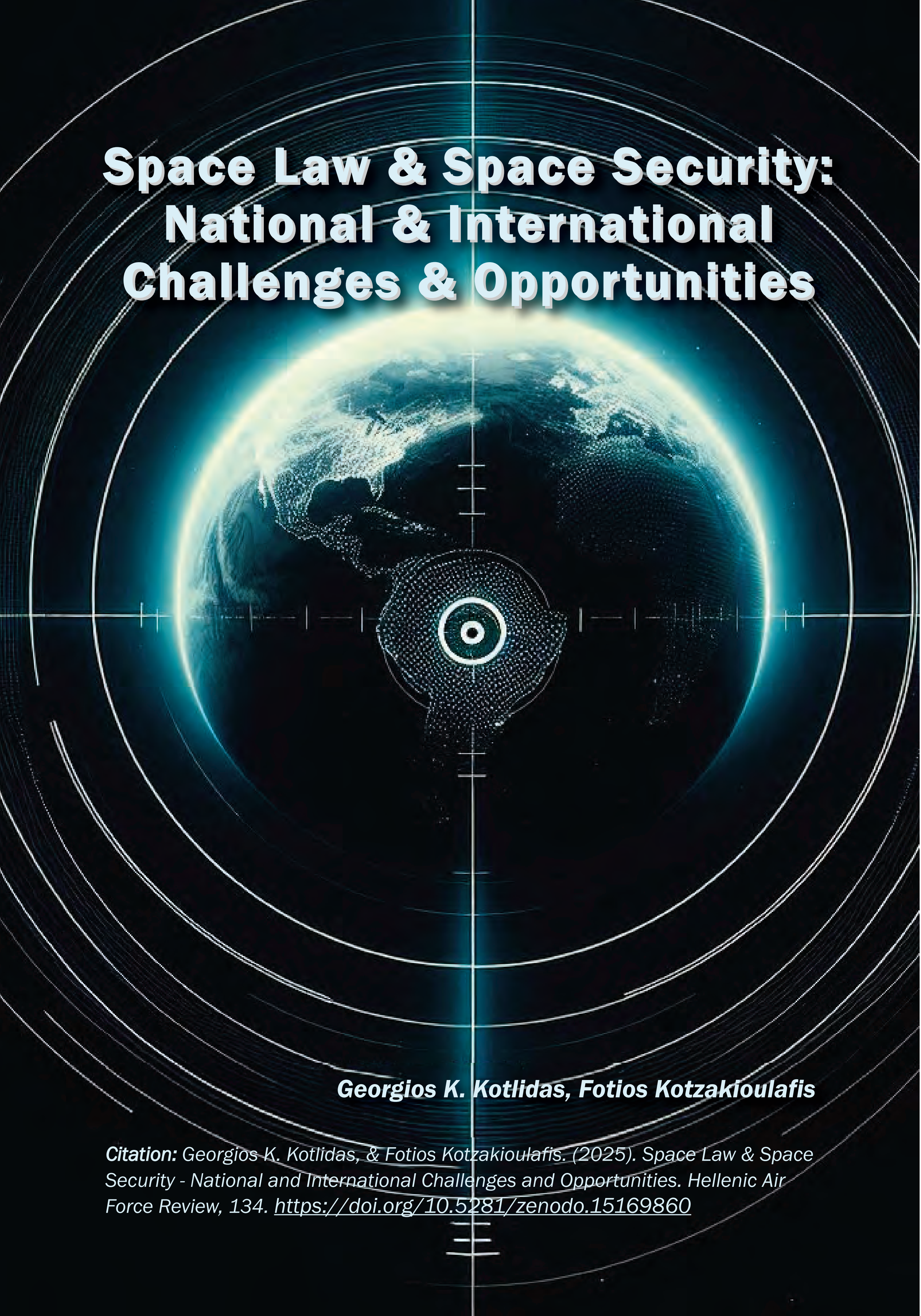
Short Biography



Konstantinos Pilaftsis, a former Hellenic Air Force Colonel with 25 years of progressive military experience in Intelligence, Surveillance, and Reconnaissance (ISR) operations, transitioned to a civilian career in the space domain in 2012. Holding an MA in Diplomatic Studies from Westminster University and an MSc in Geoinformatics from the National Technical University of Athens, his expertise spans from analogue to digital geospatial systems, orbital remote sensing, and defense and security space programs.

He held senior military roles, including Head of Geospatial Intelligence Analysis for the Hellenic Armed Forces, served as an EU Satellite Centre Expert, and completed UN field missions in Iraq and Sudan.

As a former advisor to the Hellenic Government on Space Policy and the first CEO of the Hellenic Space Agency, he significantly contributed to national space initiatives. Currently, he is the Business Development Manager for Defense & Security at Planetek Hellas, leading the OptiSat cubesat mission, and lectures on space, geospatial intelligence, and ISR operations.



Space Law & Space Security: National & International Challenges & Opportunities

Georgios K. Kotlidas, Fotios Kotzakioulafis

Citation: *Georgios K. Kotlidas, & Fotios Kotzakioulafis. (2025). Space Law & Space Security - National and International Challenges and Opportunities. Hellenic Air Force Review, 134.* https://doi.org/10.5281/zenodo.15169860

Abstract

With every aspect of space-related technology in a climactic development phase, and with all the more actors being either interested to or already engaged in space exploration and the exploitation of capabilities the Space provides in various sectors of human activity, it is high time that robust and up-to-date legal and policy frameworks be developed, in a national and international level. The continuous rise of opportunities that space exploration provides is driving humanity in new space race, this time with governmental and non-governmental actors, and technologies hitherto unfathomable. This situation is certain to provoke security risks in various levels, and especially those linked with nations' defense and security. This essay will attempt to encapsulate the basis of existing regulation regarding the Space domain, and furthermore approach security and military-centered issues with a combined legal and policy approach. Finally, a short and specific focus will be given to the Greek and European general policies that constellate with these issues, in an attempt to highlight risks and possibilities for a stable space policy in the near future.

Keywords

space law; space security; space militarization; outer space treaty; space debris; anti-satellite weapons; esa; Greek space policy; liability; space objects; unoosa

Introduction

Space law is a complex system that governs activities in outer space. It consists of various components such as international treaties, conventions, United Nations General Assembly (UNGA) resolutions, as well as rules and regulations of international organizations (Lyall & Larsen, 2020). For Greece, as member of the European Union, and a partner of the European Space Agency, a lot of opportunities and challenges arise as per the Space exploration and utilization in general, and its Security related aspects in particular.

This article will explore the fundamental legal framework of Space Law on an international level, examining significant documents such as the Outer Space Treaty of 1967 [UN, 1967]. Additionally, the article will investigate the militarization of outer space by analyzing the intersection between space law and the evolving military activities occurring there [Giannopapa et al., 2015].

The legal framework of space law consists of five international treaties and five sets of principles that govern outer space [UN, 2002]. The UNGA resolutions and the UN Committee on the Peaceful Uses of Outer Space (COP-

UOS) documents serve as subsidiary means for interpreting and applying these treaties and principles [Cheng, 1997]. In addition, customary international law also plays a crucial role in shaping space law.

Treaties of the United Nations

The Outer Space Treaty of 1967

The Outer Space Treaty (OST) of 1967 is a pivotal legal instrument that established the foundation of the framework for space exploration. It stipulates that outer space, including the Moon and other celestial bodies, shall be used exclusively for peaceful purposes. However, the term «peaceful purposes» has been subject to interpretation, as space technology can serve both civilian and military functions. The treaty explicitly prohibits the placement of nuclear weapons or other weapons of mass destruction in orbit, on celestial bodies, or stationing them in outer space in any other manner. Notably, while the OST bans weapons of mass destruction, it does not entirely prohibit the weaponization of space, leaving room for the deployment of conventional weapons. Additionally, the treaty forbids any claims of sovereignty over the Moon and other celestial bodies, mandates that states are responsible for national space activities whether conducted by governmental or non-governmental entities, and holds states liable for damages caused by their space objects. All parties agree to conduct outer space activities in accordance with international law [UNOOSA].

The sum of these two provisions allows for certain specific conclusions relating to Security matters in Space. Firstly, there is practical and legal room for states to move military-scale security policies they already implement into the Space dimension, therefore broadening the spectrum of National Defense and National Security. Secondly, following the first conclusion, states can viably develop their military and security capabilities in Space, with dual and singular-use technologies. Furthermore, the liability (or *responsibility*) provisions described above mean that all of these capabilities require strict and robust safety frameworks, in both practical and legal levels. Hence, it can be said that Space Security will determine National Security capabilities in a structural level, in the very near future.

The Rescue Agreement

The *Agreement on the Rescue of Astronauts, the Return of Astronauts, and the Return of Objects Launched into Outer Space*, commonly known as *the Rescue Agreement*, was adopted in 1968. This treaty obligates signatories to take all possible measures to assist astronauts in distress and ensure their safe return to the launching state. It also covers the recovery and return of space objects that land outside the territory of the launching state. In the context of militarization, if astronauts (or any other military-grade personnel) were to engage in hostilities during wartime, they would lose the protections afforded by the Rescue Agreement and be considered prisoners of war under international humanitarian law [Space Foundation].

The Registration Convention

The *Convention on Registration of Objects Launched into Outer Space*, known as the *Registration Convention*, entered into force in 1976. This treaty builds upon Article VIII of the OST and establishes a mechanism for identifying space objects. It requires states to furnish information to the United Nations about the orbit of each space object, including its general function, thereby enhancing transparency and accountability in space activities [UConn].

The Moon Agreement

The *Agreement Governing the Activities of States on the Moon and Other Celestial Bodies*, or *the Moon Agreement*, was adopted in 1979. This treaty stipulates that the Moon and other celestial bodies must be used exclusively for peaceful purposes, and their environments should not be disrupted. It also requires that any stations established on these bodies must be reported to the United Nations. However, the Moon Agreement has limited legal effect due to the small number of signatory states, as major space-faring nations have not ratified it [UNOOSA].

The Liability Convention

The *Convention on International Liability for Damage Caused by Space Objects*, or *the Liability Convention* entered into force in September 1972, and is based on Article VII of the OST. As described in the UNOOSA official webpage, "the Liability Convention provides that a launching State shall be absolutely liable to pay compensation for damage caused by its space objects on the surface of the Earth or to aircraft, and liable for damage due to its faults in space" [UNOOSA]. The treaty directly allocates full liability for damages caused by any kind of space object – whether belonging to a governmental or non-governmental entity – that happens on the ground of the Earth or in the air (within the atmosphere), while on the other hand it maintains a *proof-of-fault* liability regime for damages that happen in space. The treaty is meant to provide a legal tool for any liability claim through a state-to-state mechanism, and also making a *Claims Commission* available as a forum if direct diplomatic options fail. It is also important to stress that developments in the AI realm manifest new challenges on the existing liability regime, as the *strict-liability* and/or *fault-based liability* regimes are themselves redefined by the technological leaps of AI, with impeding implications in Space as well.

Conventional International Law

Customary international law plays a pivotal role in shaping the legal framework governing outer space activities. The development of jus cogens norms, or peremptory principles recognized as fundamental to the international community, is inherently challenging in the context of outer space [Oralova, 2015]. Such principles often emerge from consistent state practices and the jurisprudence of international courts, reflecting global public interest and moral imperatives.

The foundation of current outer space law is anchored in global public interest, as articulated in Article I of the Outer Space Treaty (OST). This article emphasizes that Outer Space shall be free for exploration and use by all states, reinforcing principles such as the non-appropriation of Outer Space, sovereign equality, freedom of use, and the prohibition of nuclear weapons and weapons of mass destruction in outer space [UNOOSA]. These principles are often regarded as having customary international law status due to their widespread acceptance and consistent application.

A core tenet of customary international law in space is the utilization of outer space for peaceful purposes. This principle underscores the importance of non-aggression and the demilitarization of outer space, advocating for cooperative and harmonious use for the collective benefit of all nations. It actively discourages hostile or military endeavors beyond Earth's atmosphere [Oralova, 2015]. Recognized jus cogens principles in outer space law encompass the exploration and use of outer space for the benefit of all peoples, freedom of exploration and use, and the prohibition of national appropriation.

A Synopsis of Space Military Operations

As space technology advances and more nations acquire capabilities in space, the potential for tension and conflict, particularly in military applications, increases. Historically, space has been utilized for military purposes, with early space-age militaries employing space technologies for intelligence, surveillance, and reconnaissance. Today, space has evolved into a distinct strategic domain, rendering military assets vulnerable to various forms of targeting. This evolving landscape has led some to argue that conflict in space is inevitable, prompting nations to seek protection for their space assets and posing threats to those of their adversaries. This intensified competition risks escalating tensions and conflicts in space, underscoring the urgent need for updated legal regulations to address emerging challenges and actors.

Despite significant advancements in space technology, the regulatory framework governing space activities has not kept pace. Since the adoption of the Moon Agreement in 1979, there has been a noticeable absence of specific treaties addressing the military aspects of space endeavors or regulating potential inter-country tensions in the event of a conflict. Consequently, while outer space lacks national sovereignty and falls beyond national jurisdiction, it should not be perceived as a lawless frontier. The Outer Space Treaty (OST) of 1967 remains a cornerstone of space law; however, its applicability to contemporary military, civilian, and commercial space activities is constrained, given its origins during the Cold War era with a focus on state-centric space endeavors. Article IV of the OST prohibits the placement of nuclear weapons or any other kinds of weapons of mass destruction in orbit, on celestial bodies, or stationing them in outer space in any other manner [UNOOSA]. It also mandates that the Moon and other celestial bodies shall be used exclusively for peaceful purposes, forbidding the establishment of military bases, installations, fortifications, the testing of any type of weapons, and the conduct of military maneuvers on celestial bodies.

Recent developments further highlight the evolving nature of military operations in space. For instance, the U.S. Space Force has observed China conducting satellite maneuvers that mimic aerial combat, resembling dogfighting tactics in space. These activities involve synchronized movements of multiple objects in geostationary orbit, indicating offensive drills and challenging existing international norms [Turner, 2025]. Such actions underscore the pressing need for an updated and comprehensive legal framework to effectively address the militarization of space and ensure its peaceful use for the benefit of all humankind.

Space Security & Military issues

The militarization of space has raised significant concerns regarding the absence of clear laws and regulations governing military activities in outer space. This ambiguity has led to inconsistent and overlapping policies, creating operational and legal challenges due to the intertwining of military and civilian interests. As space technology advances and national security considerations intensify, the issues of space weaponization and the potential for armed conflict in outer space have become increasingly pressing [Joyce, 2024]. It is crucial to distinguish between *space militarization* — the use of space resources to support and enhance military capabilities — and *space weaponization*, which involves the development and deployment of weapons intended to target objects in outer space.

The lack of clear definitions for specific terms and scenarios in space law poses significant challenges. While principles governing the use of force and the laws of armed conflict (LOAC) apply to space activities, their application to military acts in space is not always clear due to the distinct nature of the space environment. For example, assessing proportionality in the vastness of space and addressing potential collateral damage, such as debris impacting other satellites, present unique difficulties [Berrang, 2023].

Establishing a comprehensive and well-defined legal framework for space law is crucial to resolving conflicts and preventing the use of force in outer space. This framework should adhere to international law, extending the reach of established legal principles into outer space. Integrating the modern laws of armed conflict with space law can promote the peaceful and responsible use of outer space while mitigating the risks associated with potential conflicts in this increasingly contested domain [Rozpedowski, 2024].

Meanwhile, research into the legal issues surrounding armed conflicts in outer space is crucial due to the profound potential impact such conflicts could have on the rule of law. The use of ground-based or space-based weapons in outer space is considered a «use of force» under international law. The United Nations (UN) Charter, established before the space age, serves as a fundamental component of the global legal framework and is applicable to all realms of international law, including space law. Various international instruments have been adapted over time to accommodate evolving contexts and technological advancements, justifying the incorporation of the UN Charter into matters concerning outer space [UNIDIR, 2024].

The Outer Space Treaty (OST) of 1967, a cornerstone of space law, does not explicitly regulate the application of the right to self-defense in outer space. However, Article 51 of the UN Charter recognizes the inherent right of individual or collective self-defense if an armed attack occurs against a member state. This right is not confined to terrestrial domains and extends to outer space, allowing states to defend their space assets. The exercise of self-defense in outer space must comply with the principles of necessity and proportionality, ensuring that any defensive measures are appropriate and not excessive in response to the threat posed. The lack of explicit prohibitions in both general international law and space law regarding self-defense in outer space implies that spacefaring nations retain this right. Denying the right to self-defense in outer space could place these nations at a disadvantage in safeguarding national security and pursuing their interests in the space domain. Therefore, it is widely accepted that international legal norms do not prohibit asserting the right to self-defense in outer space [UNOOSA].

Given all of the above, severe contemporary challenges involving military issues can be traced in three sectors where cutting-edge technology is about to meet possible space militarization: a) regulation and use of anti-satellite (ASAT) weapons, b) space debris issues, and c) autonomous (AI-powered) space objects:

- The ASAT weapons are weapons or weapon systems specifically designed to target and destroy satellites, with the use of kinetic energy, high-intensity lasers and/or nuclear technology, and can be launched from ground, sea, air and space. While the OST may prohibit the use of nuclear and mass-destruction weapons in-orbit, conventional ASAT weapons cannot be put directly under its strict restriction. Even the *peaceful purposes* relative provisions cannot override the UN Charter's Article 51 provision on a nation's right to self-defense, hence rendering any discussion about conventional ASAT weapons one based on the result of any possible use, and not on precaution (e.g. prohibition of development). The PRC's 2007 ASAT weapons testing, for example, proved that existing regulation is far from capable of actively regulating the sector, and also created a chain of issues linked directly with environmental sustainability and – the below mentioned – *space debris* [Schellekens, 2008] It is also important to stress that any action against the earth-based components of ASAT weapon systems cannot be directly linked with Space Law provisions, and it is more likely to befall within the scope of the UN Charter's self-defense provisions.
- Space Debris issues are also becoming an increasingly important domain of legal and practical discourse, related to the rapid multiplication of human-made objects set in orbit in the recent decades, as well as the possibility of accidents or active conflict happening in space, that would create large amounts of uncontrollable debris. The OST in general seems rather outdated to face such challenges. On the other hand, Article IX of the OST specifically, may provide its "due regard" obligation[2] and the "no harm" principle[3] in combination, as a tool to allocate account-

ability appropriately in states, and entities functioning under these states' authority. However, it should be noted that the current framework is in definite need of remodeling, in order to respond to these contemporary challenges [Radi, 2023].

- The rapid development of Artificial Intelligence (AI) in every sector of the world's economies is also evident in the Space sector. AI-powered space objects operate independently, enhancing capabilities in any kind of task, including military applications. Hence, the whole legal framework concerned with the Space domain applies – or better, needs to apply – in autonomous space objects, and specifically military and security-focused assets. Furthermore, AI-powered space objects have a direct legal linkage with liability issues that have yet to be determined internationally, such as determination of the "fault" in AI systems or "gross negligence", and so produce troubles in applying strict legal rules.

These three contemporary legal and policy issues are indicative of the gaps that the age and simplicity of the already existing Space Law frameworks, and further stress out the need for new and innovative approaches.

An example of forming innovative legal structures

In the realm of space exploration, significant strides are being made to establish regulations governing military operations in outer space. A pivotal development in this area is the *Woomera Manual on the International Law of Military Space Operations*. Although it does not represent a strict and robust legal framework and its applicability is restricted to those willing to apply it, this comprehensive guide articulates legal principles applicable to military activities in space, addressing critical issues such as the definition of outer space and the criteria for peaceful purposes [Beard & Stephens, 2024]. Its primary aim is to provide clear and comprehensive guidance for decision-makers involved in space activities, promoting peace and security in outer space.

The Woomera Manual is structured to mirror national military manuals, enhancing its utility as a reference for military operators and decision-makers. However, its role has sparked ongoing debates regarding its impact on space warfare. Some scholars and practitioners question whether the manual serves to constrain or inadvertently legitimize warfare in space. These discussions are crucial, as they influence how the manual is perceived and applied within the broader context of international law and military strategy. In summary, the Woomera Manual represents a significant effort to codify existing international law as it pertains to military operations in space. While it provides valuable clarity and guidance, its influence on the conduct of space warfare continues to be a subject of active discussion and analysis.

Challenges and Opportunities entangled with Space Security for Greece (and the EU)

Greece

Given all of the above, as well as recent developments in technology, a multiplicity of challenges and opportunities arise for all actors aiming to participate in this new age of Space Exploration. Greece, both for itself as a state and as a member-state of the European Union, may prove to be increasingly involved with space activities.

Such activities will put National Defense and Security at the forefront of Greek interest, as is also suggested by the relevant proposition made by the Hellenic Space Center to the competent governmental authorities in 2021, which, though, was just a first attempt in a policy proposal that has yet to develop into a robust National Space Policy framework. In this first proposition, the Center referred to the sector of national defense and civil protection, and their boosting, as the prime pillar of a newfound Greek National Space Policy and Strategic Action Plan. It is, as such, proposed – among other actions – that the Greek administration should have a cohesive management plan for all Greek space activity (private and public), so as to safeguard national interests and achieve a sustainable and secure environment for the nation's involvement in the sector. Furthermore, developing and enhancing European Space Agency (ESA) involvement is also deemed essential.

Greece has recently moved on to a more aspiring approach on space activity, with its involvement with the *National SmallSat Program* (backed by the ESA, PlanetScope and the Greece 2.0 Recovery and Resilience Fund), with strong applications in sectors such as natural disaster prevention, e.g. with the acquirement of several Earth observation microsatellites by 2026, and management and (possibly) military-wise situational awareness in the Balkan Peninsula and Eastern Mediterranean [*National SmallSat Program*, 2023]. Also, another recent and more strategic Greek initiative led to Greece becoming a main hub of the GOVSATCOM and IRIS programs, which – among others – aim to establishing secure satellite telecommunication for all of Europe, and also partner with NATO [HUFFPOST, 2025]. Such initiatives indicate that Greece is centered on a developing and upscaling role in its space policy, keeping national security and defense pillars at the forefront. It is visible, however, that all these undertakings are at a rather nascent level, and any activity related especially with the more military issues stressed within this essay is, as of yet, only in theory level.

In any cases, Greece has to take in serious regard that any and all of these initiatives require both a strong commitment and integration with the relevant European frameworks and agencies, and serious financial resources. Especially in the financial field, the strong integration with European projects and organizations involved with space exploration and security may amplify the country's capabilities, by securing co-funding from European resources, rather than the limited national ones. Of course, in any occasion, it is essential that there exists care for balancing integration with the European industry with developing the national economy and relevant market. Else arises a strong risk of short-term policy limitation and sectorial stagnation, that Greece cannot afford if it chooses – as one can say it should – to actually invest in this domain that can play a pivotal and multifaceted role in national security and defense.

European Union

As per the EU as a whole, although it has, as of yet, maintained a more economy-orientated approach for its general space activity development, all of the above, including Greek initiatives, may prove increasingly important for Europe as a whole in the coming years. Systems such as *Galileo* and *EGNOS* may become vital for European security, and this fact is directly linked with Greek interests as well.

The two basic pillars of EU space activity are the *European Space Agency (ESA)* and the *European Union Agency for the Space Program (EUSPA)*.

- The ESA is an European intergovernmental organization established in 1975, and comprised of 23 member-states (incl. Norway and Switzerland), focusing on space research and technological development, and burdened with designing and developing space infrastructure, operational and technical expertise. It aims to promote European strategic autonomy in all aspects of space exploration and providing a safe and secure space infrastructure and technology for European partners [ESA, 2025].
- The EUSPA is an agency of the EU, established in 2021, and tasked with operational management of the EU's space program. Its activity is regulated by the 2021/696 Regulation of the EU, and it involves the operation of programs such as *Galileo,* GOVSATCOM and EGNOS, with a specified oversight. It is important to refer to the Fi-

nancial Framework Partnership Agreement (between ESA, EUSPA and the European Commission) of 2021, specifically allocates responsibilities and authorities between the three related bodies, and creates the necessary framework for their financial and operational functionality [EUSPA, 2025].

The EU, in the contemporary fluid geostrategic environment, is definite to be required to enhance its military and security capabilities in Space. In such regard, its large resources may help for a quick – and necessary – leap in infrastructure and technology development. Along with that, EU member-states' strong engagement in all relevant international organizational may prove a vital tool in shaping the frameworks with due regard to European interests, especially in fields such as autonomous space objects and space debris. In more strictly security matters, a conjunction with the rest of the NATO partners, particularly the USA, is also essential to achieving sustainable and viable solutions that safeguard both its people's interests and liberties, and at the same time guaranteeing their protection from military nature threats.

In general, it can be concluded that dual-use technologies, with their research and development, will probably play an increasingly important role in shaping Greece's and the EU's space policies. All competent authorities should therefore make sure to develop a thorough understanding of all the abovementioned frameworks and challenges, and also pioneer in multiplying national and European engagement in all relevant discussions and activities internationally. No serious future security planning and undertaking can be carried out without guaranteeing a robust Space Security approach.

Conclusion

In conclusion, for a robust modern policy framework, coupled with its legal twin, to exist functionally, either for a country such as Greece or for any kind of national, private and international entity, and with a special focus on sustainable security, it is essential to re-evaluate international law concerning space activities, focusing on the right to self-defense in space. The outdated United Nations space treaties are inhibiting progress in the face of a rapidly expanding internationalized space economy. Urgent action is needed to create clear rules protecting national security, and security-related interests, while encouraging international collaboration. As we navigate the complexities of space law, it is crucial to collaborate and form policies that ensure the safety and success of future space activities. The international society must work together to create a framework that balances the interests of spacefaring states, while fostering the responsible use of outer space for the benefit of all, with Greece and the EU having to understand the importance and the required rapidity that all this work requires, and also making sure to secure a leading and active role in such.

References

- Beard, J. & Stephens, D. (2024). The Woomera Manual on the International Law of Military Space Operations. Oxford University Press.

- Berrang, S. (2023). How would IHL apply to hostilities in outer space?. International Committee of the Red Cross.

- Cheng, B. (1997). Studies in international space law. Clarendon Press.

- ESA – The European Space Agency (2025). Found at: https://www.esa.int/ESA_Multimedia/Videos/2019/11/This_is_ESA .

- EUSPA – About EUSPA (2025). Found at: https://www.euspa.europa.eu/about/about-euspa .

- Giannopapa, C., Moura, D., Robinson, J., Hays, P., & Schrogl K. (2015). Handbook of Space Security. Springer.

- Greek *National SmallSat Program* (2025). Hellenic Republic – Ministry of Digital Governance.

- HUFFPOST, Mavraganis, K. (2025). GOVSATCOM: What is the European program stationed (and) in Greece. Found at: https://www.huffingtonpost.gr/entry/govsatcom-ti-einai-to-eeropaiko-proyramma-poe-tha-edreeei-kai-sten-ellada_gr_67892ef5e4b0d7aa500678c9 .

- Joyce, J. (2024). The militarization of space: navigating the legal void. Taylor Wessing.

- Lyall, F., & Larsen, P. B. (2020). Space law: A treatise. University of Adelaide.

- Oralova, Y. (2015). Jus Cogens Norms in International Space Law. Mediterranean Journal of Social Sciences.

- Radi, Y. (2023). Clearing up the Space Junk: On the Flaws and Potential of International Space Law to Tackle the Space Debris Problem. ESIL Reflections, found at:

https://esil-sedi.eu/wp-content/uploads/2023/03/Yannick-Radi.pdf .

- Rozpedowski, J. (2024). Beyond Borders: Applying Modern Conflict Laws as Framework for Outer Space Governance. Geopolitical Monitor.

- Schellenkens, J. (2008). The Legality of Antisatellite ASAT Weapons. University of Malta.

- Space Foundation Editorial Team. (n.d.). International Space Law. Space Foundation. Thomas J. Meskill Law Library. (n.d.). Outer Space Law. UConn.

- Turner, M. (2025). China practising 'dogfights in space' with satellites and top secret objects, US chief warns. The Sun.

- United Nations (UN). (1967). Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies (Outer Space Treaty). United Nations Office for Outer Space Affairs.

- United Nations (UN). (2002). United Nations treaties and principles on outer space. United Nations Office for Outer Space Affairs.

- United Nations Institute for Disarmament Research. (2024). Outer Space and the Use of Force.

- United Nations Office for Outer Space Affairs. (n.d.). Agreement Governing the Activities of States on the Moon and Other Celestial Bodies.

- United Nations Office for Outer Space Affairs. (n.d.). Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Objects Launched into Outer Space.

- United Nations Office for Outer Space Affairs. (n.d.). Space Law Treaties and Principles.

- United Nations Office for Outer Space Affairs. (n.d.). Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies.

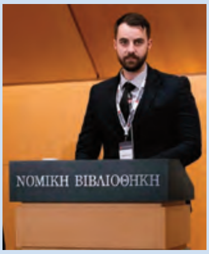
* - Georgios K. Kotlidas, Attorney-at-Law – Board Member at “Rythmisis” Greek National Institute for AI Law – SGAC Space & AI Law Jr. Researcher LL.M International Public Law, MA Syst. Philosophy, MA (cand.) Strategic Studies,

- Fotios Kotzakioulafis, Marketing Manager at “The Exploration Company” - SGAC Space & AI Law Researcher, MSc Human Resources Management, LL.B in University of Sunderland, BA International Business Management

1 All state parties are mandated to take into account the interests of other states with *due regard* while they conduct their space activities.

2 All state parties carry the obligation to conduct exploration of outer space so as to avoid its harmful contamination and, where necessary, to adopt appropriate measures.

Short Biography



Georgios K. Kotlidas is an Attorney-at-Law focused on the fields of Business Law and the Law of Artificial Intelligence.
He holds a LL.M on International & European Law (Aristotle University of Thessaloniki), with his thesis on the Law of the Sea, and also holds a MA on Systematic Philosophy (Aristotle University of Thessaloniki), while finishing another MA in Strategic Studies (University of Macedonia).

He has served for 2 years as Legal Advisor to the Regional Vice-Governor of Grevena, Western Macedonia, Greece (2022-2023) and is a member of the Board of Rythmisis – Greek National Institute for AI Law, where he also leads a Research Group for AI applications in National Defense and Cybersecurity. He is also a researcher of the Space Generation Advisory Council, participating in the Research Group for AI & Space Law.

He has participated in a multitude of academic programs related with AI Law and applications, Space Law, the Law of Armed Conflict, Business Law and European Law, while he has also participated in many MUN simulation programs focused on international politics, Defense and Security issues.

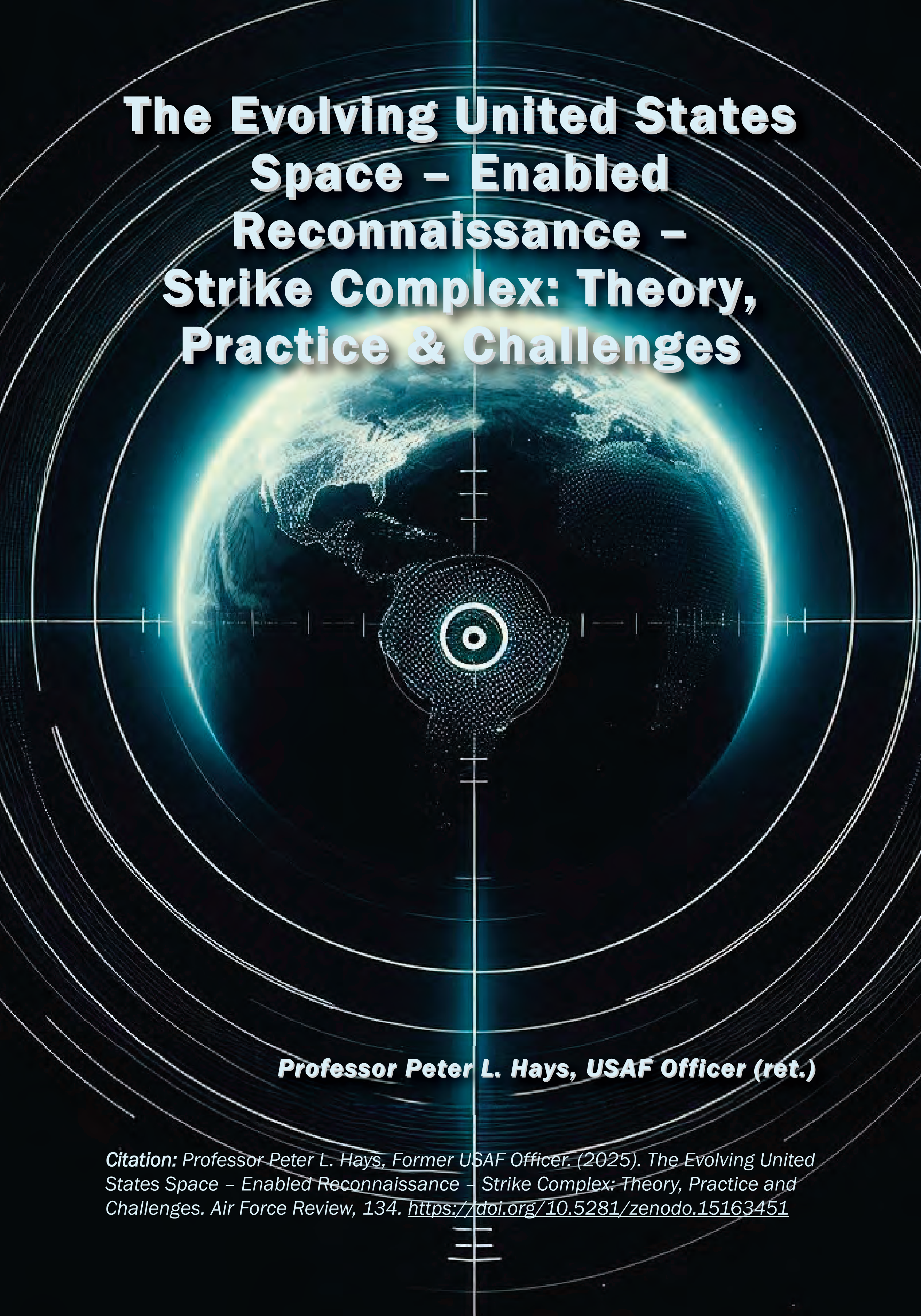
He speaks English, German, Russian, Spanish and learning Chinese.

Short Biography

With a diverse portfolio of communication, research, and business development roles spanning several European countries, Fotios Kotzakioulafis has had the opportunity to collaborate with renowned international organizations such as The Exploration Company, NATO, and the European Commission.

In the space sector, he has actively contributed to organizations, including the Austrian Space Forum's legal team, the International Institute of Space Law, and the Association for International Legal Research on Space Sustainability. His involvement extends to research initiatives, such as the Space Generation Advisory Council's Near Earth-Objects, Space Law & Policy, and Space Safety & Sustainability Project Groups.

Academically, he holds a BA in International Business Management and a M.Sc. in Human Resources Management, while currently pursuing a Law degree. His multidisciplinary educational foundation provides for a blend of business acumen, legal expertise, and strategic insight. By integrating his experience across business, law, and space policy, he attempts to drive impactful contributions within any forward-thinking organization.



The Evolving United States Space – Enabled Reconnaissance – Strike Complex: Theory, Practice & Challenges

Professor Peter L. Hays, USAF Officer (ret.)

Citation: *Professor Peter L. Hays, Former USAF Officer. (2025). The Evolving United States Space – Enabled Reconnaissance – Strike Complex: Theory, Practice and Challenges. Air Force Review, 134.* https://doi.org/10.5281/zenodo.15163451

Abstract

This article explains ways in which robust space capabilities have become an indispensable foundation for success in employing modern airpower. It considers how military space capabilities fit into conceptual models for modern warfare and uses these models to review evolution of the global reconnaissance-strike complex that first emerged in 1991 during Operation Desert Storm. It discusses specific ways space capabilities support each step in the find, fix, track, target, engage, and assess "kill chain" and outlines the many space systems the United States has deployed to modernize and improve these capabilities. The article concludes by addressing critical current space security challenges including growth in orbital debris, increasing worldwide deployment of counterspace capabilities, increasing efficacy of commercial space systems and the role of the billionaire "space barons" that control these systems, the threat of a nuclear detonation in low-Earth orbit, and the prospects and implications of the United States developing and deploying proliferated space-based interceptors capable of boost-phase intercepts as called for in president Trump's Iron Dome for America Executive Order.

Keywords

Anti-satellite (ASAT), John Boyd, Brilliant Pebbles (BPs), Reconnaissance-Strike Complex (RSC), Find-Fix- Track-Target-Engage-Assess (F2T2EA) Kill Chain, David Lupton, Nitze Criteria, Resilience, John Warden, Low-Earth Orbit (LEO), Geostationary Earth Orbit (GEO), Barry Watts.

Conceptual Models

Many analysts today believe warfare's character is changing significantly, moving away from traditional focus on annihilation or attrition of fielded forces toward seeking to induce strategic paralysis among enemy decision makers – approaches variously described as hybrid, new generation, or simply new ways of war. These discussions also include debates about whether we are currently amid a revolution in military affairs (RMA) that renders existing means of warfare subordinate or obsolete. Whether we are currently witnessing a true RMA or simply a significant transformation, space capabilities clearly make some of the most important contributions to enabling more effective and efficient use of airpower.

In the mid-1970s the Soviet General Staff began to postulate that advances in precision munitions, wide-area sensors, and computerized command and control would fundamentally change warfare and potentially make conventional weapons as effective as nuclear weapons. Marshall Nikoli Ogarkov, Chief of the General Staff from 1977-84, championed these concepts and encouraged work to combine these capabilities, labeling the concept a "reconnaissance-strike complex" (RSC).[1] Many analysts believe the decisive airpower victory of coalition forces in Operation Desert Storm (ODS) heralded the emergence of a nascent but operational RSC. ODS airpower operations included stealth, long-range precision strikes, parallel attack of many targets simultaneously, denial of enemy commanders' ability to communicate with fielded forces, and direct attack of enemy decision makers rather than fielded forces. The comprehensive military space capabilities the United States had deployed during the Cold War enabled the emergence of this RSC. U.S. Air Force Chief of Staff General Merrill McPeak labeled the conflict the "first space war" to emphasize the highly significant and comprehensive contributions of space capabilities to the coalition's victory.[2]

Recent American airpower theorists and their heirs have built on the decisive victory in ODS to refine conceptual models for effective and efficient use of modern airpower. John Boyd originally developed his energy-maneuvering and observe-orient-decide-act (OODA) concepts from visual dogfighting, but scores of subsequent analysts have applied OODA analysis to everything from business to politics; in the military context, space capabilities can provide critical observation and orientation knowledge to apply the OODA model worldwide. John Warden conceived of the enemy as a system consisting of five concentric rings focused on leadership and moving outwards toward organic essentials, infrastructure, population, and fielded forces. Warden postulated that airpower could conduct parallel attacks against all five rings simultaneously, could disrupt connections between the rings, and contradicted many traditional military theories by making fielded forces the least important target set.[3] Space capabilities again play a critical role under this concept as they are essential for identifying specific targets within each ring and enabling assessment of the effectiveness of airstrikes.

Another important conceptual model for thinking about ways space capabilities can support national security was developed by Air Force Lieutenant Colonel David E. Lupton in his 1988 book, *On Space Warfare*.[4] Lupton argued there were four schools of thought regarding broad, national-level strategies the United States could pursue in using space to improve its security: sanctuary, survivability, control, and high ground. The first two, sanctuary and survivability, emphasized the ways space capabilities could enhance strategic stability and improve the effectiveness of terrestrial forces. The sanctuary school argued that the primary value of space systems was in providing strategic stability through capabilities including nuclear command and control, missile warning, and national technical means of verification (NTM) for arms control. Adherents to this school argued that capabilities to attack satellites should not be developed because this would undermine strategic stability. The survivability school acknowledged that space capabilities were improving not just strategic stability but also significantly enhancing the effectiveness of tactical military operations. It emphasized that space systems are inherently less survivable than terrestrial forces and should be made more resilient against attacks so they could continue providing some diminished level of support to military operations even during and after attacks. Lupton's other two schools had greater emphasis on space forces and the space domain. His control school called for space to be thought of like other domains where the primary military objective is to gain control over operations in this area. Militaries seek to preserve their freedom of action and deny freedom of action to enemies; in a domain as vast as space it is unlikely that control can be maintained for large areas over extended periods of time. Lupton's final school, high ground, argued that space holds the potential to be the decisive theater of combat operations. Reasoning by historical analogy, the high ground school portends that just as holding the high ground is often the decisive factor in land combat or as airpower often prevails over land and sea forces, in the future, space forces will dominate terrestrial warfare. Lupton argued that the control school should be the basis for U.S. space strategy. Figure 1 summarizes, expands, and updates Lupton's schools by listing the primary value of military space forces, outlining deployment strategies for space systems, showing primary combat missions of space forces, and suggesting appropriate organizational structures for operations and advocacy.[5]

Evolution of the RSC

In practice, the U.S. RSC has evolved in many ways and improved significantly since its inception. Figure 2 traces satellite communication throughput to deployed brigades, lists primary air-delivered munitions (PGMs), and provides the number and percentages of PGMs used in various military operations to describe progress in the U.S. RSC during the last 35 years.[6] Figure 2 captures some of the clearest and most tangible contributions of space capabilities to the RSC, but their overall contributions

	Primary Value and Functions of Military Space Forces	Space System Characteristics and Employment Strategies	Conflict Missions of Space Forces	Appropriate Military Organization for Operations and Advocacy
Sanctuary	• Enhance Strategic Stability • Facilitate Arms Control	• Limited Numbers • Fragile Systems • Vulnerable Orbits • Optimized for NTM Verification	• Limited	• National Reconnaissance Office (NRO)

Survivability	Above Functions Plus:
	• Force Enhancement
		• Terrestrial Backups
		• Commercial and International Augmentation
		• Autonomous Control
		• Attack Warning Sensors
		• Less Vulnerable Orbits
		• Hardening
		• Redundancy
		• Crosslinks
		• Maneuver
		• Space Mission Assurance
		  • Defensive Operations
		  • Resilience
		    • Disaggregation
		    • Protection
		    • Distribution
		    • Proliferation
		    • Diversification
		    • Deception
		  • Reconstitution
		• On-Orbit Spares
		• 5Ds:
		  • Deception
		  • Disruption
		  • Denial
		  • Degradation
		  • Destruction
		• Bodyguards and Convoys
			• Force Enhancement
			• Degrade Gracefully
				• Major Command or Combatant Command

Control	Above Functions Plus: • Control Space • Significant Force Enhancement		• Control Space • Significant Force Enhancement • Surveillance, Offensive and Defensive Counterspace	• Combatant Command, Space Corps, or Space Force
High Ground	Above Functions Plus: • Decisive Impact on Terrestrial Conflict • Ballistic Missile Defense (BMD)		Above Functions Plus: • Decisive Space-to-Space and Space-to-Earth Force Application • BMD	• Space Corps or Space Force

Figure 1: Attributes of Military Space Doctrines

are more subtle and comprehensive. Most significantly, space capabilities have enabled the United States to move from being able to employ just a small percentage of PGMs to having the ability to use PGMs for every time-critical target worldwide.

During ODS, command and command and control of air operations was enabled by a comprehensive air tasking order (ATO). The ATO attempted to coordinate several thousand daily sorties launched by coalition partners to enhance unity of effort against the highest

Figure 2: Evolution of a Space Enabled Reconnaissance - Strike Complex – The New American Way of War

Military Operation, Duration, and Megabits Per Second (Mbps) Data Delivered from Satellites to Deployed Brigade-Sized Units	Primary Types of Unguided and Precision - Guided Munitions (PGM) Used	Numbers and Percentages of Unguided and PGMs Used
Desert Storm, 1991: Kuwaiti Theater of Operations, 17 Days, 1 Mbps	Unguided Munitions: Multiple Types PGM: Tomahawk (Terrain Contour Matching); Paveway II (Laser), Maverick (Electro-Optical (EO) and Infrared (IR))	Unguided: 245,000 (92%) PGM: 20,450 (8%)
Allied Force, 1999: Serbia, 78 Days, 24.5 Mbps	Unguided Munitions: Multiple Types PGM: Paveway II (Laser), Joint Direct Attack Munition (JDAM) (Global Positioning System (GPS))	Unguided: 16,000 (68%) PGM: 7,700 (32%)
Enduring Freedom, 2001-02: Afghanistan, 90 Days, 68.2 Mbps	Unguided Munitions: Wind-Corrected Munitions PGM: Multiple Types (Laser, EO/IR, GPS)	Unguided: 9,000 (41%) PGM: 13,000 (59%)
Iraqi Freedom, 2003: 29 Days, 51.1 Mbps	Unguided Munitions: Wind-Corrected Munitions PGM: Multiple Types (Laser, EO/IR, GPS)	Unguided: 9,251 (32%) PGM: 19,948 (68%)
Inherent Resolve (Counter ISIS and Worldwide Counterterrorism), 2014-19, No Conventional Brigades Deployed	Unguided Munitions: None Reported PGM: Hellfire, Small Diameter Bomb, and Multiple Other Types including Remotely Piloted Vehicle (RPV) Delivered (Laser, EO/IR, GPS, Radar)	Unguided: None Reported PGM: Totals Not Reported (100%)

priority target sets and to deconflict air traffic along ingress, egress, and aerial refueling tracks. Production of the ATO required an inflexible 72-hour cycle. The ATO was often several hundred pages long and contained such large files that it could not be electronically transmitted to all coalition airfields throughout the theater of operations. These drawbacks sometimes resulted in not attacking new targets or restriking targets already destroyed because the ATO was not flexible enough to include newly detected targets or account for recent battle damage assessments (BDA). Continuous improvements in space and other capabilities supporting the RSC have enabled far greater flexibility for air operations under the concept of dynamic retasking. Instead of operating under an inflexible 72-hour cycle, newer command and control approaches allow sorties to takeoff without assigned targets, proceed to a "kill box," and attack targets that may have just emerged or those deemed to be the highest priority once the aircraft arrives on station. PGM evolution reflects another specific example of improvements in the RSC. The standard PGM for the past 25 years, the joint direct attack munition (JDAM), normally had a 2000-pound warhead; JDAMs are being replaced with small diameter bombs, which normally carry only a 250-pound warhead, yet can often be employed more effectively and cause less collateral damage than JDAMs.

Space Support of the Kill Chain

Improvements in the RSC are driven primarily by space capabilities that provide critical contributions to joint all-domain command and control, enable time-sensitive targeting, and help compress every link in the terrestrial find, fix, track, target, engage, assess (F2T2EA) kill chain cycle. Finding enemy forces has been a difficult task for militaries throughout history; aircraft revolutionized reconnaissance within a theater of operations and intelligence, surveillance, and reconnaissance (ISR) collection from satellites has revolutionized it globally. Change detection enabled by sun-synchronous low-Earth orbit (LEO) imagery satellites often provides some of the most important contributions to ISR and enhances understanding of adversary capabilities as they develop over time. Today, pervasive global imagery provided by National Reconnaissance Office (NRO), Department of Defense (DoD), and commercial satellites means that no significant military activities can remain hidden, and if they can be detected, they can be engaged. Nonetheless, it can be challenging to provide ISR that is precise and timely enough to effectively support the most difficult and fleeting strike opportunities.

Fixing involves identifying potential

targets from the finding step and geolocating them. In the past, this was sometimes a difficult and time-consuming process; today the Global Positioning System (GPS) enables near-instantaneous geolocation anywhere in the world and makes a critical contribution to the kill chain. Tracking requires maintaining sensor custody of targets as they move. Persistent space imagery can make important contributions in maintaining custody of targets, but it can also be a challenge to fuse together data from various distributed space and non-space sensor networks. Comprehensive datasets of geospatial intelligence collected over decades from space and non-space sources such as digital terrain elevation data can contribute to target tracking in important ways by indicating likely travel routes for military systems and identifying terrain obstacles and areas where they cannot operate.

Targeting is a complex link in the cycle that is enabled by several space capabilities. Most importantly, military satellite communications, and perhaps commercial satellite communications, are usually needed to connect the entire kill chain together and allow commanders to control the operation. Commanders determine target priorities and sequencing, decide what capabilities will be used for engagement, and direct the forces that employ these capabilities. Depending on the time available and sensitivities regarding certain targets, commanders may use decision making tools that provide extremely detailed modeling of weapons effects based on the desired mean point of impact, predicted damage to target, and potential collateral damage.

Engagement is the use of fires against the target, another link in the kill chain cycle in which space capabilities provide essential contributions. The GPS system is again critical in this part of the kill chain, as most munitions use this capability to guide their employment for at least some portion of the engagement. Assessment, the final link in the kill chain is also dependent on space capabilities; this link is sometimes known as BDA. Many of the same capabilities used initially to find targets are used to assess whether the engagement achieved the desired effects. As engagements become increasingly precise and perhaps employ non-kinetic means, it can be difficult to assess whether subtle desired effects were achieved.

U.S. Space Systems Contributing to the RSC

Figure 3 provides current details about the primary space systems supporting the RSC and the orbits used by these systems.[7] The figure focuses on dedicated military systems, but it is important to emphasize that many space systems today are dual use, meaning they can support both miliary and civil or commercial applications. Data streams from space systems can support hundreds of thousands or even millions of users simultaneously and are embedded in thousands of important applications worldwide. The GPS is one of the best examples of this dual-use characteristic. GPS was designed for military use, but after the most precise data was made available without any user fees in 2000, it has become a critical infrastructure technology supporting modern digital life in applications worldwide including global telecommunications and financial transactions; today military GPS use is just a small fraction of all use. There is a dashed line in the bottom part of each column in Figure 3: The systems above the dashed line are currently operational, planned systems that are not yet operational are below the dashed line in white, those in yellow were programs of record that were subsequently cancelled. Some of the data in Figure 3 is not specific because many of the space systems the United States operates are classified, this is particularly true for the ISR mission area systems that are operated primarily by the NRO.

Figure 3: Force Enhancement Missions, Primary Orbits, Major Systems

Environmental Monitoring	Satellite Communications (Satcom)	Positioning, Navigation, and Timing (PNT)	Missile Warning/Missile Tracking/Missile Defense (MW/MT/MD)	Intelligence, Surveillance, and Reconnaissance (ISR)
Polar Low-Earth Orbit (LEO)	Geostationary Orbit (GEO) and LEO	Medium Earth Orbit (MEO)	Various	Various
Defense Meteorological Satellite Program (DMSP) --------------------- National Polar-Orbiting Operational Environmental Satellite System (NPOESS), Defense Weather Satellite System (DWSS), Electro-Optical/Infrared (EO/IR) Weather System (EWS), Weather System Follow-on Microwave (WSF-M)	Defense Satellite Communications System (DSCS) II, DSCS III, Ultra-High Frequency Follow-on (UFO), Milstar, Global Broadcast System (GBS), Iridium, commercial systems, Advanced Extremely High Frequency (AEHF), Wideband Global System (WGS), Mobile User Objective System (MUOS), Space Development Agency (SDA) satellites --------------------- Transformational Communications System (TSAT), Enhanced Polar System, Evolved Strategic Satellite (ESS) system	Global Positioning System (GPS) GPS II GPS IIR GPS IIR-M GPS IIF GPS III --------------------- GPS-Light	Defense Support Program (DSP), Nuclear Detonation Detection System (NDS), Space-Based Infrared System (SBIRS), Hypersonic and Ballistic Tracking Space Sensor (HTBSS) --------------------- Precision Tracking Space System (PTSS), SDA satellites, Next Generation Overhead Persistent Infrared (OPIR) Polar (NGP) and Geostationary (NGG), MEO satellites	Geospatial Intelligence (GEOINT) Satellites, Signals Intelligence (SIGINT) Satellites, OPIR systems, Space Based Space Surveillance (SBSS), Geosynchronous Space Situational Awareness Program (GSSAP), commercial systems --------------------- Future Imagery Architecture (FIA), Integrated Overhead SIGINT Architecture (IOSA), Space Radar

21-Sep-24 7

Critical Current Space Security Challenges

As shown in Figure 4, the world is facing exponential growth in the number and total mass of debris objects in Earth orbit.[8] Given this debris growth and the trend lines, space operations have already become somewhat compromised, and they will clearly become more dangerous, particularly for sun synchronous LEO operations. Without remediation efforts, LEO may even become increasingly unusable. Fortunately, there is widespread global recognition of this problem and there are some important orbital debris mitigation efforts underway such as the U.S. Orbital Debris Mitigation Standard Practices (ODMSP) that can help to at least slow the growth of orbital debris. Reversing the current orbital debris trends, however, will require moving past mitigation guidelines such as the ODMSP toward comprehensive remediation efforts. Unfortunately, effective remediation of orbital debris is bedeviled by the host of technical, fiscal, political, and economic externality challenges that define all "tragedy of the commons" problems. Figure 4 also shows that the largest single source of orbital debris has been destructive anti-satellite (ASAT) testing such as the Chinese DN-1 test in 2007 and the Russian Nudol' test in 2021. In this context, an important development is the April 2022 unilateral pledge by the United States that it will no longer conduct destructive direct-ascent ASAT tests. As of this writing, more than 10 other states have made similar unilateral pledges; and in December 2022, 155 states voted for a United Nations General Assembly resolution calling for states not to conduct such tests, while China and Russia voted against the resolution and India abstained (these are the only other states that have conducted destructive ASAT tests). Despite current turmoil in international security dynamics, this transparency- and confidence-building approach may be a pragmatic step toward limiting and eventually banning such tests.

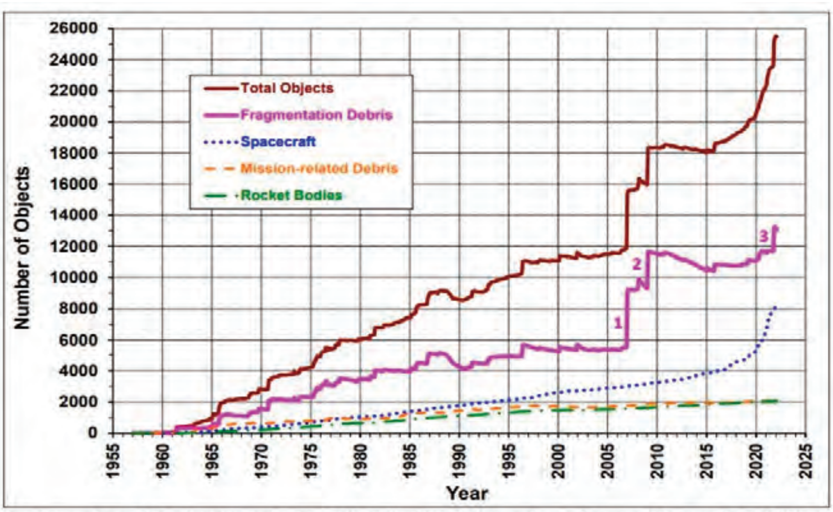


Figure 4: Historical increase of the cataloged objects based on data available on 1 March 2022. The three upward jumps in fragmentation debris correspond to (1) the ASAT test conducted by China in 2007, (2) the accidental collision between Iridium 33 and Cosmos 2251 in 2009, and (3) the ASAT test conducted by the Russian Federation in November 2021. More Cosmos 1408 fragments are expected to the added to the catalog in the coming weeks and months.

A second significant current space security challenge is posed by the rapid growth in counterspace capabilities – an array of increasingly sophisticated and capable means of disrupting or destroying space systems. Some of the worldwide growth in counterspace capabilities comes from the dual-use potential of commercial systems being developed for on-orbit servicing, but this is less worrisome than the wide range of dedicated counterspace capabilities being developed and fielded by China and Russia as shown in Figure 5.[9] Chinese and Russian counterspace capabilities increasingly challenge the ability of U.S. space systems to support terrestrial military operations and provide assured nuclear command, control, and communications (NC3) capabilities.[10] China's new Aerospace Force has developed and is now fielding a range of significant and comprehensive counterspace capabilities that go well beyond anything developed by the superpowers during the Cold War including ASATs with direct ascent capabilities to GEO and satellites with rendezvous-and-proximity and robotic arm capabilities in GEO. Russia has long developed doctrine and capabilities to target U.S. satellites, including critical NC3 systems. Thus far, the United States, China, and Russia have appeared unwilling or perhaps unable to contain the rapid growth in counterspace capabilities and the dangerous and destabilizing conditions created by these developments.

3 – CHINA

	R&D	TESTING	OPERATIONAL	USE IN CONFLICT
LEO Direct Ascent	▲	▲	▲	●
MEO/GEO Direct Ascent	■	■	–	●
LEO Co-Orbital	■	?	–	●
MEO/GEO Co-Orbital	■	–	–	●
Directed Energy	▲	■	–	●
Electronic Warfare	▲	▲	▲	■
Space Situational Awareness	▲	▲	▲	?

LEGEND: NONE ● SOME ■ SIGNIFICANT ▲ UNCERTAIN ? NO DATA –

2 – RUSSIA

	R&D	TESTING	OPERATIONAL	USE IN CONFLICT
LEO Direct Ascent	▲	▲	?	●
MEO/GEO Direct Ascent	■	–	–	●
LEO Co-Orbital	▲	▲	?	●
MEO/GEO Co-Orbital	■	–	–	●
Directed Energy	▲	■	?	●
Electronic Warfare	▲	▲	▲	▲
Space Situational Awareness	▲	▲	▲	▲

LEGEND: NONE ● SOME ■ SIGNIFICANT ▲ UNCERTAIN ? NO DATA –

A third space security issue is the increasing efficacy of commercial space systems and the role of the billionaire "space barons" that control these systems.[11] As illustrated by the stunning initial successes of the Ukrainians in defending their country following the Russian invasion three years ago, the value of commercial space systems in supporting a wide range of military operations has grown exponentially.[12] These commercial capabilities provide critical information about ground truth in Ukraine, supply communications connectivity that helps coordinate many Ukrainian military operations, and demonstrate that states do not necessarily need to own and operate space systems to use them effectively. The SpaceX StarLink system controlled by Elon Musk is arguably the single most important space capability supporting Ukraine. In the initial stages of the conflict, Musk donated thousands of StarLink receivers to Ukraine, enabled free connection with his communications network that consists of thousands of LEO satellites, and only later charged the U.S. government for these services.[13] Musk's initial strong support for Ukraine and current seeming reversal raises important questions about the role of private citizens in determining important aspects of American foreign policy.

In a most disturbing scenario, the efficacy of commercial LEO satellites in supporting Ukraine could lead the Russians (or the Chinese in a Taiwan invasion, for instance) to assess that the greatest military effectiveness from the limited use of nuclear weapons would be to detonate just one in LEO. Unfortunately, this disastrous possibility has moved beyond the hypothetical because Russia appears to be on the verge of violating its Outer Space Treaty (OST) obligations by orbiting a nuclear weapon. Article IV of the OST is one of the most specific parts of the treaty and indicates signatories are "not to place in orbit around the Earth any objects carrying nuclear weapons or any other kinds of weapons of mass destruction, install such weapons on celestial bodies, or station such weapons in outer space in any other manner."[14] In April 2024, Russia vetoed a resolution supported by 13 members of the United Nations Security Council that called on all member states not to develop nuclear weapons specifically designed to be placed in orbit.[15] As shown by Figures 6 and 7, a high-altitude nuclear detonation (HAND) would raise the peak radiation flux in parts of the Van Allen radiation belts by 3-4 orders of magnitude and cause failure in weeks to months of all LEO satellites without specific hardening against this effect.[16] There would be catastrophic and cascading worldwide consequences of such an attack. Failure of LEO satellites would cause about $500 billion in direct financial damage and the overall economic impact could be losses of over $3 trillion.[17] An orbital nuclear weapon presents extremely daunting detection, deterrence, and response challenges because there are few effective counters. The world community should address this challenge multidimensionally, including by ensuring that LEO satellites supporting critical infrastructure and safety-of-life functions have appropriate backups and hardening to deal with this threat.

A final and undoubtedly most comprehensive and impactful current space security challenge is raised by planning guidance in "The Iron Dome for America" (now called the Golden Dome) Executive Order (EO) issued by president Trump on 27 January 2025 that includes: "Development and deployment of proliferated space-based interceptors capable of boost-phase intercept."[18] By the end of March, DoD is to complete initial planning for development and deployment of the comprehensive layered

Figure 6
LEO Natural Background Radiation Conditions

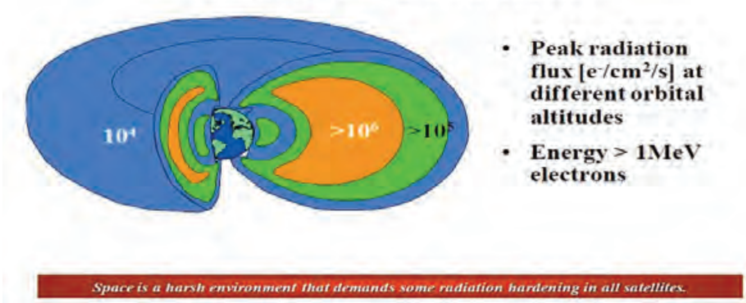
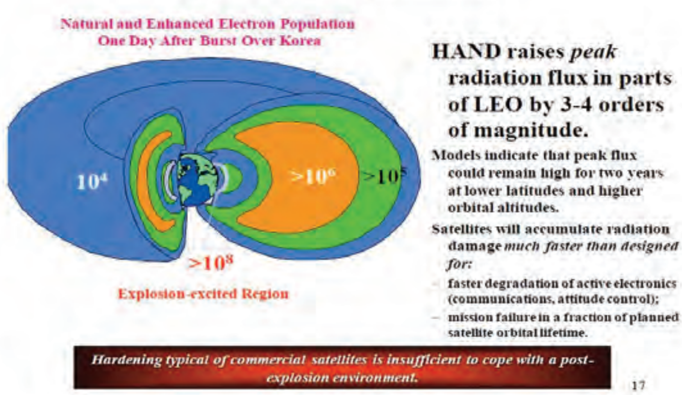


Figure 7
Post-HAND Radiation



defense system to counter hypersonic, cruise, and ballistic missiles that is called for in the EO. Trump's EO signals a radical redirection of United States missile defense efforts and represents a far more comprehensive and ambitious defensive system than ever envisioned under president Reagan's Strategic Defense Initiative (SDI) or "Star Wars" program. With the fall of the Soviet Union and end of the Cold War, the United States has never deployed any space-based ballistic missile defense interceptors, and all SDI materials have not yet been declassified, but it remains highly instructive to review the detailed planning DoD conducted for such systems in the late 1980s and early 1990s that is provided in Aaron Bateman's definitive *Weapons in Space: Technology, Politics, and the Rise and Fall of the Strategic Defense Initiative*.[19]

In 1988, the Joint Chiefs of Staff (JCS) issued effectiveness criteria for the Phase I Strategic Defense System (SDS) that included having capability to destroy half of the Soviet Union's SS-18 intercontinental-range ballistic missiles (ICBMs) attacking in the first wave and to destroy 30 percent of other attacking systems. Intercepts during boost-phase give defenders the greatest leverage because they have the potential to destroy many warheads with a single shot and this helps explain focus on the SS-18, a very large missile capable of carrying many independently targetable reentry vehicles. The intent of the criteria was to "enhance deterrence by ensuring that the structure of a full-scale attack could be disrupted."[20] In June 1990, the Defense Acquisition Board made small, individual LEO interceptors known as Brilliant Pebbles (BPs) the key component of the Phase I SDS. Substituting individual BPs for larger interceptors stored together in LEO "garages" was an important step in reducing the estimated costs for the initial defense system. It also helped make the BP-based system arguably the first defense approach capable of meeting the criteria advocated by Ambassador Paul Nitze: The system should be able to survive attacks against it and still operate effectively and incremental investments in defenses should be more valuable than incremental investments in offensive systems, this second criterion is also known as being cost effective on the margin.[21] The most detailed planning for the Phase I SDS to meet the JCS criteria called for deployment of 4614 BPs costing $1.1-1.4 million each, launch costs of $2-3 billion, and the total cost for the Phase 1 SDS deployment was estimated to be $55 billion.[22] Shortly after these estimates were made, President Bush (41) significantly reoriented the program toward far more limited objectives known as global protection against limited strikes (GPALS). A final aspect deserving of far more study and consideration is addressing all the strategic implications of potentially deploying thousands of interceptors that may have highly significant ASAT capabilities. Detecting, tracking, and targeting a ballistic missile plume is far easier than performing the same functions against a satellite, but it is likely that any large-scale deployment of interceptors will nonetheless have very significant ASAT potential.

References

1 B. Watts, "The Maturing Revolution in Military Affairs." Available: https://csbaonline.org/uploads/documents/2011.06.02-Maturing-Revolution-In-Military-Affairs1.pdf.

2 C. Hall and M. Neufeld, "The U.S. Air Force in Space: 1945 to the 21st Century." Available: https://media.defense.gov/2010/Oct/01/2001329745/-1/-1/0/AFD-101001-060.pdf.

3 D. Fadok, "John Boyd and John Warden: Air Power's Quest for Strategic Paralysis," 1995. Available: https://media.defense.gov/2017/Dec/27/2001861508/-1/-1/0/T_0029_FADOK_BOYD_AND_WARDEN.PDF

4 D. Lupton, "ON SPACE WARFARE A Space Power Doctrine," 1998. Accessed: Mar. 04, 2025. [Online]. Available: https://apps.dtic.mil/sti/tr/pdf/ADA421942.pdf.

5 P. Hays, "United States Military Space: Into the Twenty-First Century." Accessed: Mar. 04, 2025. [Online]. Available: https://apps.dtic.mil/sti/tr/pdf/ADA435077.pdf.

6 T. Mahnken, "Weapons: The Growth & Spread of the Precision-Strike Regime," American Academy of Arts & Sciences, Jul. 2011.

https://www.amacad.org/publication/daedalus/weapons-growth-spread-precision-strike-regime (accessed Mar. 04, 2025).

7 P. Hays, "United States Military Space: Into the Twenty-First Century." Accessed: Mar. 04, 2025. [Online]. Available: https://apps.dtic.mil/sti/tr/pdf/ADA435077.pdf.

8 "NASA Orbital Debris Quarterly News." 2024. Available: https://orbitaldebris.jsc.nasa.gov/quarterly-news/pdfs/ODQNv28i3.pdf.

9 B. Weedon and V. Sampson, "Global Counterspace Capabilities: An Open Source Assessment." Available: https://swfound.org/media/207826/swf_global_counterspace_capabilities_2024.pdf.

10 P. Hays and S. Mineiro, "ISSUE BRIEF: Modernizing Space-Based Nuclear Command, Control, and Communications." Accessed: Mar. 04, 2025. [Online]. Available: https://www.atlanticcouncil.org/wp-content/uploads/2024/07/Hays_-Miniero_-Modernizing-Space-Based-NC3-DRAFTJune25v2-2-1.pdf.

11 C. Davenport, The Space Barons. PublicAffairs, 2018.

12 R. Dickey and M. Gleason, "SPACE AND WAR IN UKRAINE: Beyond the Satellites." Accessed: Apr. 23, 2024. [Online]. Available: https://www.airuniversity.af.edu/Portals/10/AEtherJournal/Journals/Volume-3_Number-1/Dickey_Gleason.pdf.

13 W. Isaacson, *Elon Musk*. Simon & Schuster, 2023.

14 United Nations Office for Outer Space Affairs, "The Outer Space Treaty," UNOOSA, 1967. https://www.unoosa.org/oosa/en/ourwork/spacelaw/treaties/introouterspacetreaty.html.

15 "Remarks Before the Vote on a Russia-Drafted UN Security Council Resolution on Outer Space Security." https://usun.usmission.gov/remarks-before-the-vote-on-a-russia-drafted-un-security-council-resolution-on-outer-space-security/.

16 "High Altitude Nuclear Detonations (HAND) Against Low Earth Orbit Satellites ('HALEOS') DTRA Advanced Systems and Concepts Office," 2001. Accessed: Mar. 04, 2025. [Online]. Available: https://spp.fas.org/military/program/asat/haleos.pdf.

17 P. Hays and S. Mineiro, "ISSUE BRIEF: Modernizing Space-Based Nuclear Command, Control, and Communications." Accessed: Mar. 04, 2025. [Online]. Available: https://www.atlanticcouncil.org/wp-content/uploads/2024/07/Hays_-Miniero_-Modernizing-Space-Based-NC3-DRAFTJune25v2-2-1.pdf.

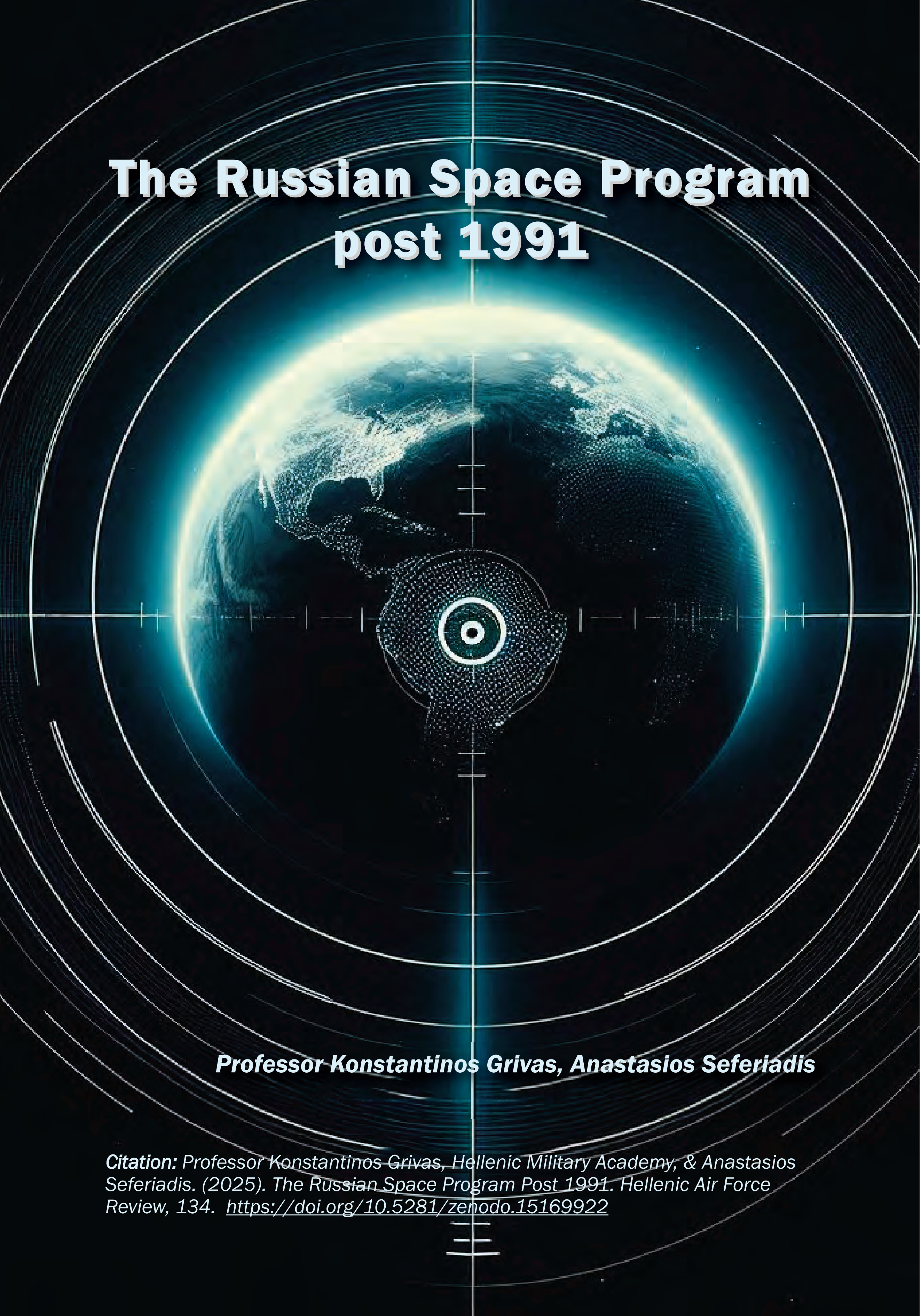
18 "The Iron Dome for America – The White House," The White House, Jan. 28, 2025. https://www.whitehouse.gov/presidential-actions/2025/01/the-iron-dome-for-america/.
19 A. Bateman, *Weapons in Space*. MIT Press, 2024.
20 Bateman.
21 Bateman.
22 Bateman and D. Baucom, "The Rise and Fall of Brilliant Pebbles," vol. 29, no. 2, 2004, Accessed: Mar. 05, 2025. [Online]. Available: http://highfrontier.org/wp-content/uploads/2012/09/The-Rise-and-Fall-of-Brilliant-Pebbles-Baucom.pdf.

Short Biography

Peter L. Hays is a Fellow for the Prague Security Studies Institute, Advisor for the Nonproliferation Policy Education Center, and Senior Associate at the Center for Strategic and International Studies.

He has been an Adjunct Professor at George Washington University for over 20 years and taught for six years at Marine Corps University's School of Advanced Warfighting. Previous service included 20 years as a defense contractor in the Pentagon and Office of the Director of National Intelligence; and 25 years as an Air Force officer where he transported nuclear weapons worldwide as a C-141 pilot, and taught at the USAF Academy, School of Advanced Airpower Studies, and National Defense University. Hays earned a Ph.D. at the Fletcher School and was an Honor Graduate of the USAF Academy.

Major publications include The Handbook of Space Security (2020), Toward a Theory of Spacepower (2011), and Space and Security (2011).



The Russian Space Program post 1991

Professor Konstantinos Grivas, Anastasios Seferiadis

Citation: *Professor Konstantinos Grivas, Hellenic Military Academy, & Anastasios Seferiadis. (2025). The Russian Space Program Post 1991. Hellenic Air Force Review, 134.* [*https://doi.org/10.5281/zenodo.15169922*](https://doi.org/10.5281/zenodo.15169922)

Abstract

Since the collapse of the Soviet Union in 1991, the Russian space program has undergone dramatic transformation amid political, economic, and institutional upheaval. This paper traces its evolution from a Cold War era superpower to a space actor navigating financial instability, international cooperation, and internal reform. It explores the shift from the Soviet legacy structures to the establishment of Roscosmos and the commercialization of the Russian space program through international collaboration, notably with NASA for the construction and operation of the International Space Station (ISS). However, Russia's space ambitions have been curtailed by economic sanctions and geopolitical isolation due to the annexation of Crimea in 2014 and the full-scale invasion of Ukraine in 2022. The war has isolated Russia from Western cooperation, forcing a strategic shift towards the East, while the Russian space program relies solely on domestic resources and technology. Despite facing severe budget constraints, corruption, and technological stagnation, Russia persists in asserting its presence through strategic projects and symbolic missions. This paper argues that the Russian space program, while diminished from its Soviet heights, remains a politically charged instrument of state power, shaped as much by conflict and ideology as by scientific pursuit.

Keywords

Russia, Space, commercialization, crisis, cooperation, war, security, satellites, sanctions.

A challenging start

Following the dissolution of the Soviet Union, Russia took over management of the former Soviet space program. Through a government decree, the Russian Federal Space Agency (RKA), later to be known as Roscosmos, was formed on the 25th of February 1992, with Yuri Koptev, placed in charge.

Under the new structure, the newborn agency oversaw the entire space program, contrary to the Soviet model in which the design bureaus handled their own initiatives, receiving governmental approval later. However, the NPO Energia was still behind the manned space program, providing it with rockets, spacecraft, and personnel. Energia eventually became a privately traded company named "Russian Space Corporation (RSC) Energia" due to the fact that it had to generate its own revenue in order to keep all the projects around Mir alive, despite the major budgetary cuts. Similarly, some other supporting bureaus which provided hardware were also privatized.[1]

The decline of the Russian space program had already begun in the late Soviet era. In 1987, the Soviet space program numbered up to 400,000 employees in the assembly lines in Moscow, in rocket factories in Dnepropetrovsk and Kyubyshev, in scientific institutes all around the country, as well as in production plants and the tracking network. A year later, in 1988, the Secretary General announced in a Party conference the introduction of two policies: glasnost (openness) and perestroika (reform). For the first time in decades, Soviet citizens were provided with the right to speak freely and openly. Although it seemed a beneficial reform for the soviet society, concerning the space program it had the opposite effect. During the 1989 elections, candidates supporting budget cuts to the space program were elected, threatening the stability of the space activities. Indeed, in April 1990, the government proposed cuts to the Soviet space budget around R300m and R220m.

The Soviet space shuttle, Buran, took the highest toll, as it saw its second autonomous flight being pushed back to 1992, although it was obvious that it would later be cancelled. This led to many workers leaving the sheds of the Baikonur cosmodrome in which the Buran mission was being prepared. The list of the delayed projects was also filled with the upcoming Mars mission, Mars 94, as it was pushed back two years, along with other projects like Spektr observatory. Other planned planetary and asteroid missions were completely erased form the launch schedule. In the meantime, the dissolution of the Soviet Union took place in 26th December 1991. In January 1st 1992, it was replaced by the Russian Federation and the Commonwealth of Independent States (CIS).

The newly formed Russian Federation was struggling from the beginning to keep the space program on track both administratively and financially. As the Soviet Union was falling apart, cosmonauts Sergei Krikalev and Aleksandr Volkov remained on board Mir unbothered as members of the ongoing mission Soyuz TM-13, but were still affected by the chaos that was unfolding on Earth. Krikalev was especially disadvantaged, since he was forced to extend his stay on Mir by almost six months, doubling the duration of his mission – Soyuz TM-12 – which was raised to ten months in total (311 days), posing risks to his health condition due to exposure to space radiation, muscle atrophy –an effect of weightlessness– etc. This was because the next mission, Soyuz TM-13, consisted of only one career cosmonaut, Aleksandr Volkov, with the other two seats being occupied by Austrian researcher Franz Viehböck (privately funded seat) and the Kazak Toktar Aubakirov, who was sent to Mir in order to keep the relations with the soon to be independent Kazakhstan harmonious. The Baikonur cosmodrome, on which the space program was heavily dependent, was located in Kazakhstan. Thus, there was no available seat for Krikalev to return to Earth, except the Randuga re-entry capsule attached to Mir which Krikalev chose not to use.[2] When both cosmonauts returned to Earth on March 25, 1992, they were named "The last Soviet citizens" as their spacesuits still had the Soviet flag on them.[3]

The road to commercialization

Commercial expeditions to Mir space station had already initiated from 1990 and the mission Soyuz TM-10[4] carrying cosmonauts Gennady Manakov, Gennady Strekalov and the Japanese TV reporter Toyohiro Akiyama, the first full paying visitor, whose week-long trip was paid for by the Japanese Tokyo Broadcasting System. It was one of the most effective ways to bring in the very needed foreign currency to the fiscally stressed Russian economy. Other measures included auctions of rare space history items, the filming of advertisements on Mir, and paid tours to the cosmonauts training centers. Astronauts from France and Germany flew to Mir on paid seats financially backed by their national space agencies and the European Space Agency (ESA). The cost of each seat varied from 12 million US Dollars up to 40 million, depending on the duration of each mission and its complexity. Those funds were under the control of the Energiya Corporation, the new Mir owner.[5]

The following year, 1993, the Energyia Buran program was formally cancelled, throwing into the waste bin almost twenty years of hard work of the country's best design bureaus and scientists, that produced only one autonomous Buran flight, accompanied by just two launches of the most powerful rocket of the time, Energyia. The loss of almost 30% of the space program's total workforce, at the same year, came as a consequence. However, in April 4th, Presidents Clinton and Yeltsin released a statement[6] for US – Russian cooperation in space, and in December of the same year, the United States officially invited Russia to become a full partner in the creation of the International Space Station (ISS), based mainly on Russian hardware and US funds. Russia accepted the proposal and, to pave the path to the ISS, the nations also agreed to establish a joint program for the operation of the Mir space station that included the launch of US astronauts and shuttle missions to the space station in exchange for good practices and to build mutual trust. This was the Shuttle – Mir program, also known as "Phase One". [7] The construction of the ISS would be "Phase Two". By joining their forces, both nations managed to strengthen their presence in space while simultaneously canceling out each other's weaknesses: lack of extended space missions for the US and lack of funding for Russia. Thus, the space race that had begun in the 50's, was effectively terminated. In the private sector, the companies Lockheed Martin (LM), Khrunichev and Energia formed a joint company, the International Launch Services (ILS) which went into operation in 1995 as a private spaceflight partnership, initially co-marketing exclusively non-military launches on both the American Atlas and the Russian Proton expendable launch vehicles.[8]

In the interim, the financial situation of the Russian space sector was still deteriorating. By the end of 1994, employment was down to less than 300,000 people. Space spending was down to 0.23% of the national budget, compared to 0.97% spent on space research in the United States. On the subject of spending, employees in space companies were left unpaid for months, some of them were effectively bankrupt, subcontractors denied the delivery of components and fuel to conduct rocket launches unless their contracts were paid off, and the military and unmanned space activities were in decline. Infrastructure in Baikonur and in Plestsek cosmodromes as well as in other space related facilities was also not in a passable state. Buildings suffered from neglect and lack of maintenance. The results involved blackouts, destroyed launch pads that were not fixed, malfunctioning air conditioning systems in offices, and uncollected trash. Eventually, in 1996 for the first time since the 60's the United States launched more rockets into space than Russia. Nonetheless, on Mir space station, two separate events, a fire onboard the Spektr module and a crash with a remotely controlled, by the Mir crew, cargo ship threatened the peaceful coexistence of the United States and Russia, highlighting the diverging approach of the two space powers concerning safety standards in space activities.[9]

By reaching its lowest point, the rebirth of the Russian space program was in fact a matter of time. Besides the agreement with the United States for the ISS, the Russian authorities also made deals with the European partners. A joint company, Starsem, was set up in July of 1996, as a part of an agreement between the TsSKB Progress plant in Samara and the French Arianespace company, with the mission of developing and commercially marketing the Soyuz rocket. Starsem's shares were divided between EADS – 35%, the Russian Space Agency – 25%, TsSKB Progress – 25%, and Arianespace – 15%. Starsem also provided the necessary funds to restore facilities at Samara and Baikonur, including rocket assembly halls, payload separation facilities, and a staff's hotel.[10] At the dusk of the 20th century, Russia was on its way to recover from the financial recession and the effects of the collapse of the Soviet Union on its space program.

company Space Adventures, with a standard price of 20 million dollars per mission. Simultaneously, seats were sold to the European Space Agency (ESA) or to national space agencies in Europe or combinations of the two. By 2001, 87 Russian space companies had entered joint ventures with American and European companies, leading to a visible flow of new money into the program. In a decade, Russia had managed to convert the most centralized

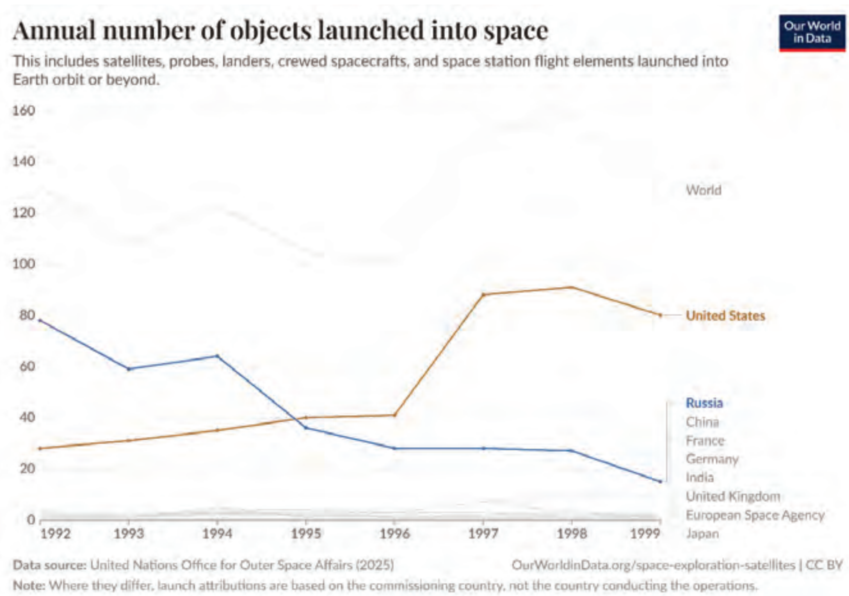


Figure 1: Annual number of objects launched into space. Source: https://ourworldindata.org/grapher/yearly-number-of-objects-launched-into-outer-space?time=1992..1999&focus=RUS~USA

Russia in the dawn of the 21st century

By 2000, an organized system of commercial space tourism was introduced, working through the American space program to the most commercial, globally connected space industry in the world.

In the early 2000's, Russia's space ambitions were rising similarly to the rise of the oil prices. Once again, the

Russian economy was flooded with foreign currency, fueling the country's industry, including the space one. In 2005, the Russian space strategy was published, complimented by President Putin's remarks that in order to achieve global leadership, strength in space was necessary. The proposed commercial and civilian plans comprised of a new space station, a return to the moon, new launch systems and robotic exploration. Another economic crisis however, that of 2008, obliged the Russian aspirations in space to subside, causing also irregularities to Proton and Soyuz launches.

In regard to the military part of the space program, Russia has been transparent about its national goal to exploit outer space as a military asset, as well as preventing the United States from being benefited by space activities for security reasons.[11] The Sino-Russian proposal of the Prevention of Placement of Weapons in Outer Space Treaty (PPWT) in 2008, is an example of this two-sided strategy, despite the fact that the Russian national strategy considered outer space and information sectors to be developed as new warfare areas. In general, the concept of the militarisation of space shares the same perception with the Soviet era, regarding it as a way to protect the Russian extensive borders and all the critical facilities which are scattered all over the country by creating a "protection zone" above the Russian soil.[12]

Thus, during the 00's Russia began restructuring its space industry, with Space and defence industries rerouting their production away from export markets and towards national armed forces. Direct ascent anti-satellite weapons (DA-ASAT), the restoration of the Global Navigation System (GLONASS), and the launch of various satellites such as those for Intelligence, Surveillance and Reconnaissance (ISR), are amongst the Russian investments in military capabilities. On top of that, on April 21, 2007, an «operational meeting» of the Security Council of the Russian Federation approved a «System of views for Russia's independent access to space from its own territory for the full spectrum of tasks until 2040.» By the end of the year, Russia made the potentially momentous decision to develop a new launch facility for manned missions in the nation's Far East, and on November 6, President Putin signed a decree on the creation of the Vostochny (= Eastern)[13] launch site in the Amur Region, planning to make Vostochny the main Russian spaceport thus making the Russian space program and its access to space fully independent from third countries (Kazakhstan in this case).[14]

It was the war in Georgia in 2008 that resulted in the formation of first cracks in the Russian relations with the West by abandoning the proposed plans for a common lunar booster for future expeditions. Under Medvedev's presidency the Russian economy managed to handle successfully the global economic crisis that year, mainly thanks to government subsidies. The conflict in Georgia revealed the limits of the Russian military capabilities along with the failure of the command-and-control system. As a result, the Russian leadership realized the need to invest more in space-based systems as highly important and essential for integration of command, control, communications, information, surveillance and reconnaissance (C31SR). Furthermore, the 'information-strike operations' were introduced, which consist of 'information-strike battles, information-weapons engagements and strikes with the goal of disrupting enemy troop command and control of weapons systems and the destruction of its information resource.[15]

The second decade: 2010 – 2022

Undoubtedly, the annexation of Crimea is be considered as the turning point for Russia's relations with the West. The sanctions against Russia that began in 2014 as a result of the invasion of Ukraine led to restrictions on technological trade and scientific exchanges between the West and Russia, along with a long-term, contractual, launch embargo on nearly 200 Russian civil-space and commercial satellites.[16] Furthermore, the budget of the Russian Space Program has been gradually reduced since then as a consequence of these sanctions.[17] As tensions increased, Russia's military doctrine included the deploymnent of weapons in space, enabling Russian forces to achieve a global strike cabability when necessary. In 2015, the Russian Aerorpace Forces (VKS) were established through the merger of the Air Force and the Airospace Defence Forces. The VKS overseas military space operations, complementing the civilian focus of Roscosmos.

Moreover, the Russian military and space strategy have the United States as their driving force, by always seeking counter measures to lower the US capabilities and their efficiency, as this seems the only way for Russia to maintain the strategic balance with the USA. In this matter, counter-space activities, especially cyber and electronic warfare play a central part in Russian strategy. However, after the retirement of the Space Shuttle in 2011, they only way to launch astronauts and cosmonauts to the ISS was by the Russian Soyuz spacecraft, until NASA's SpaceX Crew-1 mission in 2020.[18]

The submission by China and Russia in 2014, of the renewed version of their draft Treaty on the PPTW, fosters the opinion that the Russian Federation's diplomatic strategy is in compliance with the United Nation's context, probably in a quest to maintain a key role in the shaping of the global security architecture, especially in a multipolar international system.[19]

During this decade, the Russian space program and capabilities kept growing. The first launch from the new Vostochny cosmodrome took place in 2016. At the same year, the new National Security Strategy was introduced replacing the one of 2010. Also, Roscosmos, was transformed from a stage agency to a state company in an attempt to boost its performance and to combat corruption within the organization and in 2017 Russia announced a decrease in space launch incidents from 6.9% in 2015, to 4.7%. In 2019 and 2020, the country tested prototype space weapons, soliciting protests from the United States and others.[20] Once again in 2021, Russia drew the attention of the international community during a DA-ASAT weapon test which generated approximately 1.500 pieces of debris posing a threat to the integrity of the ISS and its cosmonauts onboard.[21]

Russia in space after 2022

Once more, the Russian space program took a sharp turn, this time as a result of the full-scale invasion of Ukraine on 24 February 2022. In a sense, Russia now had to put in practice the doctrines and the weapons tested during the previous decade. The effects of this invasion however, were immediate, severe, multinational and multileveled.

Orbital launches plummeted to just 22 in 2022, as companies like the UK's OneWeb, looked for other means of launching their payloads, through SpaceX and India, concluding any further international cooperation with the Russian authorities in space due to the posed sanctions. In the same manner, ESA suspended in March 2022, the launch of the ExoMars Rover and Surface Platform mission that was scheduled for September 2022, seeking for other means of launching this mission.[22] Despite the hostile relations with the United States, the two nations coexistence in the ISS and the need to launch crewed missions to the space station, have prevented the complete cut off of their relations, limiting their interactions to the absolute necessary.[23] In respect to China, the proposed collaboration in space stalled too. Initially, China had announced a joint project in 2021 to construct an International Lunar Research Station (ILRS) with Russia, however, its 2022 national space strategy did not even mention Russia, and Beijing refused to host Russian cosmonauts on board the Tiangong space station,[24] announcing in March 2025 the intention to train and later host Pakistani astronauts onboard the Tiangong

Space Station.[25] On his side, President Putin welcomed the North Korean leader Kim Jong Un to the Vostochny cosmodrome in September 2023, seeking military cooperation with North Korea in the context of "a fight against imperialism" as Kim Jong Un stated himself.[26] Indeed, in fall of 2024, North Korea reportedly sent military personnel to Russia who fought against Ukraine for Russia in Russian uniforms and under Russian command.

Russian space activities during the Russo-Ukrainian war

In many occasions, the Russo-Ukrainian war is characterized as a future warfare and not in vain. On February 24, one hour prior to the Russian invasion of Ukraine, a cyberattack was launched on the American satellite company Viasat. Russian hackers launched destructive "wiper" malware called AcidRain against Viasat modems and routers, quickly erasing all the data on the system. The machines then rebooted and were permanently disabled. Approximately, 4000 modems in all zones of operation of the KA-SAT satellite, notably Ukraine, were effectively deemed unusable. The decision to attack Viasat was of course not random: Viasat works with the US military and its partners around the world. "*The attack has turned out to be typical of the "hybrid" war strategy employed by Moscow*", say experts.[27] This cyberattack complemented the invasion by ground forces on the field, demonstrating the fact that in the modern warfare the conflicts are multilayered and the cyber sector's role and significance is growing. Just a few hours before, Russian hackers used another wiper, called HermeticWiper, against Ukrainian government computers. In this case, the targets were Windows machines on networks that would be important for the government in Kyiv to mount an effective resistance in the early hours of the invasion. A second cyberattack against Viasat followed, disrupting the connection between government and military bodies as well as the access of Ukrainian households and public infrastructure to the internet.

Russia also has some dependence on space capabilities for its warfighting. For example, the Russian GLONASS system is a constellation of precision, navigation, and timing (PNT) satellites which provide Russia with its own GPS-like capability. On field, it delivers PNT services for commercial aircraft, military navigation and weapons guidance. Although the GLONASS system is supposed to guide weapons to long-range target with high accuracy, in reality, the incomplete and aged GLONASS constellation has been unable to fulfill its mission, causing Russian rockets to miss their targets in Ukraine by a large margin in some cases.[28] The Western sanctions, already in effect since 2014, have hampered maintenance, upgrade and introduction of new space hardware by Russia. Another example of Russia's limited operational readiness and effectiveness, is the failure of the Luna-25 mission, carrying Russia's lunar lander.[29]

The limited in quantity orbital hardware, is not the only issue affecting the Russian space program. Until 2023, the country counted for 160 satellites in orbit, of which more than 100 are military equipment, including 25 GLONASS satellites, 47 communications satellites, 7 Liana oceanic electronic reconnaissance satellites, and others. However, it is noted that Russia doesn't possess neither the proper mix of satellites, nor the suitable ground systems and procedures to work on, and benefit from the data transmitted by those satellites. As an example, the Liana spacecraft has been designed to track ships and US aircraft carriers in the Pacific Ocean. Thus, Liana spacecraft has little effect in the Ukrainian ground war.[30]

On the other side, the one of the Electronic War, Russia has made some accomplishments, in the direction of reducing Ukraine's benefits from space capabilities. The US launched and operated Starlink system has been the prime target of the Russian actions. It is due to the heavy reliance of the Ukrainian forces on Starlink for battlefield communications, and on its ability to help coordinate devastating artillery strikes, that Russia has been looking for ways to disable it through jamming or by attacking it. By jamming Starlink satellites and the GPS receivers, Russians manage to "blind" Ukrainian drone operators and the Ukrainian artillery, who are unable to fulfill their missions.[31] Especially for the second, Ukraine has received an increasing and substantial quantity of High Mobility Artillery Rocket Systems (HIMARS) and Joint Direct Attack Munitions (JDAMs) from the US. In fact, Starlink satellites are so popular at the Russo-Ukrainian battlefield, due to the fact that they possess an unmatched advantage in comparison to the High Earth Orbit satellites: Operating constellations on Low Earth Orbit (LEO) makes it more difficult, if not impossible, to take them offline because an attacker would have to target all the satellites at once, to disable the entire system. Also, it is cheaper and easier to set up a constellation on LEO, and in large numbers.[32]

Since the invasion of Ukraine, in order to improve its ISR capabilities, Russia has launched a series of satellites: In August 9, 2022, the Russian made, Iranian Khayyam 1[33] Earth observation satellite was launched by Russia for government and military use. Yet, the Russian officials announced the intention to not deliver the satellite to Iran immediately, as Russia intended to use it in order to enhance its surveillance of military targets in the Ukrainian war.[34] The Russian Lotos-S1 (14F145) satellites, which are part of the next generation ELINT satellite system "Liana". From April 4, 2022, Russia has launched four Lotos satellites. Lotos-S1 No. 5,6,7,8.[35] The Razbeg (14F169) satellites, which are small military optical reconnaissance satellites similar to the Iranian Khayyam. They were launched in December 27, 2023 and in February 2, 2024.[36] Then, the Uragan-K2 (GLONASS-K2, 14F160) navigation satellites, the upgraded versions of Uragan-K (GLONASS-K) satellites, that also carry classified military payload. They were launched in August 7, 2023, and in March 2, 2025.[37] Also, the civil Earth observation satellites Resurs-P 4 and 5 (47KS), capable of acquiring high-resolution imagery (up to 1m), which are used for defense purposes too. They were launched in March 31, 2024 and in December 25, 2024.[38] Finally, the classified military satellites labeled as Kosmos 2581, 2582 and 2583, launched in February 5, 2025, with an unknown purpose.[39]

Conclusions and future prospects

The Russian space program has been dealing with challenges even before the collapse of the Soviet Union. The economic recession of the first decade after the creation of the Russian Federation, left its footprint on the integrity and effectiveness of the Russian space program in terms of the state of the existing infrastructure and hardware, as well as the operational readiness. In a sense, Russia was forced to turn to international synergies, just like the United States also did at the same time, but in this case not for the projection of power in space (Interkosmos program), but instead, in order to preserve its entity.

In the first decade of the 21st century, the Russian space program had restored its former glory, and had managed to foster a concrete joint effort with the West through the construction and operation of the ISS. However, the conflict in Georgia in 2008 formed the first (of the many later on) cracks on the relations of Russia with the West. In fact, the Russian space program has been suffering until today, from sanctions posed by the West as a consequence of the Russian invasions in Ukraine in 2014 and 2022. These sanctions have had significant implications to the Russian space industry which has been struggling to deliver new space hardware, nevertheless to keep the existing one in operation.

As the Russian Federation has been moving away from the major global powers during the war in Ukraine, it has turned to regional, and in some cases, isolated powers like Iran and North Korea to form alliances. Russia aspires to achieve its national goals, especially to prevail over Ukraine in the battlefield, and to combat technological deficits. In this context, the national security policies have gone anti-West, focusing on countering the Western advantages, especially the technological ones. Thus, Russia is focusing on anti-satellite weapons, electronic war and cyberattacks against Western infrastructure and tech companies like Starlink and Viasat. It is expected that unless the conflict in Ukraine is resolved, little of the above will change in the future. Unless a reapproach with China takes place, Russia will keep walking on the isolation path, and the technological gap with the West will possibly spread and Russia will enter the projected new space race with a handicap. Already the proposed Russian Orbital Station (ROS) after the abandonment of the lunar ambitions due to lack of funding, is an example of the possible fate of the Russian space program.

Bibliography

[1] Jay Chladek, Outposts on the Frontier: A Fifty-Year History of Space Stations. in Outward Odyssey: A People's History of Spaceflight. Lincoln & London: University of Nebraska Press, 2017. [Online]. Available: https://doi.org/10.2307/j.ctt1qv5pdp

[2] Y. Sinelschikova, "The last Soviet citizen: The cosmonaut who was left behind in space," Russia Beyond. Accessed: Mar. 07, 2025. [Online]. Available: https://www.rbth.com/history/330415-last-soviet-citizen-cosmonaut

[3] Anatoly Zak, "Mir missions in 1990," russianspaceweb.com. Accessed: Mar. 07, 2025. [Online]. Available: https://russianspaceweb.com/mir_1990.html

[4] B. Harvey, The rebirth of the Russian space program: 50 years after Sputnik, new frontiers, 1st ed. New York: Springer, 2007.

[5] "Text of a joint statement by President Clinton and President Yeltsin at the summit in Vancouver." Accessed: Mar. 07, 2025. [Online]. Available: https://clintonwhitehouse6.archives.gov/1993/04/1993-04-04-joint-statement-at-vancouver-by-clinton-yeltsin.html

[6] NASA, "Shuttle-Mir History/Background/Lessons Learned." Accessed: Oct. 25, 2023. [Online]. Available: https://web.archive.org/web/20011116160227/http://spaceflight.nasa.gov/history/shuttle-mir/history/h-b-lessons.htm

[7] Bruce McClintock, "The Russian Space Sector: Adaptation, Retrenchment, Stagnation," SD, vol. 10, no. 1, 2017, doi: 10.32873/uno.dc.sd.10.01.1101.

[8] Anatoly Zak, “Mir close calls,” russianspaceweb.com. Accessed: Mar. 08, 2025. [Online]. Available: https://russianspaceweb.com/mir_close_calls.html

[9] Roger E. Kanet, Ed., Routledge handbook of Russian security. in Routledge handbooks. London New York: Routledge, Taylor & Francis Group, 2021.

[10] Bruce McClintock and Mélusine Lebret, “Russian Space Strategy and Capabilities: A Tale of Decline,” in The Sky Is Not the Limit. Geopolitics and Economics of the New Space Race., 1st ed., Alessandro Gili, Ed., Milan: Ledizioni LediPublishing, 2024, p. 239. [Online]. Available: https://www.ispionline.it/wp-content/uploads/2024/12/Report-ISPI-2024-The-Sky-is-not-the-Limit.WEB_.pdf

[11] Anatoly Zak, “Vostochny cosmodrome,” russianspaceweb.com. Accessed: Mar. 12, 2025. [Online]. Available: https://www.russianspaceweb.com/vostochny.html

[12] Anatoly Zak, “Russian space program in the first decade of the 21st century,” russianspaceweb.com. Accessed: Mar. 12, 2025. [Online]. Available: https://www.russianspaceweb.com/russia_2000_2010.html

[13] Paweł Bernat, “Russia’s Strategic Shift in Space Policy,” per Concordiam. Accessed: Mar. 12, 2025. [Online]. Available: https://perconcordiam.com/russias-strategic-shift-in-space-policy/

[14] “NASA’s SpaceX Crew-1 Astronauts Headed to International Space Station,” NASA. Accessed: Mar. 12, 2025. [Online]. Available: https://www.nasa.gov/news-release/nasas-spacex-crew-1-astronauts-headed-to-international-space-station/

[15] Michael Listner and Rajeswari Pillai Rajagopalan, “The 2014 PPWT: A new draft but with the same and different problems,” The Space Review. Accessed: Mar. 12, 2025. [Online]. Available: https://www.thespacereview.com/article/2575/1

[16] Stephen Clark, “U.S. officials say Russia tested a new anti-satellite weapon,” Spaceflight Now. Accessed: Mar. 12, 2025. [Online]. Available: https://spaceflightnow.com/2020/07/23/u-s-officials-say-russia-tested-a-new-anti-satellite-weapon/

[17] Ankit Panda, “The Dangerous Fallout of Russia’s Anti-Satellite Missile Test,” Carnegie Endowment for International Peace. Accessed: Mar. 12, 2025. [Online]. Available: https://carnegieendowment.org/posts/2021/11/the-dangerous-fallout-of-russias-anti-satellite-missile-test?lang=en

[18] “FAQ: The ‘rebirth’ of ESA’s ExoMars Rosalind Franklin mission.” Accessed: Mar. 12, 2025. [Online].

Available:
https://www.esa.int/Science_Exploration/Human_and_Robotic_Exploration/Exploration/ExoMars/FAQ_The_rebirth_of_ESA_s_ExoMars_Rosalind_Franklin_mission

[19] Anatoly Zak, "ISS comes to the brink," russianspaceweb.com. Accessed: Mar. 12, 2025. [Online]. Available:
https://www.russianspaceweb.com/protected/iss_2022.html

[20] Andrew Jones, "Russia's war on Ukraine has caused lasting damage to international spaceflight cooperation," Space.com. Accessed: Mar. 12, 2025. [Online]. Available:
https://www.space.com/russia-war-ukraine-damage-international-spaceflight-cooperation

[21] 闫星周 (Zhao Lei), "Tiangong to welcome Pakistani astronaut," China Daily. Accessed: Mar. 12, 2025. [Online]. Available:
https://www.chinadaily.com.cn/a/202503/01/WS67c24853a310c240449d7f02.html

[22] Anthony Kuhn, "Kim Jong Un vows full support for Russia as Putin pledges space tech for North Korea," NPR, Sep. 13, 2023. Accessed: Mar. 12, 2025. [Online]. Available:
https://www.npr.org/2023/09/13/1199190066/russia-north-korea-putin-kim-jong-un-summit

[23] Patrick Howell O'Neill, "Russia hacked an American satellite company one hour before the Ukraine invasion," MIT Technology Review. Accessed: Mar. 12, 2025. [Online]. Available:
https://www.technologyreview.com/2022/05/10/1051973/russia-hack-viasat-satellite-ukraine-invasion/

[24] Associated Press, "Russia's lunar mission failure raises questions about state of space program," PBS News. Accessed: Mar. 13, 2025. [Online]. Available:
https://www.pbs.org/newshour/world/russias-lunar-mission-failure-raises-questions-about-state-of-space-program

[25] Michael Peck, "Why Russian Space Satellites Are Failing in the Ukraine War," Popular Mechanics. Accessed: Mar. 13, 2025. [Online]. Available:
https://www.popularmechanics.com/military/a43444628/why-russian-satellites-are-failing-in-ukraine/

[26] Sam Skove, "Using Starlink Paints a Target on Ukrainian Troops," Defense One. Accessed: Mar. 13, 2025. [Online]. Available:
https://www.defenseone.com/threats/2023/03/using-starlink-paints-target-ukrainian-troops/384361/

[27] "UkraineX: How Elon Musk's space satellites changed the war on the ground," POLITICO. Accessed: Mar. 13, 2025. [Online]. Available:
https://www.politico.eu/article/elon-musk-ukraine-starlink/

[28] "Khayyam 1, 2, 3, 4," Gunter's

Space Page. Accessed: Mar. 13, 2025. [Online]. Available: https://space.skyrocket.de/doc_sdat/khayyam-1.htm

[29] Joby Warrick and Ellen Nakashima, "Russia to launch spy satellite for Iran but use it first over Ukraine," The Washington Post, Aug. 04, 2022. Accessed: Mar. 13, 2025. [Online]. Available: https://www.washingtonpost.com/national-security/2022/08/04/russia-iran-spy-satellite/

[30] "Lotos-S1 (14F145) - Gunter's Space Page." Accessed: Mar. 13, 2025. [Online]. Available: https://space.skyrocket.de/doc_sdat/lotos-s1.htm

[31] "Razbeg (14F169)," Gunter's Space Page. Accessed: Mar. 13, 2025. [Online]. Available: https://space.skyrocket.de/doc_sdat/razbeg.htm

[32] "Uragan-K2 (GLONASS-K2, 14F160)," Gunter's Space Page. Accessed: Mar. 13, 2025. [Online]. Available: https://space.skyrocket.de/doc_sdat/uragan-k2.htm

[33] "Resurs-P 4, 5 (47KS)," Gunter's Space Page. Accessed: Mar. 13, 2025. [Online]. Available: https://space.skyrocket.de/doc_sdat/resurs-p4.htm

[34] "Kosmos 2581, 2582, 2583," Gunter's Space Page. Accessed: Mar. 13, 2025. [Online]. Available: https://space.skyrocket.de/doc_sdat/kosmos-2581.htm

Endnotes

1 Jay Chladek, *Outposts on the Frontier*, 301.

2 Sinelschikova, "The Last Soviet Citizen."

3 Jay Chladek, *Outposts on the Frontier*, 302.

4 'Mir missions in 1990', https://russianspaceweb.com/mir_1990.html.

5 Harvey, *The Rebirth of the Russian Space Program*, 13–14.

6 'Text of a joint statement by President Clinton and President Yeltsin at the summit in Vancouver', https://clintonwhitehouse6.archives.gov/1993/04/1993-04-04-joint-statement-at-vancouver-by-clinton-yeltsin.html.

7 NASA, "Shuttle-Mir History/Background/Lessons Learned."

8 Bruce McClintock, "The Russian Space Sector," 5.

9 'Mir close calls', https://russianspaceweb.com/mir_close_calls.html.

10 Harvey, *The Rebirth of the Russian Space Program*, 15.

11 Roger E. Kanet, *Routledge Handbook of Russian Security*, 227–28.

12 Bruce McClintock and Mélusine Lebret, "Russian Space Strategy and Capabilities: A Tale of Decline," 144.

13 Anatoly Zak, 'Vostochny cosmodrome', russianspaceweb.com, https://www.russianspaceweb.com/

vostochny.html.

14 Anatoly Zak, 'Russian space program in the first decade of the 21st century', russianspaceweb.com, https://www.russianspaceweb.com/russia_2000_2010.html.

15 Roger E. Kanet, *Routledge Handbook of Russian Security*, 230–31.

16 Bruce McClintock and Mélusine Lebret, "Russian Space Strategy and Capabilities: A Tale of Decline," 148.

17 Paweł Bernat, "Russia's Strategic Shift in Space Policy."

18 'NASA's SpaceX Crew-1 Astronauts Headed to International Space Station - NASA', https://www.nasa.gov/news-release/nasas-spacex-crew-1-astronauts-headed-to-international-space-station/.

19 Michael Listner και Rajeswari Pillai Rajagopalan, 'The 2014 PPWT: A new draft but with the same and different problems', The Space Review, https://www.thespacereview.com/article/2575/1.

20 Stephen Clark, "U.S. Officials Say Russia Tested a New Anti-Satellite Weapon."

21 Ankit Panda, "The Dangerous Fallout of Russia's Anti-Satellite Missile Test."

22 'FAQ: The 'Rebirth' of ESA's ExoMars Rosalind Franklin Mission', https://www.esa.int/Science_Exploration/Human_and_Robotic_Exploration/Exploration/ExoMars/FAQ_The_rebirth_of_ESA_s_ExoMars_Rosalind_Franklin_mission.

23 Anatoly Zak, "ISS Comes to the Brink."

24 Andrew Jones, "Russia's War on Ukraine Has Caused Lasting Damage to International Spaceflight Cooperation."

25 闫星周 (Zhao Lei), "Tiangong to Welcome Pakistani Astronaut."

26 Anthony Kuhn, "Kim Jong Un Vows Full Support for Russia as Putin Pledges Space Tech for North Korea."

27 Patrick Howell O'Neill, "Russia Hacked an American Satellite Company One Hour before the Ukraine Invasion."

28 Bruce McClintock and Mélusine Lebret, "Russian Space Strategy and Capabilities: A Tale of Decline," 151–52.

29 Associated Press, "Russia's Lunar Mission Failure Raises Questions about State of Space Program."

30 Michael Peck, "Why Russian Space Satellites Are Failing in the Ukraine War."

31 Sam Skove, "Using Starlink Paints a Target on Ukrainian Troops."

32 "UkraineX."

33 "Khayyam 1, 2, 3, 4."

34 Joby Warrick and Ellen Nakashima, "Russia to Launch Spy Satellite for Iran but Use It First over Ukraine."

35 "Lotos-S1 (14F145) - Gunter's Space Page."

36 "Razbeg (14F169)."

37 "Uragan-K2 (GLONASS-K2, 14F160)."

38 "Resurs-P 4, 5 (47KS)."

39 "Kosmos 2581, 2582, 2583."

Short Biography

Dr. Konstantinos Grivas is Professor of Geopolitics and Modern Military Technologies and Director of War Theory and Analysis Sector at the Hellenic Military Academy.

He also teaches Geography of Security at the Department of Turkish and Modern Asian Studies of the National and Kapodistrian University of Athens. As a lecturer and visiting professor, he also teaches at the National Defense School, the National Security School, and the School of Command and Staff of the Air Force.

He has worked as the head of the research division for new military technologies at the Defense Analysis Institute of the Ministry of Defense. He has worked as the editor-in-chief of the journals «Strategy» and «War and History» and as the managing editor of the journal «Geopolitics.»

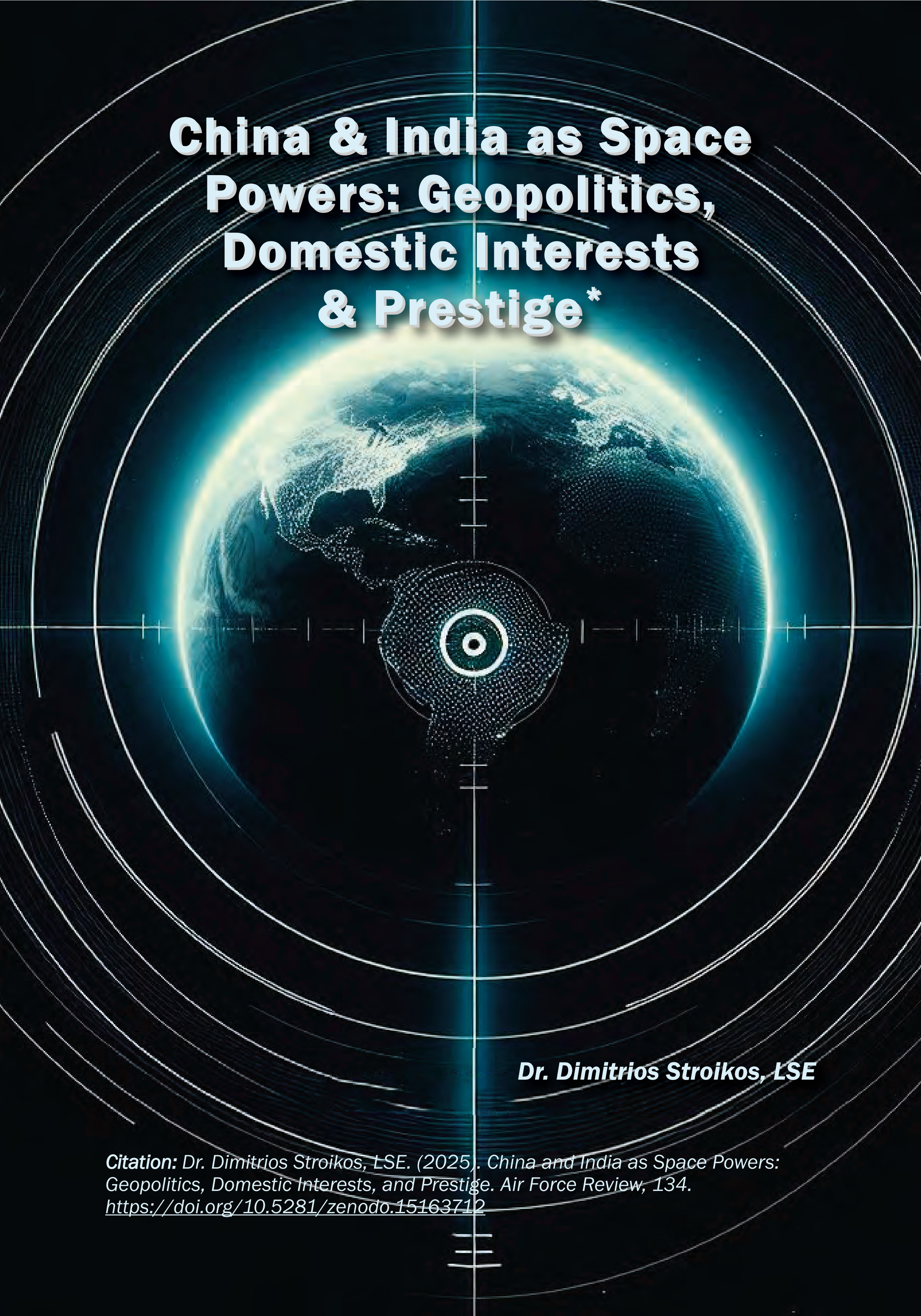
His articles have been published in various other newspapers and journals. From 1996 to 2004, he was an accredited journalist at the Ministry of Defense.

Short Biography

Mr. Anastasios Seferiadis is a Geopolitical Analyst and holds a Master of Science with distinction from the National and Kapodistrian University of Athens in Geopolitical Analysis, Geostrategic Synthesis, and Defense and International Security Studies.

He has participated in numerous seminars and military Erasmus programs under the auspices of the European Security and Defence College. He has worked for the Greek Ministry of Foreign Affairs, serving at the Consulate General of Greece in New York and the Permanent Mission of Greece to the United Nations. He has also completed an internship at the Hellenic Foundation for European and Foreign Policy (ELIAMEP) and has served as an Assistant Researcher at the Institute of International Economic Relations.

China & India as Space Powers: Geopolitics, Domestic Interests & Prestige*



Dr. Dimitrios Stroikos, LSE

Citation: _Dr. Dimitrios Stroikos, LSE. (2025). China and India as Space Powers: Geopolitics, Domestic Interests, and Prestige. Air Force Review, 134._
https://doi.org/10.5281/zenodo.15163712

Abstract

This paper employs an eclectic analytical framework, incorporating structural, domestic, and normative perspectives to assess the drivers behind China and India's space programs. While security concerns, particularly China's competition with the U.S. and India's response to China, are significant in explaining military space ambitions, domestic political dynamics and bureaucratic interests also play a critical role in shaping space policy decisions. Moreover, space accomplishments serve as sources of national prestige, political legitimacy, and international standing.

Keywords:

China, India, space, technonationalism, prestige

Introduction

Any discussion of contemporary space security has to pay particular attention to the role of China and India as space powers. It is not difficult to see why. China has been expanding its space capabilities in a systematic manner over the past two decades or so, emerging as a key player in civilian space activities. Indicative of its ambition to position itself as a global space power, China's achievements include a series of human spaceflight missions, a vigorous lunar space program, the completion of the *Tiangong* space station, and the deployment of the *Beidou* satellite navigation system, which provides Beijing with an independent global positioning capability. Alongside this, as discussed below, space has become increasingly central to China's military modernization, reflecting broader strategic goals and the growing importance of space-based assets for national security.

While China's emergence as a major space power has been widely recognized, India has also made substantial strides in space in recent years in both civilian and military space capabilities. Despite the fact that India has traditionally emphasized the use of space for socio-economic development, its space program has increasingly focused on prestige projects, achieving significant milestones in space exploration. At the same time, like China, India has been gradually integrating space into its broader national security, demonstrating a growing awareness of the military and geopolitical significance of space.

In light of the above, the aim of this short essay is to provide a brief overview of China and India as space powers. It begins by examining China's space program, outlining its major civilian achievements before briefly considering how China utilizes space for military purposes. The discussion then shifts to India, first highlighting its civilian space advancements and then offering a succinct review of how space has increasingly been integrated into national security. In lieu of a conclusion, the final section briefly examines the key drivers of China and India's space programs through the prism of an analytical eclectic approach, integrating insights from structural, domestic, and normative perspectives to provide a more comprehensive understanding of their strategic, political, and technological motivations.

China: A major power in space

China's recent remarkable achievements in space mean that one may be forgiven for thinking that its space program is a relatively new endeavor.[2] And yet, China has one of the world's longest-running space programs, with origins dating back to the mid-20th century, driven by a combination of national prestige and strategic considerations echoing the United States and the Soviet Union. Indeed, as Handberg and Li note "the reality of the Chinese space program was that their effort grew out of that same sense of military necessity along with the clear ancillary value of fostering China's international political prestige in a manner" that "clearly mirrored those of the United States and Soviet Union.[3] In this respect, a few useful observations are worth making from the outset. First, underpinning China's space endeavor from its inception was its closed ties with the country's strategic weapons program. This connection became evident with the establishment of the Fifth Academy of the Department of Defense in 1956, led by the renowned scientist Qian Xuesen. As a missile research and development center, the academy played a crucial role in laying the groundwork for China's space ambitions.[4]

Second, the launch of Sputnik in 1957 was a pivotal moment that spurred China's interest in space. The Soviet achievement left a strong impression on Mao Zedong, who frequently referenced it in his speeches. At the Second Plenary Meeting of the Eighth Party Congress in May 1958, the Chinese premier famously announced, "We too should produce satellites," but insisted that China aim high: "If we're going to launch one, it should be at least two tons—not a small one like the Americans' chicken egg!".[5]

Mao's interest led to a push for the development of a Chinese satellite. But China's space ambitions were initially stalled by a combination of domestic political upheavals, including the Great Leap Forward and the Cultural Revolution, and the withdrawal of Soviet technical assistance for its missile program following the Sino-Soviet split.

Even so, the Chinese leadership acknowledged the significance of the missile and space programs. Consequently, it sought to protect the engineers and scientists working in these fields from the political instability that disrupted other aspects of policymaking and society at large. These efforts bore fruit when, on April 24, 1970, China successfully launched its first satellite, Dong Fang Hong 1 (The East is Red), becoming the fifth country to place a satellite in orbit.[6]

China's early space ambitions were not limited to satellites. The successful launch of Dong Fang Hong 1 was made possible by the Long March 1 rocket, part of a broader effort to develop an indigenous launch capability. Around the same time, the Chinese leadership also initiated the early phases of a human spaceflight program, but Mao eventually decided to cancel it. Nevertheless, this brief interest in human spaceflight underscores the country's long-term commitment to establishing itself as a major space power.

What merits emphasis for the purposes of this discussion is that the space program's synergies with the strategic weapons program continued apace in the 1960s and 1970s. In fact, the launch of the first Chinese satellite was part of what is known in China as the "Two Bombs, One Satellite" or *Liangdan Yixing* (两弹一星) project. "Two Bombs" refers to the development of both the atomic and hydrogen bombs, along with intercontinental ballistic missiles (ICBMs), while "One Satellite" denotes the advancement satellite technology. Embodying China's integrated approach to national defense and technological self-reliance, the *Two Bombs, One Satellite* project highlights a techno-nationalist approach to strategic technologies that remains influential today.[7]

Deng Xiaoping reoriented China's space program toward economic development, emphasizing practical applications such as satellite communications.[8] However, in 1986, an important effort was made to reassert a techno-nationalist approach to advanced technological development, drawing inspiration from the *Two Bombs, One Satellite* project. Initiated by four prominent scientists, this push resulted in the launch of the 863 High-Technology Research and Development Plan, commonly known as the 863 Program. Its primary objective was to drive innovation and enhance China's technological capabilities in critical fields, including space.[9] This, in turn, led the 863 Program to reignite interest in China's space efforts, culminating in the launch of its human spaceflight program in the early 1990s.[10]

Progressing from this basis, China has since pursued its space program with consistency and a gradual, methodical approach. Over time, it has developed across the board space capabilities enabling a wide range of applications. Not surprisingly, China's remarkable feats in human spaceflight and space exploration have attracted much global attention, solidifying its position as a leading space power. Apart from a rigorous human spaceflight and space exploration program, China has also made significant strides in satellite and rocket technology. China has developed an extensive array of satellites for communications, remote sensing, and navigation, with the *Beidou* satellite system standing out as a major milestone. More recently, it has shown a growing interest in the development of satellite megaconstellations, aiming to establish its own large-scale network for global broadband coverage, akin to Starlink.[11] As far as rocket development is concerned, China has made significant progress in advancing its launch capabilities. The Long March rocket family has undergone continuous upgrades, enabling the deployment of satellites, crewed missions, and deep-space probes.[12] Furthermore, there has been an effort to step up the commercialization and privatization of its space sector, fostering the growth of private enterprises involved in satellite manufacturing, launch services, and space-based applications.[13]

Beyond technological advancements, it should be noted that China has also leveraged its space capabilities as a tool of foreign policy, particularly in its engagement with the Global South. For example, in 2008, it established the Asia-Pacific Space Cooperation Organization (APSCO) to promote collaboration among member states through training, data sharing, and capacity building in space technology.[14] Similarly, it has integrated space activities into the Belt and Road Initiative (BRI) through the Space Information Corridor or Space Silk Road.[15] Equally, China attempts to bolster its image as a great power in space through initiatives such as the United Nations/China Cooperation on the Utilization of the China Space Station, which offers international scientists the opportunity to conduct experiments aboard its space station, enhancing its soft power.[16] Likewise, the International Lunar Research Station (ILRS), launched in partnership with Russia's Roscosmos in 2021, is a planned lunar base for scientific research and exploration.[17] Unlike China's UN-backed space initiatives, however, it is notable that the ILRS follows a bilateral framework but remains open to international participation.[18]

The point to make is here is that these initiatives reflect Beijing's effort to demonstrate its commitment to assuming great power responsibilities through the provision of public goods, though with certain limitations.[19]

China and Military Space

Symptomatic of its growing space activities, its expanding interests across the globe, and its wider military modernization, China has intensified its focus on the military uses of space. The increasing role of space technology in modern warfare after the Cold War drew significant attention from Chinese strategists, particularly following the 1991 Gulf War, often called the first space war. This conflict demonstrated how space assets could enhance both strategic and tactical military operations, prompting China to reassess its military doctrine and training. In 1993, under Jiang Zemin's leadership, China introduced the concept of "local wars under modern high-tech conditions," signaling a shift from industrial-age warfare to modern, technology-driven military capabilities. This modernization drive prioritized research and development in space-based technologies, including satellites, early warning systems, command networks, and advanced communication infrastructure. This process accelerated with the emergence of the Revolution in Military Affairs, alongside other external developments, such as the transition to information warfare, the Kosovo War, and U.S.-led interventions in Afghanistan and Iraq, which reinforced the critical role of technology in contemporary warfare. By 2002, the strategic guidelines adopted the term "local wars under modern informationalized conditions," emphasizing the growing nexus between information technology and military operations.[20]

Since Xi Jinping took power in 2012, interest in the military uses of space has gained significant momentum. In 2014, Xi urged the PLA Air Force to "speed up air and space integration and sharpen their offensive and defensive capabilities". China's 2015 defense white paper reinforced this priority, describing outer space as a "commanding height in international strategic competition." Similarly, China's most recent defense white paper, released in 2019, highlights "China's security interests in outer space" as a key "national defense aim" and affirms that "[o]uter space is a critical domain in international strategic competition".[21]

This growing focus on military space aligns with Xi's broader push for military modernization, which prioritizes transforming the PLA into a world-class military by mid-century. A central aspect of China's military transformation is the policy of military-civil fusion (MCF), aimed at integrating civilian technological advancements into military applications to enhance China's defense capabilities. Moreover, PLA reforms under Xi have sought to streamline operations across key domains.[22] In 2015, China established the PLA Strategic Support Force (PLASSF) to centralize space, cyber, and electromagnetic operations. However, in a major restructuring announced in April 2024, the PLASSF was disbanded and replaced with new military units, including an Aerospace Force.[23] While the full implications of this restructuring remain unclear, it reflects the growing importance of space assets under informationized warfare and the need for greater coordination in joint military operations across multiple domains.

This shift in military organization and doctrine has been accompanied by China's growing investment in counterspace capabilities. The most visible demonstration of this was the 2007 direct-ascent anti-satellite (ASAT) test, which destroyed a defunct weather satellite, making China the third country to conduct such a test. The resulting debris, estimated at over 3,000 pieces, sparked international condemnation and raised concerns over China's stance on space security. While China has since refrained from further debris-generating ASAT tests, it has continued developing non-destructive direct-ascent ASAT systems, including a 2013 test that reached approximately 30,000 km, suggesting the ability to target satellites in medium Earth orbit or higher. Aside direct-ascent ASATs, China is believed to be advancing a range of counterspace technologies, including co-orbital systems, directed energy weapons, and electronic warfare capabilities, all aimed at disrupting or neutralizing adversary space assets.[24]

Concurrently, space has become integral to the PLA's ability to conduct operations far beyond continental China, reflecting its expanding strategic reach. Traditionally focused on internal security and defense of the mainland, the PLA has increasingly prioritized long-distance missions, with space-based assets playing a key role as a force multiplier. In this context, a major focus has been enhancing command, control, communications, intelligence, surveillance, and reconnaissance (C4ISR) capabilities through an extensive network of both dedicated military and dual-use satellites. This includes communication satellites, high-resolution remote sensing satellites such as *the Yaogan*, *Haiyang*, *Huanjing*, *and Gaofen* series, as well as Tracking and Data Relay Satellites (TDRS) and the *Beidou* navigation system. Estimates suggest that nearly half of China's satellite launches since 1970 have served military functions.[25] Alongside its 300 surveillance satellites in low Earth orbit, China has also expanded its geostationary orbit (GEO) surveillance capabilities with dual-use satellites like Yaogan-41 and Ludi Tance-4, which enhance continuous monitoring over Taiwan and the Indo-Pacific, complicating U.S. and allied military operations in the region.[26]

India: A Rising Space Power

Like China, India's space program is one of the oldest, with its origins tracing back to the early 1960s.[27] However, some scholars trace its foundations even earlier, linking it to India's participation in the International Geophysical Year (IGY) of 1957–1958, a global scientific initiative that contributed to the emergence of the Space Age with the launch of Sputnik 1 in 1957.[28] Notably, Vikram Sarabhai, often regarded as the father of India's space program, played an important role in these early efforts, which helped lay the foundation for India's later advancements in space technology. This led to the establishment of the Indian National Committee for Space Research (INCOSPAR) in 1962 and the launch of the first Nike-Apache sounding rocket from the Thumba Equatorial Rocket Launching Station (TERLS) in 1963, followed by the creation of the Indian Space Research Organisation (ISRO) in 1969.

Unlike other space powers that heavily relied on military programs, however, India's space and missile development efforts remained distinct, with minimal technological overlap. Indian scientists prioritized practical applications deriving from space-based assets aligning with Sarabhai's vision of utilizing space for socio-economic development. In this respect, India's space program evolved around three key pillars: communications and remote-sensing satellites, practical applications, and space transportation systems.[29] In particular, the Indian National Satellite System (INSAT), operational since 1983, and the Indian Remote Sensing (IRS) satellite program, launched in 1988, supported vital functions such as meteorology, disaster monitoring, and resource management. Simultaneously, India established its own launch capabilities, starting with the Satellite Launch Vehicle (SLV)-3 in 1980 and later advancing to more sophisticated systems such as the Augmented Satellite Launch Vehicle (ASLV), the Polar Satellite Launch Vehicle (PSLV), and the Geosynchronous Satellite Launch Vehicle (GSLV).[30]

Although socio-economic priorities remain central, in recent years, India's space ambitions have broadened to encompass exploration and strategic objectives, reflecting its aspirations for great power status, its growing economic clout, and an increasingly challenging security environment.[31] The launch of Chandrayaan-1 in 2008, which confirmed the presence of water molecules on the Moon, signaled this shift. It was followed by the Mars Orbiter Mission (Mangalyaan) in 2013, making India the first Asian nation to reach Mars, a milestone some analysts viewed as strategically motivated in light of China's space advancements. In 2018, Prime Minister Narendra Modi announced India's first human spaceflight mission, *Gaganyaan*. As part of its long-term ambitions, India has also outlined plans to establish its own independent space station by 2035, further solidifying its position as a major space power. As well, India has increasingly promoted commercialization and privatization in its space sector.

Importantly, as part of this reorientation of Indian space policy, New Delhi has become more willing to use space technology as a foreign policy tool, partly in response to China's growing influence in South Asia. A key example has been Modi's 2014 proposal for a South Asian Association for Regional Cooperation (SAARC) satellite, aimed at enhancing regional connectivity. Renamed the South Asia Satellite after Pakistan withdrew, it was successfully launched in May 2017, providing disaster management support, telemedicine, tele-education, and weather forecasting services to Afghanistan, Bangladesh, Bhutan, Nepal, the Maldives, and Sri Lanka.[32]

India and military space

While these advancements serve to highlight India's expanding civilian space capabilities, its space program has also taken on an increasingly strategic dimension. This has been manifested in the deployment of satellites that enhance India's defense capabilities.[33] Since 2000, ISRO has launched several dual-use Earth observation satellites capable of providing high-resolution imagery with military applications. The 1999 Kargil War exposed weaknesses in India's surveillance infrastructure, leading to greater investment in space-based reconnaissance.[34] Some satellites in the IRS series are believed to have military utility, while the CARTOSAT series delivers high-resolution data. Furthermore, the RISAT (Radar Imaging Satellite) series, equipped with synthetic aperture radar (SAR) enable Earth observation for dual-use purposes. India has also established NavIC (Navigation with Indian Constellation), an independent regional navigation system providing positioning, navigation, and timing (PNT) services. While its Standard Position Service (SPS) is open to civilian users, the Restricted Service (RS) is encrypted for military operations. ISRO has also collaborated with the Airport Authority of India (AAI) to develop GAGAN (GPS Aided Geo Augmented Navigation), which has potential dual-use utility.

Apart from these dual-use capabilities, India has also prioritized the development of dedicated military space assets to strengthen its defense posture in space. In 2013, ISRO launched GSAT-7, India's first military communications satellite, enhancing the Indian Navy's maritime surveillance and operational capabilities. This was followed by GSAT-7A in 2018, designed to improve communication for the Indian Air Force. In 2019, India launched EMISAT, an electronic intelligence (ELINT) satellite jointly developed by ISRO and the Defence Research and Development Organisation (DRDO), aimed at detecting and intercepting hostile radar signals.[35]

But India's growing focus on military space capabilities has not been limited to satellites. A significant demonstration of the shift toward the use of space for national security came with Mission Shakti, in which a missile launched from the Kalam Island missile complex successfully intercepted the Microsat-R satellite, which was developed by the Defence Research and Development Organisation (DRDO) and launched by ISRO in January 2019, in low Earth orbit at approximately 300 km. The destruction of Microsat-R marked a major milestone in India's military space program. With this test, India became the fourth country, after the United States, Russia, and China, to demonstrate ASAT capabilities, signaling its intent to strengthen its counterspace capabilities.[36]

To further integrate space into military operations, India established the Integrated Space Cell in 2010 under the Integrated Defence Services (IDS) Headquarters to coordinate the use of space assets across the three branches of the armed forces, ISRO, and the Department of Space. Following the 2019 ASAT test, India reinforced this by creating the Defence Space Agency (DSA) to address space-based threats and expand its defense capabilities. Together with this, the government approved the Defence Space Research Organisation (DSRO) to support space warfare development and provide technical expertise to the DSA. To complement these efforts, ISRO initiated Project NETRA (Network for Space Objects, Tracking, and Analysis), a space situational awareness system designed to monitor space objects and provide early warnings of potential threats, further securing India's space assets. In tandem with improving its independent military space capabilities, India has deepened strategic space partnerships, particularly with the United States, to counter China. Another example is the Quadrilateral Security Dialogue (Quad), comprising Australia, India, Japan, and the United States, which has expanded its focus to space.[37]

In lieu of a conclusion: Making sense of China and India as space powers

The rise of China and India as space powers cannot be understood through a single International Relations theoretical lens.[38] Instead, an eclectic approach integrating structural imperatives, domestic politics, and normative considerations provides a more comprehensive understanding of their space programs.[39] A focus on structural factors and systemic pressures associated with a realist-oriented approach offers a compelling explanation for both countries' pursuit of military space capabilities, including anti-satellite ASAT weapons. China's 2007 ASAT test was largely seen as a response to US military space dominance. Similarly, India's 2019 ASAT test reflected its strategic concerns about China's growing space power. The action-reaction dynamic between these states suggests a security dilemma in space, where one country's advancements prompt others to develop similar capabilities. However, while such concerns explain why China and India pursue military space capabilities, they do not fully account for the timing of key decisions and the rationales behind specific projects, including ASAT tests.

Looking at the impact of domestic political consideration helps bridge this gap, highlighting how internal bureaucratic and political factors shape space policies. In China's case, the 2007 ASAT test may have been driven by project managers seeking to demonstrate technological maturity and secure political approval for the program. Similarly, India's ASAT test was not solely about deterring China but also had strong domestic political motivations. The Modi government's decision to authorize the test despite the technology being available since 2012 coincided with the 2019 general elections, leading to accusations that it was exploited for electoral gain. Further reflecting domestic political considerations, space projects in China are tightly woven into state narratives, boosting national pride as well as the legitimacy of the Chinese Communist Party. Similarly, for political leaders like Modi, space achievements can serve as a means to bolster their personal image by associating their leadership with national strength and technological success.

Beside structural imperatives and domestic politics, taking into consideration the role of history and identity provides further insights into the motivations behind China and India's space ambitions. Both countries have sought to leverage space capabilities for great power status and prestige, using high-profile space achievements to signal their emergence as great powers. The 19th-century idea of scientific and technological progress as a "standard of civilization" reinforced a hierarchical view that distinguished European from non-European societies, influencing China and India, which continue to use space projects as symbols of power, status, and modernity, driven by an influential techno-nationalist ideology.[40]

Therefore, China and India's space

programs reflect a complex interplay of strategic, political, and identity-driven factors. While national security concerns have played a role, their pursuit of space capabilities, including ASATs, cannot be understood solely through a military lens. Domestic political considerations, bureaucratic interests, and leadership ambitions have shaped key decisions, while space achievements serve as symbols of national pride, political legitimacy, and great power status. An eclectic approach is essential to fully grasp the motivations behind their space programs, showing that space power is not just about power politics but also about prestige, domestic legitimacy, and broader aspirations for recognition in the ensuing global space order.

To conclude, China has firmly established itself as the world's second space power, with cutting-edge advancements across human spaceflight, space exploration, and military space capabilities. India, still a rising space power with a distinct scale of operations, has showcased technological prowess and strategic ambition, establishing itself as a significant actor in space.

Their rise signals a fundamental shift in the global space order, where non-Western actors are playing an increasingly decisive role. As China continues its rapid ascent and India strengthens its position, their space programs will shape the future of space security, commercial space activities, and global space governance. Understanding their roles is essential for moving beyond a Western-centric view of space and recognizing the complex dynamics of contemporary space security.

References

* This essay is an abridged, updated, and significantly revised version of Dimitrios Stroikos, 2023. 'Still Lost in Space? Understanding China and India's Anti-Satellite Tests through an Eclectic Approach,' *Astropolitics* 21 (2–3): 179–205.

1 For detailed accounts of China's space program, inter alia, see: Marco Aliberti. 2015. *When China Goes to the Moon...* Cham: Springer; S. Chandrashekar. 2022. *China's Space Programme: From the Era of Mao Zedong to Xi Jinping.* Bangalore: National Institute of Advanced Studies and Cham: Springer; Roger Handberg and Zhen Li. 2006. *Chinese Space Policy: A Study in Domestic and International Politics.* London: Routledge; Brian Harvey. 2019. *China in Space: The Great Leap Forward.* 2nd ed. Cham: Springer-Praxis; Kevin Pollpeter, Timothy Dit-

ter, Anthony Miller, and Brian Waidelich. 2020. *China's Space Narrative.* Montgomery, AL: China Aerospace Studies Institute, Air University; and Xiaodan Wu. 2022. *China's Ambition in Space: Programs, Policy and Law.* The Hague: Eleven International Publishing. Also see China's latest white paper on space: State Council Information Office of the People's Republic of China. 2022. *China's Space Program: A 2021 Perspective.* https://www.cnsa.gov.cn/english/n6465645/n6465648/c6813088/content.html.

2 Handberg and Li, Chinese Space Policy, p. 41.

3 Yanping Chen. 1991. "China's Space Policy: A Historical Review." *Space Policy* 7 (2): 172; John Wilson Lewis and Di Hua. 1992. "China's Ballistic Missile Programs: Technologies, Strategies, Goals." *International Security* 17 (2): 7.

4 Gregory Kulacki and Jeffrey G. Lewis. 2009. *A Place for One's Mat: China's Space Program, 1956–2003.* American Academy of Arts and Sciences, 5. Iris Chang. 1995. *Thread of the Silkworm.* Basic Books, 226.

5 Chen, China's Space Policy.

6 Tai Ming Cheung. 2009. *Fortifying China: The Struggle to Build a Modern Defense Economy.* Ithaca, NY: Cornell University Press; Evan A. Feigenbaum. 2003. *China's Techno-Warriors: National Security and Strategic Competition from the Nuclear to the Information Age.* Stanford, CA: Stanford University Press).

7 Guoxiang Wu, 'China's Space Communications Goals' (1988) 4(1) *Space Policy* 41–45.

8 One of the best accounts of the 863 program is Feigenbaum, China's Techno-Warriors.

9 Chengzhi Li, Bingtao Ma, and Xiang Li. 2022. "The Decision-Making Process of China's Human Spaceflight Program." *Space Policy* 61: 101492.

10 Cissy Zhou. 2024. "China Races to Outflank Elon Musk's Starlink Satellite Internet Service." *Nikkei Asia*, October 11, 2024. https://asia.nikkei.com/Spotlight/Policy-Asia/China-races-to-outflank-Elon-Musk-s-Starlink-satellite-internet-service.

11 Qin Tong, Xu Lijie, Li Pingqi, and Liu Jiajia. 2018. "Development of China's New Generation Launch Vehicles." *Chinese Journal of Space Science* 38 (5): 593–597.

12 On the commercialization and privatization of space activities in China, for example, see Mingyan Nie. 2022. "The Growth of China's Non-Governmental Space Sector in

the Context of Government Support for Public-Private Partnerships: An Assessment of Major Legal Challenges." *Space Policy* 59: 101461.

13 More information on APSCO is available on its website: http://www.apsco.int.

14 State Administration of Science, Technology and Industry for National Defense and National Development and Reform Commission. 2016. *Jiakuai tuijin "yidai yilu" kongjian xinxi zoulang jianshe yu yingyong de zhidao yijian [Guiding Opinions on Accelerating the Construction and Application of the "Belt and Road" Space Information Corridor]*. People's Republic of China, October 23, 2016. https://www.ndrc.gov.cn/fzggw/jgsj/kfs/sjdt/201611/t20161123_1086163.html.

15 United Nations Office for Outer Space Affairs. 2022. *Access to Space for All Initiative.* Vienna: United Nations.

16 China National Space Administration and Roscosmos. 2021. *International Lunar Research Station (ILRS) Guide for Partnership (V1.0).* https://www.cnsa.gov.cn/english/n6465652/n6465653/c6812150/content.html

17 A useful discussion of China's approach to space diplomacy concerning the CSS and the ILRS is provided in Kunhan Li and Maximilian Mayer. 2023. "China's Bifurcated Space Diplomacy and Institutional Density." *The Hague Journal of Diplomacy* 18 (2–3): 253–281.

18 Dimitrios Stroikos. 2022. "Power Transition, Rising China, and the Regime for Outer Space in a US-Hegemonic Space Order." In *Power Transition in the Anarchical Society: Rising Powers, Institutional Change and the New World Order*, edited by Tonny Brems Knudsen and Cornelia Navari, 329–352. Palgrave Macmillan.

19 For detailed discussions, see Dean Cheng. 2012. "China's Military Role in Space." *Strategic Studies Quarterly* 6 (1): 55–77; David M. Finkelstein. 2007. "China's National Military Strategy: An Overview of the 'Military Strategic Guidelines.'" In *Right Sizing the People's Liberation Army: Exploring the Contours of China's Military*, edited by Roy Kamphausen and Andrew Scobell, 69–140. Carlisle: Strategic Studies Institute, US Army War College; and David Shambaugh. 2004. *Modernizing China's Military: Progress, Problems, and Prospects.* University of California Press.

20 Dimitrios Stroikos. 2023. "Still Lost in Space? Understanding China and India's Anti-Satellite Tests through an Eclectic Approach." *Astropolitics* 21 (2–3): 184-5.

21 On the potential impact of MCF on Chinese space activities, see Xiaodan Wu and Jie Long. 2022. "Assessing the Particularity and Potentiality of Civil–Military Integration Strategy for Space Activities in China." *Space Policy* 62: 101514.

22 Xinhua. 2024. "Xi Focus: Xi Presents Flag to PLA's Information Support Force." *Xinhua*, April 19, 2024. https://english.news.cn/20240419/58e7b3a4d1f043858a0d29fce5da4cf4/c.html

23 For a fuller discussion, see Stroikos, Still Lost in Space.

24 Chandrashekar, China's Space Programme, p. 229.

25 Clayton Swope. 2024. "No Place to Hide: A Look into China's Geosynchronous Surveillance Capabilities." Center for Strategic and International Studies, January 19, 2024. https://www.csis.org/analysis/no-place-hide-look-chinas-geosynchronous-surveillance-capabilities.

26 On India's space program, among others, see Marco Aliberti. 2018. *India in Space: Between Utility and Geopolitics.* Cham: Springer; Gopal Raj. 2000. *Reach for the Stars: The Evolution of India's Rocket Programme.* New Delhi: Viking; and Gurbir Singh. 2017. *The Indian Space Programme: India's Incredible Journey from the Third World Towards the First.* London: Astrotalkuk Publications.

27 S. Vijayasekhara Reddy. 2008. "India's Forays into Space: Evolution of Its Space Programme." *International Studies* 45 (3): 215–245.On the importance of the IGY, see Dimitrios Stroikos. 2018. "Engineering World Society? Scientists, Internationalism, and the Advent of the Space Age.
" *International Politics* 55 (1): 73–90.

28 Ajey Lele, *ISRO: Institutions that Shaped Modern India* (New Delhi: Rupa Publications India Pvt. Ltd., 2021), 7.

29 Reddy, India's Forays, p. 238; Lele, ISRO, pp. 23–40.

30 For a detailed discussion of this transformation of Indian space policy, see Rajeswari Pillai Rajagopalan and Dimitrios Stroikos. 2024. "The Transformation of India's Space Policy: From Space for Development to the Pursuit of Security and Prestige." *Space Policy* 69: 101633.

31 Dimitrios Stroikos. 2024. "Space Diplomacy? India's New Regional Policy under Modi and the 'South Asia Satellite.'" *India Review* 23 (1): 46–70.

32 This section draws from Stroikos, Still Lost, pp. 187-189.

33 Bharath Gopalaswamy. 2019. *Final Frontier: India and Space Secu-*

rity. Chennai: Westland Publications, 80–81.

34 Rajeswari Pillai Rajagopalan. "India's Space Strategy: Geopolitics is the Driver." *ISPI Online*, December 11, 2020. Available at: https://www.ispionline.it/en/pubblicazione/indias-space-strategy-geopolitics-driver-28607.

35 Stroikos, Still Lost.

36 On India's space partnerships, see Rajagopalan and Stroikos, the Transformation.

37 On International Relations theory and space, see Dimitrios Stroikos. 2022. "International Relations and Outer Space." *Oxford Research Encyclopedia of International Studies.* Available at: https://oxfordre.com/internationalstudies/view/10.1093/acrefore/9780190846626.001.0001/acrefore-9780190846626-e-699.

38 A detailed discussion of this section is provided in Stroikos, Still Lost.

39 Dimitrios Stroikos, "China, India, and the Social Construction of Technology in International Society: The English School Meets Science and Technology Studies," *Review of International Studies* 46, no. 5 (2020): 713–731.

Short Biography

Dimitrios Stroikos is Head of the Space Policy Programme at LSE IDEAS and teaches at the Department of International Relations, LSE. He serves as the editor of Space Policy: An International Journal. His research has appeared in such publications as Astropolitics, India Review, International Politics, Journal of Contemporary China, Review of International Studies, and Space Policy.

He has also co-edited the book Rising Power, Limited Influence: The Politics of Chinese Investments in Europe and the Liberal International Order (Oxford University Press). Stroikos holds a PhD in International Relations from LSE and an MSc in Chinese Studies from the University of Oxford, both supported by scholarships from the Greek State Scholarships Foundation (IKY).

Israel's Approach Towards Space Security & Sustainability[i]

Dr. Deganit Paikowsky

Citation: Paikowsky, D., Azoulay, T., Israel, I.B. (2020). Israel's Approach Towards Space Security and Sustainability. In: Schrogl, KU. (eds) Handbook of Space Security. Springer, Cham. https://doi.org/10.1007/978-3-030-23210-8_17

Abstract

In the last forty years, Israel developed an indigenous space capability to launch, develop, operate, and maintain satellites in two main niche areas: Earth observation and communications, including the ground segment of communications satellites. Israel's space program was born out of acute national security needs. However, it has led to the growth of commercial activity. In recent years, Israel has expanded its cooperation with international partners and established a civilian space policy backed by modest government funding. Space activities are contributing significant and cross-cutting benefits to Israel's national security. Within this context, Israel considers international space security, safety and sustainability to be of importance.

Keywords

Israel, space security, national security, strategic depth, early warning, deterrence, self-reliance, space policy, international cooperation.

Introduction

This chapter, a condensed form of a chapter published in 2020,[ii] analyzes Israel's overall approach to space security and posits that Israel's approach to space security may be described as threefold: 1. Promoting a robust and diversified space sector that provides for Israel's national security needs and (2) protecting and safeguarding Israel's space assets, while 3. Maintaining a safe and sustainable space environment.

Since its establishment, Israel has suffered from acute security threats beyond its immediate borders. Israel's space program was set to meet these threats by supporting early warning, intelligence, deterrence, and self-reliance in advanced technologies. Israel adopted a pragmatic approach to space as a small country with limited resources. Israel's pragmatic approach contends that its space program includes the capability to build, operate, and launch remote sensing satellites into space and develop and operate communication satellites. Israel does not undertake to build all systems entirely on its own. It has, for example, no navigation or weather satellites and no indigenous human spaceflight missions. However, Israel increasingly cooperates with international partners on projects of this nature and on scientific projects.

Beyond its security needs, Israel's long legacy as a spacefaring nation with a growing space ecosystem drives an orientation toward space security and sustainability. Therefore, Israel attributes great importance to securing the space environment for peaceful uses for all nations.

An Overview of Israel's Space Program considering its security conception

Understanding Israel's perception of space and space security demands an analysis of its national security conception.[iii] Israel's security conception is based on the understanding that it suffers from a significant quantitative inferiority against its rivals. To overcome this numeric disadvantage, Israel's leadership has focused on developing a qualitative edge. From this perspective, Israel's space program plays a significant role in the overall answer to its strategic challenges. First, Israel's space program provides significant tangible capabilities to deal with the threats imposed by Israel's enemies. Second, and equally important, a national space program, which includes the ability to develop and launch satellites into space, indicates very advanced national capabilities. Israel's achievements in space, whether civilian or military, project a clear message of national might. They emphasize the qualitative gap between Israel and its neighbors; they contribute to the country's accumulated achievements, aimed at deterrence; and philosophically, they reinforce the image of the «Iron Wall» in the eyes of its enemies, i.e. a phrase that in Israel's strategic culture means a power which cannot be overcome easily. All of that is accomplished without articulating an explicit military threat, which could provoke an unwanted and dangerous chain reaction in the region.[iv]

More specific and tangible is the role the space program fulfills in mitigating the challenge of Israel's lack of strategic depth and acute need for early warning caused by Israel's narrow borders. Under these geopolitical circumstances, it was necessary to avoid the elements of strategic surprise and sudden attack. For these reasons, Israel's security doctrine demands advanced intelligence capabilities for early warning, as well as combat capabilities for a rapid transfer of battle away from Israel's population centers. The orientation towards space assists Israel in coping with the challenges presented by the lack of strategic depth and the need to provide early warning.

With this in mind, the major impetus leading to the decision to embark on an independent Israeli space program was the 1979 Egypt-Israel Peace Treaty and the perceived need to protect Israel, including through the need to verify Egypt's compliance with the treaty. The treaty did not neutralize Israel's concerns of hostile Egyptian aspirations. Moreover, Israel was to withdraw from the Sinai Peninsula. The greater distance from Egyptian territory meant that the Israeli military lost much of its early-warning intelligence-collection capabilities, including the ability to carry out manned reconnaissance flights over the Sinai Peninsula, now part of the Egyptian sovereign state.[v] Therefore, there was a clear need for intelligence on what was happening in Egypt without violating its sovereignty. One potential solution to the early-warning problem was using reconnaissance satellites.[vi] In 1981, the Israeli space program was established based on a pragmatic approach aimed at satisfying national security needs of early warning, deterrence, and self-reliance in advanced technologies. In 1988, Israel successfully launched its first satellite, Ofeq–1. Ofeq would become a very successful line of increasingly advanced earth observation capabilities.

The opportunity to observe Earth from space is a technological solution that enables Israel to cope with threats from hostile countries directly bordering the country, as well as those that threaten Israel but are located farther away geographically. The Israeli Air Force Commander, Major General Amir Eshel, clearly explained the value of Israel's space capabilities as relates to strategic depth in 2013: "The threats we must deal with come from the border fence and from far away. Today, space is our strategic depth, and it is what allows us to maintain our qualitative advantage. Thanks to our indigenous satellites, our ability to operate at any distance increases tremendously.»[vii]

The issue of Israel's self-sufficiency is complex, and as a small country, Israel cannot be completely self-reliant. However, thanks to its space assets, Israel has a great deal of autonomy in the field of intelligence. Possession of independent intelligence capabilities has many implications for Israel beyond the intelligence field. It enhances the power of the state and its image in the eyes of its opponents as well as its allies. It provides flexibility, both in its ability to collect information and the resulting autonomy in decision-making. Independent capabilities also permit the country to conceal its operational plans and areas of interest and to collect information unhindered. The space program is an important building block of this capability.

Israel's space program also contributes to its deterrence. The following statement by Major General (Ret.) David Ivri, former Air Force Commander (1977-1982) and later Director General of the Ministry of Defense provides valuable insight into the role of the Israeli space program in Israel's deterrence strategy: "The perception of one's capabilities and one's willingness to use those capabilities are important components of deterrence. The perception of space capabilities is one of the primary components in Israel's future deterrence. Therefore, Ofeq 1, 2, and 3 contributed far more than anyone estimated. Imaging resolution is not the strategic measurement. Rather, the strategic measurement is the perception of capabilities that the State of Israel displays. Not what we possess, but rather what the enemy estimates that we possess. The gaps in capabilities and information, in the tactical field, miniaturization field, and others are an immeasurably important component in the dimension of our strategic deterrence."[viii]

Israel remains one of very few countries in the world with the capability to launch satellites into space. This is even though Israel is the only country that launches westward, against the rotation of the earth, to avoid launching over its neighbors to the East with which it has strained relations. Launching westward incurs a 'cost' of approximately one-third of boost efficiency, which leads to significant constraints on payload weight. Israel overcame this disadvantage by developing expertise in the miniaturization of components. This expertise was one of many that served the development of commercial space presence.

In the 1990s, Israel's space industry followed in the footsteps of many other technological sectors that were originally related to defense and began commercial spin-offs. As such, Israel developed commercial platforms such as the Amos communication satellite series, EROS remote-sensing electro-optical series, subsystems, and other equipment.

Israel's space activity has undergone a comprehensive change since 2012. In November 2009, a national task force was appointed to reexamine the Israeli space effort and recommend a new framework.[ix] The main mission of the task force was to focus on civilian applications and scientific activity that would allow Israel greater industrial scale and competitiveness in the growing world space market. A detailed report and recommendations were submitted in June 2010, outlining Israel's strengths, weaknesses, opportunities, and challenges for achieving its goals in space.[x] Scrutinizing all of these parameters, the argument was that Israel has great potential to lead in space technology in specific areas, but because of insufficient investments, Israel is in danger of gradually losing its competitive edge. In order to upgrade the scale of the local space industry, it was suggested that the Israeli government prioritize a national civilian space program focused on developing and renewing infrastructures, supporting academic research, and promoting international collaborations with other spacefaring nations. After careful review by the treasury officials, the Finance Ministry approved funding for Israel's new civil space program in December 2012. However, it was about a third of the recommended amount.[xi]

Nevertheless, based on this new funding, the space agency began implementing its new policy, geared towards R&D and modernization of its civilian space activities. Among its objectives were advancing the local space industry, strengthening academic research, and raising the Israeli public's awareness of space activities and research, as well as reinforcing and expanding international cooperation.

Israel is often referred to as the Start-Up Nation, and this is true for the space field as well. Following the impressive defense-related space advances and subsequent commercial space enterprises, a community of space start-ups emerged in Israel. Aside from these initiatives, various educational projects have evolved as well, such as the Herzliya Science Center for high school students. In 2014, this project launched its first nano-satellite, Duchifat-1, which was built by high school students[xii] Duchifat-2 was launched in 2017. In 2018, the Israel Space Agency initiated a wider project for high-school students that spread around the country. [xiii] This initiative led to establishing a dedicated research center for small satellites at Tel Aviv University.

A particularly profound educational initiative, albeit non-governmental, is SpaceIL. This project began as a competitor in the GoogleX Prize to land a spacecraft on the moon. Despite the later cancellation of the GoogleX Prize, SpaceIL continued and, in February 2019, launched its spacecraft aboard a SpaceX Falcon-9 launcher. Several weeks later it succeeded putting its spacecraft "Beresheet" into lunar orbit, making Israel only the 7th country to achieve this feat. Unfortunately, the landing was not successful, and the craft crash-landed on the lunar surface on April 11, 2019.

To conclude this part, the rationale for Israel's engagement in space activities described above reveals that Israel, which operates a successful space program on a modest budget, views space as a significant opportunity, especially as a force multiplier projecting the quality of force over its quantity in the broadest manner. This opportunity is accompanied by significant challenges, especially in maintaining its qualitative advantage and preserving Israel's position at the forefront of technology. The significance of space in Israel's strategic conception and its long-term and growing space capabilities in the defense, civilian, and commercial fields lead Israel to look for ways to protect its satellites and shape its perspective on space security. The next section provides an overview and an analysis of Israel's perspectives and activities regarding space security and sustainability.

Israel's Perspectives on Space Security and Sustainability

Israel attributes great importance to space security and sustainability. This interest extends beyond security needs and derives also from the desire to compete in the global space market and maintain a safe and sustainable space environment for all users. Should outer space become inaccessible and unsafe, this will negatively impact Israel's overall space activities.

At the heart of Israel's approach to advancing space security and sustainability is promoting a robust and diversified space sector that provides for Israel's national security needs and protects and safeguards Israel's space assets, systems, and capabilities. For example, the following statement was made by the Commander of the Israeli Air Force, Eliezer Shkedy, in 2007: «The operational importance of space is increasing constantly. Why is this field critical? There exists a concern that others who recognize its importance will try to attack space assets. We must consider defense measures against physical harm, jamming, blinding, or any other technique. One of the greatest surprises that can happen in the modern world, in advanced countries with space assets, is a situation in which a country is surprised to find its space assets damaged.»[xiv]

In addition to building assets and capacities, Israel values international cooperation. For example, in Space Situational Awareness (SSA). Israel signed a data-sharing agreement with the US STRATCOMM for Space Situational Awareness in 2015. This agreement enables Israel to benefit from the collective data of dozens of countries and many commercial entities to avoid collisions with satellites and space debris.[xv]

Israel's perspective on space security and sustainability is broad and concerns a safe and sustainable space environment for all users. To achieve this goal of greater space security and sustainability for all users, Israel is actively looking to contribute to a sustainable space environment. In this capacity, Israel shares the idea that achieving the goal of space security and sustainability requires international collaboration and the development of best practices for responsible behavior. In this regard, Israel recognizes the significance of contributing to multi-national efforts. An example of Israel's efforts to promote the responsible, peaceful, and safe use of space is its involvement in UN-COPUOS and its support of the LTS. Additionally, Israel favorably views legally non-binding efforts toward space sustainability. For example, Israel contributed to the consultations on the International Outer Space Code of Conduct.[xvi]

A final note

To summarize, Israel's space program was launched in response to national security needs. Over the years, with Israel's development and evolution as a country, its needs and capabilities have also evolved. Today, Israel has commercial, scientific, and civilian space assets and is expanding its involvement in international space cooperation. These developments, combined with increasing reliance on space for day-to-day activities and the nation's continuing security issues, make space security a concern for Israel and demand orientation to space sustainability from diverse perspectives and activities. For example, as Israel's local civil and commercial space activity grows and flourishes, there will be a greater need to update national space security and sustainability regulations. On the international level, as these global trends of advancing space technologies and reliance on space systems and capabilities continue to grow, the need to maintain the space environment safe and secured will only rise. Hence, Israel will continue to support global efforts to promote responsible behavior and pursue partnerships of this kind.

References

[i] The views expressed are solely the authors and do not reflect an official policy or opinion of any Israeli entity.

[ii] Paikowsky, D., Azoulay, T., Israel, I.B. (2020). Israel's Approach Towards Space Security and Sustainability. In: Schrogl, KU. (eds) Handbook of Space Security. Springer, Cham. https://doi.org/10.1007/978-3-030-23210-8_17

[iii] Ben Israel, I., and Paikowsky, D. (2017) The Iron Wall Logic of Israel's Space Programme. Survival 59(4):151-166

[iv] Ben Israel, I., and Paikowsky, D. (2017) The Iron Wall Logic of Israel's Space Programme. Survival 59(4):151-166

[v] Such flights were considered a violation of Egyptian sovereignty and were a very sensitive issue in the embryonic relations between the two countries.

[vi] For a review of the history of Israel's space effort see: Paikowsky, D., «From the Shavit-2 to Ofeq-1- A History of the Israeli Space Effort», *Quest*, Vol. 18, No. 4, Fall 2011, pp. 4-12.

[vii] Chanel, L. and Michael, T. (2013). *Ha Halal Hu Ha'Omek Ha'astrategi [Space as strategic depth]*. [online] Israeli Air Force.

Available at: http://www.iaf.org.il/4391-40401-he/IAF.aspx [Accessed 12 Jan. 2019].

viii Ivry, David (2006) 'Hahalal Kezira Estrategit Ba'avar, Bahove, Ve-ba'atid' [Space as a Strategic Arena in the Past, Present and Future]. Fisher Institute for Air and Space Strategic Studies :50

ix The task force was headed by Mr. Menachem Greenblum, Director General Ministry of Science and Technology and Prof. Isaac Ben Israel, Chairman of the Israeli Space Agency.

x Paikowsky D, Levi R (2010). *Space as a National Project – An Israeli Space Program for a Sustainable Israeli Space Industry, Presidential Task-Force for Space Activity Final Report*. Jerusalem: Israel Ministry of Science and Technology.

xi The Marker (2012) State will invest 90 million shekels in international space cooperation. https://www.themarker.com/news/macro/1.1826164. Accessed March 2 2019

xii Winer, S. (2017). *Nanosatellite built by Israeli high-schoolers blasts into space*. [online] Timesofisrael.com. Available at: https://www.timesofisrael.com/nanosatellite-built-by-israeli-high-schoolers-blasts-into-space/ [Accessed 1 Apr. 2019].

xiii More Information is available on the Israel Space Agency website: https://www.space.gov.il/news-space/131327 Accessed on April 15, 2019.

xiv Shkedy, E., General, (2007), Address at the 2007 Ilan Ramon Annual Space Conference, Fisher-Institute for Strategic Air and Space Studies, Herzliya.

xv Pomerleau, M. (2019). *Stratcom expands space surveillance with Israel agreement — Defense Systems*. [online] Defense Systems. Available at: https://defensesystems.com/articles/2015/08/13/us-stratcom-israel-space-surveillance-agreement.aspx [Accessed 9 Jan. 2019].

xvi For the updated version of the European initiative of the Outer Space Code of Conduct dated June 2012 please see: http://www.consilium.europa.eu/media/1696642/12_06_05_coc_space_eu_revised_draft_working__document.pdf

Short Biography

Dr. Deganit Paikowsky is an expert in international relations, specializing in the intersection of global politics and technological domains, with a focus on space, cyber, and emerging technologies. She is a Senior Lecturer in the Department of International Relations at the Hebrew University of Jerusalem, where she leads the Techno-Strategic Research Lab.

Dr. Paikowsky is also a Non-resident Scholar at the Space Policy Institute at George Washington University. Her work bridges academic research and practical policy experience. She has played a key role in shaping space and cyber-security policies in Israel, including serving as Vice President of the International Astronautical Federation (IAF) on behalf of the Israel Space Agency.

Dr. Paikowsky is the author of The Power of the Space Club (2017) and other significant publications on space policy, security, and governance.

The Space Program of Turkiye

Lt. Colonel Panagiotis Katsaounis

Citation: *Lt. Colonel Panagiotis Katsaounis. (2025). The Space Program of Turkiye. Hellenic Air Force Review, 134. https://doi.org/10.5281/zenodo.15166530*

"The only way to ensure justice in the world is to exist in space in a powerful manner"

Recep Tayyip Erdogan (February 2021)

Abstract

From the launch of the first satellites (1950s) to the modern era, progress in the exploration and exploitation of space for political, scientific and military purposes has been rapid. As access to space becomes more affordable, so too does the effort of states to exploit it.

In addition, space is considered one of the dimensions of the unified battlefield and its use can give a military force significant advantages.

The 10 objectives of the Turkish space program emphatically state that Turkey is seeking a new, upgraded role in the world. Despite the fact that the development of autonomous space capabilities by Ankara requires significant funding, which is seriously hampered by the serious problems of the Turkish economy (high inflation, devaluation of the national currency, etc.), the main axes of the Turkish space program are being implemented, albeit with a delay.

Taking into account Turkey's capabilities in the space sector, the development of national space capabilities by our country (Greece) in the field of telecommunications and earth observation satellites is a one-way street, in order to compensate significantly for the advantages that the Turkish Armed Forces (TAF), currently possess.

Keywords

Turkiye, National Space Program, Autonomous Space Capabilities, Soft Power

Introduction

From the time of the launch of the first satellites[1] and the subsequent rivalry between the two superpowers, the USA and the former USSR, to modern times, progress in the exploration and exploitation of space for political, scientific and military purposes has been and remains rapid.

Moreover, space is considered one of the dimensions of the modern unified battlefield, hence it should be taken into account in the planning and conduct of operations, since they depend on the exploitation of the capabilities provided by existing satellite systems, which gives significant advantages to a military force that exploits it.

A characteristic example of the importance of space is the continuous increase in investments, at the level of governments worldwide, which for the year 2024 amounted to approximately 135 billion dollars[2], representing a 10% increase compared to 2023. Of the above amount, spending related to defense constitutes the majority of budgets ($73 billion, percentage 54%), underlining the strategic importance of space.

strengthen their economies and international partnerships, and enhance their reputation on the international stage.

- Space activities enhance innovation, paving the way for the use of new inventions and technologies in various fields. As space programs are not limited to space, they increase employment and productivity in all sectors.

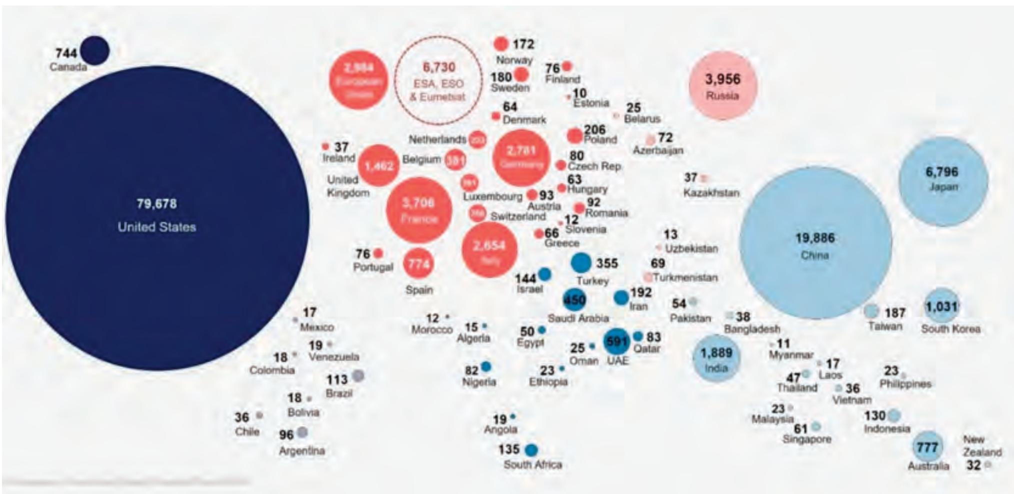


Figure 1: Government Space Programs (GSP). Amounts in millions of dollars. Source: Novaspace

The main reasons for the surge in investment in space programs are:

- Space programs do indeed have very high costs for countries budgets. However, the achievements, fame and power gained as a result of implementing such programs, make the costs negligible.

- Space programs increase the geographical value of countries, add to their technological capabilities,

- Space-related activities make people's lives easier in many ways, including:

- With the production of microscale satellites, observation has become possible, increasing productivity in many sectors, especially in the agricultural sector.
- Thanks to the capabilities of observation satellites, it is now

possible to monitor natural resources, transport networks, etc., in real time.

- Remote sensing satellites provide real-time information for national defense purposes (intelligence gathering, early warning of missile threats, targeting, etc.).
- Communication satellites are also used to transmit TV and radio signals and in other communication sectors-areas (civil-military), such as internet access.
- In the near future, communication satellites will allow access to high-speed internet connections everywhere in the world.
- Location and time information can be collected at any time in the world in a fast and accurate way.
- In the coming years the space economy will further develop in areas such as space tourism, space mining, etc.

Brief History

Turkey's satellite program was launched in 1989 and aimed at acquiring national capabilities in the field of satellite communications. In this context, Turkey has been developing the TÜRKSAT program since the 1990s when it launched its first communication satellite named TÜRKSAT-1A on 24 Jan 94, but it crashed into the sea about 12 minutes after the launch due to a problem with the launch vehicle's propulsion rocket.

In the same year Turkey launched the communications satellite TÜRKSAT-1B, and in 1996 it launched a satellite of the same type, TÜRKSAT-1C. The above satellites ceased operations in 2006 and 2010, respectively. Since 1995, the Turkish government set the objective of establishing a central structure for space policy-making, followed by political processes, proposals, decisions and bills, which came to fruition on 13 Dec 18, when a Presidential Decree established the establishment and operation of the Turkish Space Agency (Türkiye Uzay Ajansı/TÜA).

TÜA is the government agency for national aerospace research. It is based in Ankara and comes under the Ministry of Science and Technology. With its establishment, the Department of Aviation and Space Technologies in the Ministry of Transport and Infrastructure was abolished. TÜA prepares strategic plans that include medium and long-term goals and priorities, key principles and methods to be followed and resource allocation for aerospace science and technologies. TÜA co-operates closely with the TÜBİTAK (Space Technology Research Institute).

The main institutions and companies involved in Turkish satellite programs and space policy, apart from TUA, are TAI, ASELSAN and the Turkish Defense Industry Presidency (SSB), with the latter two companies having a major role in satellite programs used for military purposes.

On 09 Feb 21, Turkish President R.T. Erdogan presented the National Space Program at the Turkish Presidency's Conference and Cultural Center (BEŞTEPE MİLLET KONGRE VE KÜLTÜR MERKEZİ). The main objectives of the Turkish Space Program are:

- On the 100th anniversary of the establishment of the Republic of Turkey, participation of a Turkish astronaut in an international space mission.
- Establishment of a satellite production company.
- Establishment of a launch site within the Turkish territory and on the territory of a third country (Somalia).
- Increase in space capabilities through research and development of expertise in space weather and meteorology.
- Development of an Earth-based meteor and planetary observation capability.
- Conduct integrated studies by the space industry.
- Establishment of a space center and a space technology development zone.
- Providing undergraduate and postgraduate space education
- Creation of Turkish GPS.

Figure 2: The 10 objectives of Turkey's space program. Source: Anadolu News Agency.

Recent Developments

Satellite Launches

The developments of the last five years regarding the launch of Turkish satellites are as follows:

- In 2021, 2 communication satellites were launched, TÜRKSAT-5A (08 Jan 2021) and TÜRKSAT-5B (20 Dec 2021). TÜRKSAT-5B was launched in December 2021 from Florida, USA on SpaceX's FALCON 9 rocket and serves as a backup for the TÜRKSAT-3A (launched in 2008) and TÜRKSAT-4A (launched in 2014) satellites.

Figures 3-4: The communications satellites TÜRKSAT-5A and 5B Source: TUA

- On 24 Jan 21 the launch of the domestic mini observation satellite ASELSAT-3U took place. The launch was carried out by the American private company SpaceX. ASELSAT-3U collects data on the space environment and transmits them to a ground station.

Photo 5: The ASELSAT-3U satellite Source: TÜA

- On 13 Jan 22, the experimental satellite Pocket Qube (5X5X5 cm and weight 237 grams), a Turkish-made experimental satellite called Grizu-263A, was launched from Cape Canaveral, USA. The satellite was designed by the Grizu-263 Space Team of the Faculty of Engineering of Bulent Ecevit University (BEU).

Photo 6: The Grizu-263A nanosatellite
Source: NanoSats Database

- On 15 Apr 23 earth observation satellite IMECE (built by the Turkish company TUBITAK UZAY) was launched.

Photo 7: IMECE earth observation satellite
Source: TÜA

- On 09 July 24 the communications satellite TURKSAT-6A (built by the Turkish company TÜBITAK UZAY) was launched.

Photo 8: The communications satellite TÜRKSAT-6A Source: TÜBITAK UZAY

-On 14 Jan 25, Fergani Space, a company founded in 2022 by Selcuk Bayraktar, President of the Turkish company Baykar (manufacturer of the BAYRAKTAR and AKINCI UAVs), announced the successful launch of the FGN-100-d1 satellite from the Vandenberg space base in the USA. The 102-kilogram satellite is part of Fergani Space's ambitious Positioning Satellite Constellation Project.

FGN-100-d1 was launched along with other satellites as part of the Transporter-12 mission, through a Rideshare program. Its operation began immediately, transmitting telemetry data and implementing the first step of an ambitious plan to complete a Turkish geolocation satellite system.

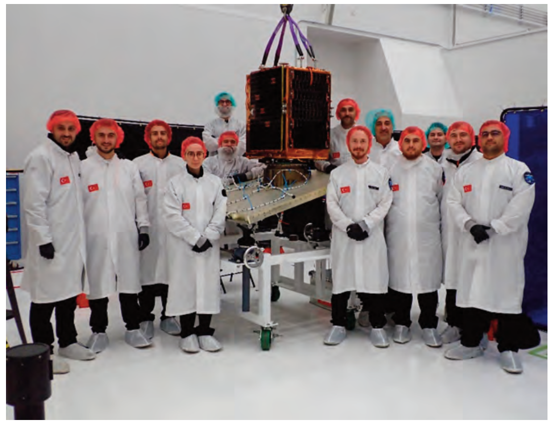


Photo 9: The FGN-100d1 satellite. Source: FERGANI SPACE

Turkey has so far launched a total of:

- Eleven (11) communication satellites, of which 6 are in operation (TÜRKSAT-3A/4A/4B.5A,5B and 6A).

- Five (5) earth observation satellites, of which 3 are operational (GÖTURK I and 2, IMECE).

- Three (3) satellites of various types (ASELSAT-3U, GRIZU-263A and FGN-100d1), which are in operation.

It is worth noting that both the communication satellites and the remote sensing satellites have a dual use since they are used for civil and military purposes (a percentage of their resources, which varies depending on the satellite, is used exclusively by the Turkish Armed Forces).

Staff Training

In the context of making the Turkish space program as independent as possible from foreign sources, Turkey has sought and is seeking to train appropriate personnel in space technology. Thus, postgraduate space degree programs have been established at the Turkish Aviation Academy as well as Know How Technology Transfer programs from the British SSTL (Surrey Satellite Technology Ltd). At the same time, TÜBİTAK funds scholarships for postgraduate and doctoral studies abroad (TÜBİTAK BİDEB 2213 and 2230 Scholarship Programs).

Creation of a Space Station in Somalia

According to Turkish and international media, Turkey will build a space station in Somalia to carry out missile tests and long-range launches.

The decision to build this facility in Somalia is attributed to its proximity to the equator, a location that is advantageous for missile launches due to its lower fuel requirements and better payload capacity. Somalia is one of the three ideal locations for launches near the equator, along with Kazakhstan's Baikonur Cosmodrome and the launch complexes used by NASA and SpaceX in Florida, USA.

The planned project follows a maritime exploration agreement in the African country's EEZ by a Turkish seismic survey ship and marks a deepening of relations between the two countries. It will be recalled that Turkey has built and operates a large military base in Somalia.

Future Developments

Turkey remains committed to its space program in all areas of space applications, building and designing new satellites for both civil and military purposes. At the same time, it is seeking to develop indigenous capabilities in areas where it does not yet have sufficient expertise.

In particular, Turkey has for years set itself the goal of acquiring autonomous space capabilities in at least two areas, the development of satellite platforms and the development of payloads for communications, reconnaissance (optical, IR and RADAR) and tracking/navigation purposes.

Its intention is that by 2028 it will be able to use its own satellite launchers in order not to be dependent on other countries or private companies. The rockets are planned to be launched from the space station to be built in Somalia, as mentioned above.

The Turkish space program has as its main future goal the landing of an unmanned spacecraft with a national hybrid rocket. In this context, a test vertical launch of a hybrid rocket carrier (SORS) was successfully carried out on 19 Jul 21. The launch was carried out from Sinope, while the first vertical propulsion test of the SORS hybrid rocket carrier was carried out on 11 Apr 21.

The ultimate goal of the space program is to send a Turkish astronaut into space or to carry out a Turkish scientific mission to the Moon, manned or unmanned, within the current decade.

As far as the creation of a Turkish GPS is concerned, the milestone is the launch of the FGN-100d1 satellite, while the desired end state is the ability to provide dedicated positioning information in areas such as transport, communications and military operations.

For the coming years there are plans for the new TÜRKSAT 7 series of telecommunications satellites, as well as new telecommunications satellites, both in geostationary and earth orbit. As far as new systems are concerned, an exclusively military telecommunications satellite for use by the TEDs only (MAHU: Milli Askeri Haberleşme Uydusu) is already in the planning stage. For the first time, the military satellite will have UHF-Band and EHF-Band transponders developed by ASELSAN.

Another area under consideration is the development of a Space Surveillance System. This system is related to ground-based space surveillance which is necessary for those countries that have made a significant investment in their space infrastructure, since satellites are valuable assets that need to be protected from a number of events such as collision with each other, avoidance of space debris, etc. For this reason, Turkey, like other countries, and the EU (with the Space Situational Awareness-SSA system) intends to develop a space situational awareness capability by deploying ground-based RADARs.

TÜBİTAK UZAY (SPACE), with the experience gained from the management of earth observation satellites, has a national program underway to develop ground stations for earth observation satellites [Milli Yer Istasyonu Gelistirme Projesi (MİYEG)]. The aim of this program is also to develop a station that will be able to cooperate with all types of satellites.

Capabilities - Advantages at Military Level

Turkey's space program and in particular the capabilities provided to the Turkish Armed Forces, the services of Turkish satellites, give significant advantages both in the planning and in the phase of conducting operations, such as:

- Communication satellites provide the possibility of continuous communication of troops and assets, regardless of the communication difficulty and distance. They are an important part of the Command, Control, Communications and Intelligence (C3I) function which aims to ensure uninterrupted communications in the theatre of operations with high security. Timely transmission of orders ensures a common understanding of the current operational situation and contributes to effective Command and

Control. It promotes interoperability since everyone communicates with everyone in a short time. This ensures short response times, seamless flow of information and timely information for decision making, achieving centralised control and decentralised execution.

- The use of communication satellites provides the possibility of becoming independent of vulnerable and expensive land lines, coupling nodes or submerged submarine cables and relay stations, which require high maintenance costs in peacetime and can be destroyed either by attack or sabotage in times of operations.

- The use of TÜRKSAT telecommunication satellites by the Turkish Armed Forces units ensures the ability to transfer tactical data and imagery over the horizon, under any conditions, from multiple platforms (e.g., aircraft, FMS) and to any Command and Control Centre. Satellite linking capabilities upgrade the operational capabilities of Turkish UAVs (UAVs) by increasing the range of action by ensuring deep penetration missions beyond the horizon (BEYOND LINE OF SIGHT - LOS). This facilitates intelligence gathering and early threat detection, while providing the military hierarchy with the ability to fully understand the current joint operational picture in a short time, which in turn facilitates the decision-making process and the conduct of operations.

- The uninterrupted operation of satellite telecommunications by the TDFs, and indeed in a secure manner, enables military units and assets to be deployed over long distances from their bases, especially in isolated areas, thus extending their area of operations.

-Peacetime remote sensing satellites have been contributing to the collection of information on the enemy by obtaining high-resolution satellite images. Satellite images provide information on terrain, layout and facilities, thus facilitating the targeting process. At the same time, the use of national remote sensing satellites ensures secrecy as to the type of information nationally sought.

- In times of crisis, remote sensing satellites enable early detection of any military preparations, troop movements and asset redeployments, revealing enemy intentions and movements, thus contributing to the prevention of strategic surprise.

- In the course of operations, early identification of the battle layout enables the disclosure of enemy intentions and feeds back the targeting process, especially when identifying high value and priority targets, while facilitating the assessment of post-attack effects (Battle Damage Assessment - BDA). Military installations, defensive protection assets and critical infrastructure (power stations, oil refineries, airports, bridges, telecommunication infrastructure, etc.) are identified and inter-agency coordination is facilitated.

- Possible future use by the Turkish Armed Forces of new satellite systems capable of providing GPS services will enable complete independence from third country satellites and ensure uninterrupted operational use of high-tech and lethal GPS/INS-guided missiles and munitions.

Capabilities at Political Level

Turkey, as part of its strategic goal to become a global power, has expanded the coverage area of its telecommunications satellites, covering communication areas in North, Central and Southern Africa, Asia and the Middle East, thus facilitating Turkish penetration in the framework of «soft power» in countries and regions of interest.

Ankara's continuous effort to create autonomy in terms of space capabilities is also aimed at gaining economic benefits and creating dependency relations with third countries to which space services will be provided. Therefore, it is expected that in the near future Turkey will seek to commercialize its space capabilities, as its ultimate goal is to become a country that will produce and launch satellites, exporting related technology and providing space services.

Challenges - Weaknesses

Despite its space ambitions, Turkey faces many challenges. Space exploration requires financial resources, high-tech infrastructure and a skilled workforce. Managing these costs while balancing other national priorities will be of key importance for Ankara.

The economic constraints resulting from the state of the Turkish economy (high inflation, continuous devaluation of the national currency, etc.) may have a negative impact on the funding of Turkey's space program, preventing it from achieving its objectives.

In addition, possible cooperation with China and Russia on the International Lunar Research Station could further complicate Turkey's relations with Western allies.

Overall, while Turkey is pursuing technological advancement and national prestige through its space program, its economic aspects and geopolitical alliances present challenges that could lead to friction with Western alliance partners.

Challenges for Greece

Turkey's space program is bound to pose challenges for Greece, at least at the military level.

The neutralization of Turkish satellites in wartime is considered challenging by Greece, since it is estimated that countries with high space technology capabilities such as the US, Russia, China, etc. have the ability to attack and destroy enemy satellites.

For this reason, it is estimated that measures should be considered to limit the impact of the satellite capabilities of the Turkish Armed Forces, such as:

- Locating and recording as far as possible the transit times of Turkish earth observation satellites over Greek territory, so that on the one hand our country's ED can significantly limit the movement of forces and appropriate measures are taken to conceal military units and assets.

- Wide use of homologated weapons systems and assets.

- Meticulous concealment of weapon systems and means by appropriate means of camouflage, in order to make it difficult to identify them in terms of their number, deployment locations and type.

- Taking into account that in a period of operations part of the movements of military forces and means, due to the speed of the operations, will take place in good weather conditions and therefore may be perceived by the enemy, it is necessary in all phases of the battle and at all levels of command to plan and implement plans and actions of deception in order to create confusion for the enemy, difficulty in making a decision and fragmentation of his forces, which is necessary especially when facing an opponent with greater numerical strength.

Conclusions

The Turkish space policy is a long-term one, and has been a long-standing government priority since the 1990s, which, despite any delays, has been implemented consistently, at least in its main axes.

Turkey has maintained a largely harmonized national approach, characterized by a common vision and culture, and close cooperation between the relevant ministries, research organizations and the academic community, as well as the domestic and international aerospace industry.

Turkey's main objectives are to be present in all space themes, to be oriented towards serving foreign policy, security and defense needs and to strive for autonomy through indigenous design and production of satellite systems.

The main areas in which it has focused are the development of telecommunications, earth observation satellites and positioning-navigation satellites. These satellites have a dual use since they are used for both civil and military purposes.

The Turkish plan to develop space capabilities places particular emphasis on the training of personnel in order to create a 'pool' of qualified personnel and then to use them appropriately.

Turkey, in the context of its strategic objective to become a global power, has expanded the coverage area of its telecommunications satellites, covering communication areas in North, Central and Southern Africa, Asia and the Middle East, thus facilitating Turkish penetration in the framework of «soft power» in countries and regions of interest. Ankara's continuous effort to create autonomy in terms of space capabilities is also aimed at gaining economic benefits and creating dependency relations with third countries to which space services will be provided.

Given Turkey's capabilities in the space sector, the development of national space capabilities by Turkey in the field of communications and observation satellites and in the field of space in general is a one-way street, since space is gradually becoming, among other things, a new dimension of the unified battlefield, in order to compensate significantly for the advantages that the Turkish Armed Forces currently possess.

References

[1] Official Website of Turkish Space Agency (TÜA) https://tua.gov.tr/en

[2] Novaspace emerges from the combined strength of Euroconsult and SpaceTec Partners https://nova.space/about-us/

[3] Turkey's Space Ambitions: Entering the Global Space Race https://www.turkeytribune.com/el/turkey-space-ambitions/

[4] Impact of Turkey's Space Program on the Security Environment in CENTCOM's AOR https://nesa-center.org/impact-of-turkeys-space-program-on-the-security-environment-in-centcoms-aor/

[5] Defense Spending Drives Government Space Budgets to Historic High https://nova.space/press-release/defense-spending-drives-government-space-budgets-to-historic-high/

[6] Turkey's space ambitions «launched» in Somalia https://www.militaire.gr/oi-diastimikes-filodoxies-tis-toyrkias-quot-ektoxeyontai-quot-sti-somalia/

[7] Turkey's space program: The invisible threat https://e-amyna.com/%CF%84%CE%BF-%CE%B4%CE%B9%CE%B1%CF%83%CF%84%CE%B7%CE%BC%CE%B9%CE%BA%CF%8C-%CF%80%CF%81%CF%8C%CE%B3%CF%81%CE%B1%CE%BC%CE%

BC%CE%B1-%CF%84%CE%B7%CF%82-%CF%84%CE%BF%CF%85%CF%81%CE%BA%CE%AF%CE%B1%CF%82/

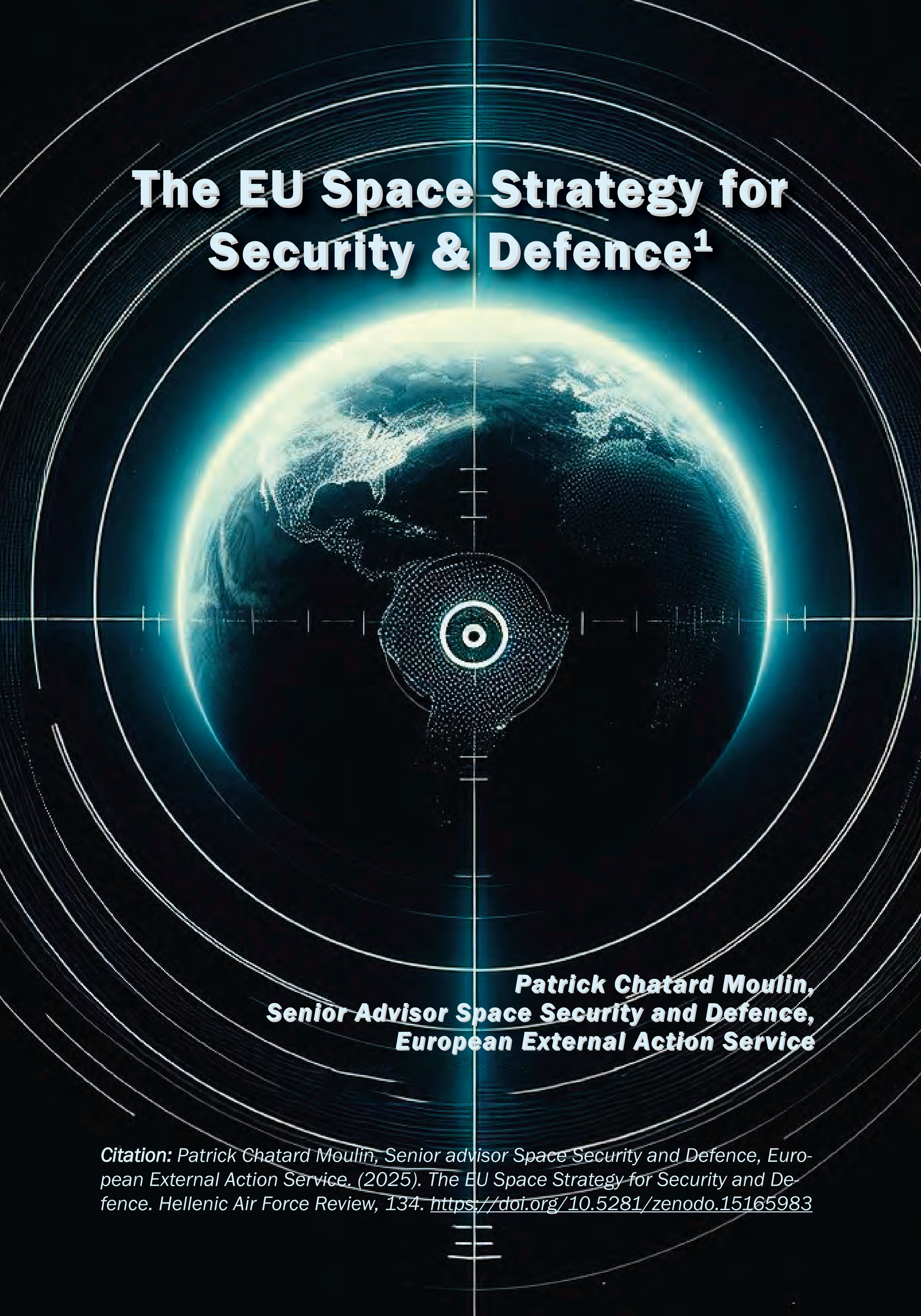
1 On 04 October 1957 the first satellite (SPUTNIK-1) was launched by the USSR

2 Source: https://nova.space/press-release/defense-spending-drives-government-space-budgets-to-historic-high

Short Biography

Lieutenant Colonel Panagiotis Katsaounis serves at Hellenic General Staff of the Army (HAGS) as an Intelligence Analyst. He has been trained in the fields of Intelligence Collection and Analysis, Counter-Intelligence, Cyber Defence, Counter-Terrorism and Strategic Communication.

In addition, he lectures as a military instructor on subjects related to his specializations at numerous Armed Forces Schools, such as the Army Land Warfare School, the Air Force Warfare School, etc.



The EU Space Strategy for Security & Defence[1]

Patrick Chatard Moulin,
Senior Advisor Space Security and Defence,
European External Action Service

Citation: *Patrick Chatard Moulin, Senior advisor Space Security and Defence, European External Action Service. (2025). The EU Space Strategy for Security and Defence. Hellenic Air Force Review, 134.* https://doi.org/10.5281/zenodo.15165983

Abstract:

In 2022, EU leaders identified space as a strategic domain in the Strategic Compass and called for an EU Space Strategy for Security and Defence. In a joint endeavour between the European Commission and the High Representative, the first EU Space Strategy for Security and Defence (SSSD) was published in 2023. The Strategy establishes a foundation for a shared understanding of space threats among EU Member States and enhancing the resilience and protection of space systems and services of the EU. It outlines measures for responding to space threats, strengthening the use of space for security and defence, and promoting partnerships to encourage responsible behaviour in space. This article explores the development of the SSSD and the EU's recognition of space as a strategic domain, outlining its main pillars and reporting on the current state of implementation. Moreover, it explores the evolving role and growing significance of a coherent EU space strategy amid changing geopolitical dynamics.

Keywords:

EU Space Policy; Space Strategy; Strategic Compass; Space Security and Defence; Space Threats; Space Diplomacy

Introduction

Space services have become indispensable and integral to the daily functioning of our societies and economies. At the same time, space has always involved a security and defence dimension. Space is a critical enabler of modern warfare, providing vital intelligence and situational awareness capabilities that allow for near real-time tracking of troop movements and manoeuvres, precision guidance, as well as communications services. These are crucial for ensuring swift and coordinated military responses on the battlefield: The Ukrainian army, for example, in its continued fight against Russia's war of aggression makes extensive and decisive use of space systems every day.

As space is becoming more and more essential, space systems and services also become targets. Over the recent decades, the number of space threats has intensified significantly. Several nations have developed so-called counter space capabilities, which cover a range of abilities for disrupting, degrading, destroying, or denying the use of space systems.

Space is now regarded as a strategic domain. In 2019, the North Atlantic Treaty Organization (NATO) for the first time recognized space as its fifth operational domain, next to air, land, maritime, and cyberspace. Following several discussions among EU leaders, the EU Strategic Compass,[1] formally approved by the EU and its Member States in March 2022, also referred to Space as a strategic domains and called for a European Union Space Strategy for Security and Defence (SSSD).

A few months later, in the eve of the Russian invasion, a number of threats in the space domain became reality: A major SatCom infrastructure was cyber-attacked by Russia, and the supply of launchers and other key components of the EU space programmes became more difficult. A few years after having destroyed one of their own satellites with an anti-satellite missile back in November 2021, a test which was widely condemned, Russia started to publicly declare threaten commercial satellites used by Ukraine to defend itself.

The Genesis of Space Strategy for Space Security & Defence

The preparation of the EU Space Strategy for Space Security & Defence mobilized a lot of relevant actors across EU institutions and Member States. In its format of a Joint Communication, the SSSD was a joint endeavour between the European External Action Service (EEAS) serving the High Representative for Foreign Affairs and Security Policy and the Directorate General for Defence Industry and Space (DG DEFIS) of the European Commission. Further expertise was supplied by the European Defence Agency (EDA) as well as the European Union Military Staff (EUMS). The EU Member States were involved throughout the entire process through a series of informal consultation workshops, briefings as well as bilateral exchanges. Consultations of the space industry, think tanks, and academia also provided very useful inputs.

Few month after the Joint Communication on the SSSD was adopted the Council adopted Conclusion and the European adopted a Reports both of which were very supportive to the proposed action of the strategy.[2]

Understanding Space Threats

The first element of the SSSD addresses the scope and what we understand as ‘space domain’ which “*includes any element relevant for the functioning of space systems and the delivery of space-based services in the EU and the Member States*”. Importantly, this definition not only encompasses the space environment and space-based assets such as satellites, but also ground facilities, radio frequency links, user terminals, as well as the industrial space sector and their underlying supply chains.

The first actions envisaged in the strategy relate to awareness and the need to develop a strategic culture of space security across Europe. The SSSD emphasises the importance of a shared understanding of space threats. The EU now provides an annual, classified analysis of the space threat developments based on the intelligence contributions by the EU Member States.

Increasing the resilience of the European Space sector

The SSSD then addresses the need to increase the resilience and the protection of space systems delivering services to the EU. This goes beyond the systems and services of the EU Space Programme, such as the Galileo navigation system and the Copernicus earth observation system: The European Commission and its EU Agency for the Space Programme is working with the EU industrial space sector to increase both security awareness and the exchange of best practices through so-called Information Security Awareness Centres (ISACs). The Commission is also preparing a new European Space Act to shape a European internal market of space systems and services, with a view to ensure a level playing field for security, sustainability, and resilience across the EU.

Responding to Space Threats

The EU also needs to deter others from threatening the EU and its Member States' space systems and services. To this end, the SSSD proposes to further develop the EU Space Threat Response Architecture originally established to ensure security of systems and services deployed, operated and used under the Union Space Programme which may affect the security of the Union. The High Representative will propose to amend the existing legal framework to ensure an even more thorough and swift EU-level reaction to a wider range of space threats through a toolbox for countering space threats using diplomatic, technical, economic, and potentially military responses. Such a mechanism would complement and interoperate with the already existent cyber diplomacy and hybrid toolboxes. The EU regularly exercises its response to space threats along with the mutual defence clause (Article 42.7 TFUE), in case a space incident would amount to an armed aggression on the territory of a Member State.

Enhancing the use of space for security and defence

The SSSD also addresses the need to make better use of the space systems and services for security and defence. This includes capabilities such Galileo's Public Regulated Service (PRS) for military-grade positioning and timing, a strategic enabler for military operations, or how sensor development can support the national Space Domain Awareness capabilities of our Member States. The new flagship IRIS^2, which will provide secure and highly resilient communications to Member State governments, is set to become fully operational by 2030. Meanwhile, the GovSatCom component of the EU Space Programme already helps with the pooling and sharing of Governmental Satellite Communication capabilities of EU Member States.

Earth Observation is also essential for security and defence: Copernicus is a success story of the European Space programme but its main purpose relates to environmental monitoring and climate change. The SSSD now calls for the establishment of a dedicated EU Earth Observation Governmental Service (EOGS) in order to ensure a highly resilient and continuously available situational awareness service in support of high-end security and defence applications. This new capability would help increase the strategic autonomy of SatCen, the EU's geospatial intelligence centre, our eyes in orbit in support of the EU's common security, defence and foreign policy CFSP and CSDP.

External engagement

Finally, the SSSD highlights the essential role of partnerships to ensure responsible behaviour in space. The EU is committed to preventing an arms race in outer space both because it would prevent the use of space for future generation and because it could dangerously amplify tensions, given the strategic nature of space. The EU, as permanent observer in the United Nations (UN) supports its Member States in relevant discussions, particularly in the newly established Open-Ended Working Group on Preventing an Arms Race in Outer Space. The EU frequently addresses space security issues as part of dedicated EU dialogues with third countries. Such dialogues help coordinate efforts with our partners and allies, share our vision of peaceful uses of outer space, and the establishment of relevant diplomatic channels to avoid miscalculation.

NATO is an essential partner. In December 2023, the EU and NATO launched a Structured Dialogue to explore cooperation in areas including space security, the need for education and training, as well as responsible space behaviours.

Conclusion

Since the adoption of the SSSD in 2023, the geopolitical context has considerably evolved and the risks did not decrease. For the first time since the adoption of the Outer Space Treaty, a resolution on space security was brought to the attention of the UN Security Council, reminding us of the risks posed by the possible deployment of nuclear weapons in space.

In this context the reports of the Sauli Niinistö on Strengthening the Europe's Civilian and Military Preparedness of 2024,[3] as well as of Mario Draghi on the Future of European Competitiveness in September 2024 refer to the importance of Space.[4]

To implement all of the above action, Europe needs to revisit its approach of space cooperation. We need to train and educate our workforce and industry in space security and defence, enable the EU to protect its interests, reduce dependency on external partners, and strengthen our strategic autonomy in an increasingly competitive global landscape.

[1] *This article is the abstract of the presentation delivered on 28 November 2024 at the Hellenic Air Force Academy, as part of the Common Module on Space Applications for Security and Defence 2024. The event was organised under the auspices of the European Security and Defence College (ESDC) of the European Union.*

References

1 Council of the European Union, "A Strategic Compass for Security and Defence - For a European Union that Protects its Citizens, Values and Interests and Contributes to International Peace and Security", 2022. Available: https://data.consilium.europa.eu/doc/document/ST-7371-2022-INIT/en/pdf

2 European Commission and High Representative of the Union for Foreign Affairs and Security Policy, «Joint Communication to the European Parliament and the Council on the European Union Space Strategy for Security and Defence,» JOIN(2023) 9 final, Brussels, 2023

3 Niinistö, Sauli. Safer Together: Strengthening Europe's Civilian and Military Preparedness and Readiness. European Commission, 30 Oct. 2024, https://commission.europa.eu/document/download/5bb2881f-9e29-42f2-8b77-8739b19d047c_en?filename=2024 _Niinisto-report_Book_VF.pdf.

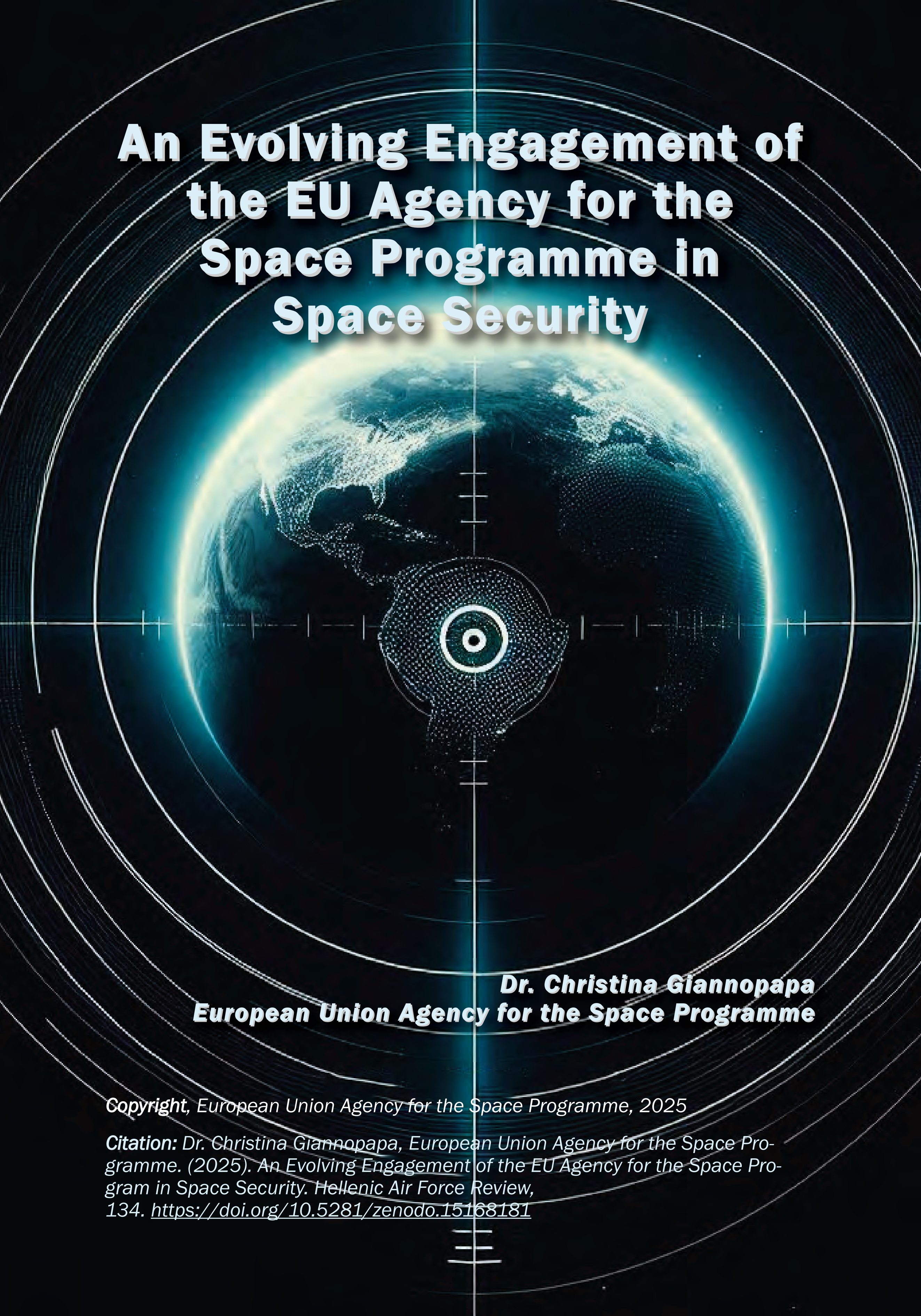
4 Draghi, Mario. The Future of European Competitiveness. European Commission, 9 Sept. 2024, https://commission.europa.eu/topics/eu-competitiveness/draghi-report_en.

Short Biography

Patrick Chatard Moulin is Senior Adviser on Space Security and Defence at the European External Action Service (EEAS), focusing on space security, defence, and international aspects of European Space Policy.

With 15 years of EU experience, he has worked on initiatives such as Space Surveillance, GOVSATCOM, and EU SatCen. He joined the European Defence Agency in 2005, launching co-operative projects, before serving in the EU's General Secretariat of the Council and DG GROW's Space Policy unit.

From 2017 to 2021, he oversaw EUROSUR and contributed to drafting the European Border and Coast Guard Regulation at DG HOME. A former French Air Force Engineering Officer with over 15 years of service, Patrick graduated from the French Air Force Academy and Telecom Paris as a SATCOM Engineer. He is an International Space University alumnus and guest lecturer.



An Evolving Engagement of the EU Agency for the Space Programme in Space Security

Dr. Christina Giannopapa
European Union Agency for the Space Programme

Citation: *Dr. Christina Giannopapa, European Union Agency for the Space Programme. (2025). An Evolving Engagement of the EU Agency for the Space Program in Space Security. Hellenic Air Force Review, 134. https://doi.org/10.5281/zenodo.15168181*

Abstract

The EU Space Programme integrates security and defence considerations, marking a significant transformation in the Union's strategic posture and strategic autonomy, reducing dependence on non-EU space systems and ensuring uninterrupted access to critical space-based services. At the heart of this evolution lies the European Union Space Programme and European Union Agency for the Space Programme (EUSPA). EUSPA has a central role in the operational management of the EU Space Programme, and a pivotal role in the space security of the EU space assets while supporting the emergence of safety and security-related applications. This article provides and overview of the evolving role of the European Union Agency for the Space Programme (EUSPA) in space security.

Keywords:

Space Security, EU Space Programme, EUSPA, Strategic Autonomy, Space Infrastructure

Introduction

Space has become part of everyday life, offering a multitude of applications and services. It can serve as an enabler for sectorial policies. These include agriculture, fisheries, transport, energy, urban development, environment, climate change, etc. Space technologies and applications also support safety, security, and defence. It can assist in disaster management, search and rescue, border monitoring and control, etc. which currently occupies decision and policy makers with the overall geopolitical setting.

Space security is a concept that has been evolving over the past few years with no universally accepted definition. Traditionally, it has been defined as the ability to access and use space for all nations. However, with the increase in space activity and the development of new technologies, the concept of space security has been broadened to include the protection of space assets and the prevention of an arms race in space. The policies and strategies of the European Union (EU) outline the concept as encompassing the protection of space-based assets, ensuring the resilience of space systems, and safeguarding the interests of the EU and its Member States in the space domain (Figure 1).

The EU Space Programme integrates security and defence considerations, marking a significant transformation in the Union's strategic posture. At the heart of this evolution lies the European Union Space Programme and European Union Agency for the Space Programme (EUSPA) [1]. EUSPA has a central role in the opera-

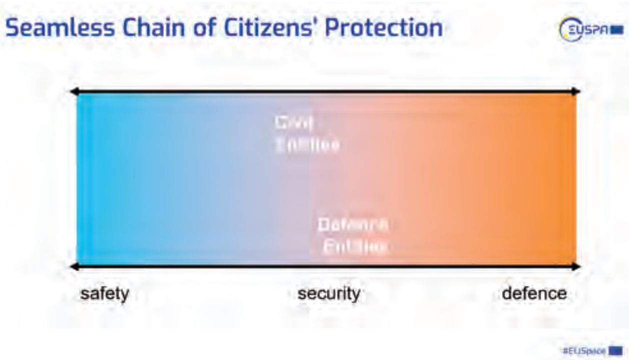


Figure 1: The seamless chain of citizens protection encompassing safety, security and defence.

tional management of the EU Space Programme, and a pivotal role in the space security of the EU space assets while supporting the emergence of safety and security-related applications. This shift aligns with broader EU policy initiatives, including the 2022 Strategic Compass for Security and Defence[2] and the 2023 EU Space Strategy for Security and Defence (EUSSD) [3], both of which underscore space as a strategic domain critical to the Union's resilience, autonomy, and security[2,3]. The integration of security elements enhances the resilience of EU space infrastructure against emerging threats, including cyberattacks, space debris proliferation, and counterspace capabilities.

Against this backdrop, this paper provides an introduction to the EU Space Programme and the EU Agency for the Space Programme and highlights specific elements related to space security. Moreover, the analysis delves into the specific activities in space technologies and services for space security. Furthermore, this study contributes to the broader discourse on the EU's strategic autonomy in space and its capacity to safeguard critical space infrastructure in an increasingly contested environment.

The EU in space

EU space framework

The European Union (EU) has increased over the years its engagement in the space landscape. Historically, the EU's engagement in space activities was primarily oriented towards the enhancement of technological innovation and industrial competitiveness. This orientation mirrored the broader tenets of European integration, prioritizing economic expansion and scientific advancement.

The Lisbon Treaty, which came into force on December 1, 2009 [4] provides the first explicit legal basis for EU action in space. Article 189 of the Treaty on the Functioning of the European Union (TFEU) granted the EU competence in particular in drawing up a European space policy (Art. 189.1); establish the necessary measures which may take the form of a European space programme (Art. 189.2) and establish appropriate relations with the European Space Agency (ESA). Today the EU has set up an elaborate framework based on Art. 189 (Table 1).

Dec 2009	The Lisbon Treaty, Article 189
Apr 2011	*Communication [COM (2011) 152] "Towards a space strategy for the European Union that benefits its citizens"*
Oct 2016	*Communication [COM (2016)705 final] "Space Strategy for Europe"*
Oct 2016	*Joint statement on shared vision and goals for the future of Europe in space by the EU and ESA*
April 2021	*Regulation (EU) 2021/696 establishing the EU Space Programme and the European Union Agency for the Space Programme.*
Feb 2022	*Joint Communication [JOINT (2022) 4] "An EU Approach for Space Traffic Management"*
June 2022	*Financial Framework Partnership Agreement (FFPA) between EC, ESA, EUSPA*
Mar 2023	*Regulation (EU) 2023/588 of the European Parliament and of the Council of 15 March 2023 establishing the Union Secure Connectivity Programme for the period 2023-2027*
Mar 2023	*Joint Communication [JOINT (2023) 9] "European Union Space Strategy for Security and Defence"*

Table 1: Main documents of the EU space framework after the Lisbon treaty

The changing geopolitical environment has prompted the EU to reconsider its strategy for space. Over the past two decades, space has increasingly become a competitive and strategic area, necessitating the integration of security goals into what was once a primarily civilian-focused policy. This changing environment has gradually brought security issues into the EU's space policy, most recently demonstrated by the 2022 Strategic Compass for Security and Defence [2] and the 2023 EU Space Strategy for Security and Defence [3].

Union Space Programme

The Union Space Programme, under Regulation (EU) 2021/696, [1] consolidates all space-related activities under a single framework. With a budget for the period 2021 to 2027 of €14.8 billion, it surpasses previous investments, reflecting the increasing importance of space in European security and competitiveness.

Galileo and EGNOS

The involvement of the EU in the Galileo project was defined in its initial stage through a Council Resolution in 1999 [21]. The first phase of Galileo went from 2003 to 2005, when the first experimental satellite, GIOVE-A, was launched. Galileo kept developing and in 2008 GIOVE-B was launched, followed by the first two In-Orbit Validation (IOV) satellites in 2011, as well as the first two Full Operational Capability (FOC) satellites in 2014 [5].

In 2016 Galileo entered into Initial Services. Since then, billions of people worldwide with a Galileo enabled device have been able to use its signals for positioning, navigation and timing. This was a milestone that corresponded to the availability of the first operations of the Open Service (OS), Public Regulated Service (PRS), and Search and Rescue (SAR) services. In December 2016, EUSPA (then GSA) became the service operator for Galileo. Later in 2019, the phase of Enhanced Services started, which implemented the OS Positioning for improved navigation performances, and made available the SAR Return Link Service (RLS).

The Open Service FOC phase is now under preparation, and it will mark the availability of the various services in their final configuration. The Initial Operational Capability of the Public Regulated Service is under preparation, and the new OSNMA (Authenticated-Open Service) is under testing. The High Accuracy Service (HAS) was declared operational in 2023, and its evolution is under preparation.

The launch of the EGNOS Programme was approved by the European Council in 1994. It was confirmed to be a component of Europe's satellite navigation policy in 2003. In 2005, the version 1 (v1) of the system started its initial operations phase, followed by the v2.1 which implemented the EGNOS Data Server, while the v2.2 allowed for an extended coverage through the Regional Extension Module concept. In 2009, EGNOS assets were transferred from ESA to the European Commission, and the OS was declared operational; since 2014 the EGNOS exploitation has been delivered by EUSPA (previously GSA) under delegation from the European Commission. In 2018 a contract was signed for the development of the next version of EGNOS [5].

Copernicus

Copernicus was born from the idea of creating a European environment monitoring programme, agreed upon in 1998. The programme was initially introduced as "Global Monitoring for Environmental Security"; then, in 2004, a space-based observation component was proposed, therefore the European Commission and ESA signed an agreement setting the stage for the Sentinel satellites family. In 2011, the Initial Operation phase began, and the programme was renamed Copernicus the subsequent year. The deployment of the space component began in 2014 with the launch of Sentinel 1-A radar satellite and continues until today, [7] carrying on a process aiming to place a complete constellation of almost 20 satellites in orbit before 2030 [8]. EUSPA has undertaken various market uptake activities in Copernicus since 2021.

GOVSATCOM and IRIS²

The implementation of the GOVSATCOM component of the EU Space Programme started in 2021, under the new Space Programme Regulation, while the GOVSATCOM Preparatory Action was initiated by the European Parliament already in 2020. The GOVSATCOM will use the capacities and services provided by existing national satcom systems and accredited private operators [9]. The Union Secure Connectivity Programme, the so-called IRIS², under Regulation (EU) 2023/588 [10] aims to deliver secure, autonomous, reliable, and cost-effective satellite communication services to government-authorized users, enhancing the Union's resilience, autonomy, and technological and industrial base in satellite communication. The programme will be implemented in phases, focusing on developing space and ground infrastructure for governmental services, while also enabling commercial services by the private sector, thereby fostering innovation and competitiveness in the European space industry. The programme integrating and complementing existing and future national and European capacities in the framework of the GOVSATCOM component, and developing further and gradually integrating the European Quantum Communication Infrastructure (EuroQCI) initiative into the secure connectivity system[1].

Space Situational Awareness (SSA)

The Space Situational Awareness (SSA) component of the EU Space Programme means a high-level comprehensive approach to hazards in space which could harm space-based or ground-based infrastructure or endanger any activity in, or going to, space, or which could endanger life or health. It includes the following sub-components: (i) 'SST sub-component', a space surveillance and tracking system aiming to improve, operate and provide data, information and services related to the surveillance and tracking of space objects that orbit the Earth; (ii) 'SWE sub-component', observational parameters related to space weather events; and (iii) 'NEO sub-component', the risk monitoring of near-Earth objects approaching the Earth.

EU Space Programme and services

The EU Space Programme plays a multifaceted role in safety and security due to its multipurposed nature. The programme contributes to the EU's strategic autonomy in the space domain, reducing dependence on non-EU space systems and ensuring uninterrupted access to critical space-based services. In particular, a number of services provided relate to space security.

Galileo Services

Galileo, the European Union's global navigation satellite system (GNSS), offers a suite of services designed to cater to a wide range of users, from the general public to specialized sectors. These services are crucial for positioning, navigation, and timing (PNT) applications, and are integral to various aspects of modern life, including transportation, emergency response, and scientific research. Several services are developed or are under development.

Open Service (OS)

The OS is a free-of-charge service designed for mass-market applications. It provides positioning, navigation, and timing information to users with Galileo-enabled devices. The OS is fundamental for everyday applications such as smartphone navigation, location-based services, and is included in various consumer electronics. Its open nature ensures widespread accessibility and fosters innovation in related industries. The OS has a significant role in enhancing the accuracy and reliability of GNSS in urban environments and challenging signal conditions, contributing to the broader field of ubiquitous positioning.

Public Regulated Service (PRS)

The PRS is an encrypted service designed for authorized governmental users, such as law enforcement, emergency services, and critical infrastructure operators. It offers robust and secure PNT information, resistant to jamming and spoofing. The PRS is crucial for national security and sensitive applications where integrity and confidentiality are paramount. Its secure nature safeguards critical operations against potential threats. The PRS employs cryptographic techniques enhancing the resilience of governmental operations in the face of evolving security challenges.

Search and Rescue Service (SAR)

The SAR service contributes to the international Cospas-Sarsat system, which aids in locating and rescuing people in distress. Galileo's SAR service provides faster and more accurate detection of distress signals, and also provides an important and unique Return Link Service (RLS) (Figure 2). The SAR service plays a vital role in saving lives by significantly reducing the time it takes to locate individuals in emergency situations. The RLS, a distinctive feature of Galileo, provides feedback to the person in distress, confirming that their signal has been received. The SAR service contributed to improving emergency response times and enhancing the overall effectiveness of search and rescue operations, particularly in remote or challenging environments.

advanced signal processing algorithms, which are fundamental to the HAS (Figure 3).

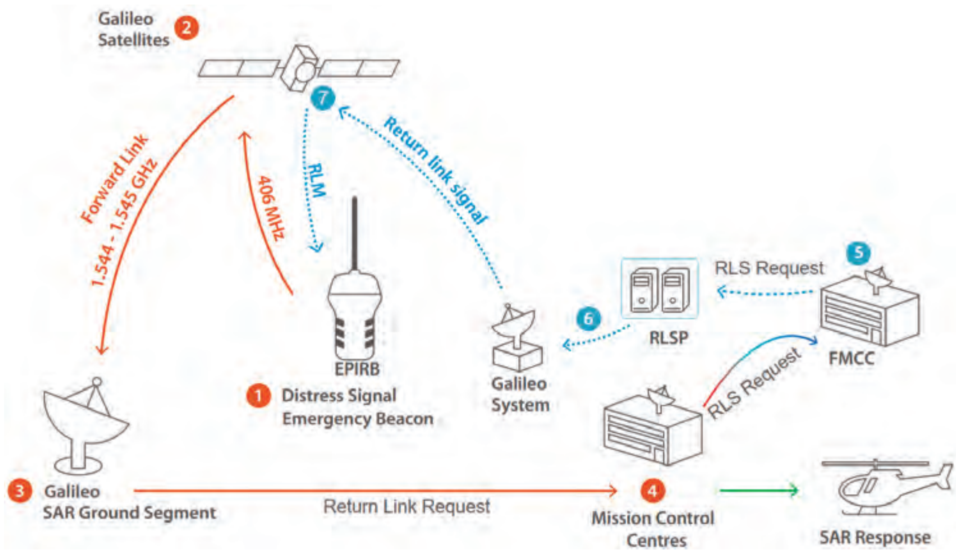


Figure 2: Galileo Search and Rescue (SAR) Return Link Service (RLS) (Source: EUSPA)

High Accuracy Service (HAS)

The HAS is a commercial service that provides high-accuracy positioning information, with accuracy down to centimetres. It is designed for professional applications requiring precise location data, such as surveying, precision agriculture, and autonomous driving. The HAS caters to the growing demand for high-precision PNT solutions in various sectors, enabling advancements in autonomous systems and location-based services. There are technical aspects incorporated for achieving high accuracy in GNSS, including the use of precise point positioning (PPP) techniques and

Signal Service-Authentication (SAS)

Signal Authentication service (SAS) is understood as the ability to provide a level of guarantee to users regarding the use of signals and data from actual Galileo satellites and not from any other source. This capacity will increase the degree of trust on the services based on Galileo positioning and prevent spoofing of Galileo signals, which may lead to committing fraud. The purpose of this service is to satisfy the demand of GNSS users and applications of a trusted navigation solution provided by GNSS systems.

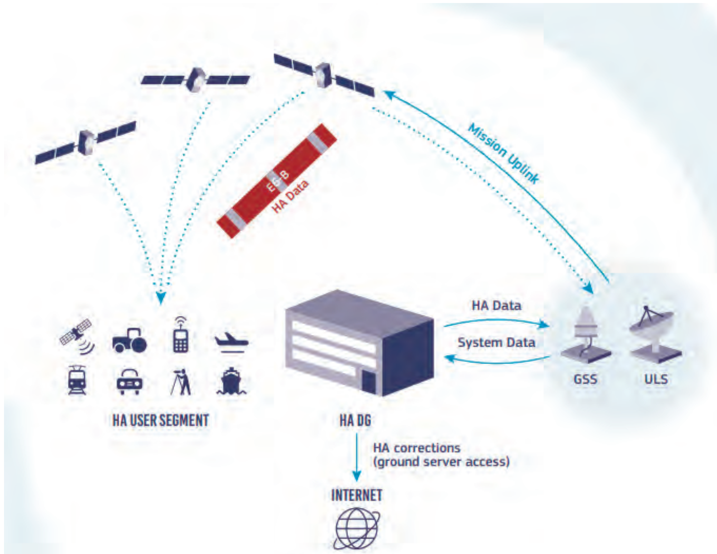


Figure 3: Galileo High Accuracy Service (HAS) (source: EUSPA)

Emergency Warning Service (EWS)

The EWS is designed to broadcast emergency warnings to users in affected areas, providing timely information about natural disasters or other critical events. It is based on the Return Link Service (RLS) capabilities of Galileo satellites. The EWS plays a crucial role in enhancing disaster preparedness and response, enabling timely dissemination of warnings to potentially affected populations. There are activities ongoing that are further developing the integration of GNSS with early warning systems and the development of effective communication strategies for disseminating emergency information.

EGNOS Services

The European Geostationary Navigation Overlay Service (EGNOS) is a satellite-based augmentation system (SBAS) that improves the accuracy and reliability of GPS signals over Europe. It plays a crucial role in enhancing the performance of Global Navigation Satellite Systems (GNSS) for various applications, particularly in safety-critical domains. Several services are developed or are under development.

Open Service (OS)

The OS is a free-of-charge service that enhances the accuracy of GNSS positioning for general users. Today, it provides corrections and integrity information to improve the performance of GPS signals. The OS benefits a wide range of applications, including con-

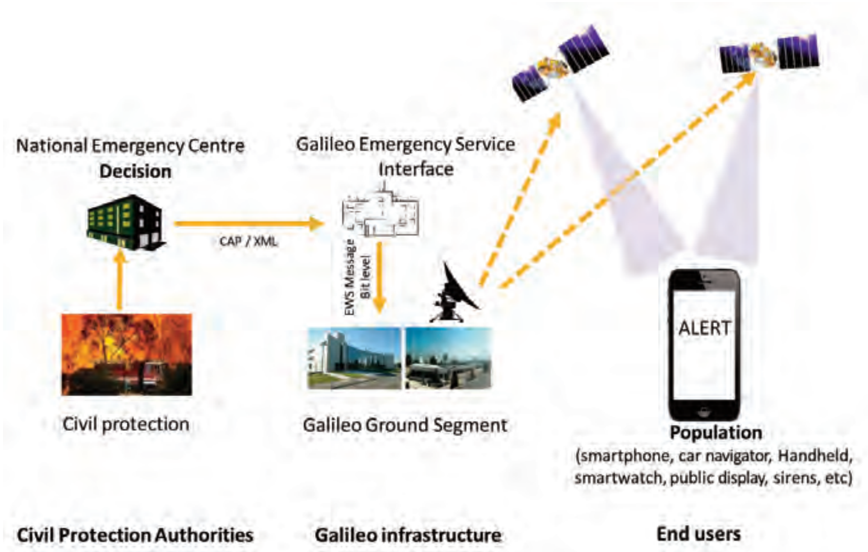


Figure 4: Emergency Warning Service (EWS) based on the Return Link Service (RLS) (Source: EUSPA)

sumer navigation, location-based services, and general positioning needs. By improving accuracy, it enhances the user experience and enables more precise location determination. The OS plays a role in mitigating errors inherent in GPS signals, such as ionospheric and tropospheric delays, thereby improving positioning accuracy and reliability for mass-market applications.

Safety of Life Service (SoL)

The SoL service is designed for safety-critical applications, such as civil aviation. It provides high-integrity information to ensure the reliability of GNSS signals for operations where safety is paramount. The SoL service is essential for aviation, enabling the use of GNSS for precision approaches and other critical operations. It adheres to stringent international standards, such as those set by the International Civil Aviation Organization (ICAO), to ensure the safety of air navigation. The SoL service plays a role in enhancing the safety and efficiency of air traffic management. It is crucial in enabling the transition to performance-based navigation (PBN) and supporting the development of advanced air traffic management systems.

EGNOS Data Access Service (EDAS)

EDAS is a commercial service that provides access to EGNOS data through the internet. It offers high-quality data for professional and commercial applications requiring precise positioning and timing information. EDAS caters to users who need reliable and accurate data for specialised applications, such as surveying, precision agriculture, and maritime navigation. It provides a convenient and efficient way to access EGNOS data for various professional needs. There are various developments of data processing techniques and algorithms for utilizing EGNOS data in high-precision applications. EDAS facilitates the integration of EGNOS data into various commercial and scientific tools.

Copernicus Services

Copernicus, the European Union's Earth Observation and Monitoring programme, provides free and open access to a wealth of data about our planet. It plays a crucial role in understanding and addressing environmental challenges, supporting policy-making, and fostering innovation in various sectors.

Atmosphere Monitoring

This service provides information on air quality, atmospheric composition, ozone layer and ultraviolet radiation, emissions and surface fluxes, solar radiation, and climate forcing. It supports air quality monitoring and forecasting, climate change research, and the development of policies to mitigate air pollution and greenhouse gas emissions. Atmospheric monitoring is essential in understanding the complex interactions between human activities and the environment. Copernicus data contributes to studies on air pollution, climate change, and atmospheric chemistry.

Marine Monitoring

This service provides information on the forecasting of ocean state for improved maritime safety, marine resources, coastal and marine environment, and ocean and climate. It supports maritime operations, fisheries management, coastal zone management, and climate change research related to the oceans. Marine monitoring plays an important role in understanding ocean dynamics, marine ecosystems, and the impacts of climate change on the oceans. Copernicus data contributes to research on ocean currents, sea level rise, and marine biodiversity.

Land Monitoring

This service provides information on systematic monitoring of biophysical parameters, land cover and land use mapping, thematic hot-spot mapping, and imagery and reference data. It supports agriculture, forestry, urban planning, and environmental monitoring. Copernicus data contribute to land use mapping, vegetation monitoring, and the assessment of natural resources. Land monitoring plays a role in understanding land use change, deforestation, and the impacts of agriculture on the environment. Copernicus data contribute to studies on land degradation, desertification, and sustainable land management.

Climate Change Monitoring

This service provides information on climate observations, reanalysis, forecasts and projections, data, tools and best practices supporting climate assessments, adaptation and mitigation. It supports climate change research, policy-making, and the development of adaptation and mitigation strategies. Copernicus data contributes to climate modelling, sea level rise monitoring, and the assessment of climate change impacts. Climate change monitoring plays a role in understanding the Earth's climate system, predicting future climate scenarios, and assessing the impacts of climate change on society and ecosystems. Copernicus data contributes to research on climate variability, extreme weather events, and climate change adaptation.

Security Monitoring

This service provides information on border surveillance, maritime surveillance, and support to EU security actions. It supports border management, maritime security, and the monitoring of security threats. Copernicus data contribute to the detection of illegal activities, the monitoring of maritime traffic, and the assessment of security risks. Security monitoring plays a role in addressing security challenges, such as illegal immigration, piracy, and terrorism. Copernicus data contribute to the development of early warning systems and the assessment of security vulnerabilities.

Emergency Management Service (EMS)

This service provides on-demand mapping (all phases of the disaster management cycle), early warning and monitoring service (for floods, wildfires, droughts), and exposure mapping (different indicators for exposure). It supports disaster preparedness, response, and recovery. Copernicus data contribute to the mapping of disaster-affected areas, the monitoring of natural hazards, and the assessment of disaster risks. Emergency management plays a role in reducing disaster risks and enhancing disaster resilience. Copernicus data contribute to the development of early warning systems, the assessment of disaster impacts, and the planning of disaster response and recovery operations.

GovSatCom Services

GovSatCom is designed to provide a suite of secure and reliable communication services tailored for governmental users. These services address a wide range of critical applications, from crisis management and surveillance to the protection of critical infrastructure. GovSatCom is integral to ensuring the EU's strategic autonomy in secure communications, offering capabilities that are essential for national security and defence. The service portfolio, as defined by Commission Implementing Decision (EU) 2023/1054, comprises three core service categories [11]:

End-to-end services

These services allow the user to connect to a satellite network that can provide the required user-to-user connectivity services (Mbps) typically based on SLAs. This means the governmetal customers can access to a complete end-to-end communication solution including their satellite terminal without needing to set up their own infrastructure. Under this service modality, also known as manged services. The satellite service provider handles all aspects of the satellite communications to ensure the delivery of assured Mbps.

Raw capacity services

These services allow the users to utilise satellite capacity (bandwidth in MHz). An example of this would be a military unit using satellite capacity (MHz) to transmit data from a drone. The military user would be responsible for setting up and managing the satcom ground infrastructure, the drone terminal and the communication link between the drone and the satellite.

Anchored capacity services

This service, also known as teleport or uplink facilities, can complement raw capacity services with additional satellite communications ground infrastructure and be also embedded as part of the end-to-end services category. It can be then comprised of raw satellite capacity and ground station facilities provided by the service provider. The user has the flexibility to install its own ground equipment (e.g. network, baseband equipment) and establish its network and communication links with the satellite terminals.

The service's architecture, which includes a 'Common Union Pool' and a token-based compensation mechanism, allows for flexibility and prioritization in service allocation. This approach not only optimises resource utilisation but also reinforces the EU's capacity to respond effectively to security challenges, underscoring the program's significance in the European security framework. Govsatcom services will be accessible through the Govsatcom Hub currently under development. Each participating EU Member State will have a designated authority Competent Govsatcom Authority (CGA) to manage its requests and interactions with the GOVSATCOM hub (Figure 5).

Space Situational Awareness Services

Space Situational Awareness (SSA) is a critical capability for ensuring the long-term safety and sustainability of activities in space. By providing data, information, and services related to the

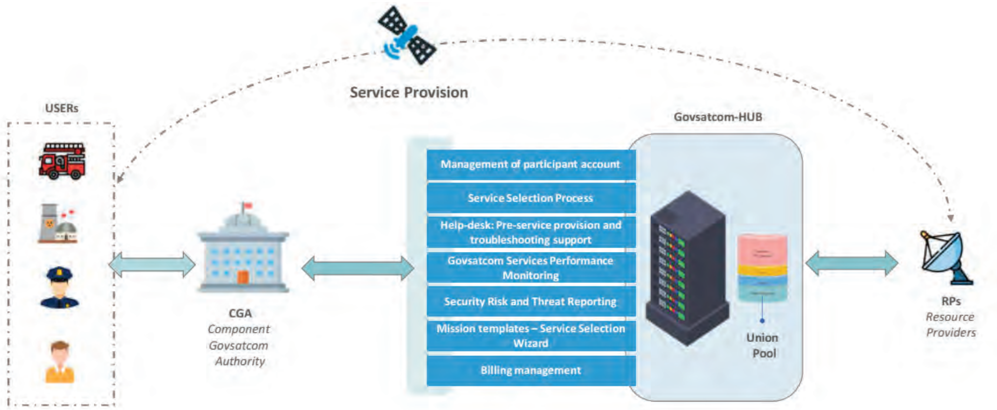


Figure 5: The Govsatcom service provision (Source: EUSPA)

space environment, SSA enables informed decision-making to mitigate potential risks and protect space-based assets. The SSA framework encompasses the following key components:

Space Surveillance and Tracking (SST)

SST involves the detection, tracking, and cataloguing of artificial objects orbiting Earth, including active and inactive satellites, rocket bodies, and debris, to help prevent collisions between space objects, predict re-entry of objects into Earth's atmosphere, and detect and characterise fragmentations events (Figure 6).

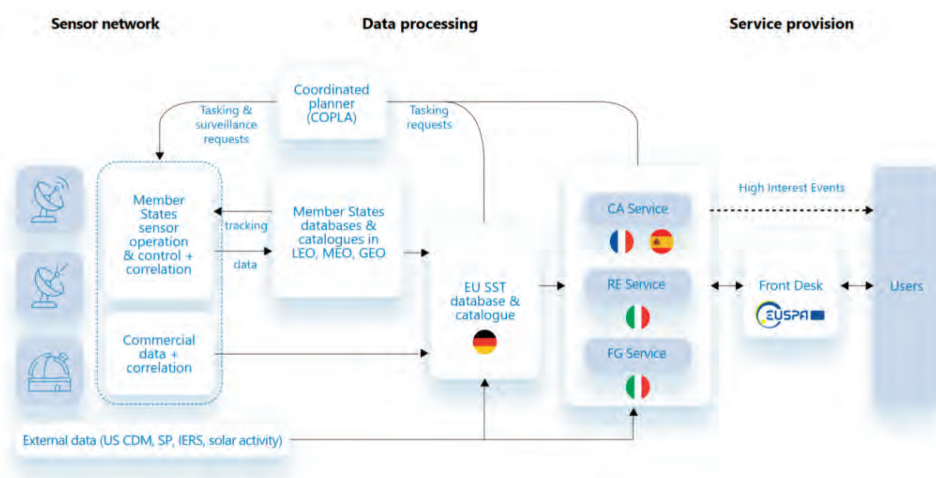


Figure 6: The EU SST service provision (Source: EUSST)

Space Weather Events (SWE) monitoring

SWE monitoring focuses on observing and forecasting space weather phenomena, such as solar flares, coronal mass ejections, and geomagnetic storms. These events can disrupt or damage space-based and ground-based infrastructure, including communication and navigation systems, power grids, and pipelines.

Near-Earth Object (NEO) tracking

NEO tracking involves the detection and monitoring of asteroids and comets that may pose a collision risk to Earth. This service provides data on the orbits and physical characteristics of NEOs, enabling the assessment of potential impact hazards and the development of mitigation strategies.

The European Union Agency for the Space Programme: its role

EUSPA history and main competences

The origins of the EU Agency for the Space Programme can be traced back to 2002, when the Council Regulation (EC) No 876/2002 set up the Galileo Joint Undertaking (GJU). The main task assigned to this legal entity was the management of the Galileo development phase [12]. Later in 2004, the European GNSS Supervisory Authority (GSA) was established by the Council Regulation No 1321/2004, to supervise the development of the European Geostationary Navigation Overlay Service (EGNOS) and Galileo [13]. GSA officially took over GJU and assumed its tasks on 1 January 2007. In 2010, another change took place since GSA acquired the status of an EU Agency and therefore became the European GNSS Agency as settled by Regulation (EU) No 912/2010. It was entrusted with the Galileo and EGNOS service provision and uptake and its location was set in Prague [5]. The most recent stage in the evolution of the Agency happened in May 2021 when the Regulation (EU) 2021/696 was adopted, establishing the Union Space Programme and EUSPA, which replaced GSA [1].

As specified under Article 29 of the EU Space Programme Regulation, the Agency has tasks such as to ensure the security accreditation of all of the Programme's components through its Security Accreditation Board (SAB), to carry out risk and threat analysis (in particular setting of technical specifications and operational procedures) for Galileo and EGNOS, to provide the Commission with its technical expertise, to undertake communication, market development and promotion activities as regards the services offered by Galileo, EGNOS, and Copernicus. In addition, the Agency is entrusted with managing the exploitation of EGNOS and Galileo, coordinating user-related aspects of Governmental Satellite Communications Programme (GOVSATCOM) for the purpose of crisis management missions and operations, with actions in support of an innovative and competitive Union space sector [1]. The European Commission may also decide to entrust the Agency with other tasks in the future.

In order to accomplish the specific tasks specified under Article 29, the Agency ensures the safe and secure management of all space components. In addition, it provides support to research and innovation through various projects such as CASSINI to stimulate innovation and entrepreneurship, and Fundamental Elements and Horizon to increase the EU industry competitiveness. EUSPA additionally engages with market stakeholders to develop innovative and effective applications for Galileo, EGNOS, Govsatcom, as well as leverages synergies between the different components of the Union Space Programme. Furthermore, EUSPA is engaging in promoting the development of applications for the commercialisation of Copernicus and has been operating the Front-Desk of EU SST. The Agency further provides its expertise through in-depth market analysis and ensures that Europe's space-based services are secure, safe, and accessible. [14,15,16]

EUSPA engages with multiple partners on the European, national and international levels. The European Commission, and specifically the Directorate General for Defence Industry and Space (DG DEFIS), is in charge of the Union Space Programme and entrusts EUSPA with all its tasks related to Galileo, Copernicus, EGNOS, GOVSATCOM and the Space Situational Awareness (SSA). The European Space Agency (ESA) is also a key partner of EUSPA for the implementation of the Union Space Programme. Furthermore, the Union Space Programme counts several partnerships beyond the EU borders that let it ensure the compatibility and interoperability of the European GNSS with the other constellations around the world. The European Commission, together with the Member States and the European Parliament (as a non-voting Member), is member of the Administrative Board of EUSPA. The EU Member States are also in charge of overseeing the Security Accreditation of the Programme through the Security Accreditation Board, as does the High Representative of the Union for Foreign Affairs and Security Policy [5].

Apart from the headquarters in Prague, EUSPA's workforce is present in various sites across Europe (Figure 7): the Galileo Security Monitoring Centre with a site in France and another site in Spain with the EU SST front-desk, the Galileo Reference Centre in the Netherlands, and the European GNSS Service Centre in Spain. The EUSPA EGNOS team is located in France. The Interinstitutional Relations team and the Joint Office are located in Belgium. Additionally, EUSPA manages industrial teams in the Galileo Control Centres based in Italy and Germany, as well as in other facilities [17].

In addition to the current EUSPA sites, the Commission Implementing Decision (EU) 2024/3195 [18] focuses on the location of the GOVSATCOM Hub under the EU Space Programme. This decision specifies that the GOVSATCOM Hubs, which are central to organising and managing demand and supply for governmental satellite communications, will be located in two sites: Agios Ioannis in Greece, and Cologne in Germany. Furthermore, the Commission Implementing Decision (EU) 2024/1067 [19] concerns the implementation of the Union Secure Connectivity Programme, specifically focusing on the location of control centres for the program's ground infrastructure, which will be Toulouse in France, Fucino in Italy, and Bettembourg in Luxembourg.

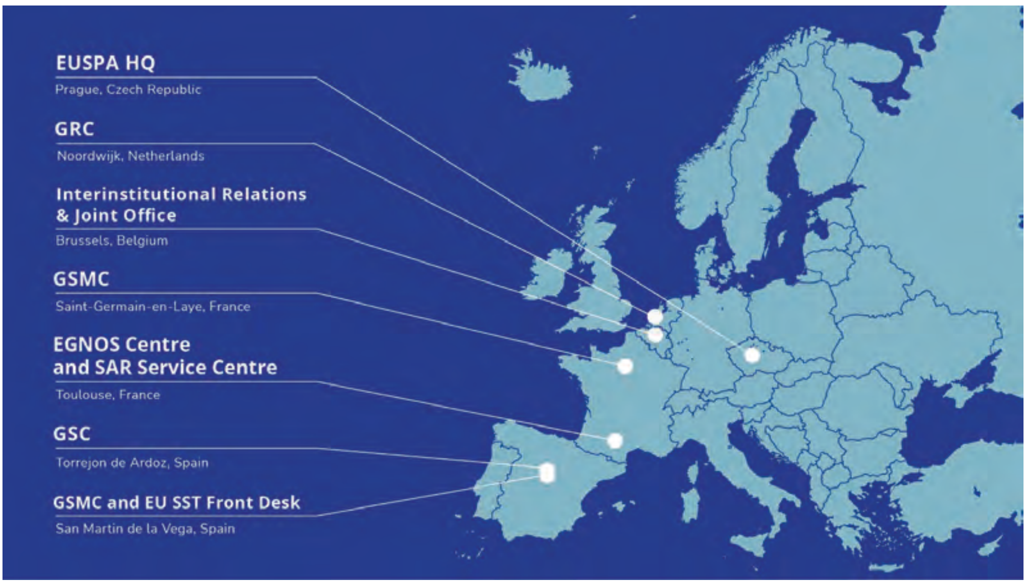


Figure 7: EUSPA sites across the EU Member States (Source: EUSPA)

The role of EUSPA in security

EUSPA is an agency with security at its core. The role of EUSPA according to the Regulation (EU) 2021/696 [1] in security is multifaceted, encompassing governance, operations, and accreditation. The agency acts as a central hub for security-related activities, ensuring the protection of the EU Space Programme's assets and services. The three-pillar structure is elaborated as follows:

Security Governance:

- **Operational Security:** EUSPA is responsible for carrying out all the necessary activities to ensure and monitor the security of Galileo and EGNOS, in particular setting of technical specifications and operational procedures, and monitor their compliance with the general security requirements established by the European Commission. EUSPA supports the European Commission in performing such tasks also for the other Space Programme Components.
- **Security Risks and Threat Analysis:** EUSPA conducts security risk assessments and threat analyses to identify potential vulnerabilities and develop mitigation strategies.

Security Operations:

- **24/7 Monitoring Operations:** EUSPA oversees security monitoring of the EU Space Programme's navigation (Galileo and EGNOS) infrastructure and services to detect and respond to security incidents.
- **Galileo Public Regulated Service Provision with Competent Authorities in EU Member States:** EUSPA ensures, in collaboration with competent authorities in EU Member States, the access management of the Galileo Public Regulated Service.

Security Accreditation Board (SAB):

- **Security Accreditation Authority for All Components of the EU Space Programme:** The SAB, established within the Agency, is the central authority for security accreditation of all components of the EU Space Programme. This involves assessing the security posture of systems and services, and granting security accreditation based on compliance with established security standards.

In order to ensure the security and uninterrupted operation of critical space-based services of the EU, the Council Decision (CFSP) 2021/698 [20] establishes the legal framework for the security of the EU Space Programme. It focuses on securing the EU Space Programme (EUSP) from various threats. It establishes a framework for how the Council of the European Union and the High Representative will respond to security threats affecting the EUSP systems and services.

Overall, this Council Decision helps ensure a coordinated and effective response to security threats impacting the critical space infrastructure of the European Union.

In addition, the EU Space Strategy for Security and Defence [3] calls for an EU Space Information Sharing and Analysis Centre (ISAC). The EU Space ISAC has been established by the European Commission (EC) with the support of EUSPA. It was inaugurated in 2024 and is a network of EU companies from the space sector who are willing to develop their expertise to better prevent, tackle and mitigate security-related challenges, including cybersecurity.

The road ahead

The European Commission, under President Ursula von der Leyen, has outlined seven key priorities for its 2024-2029 mandate. [23]. These priorities aim to address current challenges and shape a stronger, more resilient Europe for the future. These include a new plan for Europe's sustainable prosperity and competitiveness, a new era for European Defence and Security, supporting people and strengthening societies, sustaining quality of life with a focus on food security, water and nature, protecting democracy and upholding values, leveraging global power and partnerships, and delivering together while preparing the Union for the future.

For the first time there is a dedicated Commissioner for Defence Industry and Space, which underscores the European Union's engagement to elaborate its position in the space domain [24]. The mission letter the Commissioner received from the President delineates a comprehensive approach, prioritising the implementation of the EU Space Strategy for Security and Defence, thereby solidifying the inextricable link between space activities and the Union's broader security framework. Simultaneously, it emphasises the cultivation of a robust and innovative space industry, advocating for autonomous and cost-effective access to space through the strategic development and utilisation of key EU space assets, including Copernicus, Galileo, and GovSatCom/IRIS[2]. A notable emphasis is placed on the development of an EU Space Law, aimed at establishing common standards and licensing procedures. Furthermore, the Commissioner is tasked with formulating a Space Data Economy Strategy, recognising the transformative potential of space-derived data for economic growth and technological advancement. These directives collectively reflect a concerted effort to enhance the EU's strategic autonomy, technological competitiveness, and regulatory coherence within the dynamic and increasingly contested space domain.

Finally, on February 2025, the European Commission provided its perspective on the upcoming Multiannual Financial Framework (MFF) [22]. It emphasises the necessity for the EU budget to strategically address key policy challenges, including enhancing European competitiveness through research and innovation, and tackling security threats amidst geopolitical tensions. There is a reference to the need for *'Stronger defence readiness, including through space assets, and military mobility is* *necessary both as a deterrent against future aggression and to support Ukraine towards peace'*. It is highlighted that there is a need for increasing and optimising financing for defence across the EU. The document also calls for a more focused, simpler, and impactful EU budget to ensure that the funds deliver on EU policy priorities.

Concluding remarks

The EU's evolving approach to space security reflects a strategic shift from a traditionally civilian-centric policy to one that integrates also key security and defence considerations, as seen in the EU Space Strategy for Security and Defence [3] and the Strategic Compass [2]. In this context, EUSPA plays an increasingly vital role in the EU Space Programme, ensuring the operational security and resilience of key components such as Galileo and EGNOS. Its mandate in security-related applications underscores its contribution to the protection of critical space infrastructure and the delivery of secure services. As counterspace threats, cyber vulnerabilities, and geopolitical tensions grow, the EU continues to enhance the resilience and autonomy of its space infrastructure within the broader security framework [23,24].

References

1 Regulation (EU) 2021/696 of the European Parliament and of the Council of 28 April 2021 establishing the Union Space Programme and the European Union Agency for the Space Programme and repealing Regulations (EU) No 912/2010 (EU), No 1285/2013 and (EU) No 377/2014 and Decision No 541/2014/EU, Off. J. Eur. Union L, vol. 170, pp. 69-148, 2021. Available: Publications Office (europa.eu) (Accessed: March 6, 2025).

2 Council of the European Union, "A Strategic Compass for Security and Defence - For a European Union that Protects its Citizens, Values and Interests and Contributes to International Peace and Security", 2022. Available: https://data.consilium.europa.eu/doc/document/ST-7371-2022-INIT/en/pdf (Accessed: March 2, 2025).

3 European Commission and High Representative of the Union for Foreign Affairs and Security Policy, «Joint Communication to the European Parliament and the Council on the European Union Space Strategy for Security and Defence,» JOIN(2023) 9 final, Brussels, 2023.

4 Treaty of Lisbon amending the Treaty on European Union and the Treaty establishing the European Community, signed in Lisbon, 13 December 2007. Off. J. Eur. Union C, vol. 306, pp. 1-244, 2007.

5 European Union Agency for the Space Programme (EUSPA) Official Website. EU Agency for the Space Programme (europa.eu) (Accessed: March 6, 2025).

6 European Commission Directorate-General Defence, Industry and Space, Galileo FOC Programme Roadmap, 2021.

7 European Commission Directorate-Gen-

eral Defence, Industry and Space, "Copernicus History Overview", Copernicus History Factsheet, 2022. Available: Copernicus | Earth Observation - European Commission (Accessed: March 6, 2025)

8 European Commission Directorate-General for Communication, "Copernicus – Europe's Eyes on Earth", Copernicus brochure, Publications Office of the European Union, Luxembourg, 2015. Available: Copernicus_brochure_EN_web_Oct2017_0.pdf (Accessed: March 6, 2025)

9 European Commission Directorate-General Defence, Industry and Space Website. Defence Industry and Space (europa.eu) (Accessed: March 6, 2025).

10 Regulation (EU) 2023/588 of the European Parliament and of the Council of 15 March 2023 establishing the Union Secure Connectivity Programme for the period 2023-2027, Off. J. Eur. Union L, vol. 79, pp. 1-39, 2023.

11 Commission Implementing Decision (EU) 2023/1054 of 30 May 2023 laying down rules for the application of Regulation (EU) 2021/696 of the European Parliament and of the Council as regards the service portfolio for the Governmental Satellite Communications services offered by the system established under the Union Space Programme, Off. J. Eur. Union L, vol. 141, pp. 49-56, 2023.

12 Council Regulation (EC) No 876/2002 of 21 May 2002 setting up the Galileo Joint Undertaking, Off. J. Eur. Union L, vol. 138, pp. 1-8, 2022.

13 Council Regulation (EC) No 1321/2004 of 12 July 2004 on the establishment of structures for the management of the European satellite radio-navigation programme, Off. J. Eur. Union L, vol. 246, pp. 1-9, 2004.

14 European Union Agency for the Space Programme (EUSPA), "EUSPA EO and GNSS Market Report," Publications Office of the European Union, Luxembourg, 2024.

15 European Union Agency for the Space Programme (EUSPA), "EUSPA Secure SATCOM Market and User Technology Report," Publications Office of the European Union, Luxembourg, 2023.

16 European Union Agency for the Space Programme (EUSPA), "GNSS and Secure SATCOM User Technology Report," Publications Office of the European Union, Luxembourg, 2025.

17 European Union Agency for the Space Programme (EUSPA), Single Programming Document Years 2022-2024, 2022.

18 Commission Implementing Decision (EU) 2024/3195 of 18 December 2024 laying down rules for the application of Regulation (EU) 2021/696 of the European Parliament and of the Council as regards the location of the GOVSATCOM Hub, Off. J. Eur. Union L, vol. 2024/3195, pp. 1-2, 2024.

19 Commission Implementing Decision (EU) 2024/1067 of 12 April 2024 laying down rules for the application of Regulation (EU) 2023/588 of the European Parliament and of the Council as regards the location of the control centres belonging to the ground infrastructure of the Union Secure Connectivity Programme, Off. J. Eur. Union L, vol. 2024/1067, pp. 1-2, 2024.

20 Council Decision (CFSP) 2021/698 of 30 April 2021 on the security of systems and services deployed, operated and used under the Union Space Programme which may affect the security of the Union, and repealing Decision

2014/496/CFSP, Off. J. Eur. Union L, vol. 170, pp. 178-182, 2021.

21 Council Resolution of 19 July 1999 on the involvement of Europe in a new generation of satellite navigation services – Galileo – Definition phase, Off. J. of the European Communities C, vol. 221, pp. 1-3, 1999.

22 European Commission, «Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions: The road to the next multiannual financial framework,» COM(2025) 46 final, Strasbourg, 2025.

23 European Commission, «European Union priorities 2024-2029», 2024. Available: https://european-union.europa.eu/priorities-and-actions/eu-priorities/european-union-priorities-2024-2029_en (Accessed: March 2, 2025).

24 European Commission, «Mission letter - KUBILIUS», 2024. Available: https://commission.europa.eu/document/download/1f8ec030-d018-41a2-9759-c694d4d56d6c_en?filename=Mission%20letter%20-%20KUBILIUS.pdf (Accessed: March 2, 2025).

[1] REF [10], Art.10, L79/3

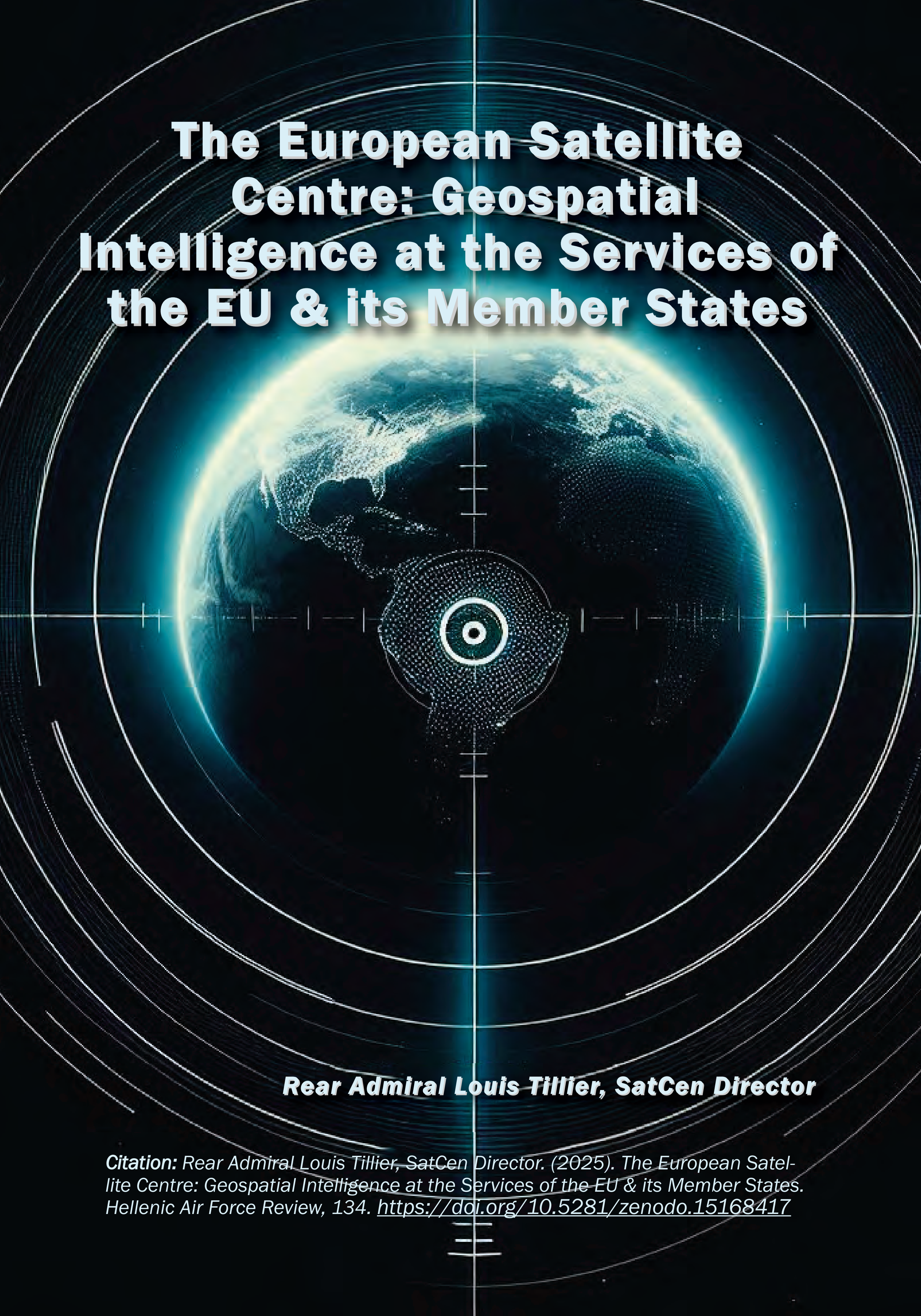
Short Biography

Dr. Christina Giannopapa is the Head of the Office of the Executive Director of EUSPA. Previously, she was advisor in the Greece's Ministry of Digital Governance, seconded from ESA.

In ESA she held various roles including Head of Political Affairs Office of the Director General. From 2010-2012 at ESPI, lead studies on Galileo and Copernicus and the EISC secretariat. Prior consulted high-tech industries and taught at Eindhoven University of Technology and the University of London.

With 14 scholarships, over 80 publications, and co-editorship of the «Handbook on Space Security,» she is an elected member of IISL and IAA, vice-chair of IAF's Space Security Committee, and Chair of Women in Aerospace Europe (WIA-E).

She holds a Ph.D, MEng and MBA from the University of London, and serves as an assistant professor at Eindhoven University of Technology.



The European Satellite Centre: Geospatial Intelligence at the Services of the EU & its Member States

Rear Admiral Louis Tillier, SatCen Director

Citation: *Rear Admiral Louis Tillier, SatCen Director. (2025). The European Satellite Centre: Geospatial Intelligence at the Services of the EU & its Member States. Hellenic Air Force Review, 134.* https://doi.org/10.5281/zenodo.15168417

Abstract

In view of an increasingly tense geopolitical landscape, caused by conflicts such as Russia's aggression in Ukraine and crises in the Middle East and Africa, the EU's need for an autonomous and responsive decision-making capacity in security and defence has drastically increased. The European Union Satellite Centre (SatCen) in Torrejón / Madrid is the EU's central provider of imagery and geospatial analysis services for CFSP/CSDP. Working under the political guidance of its Member States, the Centre plays a crucial role in enhancing the EU's situational awareness at the nexus of external and internal security. It has become an essential capacity for swift and decisive action, in direct support to key intelligence and security actors in Europe. The article traces SatCen's evolution from its establishment in 1992 as a strategic Western European Union initiative to its current function as the EU's agency at the crossroads of space, defense and security. Beyond strategic situational awareness, the Centre supports EU military operations and civilian missions, disaster relief operations, and collaborates with European agencies like FRONTEX and strategic partners such as the UN. It also acts as the entrusted entity for the Copernicus Support for External and Security Action (SESA) service. To stay ahead of the rapid evolution in data management and secure processing, SatCen invests heavily into advanced technologies like Artificial Intelligence (AI). Through its timely and accurate geospatial intelligence services, the Centre functions as Europe's "eyes from the sky", supporting EU decision-making by exploiting data coming from space assets.

Keywords

Geospatial Intelligence (GEOINT); European Union Satellite Centre (SatCen); Situational Awareness; EU Strategic Compass; Common Security and Defence Policy (CSDP); Space-based Intelligence.

Introduction

The geopolitical landscape is becoming increasingly tense, as demonstrated by Russia's war of aggression in Ukraine as well as rapidly evolving crises and wars in the Middle East and Africa. In this context, European *strategic autonomy* has become more vital than ever[1]. This applies especially to the domain of security, defence and space aligned with the Strategic Compass objective to enhance the EU's capacity to act swiftly and decisively in response to emerging threats.

In this context, situational awareness is an essential capability on which effective decision-making is based, across the full spectrum from operational to the top political level. As Europe's "eyes from the sky", the European Union Satellite Centre (SatCen) in Torrejón (Madrid) is the EU's geospatial intelligence agency, providing analysis services to the EU member states, its institutions and international partners.

SatCen's path

In 2022, SatCen celebrated its 30th anniversary, marking three decades of dedicated service in geospatial intelligence. The origins of the Centre date back to 1991, when the Western European Union (WEU) Ministerial Council, composed of Foreign and Defence Ministers, convened on 27 June in Vianden, Luxembourg, and made the strategic decision to establish a satellite data interpretation centre. Later that year, on 19 November, the WEU Council of Ministers met in Bonn and chose Torrejón Airbase, near Madrid in Spain, as the Centre's location. Formally created as a body of the WEU, its mission was to provide actionable geospatial intelligence analysis services, based on satellite imagery and other relevant data, to support the European security and defence efforts.

The creation of this Centre in the early 1990s was a visionary initiative, shaped by the strategic minds surrounding WEU Deputy Secretary, Mr. Horst Holthoff. He pushed for an independent WEU military capability to exploit satellite imagery for defence

[1] In 2014 the COUNCIL DECISION 2014/401/CFSP of 26 June 2014 revised the Centre's mission and activities. Article 2 states that: "*SATCEN shall support the decision making and actions of the Union in the field of the CFSP and in particular the CSDP, including European Union crisis management missions and operations, by providing, at the request of the Council or the HR, products and services resulting from the exploitation of relevant space assets and collateral data, including satellite and aerial imagery, and related services.*"

purposes[2]. In recognition of his strategic foresight, his name was given to the Centre's main meeting room[3].

One of the Centre's earliest support missions in 1996 was assisting on-site inspectors in Kosovo in verifying the dismantling of armaments and equipment, a milestone in operational support. The WEU's experimental capability for situational awareness during crisis events proved so successful that it was transferred to the EU in 2002, then re-named the European Union Satellite Centre (SatCen), by decision of the Council of the European Union. And until today, it has remained a unique operational geospatial analysis agency in the EU's security and defence toolbox[4].

A year later, in 2003, the European Security Strategy was introduced, marking a pivotal moment as the EU began launching military operations and civilian missions. SatCen, in coherence with the European Security Strategy, was mandated to enhance the decision-making of the European Union in the field of Common Foreign and Security Policy (CFSP), in particular the European Security and Defence Policy (ESDP), renamed the Common Security and Defence Policy (CSDP) in 2009. The first EU operation supported by SatCen was EUFOR Althea in Bosnia and Herzegovina[5].

The Council Decision «European Space Policy: ESDP and Space» of 2004 emphasised the critical role of the SatCen in bolstering the European Security and Defence Policy through satellite imagery analysis for intelligence, early warning, and crisis management operations.[6] It highlighted SatCen's cooperation with EU entities, such as the Joint Research Centre and other key actors, to improve decision-making and effectively tackle capability gaps, thereby strengthening the EU's capacity to address security threats.

The European External Action Service (EEAS) was created in 2011 and over time it became one of SatCen's main users[I]. Following this, in 2016, the *Global Strategy for the EU's Foreign and Security Policy* was published, reinforcing the EU's commitment to a stronger and more autonomous security and defence framework. In 2022, the EU Strategic Compass identified space as a critical strategic domain, paving the way for the first Council Conclusions on the *EU Space Strategy for Security and Defence* in November 2023, to address relevant CSDP challenges including protecting space assets and deterring threats.

SatCen is now a pillar of the EU's strategic autonomy. By providing fast, reliable and accurate geospatial intelligence services, the Centre strengthens the EU's ability to take autonomous decisions in security and defence, crisis management and foreign policy. It is SatCen's mission to enhance operational effectiveness by providing support for both civilian missions — such as humanitarian aid, disaster relief, and emergency management — and military operations. Currently the EU is engaged in 21 civilian and military missions, including military and naval operations[7]. European engagement worldwide centres on peacekeeping efforts, conflict prevention, international security, upholding the rule of law, combating piracy, enhancing maritime security, and supplying military equipment and support to EU partners. SatCen thus supports national as much as EU leaders, providing situational awareness to support their strategic priorities on both national and collective security challenges.

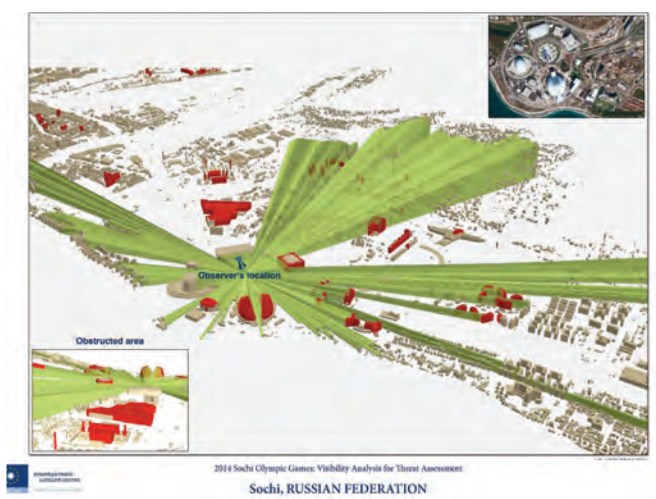
Operations

The Geospatial Intelligence (GEOINT) discipline integrates multiple elements, including mapping, cartography, imagery analysis, and imagery intelligence. Its core principle is to consolidate all available data related to a specific geographic location and analyse it to produce actionable information.

These insights are then transformed into user-friendly products designed to support decision-makers at political and operational levels.

SatCen is a task-based agency, which means "everything starts with a question, or more precisely with many questions"[8]. The request which could e.g. originate from a Member State or from within the European External Action Service (EEAS) are then prioritised by the EU High Representative, according to political guidance given by the Council.

SatCen's analysis room serves as the core of the Centre, where highly skilled analysts — drawn from both military and civilian backgrounds — work on large screens displaying satellite imagery and other suitable data sources. Organised into several specialised teams, this structure is optimised for high performance in a fast-paced operational environment, reaching an output of approximately 6,000 products annually[9].

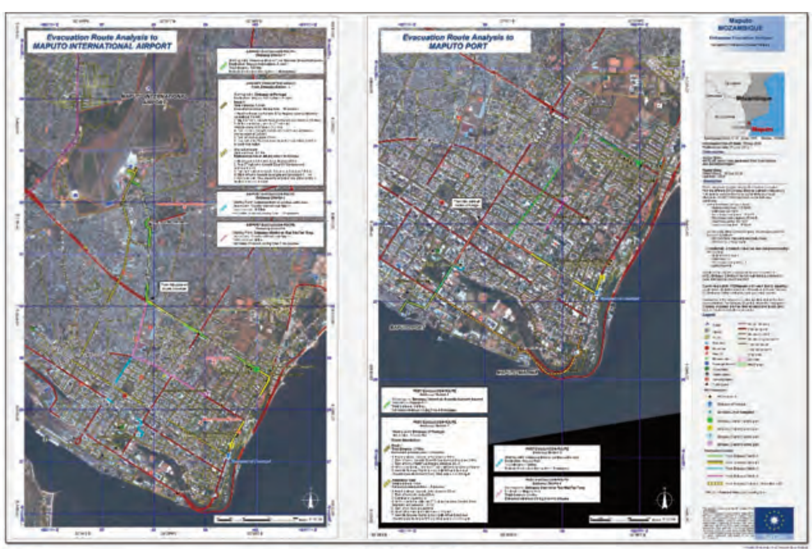


Transformation of an Atoll into an Island
SOUTH CHINA SEA

Engagement

Which specific activities does SatCen support? The counter-piracy naval operation EUNAVFOR ATALANTA off the Horn of Africa, EUNAVFOR MED IRINI, a naval operation aiming at enforcing the arms embargo in Libya, as well as EUNAVFOR ASPIDES in the Red Sea are just a few examples. The Centre also contributes to civilian missions for border monitoring or the assessment of military activities, like EUMM Georgia or the EU Mission in Armenia[10].

Another essential and time-critical aspect of SatCen's mission is its sup-



Evacuation Route Analysis (Product Example)
Maputo, MOZAMBIQUE

Mauritania - Possible departure point for illegal migration

port for disaster relief and rescue operations: in October 2024, torrential rains devastated Valencia in Spain, resulting in over 200 fatalities, submerging streets and homes, and displacing hundreds of residents. In response, Spanish authorities launched an emergency operation to coordinate relief efforts. As the full scale of the disaster became clear, the responsible units of the Spanish Ministry of Defence activated SatCen to support its emergency operations.

In response to this urgent request, the Centre established an ad-hoc operations team, working around the clock to provide critical geospatial intelligence. Within six hours, the team delivered its first mapping product, followed by a series of additional outputs. The intelligence products enabled the Spanish authorities to assess accessible and restricted ("no-go") areas within the affected region. This information proved instrumental in allowing emergency rescue teams to take informed decisions for optimising search and rescue operations.

SatCen also closely collaborates with other EU agencies and international partners focusing on common security challenges. Most notably, the Centre is supporting the European Border and Coast Guard Agency (FRONTEX) on migration issues. In 2025, this collaboration will mark 10 years, representing a significant milestone in EU institutional interoperability. Joint efforts are focused on combating irregular immigration and cross-border crime. For the last decade, SatCen has provided more than 6000 geospatial products and services to Frontex[11]. This effective collaboration is taking place as part of the Border Security service of Copernicus, the EU's flagship space programme.

International users of SatCen's services include the Organisation for Security and Co-operation in Europe (OSCE) and the Organisation for the Prohibition of Chemical Weapons (OPCW). The requests typically involve facility assessments, analysis of surrounding areas, and road network evaluations.

Capabilities Development and Training

SatCen continuously invests into expanding and further developing its capabilities, and in this effort collaborates closely with relevant national and EU entities like the European Commission and European Defence Agency (EDA), and international partners as European Space Agency (ESA)[12]. In line with its mandate, the Centre focuses on service evolution, synergy and complementarity, continuous improvement, innovation, and knowledge transfer.

As a special focus complementing its mission, SatCen has established strategic cooperation across various components of the EU Space Programme. Also, within the framework of EU research and innovation initiatives, such as Horizon Europe, SatCen has successfully implemented projects aligned with and supporting its core mission.

The evolving global security environment has highlighted the necessity for European strategic autonomy, driving key EU security initiatives. As an operational geospatial analysis entity, SatCen plays a pivotal role in their implementation, strengthening the EU's capacity to

respond effectively to emerging crises. The Centre's collaboration across the EU in space, defense and security enables the deployment of cutting-edge technologies for its operational use as well as the collective benefit of the EU and its Member States.

In a key operational function, SatCen serves as the entrusted entity for Copernicus Support for External and Security Action (SESA). The Centre's engagement in maritime security and border surveillance in cooperation with Frontex, which is a clear demonstration of interoperability, complementarity and synergies, in line with the Centre's mandate.

In addition to its research and innovation activities, SatCen provides specialised training courses to further develop geospatial capabilities for its staff as well as across Member States and users. These trainings cover essential topics like data processing and imagery analysis, as well as advanced training in Synthetic Aperture Radar imagery, industrial site interpretation, and nuclear facility analysis: in 2024 alone, the Centre recorded almost 3.000 attendees per day at SatCen courses.

High-Tech

Processing large amounts of data from a wide range of satellites would be impossible without the extensive computing capacities available today. The Centre maintains extensive on-site data storage and processing capacities, but - more importantly - it hosts the first ever "EU SECRET" cloud service. This important innovation is available since 2021, providing its users with real-time access to secure operational services and processes including an innovative and operational AI factory[13].

Further, the development and integration of Artificial Intelligence tools into the operational process has significantly enhanced efficiency in satellite image analysis. For instance, when examining maritime imagery, traditional methods require analysts to manually inspect each section for relevant details. AI, however, can automatically identify small vessels, such as migrant boats, within vast oceanic areas. To ensure the required level of accuracy and reliability, and while the AI tool is providing effective semi-automatic support, the final output is still produced under the control and supervision of the essential expertise of highly trained, experienced analysts[14].

Challenges

In line with the continuously growing level of EU ambition in security and defence, as well as responding to the drastic changes in the European security landscape, SatCen has increased its output about tenfold in the past decade. This trend is multiplied by increasing demands on product complexity, speed of delivery, and quality expectations[15].

To stay ahead of the quickly evolving geopolitical context, as much as preparing for the requirements expressed in the EU Strategic Compass and the EU Space Strategy for Security and Defence, the Member States have mandated the Centre to implement an ambitious development plan, further increasing the Centre's operational capacity over the next years. SatCen will thus continue its investment in IT, data and expert staff, to meet the challenges ahead and to satisfy the demands posed by the EU and its Member States for state-of-the-art geospatial intelligence services in the 21st century.

The way forward

In the current geopolitical context of evolving threats to European security and stability, SatCen as the geospatial intelligence agency remains a key asset for the EU and its Member States, with the mission to support situational awareness and thus strengthen the EU's strategic autonomy, particularly for the CSDP. The Centre will continue to operate within the guidelines provided by – inter alia - the Strategic Compass and the EU Space Strategy for Security and Defense, while also responding to further challenges in non-proliferation and space, the maritime domain, the climate and environmental crisis and hybrid warfare.

To meet these evolving requirements, SatCen is establishing a dedicated maritime analysis team, while also expanding capabilities in AI and cybersecurity to counter emerging threats. Continued investments in automation and machine learning will improve scalability and efficiency, ensuring timely and reliable analysis processes. Additionally, reinforcing the training unit will allow SatCen to better support Member States and key institutional partners in decision-making for security, crisis management, and defence operations.

Further projects of high priority are the Centre's potential role in the future Earth Observation Governmental Service (EOGS) and the envisioned Climate and Environment Security Data and Analysis Hub (CESDA). These initiatives aim to enhance Europe's climate situational awareness and security foresight.

SatCen will thus continue to serve as Europe's «eyes from the sky», delivering tailor-made, user-driven geospatial intelligence services to support the EU's decision-making in security and defence. Through its advanced analysis capabilities, the Centre plays a pivotal role in supporting European security and defence, equipping decision-makers with the intelligence necessary to respond effectively to crises, threats, and strategic challenges.

References

1 Fiott, Daniel. "Strategic Autonomy: Towards 'European Sovereignty' in Defence?" European Union Institute for Security Studies (EUISS), 2018, page 1. http://www.jstor.org/stable/resrep21120

2 Kolovos, Alexandros. "Development of a Space Security Culture: Case of Western European Union in Schrogl KU (Ed), Handbook of Space Security. Policies, Applications and Programs, Volume 2, Springer, (2020); page 401-420

3 Geospatial Intelligence in Support of the EU's Foreign, Security and Defence Policy and Beyond: 30 Years of the European Union Satellite Centre (SatCen),» *The European*, no. 41 (2022); page 40-41, https://www.magazine-the-european.com.

4 *The European*, no. 41 (2022): (41p)

5 European Union Satellite Centre, *30 Years of SatCen*, accessed [17.02], https://30years.satcen.europa.eu/

6 Council of the European Union, European Space Policy: ESDP and Space, 11616/3/04 REV 3. Brussels. Available at: http://register.consilium.europa.eu/pdf/en/04/st11/st11616-re03.en04.pdf.

7 *IMPETUS – The EUMS Common Security and Defence Policy Magazine*, no. 33 (December 13, 2024)

8 Nannette Cazaubon, «Europe's Eyes in the Sky – A Story from Spain,» *The European – Security and Defence Union* 51 (July 2024): [32]

9 Cazaubon, «Europe's Eyes in the Sky,» [33]

10 *Ibid*

11 SatCen and Frontex Forge Deeper Ties in Virtual Signature Ceremony,» European Union Satellite Centre, accessed [17/02/2025], https://www.satcen.europa.eu/News/satcen-and-frontex-forge-deeper-ties-in-virtual-signature-ceremony

12 Council Decision 2014/401/CFSP on the establishment of a European Union Satellite Centre, OJ L 188, 27.6.2014, p. 73–84, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32014D0401

13 *The European*, no. 51 (2024): (33p)

14 Ibid

15 EU's Satellite Centre Overstretched Amid Crises,» *Euractiv*, February 7, 2024, https://www.euractiv.com/section/defence-and-security/inter-

view/eus-satellite-centre-over-stretched-amid-crises-its-boss-warns/

Short Biography

Rear Admiral Louis Tillier became Director of the EU Satellite Centre (SatCen) on 1 June 2024, following his appointment by the SatCen Board and confirmation by Josep Borrell, having served as Deputy Director since September 2021.

His naval career, commencing in 1995, included service on various vessels and significant responsibilities, alongside advanced engineering training in telecommunications, culminating in his role as Joint Staff Program Officer for Defence Satellite Communications, contributing to EDA and NATO SatCom groups.

He commanded the French Ship Dupuy de Lôme and the Maritime Intelligence Centre, before transitioning to the French Space Command, where he oversaw European and international space cooperation, leading efforts on European space security and defence, collaborating extensively with EU stakeholders and allies, prior to his SatCen appointment.

NIS 2 in Orbit: Cyber Challenges & Risk Management in Space

Dimitrios Papamartzivanos,
Evangelos Rekleitis, Nikolaos Tantouris (ENISA)

Citation: *Dimitrios Papamartzivanos, Evangelos Rekleitis, Nikolaos Tantouris. (2025). NIS 2 in Orbit - Cyber Challenges & Risk Management in Space. Hellenic Air Force Review, 134. https://doi.org/10.5281/zenodo.15168580*

Abstract

The rapid expansion of space-based services has introduced significant cybersecurity challenges. Satellites support essential services such as communications, navigation, and Earth observation, making them prime targets for cyber threats. Building upon the foundational analysis presented in the ENISA «Space Threat Landscape», this paper examines the evolving threat landscape dynamics of the space domain, taking into account the entire lifecycle of satellite systems—from design and development to decommissioning—while considering a comprehensive taxonomy of assets. The threat landscape constructed through an analysis of historical cyber incidents, highlights key threats and proves an assessment of the major threat actors operating within the domain. The paper introduces an interactive tool designed to offer clear and actionable recommendations for securing space systems. This tool leverages a comprehensive analysis of 281 controls, drawn from 13 frameworks, and maps them to each phase of the satellite lifecycle. Additionally, the paper underscores the importance of international cooperation and adherence to cybersecurity standards and regulatory frameworks, such as the NIS 2 Directive, to safeguard the space sector.

Keywords

Cybersecurity, ENISA, Space threat landscape, Risks, Controls, NIS 2

Introduction

As satellites are essential for global communications, navigation, and a wide spectrum of critical services, the economic and societal impact of a cybersecurity incident disrupting their operation makes (cyber)security a critical concern. As a matter of fact, Directive (EU) 2022/2555 of the European Parliament and of the Council of 14 December 2022 on measures for a high common level of cybersecurity across the Union[1], (NIS2 Directive) recognizes the space sector as a sector of high criticality, underscoring the need for robust cybersecurity measures to protect this critical ecosystem [2].

Satellite navigation systems like GPS (USA), GLONASS (Russia), BeiDou (China), and Galileo (EU), constitute the backbone of modern life as they play a crucial role in the delivery of a wide range of applications, from geolocation and emergency response to scientific research. However, their widespread use makes them attractive targets for cyber-attacks causing the disruption of critical services [3].

While navigation satellites are essential for geo-positioning, another crucial type of satellites is the communications satellites used for internet access, broadcasting, and global connectivity. Companies like SpaceX (Starlink), OneWeb, Iridium, and GlobalStar are revolutionizing global internet access, especially for remote areas, operating in total over 8,000 satellites in orbit, making cybersecurity critical to preventing data interception, signal disruption, and unauthorized access. Furthermore, earth observation satellites provide crucial data on weather, climate, and environmental monitoring, supporting disaster response and resource management. With nearly 600 active satellites dedicated to Earth observation, establishing secure communication channels and preventing data manipulation is vital to ensure accurate and reliable information. Space observation satellites are used for monitoring deep-space phenomena and measuring cosmic events. Despite their direct impact on daily life being less, securing their operation and data ensures the integrity of astronomical research.

The current surge in satellite launches is mainly driven by private companies and marks a new space race, resulting to over 75 countries operating satellites nowadays. Commercial reports postulate an ever-increasing reliance on space applications, predicting 38,000 additional satellites to be build and launched by 2033, 52 Exabytes of data traffic passing through satellites by 2029, and a $1.7 trillion market revenue for space industry by 2032[3]. While this fosters innovation, it also introduces risks. A 2022 report from Northern Sky research[4] highlights the growing cyberthreats to space-based assets and ground infrastructure. The rapid proliferation of commercial satellites, particularly small, inexpensive, and rapidly deployable ones, exacerbates cyber risks.

Undoubtedly, the space sector's rapid growth brings immense opportunities, but also significant cybersecurity challenges. This requires a fundamental shift in mindset, moving away from the assumption that the physical inaccessibility of satellite systems provides inherent security and, in general, security exceptionalism and security by obscurity. Instead, we must prioritize cybersecurity from the design phase and throughout the entire lifecycle, recognizing that vulnerabilities in satellite infrastructures could have far-reaching consequences for global security and connectivity. This involves adopting long-established cybersecurity practices, such as security by design, privacy by design, zero-trust architectures, robust supply chain security, secure coding practices, and cryptographic agility.

To this end, this paper builds upon of the foundational analysis presented in the ENISA «Space Threat Landscape» [1] leveraging its insights to explore the evolving threats and threat actors within the space domain, with respect to a structured analysis of lifecycle phases of satellites. Using the «Space Threat Landscape» as our “launch platform”, this work underscores the urgent need for tool-aided risk management in space operation and emphasizes the importance of adhering to robust cybersecurity standards. In response to these challenges, we introduce an interactive mapping tool [13] designed to facilitate the implementation of security controls, along with the control dataset, for easy consumption though GRC tools. This tool is the result of a systematic analysis of 13 prominent risk management frameworks, tailored to address the unique complexities of space systems. Furthermore, we position the NIS 2 Directive as a main driving force for enhancing risk and incident management practices, as well as fostering greater cooperation among stakeholders in space operations. By integrating these elements, this paper aims to contribute to a more secure and resilient space ecosystem.

and structured analysis approach. Various satellite lifecycle models are employed by prominent organisations governing the space sector and cybersecurity. However, despite variations in the ways in which actions are grouped into phases or the terminology employed, at their core these lifecycles remain the same, regardless of the ownership or intended use of the satellite systems, and whether they are commercial, military, or state-owned. Well-known satellite operation lifecycle models[12] are those of ESA[8], NASA[7], and JAXA[9], while BSI[10] and NIST[11] are similarly phased lifecycle models but with particular focus on cybersecurity aspects of operations. ENISA in [1], follows a unified perspective for the lifecycle model (see FIGURE 1) that allows easy mapping to the aforementioned models. With this unified model as a frame and search space analysts can systematically analyse the threat landscape of space

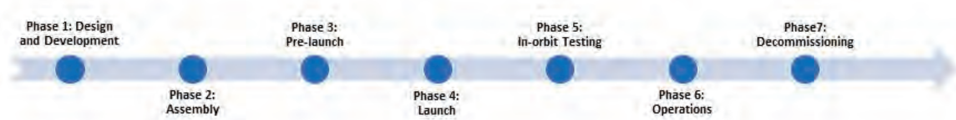


FIGURE 1 - SPACE LIFECYCLE

Space Ecosystem Lifecycle

Towards identifying the challenges and threats of an ecosystem, it is vital to first identity all phases that comprise its lifecycle so as to follow a systematic

domain and highlight the hostile actions and threat actors that can potentially appear in each phase.

Phase 1 – Design and Development phase focuses on defining requirements and mission goals and objectives. Apart from mission concepts, system-level requirements, and technology needs, security requirements shall be incorporated into the technical documentation for satellite components. Thus, security must be integrated from the start and be ensured, through rigorous testing and controls, throughout the entire lifecycle.

Phase 2 - Assembly phase involves integrating spacecraft components, including hardware and software assets for satellite operations. Supply chain cybersecurity and risk mitigation measures are crucial, requiring validation through tests and compliance audits for SW/HW used in the assembly. While SW modifications may be possible after the mission launch, hardware changes are limited.

Phase 3 – Pre-launch phase focuses on testing satellite functionality and establishing connectivity with ground control. Cybersecurity is crucial as it involves the secure integration, validation, and verification (IVV), of the satellite with the launch vehicle, infrastructure, operations centre and all the supporting and operational systems, while verifying hardware, software, and human interactions.

Phase 4 – Launch phase sends the space system to its operational environment and involves several safety and security-sensitive steps. Due to high costs and complexities, this phase is often outsourced. Cyber threats can target launch devices, installations and safety systems, requiring robust cybersecurity measures, while outsourcing also introduces supply chain risks.

Phase 5 – In-orbit testing takes place to verify systems' operational integrity. This phase includes the steps of injecting the satellite to transfer orbit and transfer of custody to the customer. Cybersecurity is crucial to ensure operational integrity of systems and ensure that there are no opportunities for malicious actors to exploit vulnerabilities during the transfer of custody.

Phase 6 – Operations phase involves mission-specific functions like data acquisition, processing, and communication, managed via ground stations. Cybersecurity is essential to protect sensitive data, communication, system integrity and secure firmware/software updates.

Phase 7 - Decommissioning is a high-risk process involving disposition of satellites and space structures. During this phase there are considerations for the secure handling and disposal of sensitive data, including intellectual property. Cybersecurity risks include data loss, unauthorized access, and potential hijacking of decommissioned satellites.

Asset Taxonomy And Domain Segmentation

For defining an assets' taxonomy

for space landscape, one needs to look on the Ground, in Space and also consider the end users of services and the human resources that underpin the operational aspects of satellites throughout their lifecycle.

The ground segment includes the terrestrial systems that facilitate communication, monitoring of satellite activities, and relaying of essential telemetry data, as well as ground physical facilities. In fact, one needs to consider the assets that play a crucial role during the lifecycle of satellites on the ground, considering the union of the *Production, Transportation, Launch* and *Operation* phases.

The Space segment contains satellite(s) orbiting the Earth, either in the form of constellations or under arbitrary synergies in the context of specific missions and services. The assets comprising the space segment stem from two categories: *Satellite Operations (BUS),* including all assets required to operate and maintain a satellite in orbit (e.g., RTOS, Antennas, etc.), and *Mission Execution*, referring to assets needed to fulfil the mission (e.g., payload data handling system). Although, mission execution assets may rely on BUS assets there is an increasing trend for keeping these two systems separated to serve distinct functions among different consumers.

The User segment contains interfaces and devices that enable end users to access and benefit from the services provided by a satellite, either through ground stations or the satellite directly. Thus, assets of the user segment fall into the categories of *Consumer interfaces,* such as Very-small-aperture terminals (VSATs) and antennas, and C*onsumer endpoint devices* (e.g., SAT phones and TV receivers, vehicles, etc.)

Finally, humans participating in development activities (Human Resources segment), supporting tasks and satellite operations, is an overarching aspect spanning across the entire lifecycle of satellites and segments, as they are inextricably linked to the security of mission-critical assets.

Space Threat Landscape

Understanding the threat landscape for satellite systems is crucial for safeguarding their operations and continuity of satellite-based services. This chapter delves into the web of threats and offers a threat taxonomy based on ENISA's work in [1].

I. Threats

In an effort to create a threat taxonomy, ENISA examined publicly know attacks against satellite systems as those collated by the Space Attacks Open Database Project[5] covering the period between 1977 and 2019, alongside available information on more recent incidents included in ENISA Foresight Cybersecurity Threats for 2030[6].

The majority of the space-based attacks took place on government and commercial targets. The majority of observed attacks took place between 2001 and 2010 (30 recorded attacks in total), with a slight reduction from 2011 to 2019. Prior to 2000, only 12 attacks had been identified. This list can be updated with an additional three major attacks in the space domain which took place by 2022. These attacks involved hijacking, jamming and Distributed Denial of Service and were primarily targeted the commercial satellite sector. Overall, Jamming was among the most frequent materialised threats targeting mainly Global Navigation Satellite Systems (GNSS), followed by hijacking and Computer Network Exploitation (CNE). Attacks aimed at control functions, as well as spoofing, eavesdropping and the employment of anti-satellite weapons (ASATs) were far less frequent during the observed period.

II. Threat Actors

By examining the incidents outlined in the previous paragraph, the threat actor taxonomy from ENISA's Threat Landscape [2] can be adapted to the space domain. The following threat actors have been identified as the most prominent within the domain:

State-nexus actors, rely on government resources to achieve their objectives. Primarily engaged in espionage and disruption, state-nexus actors are sometimes directed by the military, intelligence or state control apparatus of their country and often spend considerable time investigating their targets to identify weaknesses and entry points.

Cybercrime actors and hacker-for-hire actors, are primarily motivated by financial gain. Mainly targeting data or infrastructure, cybercrime actors often employ social engineering and either steal from their victims, engage in extortion, or aim to monetise the stolen information.

Private Sector Offensive Actors (PSOA), who are engaged in the cyber-surveillance industry. Focused on enabling other actors (e.g., governments, private individuals) to gain a competitive advantage against their peers, PSOAs specialise in developing and selling cyberweapons to their clients, equipping them with advanced cyber capabilities.

Hacktivists (a.k.a. Civil Activists), whose primary goal is to extract and expose data or disrupt business operations for ideological reasons or to draw attention to a specific cause.

Hackers, comprising a diverse set of malicious actors' subgroups that vary in their motivation, objectives, skillsets and capabilities. These may range from Cyberwarriors and Cyber Fighters to Blackhat hackers/Crackers.

Disgruntled Employees or Insider Attackers, who have detailed insight of the organisation and its systems. This includes staff, contractors, vendors, customers, or former employees.

Untrained/Reckless Employees, who may not have the intention to cause harm but may still do so as a result of negligence or insufficient training.

The above analysis highlights that threat actors, regardless of whether they utilise resources of their supporting organisation -if any-, can execute a wide range of attacks. That is, the profile of these attackers is a critical factor to consider as part of comprehensive risk assessment efforts.

III. Threat Taxonomy

Building upon the asset taxonomy, the following threat taxonomy focuses on applicable attacks against assets for which a direct cyber-relevant threat has been identified via a thorough analysis of academic and industrial resources for attacks applicable to the space domain as part of [1]. The taxonomy includes:

Nefarious Activity/Abuse (NAA): refer to intended actions that target ICT systems, infrastructure, and networks by means of malicious acts with the aim to either steal, alter, or destroy a specified target.

Eavesdropping/Interception/ Hijacking (EIH): actions aiming to listen, interrupt, or seize control of a third-party communication without consent.

Physical Attacks (PA): actions which aim to destroy, expose, alter, disable, steal or gain unauthorised access to physical assets such as infrastructure, hardware, or interconnection. While one could think that physical attacks can happen only on the ground, interestingly, recent advancements make suck attacks applicable also in space[7].

Unintentional Damage (UD): unintentional actions causing destruction, harm, or injury of property or persons and results in a failure or reduction in usefulness. This is usually related with Untrained/Reckless Employees actors.

Failures or malfunctions (FM): partial or full insufficient functioning of an asset (hardware or software).

Outages (OUT): unexpected disruptions of service or decrease in quality falling below a required level.

Disaster (DIS): a sudden accident or a natural catastrophe that causes great damage or loss of life.

Legal (LEG): legal actions of third parties (contracting or otherwise), in order to prohibit actions or compensate for loss based on applicable law.

On top of the above, one needs to consider threats stemming from the use of legacy infrastructure and systems, which is a common case in the space domain, as well as the vulnerabilities that arise as result of the extended use of commercial off-the-shelf software (COTS) for different satellite components, as an aftermath of the intensive commercialisation of the domain.

Risks and Challenges

- So, what are the main risks and challenges identified then?

To answer this question, we examine the interplay between the lifecycle model, asset taxonomy, real-life incidents, and threat actors along with their motivations. In what follows, we present a set of risk cases worth highlighting due to their likelihood of occurrence and possible cascading effects.

Supply Chain Risk: the space sector is heavily dependent on vast global supply chains, introducing potential vulnerabilities that adversaries could exploit to compromise critical systems. The risk of supply chain intrusion is two pronged: software components are vulnerable to insertion, modification, or removal of information, and corruption of the code or functionality during development, upgrade, or update of the system; hardware components are susceptible to intentional or unintentional introduction of components or electronic chips containing defects, malware, or backdoors for system sabotage or espionage.

Use of Commercial Off-The-Shelf (COTS) components: economy of scale leads to increasingly rely on off-the-shelf components for communication, launch, data reception, and control facilities. This poses a challenge as details components used in satellites and infrastructures are publicly available, easing malicious actors to familiarise themselves with the targeted systems.

Legacy Systems: given the nature and the location of the space systems, many space-based assets have been designed without the security considerations needed to foresee or mitigate some of the present-day cyber challenges. Their remote nature adds another layer of complexity, making necessary updates difficult and in some instances impossible, leaving vulnerabilities that render satellite systems susceptible to cyberattacks.

Limited Visibility: the remote nature of the space systems poses challenges in detecting and responding to cybersecurity incidents and addressing vulnerabilities. In contrast to legacy systems, modern satellites require regular updates through remote access, which creates another layer of risk for intrusion into the system.

Weak Configuration/Lack of Encryption: depending on the nature of the space system and communication infrastructure and protocols employed, there is a high potential for interception. This is particularly the case for systems relying on radio frequency signals, which may lack encryption or use a low-grade one, heightening the risk of unauthorised access and collection of transmitted information. Bear in mind that the very same communication channels are used for transmitting software updates and operational commands.

Human Error: with space systems having a high degree of human interaction, there are increased risks of unintentional data leaks, system misconfigurations, and insider threats.

Sophisticated Cyber Attacks: with space systems serving an interconnected web of services and industries, there is an increased risk of nation-state actors and APT groups, which may attempt to gain unauthorized access and exfiltrate data or disrupt critical systems and could affect constellations of satellites operating in synergy.

in the frame of [1], ENISA offers an open-source “Controls-to-Threats Mapping” interactive tool [13] to aid experts navigate through mazelike regulations, international frameworks, best practices, and national guidelines, as an all-encompassing tool. The tool aims to assist cybersecurity analysts identify clear and actionable recommendations for securing space systems through a thorough mapping of controls. More specifically, each control is mapped to identified threats and applied across relevant lifecycle phases.

An instance of the interactive tool is illustrated in Figure 2, where for each

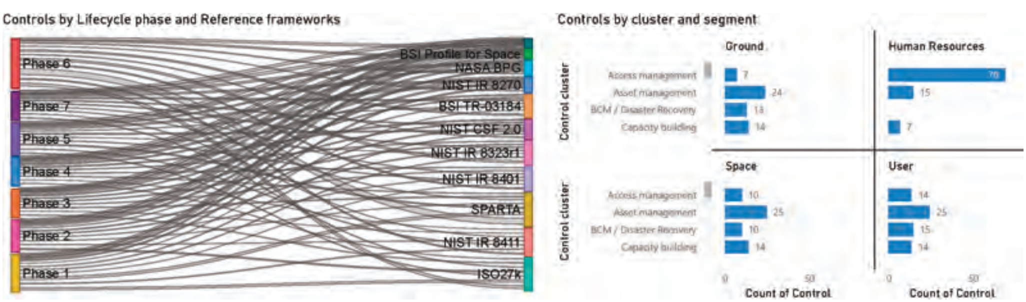


FIGURE 2 - INSTANCE OF “CONTROLS-TO-THREATS MAPPING” INTERACTIVE TOOL

Risk Management And Recommendations

Given the evolving threat landscape of the space domain, security experts and domain-specific professionals need to capitalise on validated tools and frameworks for getting informed decision on the implementation of cybersecurity controls. As part of this work and

phase of the satellite lifecycle the tool maps the available controls to the corresponding Risk Management Framework. Built for versatility, more views and mapping variations are provided by the tool to enable experts navigate and pinpoint the proper control that fits to the nature of the incident that needs to be tackled or the space mission at hand. Overall, as indicated in Table I, 281 controls of 13 frameworks under 18 control clusters are considered by the tool, covering all the 7 phases of the satellites' lifecycle, addressing 58 different threats.

Apart from tools, recommendations and proactive measures are essential to mitigate risks and enhance satellite security. At the EU level, NIS 2 is now at the forefront. Satellite operators must comply with it, which mandates incident reporting to facilitate information sharing and improve response strategies. *TABLE II* elaborates on the applicability of NIS 2 risk management measures (Art. 21) and reporting obligations (Art. 23) in the space domain, while in parallel it provides a mapping with the control clusters of our tool.

In addition, the Directorate-General for Defence Industry and Space (DG-DEFIS) is the European Commission's department tasked with developing and enforcing the regulatory frameworks that govern space activities within the EU while actively supporting the growth and competitiveness of the European space industry.

As aforementioned, complex supply chains exist in the space domain, implying the need for continuous monitoring of suppliers to prevent vulnerabilities, while thorough analysis and testing should be conducted to avoid blindly trusting and integrating commercial off-the-shelf (COTS) solutions. Furthermore, integrating security-by-design principles from the outset is crucial.

Leveraging lessons learned from other critical sectors can strengthen satellite security. Best practices include implementing cryptographic mechanisms that offer crypto agility (e.g., hybrid Post Quantum Cryptography systems[8]) in alignment with aspiring technologies of the future where satellites will play a role, such as Quantum Secure Communication in Space based on Quantum Key Distribution (QKD)[9]. Security measures such as network segmentation, thorough patch testing, system hardening, and a zero-trust approach are vital to minimizing risks.

Finally, adopting rigorous cybersecurity hygiene practices across all satellite operations will enhance resilience against cyber threats stemming from human factors. By prioritizing these strategies, the space sector can safeguard its infrastructure and ensure the continued security and reliability of satellite-based services.

TABLE I
REFERENCE FRAMEWORKS AND CONTROLS CONSIDERED IN THE ENISA TOOL [13]

Ref. Frameworks	#Controls	Ref. Frameworks	#Controls
SPARTA	*64*	NIST CSF 2.0	*17*
ISO27k	*39*	NIST IR 8270	*16*
BSI TR-03184	*30*	NASA BPG	*16*
NIST IR	*29*	BSI Profile for	*10*
8323r1	*27*	Space	*7*
NIST IR 8401	*26*	METI	-
NIST IR 8411		UKSA CST	-
		NIS 2	

Total: 281 out of which 125 distinct controls

Conclusions

The increasing reliance on space-based assets for critical infrastructure and global connectivity demands immediate attention to cybersecurity threats. As demonstrated in this paper, satellites are vulnerable to a range of cyber threats, including state-sponsored espionage, cybercriminal activities, and operational disruptions. The growing commercialization of space, combined with legacy infrastructure and complex supply chains, further amplifies risks. Addressing these challenges requires a proactive security-by-design approach (e.g., [5][6]), continuous threat monitoring, and adherence to international cybersecurity standards. The implementation of encryption, resilient network architectures, and supply chain security measures will be critical in mitigating future threats. Moreover, international cooperation and adherence to regulatory frameworks, such as NIS 2, is essential for establishing best practices and increasing the resilience of the space sector. As the space industry continues to evolve, cybersecurity must be an integral part of its development [4], ensuring the resilience of space systems and the security of global satellite-dependent services.

References

[1] European Union Agency for Cybersecurity ENISA, «Space Threat Landscape.», doi:10.2824/8841206, 2025

[2] European Union Agency for Cybersecurity, Lella, I., Theocharidou, M., Magonara, E. et al., "ENISA threat landscape 2024: July 2023 to June 2024". doi:10.2824/0710888, 2024

[3] Tantouris, N., Polemi D., and Dellios K.. «On the path to cyber-peace: a robust'diagnosis-filter' for safeguarding future systems and machines.» Proceed. of the Second Int. Conf. on Internet of things, Data and Cloud Computing. 2017.

[4] Tantouris N. «Robust fault tolerant detection and isolation techniques for actuator failures in dynamical systems», 2017.

[5] Tantouris N, Polemi D., and Dellios K. «Euresis-filter: a robust multiple-model FDI technique for small satellites' thruster faults.» Int. Journal of Modelling, Identification and Control 28.4 (2017): 349-360.

[6] Tantouris N., and Dellios K. «Euphoria-filter: a robust H2/H∞ technique amenable to the Lisa-Pathfinder thruster faults.» Int. Journal of Space Science and Engineering 4.1 (2016): 45-63.

[7] NASA, «NASA Systems Engineering Handbook, NASA/SP-2007-6105,» NASA, December 2007.

[8] European Cooperation for Space Standardization, «Space project management: Project planning and implementation, ECSS-M-ST-10C, Revision 1,» ECSS, March 2009.

[9] JAXA, «System Safety Standard, JMR-001, Revision B,» JAXA, March 2008.

[10] BSI, 2022, IT-Grundschutz Profile for Space Infrastructures, https://www.bsi.bund.de/Shared-

Docs/Downloads/EN/BSI/Grundschutz/profiles/Profile_Space-Infrastructures.html
[11] Scholl, M. & Suloway, T. NIST, 2023. Introduction to Cybersecurity for Commercial Satellite Operations. https://nvlpubs.nist.gov/nistpubs/ir/2023/NIST.IR.8270.pdf
[12] Shiotani, Bungo & Fitz-Coy, Norman & Asundi, Sharan. (2014). An End-to-End Design and Development Life-Cycle for CubeSat class Satellites. 10.2514/6.2014-4194.
[13] ENISA Space Threat Landscape Control Framework interactive tool and dataset https://github.com/enisaeu/Space-Threat-Landscape

1 Directive (EU) 2022/2555 of the European Parliament and of the Council of 14 December 2022 on measures for a high common level of cybersecurity across the Union, amending Regulation (EU) No 910/2014 and Directive (EU) 2018/1972, and repealing Directive (EU) 2016/1148 (NIS 2 Directive). https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:32022L2555

2 NIS 2 Directive considers under the Space sector: "Operators of ground-based infrastructure, owned, managed and operated by Member States or by private parties, that support the provision of space-based services, excluding providers of public electronic communications networks."

3 Cloud Computing via Satellite report (source: Northern Sky Research)

4 Northern Sky Research. 2022. Space Cybersecurity: Current State and Future Needs. White Paper. April. www.nsr.com/wp-content/uploads/2022/04/NSR-Space-Cybersecurity-White-Paper-FINAL.pdf.

5 Space Security Community. Space Attacks Open Database Project. https://www.spacesecurity.info/en/space-attacks-open-database/

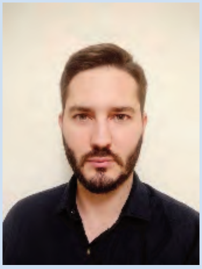
6 ENISA. 2023. ENISA Foresight Cybersecurity Threats for 2030. https://www.enisa.europa.eu/publications/enisa-foresight-cybersecurity-threats-for-2030

7 Although innovations in on-orbit servicing capabilities might be rendering this restriction moot, e.g., China's Shijian-21 [Krebs, Gunter D. "SJ 21";. Gunter's Space Page. https://space.skyrocket.de/doc_sdat/sj-21.htm], and NASA's OSAM-1 https://www.nasa.gov/mission/on-orbit-servicing-assembly-and-manufacturing-1

8 In this context a hybrid implementation uses a combination of pre-quantum (classical) and post- quantum schemes, and the mixing of pre-shared keys into all keys established via public-key cryptography (vide ENISA "Post-Quantum Cryptography - Integration study" (2022), https://www.enisa.europa.eu/publications/post-quantum-cryptography-integration-study)

9 https://defence-industry-space.ec.europa.eu/eu-space/research-development-and-innovation/quantum-technologies_en

Short Biography



Dr. Dimitrios Papamartzivanos is a Cybersecurity Officer at the European Union Agency for Cybersecurity (ENISA) since 2024. With over 13 years of experience in cybersecurity across both academia and industry, he has contributed to various research and cybersecurity projects.

He holds an MSc and a Ph.D. in Information & Communication Systems Security, with his research focusing on advanced machine learning methods for network intrusion detection and response systems.

He has published numerous papers in international journals and conferences and has submitted patent applications in the field of adaptive intrusion detection and response systems. Dimitrios has actively participated in several EU-funded cybersecurity research projects and innovation initiatives, serving as both a research associate and a technical coordinator.

His research interests include security and privacy for the Internet of Things (IoT), Intrusion Detection and Response Systems, Artificial Intelligence and Bio-inspired Algorithms, Adversarial AI, and Trusted Computing.

Short Biography

Evangelos Rekleitis is a Cybersecurity Expert working at the European Union Agency for Cybersecurity (ENISA) since 2019. With over 17 years of experience in cybersecurity, he has been providing expert advice and technical assistance to the EU Member States.

He specializes in risk management, capacity building, and emerging threats. Currently, he is responsible for capacity building activities, including trainings and exercises, under the Support Action program, providing cybersecurity services to NIS 2 essential sectors across EU Member States.

He contributed to significant projects like the ENISA Space Cyber Threat Landscape report, publications on Security Operations Centers (SOCs), cryptography, and AI, organizes the ENISA Learning and Training (Letra) events and is supporting the biannual Cyber Europe Exercise project. Before joining ENISA, he provided cybersecurity consultancy services to critical infrastructure in the Greek and Cypriot public sectors. he holds a MSc in Advanced Computing from Imperial College London and is certified as a CISM and GIAC Security Operations Manager.

He is a member of IEEE and ACM, as well as has authored academic publications in journals, conferences, and cybersecurity textbooks.

Short Biography

Dr. Nikolaos Tantouris is the Head of Sector Security and Infrastructure at the EU Agency for Cybersecurity (ENISA). He is also a member of the Knowledge and Information Team, where he focuses on the Space Cybersecurity domain.

With over 12 years of experience in both industry and academia, Nikolaos is a cybersecurity expert who has worked on various projects, including space projects, the Internet of Things, Industry 4.0, smart cities, and smart mobile.

He has considerable expertise overseeing and safeguarding network systems and interconnected and smart devices. Nikolaos has authored and co-authored numerous research papers and scientific reports and is a regular presenter at various international conferences.

TABLE II NIS 2 CONTROLS/REQUIREMENTS AND THEIR APPLICABILITY IN THE SPACE DOMAIN

#	Control cluster	NIS 2 risk-management measures & obligations	Applicability of Controls in Space Domain
1	Risk management / Policies & procedures	Policies on risk analysis and information system security (Art 21 2.a)	The establishment of policies on risk analysis and information system security is both a fundamental technical requirement and a strategic necessity, enabling the systematic management of cyber risks.
2	IR / BCM/DR	Incident handling (Art 21 2.b)	Effective cyber incident handling is not just a technical necessity, but a strategic measure for safeguarding the reliability, security, and resilience of satellite-based services. Definition of incident handling playbooks is important for business continuity management.
3	IR / BCM/DR	Business continuity, such as backup management and disaster recovery, and crisis management (Art 21 2.c)	Potential service disruptions in space domain could lead to "dead" objects in orbit or significantly impair economic activities and societal functions reliant on space-based services. Business continuity and recovery plans and playbooks are imperative to ensure continuous operation considering that physical intervention after launch is limited, if not impossible.
3	Supply chain management	Supply chain security, including security-related aspects concerning the relationships between each entity and its direct suppliers or service providers (Art 21 2.d)	Supply chain risks have been highlighted as the most prominent risk category in the space domain, due to the complexity of the chains, the number of stakeholders and their interdependencies.
4	Security by design / Vulnerability management / Network security	Security in network and information systems acquisition, development and maintenance, including vulnerability handling and disclosure (Art 21 2.e)	Attacks such as hijacking, jamming and DDoS of Service have been frequently materialized in the satellite sector, while complex supply chains and the use of legacy systems introduce vulnerabilities that render satellite systems susceptible to cyberattacks. The extended use of COTS combined with the fact that physical remoteness is not an adequate countermeasure means space operators should incorporate security by design and SDLC throughout all the phases of their operations.
5	Risk management	Policies and procedures to assess the effectiveness of cybersecurity risk-management measures (Art 21 2.f)	Cybersecurity and risk mitigation measures are crucial, but validation through tests and compliance audits is necessary. See Phase 2 & 3 of satellite lifecycle.
6	Capacity building	Basic cyber hygiene practices and cybersecurity training (Art 21 2.g)	Adopting rigorous cybersecurity hygiene practices can enhance resilience against cyber threats stemming from human factors (Human resources segment). Recall that untrained/reckless employees have been recognized as main threat actors.
7	Network security	Policies and procedures regarding the use of cryptography and, where appropriate, encryption (Art 21 2.h)	The rapid proliferation of small, inexpensive, and rapidly deployable satellites may result to weak/lack of encryption (due to cost and time constraints) meaning there is high potential for interception, unauthorized access and collection of transmitted information.
8	Capacity building / Access management / Asset management	Human resources security, access control policies and asset management (Art 21 2.i)	Humans participating in development activities and satellite operations, is an overarching aspect spanning across the entire lifecycle of satellites and they are inextricably linked to the security and management of mission-critical assets.
9	Access management / Network security	The use of multi-factor authentication or continuous authentication solutions, secured voice, video and text communications and secured emergency communication systems within the entity, where appropriate (Art 21 2.j)	Securing SAT-to-X communication is of paramount importance, especially safeguarding Ground-to-SAT channels as those are used for transmitting software updates and operational commands. Thus, strong authentication of entities accessing, interacting and transmitting information to satellites is vital.
10	Compliance	... essential and important entities notify, without undue delay, its CSIRT or, where applicable, its competent authority... (Art. 23)	Reporting of incidents is now an obligation for satellite operators as the proliferation of satellite-based services entails to high economic and societal impact.
11	Compliance	... essential and important entities communicate, without undue delay, to the recipients of their services that are potentially affected by a significant cyber threat. (Art. 23)	Satellite-based services have a vast number of end users worldwide. Many services are privacy-sensitive, such as SAT phones and geolocation-based services. Thus, it is essential to ensure that EU users impacted by significant events (e.g., data breaches) are promptly informed and be in position to take measures.

ESA's Potential Contribution to the EU Space Strategy for Security & Defence (EU SSSD), From Ambition to Implementation

Pascal Legai, Senior Security Advisor to ESA DG

Citation: *Pascal Legai, Senior Security Advisor to ESA DG. (2025). ESA's Potential Contribution to the EU Space Strategy for Security & Defence (EU SSSD) - From ambition to implementation. Hellenic Air Force Review, 134.*
https://doi.org/10.5281/zenodo.15168912

Abstract

ESA welcomes the important step taken with the publication of the EU Space Strategy for Security and Defence (EU SSSD) in 2022, giving the Space domain a key role for security and defence purposes. Thers is no European Defence without Space. However, the key challenge remains now the concrete implementation of the EU SSD. In this regard, the European Space Agency can play a significant role as a unique R&D organisation in the space domain in Europe, able to lead complex space architectures and procurement processes involving relevant European companies. In a fierce competitive and aggressive international context, emphasized by the new US administration and a critical international security situation, only a collective and coordinated approach mobilizing all the European Space Actors involved (EU, ESA and their Member States) in their respective fields of responsibilities, existing or already planned capabilities, but also missing capabilities to be identified, the available resources must enable the implementation of the EU Space Strategy for Security and Defence within the tightest deadlines.

Keywords

EU Space Strategy for Security and Defence (EU SSD), European Space Agency (ESA), resilience, Information Sharing and Analysis Centre (ISAC), accelerator, Galileo, Copernicus, secure connectivity, space safety, cyber security, critical technologies.

Introduction

In 2022, EU leaders identified space as a strategic domain in the Strategic Compass[1] and called for an EU Space Strategy for Security and Defence. Building on this political momentum, the Commission and the High Representative have developed the first-ever EU Space Strategy for Security and Defence (EU SSD)[2].

In a disrupted geopolitical context by the two major powers, Russia and the USA, creating total uncertainty for the future, increasing power competition and intensification of threats, the EU must take action to protect its space assets, defend its interests, deter hostile activities in space and strengthen its strategic posture and autonomy.

In this highly competitive and aggressive international context, only a collective and coordinated approach mobilizing all the European Space Actors involved (EU, ESA and their Member States) in their respective fields of responsibilities, existing or already planned capabilities, but also missing capabilities to be identified, the available resources must enable the implementation of the EU Space Strategy for

Security and Defence within the tightest deadlines.

Like any strategy, the next phase is indeed that of its implementation by mobilizing all the good will, the necessary human and financial resources. It is ultimately the political will of the EU and its Member States to make this strategic work a reality. In this regard, the European Space Agency presents all the skills and experience to contribute significantly to the EU's objectives.

The EU Space Strategy for Security and Defence

The EU SSD constitutes an important step in awareness and recognition of the contribution of space systems to our daily lives, but also for the vital needs of guaranteeing their use for security and defense purposes.

The EU SSD identifies the following broad areas of interest and action(2).

The Strategy outlines the counter-space capabilities and main threats in space that put at risk space systems and their ground infrastructure, building on a common definition of the space domain. To increase the common understanding of threats across Member States, the High Representative will prepare a classified annual space threat landscape analysis at EU level, drawing on Member States intelligence. The Strategy proposes as well actions to strengthen the resilience and protection of space systems and services in the EU. For this purpose, the Commission will:

- Consider proposing an EU Space Law to provide a common framework for security, safety, and sustainability in Space that would ensure a consistent and EU-wide approach. That also means to set up an Information Sharing and Analysis Centre (ISAC) in order to raise awareness and facilitate exchange of best practices among commercial and relevant public entities on resilience measures for space capabilities.
- Launch preparatory work to ensure long-term EU autonomous access to space, addressing in particular the security and defence needs.
- Enhance the technological sovereignty of the EU by reducing strategic dependencies and ensuring security of supply for space and defence, in close coordination with the European Defence Agency and the European Space Agency.
- Propose to expand the existing space threat response mechanism which is already used for the protection of Galileo to all space systems and services in the EU.

It calls for the efficient and timely mobilisation of relevant EU tools to respond to space threats. The Strategy proposes appropriate access to space domain awareness information through relevant national space commands to characterize inappropriate behaviours in orbit and protect EU assets. Space exercises, including with partners, will help to test and develop EU response to space threats and to explore solidarity mechanisms.

The Strategy proposes to maximise the use of space for security and defence purposes. The development dual-use services requires to take into account defence requirements when preparing the evolution of the EU space programmes.

The Strategy proposes the launch of two pilots: one for the delivery of initial space domain awareness services building upon capacities of Member States, and another for a new earth observation governmental service as part of the evolution of Copernicus and complementing existing assets.

The strategy also commits to better connect space, defence and security at EU level and ensure synergies and cross-fertilisation, notably in terms of research and development. It proposes concrete measures to foster collaborative work between space and defence start-ups and to enhance skills.

The EU will strengthen its engagement in multilateral fora to partner for responsible behaviours in space and promote norms, rules and principles of responsible behaviours in outer space through concrete and pragmatic steps.

The strategy calls for developing space security dialogues with third countries, in particular with the Unites States and other likeminded countries. EU-NATO cooperation will also be developed. However, the most reliable partner remains ESA.

ESA's analysis of the EU SSD

ESA's analysis of the EU SSD highlights the desire for continuity of space activities undertaken over the last decades, but also the need to complement existing capabilities with new services in order to have a complete and coherent space package to contribute to European strategic autonomy. These EU orientations are consistent with or complementary to ESA's activities and missions.

Indeed, the strategy constitutes a defining political and a critical step and pillar to further build the European space policy. Based on the extension of the Galileo model, this is also a critical capability step with the planned implementation of an Earth Observation Governmental Service, but also with the confirmation of the development and deployment of the IRIS2 constellation. The Strategy also strongly confirms the need for a strong space transport capacity, because access to space is clearly a major component of strategic autonomy for the orbiting of all necessary space systems, but also for transport in outer space between planets or celestial bodies, or between artificial objects.

The Space Domain Awareness (SDA) Services identified by the EUSSD would be of strategic added value to ESA operations & European autonomy. Similarly, partnerships with the United Nations, NATO or third countries that share a similar approach will allow substantial progress, sharing of capabilities and possibly costs. In this partnership context, ESA is recognized for its expertise in the field of technologies promoting EU-ESA synergies. Finally, concerning industrial policy, the EU role in space and defence is an opportunity for competitiveness.

According to the ESA assessment, the SSSD confirms the pertinent ESA's well documented and long-standing position that space infrastructure have a critical bearing on security activities (Agenda 2025[(3)], Accelerators[(4)]. ESA is mandated by its Member States to pursue its work on independent access to space, Galileo, Copernicus, secure connectivity, space safety, cyber security, critical technologies for non-dependence. Moreover, ESA's governance and regulatory framework enables it to conduct every type of activities, including of a classified nature which is of high relevance for security and defence-related activities. ESA reaffirms that security in and from space is essential for world stability, the welfare of people and health of our economies and the competitiveness of European industry.

The implementation of the EU SSD

The implementation of the EU SSD requires the mobilization of all existing, planned space capabilities and the identification of capacity gaps, and a real willingness of EU Member States to contribute, a key condition for success. As such, ESA is the only European space organization capable of leading complex space architectures and soliciting all the most relevant European companies.

For years, ESA has been a clear proponent of taking full advantage of technologies, innovation, and space-based services for security. The growing criticality of space data and technologies in security has now found resonance in key European policy orientations, such as the Strategic Compass, EU Space Strategy for Security and Defence (EU SSSD).

Through its programmes and its space-based data, ESA contributes to a better, safer and more sustainable planet and to the protection of people in Europe and around the globe. In order to avoid further fragmentation and potential duplications in terms of space and security capabilities, the ESA

DG has thus proposed to contribute to the implementation of the Strategy, with all of ESA's expertise, in support of its Member States and the EU. Based on its long-standing R&D experience in the field of security-related activities, ESA identified areas and activities where ESA can make a significant contribution and create synergies.

Indeed, ESA programmes offer a comprehensive contribution to Europe's security and world peace and stability. While the breadth of ESA programmes contributing to security, and thus to the EU SSSD, the *main* pillars of this involvement are: Independent access to space, Galileo[(5)], Copernicus[(6)], IRIS[2(7)]. Eagle1, SAGA, Civil Security from Space, Earth Explorers, Weather Forecast, ARTES 4S[(8)], Technologies, Security of Space Infrastructures, the ESTEC Test Centre and the ESTEC secure laboratory, in addition to the ESA-EDA Administrative Arrangement of 2011 and the 2012 ESA-EDA Security Agreement and the role of the ESA Security Office ensures that an harmonised approach is followed in terms of security engineering, certification and accreditation, implementing the ESA security framework across the Agency.

These are but the most noticeable ESA investments in security, which are building blocks and contributions to Europe's security at large, and space security in particular.

Security is strongly linked to the evolution of ESA. In particular, the three Accelerators (R3, PROTECT, Space for a GreenFuture) directly or indirectly security-related, focus on responding to urgent societal needs, upscaling existing space investments to the next level, with users at the centre of a programmatic evolution that would combine the strengths of ESA, EU, Member States and the private sector. These accelerators could be part of structured dialogue between involved stakeholders.

ESA, thanks to its telecommunications heritage of ARTES Programme, is a natural established leader to develop secure space communication systems based on critical technologies, aiming to satisfy societal needs in terms of resilient and sovereign connectivity for both institutions/governmental entities and citizens/business users.

Moreover, ESA supports the emergence of New Space industry through ARTES programme such as Pioneer, which aims to help space startup companies across the continent in their access to space for in-orbit demonstration and validation.

The EU SSSD is not perceived as an impacting element on ESA telecommunications on-going programmes which mainly rely on the Agency Member-states fundings and support. In particular, the development of commercial systems through public-private partnerships projects, developing New Space is, and shall remain, highly complementary to EU programmes.

This entails that all satellite communication activities that may emerge from the EUSSD's implementation ended to be tailored according to already existing and planned activities, whether in Member States or ESA in order to avoid duplicating effort at continental level. In addition, an institutional competition stemming from uncoordinated policies and programme initiatives needs to be avoided at all costs: Member States should not have different intermediaries for their funding high-risk technological developments. This inevitable dilution of resources available between European institutions and ESA will be detrimental to the effort of building a world leading European industry in security and defence.

Furthermore, ESA has consistently demonstrated in the navigation domain that it has protected and continues to protect the interests of its Member States and partners. The mechanism that ESA currently has in place through the Security Agreement with the EU has not only never been questioned, but rather lauded for its effectiveness in protecting the interests of EU and its Member States. EU classified information and also sensitive unclassified information, have been zealously protected by ESA and at no moment compromised.

In addition, The EU Space Programme Regulation[9] defines 'Copernicus', as a "civil Earth observation system under civil control, (...) offering geo-information data and services (...) where appropriate, integrating the needs and requirements of security." It further identifies as a specific Copernicus objective "to deliver accurate and reliable Earth observation data, information and services (...) to support the formulation, implementation and monitoring of the Union and its Member States' policies and actions based on user requirements".

To date, within the context of Copernicus and Security, ESA has acted on the following main lines of security related activities, upon request and in cooperation with the European Commission. Nonetheless, to perform sensitive or classified activities, including protection of data and interest of its Member States, a secure context must be guaranteed.

The Role of ESA

ESA is a civil R&D organisation. That means that ESA designs and develops space capabilities to meet various needs, and although ESA validates and demonstrates services, ESA does not play an operational role. This responsibility befalls upon national and regional actors who can best determine how they will use these space assets to serve their interests. Regardless, a tailored regulatory framework enables the delivery of such assets for its constituencies. The ESA Convention and its regulations, as well as the legal instruments binding it to the EU, guarantee the protection of the security interests of its Member States and those of its partners.

Security by design has always been ESA's approach based, in particular on policies, regulations and technological expertise: ESA can undertake any programme, at any level of sensitivity or even classification. This was clearly recognised in the Resolution by ESA's Ministerial Council in November 2023 during which Member States affirmed "the role of ESA in (...) delivering security-relevant benefits to its Member States and partners through technical excellence and its unique or leading capabilities in response to stakeholder requirements." Member States furthermore "[recognised] the Agency's internal security governance enabling it to securely manage its activities and programmes."

ESA thus ensures a comprehensive security management approach:

Credibility relies on reliability, in security-sensitive domains even more than in non-security critical areas. The reliability of the ESA security service is already today ensured by an elaborate internal security framework, with the Council-approved ESA Security Regulations and the ESA Security Authority, which is responsible, on behalf of the Director General, for the coordination of ESA Security Management activities.

The ESA security management function, delegated to the ESA Security Office, distributed across all ESA Directorates, and exercised in synergy with the security bodies of the Member States, ensures a centralized and transversal security management approach through, *inter alia*, a unique Point of contact for internal and external stakeholders and a unique, coordinated Security Strategy for Security from Space. In addition to the mechanisms provided for in the Convention[10] and programme-specific legal frameworks, this set-up is a pivotal element to the proper protection of the EU security objectives.

Conclusion

In conclusion, ESA welcomes the important step taken with the publication of the EU SSSD: with the evolution of technology, its more widespread availability, governments, and institutions need to rethink and update our structures to deliver better adapted security systems to users, in a controlled and secure manner, fully respecting national sovereignty.

The Strategy is a defining political step that will contribute positively to making Europe a better equipped strategic player. It is furthermore a critical capability step with the Earth Observation Governmental Service, the extension of the Galileo model, IRIS2, the confirmation of orientations that ESA has already begun in space transportation, while Space Domain Awareness services would be of strategic added value to all space operations, including those of ESA.

ESA has been proposing and urging for long, such as accelerating synergies in space and security, a shared understanding of space threats, the resilience and protection of space systems and services which obviously also affect ESA assets and our Member States investments.

ESA has the regulatory framework (including sensitive / classified projects) and technical *savoir faire* to accompany the EU in its new ambitions and to ensure the protection of the security interest of the EU and EU/ESA Member States.

Security can be a defining factor of ESA's future evolution: because of the increasing relevance and criticality of space in crisis response combined with the wider availability of such services, we will need to tackle a governance evolution regarding the control – which some call "sovereignty" - over some specific technologies relevant to security operations, as well as the development in cooperation of some capabilities that have up until today only been considered as strictly national.

During CM22, Member States have agreed to programmes covering independent access to space, Galileo, Copernicus, secure connectivity, space safety, cyber security, critical technologies for non-dependence.

Europe must better coordinate its space capability developments and cooperatively deliver those space services that Member States require for their domestic security and at their borders. ESA is not the sole architect of such evolutions, only a part of this evolution, as the distinction between civil and defence, or public and commercial domains become increasingly irrelevant and as we witness a growing acceptance that new synergies must be built as part of a consistent and comprehensive approach towards space and security, allowing a more efficient use of funding, public and private, concentrating on user needs addressing major challenges, shared by all on Earth.

The Accelerators form a solid basis to deepen the dialogue with EU institutions on how to better synchronise and consolidate fragmented space and security efforts in Europe.

Security *in* and *from* space is essential to the welfare of people, robustness of our economies and the competitiveness of European industry.

The Paris Ministerial Council in November 2022 invited "the strengthening of ESA's ability to serve its Member

States and cooperate with its partners, including the European Union, in the context of security, by reinforcing European industry and its competitiveness, fostering exchange and dialogue with security actors of Member States, and developing technologies and capabilities to better protect Europe and its citizens from crises and risks." It is precisely in this spirit that ESA proposes to engage the EU in a constructive space and security dialogue, that ought to not only "recognise the sovereignty of the Member States in the field of security" but also the roles and added value of both the EU and ESA.

References

(1) A Strategic compass for security and defence, European Commission, Council of the European Union, 7371/22, 21/03/2022

(2) The EU Space Strategy for Security and Defence, for a stronger and more resilient European Union, Joint communication, JOIN(2023)9, Directorate-General for Defence Industry and Space, 10/03/2023

(3) ESA Agenda 2025, Make space for Europe, 31/03/2021

(4) ESA Accelerators, Accelerate the use of space, 02/2022

(5) Galileo EU programme, https://defence-industry-space.ec.europa.eu/eu-space/galileo-satellite-navigation_en

(6) Copernicus EU programme, https://defence-industry-space.ec.europa.eu/eu-space/copernicus-earth-observation_en

(7) IRIS2, https://defence-industry-space. ec.europa.eu/eu-space/iris2-secure-connectivity_en

(8) ARTES,https://www.esa.int/Applications/Connectivity_and_Secure_Communications/ARTES/About_ARTES

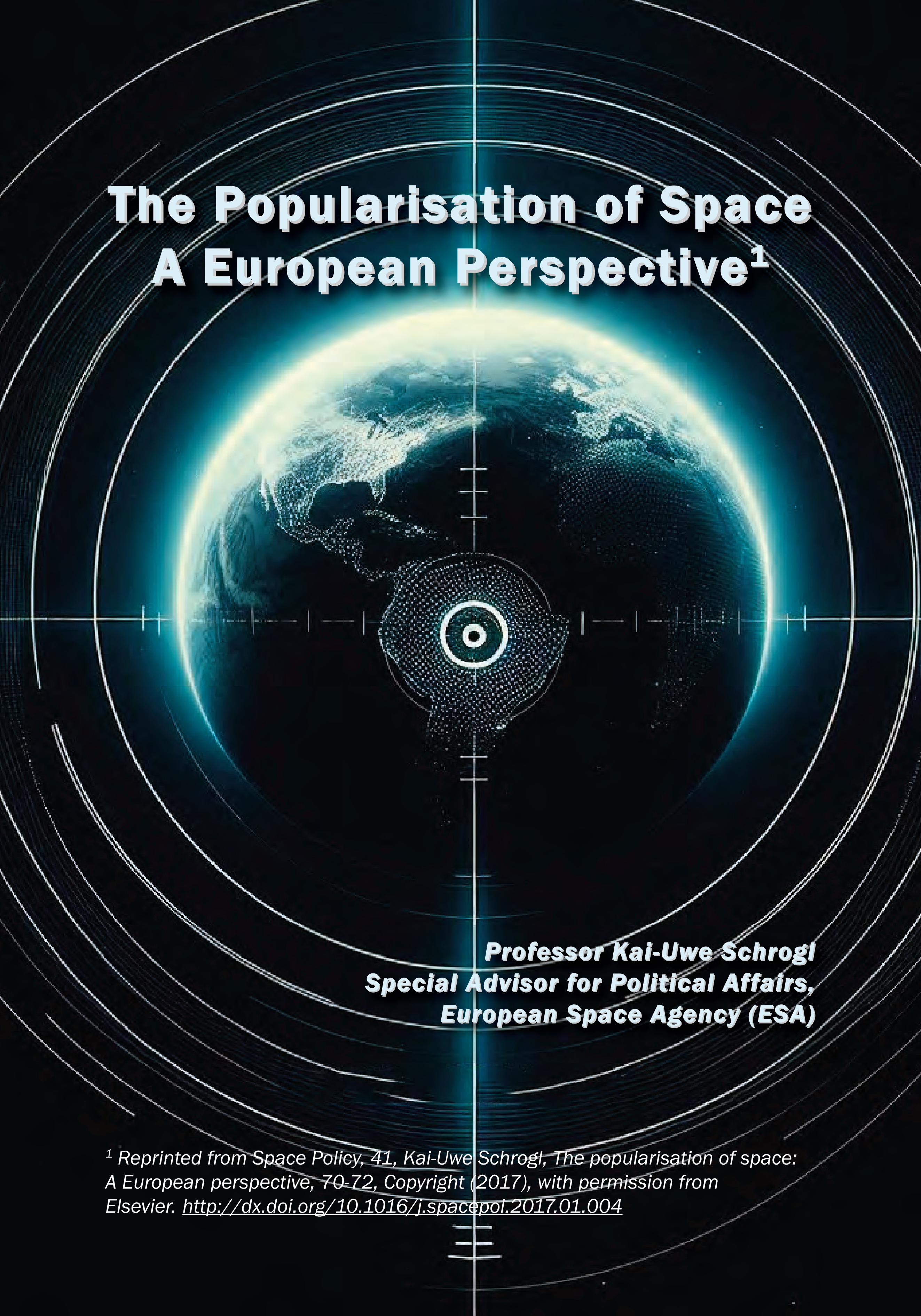
(9) Regulation (EU) 2021/696 Of The European Parliament and of the Council of 28 April 2021, article 3

(10) The ESA Convention, CSE/CS(73)19, rev.7, 31/05/1975

Short Biography

Pascal LEGAI is currently the Senior Security Adviser to ESA DG. He has a military background (Major General in the French Air and Space Force). He acquired experience mainly in the fields of geography, imagery intelligence, international relations, Space and Security issues.

He has extensive international experience in the geospatial information domain. Before joining ESA, he was Director of the EU Satellite Centre, an imagery analysis centre, based near Madrid, Spain, providing Geospatial Intelligence (GEOINT) and Imagery Intelligence (IMINT) products and services to support the EU external action. He has a PhD in International Relations, a qualification as Research Director, a law degree, several Master degrees in Imagery Processing, Computer Sciences, in History, in Irish Civilization, in Mathematics. He is an aerospace engineer and has also an Engineer Diploma in the field of the geographic sciences.



The Popularisation of Space A European Perspective[1]

Professor Kai-Uwe Schrogl
Special Advisor for Political Affairs, European Space Agency (ESA)

[1] *Reprinted from Space Policy, 41, Kai-Uwe Schrogl, The popularisation of space: A European perspective, 70-72, Copyright (2017), with permission from Elsevier.* http://dx.doi.org/10.1016/j.spacepol.2017.01.004

Abstract

It is a legitimate question to ask, whether space is really popular in Europe. But why should it be? This viewpoint tackles both the whether and the why. It looks at deficiencies as well as advancements in communicating space to the European public and decision-makers. Before anything else, it provides an idea of the aim to make space (even more) popular in Europe, reflecting the continent's development and identity

Keywords

Space Popularisation, European Identity, space activities, astronauts, space education, younger generation

What is popular today?

You like astronauts? Of course you do. And certainly you can even be characterized as being part of the Apollo generation, which does not necessarily require a birthdate before 1960, but which rather means that the Moon landing is a paramount personal memory, whether it was actually witnessed or not. In this respect, the entire space community, whether 70 or 20 years old, is part of the Apollo generation. So if you ask this space community, what makes space popular, one there is unanimous consent: astronauts!

But is that still valid for the broader public of today and even more so for the young? Astronauts, most fortunately, still draw crowds wherever they speak and share their experience. For many, they are role models. Not the heroes of the 1960s and of today's Hollywood movies, but men and women who have made a special experience. This astronaut generation is not regarded as one of outward explorers, leaving the Earth and leaving Earth orbit. They are regarded as explorers with the direction Earth. They can share and are requested to share with us their view on Earth for under-standing its vulnerability and the arbitrariness of frontiers and nationalism. People want them to provide them with a global identity and inspiration.

But is human spaceflight all there is or all that should be popular about space activities, which have developed and extended so tremendously during the past decades? Can anything else than astronauts compete with what is popular today? And what is actually popular today? Are Soccer players or rock stars more popular than space? Are games more popular than the real stuff?

Ask any young person, how much they like the websites of the space agencies. If they actually have ever visited them, they might regard them as being from the Stone Age. If not, landing on Mars or a comet, any sports star has more followers than all space agencies put together. But is this a measure for popularity? Competing for attention in a smart and modern way and popularity could there-fore be the motto for the space community.

Why should space be popular?

When dropping the word lobbying, the intention should be clear. It shall not refer to the pejorative use of the term meaning to viciously get money, benefits or undeserved privileges with which it is usually associated in Europe. It shall be the understanding that the space community wants to popularise space, because it is fully convinced of the positive effects space utilization has on society and the benefits which are derived from space for economics, sustainability, progress and prosperity. From this perspective, it is legitimate to make efforts (and spend money, the tax payers' money) to popularise space, because it has more the character of information, dissemination and education.

When looking at education, the approach and the intentions are even more diverse in Europe. Space as an attractive tool for education shall certainly lead to develop the future workforce in the space sector. Concepts for space as a tool for education are however mostly seen altruistically by the space agencies in their education programmes in that a clear objective is to raise the interest of young people in all the STEM (science, technology, engineering and mathematics) fields, even if the high school student attracted by space in his or her curriculum will not automatically become a rocket scientist, but may turn out to be a biologist or a civil engineer.

And here we are again. As the astronauts are ambassadors of an idea and an ideal, education with and through space is also dedicated to a broader benefit. These are good preconditions, one may think, to run a successful popularisation campaign meeting today's expectations of European citizens.

How to popularise space?

The real question is, how to do it? It does not help anymore if governments advertise for it. Also putting publicity in newspapers and on TV is not really promising. To give the last point a different spin: space can become the background for advertisement, but for this, it has to be popular already. Space has seen limousines on the Moon or beer-drinking astronauts watching meteorites hitting the Earth in commercials. Returning to means of popularisation, blogs, tweets and Facebook are not really promising either, since it is done now by more people than there are followers and readers. The current standards of popularisation are not enough for a high-flyer like space.

Popularisation can work through surveys. They meet the double objective of learning what people think and at the same time they engage people. Space in Europe has continuously been a topic for surveys mostly run by Eurobarometer on behalf of the European Commission. They lead to good information and intelligence. Sometimes, however, the client is happy about the result that almost 100% are in favour of using Earth observation (EO) to monitor the climate, but this delight is immediately reduced, when in the next question zero percent can name a single EO satellite mission.

So, surveys have to become smarter. ESA actually tried that out. In September 2016, it organized what was called a “Citizens’ Debate on Space”. On one day in September, around 100 persons met for a day in each of its 22 Member States to discuss space issues under the guidance of a moderator, touching all major aspects of space and thus taking a step further from a normal non-interactive sur-vey. This Citizens’ Debate was modelled after an approach applied already for COP21, where the interaction took place in 100 countries. The result was amazing and showed that with a bit of creativity traditional means can be transformed into effective new instruments.

Another instrument are prizes. In Europe, no prize can match the power of the X-Prizes. But Europe learned and adapted for this situation. The Galileo and the Copernicus Masters are the flagships in the field. They promote new ideas in navigation and EO applications. They target entrepreneurship, but they also are an effective tool for disseminating information and messages about the benefits of space applications. Other, much smaller competitions such as the ESA-EISC (European Interparliamentary Space Conference) Award on Space for Sustainability are also a means for popularisation, but they additionally have a side-effect of positive political communication. The highest scores are hit with programming competitions, be it manoeuvring rovers on celestial bodies, be it docking spacecraft to space stations. In these cases, European aficionados join with a global community in creative frenzy, which highlight the potential of space as a cool object for up-to-date pursuits.

The most modern means in this respect is certainly the hackathon. While it does not really popularise to the broadest level of society, it can tell stories of space, its infrastructure and its applications. It also provides an excitement, which can be exploited in many ways. This case shows how space in Europe is embracing new means of popularisation, transforming and enhancing them through its special touch and preparing the young generation for looking at space from diverse perspectives.

Apart from the high-end efforts, a well-crafted mix of traditional and new media is necessary to reach the broadest possible spectrum of society as well as the decision-makers. We have to continuously extend our reach through addressing new target groups with new formats and new platforms in the digital as well as the real world. And we have to overcome the negligence of building a trademark for Europe in space, which can only be to make "ESA" the brand around which Europeans' expectations in such a trade-mark converge. It is the a step towards United Space in Europe, where all partners, be they space agencies, research establishments or industry, can benefit from the power of such a rallying trade-mark. With this, co-branding comes naturally to the benefit of all those associated with it.

Space, Identity and Inspiration

One of my last projects as Director of the European Space Policy Institute (ESPI), and one of my favourite ones, was "Space and European Identity". It was driven by the idea that space can be a powerful tool for building and strengthening the European identity further and better than its little loved institutions and regulations can. A European launcher, a European navigation satellite system, European astronauts on board of a European module at the ISS - all this can help to produce a feeling of pride in joint European efforts, allowing people to feel a bit more European, which is required as a basis for any political integration.

No one should joke about UEFA and the Eurovision Song Contest. They are more powerful drivers for European integration in the minds of the people than any treaty. But only the aerospace sector has such highly-visible joint European technology developments. Popularisation of space can thus lead to direct positive political and societal effects. You want to respond to Brexit? Use space. The United Kingdom has never questioned its membership in ESA.

The second point besides identity is inspiration. Inspiration can take the most diverse forms: scientific, technological, political, ethical or societal, to name only a few. It is what brings societies forward. It is at the basis for an even better future. The Apollo generation from above has received its inspiration from the Moon landing. It worked for many decades. But where is the inspiration stemming from space today? Is it Landsat 7 or Sentinel 1B? Are you inspired by the precision of the clocks operated for GPS and Galileo? You certainly should be. But it is not easy to convince the public.

Maybe the “Moon Village” concept promoted by ESA’s Director General, understood as a growing ensemble suited for multiple uses and open to multiple users, can be the next vision for space. It already begun to create a global momentum. Until it deploys its full potential as an inspirational tool, the “overview effect” of astronauts perceiving the fragile and borderless Earth from orbit, re-mains the key emotional and inspirational facet.

You will hardly convince anyone with brochures, websites or a survey anymore. You can do that when you take the time, effort and resources to run something like a Citizens’ Debate. Rosetta and Philae inspired. They accomplished a first and they did so unimaginably far away from Earth in breath taking reality. So, inspiration as a means for as well as a result of popularisation is unbeatable. It always is authentic and it makes you wonder what can be accomplished now and what we would like to contribute to accomplishments in the future. We have to make efforts to prepare new narratives that actually touch people, making space tangible and helping to reach the level of human empathy.

On the right track?

We want to popularise space. We do that because we are convinced that space is worth being taken account of by as many people as possible, maybe even by the whole society. Not by chance, the Joint Statement between ESA and the European Union of 2016 on a Shared Vision and Goals for the Future of Europe in Space says that “Every single European citizen shall benefit from Europe’s space capacities and capabilities.” And the citizens shall know this. But it’s not so much about getting the citizens’ consent to spend their money.

It is much more that we, the space community, can and want to provide, almost dedicate, to society to achieve benefits and progress. A noble cause, which we have to justify and reaffirm continuously, through information, innovation, interaction and inspiration. We have to use space for education and making society STEM-friendly. We also have to contribute to the development of identity, a specificity for Europe in turmoil. We have to adapt our methods and instruments and should not be afraid of taking risks and using unorthodox methods. While money is scarcer for communications in the space sector than in other places, we still have the hot topics. The single most important thing to do, however, is to merge the unmatched inspiration of the long Apollo generation with modern expectations and methods. Then popularity comes unfailingly and allows us to make space work effectively for society.

Short Biography

Professor Dr. Kai-Uwe Schrogl is the Special Adviser for Political Affairs of the European Space Agency (ESA). Before, he was seconded from ESA to the German Federal Ministry for Economic Affairs and Energy in Berlin to support the German Presidency of the Council of the European Union.

Until 2019, he was the Chief Strategy Officer of ESA in Paris. From 2007 to 2011 he was the Director of the European Space Policy Institute (ESPI) in Vienna.

Kai-Uwe Schrogl is the President of the International Institute of Space Law (IISL), the global association of space lawyers from more than 50 countries. He served from 2014 to 2016 as chairman of the Legal Subcommittee of the United Nations Committee on the Peaceful Uses of Outer Space (UNCOPUOS) and was from 2020 to 2022 Co-Chair of the Global Future Council on Space of the World Economic Forum (WEF). He recently co-edited "A Research Agenda for Space Policy" at Elgar.

Advancing National Security: Greece's Strategic Plan for Next-Gen MILSATCOM Systems

Lt. Colonel (Pilot) Giantsis Fotios

Citation: *Lt. Colonel (Pilot) Giantsis Fotios. (2025). Advancing National Security: Greece's Strategic Plan for Next-Gen MILSATCOM Systems. Hellenic Air Force Review, 134.* https://doi.org/10.5281/zenodo.15169197

Abstract

This article proposes a plan for the development of the Greek satellite system (GR-MILSATCOM). The benefits of such a project would be significant for strengthening national (and international) Defence, Security and Economy. Such a system will also be a catalyst for the Hellenic Air Force (HAF) in transitioning to the new space era, enhancing its operational capabilities and the resilience of its communications. Greece currently seeks to acquire its own satellite system, primarily for military and governmental communications. Greece aims to design, develop, launch, and operate a telecommunications satellite equipped with advanced technologies and strong encryption, operating in a geostationary orbit (GEO). This satellite will provide continuous wide-area coverage and connectivity to the national Armed Forces (and governmental entities) in various operational theaters[1]. While existing national telecommunications infrastructures are capable, they have inherent limitations that hinder nations from operating with maximum efficiency and security. A modern SATCOM system can enhance existing national military communication networks, ensuring fast, reliable, and secure data transmission during military operations. Additionally, it can provide the desired nations' autonomy in the field of SATCOM while contributing to technological superiority and economic growth.

Keywords

Military Satellite Communications, MILSATCOM, Governmental Satellite Communications, GOVSATCOM, Secure SATCOM, Space Security and Defence, Hellenic Air Force, HAF

Introduction

In the modern era, information is one of the most decisive factors for national Security and Defence. Satellite Communications (SATCOM) play a central role in the defence strategies of nations, offering resilient and reliable exchange of information, in a rapidly changing geopolitical environment. Their utilisation is critical for the effective conduct of military operations and the safeguarding of national security. The strategic importance of SATCOM in national Defence is very high, offering significant capabilities for Command, Control, Communication, Computer and Intelligence (C4I).

Space is an enabler not only for the digital transformation. The Space industry is rapidly evolving as we enter a new era, including SATCOM. Agile New Space players are embracing new trends in the space technology in order to develop services benefiting diverse users in both public and private sectors[2]. By following a comprehensive roadmap for leveraging these technologies, nations can not only enhance their defence capabilities but also maintain strategic superiority in the increasingly digitised and interconnected realm of global Security.

Secure SATCOM are essential for the resilience and strategic autonomy of the nations, both in Space and on the ground. They provide the basis for security - and safety - of critical missions and operations, including crisis management, land and border surveillance, and protection of the key infrastructure[3].

Space has long been an important domain for military operations and has been used actively by NATO for its own SATCOM programme for almost 55 years. However, it was not until 2019 that NATO Allies formally recognised Space as an operational domain, opening the door to a greater focus on how Space can play a pivotal role in Defence[4].

A little later, in 2022, after the Russian invasion in Ukraine, the European Union (EU) leaders also identified Space as a strategic domain through the "EU Strategic Compass" [5] and called for an EU Space Strategy for Security and Defence. Building on this political momentum, the Commission and the High Representative have developed the first-ever "EU Space Strategy for Security and Defence, 2023" [6]. As highlighted in this Strategy, the gap between Space and Defence should be bridged, while flagship programs in Space for Security and Defense purposes must be prioritized.

The EU needs independent, secure, resilient, and high-speed space-based connectivity to satisfy the needs of EU institutions, bodies, agencies and Member States. Secure SATCOM provide one or two-way reliable, accessible and guaranteed satellite service for communications. To connect European Governments, the EU is working on both the deployment of GOVSATCOM, a component already part of the "EU Space Regulation, 2021" [7], and the deployment of the IRIS^2, the new "EU Secure Connectivity Programme" [3, 8], to be operational by 2030.

In this context, the development of a national military telecommunications satellite (MILSATCOM) is a strategic imperative to enhance a nation's defence capabilities and secure communications infrastructure. It is also an opportunity to advance technological capabilities, and enhance research and innovation in space sector. The technological advancements made during the system's development could also lead to numerous spin-off technologies that benefit civilian sectors, by Enhanced (and Secure) Communication Networks.

The primary purpose of establishing a national MILSATCOM system in Space is to provide a secure, resilient and high-capacity communication network tailored specifically for military use. This satellite will ensure fast, seamless and real-time communication across all branches of the Armed Forces, enhancing coordination, operational efficiency and decision-making capabilities.

Strategic Impact of National MILSATCOM Systems

Contribution to National Security

The development and deployment of a MILSATOM system will ensure national autonomy in safety and Security. The utilization and development of space infrastructure contribute to achieving autonomous capabilities to respond to national Security needs.

The system will also provide a dedicated, secure and resilient communication infrastructure for defence operations. It will serve as a critical component in ensuring that military forces can maintain superiority in all operational environments. The forecasted improved communication capabilities will provide a tactical advantage, facilitating real-time data sharing and decision-making.

The critical role of SATCOM in several key areas is underscored by NATO:

Secure and Reliable Communications across vast distances

This capability is vital for coordinating operations, especially in remote or hostile environments where traditional communication infrastructure is lacking. NATO's recent investment of €1 billion in SATCOM services over 15 years highlights the importance placed on these capabilities[9].

Support for Command and Control (C2)

SATCOM are fundamental for transmitting orders, intelligence, and real-time data between Command Centers and deployed forces, ensuring synchronized and efficient mission execution. NATO's SATCOM infrastructure supports operations at all levels (strategic, operational and tactical), providing access to mission-critical information[10].

Intelligence Gathering and Surveillance

SATCOM support Intelligence, Surveillance and Reconnaissance (ISR) operations by transmitting data from various sensors and platforms to analysis centers. This capability enhances Situational Awareness and decision-making processes, critical to national Security[9].

Resilience and Redundancy

In times of crisis, terrestrial communication networks may be vulnerable to disruption. SATCOM provide an alternative communication pathway, ensuring continuity of operations even when ground-based systems are compromised. NATO's strategic rivals have been conducting space operations that threaten the security of the Alliance, highlighting the need for resilient space-based infrastructure[4].

Integration of Allied Forces

SATCOM enable different nations' forces to operate cohesively, during multinational operations. NATO's reliance on member states to provide space capabilities, such as SATCOM, underscores the collaborative nature of these operations[11].

Economic Benefits

The development of a new MILSATCOM system is expected to create jobs and drive economic expansion through technological advancement and manufacturing. Apart from that, any excess telecommunications capacity can be leased to Allies, such us national/governmental organisations, or to private telecommunication companies, contributing to the rapid amortisation of the project. The Greek RFI, published in 2024, also incorporated this option[1].

Moreover, in the field of narrowband communications for the tactical domain, there has been a rapidly increasing structural shortage of satellite capability worldwide in recent years. This issue requires intensive international coordination and cooperation. By investing proactively, nations and organizations such as NATO, could have tactical satellite capability over extended areas, be well-prepared to fulfill their international role in this domain, and be able to further build this capacity[12]. These requirements could potentially be addressed by EU systems like GOVSATCOM and IRIS[2], which aim to provide secure and resilient satellite communications for EU citizens and governmental users. However, their ability to fully cover the increasing demand for tactical narrowband SATCOM—especially for highly mobile, real-time battlefield communications—remains uncertain.

SATCOM capabilities of the defence sector may be supplemented by commercial contracts as required. With the huge growth in the commercial supply of high-quality SATCOM capability, it is becoming opportune to explore dual-use scenarios in collaboration with industry: deploying commercial SATCOM infrastructure for military applications. Through limited co-investment, defence sector could have this commercial capability made suitable for military deployment, and also strengthen the business case for industry[12].

Operational Support for Forces Deployment

Some of the EU member states have deployed forces in external theatres over the last decades as part of national or international missions or operations (such as under NATO, or the EU). Those missions and operations involve the use of satellite communications either based on proprietary governmental satellites or third-party assets (such as systems managed by private commercial operators)[3, 5].

Evolving Landscape of Secure SATCOM: Drivers, Challenges and Future Trends

Factors driving the demand for secure SATCOM

The need for secure SATCOM was first presented in 2004 with the EU

Council's decision "European Space Policy: ESDP and Space" [13] and again in 2016 with the "EU Global Strategy" [14]. However, the Russian invasion highlighted the necessity to address this issue more effectively. The 2022 EU Strategic Compass is the last key driver for future demand. It is estimated to lead to new investments, modernisation of forces and new operations.

At the same time, an increase in the data transmission requirement for essentially all of the terminals used by military forces is anticipated.

The sensitivity to new and/or increasing threats (i.e. contested operations, jamming, cyber security, etc.) is also estimated to result in a demand for more "secure" capabilities compared to traditional commercial SATCOM solutions[3].

Furthermore, the locations of future threats, crises and operations is difficult to anticipate, as exemplified by the war in Ukraine in 2022. As such, the ability to rapidly adapt, with an increasing level of flexibility and mobility is estimated to represent an important driver. The trend towards an increasing number of units equipped with a communication on the move capability is estimated to increase[3].

Current Challenges in SATCOM

In today's military applications supported by SATCOM, security, resilience, information assurance, and link efficiency technologies are inextricably linked. Military operations are becoming more complex as conflict areas grow more dispersed on a global scale, with a growing need to support a diversity of on-the-move, on-the-pause and fixed platforms. At the same time, security threats are becoming more apparent, raising concerns that nations, terrorist groups, criminals and individual hackers can jam, interrupt and endanger military operations. The challenge is to meet, in a secure and guaranteed way, the increased demand for raw capacity generated by continuous growth in space data rate requirements for military purposes[15].

Existing SATCOM systems, while robust, face several critical challenges that limit their effectiveness in supporting modern military and national security operations. Primary challenges include:

- ✓ Bandwidth limitations
- ✓ Cyber Security vulnerabilities
- ✓ Coverage gaps
- ✓ Latency issues
- ✓ Aging infrastructure
- ✓ Capacity constraints

Technological Drivers transforming the Secure Satellite-based Connectivity

Several structural drivers have started to transform and largely increase the volume of capacity offered through satellite assets. These will likely also impact the capacity and services available for secure connectivity. Overall, digital technologies are at the heart of this transformation alongside the use of higher frequency bands and other features.

Ultimately, the technological benefits will likely go in three directions[3]:

- ✓ An increase in the volume of available capacity
- ✓ A higher flexibility in the ability to dynamically allocate the capacity and design of services
- ✓ A higher cost efficiency of satellite assets

Latest Trends in SATCOM

The SATCOM domain is undergoing unprecedented development across the board. Technical developments in satellites, terminals and ground infrastructure are moving at lightning speed.

New innovative launch capability providers, such as Space-X, are making satellite launches increasingly common. Today, we see huge investments in commercial constellations of satellites, mainly in Low Earth Orbit (LEO). Examples include Starlink and OneWeb. Because of the short distance between the satellite and Earth, these constellations provide connections that can compete with land-based fiber networks in terms of latency and bandwidth[12].

Beyond the prominent rise of LEO constellations, there is a growing trend toward deploying satellite constellations across various and multiple orbits, not just the traditional single satellites in GEO orbit. In GEO, innovations such as micro-GEO satellites are also emerging. Additionally, the adoption of multi-band and high-frequency bands is becoming more widespread, enhancing the flexibility and capacity of SATCOM systems.

High Throughput Satellites (HTS), software-defined satellites, and satellites equipped with on-board Artificial Intelligence (AI) and edge computing capabilities, are also key trends that are revolutionizing SATCOM. Moreover, Direct-to-Device (D2D) technology is addressing connectivity challenges in underserved regions, offering a practical solution for extending communication networks.

Meanwhile, there is evidence that state actors are increasingly focusing on developing SATCOM specific attacks. These attacks are also being developed across the spectrum: ranging from attacks in the electromagnetic domain (such as jamming, directed energy deposition and interception) to kinetic attacks and cyber-attacks on ground-based infrastructure, including management infrastructure. Technical, geopolitical and commercial developments in the SATCOM domain require a broad (re)orientation of Defence's need for more secure and robust high-capacity SATCOM links[12]. Recent advancements in quantum and laser communications, along with blockchain technology, are showing great promise in providing robust protection against the above security threats.

The GR-MILSATCOM System and its Impact on the Hellenic Air Force

The GR-MILSATCOM system

Greece is pursuing the development of a single satellite in GEO, capable of providing autonomous and secure satellite communications. The satellite should also be positioned to lease any excess capacity, which is a key element for recouping the overall project costs. Another important aspect is the Greece's intention to offer these services to allied nations and/or organisations, which will create funding requirements from those entities[1].

Since the exact budget, project timeline, and specific intentions regarding collaborations with other countries and organizations remain still unknown, only a general idea for developing such a system can be outlined. If the initial mission parameters (requirements and orbit) are not altered along the way, the recommended approach is to opt for deploying 2x Micro-GEO satellites, with a different timeline for each of them. Initially, Greece should procure a Micro-GEO satellite, which will be small and cost-effective, allowing for rapid deployment and the provision of desired services.

Although much smaller than GEO satellites, micro-GEO satellites are being placed in the geostationary orbit and already provide (successfully) satellite communications. Their advantages - such as lower weight and size, simpler construction, reduced costs, easier and quicker deployment, and streamlined licensing from regulatory authorities - make them increasingly popular. They are an ideal choice for countries with smaller budgets that still wish to develop their own MILSATCOM and/or GOVSATCOM systems. It is worth noting that Micro-GEO satellites (as well as laser communication satellites) do not require approval from the International Telecommunication Union (ITU) for GEO deployments.

The leasing of excess capacity from the Greece's first satellite could support the financing of the second one. This option offers the redundancy and uninterrupted operation required for a MILSATCOM system. A realistic estimate for the first deployment would be a budget of under €60 million, and a timeline of approximately two years. This satellite could use high military frequency bands, such as X or MIL-Ka band, and is projected to have a lifespan of 10 to 15 years in geostationary orbit.

The second Micro-GEO satellite could further improve connectivity between existing national or European satellite constellations in lower orbits by utilizing laser Inter-Satellite Links (ISLs). Additionally, it could be equipped with a Quantum Key Distribution (QKD) payload to further enhance security. This approach aligns with Greece's recent efforts to integrate into the EuroQCI framework. As a reminder, the country is already taking steps to participate in this broader EU initiative, which the country's Ministry of Digital Governance (GR-MoDG) signed on 3 December 2019[16].

Greece's focus has been primarily on developing the terrestrial infrastructure for the EuroQCI, with three Optical Ground Stations (OGS) selected in collaboration with the European Space Agency (ESA):

dinator for the HellasQCI project[18].

Additionally, the world's first commercial OGS has been established in Greece, by the Norwegian-based company K-SAT, with plans to integrate it into a multi-mission network operation[19]. This K-SAT telescope could potentially establish optical links with the proposed GR-MILSATCOM system. Furthermore, optical telescopes designed for laser communication with the system could be deployed on military ships within Greece's territorial waters and/or on Greek islands, providing additional redundancy to the overall system.

Figure 1: Greece's terrestrial infrastructure for the EuroQCI, Source: HELLAS QCI[17]

The National Infrastructures for Research and Technology (GRNET), operating under the auspices of the GR-MoDG, is at the moment, the coor-

Here is an illustration of the proposed integration of the GR-MILSATCOM system into the existing GreeCom[20] network:

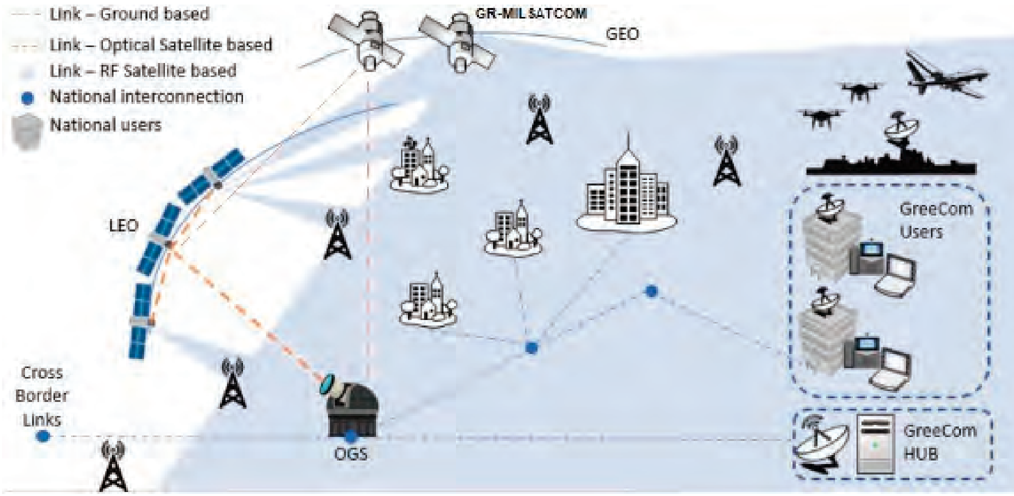


Figure 2. The Proposed Integration of the GR-MILSATCOM System into the existing GreeCom Network,
Source: C. Giannopapa, A. Staveris-Polykalas and S. Metlallinos[21]

A hybrid approach (1x Micro-GEO satellite + 1x GEO satellite) should also be considered, particularly given the extensive space heritage of "traditional" military GEO communication satellites. Additionally, part of the revenue generated from leasing the capacity of the first satellite could be allocated towards funding the larger (and more expensive) GEO satellite. This strategy could play a pivotal role in ensuring the overall economic feasibility of the project.

To further reduce the overall project costs, Greek governmental authorities could first wait to evaluate the performance of the initial satellite. If they are sufficiently satisfied with its results, they could then deploy another similar Micro-GEO satellite, rather than investing in a more expensive and slower-to-establish Full Operational Capability (FOC), GEO satellite. In any case, while the first Micro-GEO satellite is being developed and deployed, efforts to acquire the second satellite should be initiated concurrently.

Throughout all phases of the project, comprehensive cost assessments must be conducted, and funding sources should be secured in a timely manner. Additionally, technological trends (e.g., D2D connectivity or laser SATCOM) and challenges surrounding MILSATCOM systems (particularly cyber-security threats) should be continually reassessed. Adhering to the project timeline is another critical success factor for the mission.

At the same time, engaging with allied countries that have similar systems could yield benefits by helping to avoid mistakes and missteps. Greece can draw insights from the examples set by other pioneering countries and organisations that have successfully developed state-of-the-art communication satellites. In those cases, at least two GEO satellites were typically developed, with investments amounting to several hundred million euros.

Building on this approach, Greece should also pursue a system with interconnectivity capabilities, both with its national LEO micro-satellite network and with European SATCOM networks such as IRIS[2], EU GOVSATCOM or EUQCI. Regardless of which option Greece ultimately chooses, it is crucial to focus on the timeline, budget and funding, collaboration with stakeholders, partnerships with allied countries and/or organisations, risk assessment, and compliance with international regulations.

Contribution to the Hellenic Air Force (HAF)

Communications are a fundamental factor both for the effective C2 of Air Forces and for the successful conduct of operations. Military communication systems must be interoperable with the communication systems of other branches of the Armed Forces, as well as with other governmental, Allied, and civilian communication and information systems. Secure, continuous, resilient and real-time connectivity between Air Units and assets enables the dissemination of operational information, enhances shared Situational Awareness at all levels of warfare, and consequently contributes to the flexible and effective use of Air Power[22].

<u>Network-Centric Warfare (NCW) and Interoperability</u>

The HAF is shifting towards a NCW environment, where seamless interconnection of military units (aircraft, Command Centers, surface and ground forces) is critical. A MILSATCOM system will enable:

- ✓ Real-time ISR data transmission Integration of information across all branches of the Armed Forces
- ✓ Superior Situational Awareness and battlefield coordination
- ✓ Autonomous and seamless interoperability with Allied Forces

<u>Support for Unmanned Aerial Vehicles (UAVs) and C2 Systems</u>

UAVs have acquired significant payload capabilities (weapons, optical sensors, radars, etc.), leading to their increasing use in modern warfare and their integration into the military arsenals of most countries[22]. With the rapid advancement of UAVs, the HAF will require SATCOM for:

- ✓ Remote control of UAVs over long distances
- ✓ “From sensor to shooter” capability, to locate, acquire, and strike targets with pinpoint accuracy
- ✓ Transmission of high-resolution

video, images and data in real time to Operations Centers

- ✓ Better integration of UAVs with manned aircraft in a Common Operational Environment

Hostile missiles or drones interception

The MILSATCOM system will enhance the HAF's ability to intercept enemy ballistic missiles or drones by providing real-time data and intelligence through systems like the Shared Early Warning (SEW) satellite system.

Support Air Lift Operations

Airlift operations are vital to the success of joint operations, as they enable the airborne transport, deployment, sustainment and recovery of personnel, assets and equipment. At the same time, airlift provides fast and flexible options for military, national and international organizations, allowing them to respond effectively to crises at a local, regional or global level[22]. A MILSATCOM system will play a crucial role in supporting airlift operations by ensuring secure, real-time connectivity between Command Centers and airborne assets, enhancing coordination and mission effectiveness in complex operational environments.

Secure and Resilient Communications

The system will provide resilient, secure and encrypted communications, essential for modern Air Force operations. In the event of conflict or cyber attacks, communications relying on commercial networks are vulnerable, whereas a MILSATCOM system ensures exclusive use and control.

Autonomous Strategic SATCOM

A national MILSATCOM system will provide autonomy, reduce dependence on third parties, and strengthen national strategic planning for the Armed Forces, including the HAF.

Conclusion

The development of the GR-MILSATCOM system marks a significant strategic advancement in national Security, technological innovation and economic growth. By establishing a secure, resilient, and autonomous SATCOM system, Greece will enhance its defence capabilities while reducing dependence on third-party infrastructures. The proposed Micro-GEO satellite system ensures cost-effectiveness, rapid deployment, and potential revenue through leasing excess capacity. This initiative not only aligns with broader European security frameworks but also strengthens the country's position within NATO and EU defence collaborations.

Acquiring such a system will also mark the HAF's transition to the new Air and Space Force era, enabling it to operate in a modern, interoperable and NCW environment, ensuring operational superiority and resilient communications against current and future challenges.

References

1 Hellenic General Secretariat of Telecommunications and Posts, Request for Information (RFI) - Outline concept for end-to-end MILSATCOM solutions in response to national needs, Athens, GR: Ministry of Digital Governance, 2024.

2 G. Martin, New Space: The Emerging Commercial Space Industry, California, US: NASA Ames Research Center, 2017.

3 EUSPA, Secure SATCOM, Luxembourg: Publications Office of the European Union, 2023.

4 D. Eagleson, "Protecting our critical satellite infrastructure: the importance of space-based infrastructure to humanity and its status within NATO", 24 October 2023. [Online]. Available: https://www.nato.int/docu/review/articles/2023/10/24/protecting-our-critical-satellite-infrastructure-the-importance-of-space-based-infrastructure-to-humanity-and-its-status-within-nato/. [Accessed 1 February 2025].

5 European Union, A Strategic Compass for Security and Defence, Brussels: European Union, 2022.

6 High Representative of the Union for Foreign Affairs and Security Policy, European Union Space Strategy for Security and Defense, Brussels: European Commission, 2023.

7 he European Parliament and the Council of the EU, Regulation (EU) 2021/696 of the European Parliament and of the Council establishing the Union Space Programme and the EU Agency for the Space Programme and repealing Regulations (EU) No 912/2010, (EU) No 1285/2013, (EU) No 377/2014, Decision No541/2014 /EU, Brussels: Official Journal of the European Union, 2021.

8 The European Parliament and the Council of the EU, Regulation (EU) 2023/588 of the European Parliament and of the Council establishing the Union Secure Connectivity Programme for the period 2023-2027, Brussels: Official Journal of the European Union, 2023.

9 NATO, «Satellite Communications,» 23 April 2021. [Online]. Available: https://www.nato.int/cps/en/natohq/topics_183281.htm . [Accessed 1 February 2025].

10 D. Askew, Enhancing NATO's SATCOM Capability to Ensure Allied Connectivity, Virginia, US: NATO Supreme Alliance Command Transformation, 19 June 2024.

11 Nicolò Fasola; Sonia Lucarelli; Alessandro Marrone; Maria Vittoria Massarin and Francesco Niccolò Moro, Space: Exploring NATO's Final Frontier, Virginia, US: NATO Supreme Alliance Command Transformation, 2024.

12 The Netherlands MoD, Defence Space Agenda, The Hague, Netherlands: The Netherlands MoD, 2022.

13 Council of the European Union, "European Space Policy: ESDP and Space", Note from General Secretariat to COREPER / Council 11616/3/04 REV 3. Brussels, European Union, 16 November 2004,

14 European External Action Service, "Shared vision, common action: A stronger Europe: a global strategy for the European Union's foreign and security policy", EEAS, June 2016

15 European Defense Fund (EDF), «EU Funding & Tenders Portal,» 2021. [Online]. Available:

https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/opportunities/topic-details/edf-2021-space-d-epw . [Accessed 2 February 2025].

16 European Commission, «Digital-strategy.ec.europa.eu,» 28 November 2019. [Online]. Available: https://digital-strategy.ec.europa.eu/en/news/nine-more-countries-join-initiative-explore-quantum-communication-europe [Acces-sed 2 February 2025].

17 HELLAS QCI, «Hellasqci.eu,» 25 April 2021. [Online]. Available: https://hellasqci.eu/ [Accessed 2 February 2025].

18 The National Infrastructures for Research and Technology, «GRNET,» 5 January 2023. [Online]. Available: https://grnet.gr/en/business-directory/hellasqci-en/ . [Accessed 3 February 2025].

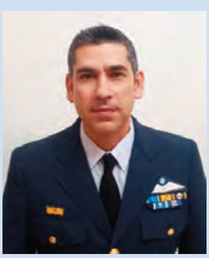
19 KSAT, «Ksat.no,» 29 April 2020. [Online]. Available: https://www.ksat.no/news/news-archive/2020/ksat-builds-the-worlds-first-commercial-optical-ground-station/. [Accessed 3 February 2025].

20 Space Hellas, «Space.gr,» 2024. [Online]. Available: https://www.space.gr/pages/DEGREES . [Accessed 3 February 2025].

21 C. Giannopapa, A. Staveris-Polykalas and S. Metlallinos, «Space as an enabler for sustainable digital transformation: The new space race and benefits for newcommers,» Acta Astonautica, vol. 198, pp. 728-732, September 2022.

22 Hellenic Air Force, "Basic Doctrine of the Hellenic Air Force", General Staff of the Air Force, Branch A - Directorate A1, Section 1, March 2023.

Short Biography



Lieutenant Colonel Fotios Giantsis graduated from the Hellenic Air Force Academy in 2002. He served for several years at the 117 Combat Wing as a pilot on F-4E AUP fighter aircraft. He has been a flight instructor and test pilot, having accumulated nearly 2,500 flight hours. He was assigned to NATO as an Air Operations Expert at NRDC-GR HQ and later commanded the Operational Support Squadron of the 113 Combat Wing. He is a graduate of the Hellenic Supreme Joint Defense College and the Hellenic Air Force War College. He holds a Master's degree (MSc) in Space Technologies, Applications & Services from the National and Kapodistrian University of Athens (NKUA). His training also includes certifications in Artificial Intelligence, Machine Learning and Cyber-security from various universities. He has authored several scientific studies on Space Technologies, and has actively participated in numerous workshops, conferences, and forums on Defence, Space and High Technologies.

BEYOND Centre - National Observatory of Athens: Securing National & European Autonomy in Earth & Space

Kontoes Charalampos (Haris) et. al, (2025)
BEYOND Centre of Excellence for Earth Observation Research and Satellite Remote Sensing, Institute for Astronomy, Astrophysics, Space Applications and Remote Sensing (IAASARS) of the National Observatory of Athens (NOA)

Citation: *Kontoes Charalampos (Haris), et. al, (2025). BEYOND Centre - National Observatory of Athens: Securing National and European Autonomy in Earth and Space. Hellenic Air Force Review, 134. https://doi.org/10.5281/zenodo.15172105*

Abstract

The BEYOND Centre for Earth Observation Research and Satellite Remote Sensing plays a crucial role in supporting both national and European autonomy through the provision of cutting-edge services in Earth Observation and Space Security. An overview of BEYOND Centre activity is highlighted herein together with its active involvement in both the Copernicus Emergency Management Service (CEMS) and the European Space Surveillance and Tracking (SST) Partnership. Moreover, the Centre supports informed decision making for disaster resilience with its specialized tools like FireHUB for wildfire management, FloodHUB for comprehensive flood risk assessment, GeoHUB for geophysical disaster monitoring and response, and DustHUB for advanced dust forecasting.

Keywords:

Disaster Risk Reduction – DRR, Emergency Management, Risk Assessment, Humanitarian Aid, Space Security, Space Surveillance and Tracking-SST, Hazard Modelling, Copernicus Emergency Management Service - CEMS

Introduction

BEYOND Centre of Excellence for Earth Observation Research and Satellite Remote Sensing is an Operational Unit of the Institute for Astronomy, Astrophysics, Space Applications and Remote Sensing (IAASARS) of the National Observatory of Athens (NOA). Poised to deliver significant services for the ultimate benefit of all European citizens, BEYOND plays a pivotal role in developing cutting-edge research and providing innovative services in crucial thematic areas of security and crisis management and social growth relating to national and EU independence such as: Space Safety and Security, Disasters and Crisis Management, Citizen Safety, Humanitarian Aid, Food and Energy Security and Societal Wellbeing and Health. BEYOND Centre addresses stakeholders needs across Europe, and the neighboring Regions including Bal-kans, Middle East, and Africa. Leveraging large scale

Visit our website for more information

satellite acquisitions established at NOA's facilities, actionable infor- mation is provided on time for enhanced decision and policy making in the aforementioned areas of expertise.

BEYOND, in the delivery of its tasks, collaborates with leading organizations, including, but not limited to, the World Meteorological Organization (WMO), the European Centre for Medium-Range Weather Forecasts (ECMWF), the Barcelona Supercomputing Center (BSC) and the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT). As key partners these institutions consistently drive together with BEYOND Centre advancements in meteorology, climate modeling, extreme weather, and man-

BEYOND Centre's Role in 2021 Wildfire Crisis: Utilizing Copernicus Data for Emergency Response

In August 11th, 2021 the whole Europe went through one of the hottest summers since records began. At this same time, the scientists of BEYOND Centre monitored and informed in real time on wildfires caused by the extreme drought and unprecedented high temperatures all over Greece and Europe. We have had about 10 days of unrelenting action to analyse EU Copernicus Sentinel-1/-2/-3/5P downloaded from the Hellenic Mirror Site (CollGS) and the Copernicus Open Access Hub, both operated by BEYOND Centre to provide warnings and situational pictures of the disaster to fire controllers, authorities, and inform citizens and health authorities about the atmospheric burden due to the transfer of black carbon over the whole Mediterranean. In Greece alone, about one hundred thousand hectares of land were on fire and many communities and local economies had been seriously hit in the last ten days. And the damages in Greece was just a small portion of the enormous disasters recorded in the same period on the Sentinel images in Europe, the western coast of the US, in Siberia, South America, Central and South Africa, the Middle East. The global need for quick reliable information to support the emergency response was reflected by the systematic use of Sentinel-1/-2/-3/5P data delivered through the Hellenic Mirror Site that was installed back in 2014 at BEYOND Centre, the first Collaborative Ground Segment ever put in routine operation at European level. Since then, BEYOND's operations have grown in line with the growth in demand for Copernicus Sentinel data worldwide and a number of additional Copernicus Data Hubs which are also based at BEYOND Centre offering petabytes of satellite data in the support of European and international critical services and authorities. For example, the host of the Sentinel-5P Data Hub, which went into operation on 11 July 2018, has been publishing on average around 54,000 images per month. This is due in large part to the global interest in both the circulation of NO2 and CO resulting from the large bushfires. In BEYOND Centre we are excited to be one of the three international nodes of the Copernicus Data Access Ecosystem that supports the uninterrupted massive publication of more than 15 million Copernicus Sentinel data on a yearly basis serving more than half a million of users over the globe.

made related hazards reduction. Furthermore, BEYOND Centre has the role of **UN-SPIDER Regional Support Office** to advance Capacity Building and services for DRR worldwide and is an active member of the CEOS Working Group on Disasters, GEO/LEO/SAR Flood Pilot "Understanding Flood Risk from Space" for the Balkan flood pilot (Evros river basin), and the **GEO Disaster Risk Reduction Working Group.** The Centre coordinates the GEO-CRADLE enabling a mechanism that is leveraging the GEO and EuroGEO innovation in Balkans, Black Sea, Middle East, Africa and Pacific Asia areas for addressing security and DRR priorities of national civil protection and civil safety authorities.

BEYOND Data & IT Ecosystem: Infrastructure, Hubs, Tools

BEYOND Centre Big Data infrastructure supports acquisition, processing, storing and disseminating of EO data at scale. Data engineering best practices enable efficient ingestion and analysis of big data for any type of application herein after, ranging from disaster response to climate monitoring and scientific production. The ecosystem encompasses high-performance computing (CUDA), container-based workflows (Docker, Kubernetes), scalable geospatial databases, STAC cataloguing and EO-specific data cubes, ensuring interoperability with European and international standards. This proprietary infrastructure provides a reliable and secure foundation for EO data utilization, and ensures national and European autonomy in space-based services.

It guarantees seamless access to Sentinel and other satellite data, enabling decision-makers, public authorities and researchers to base their

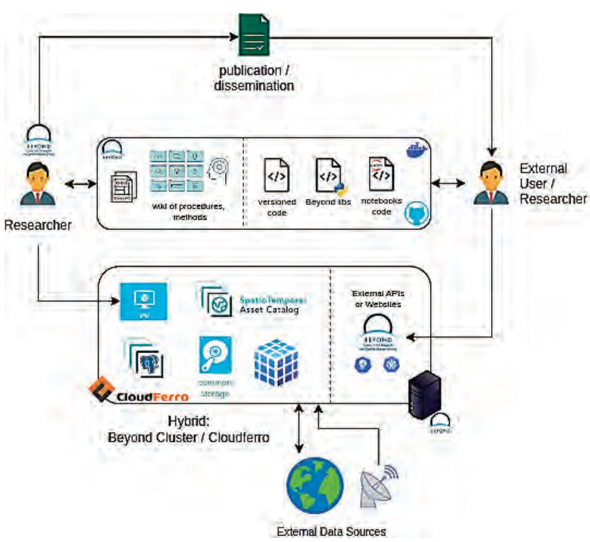


Figure 1: Infrastructure model of BEYOND, illustrating the integration of containers, data cubes, versioned code, libraries and notebooks with cloud-based infrastructure (e.g. Cloudferro). The system utilizes a SpatioTemporal Asset Catalog (STAC) and PostgreSQL for data management, enabling researchers and external collaborators to access and contribute via APIs and external data sources.

decisions on EO data analysis for dynamic landscape and surface monitoring, emergency response and security. BEYOND's infrastructure enables EU Space Strategy, EU Space Surveillance and Tracking (STT), the European Green Deal, and the Digital Europe Programme to foster technological sovereignty in EO-based services.

The infrastructure (a) Supports European & National Autonomy by reducing reliance on third-party EO infrastructure, (b) Improves Decision-Making through fast, AI-driven EO data processing pipelines, and (c) Enhances Security from Space with elastic infrastructure for monitoring and security related events. The key end users of the Data and IT Ecosystem are Governmental institutions & Civil Protection Authorities activating BEYOND Centre through Copernicus CEMS, the European Union SST, Security stakeholders employing EO analytics for situational awareness, Scientific and commercial EO analytics providers accessing large-scale, structured data.

The applied Research and Technology means include (a) Scalable Processing of Data: Cloud and on-premises hosted data pipelines to process vast quantities of EO imagery, (b) Docker & Kubernetes: Containerized deployment of processing workflows to enable scalable data workflows and automation, (c) Data Cubes: Multi-source EO data model for standardize time-series analysis and AI-powered analytics, (d) APIs & Databases: RESTful APIs and spatiotemporal databases (PostGIS, Open Data Cube) for efficient and structured retrieval of EO data, (e) High-Performance Computing (HPC-CUDA): Parallelized image processing pipelines for accelerated feature extraction and model inference.

The Infrastructure effectively performs (a) Scalability: Addressing the increasing requirement for high- resolution EO data storage and processing, (b) Interoperability: Seamlessly integrating Copernicus, DIAS platforms, and European Data Spaces, (c) Algorithms and practices: Maintain state of the art practices and provide cutting edge scientific insights for EO data processing

Links for more information on BEYOND Centre Infrastructure:

http://beyond-eocenter.eu/index.php/infrastructure
http://beyond-eocenter.eu/index.php/web-services/sentinels-greekhub
http://beyond-eocenter.eu/index.php/web-services/satellite-access-polar-orbit
https://github.com/noa-beyond/eoProcessors
https://github.com/noa-beyond/ADC
https://sentinels.space.noa.gr/
http://beyond-eocenter.eu/index.php/web-services/hellenic-mirror-site

pipelines, (d) Real-time Processing: Facilitating near-real-time ingestion and dissemination of EO data for emergency response, (e) Cybersecurity & Data Protection: Implementing secure access control and attack resilience for EO-based infrastructures. The infrastructure sector of BEYOND Centre is used by key European and national authorities, research organizations, and industry players including the Copernicus Services (CDSE, Emergency Management Service, Climate Change, Security), the National Meteorological & Civil Protection Authorities, the EU Cloud providers such as: Cloudferro, European Open Science Cloud (EOSC) & EuroHPC initiatives and Universities.

BEYOND Centre in the support of National and European Space Surveillance & Tracking: Enhancing Safety, Sustainability, and Risks in Space Operations

BEYOND Centre leads the Space Surveillance and Tracking (SST) operations in Greece in the support of the European SST Partnership. It involves detecting, tracking, cataloging, and characterizing artificial objects orbiting Earth, including active satellites, defunct spacecraft, rocket bodies, and space debris. By leveraging ground-based and space-based sensors alongside advanced data processing techniques, BEYOND as the Greek National Operations Center (GR-SST NOC) for SST enables real-time monitoring of the orbital environment, supporting informed decision-making for satellite operators, policymakers, and defense entities. The role of BEYOND and its societal and national impact in terms of security is high, considering that the number of Resident Space Objects (RSOs) orbiting Earth is continuously increasing due to the surge in satellite deployments and the accumulation of space debris.

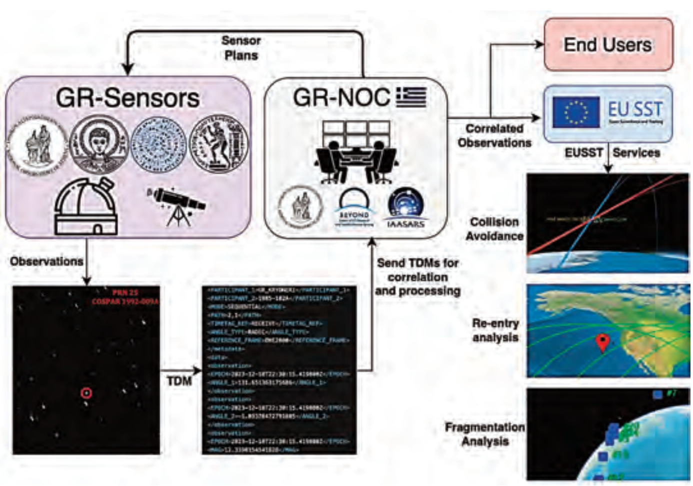


__Figure 2:__ High-level overview of the Greek SST activities. The Greek National Operations Center for SST (GR-NOC SST), hosted by the BEYOND Centre, is responsible for the coordination of the SST activities. These include, but are not limited to, the generation of sensor plans for the Greek telescopes, the correlation of observations against space object catalogs, and the contributions to EUSST and its services.

This growing congestion increases the risk of collisions, posing a challenge to the sustainability of space operations and the continuity of space services provision, reinforcing the need for effective space surveillance and situational awareness. BEYOND as GR-NOC SST, supports the operations of the Greek observing telescopes offered by NOA, AUTH, FORTH, and NTUA. The Centre is responsible for the relevant activities at the national level, and at the EUSST level, and represents the Greek SST program in broader international collaborations, including with the United States Space Command. GR-NOC SST oversees activities that involve, but are not limited to (a) Coordinating Greek sensors for conducting space surveillance observations, (b) Processing observational data in accordance with EUSST specifications, (c) Correlating observations with known objects in space catalogs and (d) Contributing correlated results (in the form of Tracking Data Messages - TDM) to the EUSST database. As part of the Greek participation in the EUSST Partnership, GR SST-NOC actively supports the main EUSST services in collaboration with the operational centers of other EU member states that include the: Collision Avoidance (CA) - Re-entry analysis (RE) - Fragmentation Analysis (FG).

Moreover, the Center GR-NOC SST runs comprehensive analysis of state-of-the-art AI methodologies for advancing SST services and security of missions in Space. Practically, BEYOND as GR SST-NOC lays the foundation for space operations toward the autonomy in both National and EU-level, while significant benefits arise for the country as a whole, including (a) Enhancing the security of Greek satellite missions and, consequently, national security, by protecting from threats originating from or passing through space, (b) Monitoring and predicting the re-entry of space debris and other objects (e.g., spent rocket stages, ballistic missiles) of known or unknown origin, (c) Advancing space surveillance technologies (detection and tracking) by leveraging Greece's existing scientific expertise and infrastructure, (d) Integrating into emerging space markets that invest in space-related services, (e) Developing technological capabilities, specialized training and expertise, fostering a skilled workforce and advancing research in space surveillance, (f) Establishing collaborations between the Greek space industry and European and international organizations, contributing to economic growth and (g) Supporting European policies on space traffic management, security, and defense, while safeguarding the interests of the EU and its Member States.

The Strategic Partners & End users of BEYOND consist of entities such as NOA, AUTH, NTUA, FORTH, HELLENIC SPACE CENTER, Hellenic Ministry of Defense, Hellenic Ministry of Digital Governance, Hellenic Ministry of Development, EUSPA, GMV, HELLAS SAT, Libre Space Foundation, USSPACECOM, NKUA, etc.

BEYOND Centre in the support of the Global Copernicus Emergency Management Service for Risk and Recovery

Links for more information on CEMS Activations of BEYOND Centre: https://mapping.emergency.copernicus.eu/ https://mapping.emergency.copernicus.eu/activations/EMSN197/ https://mapping.emergency.copernicus.eu/activations/EMSN200/
https://mapping.emergency.copernicus.eu/activations/EMSN205/
https://mapping.emergency.copernicus.eu/activations/EMSN206/

The Copernicus Emergency Management Service (CEMS) provides validated assessments primarily based on satellite imagery for before, during or aftermath crisis, as well as early warning services for disasters. The BEYOND Centre supports through CEMS the crisis managers, Civil Protection authorities and humanitarian aid actors dealing with natural disasters, man-made emergency situations, and humanitarian crises, as well as those involved in recovery, disaster risk reduction and preparedness activities at global level with a high impact in as far as the national and European security and safety are concerned.

The infrastructure and excellence developed in the BEYOND Centre are actively used in Risk & Recovery Mapping, nationally and worldwide, and on a routine basis towards the effective preparedness, prevention and recovery. The research and services developed are exploiting Earth Observation and geospatial data, when and where needed, for enhanced modelling of hazards and climate related disasters, mitigation and impact assessment for an effective and timely humanitarian aid. BEYOND has been activated in the framework of the CEMS 18 times since 2024 and has successfully been undertaken to support 12 activations worldwide from which 5 in the domain of wildfires, 2 in floods, 1 volcanic unrest, 1 in drought and water management, 1 in forest degradation, 1 in illegal waste dumping, 1 in multi-hazard analysis.

To address the challenging task of hazard and disaster management worldwide, BEYOND has developed and validated a number of methodologies which exploit big EO data, expert/domain knowledge and AI techniques to model Seismic Hazards and Seismic Risks, Fire Risk Forecast, Fire Early Detection, Burn Severity Grading, Biodiversity and Food Losses, Fire Spread dynamics in time and space, Population & Assets Impact, Tsunami and Extreme Weather Disasters Forecasting, Soil Erosion and Landslides, Volcanic Eruption and Lava Flow, Ground Deformation Dynamics; Flood Delineation, Flood Depth and Flood Damage Assessment, Disruption of Transportation and Businesses. The BEYOND strategic partners in this application area are among others: The Joint Research Center of EC, the DG DEFIS, Crisis managers and Civil Protection authorities across the globe, the Humanitarian aid actors dealing involved in natural disasters, manmade emergency situations, and humanitarian crises.

FireHUB: A Comprehensive Wildfire Management System

FireHUB is an advanced wildfire management system that leverages free and open and big satellite data to predict, detect, monitor, and assess wildfire impacts across Greece, Southern Europe, North Africa, Balkans, Black Sea and the Middle East. A multitude of satellite systems acquired at the acquisition facilities of BEYOND Centre with varying spatial resolutions (low, medium, high) and revisit times, balancing detection speed and detail are used for the delivery of the service that in turn allows the provision to first responders of situational awareness pictures and fire hazard assessments at national level every 5 minutes.

In practice, FireHUB integrates state-of-the-art models and scientific research to deliver to civil protection agencies, defense units and the public detailed fire ignition forecasts before crisis, as well as real-time warnings and fire monitoring during crisis, and last yet importantly post-fire assessments to allow informed decision-making at every stage of disaster management. Artificial Intelligence based fire risk forecasting is of utmost importance as it utilizes cutting edge Machine Learning models to handle the task of next day detailed fire prediction for the whole Greek territory in a 500mx500m wide area. Moreover, FireHUB creates a comprehensive forest fire inventory by obtaining and fusing data from multiple data sources, including the FireHUB system of BEYOND, the NASA FIRMS[1], and the European Forest Fire Information System (EFFIS)[2]. A complete Machine Learning (ML) workflow trains classification models on this large historical dataset, for which labels (occurrence or absence of fire) are derived and the trained classifiers are then able to provide binary predictions (fire or no-fire) along with the best use of firefighting resources in every area at risk

(Apostolakis et al., 2022; Girtsou et al., 2021; Alexis et al., 2023).

gests and processes medium-resolution data multiple times per day from polar-

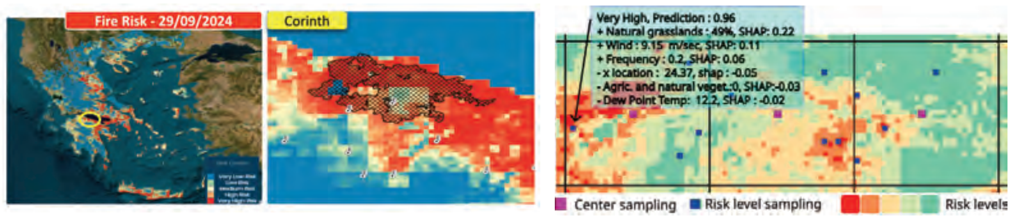


Figure 3 (left): Fire risk map generated on September 28, 2024 for the next day. Right – Actual wildfire perimeter in the Corinth area

Figure 4 (right): Model prediction explained in a very high-risk area. Key fire drivers include vegetation type

The BEYOND Centre advanced a 24/7 real-time fire monitoring service leverages cutting-edge technology to provide continuous, high-resolution fire detection and monitoring. Satellite METEOSAT MSG SEVIRI data are ideal to early and timely detect and monitor the fast evolving fires. Every 5 minutes, the FireHUB system detects active fires into 500 m × 500 m wide cell. The system runs prototype image processing and data classification algorithms, which have been developed with the active participation of fire brigades for incorporating their expert knowledge in the delivery of a useful fire disaster operational picture.

Another fundamental part of FIREHUB that is developed by BEYOND is known as Forest Fire Information System (FFIS)[3] . It provides rapid, satellite-based fire detection and burned area mapping in real-time across Europe, Balkans, North Africa, the Black Sea, and the Middle East. The system in-

orbiting satellites (EOS/Terra, EOS/Aqua, Suomi NPP, and NOAA-20), acquired in real time through the BEYOND/NOA Ground Reception Station enabling near real-time active fire detection and continuous wildfire tracking. For high-resolution burned area mapping, Sentinel-2 imagery acquired at Node 3 of Copernicus operated by BEYOND as part of the Hellenic Collaborative Ground Segment of Copernicus offers detailed assessments of fire-affected regions.

In addition, the smoke dispersion service[4] provides high-precision calculations of smoke transport resulting from wildfires, industrial accidents, and other large-scale fires on an hourly basis at national level. Elevated smoke concentrations pose serious health risks, impacting air quality and public safety across vast regions. Last yet worth noted, the Diachronic Burnt Scar Maps (BSM) service[5] is a fully automatic but off-line multi-sensor processing chain that takes as input satellite images of any available spatial and spectral resolution and produces precise diachronic burnt area and damage assessment products over the Greek territory for the last 42 years. It has been based on using archived USGS Landsat TM, SPOT XS, IKONOS, FORMOSAT and Sentinel-2/3 imagery over the entire Greece. The BSM is offered online and is publicly open, providing an invaluable dataset for public authorities, civil protection and scientific community.

The FireHUB system is connected to the Emergency Operations Center of the Hellenic Fire Service. Additionally, FireHUB serves multiple critical stakeholders, including the Hellenic Army for the safe planning of outdoor activities, the EC LUCAS for ensuring the safety of surveyors in the field, as well as the civil protection authorities and the general public. FireHUB is instrumental in Disaster Management operations, covering not only the entire Greek region but also the Balkans, North Africa, the Black Sea, and the Middle East.

FloodHUB: A Flood Risk Management and Resilience Service through Innovative Monitoring and Mapping based on Earth Observation

Floods are the most frequent disasters, affecting the largest number of people. In 2023, 164 floods were recorded worldwide, killing 7763 people, affecting 32.4 million people, and resulting in 20.4 billion USD losses (CRED, 2023 Disasters in Number). The FloodHUB services of BEYOND Centre increase flood resilience and support the flood risk management focused on early awareness, prevention, protection and preparedness to reduce the flood risk and safeguard human health. In order to mitigate flood risk, decision-makers and civil protection authorities need reliable, timely and high-resolution information on flood risk assessment, covering all disaster management stages, particularly prevention, preparedness, response, and recovery. This need is even more crucial in highly dense urban river basins that are prone to flash floods. In this regard the FloodHUB service supports the relevant authorities in adopting effective policies and practices for better flood risk management, prevention and mitigation in near-real-time. It supports the implementation of the EU Floods Directive 2007/60/EC at national level as well as the Sendai Framework for Disaster Risk Reduction, and the UN SDGs, and the UN Early Warnings for All initiatives at global level. The Near-Real-Time Floods Monitoring and Early Warning prototype service runs operationally and delivers a reliable operational awareness picture of the flood extent and depth every

The FireHUB relevant link:
http://beyond-eocenter.eu/index.php/web-services/firehub

5 minutes to all the relevant stakeholders across the river basin. It is built around a fully scalable and transferable modular architecture that allows the real-time ingestion and assimilation of a variety of data, depending on their availability, including, but not limited to, hydrometeorological parameters measured on the site by telemetric hydrometeorological stations, satellite data, crowdsourced information on the evolving flood, and pre-run simulations of a series of flood scenarios using validated tools as HEC-HMS & HEC-RAS in a multi-source data fusion concept. Moreover, the prototype Flood Diachronic Mapping Service is based on a fully automated system that searches, downloads and preprocesses Sentinel-1A/B SAR GRD data and then, using Machine Learning based models, automatically maps water surfaces across the river basin. It uses the Copernicus Dataspace Ecosystem as well as a set of technologies (Python scripts/libraries, ESA SNAP, OpenDataCube, GeoServer), and covers the time period since 2018. The service also includes the burnt scar mapping produced by the FireHUB Diachronic Mapping Service, in order to spatially correlate the burnt scar mapping and the flood mapping towards analyzing the impact of the wildfires on the floods.

The BEYOND FloodHUB Service is used by strategic partners worldwide as UN-SPIDER, the CEOS Working Group

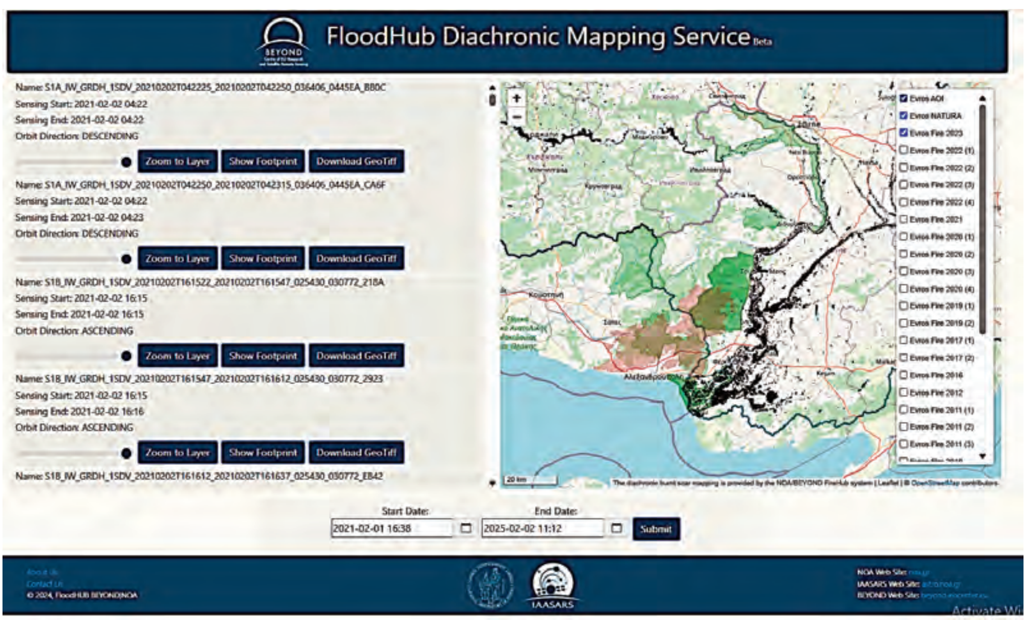


Figure 5: The Floods Diachronic Mapping Service for the Evros River Basin

The FloodHUB relevant link:
http://beyond-eocenter.eu/index.php/web-services/floodhub

on Disasters, GEO/LEO/SAR Flood Pilot "Understanding Flood Risk from Space" for the Balkan flood pilot (Evros river basin), the Civil Protection Volunteer Associations which are used for the improvement of near-real-time flood monitoring, following dedicated training. Between the key stakeholders using the FloodHUB service are the Ministry of the Environment and Energy, Prefecture of Attica, Prefecture of Eastern Macedonia and Thrace, Fire Service, Civil Protection authorities at national, regional and municipal level, Civil Protection Volunteer Associations, international scientific community.

GeoHUB: The Global Ground Deformation Monitoring Services for Timely Geophysical Disaster Assessment and Response

Timely monitoring and mapping of ground deformation worldwide, induced by major geological hazards, such as earthquakes, volcanic activity, landslides, etc. The GeoHUB's geObservatory[1] service (http://geobservatory.beyond-eocenter.eu/) provides emergency management authorities with timely assessments of ground deformation and establishes a global observatory of differential interferograms related to major catastrophic geological events. The service provides a deeper understanding of both the mechanisms driving their occurrence and the broader tectonic activity in affected regions. The produced interferograms enable the identification of the location, extent, and intensity of occurring geological hazards and related disasters. It also provides emergency management authorities with real-time information on ground deformation, facilitating informed decision-making and the implementation of appropriate disaster response measures.

The so-called geObservatory system that supports GeoHUB, is developed by BEYOND Centre to promptly deliver to stakeholders constantly updated information on the evolution of the ground deformation in the geological hazard affected area. This information is extremely useful for the local authorities responsible for decision making for evacuation, emergency response, relief and reconstruction planning, and taking measures to protect peoples' lives and their property. The service applies Differential SAR Interferometry (DInSAR) on Sentinel-1 SLC images, to produce pre- and co-seismic interferograms.

The GeoHUB provides timeliness and consistency in detecting and monitoring ground deformation on a global scale.

The GeoHUB relevant link:
http://geobservatory.beyond-eocenter.eu/

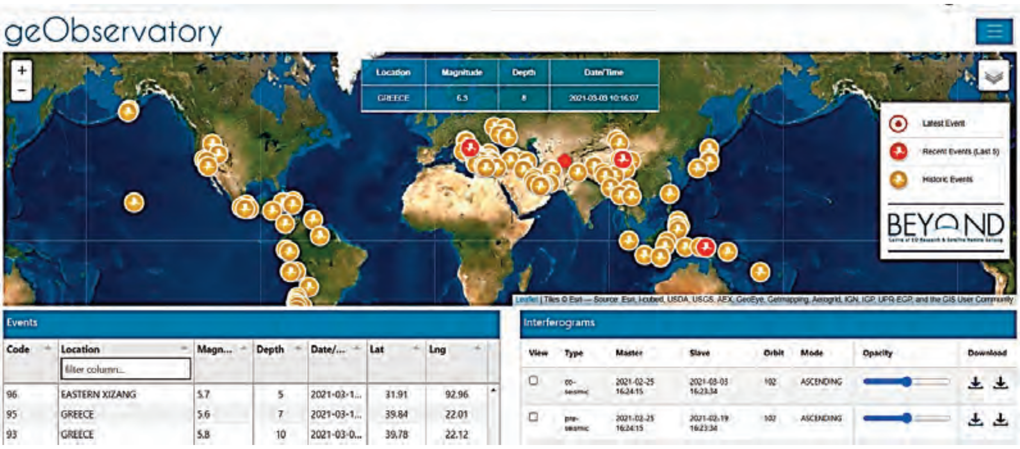


Figure 6: *The geObservatory service.*

DustHUB: Advanced Dust Forecasting Services for Environmental, Health, and Climate Impact Management

The DustHUB service in BEYOND provides timely forecasts of dust outbreaks along with their spatiotemporal and quantitative properties to local authorities and the public. The forecasting service is provided daily with a forecasting horizon of 3 days ahead. DustHUB products include the aerosol optical depth of dust, concentrations of dust at the surface as well as dry and wet depositions which make important information for a sustainable health system and solar energy ecosystem.

The impact of the service is high. Mineral dust affects radiation and al-

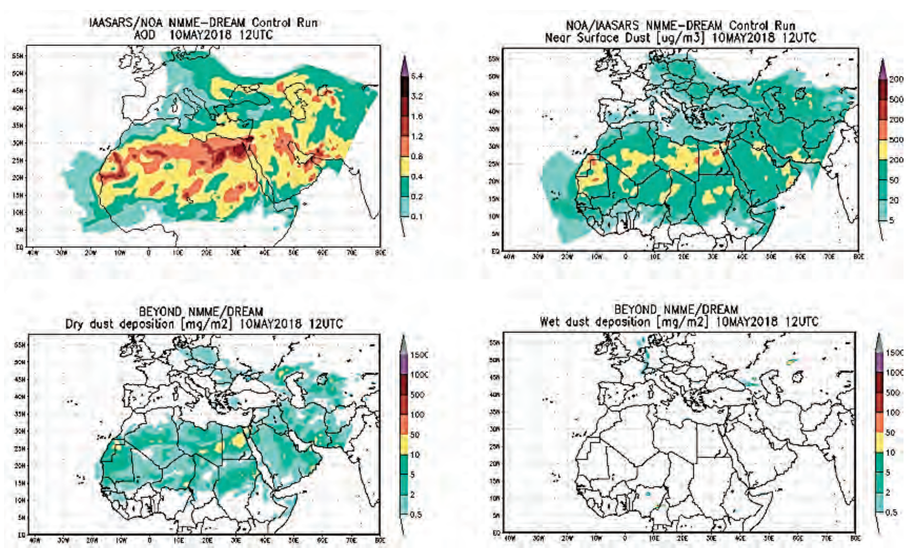


Figure 7.: *Aerosol Optical Depth, Near Surface Dust Concentration (μgr/m3), Dry and Wet Deposition of Dust (mg/m2), as forecasted by DustHUB*

The DustHUB relevant link:
http://dusthub.beyond-eocenter.eu/

ters liquid and ice cloud properties, modifying significantly the precipitation processes. The dust particles when deposited have diverse impact. The smaller PM2.5 particles are easily inhaled and deposited on the lungs and are related to human health disorders, both respiratory as well as cardiovascular. On the other end, they provide micro nutrients to the ocean and/or land ecosystems, thus affecting fishery and agriculture and food security. Desert dust is always present in North Africa, Middle East and the Mediterranean with adverse effects in various scientific and societal sectors including climate change, weather conditions, health, aviation, energy and tourism. Thus, continuous monitoring and forecasting of dust transfer as provided by BEYOND Centre through the DustHUB service assists policy makers for natural hazards and climate change mitigation activities. In the running operational version of DustHUB the forecasts are provided by using DREAM-NMM numerical model.

The meteorological core is the NCEP Nonhydrostatic Mesoscale Model on E-grid (NCEP/NMME). Surface properties are defined using the USGS global 1-km land cover data and the USDA global 1-km soil. The model is configured at 0.2°×0.2° resolution and includes 8 dust size bins with effective radii of 0.15, 0.25 0.45, 0.78, 1.3, 2.2, 3.8 and 7.1 μm respectively. The service offers (a) Prediction of dust outbreaks over the Mediterranean region, (b) Estimations of expected dry and wet dust deposition, to mitigate against impacts on energy (PV panel cleaning, etc). A future challenge is to separate the mineralogical composition of dust, through which we can identify specific attributes that induce specific impacts on radiative transfer, cloud formation, ocean fertilization and human health.

References

1. Alexis, K., Girtsou, S., Apostolakis, A., Giannopoulos, G., Kontoes, C. (2025). Next Day Fire Prediction via Semantic Segmentation. In: Meo, R., Silvestri, F. (eds) Machine Learning and Principles and Practice of Knowledge Discovery in Databases. ECML PKDD 2023. Communications in Computer and Information Science, vol 2135. Springer, Cham. https://doi.org/10.1007/978-3-031-74633-8_31
2. Apostolakis, A., Girtsou, S., Alexis, K., Giannopoulos, G., Bartsotas, N. S., & Kontoes, C. (2022). Estimating Next Day's Forest Fire Risk via a Complete Machine Learning Methodology. Remote Sensing 2022, Vol. 14, Page 1222, 14(5), 1222.

https://doi.org/10.3390/RS14051222

3. Apostolakis, A., Girtsou, S., Giannopoulos, G., Bartsotas, N. S., & Kontoes, C. (2024a). Enhancing daily wildfire risk prediction application through Interpretable Machine Learning Results. IGARSS 2024 - 2024 IEEE International Geoscience and Remote Sensing Symposium, 2066–2071. https://doi.org/10.1109/igarss53475.2024.10641551
4. Choumos, G., Tsaprailis, k., Lappas V., and Kontoes C., (2024), Artificial Intelligence for a Safe Space: Data and Model Development Trends in Orbit Prediction and Collision Avoidance, AIAA 2024-2066. AIAA SCITECH 2024 Forum. https://doi.org/10.2514/6.2024-2066
5. Drivas, T., Sitokonstantinou, V., Tsardanidis, I., Koukos, A., Kontoes, C., & Karathanassi, V. (2022). A data cube of big satellite image time-series for agriculture monitoring. In 2022 IEEE 14th Image, Video, and Multidimensional Signal Processing Workshop (IVMSP) (pp. 1-5), IEEE. DOI:10.1109/IVMSP54334.2022.9816291
6. European Space Agency, ESA's Annual Space Environment Report, Issue 2024. ESA Space Debris Office, European Space Operations Centre (ESOC), July 2024. https://www.sdo.esoc.esa.int/environment_report/Space_Environment_Report_latest.pdf
7. EUSST Partnership. EU Space Surveillance and Tracking Service Portfolio. Third Edition, 2024. Available: https://portal.eusst.eu
8. Girtsou, S., Apostolakis, A., Giannopoulos, G., & Kontoes, C. (2021). A machine learning methodology for next day wildfire prediction. International Geoscience and Remote Sensing Symposium (IGARSS), 8487–8490, https://doi.org/10.1109/IGARSS47720.2021.9554301
9. Kontoes, C., Keramitsoglou, I., Papoutsis, I., Sifakis, N. I., & Xofis, P. (2013). National Scale Operational Mapping of Burnt Areas as a Tool for the Better Understanding of Contemporary Wildfire Patterns and Regimes. Sensors 2013, Vol. 13, Pages 11146-11166, 13(8), 11146–11166. https://doi.org/10.3390/S130811146
10. Kontoes, C., Papoutsis, I., Herekakis, T., Ieronymidi, E., & Keramitsoglou, I. (2016). 6. Remote Sensing Techniques for Forest Fire Disaster Management: The FireHub Operational Platform. Integrating Scale in Remote Sensing and GIS, 157–188.

https://doi.org/10.1201/9781315373720-7

11. Kontoes, C., Papoutsis, I., Apostolakis A., (2019), Big Sentinel Data Processing for Monitoring Ground Deformations, In Proceedings of The 40th Asian Conference on Remote Sensing (ACRS 2019), October 14-18, Daejeon Convention Center, Daejeon, Korea
12. Neophytides, S. P., Mavrovouniotis, M., Christoforou, N., Drivas, T., Eliades, M., Papoutsa, C., & Hadjimitsis, D. G. (2024). An Earth Observation Data Ecosystem to Enhance Environmental Monitoring and Society's Resilience in Cyprus and the EMMENA Region. In IGARSS 2024-2024 IEEE International Geoscience and Remote Sensing Symposium (pp. 2879-2884), IEEE. doi:10.1109/IGARSS53475.2024.10641643
13. Papoutsis, I., Kontoes, C., Apostolakis A., (2019), Big Sentinel Data Processing for Monitoring Ground Deformations, In Proceedings of The 40th Asian Conference on Remote Sensing (ACRS 2019), October 14-18, Daejeon Convention Center, Daejeon, Korea
14. Peternier A., Defilippi, M., Pasquali, P., Cantone, A., Krause, R., Vitulli, R., Ogushi, F., Meroni, A., (2013), Performance analysis of GPU-based SAR and interferometric SAR image processing, Asia-Pacific Conference on Synthetic Aperture Radar (APSAR), Tsukuba
15. Sargentis, G.-F., Iliopoulou, T., Ioannidis, R., Kougkia, M., Benekos, I., Dimitriadis, P., Koukouvinos, A., Dimitrakopoulou, D., Mamassis, N., Tsouni, A., Sigourou, S., Pagana, V., Kontoes, C., & Koutsoyiannis, D., (2025), Technological Advances in Flood Risk Assessment and Related Operational Practices Since the 1970s: A Case Study in the Pikrodafni River of Attica. Water, 17(1), 112. https://doi.org/10.3390/w17010112
16. Sitokonstantinou, V., Koukos, A., Drivas, T., Kontoes, C., & Karathanassi, V. (2021). A scalable machine learning pipeline for paddy rice classification using multi-temporal sentinel data. Remote Sensing, 13(9), 1769. https://doi.org/10.3390/rs13091769
17. Sitokonstantinou, V., Koukos, A., Drivas, T., Kontoes, C., & Karathanassi, V. (2022). Datacap: A satellite datacube and crowdsourced street-level images for the monitoring of the common agricultural policy. In International Conference on Multimedia Modeling (pp. 473-478), Cham: Springer International Publishing.

doi:10.1007/978-3-030-98355-0_41

18. Tsaprailis, K., Choumos, G., Lappas, V., and Kontoes C., (2024), Survey Mode: A Review of Machine Learning in Resident Space Object Detection and Characterization, AIAA 2024-2065. AIAA SCITECH 2024 Forum. https://doi.org/10.2514/6.2024-2065
19. Tsouni, A., Antoniadi, S., Ieronimidi, E., Karagiannopoulou, K., Mamasis N., Koutsoyiannis, D., Kontoes, C., (2023), Multiparameter analysis of the flood of November 15, 2017 in west Attica using satellite remote sensing, Geoinformatics for Geosciences, Advanced Geospatial Analysis Using RS, GIS and Soft Computing, Earth Observation 2023, Pages 325-357, Chapter 18, https://doi.org/10.1016/B978-0-323-98983-1.00019-3

[1] https://firms.modaps.eosdis.nasa.gov/active_fire/

[2] https://effis.jrc.ec.europa.eu

[3] http://ffis.beyond-eocenter.eu/

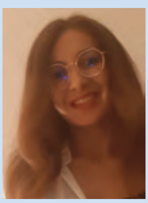
[4] http://smoke.beyond-eocenter.eu/

[5] http://ocean.space.noa.gr/diachronic_bsm/

Contributors' CVs

Kontoes Charalampos (Haris) holds the position of Research Director at the IAASARS/NOA and leads the Operational Unit BEYOND Center. He received his PhD in Earth Observation holding a grant from EC (JRC/ISPRA). He leads Space related projects funded by ESA, EC, and International Institutions (WB, EIB). He acts as National Delegate contributing to Space Policy and Program Committees of ESA, EC, COPERNICUS, SST/SSA. He is member of the Steering Committee of Geohazard Supersites and Natural Laboratories of Group of Earth Observations and the Committee of International Union of Geodesy and Geophysics, and is actively involved in the GEO Disaster Risk Reduction and Capacity Building Working Groups. He is the GRSS GEO principal and leader of the Disasters Resilience and Health Action Group of EuroGEO. He is responsible for Node 3 of Copernicus Data Access Service, the Hellenic Mirror Site, and the NOA's Ground Segment. He is author of more than 200 publications (h-index 35). He speaks English, French and Italian.

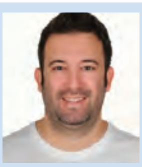
Dr. Alatza Stavroula is a Post-doc Researcher, with a focus on monitoring natural disasters using InSAR, EO, and AI techniques.
She has participated in National and European research projects and studies on natural hazards monitoring through geodetic observations and remote sensing data, as o co-investigator.



Archonti Stefania holds an M.Sc. in Computational Physics and a B.Sc. in Physics. With a background in AI, numerical methods, and astrophysical modeling, she has worked on algorithm optimization and automation using machine learning. She is supports the Greek National Operations Centre within the EU SST partnership.

Dr. Bartsotas Nikolaos (Nikos) has a Ph.D. in Atmospheric Modeling and Remote Sensing. He has been actively involved in a number of FP6/FP7/H2020/Horizon Europe research programs as well as the implementation of operational forecasting platforms and staff training in meteorological agencies around the world.

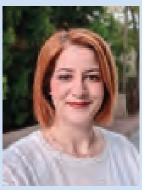
Choumos George is a PhD candidate in AI applications for Space Surveillance and Tracking at the National and Kapodistrian University of Athens. With a background in Computer Science (BSc), Data Science, he has been specializing in software engineering, DevOps and infrastructure.



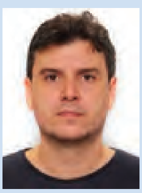
Drivas Thanassis is a software and EO data engineer, with a focus on scalable EO data processing, development of geospatial applications and design of data cubes.

Girtsou Stella is a PhD candidate focusing on Forest Fire prediction systems, with a specialization in the application of artificial intelligence (AI) techniques. She is a Rural, Surveying and Geoinformatics Engineer, while during her Master's degree in Space Applications, she was trained on advanced Machine Learning methodologies, big data management and algorithms for data analysis and prediction systems.

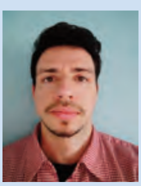
Papakonstantinou Maria (Marietta) graduated from the school of Philosophy at the University of Athens and holds an MA in Heritage Management with an expertise in Project Management. She has been working as project manager in European and national co-funded programs.



Pissaridi Katerina holds a diploma in Chemical Engineering and a PhD in the field of Biomaterials and Biospectroscopy. Her Postdoctoral studies were at the Laboratory of Food Chemistry and Biotechnology (Department of Chemistry, University of Patras). She has a strong background in fields such as food technology, food safety, nutrition and circular economy. She is Project Manager at the BEYOND Centre.



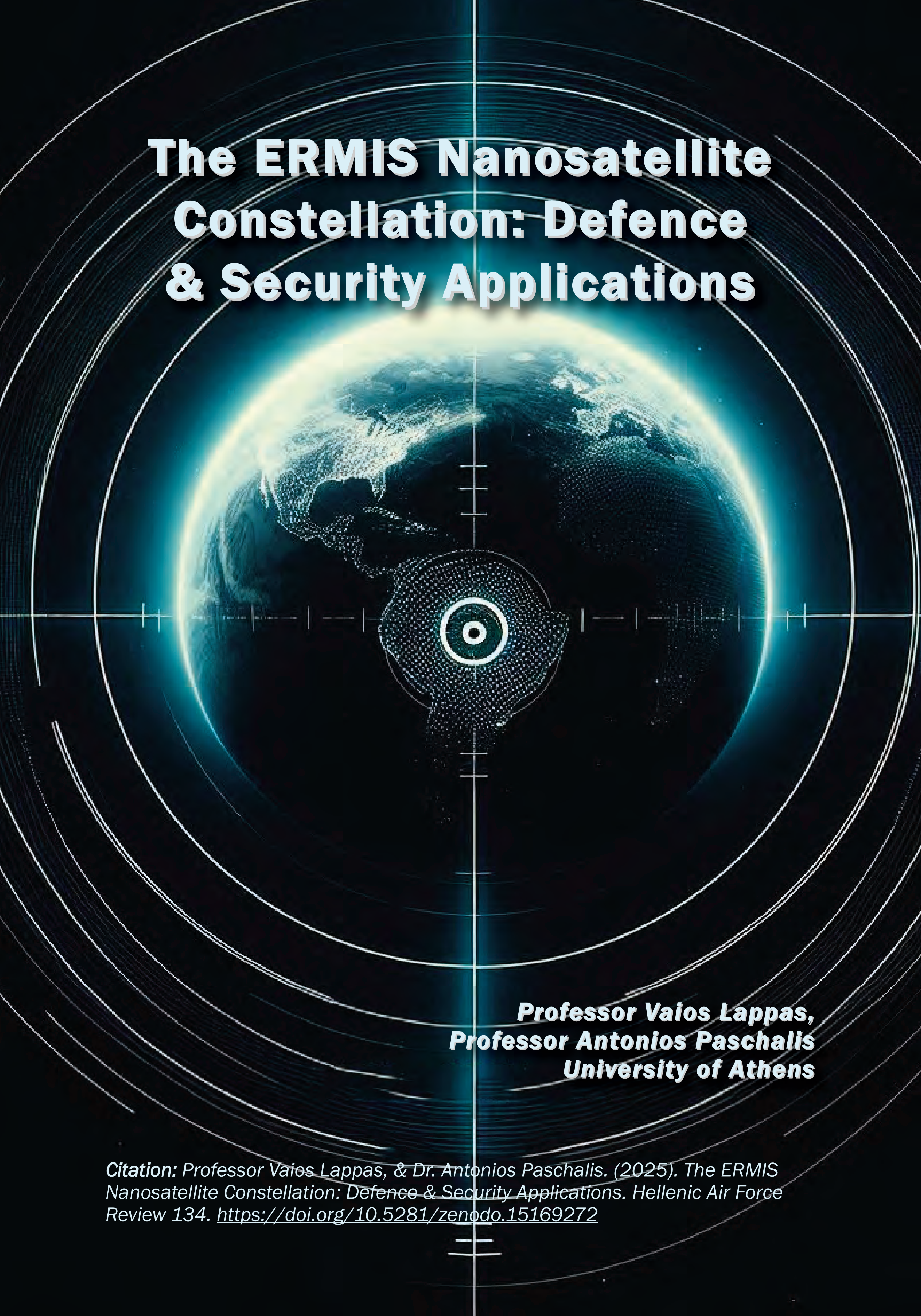
Stathopoulos Nikos is f Mining and Metallurgical Engineer. He holds two Master's Degrees, in "Science and Technology of Water Resources" and in "Geoinformatics". He completed his Doctoral research in the subject "Research Methods for Geoenvironmental Hazards & Water Resources. His research is focusing on Natural Hazards and Natural Disasters, Soil Erosion and Degradation, Water Resources.



Tsaprailis Konstantinos, is a PhD candidate in Space Situational Awareness with a background in Electrical & Computer Engineering (MEng), Data Science (MSc) and Space Technologies (MSc). He has 11 years of experience in software engineering, focusing on AI applications in Space Surveillance and Tracking and supporting the Greek National Operations Center within the EU SST partnership.

Tsouni Alexia is a Research Associate and PhD Candidate on flood risk assessment and flood monitoring in urban areas using multiple data sources. She is a graduate of the School of Civil Engineering of the National Technical University of Athens (NTUA) with specialization in Water Resources, Hydraulic and Maritime Engineering. She also holds a postgraduate diploma in Water Resources and Technology.

The ERMIS Nanosatellite Constellation: Defence & Security Applications



Professor Vaios Lappas,
Professor Antonios Paschalis
University of Athens

Citation: *Professor Vaios Lappas, & Dr. Antonios Paschalis. (2025). The ERMIS Nanosatellite Constellation: Defence & Security Applications. Hellenic Air Force Review 134. https://doi.org/10.5281/zenodo.15169272*

Abstract

The ERMIS mission, part of Greece's £200M National Small Satellite Programme, is a pioneering constellation of three cubesats (two 6U and one 8U) designed to enhance national security and defence capabilities. Coordinated by the National Kapodistrian University of Athens with key partners, ERMIS will deliver advanced connectivity and Earth observation services tailored to Greece's needs. Scheduled for launch in January 2026, the £4.8M project features a 5G-IoT network, inter-satellite links, and hyperspectral imaging (5m GSD) for applications such as precise agriculture monitoring and real-time data collection. Funded by the EU's NextGenerationEU and the Greek Ministry of Digital Governance, ERMIS bolsters Greece's space infrastructure and can support security and defence through secure laser optical downlinks (1 Gbps), paving the way for a robust national space presence.

Keywords

ERMIS mission, small satellite constellation, space security, defence applications, hyperspectral imaging, 5G-IoT connectivity, Greece space programme

Introduction

The advent of microelectronics, materials, sensors, microprocessors, artificial intelligence, new manufacturing techniques such as 3D printing, couples with private initiatives and investment has allowed for the miniaturisation of satellites and for the more frequent and affordable launch of them to orbit. This has allowed small satellites (mass < 500 kg) to become an important tool for many nations, businesses, start ups and has led to a massive expansion of space applications though constellations and mega-constellations of small satellites in remote sensing/earth observation, satellite communications, technology demonstration and space exploration. Small satellites have become the 'Personal Computer – PC – of space' allowing various actors including start ups, academia, scientists and industry to develop and demonstrate an idea, concept or business application in orbit in a very short time [1.]

ERMIS is a pathfinder demonstration of key space connectivity capabilities linked to, Greece's 200M€ national small satellite project using a constellation of small satellites. Coordinated by the National Kapodistrian University of Athens (NKUA) the consortium includes leading space, small satellite and IoT/communications entities OQ Hellas, University of Patras, University of the Aegean and the National Observatory of

Athens.

As the first Greek small satellite constellation, ERMIS will bring novel space communications (Low Earth Orbit 5G-IoT communication services, Inter-Satellite Link (ISL) and laser optical downlink), hyperspectral earth observation applications focused on national needs (e.g. precise agriculture) and small satellite technology capabilities for Greece and Europe, and create new unprecedented space capacities, synergies, and infrastructure in Greece.

The ERMIS mission consists of a constellation of three (3) advanced (two 6U and one 8U) cubesats focused on demonstrating key communications/connectivity and earth observation technologies and applications, utilizing a mixture of existing Greek space technology such as communications (IoT/5G, ISL), CCSDS on-board data processing, state-of-the-art FPGA accelerators for hyperspectral image compression and optical channel-coding, attitude control tracking algorithms, laser optical communications demonstrating 1 Gbps downlink to the Helmos Optical Ground Station, hyperspectral imaging (5m GSD), associated EO applications and national space infrastructure for its ground segment. Launch of the ERMIS constellation is planned for the end of 2025 [2].

The initiative underpins efforts – led by the European Space Agency (ESA) on behalf of the Greek Ministry of Digital Governance – to expand the nascent space industry in Greece, enabling the digital transformation of society while creating jobs and generating prosperity, as part of the nation's EU-funded Recovery and Resilience Facility. The ERMIS 4.8M€ project is funded by the European Union – NextGenerationEU and by the Greek Ministry of Digital Governance and is coordinated by the Department of Aerospace Science and Technology of the National and Kapodistrian University of Athens (www.aerospace.uoa.gr) [3].

Nanosatellites

In recent years, small satellites have opened up new possibilities for the space industry. Ranging from the size of a refrigerator to a shoebox, these very small spacecraft are much smaller than traditional ones. This allows small satellites to leverage benefits like lower development and launch costs, rapid deployment, and operation in large constellations. Countless missions, including navigation, research, and remote sensing, rely on these compact devices. The miniaturisation of spacecraft has brought in numerous attractive scientific and business possibilities, and the space sector is exploiting the benefits of this more sustainable and democratic approach.

When discussing spacecraft, the term "small" is typically used to describe their mass and size. Any satellite with a mass below 500 kg is considered a small satellite, also called a smallsat, or a miniature satellite. Satellites small in size are not new, though modern ones differ from their predecessors in many ways, the most notable of which is the use of widely accessible microelectronics in conjunction with innovative management approaches. This allows for the creation of spacecraft, working alone or in satellite constellations that can carry out complex functions with great utility while consuming far less space, money, and time than previous generations [1].

Compared to the market for large-size spacecraft, the financial and technological barriers to entry into the smallsat market are typically much lower. Because of their tiny size, easier construction, and greater launch possibilities, these devices are affordable to many businesses and organizations.

From their initial beginnings as experimental entities, smallsats have come a long way to become an independent type of satellites and market segment, that is now indispensable to space operations. Recent developments in miniaturization, in-space propulsion, onboard processing and control, and communication systems have completely transformed the space sector by allowing smallsats to carry out complex tasks that were previously achievable only with larger spacecraft [4].

There is no universally accepted categorization for small-size satellites, and various factors are considered when classifying these spacecraft. These factors include mass, size, orbit, application, mission duration, and more. Table 4 shows the most prevalent classification of small satellites which is based on mass and size.

Types of small satellites based on mass and size			
Type	Mass (kg)	Max. dimensions (m)	Orbit
Minisatellite	100-500	3-10 /	GEO, MEO, LEO, HEO
Microsatellite	10-100	1-5	LEO, HEO
Nanosatellite	1-10	0.1-1	LEO, HEO
Picosatellite	0.1-1	0.05-0.1	LEO, HEO
Femtosatellite	<0.1	0.01-0.1	LEO, HEO

Table 1: Small Satellite Classification [1, 4]

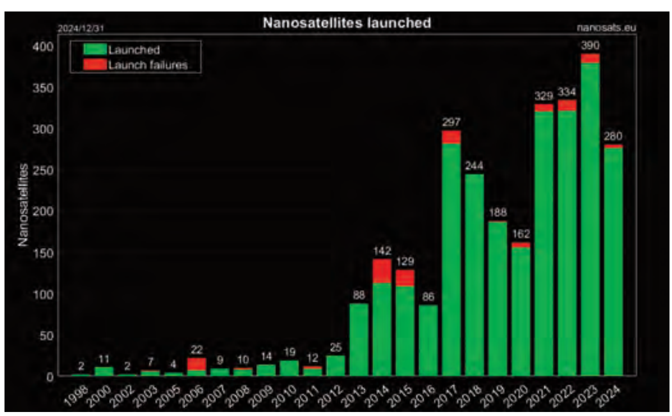


Figure 1:Nanosatellites (< 10 kg) Launch to Date (from nanosats.eu)

Figure 1 shows the significant adaptation and proliferation of small satellites and in particular nanosatellites (< 10 kg) to date.

The National Small Satellite Program

Since 2017, the General Secretariat of Telecommunications and Post of the Ministry of Digital Governance (MDG) is the responsible authority for all civilian space matters in Greece. The MDG collaborates with the Ministry of National Defence in the field of space systems and applications of MoD competence, focusing on enhancing national security and defence capabilities. The Secretariat is tasked to develop and implement the national space policy, strategy and plan. It represents Greece in all European and international organisations including European Union Space Programme Agency (EUSPA), European Space Agency (ESA), International Telecommunications Union (ITU) as well as in other European or International Organizations with focus in Space related activities [5].

Law 4727/2020 - Digital Governance (Incorporation into Greek Law of Directives (EU) 2016/2102 and (EU) 2019/1024) and Other Provisions), defines Greece's objectives for participation in the European Space Agency. Specifically, Article 119, Paragraph 9, states that these objectives arepivoting around four objectives[1]:

1. ***Strengthen national security and Defence, especially with the utilization and development of space infrastructure.*** Ensure national autonomy in safety and security (e.g border control, disaster management) by enhancing existing infrastructures (e.g. GreekCom) and developing new ones (e.g small satellites). The goal is to autonomously respond to national safety and security needs.
2. ***Development of the Greek space industry.*** Maximise the integration of Greek companies into the European industrial space landscape. The goal is to create a sustainably competitive Greek space industry.
3. ***Utilise of space data and the development of relevant applications***. Foster the integration of space into the society and economy, by facilitating the use of space technologies and applications to support public policies and business development (e.g. telecom, transport, maritime, agriculture, energy, and environment). The goal is to create public and commercial services.
4. ***Support space research and innovation.***

[1] Greek National Law, 2020 N4727.

The related activities and projects are:

1. ***Development of a national small sat programme.*** Achieving autonomous capabilities to respond to national needs, strengthening the Greek industry competitiveness with the possibility for commercial utilisation in the global market.
2. ***Flight heritage.*** Achieving flight heritage though the EU, ESA and national programmes by maximising technological and financial synergies.
3. ***Ground infrastructure.*** Utilising and further developing existing infrastructures: nationally or privately owned stations (e.g Tanagra, Koropi, Ag. Paraskeui), telescopes, lasers, radars, etc
4. ***User alignment (ministries).*** Supporting through space the development implementation and monitoring of sectorial policies (e.g. telecom, transport, maritime, agriculture, energy, environment, safety and security)
5. ***Exploit data of existing infrastructure.*** Opening of public information will increase the size of the domestic market, especially when the private and the public sector work together. In navigation Galileo will boost commercial activities and integrated applications will tie Earth Observation and navigation to telecommunications.

The National Small Satellite programme is a 200M€ multi-mode space programme funded by the European Commission Recovery and Resilience Facility focused on developing new space capabilities, capacities, technologies and applications for Greece [5]. It is composed by multiple elements such as:

- Upgrade of existing telescopes/infrastructure to Optical Ground Stations (OGS)
- A cubesat based in-orbit Verification/Validation and Demonstration (IOV/IOD) programme with the launch of 11 cubesats in 2025 and 2026
- Development of a national small satellite Assembly, Integration and Testing (AIT) facility
- Development of a radar facility for Space Situational Awareness (SSA) applications linked to the EU SST initiative
- Development of a 130M€ earth observation capability which includes the launch of 7 optical (Open Cosmos), 2 SAR (ICEYE), 4 Thermal IR (Ororatech) micro and nanosatellites in 2026, together with the development of a space data government hub and a group of specialised earth observation R&D projects for niche applications such as precision agriculture, forestry, security and water

Figure 2: ESA/Greek Cubesat in Orbit Validation Project Logo [3]

The ERMIS Hellenic Cubesat Demonstration Mission

ERMIS is a pathfinder demonstration of key space connectivity and earth observation capabilities linked to, Greece's 200M€ national small satellite project using a constellation of small satellites. Coordinated by the National Kapodistrian University of Athens (NKUA) the consortium includes leading space, small satellite and IoT/communications entities OQ Hellas, University of Patras, University of the Aegean and the National Observatory of Athens. As the first Greek small satellite constellation, ERMIS will bring novel space communications (Low Earth Orbit 5G-IoT communication services, Inter-Satellite Link (ISL) and laser optical downlink), hyperspectral earth observation applications focused on national needs (e.g. precise agriculture) and small satellite technology capabilities for Greece and Europe, and create new unprecedented space capacities, synergies, and infrastructure in Greece.

The ERMIS mission consists of a constellation of three (3) sophisticated (two 6U and one 8U) cubesats focused on demonstrating key communications/connectivity and earth observation technologies and applications, utilizing a mixture of existing Greek space technology such as communications (IoT/5G, ISL), CCSDS on-board data processing, state-of-the-art FPGA accelerators for hyperspectral image compre- ssion and optical channel-coding, attitude control tracking algorithms, laser optical communications demonstrating 1 Gbps downlink to the Helmos Optical Ground Station, hyperspectral imaging (5m GSD), associated EO applications and national space infrastructure for its ground segment. Launch of the ERMIS constellation is planned for January 2026 [2].The ERMIS 4.8M€ project is funded by the European Union – NextGenerationEU and by the Greek Ministry of Digital Governance and is coordinated by the Department of Aerospace Science and Technology of the National and Kapodistrian University of Athens [3].

Figure 3: EMIS Mission Partners and Mission Patch

The ERMIS Nanosatellite Mission objectives are:

- Demonstrate an optical laser communication payload achieving up to 1 Gbps downlink capacity to the OGS compatible to SDA Optical Communications Terminal Standard and optionally to upcoming CCSDS O3K standard.
- Acquire hyperspectral image cube focused on precision agriculture using a hyperspectral imager with 8 days average revisit time.
- Incorporate state-of-the-art high-data rate FPGA accelerators to optimize the execution of CCSDS algorithms for onboard payload data compression of both Hyperspectral and panchromatic images.
- Conduct in-orbit demonstration and validation of Attitude Determination and Control System (ADCS) control algorithms and their suitability for use with the Optical Link.
- Spearhead the development of new space connectivity capacities in Greece, including a Payload Clean Room and a small satellite ground station.
- The mission shall demonstrate the capability to operate an IoT communications payload from orbit
- The mission shall demonstrate the capability to provide IoT connectivity using a Nanosatellite platform by connecting to a (at least 1) terrestrial terminal
- The mission shall demonstrate the capability to exchange information between its platforms via an Inter Satellite Link
- Develop new space capabilities, applications and infrastructure in Greece

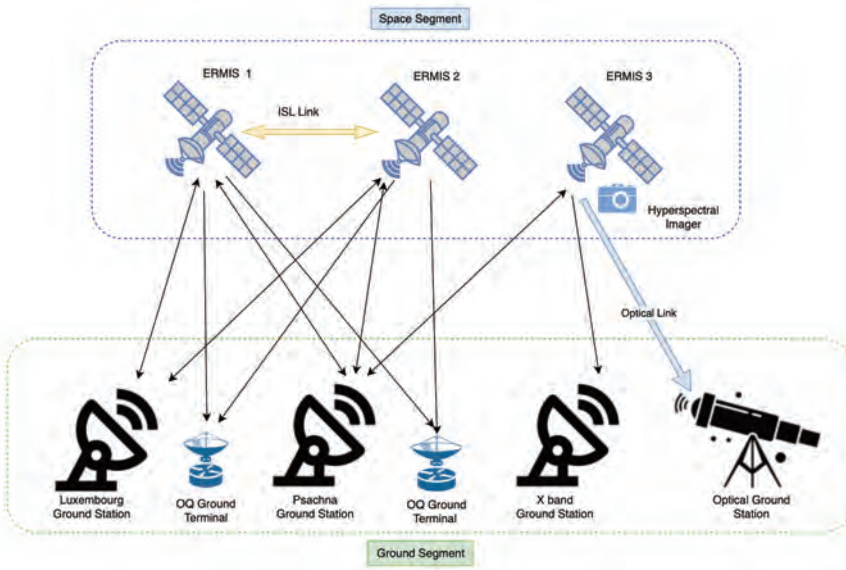


Figure 4: ERMIS Mission Architecture

Figure 4 shows the ERMIS mission architecture block diagram including all elements of the space and ground segment. The mission objectives are a combination of earth observation and connectivity goals. To address all objectives, two different platforms will be used: (i) two 6U cubesats equipped with communication payloads operating in S-Band and with an intersatellite link (ii) an 8U cubesat equipped with a high-resolution hyperspectral payload and an Optical Communications Terminal. The two platforms will share the majority of the bus, mission analysis and operations planning. Accommodating the different payloads inevitably leads to some differences in bus component selection. Table 1 shows the ERMIS orbit (500 km SSO) and launch date which will take place in January 2026 (Transporter 16) and sues a Falcon 9 rideshare opportunity.

Altitude	500 km +/- 8 km
Inclination	~97.5 +/- 0.01 deg (Sun Synchronous)
Local Time of the Ascending Node	11am/11pm
Eccentricity	0.001
Baselined Launch Provider	Exolaunch (rideshare programme)
Date	Q1 2026

Table 2: ERMIS Orbit and Launch Details

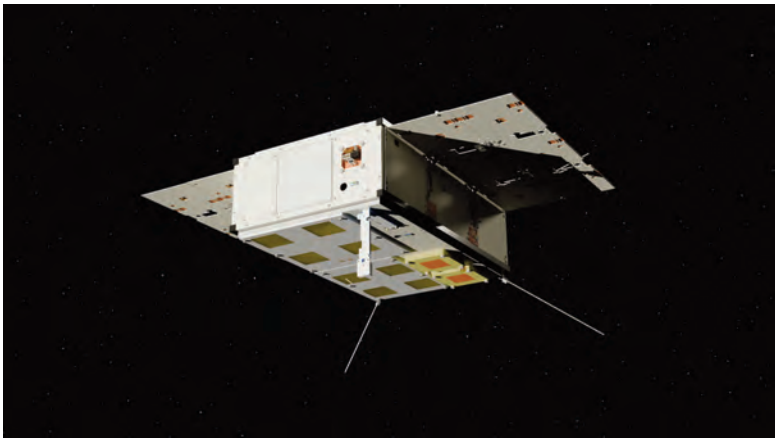


Figure 5: ERMIS 1 and 2 Nanosatellite CAD Drawings with S-band Payload based on a 6U Cubesat (OQ Tech)

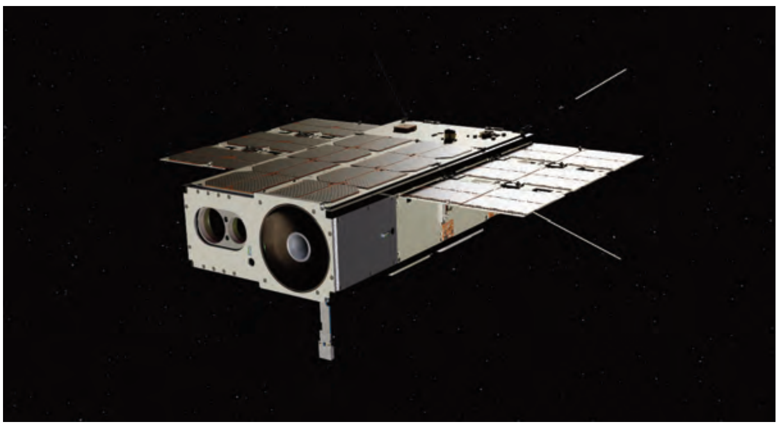


Figure 6: ERMIS 3 Nanosatellite CAD Drawings with 5-m GSD Hyperspectral and Laser Optical Link Payloads based on a 8U Cubesat (University of Athens and Patras)

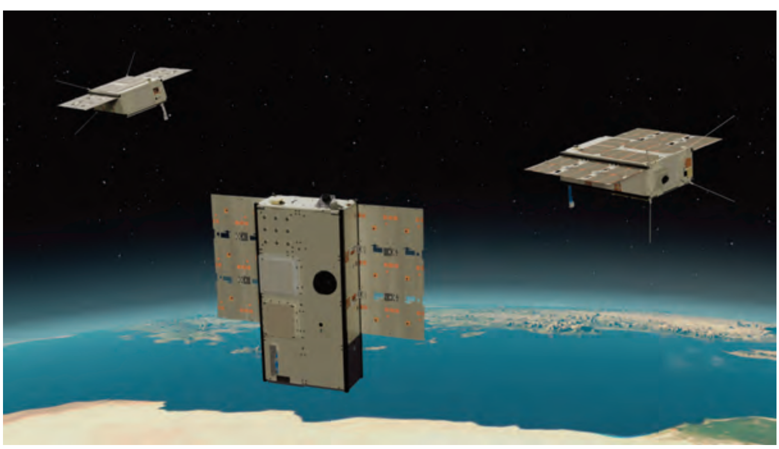


Figure 7: Computer Visualisation of the ERMIS Constellation with all 3 nanosatellites over Greece

Currently all satellite components, ground stations are being assembled in the University of Athens (UoA) clean room. ERMIS 1-3 will be tested over the summer of 2025 at the UoA AIT/clean room facilities. Delivery of the satellites to the launch broker is expected to take place in November 2025, in preparation for a launch in January 2026 on a SpaceX Falcon 9.

Defence and Security Applications

The ERMIS nanosatellite constellation will focus on demonstrating key telecommunications and earth observation capabilities which can have significant defence implications. The ERMIS 1 and 2 nanosatellites will be able to offer low memory messaging services based on OQ Hellas' S-band network and constellation as a global satellite 5G IoT operator providing uninterrupted cellular coverage for assets and machines anywhere on the planet [6]. OQ uses a fleet of nanosatellites in LEO which connect to its proprietary ultra miniature dual-mode satellite-cellular IoT modem and tracker which is a plug and play small, low-cost, and low-power solution that can collect data from more than 1000 sensors. The modem/tracker has built-in GPS, and supports 5G NB-IoT, GSM, LTE-M, and bi-directional Satellite links with data bundles ranging from few Kbytes to Megabytes per day.

Using an existing fleet of 10 nanosatellites which is being rapidly scaled up, low data services are offered for various civil and defence related applications such as:

- Hybrid Satellite-Cellular Terminal: Uses a flexible, robust, and programmable dual-mode terminal with pre-paid data packages. It is ideal for remotely monitoring and controlling fixed and mobile assets in industries as diverse as transportation, oil and gas, utilities, maritime, agriculture, and more. It supports GSM/LTE-M/NB-IoT and Satellite link both in uplink and downlink. It can connect to 1000 sensors using multiple I/Os. It supports multiple SIMs and can be powered with a battery that survives multiple years. All this is for a fraction of the cost used by incumbent operators.
- Smart Mobility: Connected smart vehicles/drones are entering the market and offer companies the chance to deliver goods further and in more efficient ways. Tracking of fleets and goods is not possible outside cities where no cellular coverage is available. OQ offers an end-to-end satellite 5G integrated solution that allows monitor assets and fleets in real time, anywhere they may go. Furthermore, bi-directional communication to machines can be offered

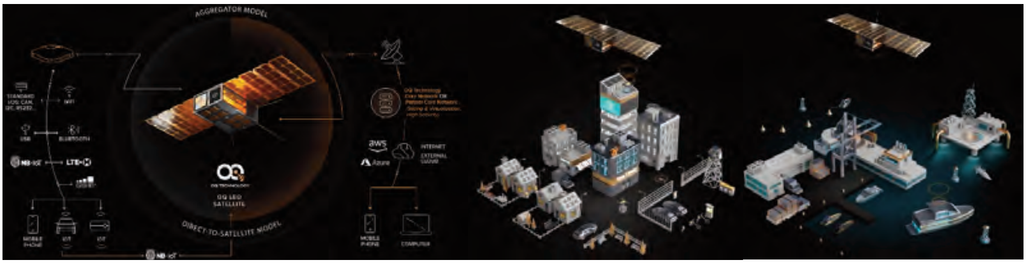


Figure 8: OQ Technology Model and Smart Mobility, Smart Ocean Applications

such as banking ATMs in poor connectivity areas. A dual satellite-terrestrial solution that can switch automatically between OQ and partner networks can create robust communications for mobile platforms.

- Smart Ocean: Maritime connectivity today is limited to expensive satellite VSAT and M2M high-end terminals, this is not suitable for IoT data collection and control. IoT/satellite solutions can help track fishing boats, smart nets, weather buoys, and commercial containers. In addition to that real-time tracking solutions can be provided for transport ships and yachts. Finally managing sensors and devices on offshore rigs, underwater pipes and oil wells have never been easier, all using a highly secure and reliable system.
- Smart Energy: IoT/satellite solutions can enable efficient operations of smart energy grids efficiently, and at full capacity and avoid disruption or loss of assets by giving full access remotely to manage your applications. This includes SCADA systems, pipeline monitoring, and leak detection, predictive maintenance reports of machinery and windmills, inventory and asset tracking, mining, environmental monitoring, oilfields monitoring, tracking of workers and their well-being, and finally industrial smart metering.

ERMIS-3 is a pilot earth observation nanosatellite with a SIMERA Sense 5m GSD hyperspectral payload, a laser optical link which can provide secure downloads of satellite data and a Greek Payload and Data Processing Unit (PDPU) which can compress, distribute satellite data on board the satellite platform. The mission application for ERMIS-3 is focused on precision agriculture and specifically:

- Vegetation mapping: Hyperspectral imagery (HyI) can support the mapping of plant varieties.
- Crop health monitoring: HyI can detect stress in crops, nutrient deficiencies, and disease outbreaks, enabling timely interventions.
- Soil analysis: HyI can assess soil

composition, moisture content, and fertility levels.

- Precision agriculture: Data from hyperspectral imagery helps optimize irrigation, fertilization, and pest control.

Hyperspectral imaging at 5 GSD can give very unique features for earth observation for a multitude of applications. Figure 9 shows the preliminary analysis of imaging Greece with a single satellite which can provide full coverage of Greece's territories and islands twice a month.

s with a minimum revisit time of 13 hours and a maximum revisit time of 60 hours.

ERMIS-3 even as a single satellite will enable unique mapping capabilities which can support various defence and security applications for Greece and enable scaling up ERMIS with multiple additional satellites to provide a high revisit earth observation capability in the near future.

Further to the ERMIS-3 imaging capabilities, ERMIS-3 carries a unique, high performance laser optical link provided by Astrolight and which will be

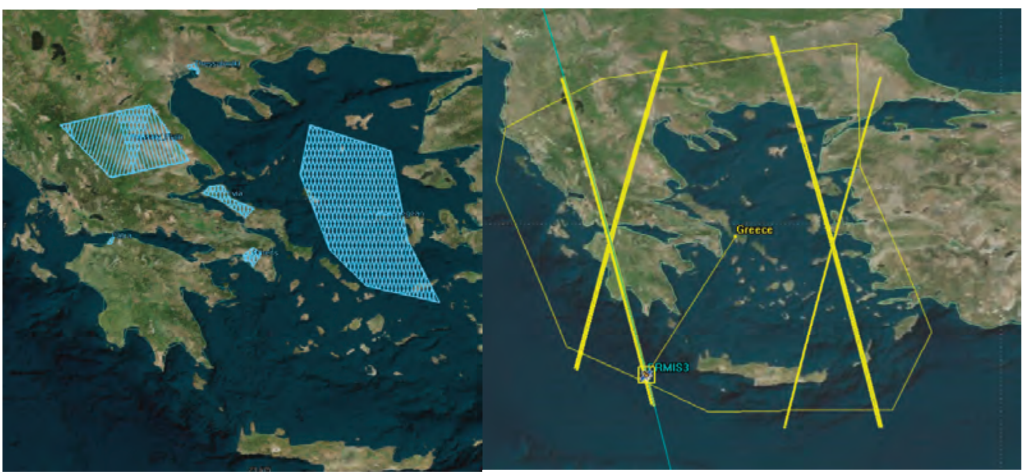
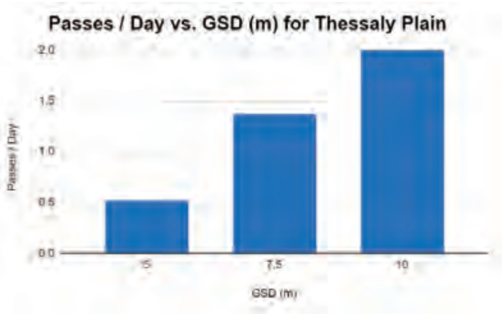


Figure 9: Coverage Analysis of Greece with the ERMIS-3 Nanosatellite

In the interest of imaging the whole Greek region, a coverage analysis was conducted to deduce the maximum imaging time required to capture a complete pass over Greece, as shown in Figure x. For a duration of 7 days with 7 passes one will have a minimum duration of 107s, maximum duration of 130

linked with multiple Optical Ground Stations (OGS) including the Helmos OGS upgraded through ESA's Scylight programme and operated by the National Observatory of Athens (NOA).



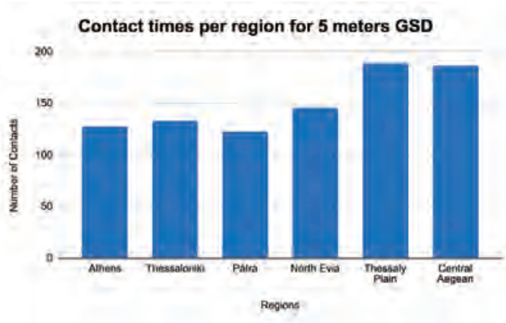


Table 3: ERMIS-3 Passes and Contact Time Analysis at 500 km SSO

Conclusion

ERMIS is a groundbreaking project which promises to push cubesat technology boundaries. Three satellites are currently being developed and assembled in Greece two 6U (10 x 20 x 30 cm) and one 8U (10 x 20 x 40 cm) for satellite communications and earth observation applications. Combined with other satellite investments currently taking place in the Greek National Small Satellite Programme, Greece will be launching 24 small satellites in the next 16 months creating a comprehensive constellation with R&D, operational, communications and earth observation capabilities which can support a multitude of national needs including defence and security. ERMIS is a cubesat constellation 'made in Greece' which is creating very unique national capabilities and links with academia and industry and can become the backbone of a new space generation in Greece.

Acknowledgements: The ERMIS project is funded by the European Union – NextGenerationEU and by the Greek Ministry of Digital Governance and managed by the European Space Agency. The project is coordinated by the Department of Aerospace Science and Technology of the National and Kapodistrian University of Athens. The authors would like to acknowledge the support and contributions of all 39 team members of ERMIS and its partners from the University of Athens, University of Patras, OQ Hellas, Aegean University and National Observatory of Athens.

References

1 'What are SmallSats ?', Link: https://www.nasa.gov/what-are-smallsats-and-cubesats/, Accessed March 1, 2025

2 'The ERMIS Nanosatellite Mission', Link: https://hub.uoa.gr/en/ermis-project/ , Accessed March 1, 2025

3 'Greek National Small Satellite Program', Link: https://www.esa.int/Applications/Connectivity_and_Secure_Communications/ESA_backs_Greek_firms_and_universities_CubeSats, Accessed March 1, 2025

4 'Small Satellites: Technology That Democratizes Space', Link: https://eos.com/blog/small-satellites/, Accessed March 4, 2025

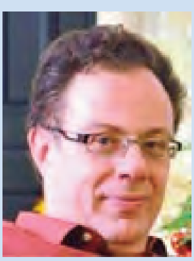
5 Greek National Small Satellite Program', Link: https://mindigital.gr/wp-content/uploads/2024/01/National_SmallSat_Programme_DEC2023.pdf , Accessed March 4, 2025

6 'OQ Technology', Link: https://www.oqtec.space/product , Accessed March 4, 2025

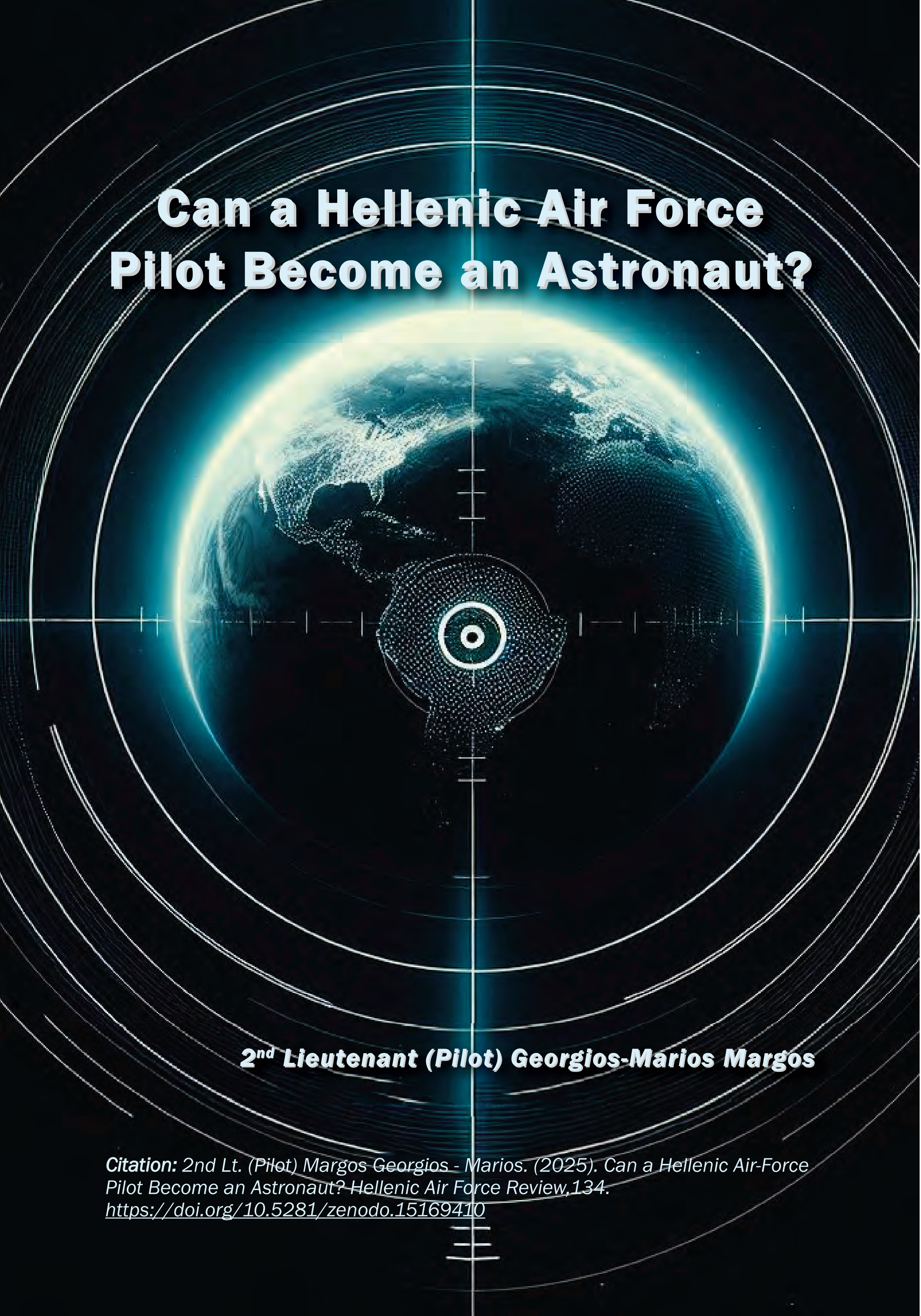
Short Biography

Professor Vaios. Lappas holds a BEng in Aerospace Engineering from Ryerson University (Canada), an MSc in Space Technology from NASA Goddard via the International Space University (France), and a PhD in Space Vehicle Control from the University of Surrey (UK), and has led significant research grants on satellite technology, space missions, and space debris, funded by the US Air Force, NASA, Airbus, ESA, and the European Commission, including the EU-funded QB50 and RemoveDEBRIS missions, the EDA EuroSWARM defence project, and the ERMIS nanosatellite constellation (Greek Ministry of Digital Governance/ESA); he currently serves as Professor of Aerospace Systems and Head of the Department of Aerospace Science & Technology at the University of Athens (Greece) and Consulting Professor at Cranfield University (UK), focusing research on unmanned vehicles for defence, satellite systems, launch vehicles, and small satellites (EU, US Air Force, ESA), while teaching Flight Controls, Dynamics, and Satellite Communications and supervising MSc and PhD students in Astronautics, Space, and Autonomous Systems at Cranfield.

Short Biography



Dr. Antonios Paschalis, born in 1960, is Professor at the Department of Computer Science and Telecommunications at the University of Athens, where he directs the Digital Systems and Computer Architecture Laboratory (DSCAL) and the Interdisciplinary MSc in Space Technologies, Applications and Services (STAR), serves as an academic member of the si-Cluster Board, and has held roles including member of the Hellenic Space Agency Board, the provisional assembly for the Department of Aerospace Science and Technology (UOA), and President of the Department of Computer Science and Telecommunications (UCA, 1916-1920); he earned a B.Sc. in Physical Sciences (1982), an M.Sc. in Electronic Automation, and a Ph.D. in High Reliability Computing (1987) with a fellowship from the National Research Centre "Demokritos," all from NKUA's Department of Physics, bringing over 10 years of experience in designing on-board payload data processing units for space applications and recognition as a Golden Core Member of the IEEE Computer Society.



Can a Hellenic Air Force Pilot Become an Astronaut?

2nd Lieutenant (Pilot) Georgios-Marios Margos

Citation: *2nd Lt. (Pilot) Margos Georgios - Marios. (2025). Can a Hellenic Air-Force Pilot Become an Astronaut? Hellenic Air Force Review,134.*
https://doi.org/10.5281/zenodo.15169410

Abstract

One of the most emblematic dimensions of outer space is the astronauts, who symbolize human exploration and the quest for knowledge. Since its inception, U.S. NASA has selected 360 astronaut candidates: 212 military and 138 civilians; 191 pilots and 169 non-pilots. The majority of astronauts remain in the military, a trend likely to continue due to the unique skills and abilities pilots bring to space missions. This article briefly describes the selection criteria for the first astronauts internationally, highlighting the significant role of pilots. It also explores the past initiative of the Hellenic Ministry of Defence to select a Greek astronaut from the Air Force, aligning with international practices and providing direction for future efforts.

Keywords

Hellenic Air Force; Pilots; Astronauts; Space Exploration; Military Personnel; Hellenic Ministry of Defence.

The Recognition of the Dimension of Space in the Hellenic Air Force Doctrine

The realm of space plays a pivotal role in the sphere of modern military operations. Satellite systems orbiting Earth provide critical operational capabilities such as global communication, earth observation, navigation, and early warning. These capabilities allow the Armed Forces to maintain uninterrupted connectivity and monitor the movements of adversaries, effectively assisting in the planning and execution of military operations.

At the same time, it is worth noting the significance of their contribution to disaster prediction and response, humanitarian assistance guidance and intelligence gathering. This enables military forces to operate and respond effectively to a broad range of security

challenges. Consequently, the operational exploitation of space enhances situational awareness, operational planning, and the overall effectiveness of defence strategies, reaffirming the crucial role of space in global security and defence.

In the context of modern Greek reality, the recognition of space as a dimension is evident in the military doctrine of the Hellenic Air Force. With the recent revision of the doctrine

Revolutionizing Connectivity through Satellite Technology [1]

(March 2023), space has been officially acknowledged for the first time by an institutional document of the Hellenic Armed Forces as a vital domain for safeguarding and advancing national interests. The concept of «Space Power» has been recognized and placed prominently in the Armed Forces, fundamentally upgrading all three levels of warfare (strategic, tactical, and operational), thus serving as an undeniable force multiplier in modern battlefields.

Furthermore, the emergence of the Space dimension by the Hellenic Air Force can ensure the potential for further development, evolution, and qualitative improvement in the planning and execution of multi-domain operations in today's multidimensional battlefield. [2] A similar initiative was undertaken on December 20, 2019, by the President of the United States of America Donald J. Trump, who institutionalized the Space Force as a separate branch of the U.S. Armed Forces. This move reflects the evolution of strategic thinking regarding Space and highlights its value in safeguarding national interests and maintaining national security and defence.[3]

However, the symbolic dimension of space presents an equally important and intriguing aspect beyond its operational utilization, the spaceflight. This term refers to astronautics and is conducted by individuals with specific qualifications who actively contribute to human exploration and the advancement of scientific knowledge.

Astronauts are educated and professionally distinguished individuals who have left their mark in the annals of world history, inspiring and motivating humanity along the path of exploration. This is admirable and praiseworthy. Nevertheless, it may prompt reflection as to why Greece, as a country, has not yet seen a Greek citizen - military or civilian - join the elite ranks of astronauts and serve as a role model for Greek society.

The First Astronauts

The origins of astronautics can be historically traced back to the Cold War era (1945-1991) between the United States of America (USA) and the Soviet Union (USSR). During this period, the two nations engaged in an endless competition for dominance in Space (Space Race), which fundamentally altered levels of human knowledge and exploration. The first major milestone focused on placing the first human in space. This was achieved by the Soviet Union on April 12, 1961, when cosmonaut Yuri Gagarin left Earth's atmosphere for 108 minutes aboard the Vostok 1 capsule. This mission was considered a tremendous success by the standards of the time, as it marked the first instance of a human leaving Earth's atmosphere, making Gagarin an international hero within Soviet society. [4]

The American response came just three weeks later when astronaut Alan B. Shepard became the first American citizen to conduct a suborbital flight aboard the Mercury Freedom 7 capsule. However, the significant decision and the ultimate goal of the space race were articulated three weeks later, when U.S. President John F. Kennedy declared in a speech the ultimate objective of the U.S. space program: landing the first human on the Moon before the end of the 1970s. [5]

In 1959, for the first time in history, NASA in its search for astronauts, requested the U.S. Air Force to prepare a list of members meeting specific criteria. Attention was focused on individuals with flight experience and a background in engineering. The list was initially narrowed down to 500 individuals, and those who stood out and were selected as the first astronauts were M. Scott Carpenter, L. Gordon Cooper, John H. Glenn, Virgil I. "Gus" Grissom, Walter M. Schirra, Alan B. Shepard, and Donald K. "Deke" Slayton, also known as the Mercury Seven.

Alan B. Shepard, May 5, 1971 [6]

From 1964 onwards, the criteria were revised, and NASA focused on individuals with strong academic backgrounds, such as master's or doctoral degrees in engineering, physical sciences, and medicine. These selected individuals formed the scientific community of astronauts, which was considered of primary importance in space exploration.[7]

In 1978, the Space Shuttle was launched for the first time, crewed by five astronauts from NASA's 8th series, four of whom were pilots from the USAF and one a scientist (astronomer). Interest was now centered on the scientific exploration of space and the construc-

The Mercury 7 Astronauts: NASA's First Space Travelers [8]

tion of an International Space Station capable of conducting scientific experiments aimed at further understanding the universe and Earth. This aspiration began to materialize in 1998 and was completed after ten years with the contribution of fifteen countries and a total of thirty space missions.

It is an undeniable fact that to this day that the preference for pilots has stood out, if not dominated, in the field of astronautics. This is mainly due to the skills that a pilot develops, such as enhanced space perception, three-axis movement, alertness, determination and the ability to multitask.

A special category of pilots, which has the greatest impact in the field of astronautics, is that of Test Pilots. The reason why test pilots stand out is their deep knowledge of flight and flying physiology, as they fly in aircraft of unknown performance and limits, a fact that cultivates instincts such as enhanced virtual-acoustic perception, alertness and decisiveness in decision-making and initiatives, in an environment where consequences truly count. The first space vehicles were constructions of unknown limits and capabilities.

For this reason, it was considered necessary that the first astronauts who would be called upon to operate them be former fighter aircraft test pilots, as only they could to a certain extent simulate the performance, speed and handling skills required of a space capsule. [9]

Hellenic Airforce (H.A.F) Rafale H3-R Jets [10]

The Role of Military Personnel in Modern Astronauts

Modern astronaut missions, due to their complex nature and high demands, require adequate and appropriate crew training and preparation. This training focuses on technical expertise, survival in harsh conditions, physical fitness improvement, scientific education, and preparation for upcoming space exploration.

These requirements make the role of military personnel extremely important and multidimensional. Military training, particularly in the Air Force, which has a flight element, shares many commonalities with astronaut training, making this branch of the Armed Forces highly preferable.

Military personnel, especially pilots, have valuable experience in managing dangerous and critical situations, coordinating crews, and adhering to mission schedules. These skills are vital for the effectiveness of space missions. History has shown that combining military expertise and astronautics shapes disciplined and fully prepared individuals capable of taking responsibility for space missions and meeting any risky demands.

An example worth noticing, is the Gemini VIII mission that took place on March 16, 1966, in which astronauts Neil Armstrong and David Scott attempted a space rendezvous and docking of two different spacecraft. Minutes after the successful docking, the astronauts faced a series of malfunctions that caused the unified spacecraft to spin at a rate of one full rotation in less than a second.

This was masterfully handled by former test pilot and fighter aircraft pilot Neil Armstrong (and the first man to set foot on the Moon), as he managed to regain control manually, thus demonstrating the great importance of aviation training in addressing the unexpected of space.[11]

Neil Armstrong and David Scott after Gemini VIII Mission [12]

The first selection of astronauts (Mercury Seven), focused exclusively on military personnel, as NASA was in close cooperation with the US Department of Defence at the time. In the following years, many believed that space exploration, especially by humans, should be a civilian, not a military, pursuit.

This view was strongly opposed by the US Air Force, which argued that space flight had many inherent characteristics with that on Earth and that Space was simply an extension of the scope of its operational scope. At the same time, an equally widespread view was that until then, human exploration and discovery of new areas had been carried out mainly by civilians, not by military forces. This fact led to the modification of the selection restrictions and opened the path of astronautics to many civilians.

Since its inception, NASA has selected 360 astronaut candidates: 212 military and 138 civilians; 191 pilots and 169 non-pilots. The absolute majority of astronauts remains in the military, a percentage that is unlikely to decrease, considering that space exploration will always require the skill and abilities possessed by a pilot. [13]

The question that arises and may essentially concern the Hellenic Air-Force is whether a Greek pilot could meet the difficulties and high demands of astronautics and why it has not already been done, given that a specific path for selecting astronauts is observed and at a time when more than 60% of the global astronaut community are former military personnel and pilots in particular.

Space Shuttle Launch April 4, 1983 [14]

Hellenic Minister of Defence Guideline for a HAF Astronaut

In Greece, to date, there has been one astronaut of Greek descent, Theodore Yurchikhin, who participated in the 2002 joint American - Russian Atlantis mission and later (2006-2007) worked on the International Space Station (ISS).

The Greek government's willingness to select an astronaut was first expressed in 2003 by the Minister of Development, who conveyed the country's desire to explore the possibility of selecting and training an astronaut to the Director of External Relations of ESA (European Space Agency) and former Belgian Minister of Defence, Jean-Pol Poncelet. The Greek request at the time, concerned the individual national selection and training of a Greek astronaut, given that there was no open ESA astronaut selection competition in progress at that time.

Two years later, the Minister of Defence, Spilios Spiliotopoulos, a former pilot of the Hellenic Air Force, showed genuine interest in the scenario of selecting an astronaut from the HAF personnel. To this end, he accepted a relevant proposal from the Space Office of the Ministry of Defence Staff, which

Theodore Yurchikhin (bottom row, centre), pictured with the Expedition 37 and 38 crew [15]

was established in 2005 following a suggestion by the Hellenic Air Force. ESA, through its representative Daniel Sacotte, responded positively to the Greek request. An initial cost estimate for astronaut training was set at 20 million euros. [16]

Interest was focused on the ranks of the Hellenic Air Force, as the required qualifications included completing over 1,000 hours in high-performance aircraft (fighter jets), a test pilot license, a master's or doctoral degree in the physical sciences, and fluency in Russian. However, none of the Hellenic Air Force personnel met all those qualifications. The change in ministerial leadership eventually diminished the enthusiasm for astronaut selection.

Although the Greek effort to select an astronaut has not garnered significant attention from subsequent governments, it has not deterred citizens of Greece from applying to ESA's open astronaut selection competitions. Two particularly inspiring examples are that of Aeronautical Engineer and ATPL pilot Dr. Panagiotis Vitsas, and former Fighter Pilot and holder of two Postgraduate Diplomas, Major (HAF, ret) Ioannis Lignos. Both managed to advance in ESA's 2021 astronaut selection reaching the fourth and third stage of the competition respectively. Given these data, it is hoped that in the future another Greek will manage to complete their effort, highlighting Greece and the Air Force, provided that the astronaut comes from its ranks.

Epilogue

Becoming an astronaut, from the early days of space exploration to the present, highlights the critical role of skilled pilots and military personnel in advancing human presence in space. Looking ahead, the role of astronauts will continue to evolve, driven by technological advancements and the expanding frontiers of space exploration. The Hellenic Ministry of Defence's initiative to select an astronaut from the Air Force exemplifies a forward-thinking approach, aligning with international practices and recognizing the strategic importance of space. By fostering such initiatives, Greece can contribute to the global effort of space exploration and inspire future generations to reach for the stars. The path to becoming an astronaut is demanding, but with dedication, expertise, and international collaboration, it remains an attainable goal for many aspiring space explorers.

References

1 Telecom Review Asia, «Revolutionizing Connectivity Through Satellite Technology,» *Telecom Review Asia*. Available: https://www.telecomreviewasia.com/news/featured-articles/3865-revolutionizing-connectivity-through-satellite-technology/.

2 Hellenic Air Force, "BASIC-DOCTRINE-HAF.pdf," Accessed September 19, 2023. [Digital Edition]. Available: ΒΑΣΙΚΟ-ΔΟΓΜΑ-2023.pdf.

3 U.S. Space Force, "About Space Force," *U.S. Space Force*. Accessed September 22, 2023. Available: https://www.spaceforce.mil/About-Us/About-Space-Force/.

4 National Aeronautics and Space Administration (NASA), "April 1961 - First Human Entered Space," *NASA*, May 7, 2015. Accessed September 18, 2023. Available: http://www.nasa.gov/directorates/heo/scan/images/history/April1961.html.

5 Flashbak, «May 5, 1961: Alan Shepard Blasts Off to Outer Space and Comes Back Alive,» *Flashbak*, 2014. Available: https://flashbak.com/may-5-1961-alan-shepard-blasts-off-to-outer-space-and-comes-back-alive-25611/.

6 National Aeronautics and Space Administration (NASA), "60 Years Ago: Alan Shepard Becomes the First American in Space," *NASA*, May 4, 2021. Accessed September 18, 2023. Available: https://www.nasa.gov/image-feature/60-years-ago-alan-shepard-becomes-the-first-american-in-space.

7 Free Cape Cod News, «The Mercury 7 Astronauts: NASA's First Space Travelers,» *Free Cape Cod News*. Available: https://freecapecodnews.com/the-mercury-7-astronauts-nasas-first-space-travelers.

8 National Aeronautics and Space Administration (NASA), "Astronaut Selection and Training," *NASA*, May 2011. Accessed September 19, 2023. [Digital Edition]. Available: https://www.nasa.gov/centers/johnson/pdf/606877main*FS-2011-11-057-JSC-astro*trng.pdf.

9 National Aeronautics and Space Administration (NASA), "Astronaut Fact Book: June 2022," *NASA*, June 2022. Accessed September 19, 2023. [Digital Edition]. Available: https://www.nasa.gov/sites/default/files/atoms/files/astronaut-

*fact*book*june*2022.pdf.

10 Greek City Times, «Image of HAF Air Force Rafale,» *Greek City Times*. [Online]. Available: https://www.bing.com/images/search?view=detailV2&ccid=%2bCj4qwXa&id=A69EB600512DC784F276F7D0FF9ACBA401E491AD&thid=OIP.-Cj4qwXavKrlH_ n l g j l 3awHaDz.

11 Smithsonian National Air and Space Museum, "Spinning Out of Control: Gemini VIII's Near-Disaster," *Smithsonian Air and Space Museum*. Accessed September 19, 2023. Available: https://airandspace.si.edu/stories/editorial/spinning-out-control-gemini-viii.

12 Smithsonian National Air and Space Museum, «Multimedia Gallery: 104-ksc-66c-1879,» *Smithsonian National Air and Space Museum*. Available: https://airandspace.si.edu/multimedia-gallery/104-ksc-66c-1879mediumjpg.

13 J. M. Logsdon, "The Space Shuttle Decision: Chapter 2-1: The Politics of Decision-Making," *NASA History Division*, 1976. Accessed September 19, 2023. [Digital Edition]. Available: https://history.nasa.gov/SP-4407/vol2/v2chapter2-1.pdf.

14 Scrolller, «April 4, 1983: Space Shuttle Challenger makes its first flight,» *Scrolller*. Available: https://scrolller.com/april-4-1983-space-shuttle-challenger-makes-its-4vti3aycyq.

15 Wikipedia, «Fyodor Yurchikhin,» *Wikipedia*. [Online]. Available: https://en.wikipedia.org/wiki/Fyodor_Yurchikhin.

16 A. Kolovos, "A Window of Opportunity for a Greek Astronaut," *Defence and Diplomacy*, pp. 44–47, 2008. Accessed September 29, 2023. Available: https://bit.ly/3M4hycn.

Short Biography

Second Lieutenant (Pilot) Margos Georgios Marios graduated from the Hellenic Air Force Academy in 2024.

He has accumulated a total of 150 flying hours in Technam P2002JF and T-6 Texan II aircrafts. Currently, he is undergoing advanced jet training on the M-346 Aermacchi Jet at the 120 IFTC (International Flight Training Center), further honing his skills in fast-jet operations and combat aviation.

He is particularly interested in the expansion of the role of Air Πower in Space. His HAFA thesis focused on "The Role of Mega-Constellations of small Satellites in Defence."

HELLENIC AIR FORCE REVIEW

TERMS OF COOPERATION

1. The Journal's topics focus mainly on aviation interest issues of, but also on issues of civil-military nature such as:

   a. Strategic, operational and tactical options for the projection of air power.

   b. Developments in the field of research and technology of the defence industry.

   c. Historical, politico-military, geopolitical, economic, social and cultural issues of interest to the Hellenic Air Force (HAF).

   d. Air Force issues related to the promotion of Flight and Ground Safety issues.

2. Candidate papers for publication will be sent to the Magazine by e-mail to the address: aero_epi@haf.gr, submitting the candidate article and providing full details of the author (full name, contact info).

3. It is necessary that the papers are accompanied by diagrams, sketches or photographs (original if possible) with the relevant explanations, mentioning the necessary details of the bibliography used with reference to the source. The required resolution for the accompanying photographs of the articles is 1240x800 pixels. The author must also explicitly state in his/her e-mail that the article in question is not a product of plagiarism.

4. The author is responsible for the content of his/her paper, both for the accuracy of the facts or opinions recorded in it, and for the validity and rights of the sources used.

5. The content of the assignments must be "UNCLASSIFIED" and the texts must be written in the Greek monotone system.

6. The opinions expressed in the papers reflect the authors' personal opinions only.

7. Candidate papers should not contain:

a. Judgments against persons or agencies.

b. Phrases that may cause misunderstandings and unfavorable comments.

c. Any spikes of political nature.

d. Statements contrary to the Country’s national policy.

8. All published articles are selected by a special committee. The person in charge of the publication reserves the right to make any changes he deems necessary for the better presentation of the material, without, of course, altering its meaning.

9. Articles nominated for publication will be accompanied by a short biographical note of the author of approximately ten lines, and by a recent photograph.

10. In case the submitted papers are derived from a translation, then in addition to the translator's details, the title, month, year and number of the foreign publication should be clearly indicated, as well as the the full name of the author.

11. Whenever a candidate paper is finally rejected by the Selection Committee, the Air War College Journal Publication Department will send the author an email or letter to that effect.

12. The authors' fees are subject to the Joint Ministerial Decision No. 2/76198/0022/Common Ministerial Decision (Government Gazette 208/B'/11-02-2008). Recipients of royalties, immediately after the release of the corresponding issue, may contact the Financial Services Directorate of the Aviation Training Command (telephone number: +30 210 819 1213), which is located at the Dekelia Air Force Base.

The terms of cooperation of the Journal are posted on the official Hellenic Air Force website: www.haf.gr.