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The strategic transformation of outer space

Economic, Geopolitics, and Future Implications

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Abstract

This thesis explores the evolution of outer space as a strategic domain. Once reserved for scientific exploration, space is now essential for technological development and increasingly congested. The advent of satellites has revolutionized telecommunications, while the decreasing cost of access to orbit has fostered a growing commercial sector, with key players such as SpaceX and OneWeb accelerating private involvement.

For global powers, space represents a strategic priority, not just technologically, but geopolitically. Unlike the Cold War-era Moon race, which focused on peaceful goals, today's advancements reflect a more competitive approach. The idea of space as a global commons is eroding, giving way to rivalry and national interests. This shift has led to the militarization and weaponization of space, from dual-use technologies to the development of anti-satellite (ASAT) and kinetic weapons, officially defensive, but raising global concerns over their real purpose.

The thesis examines the growing relevance of the space domain through economic, strategic, and geopolitical lenses. Why are world powers investing so heavily in space, and what consequences arise from these choices?

It begins by analyzing the evolution of the space sector and the rise of the space economy. Commercial applications, telecommunications, logistics, agritech, and Earth observation, highlight why states and companies seek access to space. This sets the stage for understanding how space has become a symbol of global influence. Case studies of emerging space powers are used to assess the increasingly military dimension of national space programs.

The focus then shifts to the militarization of space, addressing the dual-use nature of many technologies, drivers of innovation that can also be weaponized. It explores the growing deployment of space weapons, officially defensive but with offensive implications. The war in Ukraine, particularly the use of satellite systems like Starlink, illustrates the rising involvement of private actors in modern conflicts.

The strategic positioning of major players: China, the U.S., Russia, India, France, and Japan, is analyzed in light of this trend. The new race to the Moon, once scientific, now carries geopolitical weight. Lunar missions are viewed as tools of soft power and influence, shaping international hierarchies.

This geopolitical shift is also evident in the legal domain. The polarization between the U.S. and its allies versus the Russia-China axis raises fundamental questions about future space governance. As tensions rise, the lack of a clear, shared regulatory framework becomes a growing challenge.

In conclusion, the militarization of space has profound implications for global security and economic development. The use of private technologies in warfare, as

seen in Ukraine, introduces ethical dilemmas. The return to the Moon, framed by strategic goals, underlines the need for updated, cooperative international rules to ensure space remains a sustainable and peaceful domain.

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In the end, it was a great journey, with many falls, many worries, but ultimately I learned to appreciate it mostly thanks to the people who were close to me and around me.

Thank you all.

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Glossary

ASAT

Anti-Satellite Weapons

EO

Earth Observation

GNSS

Global Navigation Satellite Systems

JADO

Joint All-Domain Operations

C5ISTAR

Command, Control, Computers, Communications, Cyber, Intelligence, Surveillance, Target Acquisition, and Reconnaissance

OST

Outer Space Treaty

PPWT

Prevention of the Placement of Weapons in Outer Space

SDA

Space Domain Awareness

New Space

New commercial phase of the space economy driven by private actors

Starlink
: Satellite internet constellation developed by SpaceX

Artemis Program
: NASA-led program for returning humans to the Moon

Space Club
: Informal group of nations with advanced space capabilities

Spacefaring Nations
: Countries capable of autonomous spacecraft and satellite operations

Militarization of Space
: Use of space for military support purposes

Weaponization of Space
: Deployment of weapons in space or from space

Dual-use Technologies
: Technologies with both civilian and military applications

Techno-nationalism
: National policy promoting technological independence as a symbol of sovereignty

PNT
: Positioning, Navigation, and Timing

GPS
: Global Positioning System

GDP
: Gross Domestic Product

ISS
: International Space Station

OECD
: Organisation for Economic Co-operation and Development

EUSPA
European Union Agency for the Space Programme

CAGR
Compound Annual Growth Rate

ESA
European Space Agency

IoT
Internet of Things

C3C
Command, Control, and Communications

IoBT
Internet of Battlefield Things

RMA
Revolution in Military Affairs

OOS
On-Orbit Servicing

RPO
Rendezvous and Proximity Operations

GEO
Geostationary Earth Orbit

LEO
Low Earth Orbit

ADR
Active Debris Removal

SATCOM
Satellite Communications

MDA

Maritime Domain Awareness

KA-SAT Network

High-throughput satellite broadband network operated in the Ka-band

A2/AD

Anti-Access/Area Denial

Chapter 1

Introduction: Evolution, current landscape and strategic trends of the space sector

1.1 The importance of space in 2024

A large part of our lives in 2024 is affected by space technologies; much of our daily activity relies on satellite-based systems, from sending a message with our smartphones to using Google Maps for directions, checking the weather forecast, or listening to music online. It's difficult to imagine life thirty years ago, without instant messaging, GPS, or the ability to quickly send an email. Thanks to space-based technologies we improved the quality and safety of our lives, and we increased the efficiency of many sectors, from telecommunications, to food and beverage and transportation. Some key data illustrate the significance of space technology in 2024.

- In most developing countries, 95% of people have access to the internet with mobile broadband (3G or greater).
- ITU estimates that approximately 5.4 billion people (67% of the world's population) will use the Internet in 2023. This represents an increase of 45% since 2018, with 1.7 billion people increasing.
- The number of Internet of Things (IoT) devices worldwide is projected to almost double from 15.9 billion in 2023 to more than 32.1 billion IoT devices in 2030.

- In 2023, there were an estimated total of 9,115 active satellites orbiting Earth, representing a 35 percent increase compared to the previous year's active satellites.
- The total space economy is valued at 450 billion dollars right now

1.2 The evolution of the space sector

The start of the space era can be associated with the launch of the Sputnik I by the URSS the 4th october 1957. Sputnik I was the first satellite launched into space.

During the 'Cold War' there was a competition between US and URSS for the monopoly of space. The objective was to demonstrate technical and scientific superiority, but there were also military reasons: satellites can be used as spies, to obtain information on the rivals. The launch of Sputnik created worry in the Usa government, which established in 1958 a new agency, called Nasa. Nasa incorporated the Naca (National Advisory Committee for Aeronautics), and in some years counted more than 360 thousands employees and had an enormous budget for the upcoming years.

Nasa was founded with the objective to bring a man on the moon. This mission was reached thanks to the Apollo programme, and the 20th July 1969, in the famous Apollo 11 mission, Neil Armstrong was the first man to walk on the moon, and the US won the race in space.

After the Moon's landing, both URSS and USA lost interest in the space race, and the new space programs were cheaper and more oriented towards cooperation. Nasa launched the first space station, Skylab, and Urss started to construct their space station, Saljut. Moreover, in 1975 there was a collaboration between Usa and Urss: the Apollo-Soyuz programme, the first international human spaceflight. In these years also other countries established their space agencies, in the 1975 born ESA (European space agency), and China launched its first satellite, in 1980 was the turn of India. In the next years cooperation had a central role, and all the main projects present a partnership of many space agencies. The International space station, launched in 1988, and Hubble telescope in 1990, were the main projects completed.

The significant turning point occurred in the final decades of the 20th century, when NASA and the U.S. government gradually began transferring leadership of human space activities to private enterprises. During the Cold War, a centralized approach had been not only practical but ideologically strategic, as it contrasted sharply with the Soviet Union's fully state-controlled model. Within this centralized framework, private contractors collaborated with NASA under cost-plus contracts, which protected them from financial risk but limited their access to the potential profits of an emerging commercial space sector. This structure allowed the United

States to maintain technological leadership in space exploration, with NASA at the forefront. However, the centralized model exhibited several limitations: it provided weak incentives for efficient resource use, failed to effectively consolidate fragmented knowledge, and often hindered innovation due to a lack of market-driven competition. Moreover, there were some political, technological and economical problems that created this change. During the Apollo program, in the 60's, US investments were more than 0.7% of the GDP. After the finish of the Moon's race, these investments decreased until 0.1%: it was clear the need for Nasa to finance their programs in another way.

Also the shuttle program had a central role in this shift: the aim of the shuttle program was to create a reusable spacecraft, but due to the high production costs and the technological results under the expectations, it laid bare the limits of the centralized model.

Finally, in the 80's the US favored the birth of private companies with the Commercial Space Launch Act (1984). President Ronald Reagan signed this act, saying: "One of the important objectives of my administration has been, and will continue to be, the encouragement of the private sector in commercial space endeavors", and in the 2005, when the space shuttle program wound down, Nasa founded the Commercial Orbital Transportation Service "to stimulate U.S. commercial space transportation capabilities by pursuing a new way of doing business with industry"[1]. In November 2005, Dr. Griffin articulated that: "With the advent of the ISS, there will exist for the first time a strong, identifiable market for 'routine' transportation service to and from LEO, and that this will be only the first step in what will be a huge opportunity for truly commercial space enterprise. We believe that when we engage the engine of competition, these services will be provided in a more cost-effective fashion than when the government has to do it."[2]

All these reasons drove the birth of the first private company in 1982: Orbital science corporation. Orbital science corporation was a provider of small-medium size satellites. Unfortunately it was a seed in the desert, and for many years no one followed his example. We have to wait until 1993, with Kistler aerospace (they tried to create a reusable rocket, without fortune) for the birth of the second startup. Finally, at the turn of millennium there was a boom in the space sector, with the birth of many startups, some of them are now giants in the space segment. Blue Origin (2000), is dedicated to developing reusable rockets and spacecraft, promoting commercial space travel, and is a partner of Nasa in the Artemis program (a program with the aim to bring astronauts to the moon). SpaceX (2002) was born from a desire to reach Mars, right now it is involved in the rocket reusability challenge, and it earns half of all satellites present in the Earth orbit (more than 3395) thanks to his satellite's constellations (Starlink). Moreover, in 2008, SpaceX became the first private firm to successfully launch a liquid-fueled rocket into orbit. One Web (2012) is the owner of the second largest satellite constellation in Earth orbit (more than 500 satellites). It is supported by the UK government, and has the aim to bring fast internet to the rural areas of the world. It is right now with Amazon's Kuiper project, the main rival of SpaceX in the communication sector. Northop Grumman (1994) was born from the union between Northrop and Grumman, is a giant in the aerospace and defense sector.

As more private enterprises participate in this new market space, technological innovation will become the driving force for the sustainable development of this new economy. Space systems and products could be produced and launched faster, with cheaper costs, satellite data and signals could also be more easily exploited. Some important effects were the disruptive and new applications from micro and nano satellite constellations (for geospatial and signal intelligence , weather and emissions monitoring, Internet-of-Things), but also the commercial development and/or introduction of "new" services (space tourism, on-orbit servicing, in-space manufacturing are some examples).

1.3 The Evolution and Impact of the Space Economy

"The space economy is the full range of activities and the use of resources that create and provide value and benefits to human beings in the course of exploring, understanding, managing and utilizing space. Hence, it includes all public and private actors involved in developing, providing and using space-related products and services, ranging from research and development, the manufacture and use of space infrastructure (ground stations, launch vehicles and satellites) to space-enabled applications (navigation equipment, satellite phones, meteorological services, etc.) and the scientific knowledge generated by such activities. It follows that the space economy goes well beyond the space sector itself, since it also comprises the increasingly pervasive and continually changing impacts (both quantitative and qualitative) of space-derived products, services and knowledge on economy and society."[3]

The OECD recognises Space Economy as a strategic sector for economic development. Thanks to aerospace activities, humans can accelerate the technological and industrial progress of an area, in fact the innovations in this field have impacts in multiple areas of industry, bringing significant social benefits. Looking at the increase in the allocation of resources by governments and institutions in the space sector, it's clear the importance of the segment. The first phase of the space economy (Cold war period) was mostly guided by government and big aerospatial companies. The focus was on space exploration and military activities on space. The initial growth of the Space Economy was driven, from the early 2000s, by a combination of diverse factors, such as the lower cost of space technologies and the possibility to exploit these further by developing new ground-based applications, the interconnection with the Internet economy, the use of smart manufacturing techniques and the emergence of new geopolitical dynamics. In the second half of the 2010s, the segment became mature, and changed the financing dynamics of the sector: traditional institutional backing was flanked by growing and ambitious investments by private investors, redefining the relationship between public and private and opening up a new phase that goes by the name of "New Space Economy". The terminology of "New Space" has come to represent a new approach, where private investors, companies, and start-ups are investing and contributing to space exploration and technologies, and share the enormous risks and (potential) returns of investments in space. The new space economy is guided by private innovations, driven by the goal of creating more commercial opportunities in space.

"This shift represents a departure from the era historically dominated by government agencies, marking the dawn of a new age where private companies are not only democratizing access to space but also pioneering novel business models and services. The term 'New Space' aptly encapsulates this evolution, denoting the emerging trend of innovative private space ventures that autonomously seek business opportunities, liberated from the confines traditionally imposed by governmental space missions" [4].

1.4 Data and trends of the sector

Projections indicate that the global space economy could reach a value of $1.8 trillion by 2035, a substantial rise from the estimated $630 billion recorded in 2023. This translates to a compound annual growth rate of approximately 9%, nearly double the forecasted global GDP growth rate of 5% over the same period. This expansion is expected to be primarily driven by technologies that are either space-based or space-enabled—particularly in the areas of satellite communications, Global Navigation Satellite Systems (GNSS), and Earth observation. These technologies are increasingly delivering tangible value to a broader range of industries and actors. Among the most impacted sectors are logistics and transportation, the food and beverage industry, national defense initiatives, digital communications, and consumer-oriented markets such as retail and lifestyle. Collectively, these five sectors are projected to account for over 60% of the total growth in the space economy by 2035.

1.4.1 Communications

The space communications sector is experiencing steady growth, fueled by the rising number of artificial satellites in orbit and the increasing demand for broadband services on Earth. The deployment of satellite constellations for telecommunications

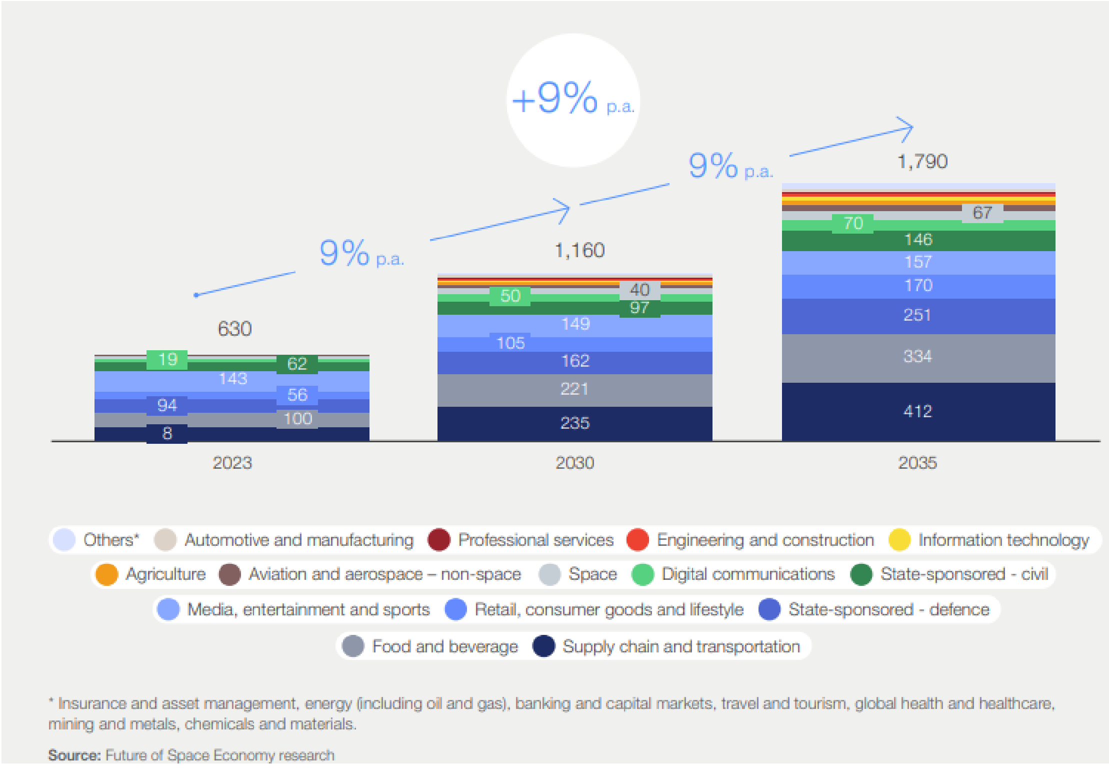

Figure 1.1: Space economy size by industry ($ billion)

Source: Future of space economy paper, by World economic forum, April 2024

highlights strong market demand and presents both challenges and opportunities for service providers and infrastructure operators. Technological advancements are creating new possibilities, such as significant reductions in launch costs and the miniaturization of data transmission and reception equipment, allowing for the construction of cost-effective small satellites that support global connectivity. The cost per kilogram for payloads has decreased dramatically, from $10,000-20,000 previously to approximately $951 per kilogram for Falcon Heavy by 2020. SpaceX's reusable rockets further demonstrate the potential for lowering costs for payloads, especially in low Earth orbit missions. Innovations like electric propulsion technology and advanced onboard data storage and processing capabilities, particularly through artificial intelligence, are enabling satellites to operate with increasing autonomy, with electric propulsion offering lightweight alternatives to traditional thrusters.

- GNSS: Global Navigation Satellite Systems (GNSS) consist of satellite constellations that transmit signals back to Earth, enabling users to accurately determine their locations. Originally developed for military applications by the US and USSR, systems like GPS and GLONASS have transitioned into

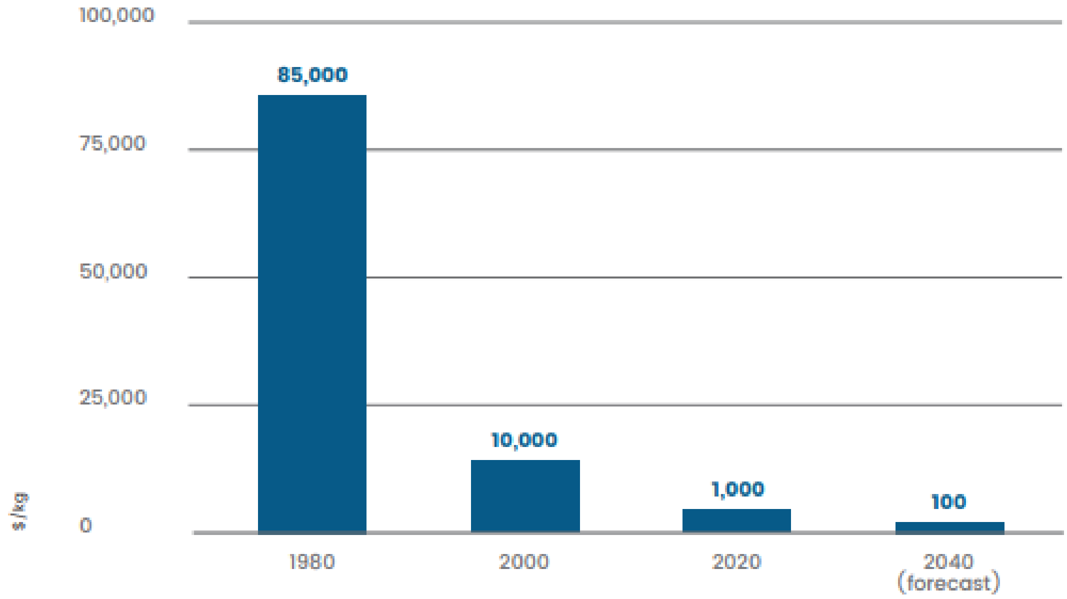

Figure 1.2: Change in launch costs from 1990 to 2020 and forecast to 2040

Source: Intesa Sanpaolo innovation center calculation based on futuretimeline data

dual-use infrastructures widely utilized in civilian applications. The prominence of GPS in civilian sectors, particularly transportation and logistics, has established it as a vital enabling technology. Today, various countries operate their own GNSS: the US GPS, Russian GLONASS, Chinese BeiDou (COMPASS), and European Galileo systems. These systems ensure continuous signal availability, making them essential for a wide range of services and products. According to EUSPA, revenue from the satellite navigation market is projected to grow from €199 billion in 2021 to €492 billion by 2031, with a CAGR of 9.2%. The global installed base of GNSS devices is anticipated to reach 10.6 billion by 2031, with most receivers found in consumer products like smartphones and IoT devices. Sectors such as air, maritime, city transportation, drones, agriculture, and emergency management will all experience significant impacts due to advancements in GNSS.

- EO: Earth Observation (EO) entails applications utilizing orbiting satellites to gather data about our planet. Initially developed for military and security purposes, EO has evolved to cover numerous areas, including monitoring coastlines, air quality, water resources, and meteorology. The EUSPA EO and GNSS Market Report indicates revenues from advanced Earth Observation data and services are set to rise from €2.8 billion in 2021 to €5.5 billion by 2031, with a projected CAGR of 6.8%. The global data-related market is expected to grow steadily, with revenues forecast to reach approximately €800 million by 2031. The upstream segment, related to the construction, launch, operation, and maintenance of EO satellites and constellations, continues to dominate the market, accounting for about 70% of total revenues. Governmental, military, and emergency management applications remain prevalent, comprising 50% to 60% of revenues

1.4.2 Supply chain and transportation

The supply chain and transportation sectors are expected to increasingly rely on satellites and other space technologies, with predictions of reaching $410 billion by 2035, growing at an impressive annual rate of 14%. Positioning, Navigation, and Timing (PNT) technologies will enhance vehicle tracking and management, reducing costs and improving efficiency for business-to-business and business-to-consumer services. Integrating AI and EO data can revolutionize information flows within industries, enabling optimized routing and timely deliveries while mitigating risks. Weather services will play a crucial role in minimizing delays and ensuring the safety of goods and personnel along transportation routes. The ESA's Navigation Innovation and Support Program (NAVISP) exemplifies this trend, aiming to foster innovative propositions that extend beyond traditional satellite navigation.

"The main NAVISP objective is to facilitate and support the generation of innovative propositions that go beyond the exclusive use of satellite navigation signals and data and include the development of competitive industrial capabilities and the development of new, innovative technologies to complement, upgrade or replace current PNT technologies."[5]

For instance, a current NAVISP project, in collaboration with Grimaldi Group, focuses on developing a satellite-based guidance system for large-vessel docking to enhance maritime safety and reduce emissions. Another project involves establishing the first autonomous shipping test site, showcasing the potential for autonomous long-distance deliveries enabled by high-speed, low-latency, low-cost satellite connections.

1.4.3 Food and beverage

Food and beverage is the sector that will reach the second major revenues by 2035: 334 billion dollars from the actual 100 billion, with an annual growth of 11%, and will continue to be transformed by the space services, due to the demand of flexibility and mobility from end users.

The impact of space technologies is most visible in time-sensitive, last-mile delivery (it is primary in case of perishable goods). The booming of deliveries apps

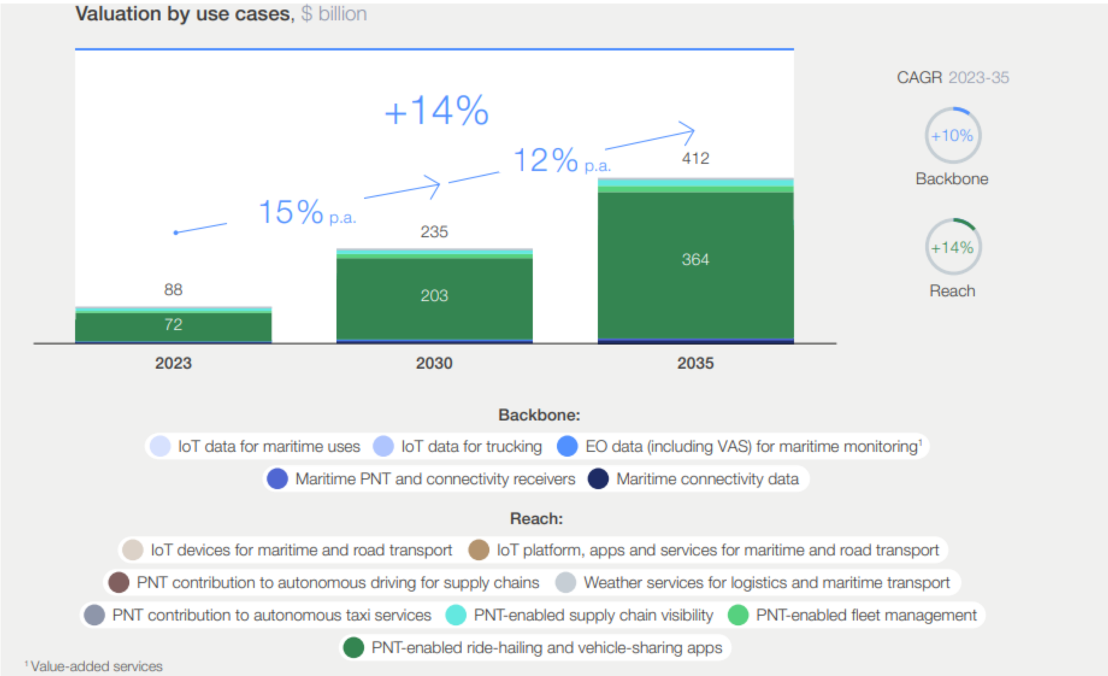

Figure 1.3: Valuation by use cases ($ billion) of supply chain and transportation

Source: Future of space economy paper, by World economic forum, April 2024

The PNT is the invention of the century for the segment, and will impact it in an incredible way, skyrocketing the revenues

like Glovo and UberEats create a growth in the necessity of signal integrity and PNT precision to have efficient deliveries and to fight frauds.

We must also highlight the significance of precision agriculture. According to a 2021 OECD-FAO Report, global demand for agrifood products is projected to grow by over 1% annually from 2021 to 2030. The integration of new technologies in agriculture is essential for ensuring the sector's long-term sustainability. In the processing chain, technological innovations can enhance food safety and significantly extend the shelf-life of products. Specifically, there are five major areas where aerospace technology can support the AgriFood industry: satellite monitoring for precision agriculture, satellite positioning systems for autonomous farming vehicles, development of crops that are more resilient to diseases and extreme weather, efficiency-boosting technologies such as soilless farming methods, innovations that improve food safety and security. These advancements will play a critical role in addressing the rising demand for food while maintaining sustainable agricultural practices.

Not by chance the U.S. Agency for International Development (USAID) and Nasa are moving towards this direction, with the implementation of the SERVIR

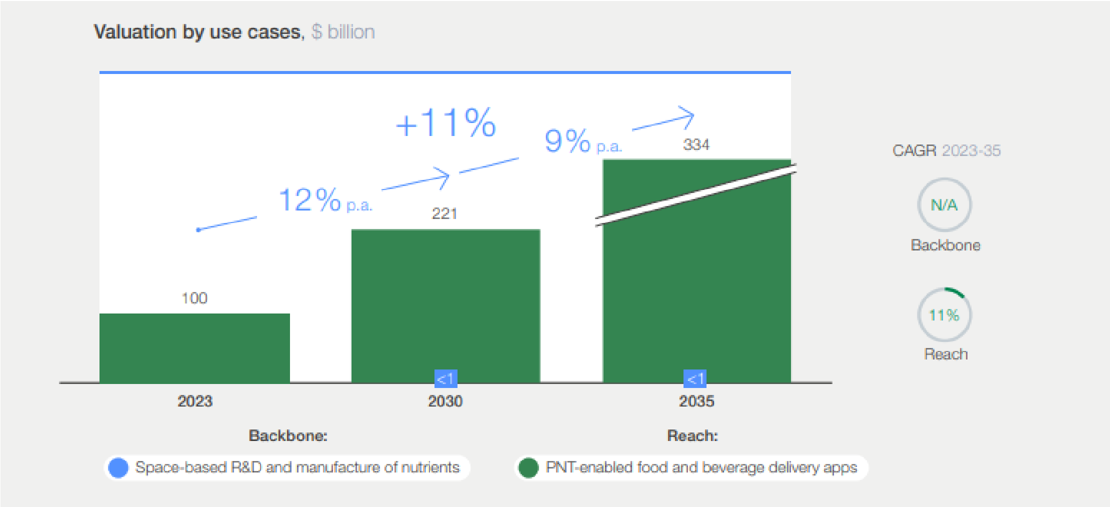

Figure 1.4: Valuation by use cases ($ billion) of food and beverage

Source: Future of space economy paper, by World economic forum, April 2024

A lower impact for now, but maybe in the next few years will have an important part, is the space based research: it's advancing nutrient development in zero gravity environment, opening up possibilities for high quality functional ingredients.

programme. "SERVIR works in partnership with leading regional organizations world-wide to help countries use information provided by Earth observing satellites and geospatial technologies. SERVIR's hubs in West Africa, Eastern and Southern Africa, Hindu Kush-Himalaya, Southeast Asia, Central America, and South America manage challenges of food security, water resources, land use change, and disasters." [6]

1.4.4 Retail, consumer goods and lifestyle

Every year the retail sector is more E-commerce dependent, but also consumer goods and electronics will benefit from space connected electronics and services enabled by satellite internet connections.

Satellites provide internet connectivity in remote areas, thanks to it people in underserved regions can participate in online shopping and E-commerce. Moreover, the interest in the satellite data equipped products for enhanced tracking and navigation experiences is skyrocketing.

A great example of the impact that space could bring to this sector is amazon's investment in the Kuiper project. "Project Kuiper is an initiative to increase global broadband access through a constellation of more than 3,000 satellites in low Earth orbit. Its mission is to bring fast, affordable broadband to unserved and underserved communities around the world."[7] With better internet access,

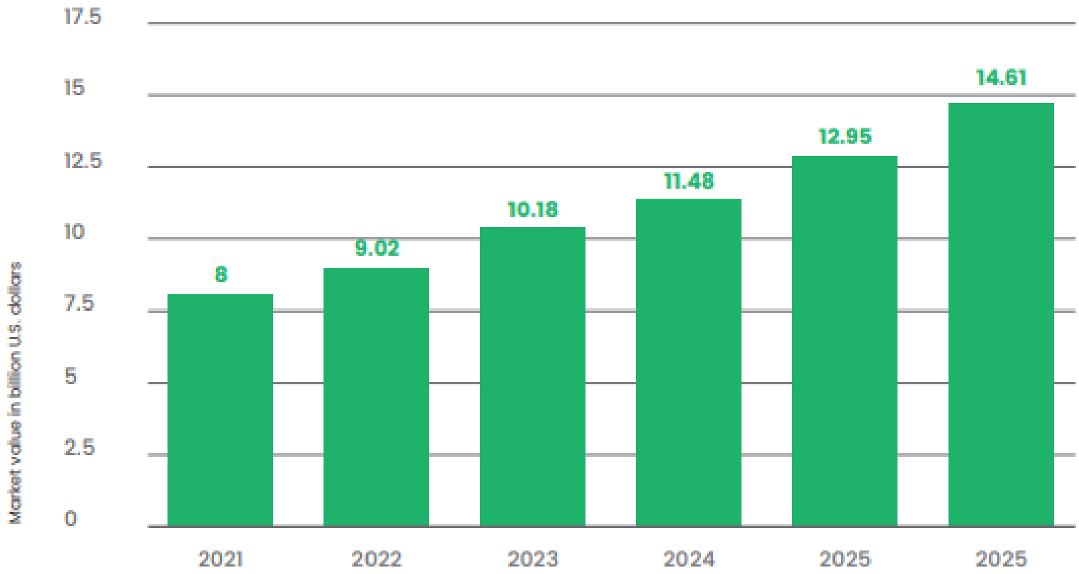

Figure 1.5: Forecasted market value of precision farming worldwide from 2019 to 2026

Source: Statista

Amazon can tap into new markets, enhance online shopping experiences, and improve services like Prime Video and cloud-based offerings, also it will improve the logistics and supply chains for the retail sector. Thanks to this project, and the integration of satellite based PNT, EO and communication data, amazon can identify early trends, informing strategic decision making for retail and consumer goods players.

1.4.5 Digital Communications

Communications is the largest commercial source of revenues of the sector, offset only by a decline in satellite tv consumption. Nevertheless there will be an increase from 133 billion dollars in 2024 to 218 billion dollars in 2035. The primary contribution of aerospace technologies to the telecommunications sector is their ability to facilitate data transmission across the globe, even in the most remote and challenging environments. Satellite constellations enable widespread connectivity, overcoming barriers posed by long distances and difficult terrain, ensuring access to reliable communication in areas where traditional infrastructure is impractical. They will improve connectivity, especially in underserved areas, for uses like residential internet, IOT or corporate networks. It is expected to reach 70 billion dollars by 2035, with a growth rate of 12%, slowing down in the last few

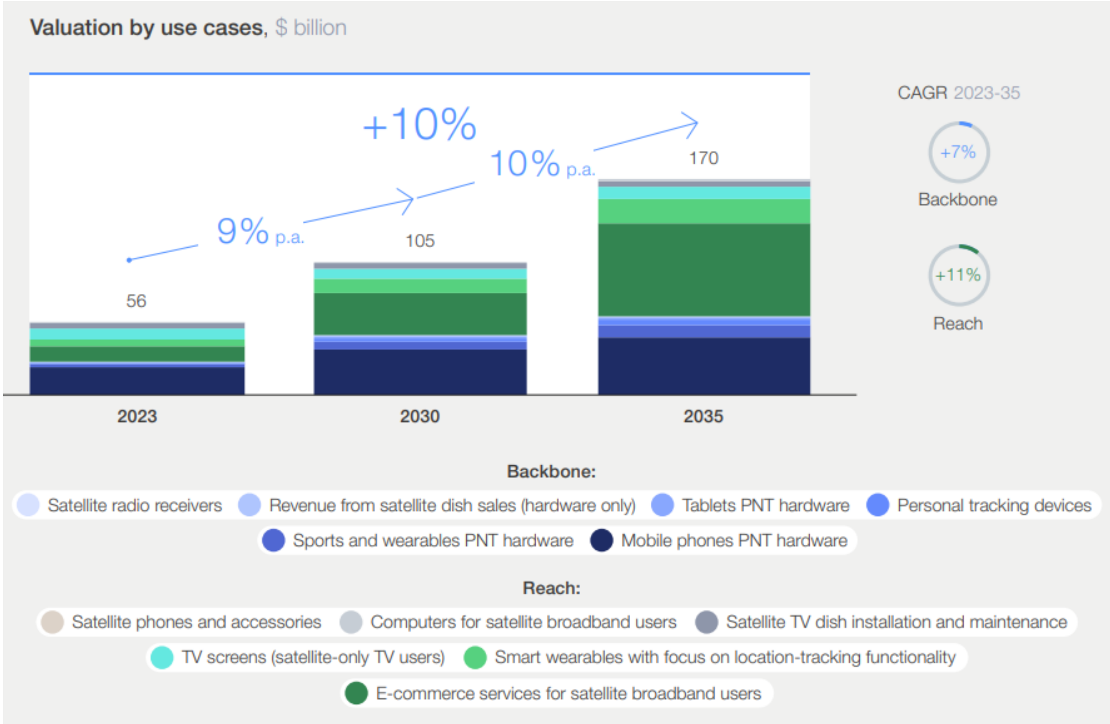

Figure 1.6: Valuation by use cases ($ billion) of Retail, consumer goods and lifestyle

Source: Future of space economy paper, by World economic forum, April 2024

The sector will reach 170 billion dollars by 2035, with a growth of 10% annually. The graph clarifies the major impact of E-commerce, but also the big increase in smart and sport wearables. Some smart wearables are including the functionality for emergency and natural disaster alerts, that will increase the necessity to have one for the customers.

years as the market matures.

In the next few years satellite operators need to anticipate and adapt to a pricing competition with expanding coverage. Downstream players explore partnership with public sector entities, to adopt, harmonize and drive innovation. An example of what is gonna happen is the partnership between Globstar's constellation and Apple. During the launch of the iPhone 14 series, Apple introduced a new "Emergency SOS" feature, enabling users to send emergency messages via satellite when they are outside of cellular or Wi-Fi coverage. Globalstar confirmed it would provide satellite connectivity for Apple's Emergency SOS feature. The agreement between them includes the construction of 10 new global gateways and the launch of a backup satellite in June. Apple will cover 95% of the costs for a new generation of satellites ordered by Globalstar. Additionally, Globalstar will dedicate 85% of its network capacity to support Apple's services. The company will continue offering other services, like IoT connectivity, using the remaining 15% of its network and

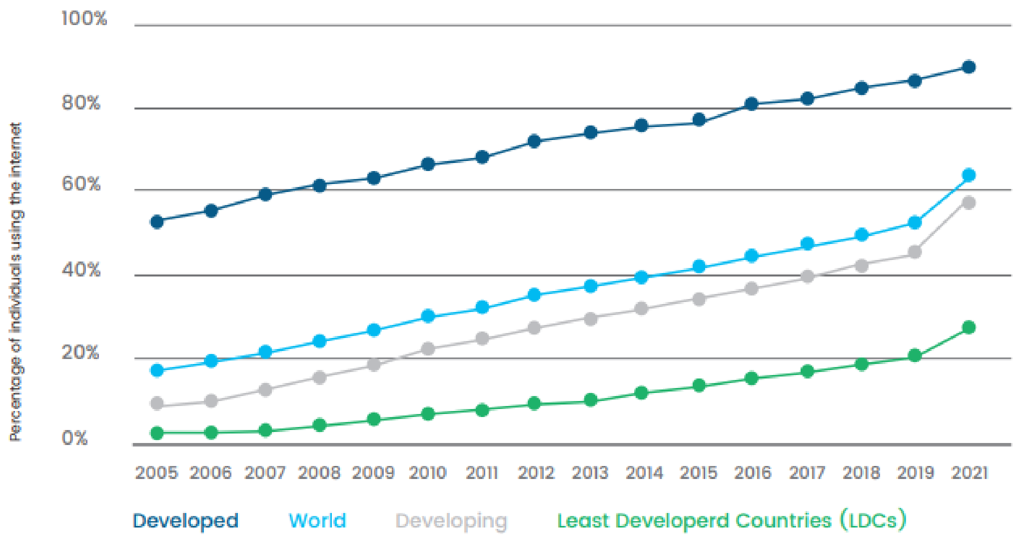

Figure 1.7: Number of Internet connected devices worldwide from 2019 to 2030, satellite-based

Source: Statista

Internet usage continues to grow globally, with developed countries nearing saturation above 85%, while developing and least developed countries show a slower but steady increase, highlighting the digital divide.

exploring potential terrestrial uses for its spectrum.

The coming years will see an integration of space and terrestrial networks that lead to a ubiquitous connectivity and high speed internet connection for business to business and business to consumer users, and due to the necessity of secure and private communication networks, a decentralization of communication adoption, that allow a greater control over personal data, increase efficiency and cost savings.

1.4.6 State-sponsored: Defence

We saw previously that some features used for customer commodities (GPS, EO) were born for military interest: it's clear that analyzing the defense sector is difficult, because a lot of features have a double use, and the data reported could be undervalued.

Statista reported that the aerospace sector (including the defense segment) employs around 890,000 people only in Europe and offers a high return on investment: 11 euro for every euro invested. This benefit will justify the 99 billion (military and civil) of global space investment in the sector (+9%) in 2022. Defense sector will grow at a CAGR of 9% per year, and is expected to reach a market size of 250 billion dollars in 2035.

This growth underscores an increasing importance in global security, and is driven

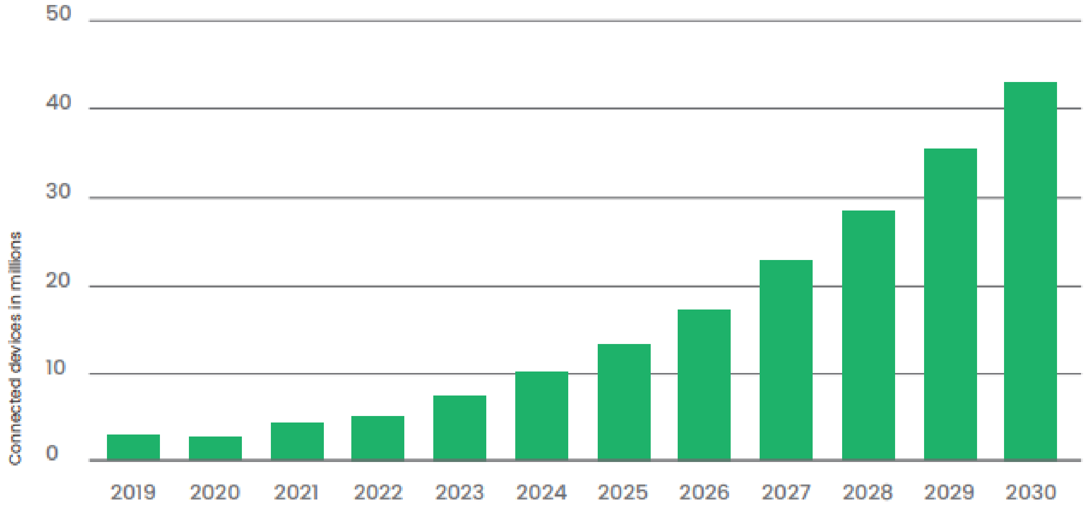

Figure 1.8: Percentage of global population accessing the internet from 2005 to 2021, by market maturity

Source: Statista

The number of satellite-connected internet devices is expected to increase more than tenfold by 2030, reflecting accelerating adoption of satellite solutions for connectivity in underserved areas.

by the increasing importance of space sensing. Demand will drive partnerships with leading sensor manufacturers and AI analytic firms, increasing data acquisition and interpretation capabilities. JISR (joint intelligence, surveillance, reconnaissance) is vital for military operations, and space based technologies plays a critical role in JISR, "Russia's invasion of Ukraine has underlined the need for the Alliance to have a clear picture of all developments on the ground, in the air and at sea. The space domain offers NATO an intelligence edge and allows Allies to gather insights while reducing vulnerabilities"[8]. Not only, space based technologies are crucial also for other types of military operations: C3C (developing command, control and communications) and IoBT (internet of battlefield things). Expanding space economy and satellites will bolster real time global ISR, will help communications and the global connection needed by IoBT. The improvement of real time monitoring and tracking of troops or construction activities will be a topic point for the future, that could guarantee the border control of states and predict and monitor geopolitical evolutions. Quantum communication satellites are the next step of this innovative process: ultra secure and temper proof, are going to create a new era for strategic communications. The expected growth in advanced communications and navigation modules embedded in military equipment is 68 billion dollars in 2035 from the actual 27.

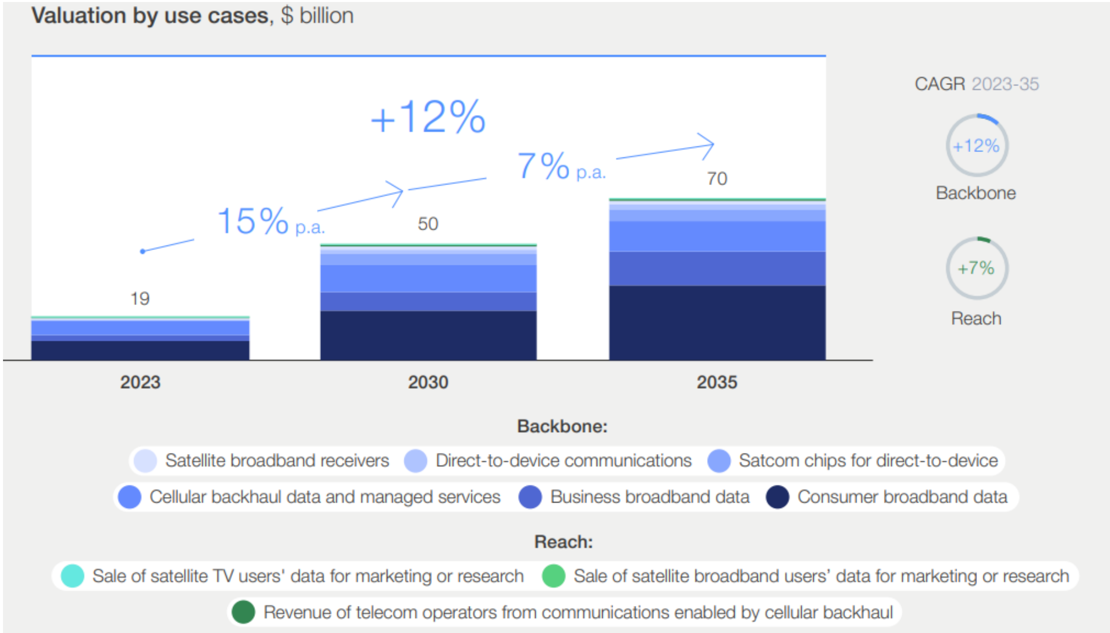

Figure 1.9: Valuation by use cases ($ billion) of digital communications

Source: Future of space economy paper, by World economic forum, April 2024

Projected growth in commercial satellite services shows strong momentum, with a CAGR of 12% in core infrastructure ("Backbone") use cases like broadband and cellular backhaul, and 7% in revenue-generating applications ("Reach"), such as telecom services and user data monetization.

Space based activity for defense is going to be important also for monitoring but also for neutralizing long range missiles threats (ASAT weapons for example). New generation of super heavy launchers (Falcon Heavy, New Glenn) could also be used for long range missiles. Finally, this trend of increasing defense systems is confirmed by the launch of dedicated space defense units in some countries: US space force, French commandement de l'espace, China's strategic support force.

According to a Morgan Stanley analysis shared by Statista, the indirect economic impacts (revenue generated in various sectors through the adoption of space technologies or services) are expected to reach $100 billion by 2030 and rise significantly to $411 billion by 2040. By that time, these secondary impacts are anticipated to comprise approximately 40% of the total value of the global Space Economy, underscoring space technology's expanding influence across multiple industries. Beyond revenue generation, space will play an increasingly crucial role in mitigating world challenges, from disaster warning and climate monitoring, to improved humanitarian response and military defense.

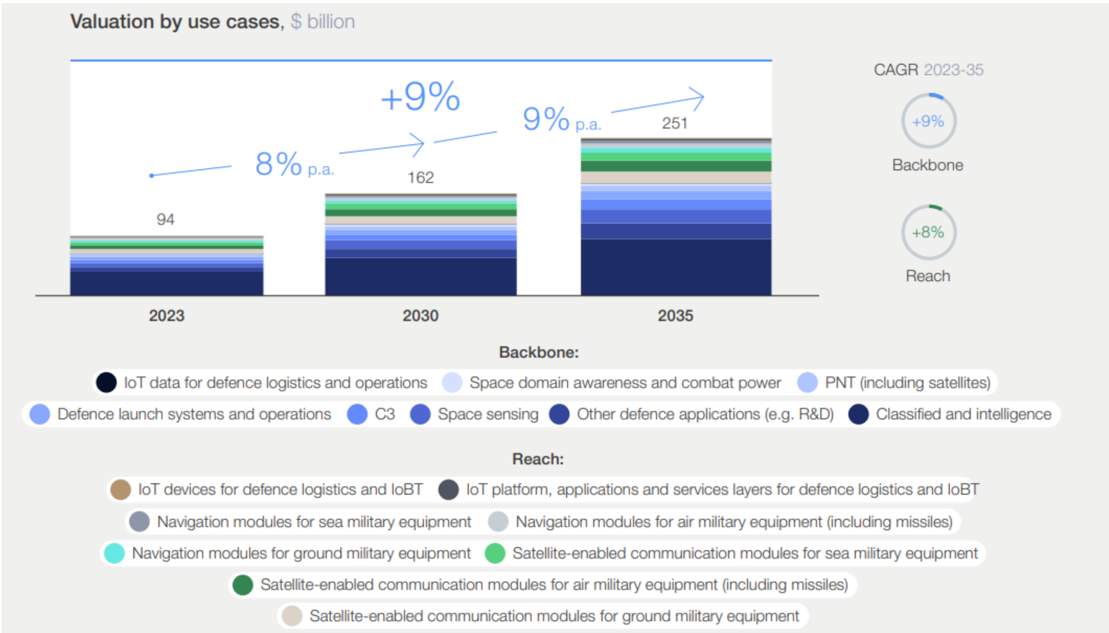

Figure 1.10: Valuation by use cases ($billion) of State-sponsored: Defence

Source: Future of space economy paper, by World economic forum, April 2024

All segments of the Space Economy experienced growth between 2016 and 2020 and are projected to continue this upward trend through 2030, with a CAGR of 9% in critical infrastructure such as ISR, secure communications, and PNT. New domains like Space Domain Awareness (SDA) and satellite-enabled logistics are gaining importance in military strategies.

Chapter 2

Emergent countries in space

2.1 Importance of space for nations: why space programs?

From the beginning of the world, the acquisition of certain capabilities has signified power. There are many recent examples: in the early twentieth century, the acquisition of battleships symbolized power; after WWI, the complete mechanization of air and ground warfare became a key indicator of global standing; in the 1950s, the possession of nuclear weapons established a nation's status as a world power. Today, controlling space is increasingly seen as synonymous with global influence and military dominance.

Widely accepted explanations for why states pursue space capabilities tend to focus on tangible, materialistic, or functional reasons, typically categorized into three main areas: national security and military considerations, economic growth and prosperity, and societal development and benefits. Additionally, the desire for international prestige often motivates nations to invest in space programs. However, while these factors help explain the interest in leveraging space applications, they do not fully capture the deeper strategic and symbolic motivations behind large-scale space initiatives. Despite the significant resource investment, the advanced technological capabilities, and the robust scientific infrastructure needed, a growing number of states remain active in space, striving to develop their own independent capacities. This commitment to space programs often goes beyond purely practical considerations, revealing a combination of strategic ambitions and the symbolic value associated with technological leadership.

- **Space Economy and National Prestige:** The space economy represents a global sector in continuous evolution, where space capabilities enable states to develop commercial expertise, diversify their economies, and enhance international competitiveness. Advanced space technologies are often seen as a means to rapidly transition from traditional societies to industrial and post-industrial nations.

In many countries, developing a space program is seen as an essential component of sovereignty and national autonomy. In India, the space program has long been regarded as a vital aspect of statehood. As early as the 1960s, Indian officials emphasized that space technology should contribute to India's development and elevate its status as a significant global player. Similarly, in 1993, Andriy Zhalko-Tytarenko, Deputy General Director of Ukraine's space agency, highlighted the strategic importance of space exploration saying "we are one of the strongest space powers, if we lose the possibility to work in the aerospace sphere, we will automatically turn into an ordinary third-world country"[9]. Likewise, Israeli Minister of Science and Technology, Matan Vilnai, in 2001 articulated Israel's motivations to join the ranks of spacefaring nations, underscoring the importance of technological advancement and national prestige "Any nation that isn't part of the world's space community is essentially an handicapped nation"[10].

- **Techno-Nationalism:** While cost-benefit and security considerations are important, they are not always the primary motivations for states to develop space programs. Geostrategic needs and material factors may lay the groundwork, but they alone are rarely sufficient to justify such large-scale initiatives. States' actions are also influenced by narratives of national pride, geopolitical aspirations, and cultural identity.

  The perception of prestige associated with possessing advanced technologies drives governments to promote domestic research and development, avoiding dependence on other countries. This phenomenon, known as techno-nationalism, is often triggered by perceived threats and is expressed through policies that foster internal innovation, including government funding, tax incentives, and investments in scientific research.

  Governments adopting techno-nationalism emphasize the importance of in-house development rather than outsourcing or relying on foreign nations. For these states, achieving technological capability is not merely a functional goal but a symbolic assertion of national power and independence.

- **Geopolitical Power and Technological Leadership:** Large and expensive projects, such as space programs, are often viewed as symbols of power and prestige within the broader context of a state's struggle for influence and survival. Today, having an advanced space program remains a hallmark of global influence, with major powers and aspiring regional leaders actively pursuing such initiatives to assert their status.

For example, Egypt, identifying as a regional power in the Middle East, announced plans in the mid-1960s to launch a satellite into orbit as a demonstration of its growing political and military strength. Similarly, Brazil developed its space program in the 1970s under military rule as part of a series of ambitious projects (including the Trans-Amazon Highway, the world's longest bridge, and nuclear energy facilities) to bolster its international presence. Major General Hugo de Olivera Piva stated, "If we want to be an important country, we would have to use space extensively, for remote sensing, communications, meteorology, and data collection."[11].

- **Cooperation and Control:** Space activity can't be treated only as a technical matter or a military matter. Value the public elements of space activity and approached space explorations, is an important component of geopolitics. The cold war and the first years of the space age, are a clear example of this geopolitics importance. The strategy of international cooperation was employed by superpowers to draw allies and other states into closer alignment, thereby expanding and consolidating their spheres of influence and asserting global leadership. Collaborative projects served as tools to monitor and regulate the activities and developments of other states, ensuring they adhered to established standards and regulations, which reinforced the superpower's dominance. Additionally, the dual-use nature of the technologies involved (applicable for both peaceful and military purposes) combined with economic interests, led to stringent controls and restrictions on international cooperation. These measures aimed to limit the number of states gaining access to advanced technologies.

- **Space Programs and Political Consensus:** National achievements of space technology and exploration are often used to increase the popularity of the government or national leaders. The leaders of non democratic states are more likely to use their investments in large scale national programs like space programs to receive credit for it. For example the Soviet space program was crucial for Khrushchev's domestic political context. Also in China, after the successful launch of the first satellite in 1970, Chinese media thanked and praised the great Mao Tse-tung for this impressive goal. Also, such events are timed to coincide with political events like elections: French's president De Gaulle timed the first French launch some days before national elections, Israel's Shavit 2 was launched a month before the elections for the parliament. A project of this kind means and symbolizes power and glory in the overall context of the state's struggle for power and survivability.

- **Technological Self-Sufficiency as a Defense Strategy:** One of the key aspects of the space economy is achieving technological self-sufficiency, perceived as a message of peaceful strength and a strategic element of deterrence. A state that lacks independent technological capabilities risks relying on the goodwill of other nations, thus limiting its autonomy. Developing space technology, however, is a risky and highly expensive endeavor that places a significant strain on national economies, even for superpowers. Despite these challenges, successfully undertaking such projects conveys a powerful message of national strength and determination to citizens, allies, and adversaries alike.

The ability to independently launch satellites is particularly significant, as it demonstrates technological strength without posing direct threats to other states. This approach helps avoid tensions and sends a message of power without provoking hostile reactions, unlike other, more explicitly aggressive military tools.

Countries pursue space programs primarily for two reasons: either to meet the expectations associated with maintaining their power and international standing or to elevate their status and influence on the global stage. These efforts are often driven by geopolitical ambitions and domestic aspirations, even when the tangible cost-benefit analysis may not clearly justify such investments.

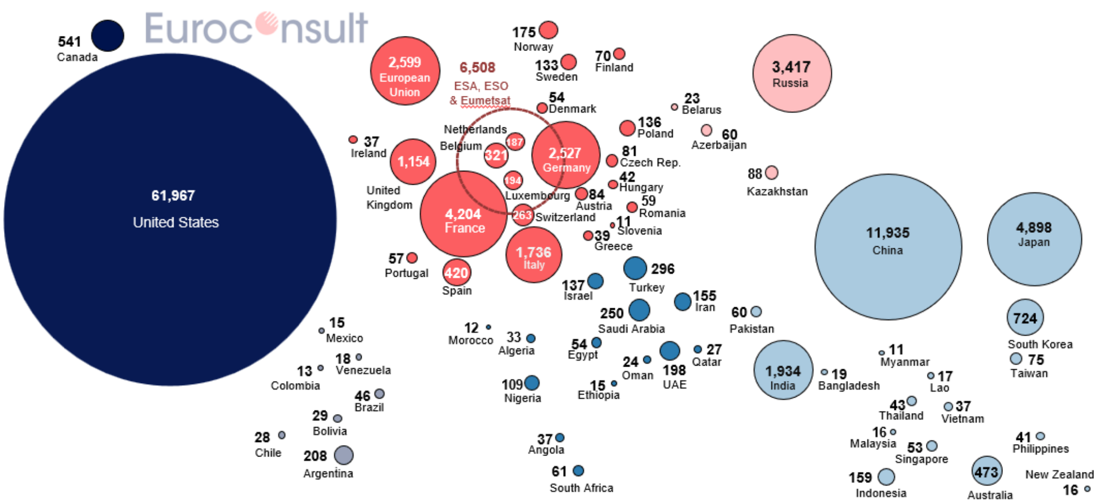

Figure 2.1: World government expenditures for space programs in 2024 for a total investment of $135 billion.

Source: Euroconsult

In 2024, government space budgets surged to $135 billion, marking a 10% increase compared to 2023 and setting a record high for government space investments.

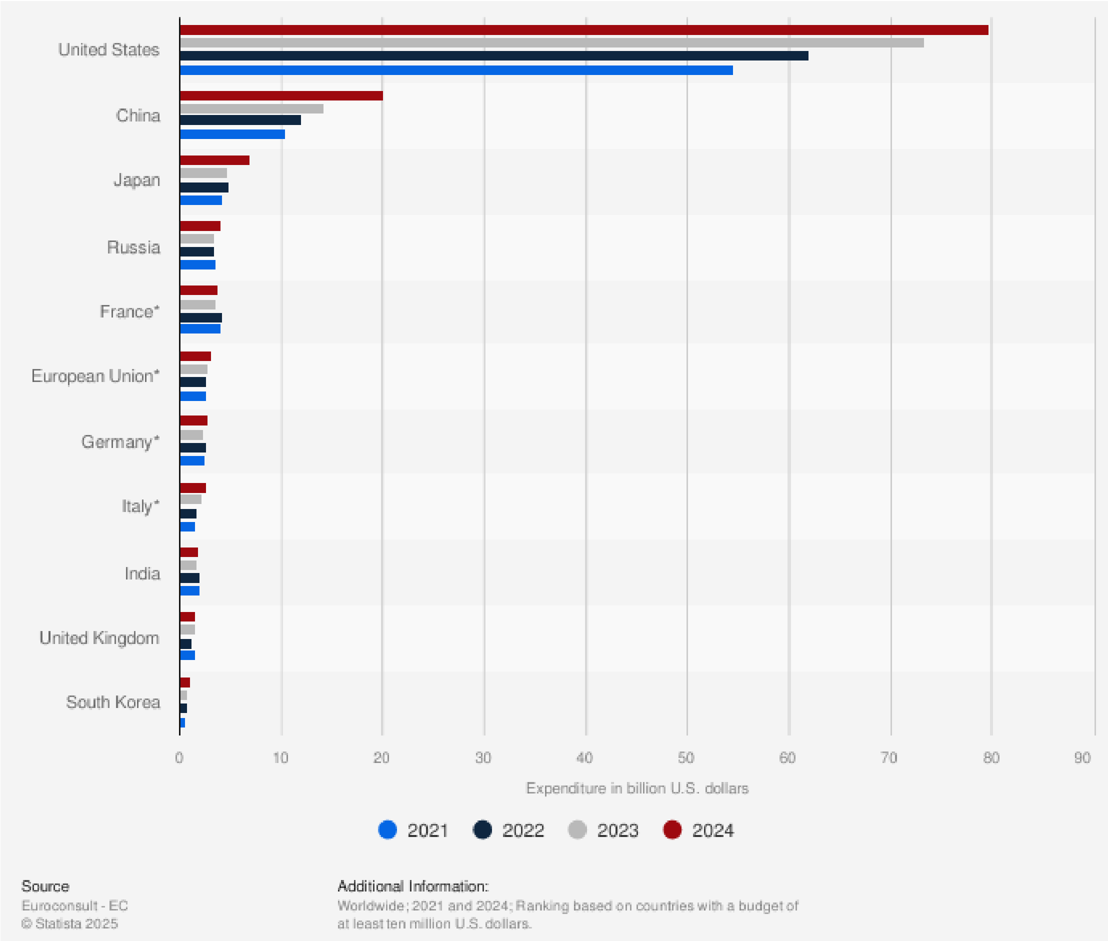

Figure 2.2: Government expenditure on space programs in 2022 and 2024 by major country ($ billion)

Global government space budgets are steadily increasing year by year. The chart shows a consistent upward trend in expenditures from 2021 to 2024, with the United States leading significantly, followed by China and Japan. Notably, all major spacefaring nations have increased their annual budgets, underlining the growing strategic and economic importance of space activities worldwide.

2.2 The Space Club

A "nation-state club" refers to a political framework that distinguishes a select group of countries from the rest of the world due to their exclusive and unique capabilities. These nations possess skills and technologies that others do not, and they cooperate with one another, even if only to a limited extent. The separation between the "haves" and "have-nots" is based on the widespread recognition of these unique capabilities as force multipliers or currencies of power and status. By creating a clear divide between powerful and less powerful nations, such clubs serve as structural expressions of the global distribution of power, status hierarchies, and roles in global governance.

The politics of space, marked by a dynamic tension between competition, limited cooperation, and strict controls over the transfer and flow of technology, gave rise to what is often referred to as the “space club.” Spacefaring nations formed an exclusive community, bound by shared knowledge and capabilities that captivated millions worldwide, fueling both aspirations and expectations for technological and exploratory achievements.

2.2.1 Story of the ‘Space club’

The concept of "space club" emerged during the early days of the space race as a way to describe the competition among nations for space achievements. The first recorded use of the term dates back to the early 1960s, when the United States sent its first astronaut, Alan B. Shepard, into space. This milestone was celebrated as America’s entry into the "space club": “The United States now can claim membership in the space club, with the 11-minute flight of Alan B. Shepard paving the way for many more ventures beyond the limits of Earth.”[12]

Although the "space club" lacks a formal organizational structure, it holds a significant role in both global and space politics. For example, in December 2013, India successfully launched the Mangalyaan mission, which entered Mars’ orbit in late September 2014. Following this achievement, The New York Times published a cartoon depicting a traditionally dressed Indian man with a cow knocking at the door of the "elite space club," while the white male members inside, surprised and seemingly displeased, read about India’s Mars mission. This cartoon underscores the global acknowledgment of the "space club" as a tangible and significant entity in world politics, highlighting its role in symbolizing power, prestige, and technological prowess. From the start of the space race, officials from major spacefaring nations like the United States and the Soviet Union used the idea of a "space club" to describe international activity in space exploration and technology. Both superpowers carefully monitored the spread of space technology by imposing strict restrictions on its transfer, ensuring that space activities remained an exclusive domain limited to a few dedicated states. In doing so, they transformed space exploration into a highly exclusive field. This exclusivity was not only a means of safeguarding technological dominance but also a way to cultivate soft power. Other nations’ efforts to emulate the superpowers by developing their own space programs reflect how deeply the idea of space as a symbol of power was embedded in global politics. Membership in the "space club" became a public and visible projection of power, status, and technological achievement. By claiming membership, states sought to persuade others to recognize the social and political significance of their accomplishments. This, in turn, provided a framework to assess national power, prestige, and status. Membership in the "space club" thus became a benchmark for signaling a nation's strength and global standing. Nations with established global influence, as well as those seeking to elevate their international standing, often attempt to replicate the strategies of traditional space powers by launching ambitious initiatives aimed at developing autonomous technological capabilities. For these countries, attaining membership in the so-called "space club" acts as a symbolic affirmation of power and a means to legitimize their geopolitical aspirations. In contrast, states with more limited resources or ambitions tend to adopt more restrained approaches, either by opting out of full-scale capacity building or by depending on partnerships with established actors. For smaller or less influential nations, the pursuit of club membership can serve as a strategic tool to elevate their perceived status, allowing them to position themselves in a higher tier of technological and political relevance than their actual capabilities might suggest. Ultimately, the club operates on two levels: as a mechanism for social integration among nations with shared ambitions, and as a structured environment in which states strategically engage in negotiations over influence, prestige, and access—often through deliberate processes of inclusion and exclusion.

2.2.2 Why join the club?

"The exploration of space will go ahead, whether we join in it or not, and it is one of the great adventures of all time, and no nation which expects to be leader of other nations can expect to stay behind in the race for space"[13]. In these simple words Kennedy summed up the political logic that became the premise of the space club: space technological development and exploration is what powerful countries do. To gain membership in the space club, a nation must be both recognized and accepted by the existing members. To join the space club, a nation must first demonstrate its capabilities, such as by successfully launching a satellite. Next, it formally declares its intent to be part of the space community through an official announcement. Finally, existing members acknowledge the new entrant by engaging in collaborative activities or providing recognition, solidifying its acceptance. Importantly, existing members wield the power to exclude a country from the club by withholding cooperation and denying partnership opportunities.

Joining state clubs within the nation is a valid, rational, and important consideration that sheds light on decision-making processes and national inclinations. Nation-states play a crucial yet often overlooked role in global politics. By seeking membership in these exclusive groups, national leaders aim to persuade others to embrace their interpretations of power, status, and prestige based on their capabilities. Membership serves as a conceptual framework for assessing a country's accomplishments. Being part of this club is a valuable asset for countries to declare their superpower status, enabling them to influence global governance and political dynamics. Furthermore, they leverage the appeal of club membership to attract less powerful nations, allies, and others, thereby securing recognition for their aspirations of global leadership. Members of the superpowers club often propose collaborative ventures to appease these weaker countries and draw them into their sphere of influence. As such, club members work with potential or new member nations to advance their own interests, uphold their leadership roles, and exert control over less powerful countries. However, this collaboration may result in a swift spread of capabilities, potentially diminishing the exclusivity and desirability of these skills in terms of power and prestige. To safeguard their superiority, superpowers impose barriers to prevent other nations from acquiring the necessary capabilities for elevated international standing, utilizing measures such as restrictions, limited cooperation, export controls, and suppliers' groups.

Membership in the space club serves as a critical marker of power in the international system, with significant implications for both prestige and military strategy. Membership in the space club allows states to project a message of deterrence under the guise of peaceful development, deflecting scrutiny from the potential military applications of their space technologies. For adversaries, this framing offers a way to accept the reality of a state's growing capabilities without openly addressing the implications, thereby reducing tensions and avoiding direct confrontations over military expansion. The military importance of the space club lies in its ability to normalize and legitimize advancements in dual-use technologies, such as delivery systems that can serve both peaceful purposes (like launching satellites) and military objectives (such as ballistic missiles). By associating these developments with the peaceful objectives of the space club, states gain proximity to powerful club members and legitimacy for actions that might otherwise be perceived as threatening or aggressive. This strategic framing makes it difficult for others to object to the new technological reality, even when such advancements are closely tied to military ambitions. In some cases, claims of peaceful membership in the space club have been used as a cover for developing military technologies, underscoring the club's critical role in enabling states to enhance their defense capabilities while maintaining an image of peaceful intent.

2.2.3 A look to the future

The number of countries active in space and the number of worldwide individual users grew quickly, leading to fast commercialization of applications, services and infrastructures: space technology became a commodity. These trends challenge the current structure of the space club and will shape its future. The increase in the number of states that are active in space blurs the threshold for entry into the space club. Importantly, the growing involvement of private players in space, especially in launchings, previously the exclusive domain of states, undermines the hegemony of states, eroding the status of the space club and raising questions about his future.

2.3 Emerging spacefaring nations

As access to space becomes more attainable, a global race has emerged to dominate the burgeoning space economy and leverage it to address critical societal and planetary challenges. The growing recognition of space as a powerful tool for transformative change is a key driver of this rapid expansion. To maximize the impact of these efforts and capitalize on global opportunities, governments are establishing national executive forums and cross-sector task forces. These initiatives ensure that space remains a strategic priority at the highest levels of government, fostering coordinated and results-driven policies. The United States exemplifies this approach with its National Space Council, housed within the Executive Office of the President and chaired by Vice President Kamala Harris. Similarly, the European Union and spacefaring nations such as France, China, Russia, and India have elevated space to the executive level, collectively investing billions of dollars annually in advancing their domestic space capabilities and strengthening their positions in the global space economy.

Emerging spacefaring nations are actively increasing their efforts in the space sector, building autonomous capacities to access and operate in space, and benefiting from a wide range of space activities. This category includes a growing number of states, reflecting a significant acceleration of new players in the space domain over the past decade. Many nations are raising their ambitions and mobilizing more resources for space, making this trend more prominent and widespread than ever before. A key difference from earlier eras is the diversity of countries now pursuing space capabilities. This trend spans developing nations, such as Vietnam and Malaysia in the Asia-Pacific region, and Argentina and Peru in Latin America, to states aspiring to global or regional power status, like Saudi Arabia, Iran, Egypt, and Turkey in Africa and the Middle East. Space is no longer the exclusive domain of developed nations such as the United States, European countries, China, and Russia. Instead, it has become a field of interest and competition for a broader spectrum of states worldwide.

Recent years have also seen a sharp rise in the establishment of national space agencies. This institutional growth reflects the broader expansion of global space activities. The once-exclusive club of nations with space infrastructure now includes a diverse group of developed and developing countries, each with varying levels of capability and ambition. This shift underscores the increasing accessibility and strategic importance of space. A clear indication of this trend is the growing number of countries with satellites in orbit. These satellites vary in complexity, from advanced telecommunications systems purchased internationally to small

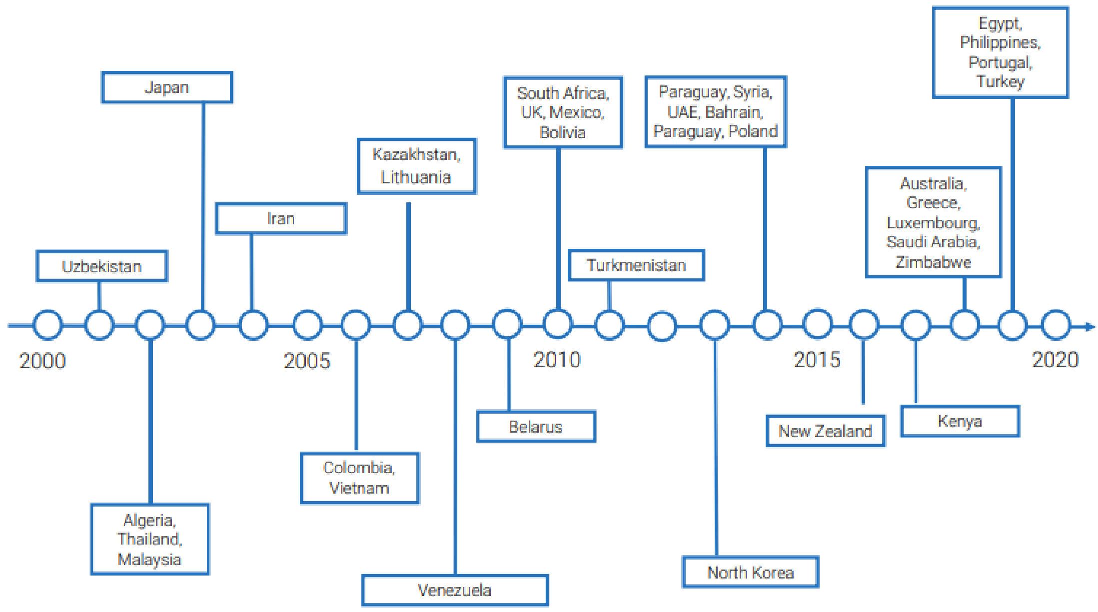

Figure 2.3: Creation of space agencies since 2000

Source: Espi database. Espi report on Emerging Spacefaring Nations

CubeSats developed by universities. As the OECD's report on the space economy notes, "the possibility to have one's satellite in orbit, registered with one's own national administration, has never been so affordable."

This increase in satellites is often linked to national narratives, as states use technical achievements to enhance national pride, support their scientific and industrial communities, and compete for prestigious milestones. Such achievements hold significant political value, shaping national history and collective memory. China takes pride in being the third nation to send humans into space and achieve a soft landing on the Moon, while Canada celebrates being the third to develop its own satellite. France is recognized as the third nation to develop and launch a satellite, while Japan claims the fourth spot in demonstrating independent satellite launch capabilities. Australia highlights its status as the fourth country to host a satellite launch from its territory. Brazil is proud to be the first South American nation to launch a satellite, and Israel marks its milestone as the seventh nation to launch a sounding rocket and the eighth to develop and launch a satellite. Iran emphasized its achievement as the first Islamic nation to launch a satellite in 2009, outpacing South Korea, which later aimed to join the world's leading spacefaring nations. In 2014, the European Space Agency (ESA) took pride in being the first to land on a comet.

While many of these milestones are framed as contributions to humanity, science, or space exploration, early satellites launched as "national firsts" often had limited scientific value. Some served mainly symbolic purposes, transmitting basic signals. Despite their simplicity, these achievements carried significant political and strategic implications. Demonstrating the ability to launch a satellite signaled technological competence and secured claims of membership in the exclusive group of spacefaring nations. Today's space arena is populated by a diverse array of actors pursuing

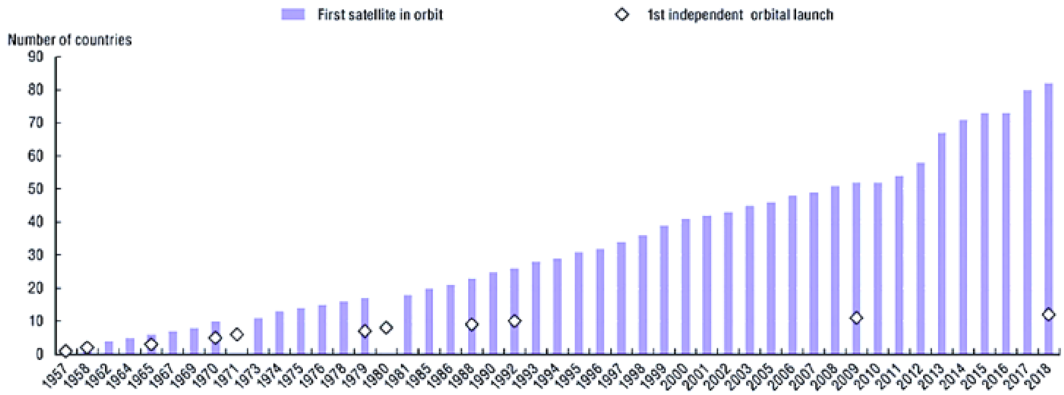

Figure 2.4: Number of countries with a spacecraft in orbit from 1957 to 2018

Source: OECD, 2019

The number of countries operating spacecraft has expanded steadily since 1957, surpassing 80 nations by 2018. Milestones include both first satellites in orbit and first independent orbital launches, reflecting the democratization of access to space.

activities at various scales and for different purposes. Alongside countries with a long history and substantial investment in space capabilities, there are those focusing on specific services, such as socioeconomic applications. Others are acquiring capabilities through private initiatives. Meanwhile, an increasing number of nations are tailoring their development strategies, building capacities such as spacecraft manufacturing and launch systems to meet domestic objectives and resource constraints.

2.4 Real cases: Uae, Australia, South Korea, Argentina

2.4.1 UAE

The UAE's journey into space began in 1997 with the establishment of the Thuraya communication company, followed by the launch of its first communication satellite in 2000. A pivotal milestone for the UAE space sector was the creation of the Emirates Institute for Advanced Science and Technology (EIAST) in 2006. EIAST focused on the design, manufacture, and operation of Earth observation satellites and marked the start of UAE's development of national space capabilities through technology transfer programs with South Korea. In 2014, the UAE Space Agency was established to oversee and promote the country's burgeoning space sector. Its mission includes organizing, supervising, and advancing UAE space activities. The agency's creation complemented the efforts of EIAST and laid the groundwork for the UAE's National Space Policy (NSP), introduced in 2016. The NSP's goal is to build a robust and sustainable space sector that supports national interests, drives economic diversification, fosters innovation, and strengthens the UAE's regional and global influence. This strategy led to the launch of KhalifaSat in 2018, the first satellite entirely designed and manufactured in the UAE, and the UAE becoming the sixth nation to launch a Mars mission with the Emirates Mars Mission in 2020. The UAE is also developing an astronaut program, with one astronaut having already traveled to the ISS.

Initially, the UAE's space ambitions were centered on communication satellites to serve the Arab region. However, in the early 2000s, space became a strategic element of the UAE's economic diversification efforts. The country adopted a phased approach to building its space industry, beginning with international partnerships for knowledge transfer, followed by in-house capabilities development, and finally, focusing on fostering investments and creating a supportive environment for the sector.

From a defense perspective, the establishment of the Space Reconnaissance Center (SRC) in 2000 marked the UAE's interest in using satellite imagery for early warning, monitoring, and planning security missions. Satellite data, sourced from international partners and aerial platforms, plays a crucial role in maritime domain awareness, border security, and crisis management. Under Mohammed bin Zayed's leadership, space systems became integral to national security, reflecting his emphasis on border protection and military modernization. Regional cooperation is another key pillar of the UAE's space strategy. The UAE aims to position itself as a regional leader in space, exemplified by the creation of the Arab Group for Space Collaboration in 2019. This initiative unites 11 Arab states to share knowledge and develop joint projects, including a satellite to monitor climate change.

In a region characterized by geopolitical tensions and competition, space has become a new arena of rivalry among Middle Eastern nations. Most spacefaring nations in the region now have at least one military satellite, emphasizing the strategic importance of space. Through its proactive policies and successful missions, the UAE has established itself as a leader in the regional space sector.

2.4.2 Australia

Australia's involvement in space began in the 1960s. In collaborations with European nations the first stage of a rocket was tested in South Australia in 1964. A few years later, in 1967, the WRESAT satellite was launched and Australia became the seventh country to place a satellite in orbit. However, space was not considered a priority at the time, and the country did not pursue a dedicated space program. The situation changed in 2018 with the creation of the Australian Space Agency (ASA), which aims to triple the size of Australia's space industry by 2030, creating 20,000 jobs and generating AUD 10–12 billion annually. Moreover, the Civil Space Strategy 2019–2028 outlines plans to diversify the economy, build national space capabilities, and ensure the security of space infrastructure while fostering international partnerships. Implementation is divided into three phases: setting the foundation for growth (2019), focusing on SATCOM and Earth observation (2019–2021), and emphasizing RD, robotics, automation, and space situational awareness (2021–2028).

Instead of other space related technologies, space-related defense and security initiatives have long been a priority for Australia. Ground stations supporting U.S. missile programs were established in the 1970s, and the Defence Science and Technology Group (DSTG) was created in 1974 to support national security and armed forces. Today, DSTG focuses on integrating strategic intelligence and enhancing situational awareness. Geopolitical tensions in the Asia-Pacific region, especially the military and space advancements of China, have further spurred Australia to develop sovereign space capabilities. Space is increasingly seen as a warfighting domain, with a focus on intelligence, surveillance, and reconnaissance (ISR) systems. The government plans to invest AUD 7 billion in space defense over the next decade, as highlighted in the 2020 Force Structure Plan and the Strategic Update. Moreover, international cooperation remains a cornerstone of Australia's space strategy. Partnerships with the U.S., Five Eyes allies, and regional neighbors enable access to satellite services and foster joint projects. The establishment of the Space Division Headquarters in 2022 reflects Australia's emphasis on integrating space into multi-domain military operations.

2.4.3 Argentina

Argentina's space development began in the 1950s and 1960s, initially focused on military interests, including liquid rocket engine research and the development of sounding rockets. The country's primary motivation during this early period was defense and security, particularly the advancement of its ballistic missile program. In 1961, Argentina established the National Commission for Space Research (CNIE), the first space-related institution in the country. A major milestone in Argentina's space history was the Condor missile program, initiated in the 1970s. This program was significant during a time of heightened tensions with neighboring Chile over border disputes and the Falklands War. However, the Condor missile system had limited capabilities (its range was only about 100 km), which was insufficient to reach the Falkland Islands during the conflict. After the war, Argentina continued to develop its ballistic missile technology with the Condor II program. However, under pressure from the United States, Argentina dismantled its missile and nuclear programs in the 1990s, largely due to concerns over the export of missiles and space technologies to countries like Egypt and Iran.

In 1991, the country established the National Commission on Space Activities (CONAE), tasked with formulating and implementing the National Space Plan. Argentina's space program then pivoted toward the development of launch vehicles and satellites for peaceful purposes. One of Argentina's key achievements in this period was the development of the Tronador series of suborbital rockets: Tronador I was successfully launched in 2007, marking a significant step in Argentina's pursuit of autonomous space launch capabilities. Argentina's space strategy is outlined in the National Space Plan (PEN), and focuses on three key objectives: Earth observation, peaceful space exploration and utilization, and technological development for space applications. A significant milestone in Argentina's space development was the approval of the Argentine Geostationary Satellite Plan (PSGA) in 2015. The plan aims to strengthen Argentina's capacity to develop and deploy geostationary communications satellites, with the goal of launching eight satellites by 2035. In recent years, Argentina has significantly increased its space budget. For example, in 2021, the budget for CONAE was doubled compared to the previous year. Additionally, Argentina has invested heavily in broadband infrastructure as part of its Connectivity Plan, which aims to bridge the digital divide by expanding access to ICT services, particularly in rural areas.

Argentina is a leader in space technology in Latin America, along with Brazil. The two countries have cooperated extensively on space projects, and both have transitioned from military to civilian space activities since the 1990s. In 1989, Argentina and Brazil signed the Joint Argentine-Brazilian Declaration on Bilateral Cooperation in the Peaceful Uses of Outer Space, establishing a framework for joint space programs. One of the products of this collaboration is the SABIAMAR Earth observation satellite, which is designed to monitor the seas, agriculture, deforestation, and geology. In 2011, Argentina proposed the creation of a South American Space Agency, though this initiative did not materialize. However, in 2020, Argentina signed a strategic agreement with Mexico aimed at establishing the Latin American and Caribbean Space Agency (ALCE). This new regional agency is designed to pool the financial, technological, and human resources of countries across Latin America and the Caribbean, with Bolivia, Ecuador, El Salvador, and Paraguay expected to join, and Colombia and Peru as observers.

Although Argentina's space program originated with military motives, it has since evolved into one of the leading advocates for the peaceful use of outer space. In 2018, Argentina's Permanent Mission to International Organizations in Vienna emphasized that access to space for all nations is crucial for the peaceful use of outer space, viewing space as a common heritage of humanity and a vital tool for socio-economic development and improved living standards. Today, Argentina stands as a prominent player in the global space community, balancing its historical defense-related interests with a strong commitment to using space for peaceful and development-driven purposes.

2.4.4 South Korea

South Korea's space activities began in the 1970s, with the goal of boosting industrial development. Space was seen as a means to improve the country's competitiveness, develop new technologies, and catch up with more industrialized nations. In 1974, the Korean Astronomy and Space Science Institute (KASI) was established, marking the beginning of South Korea's space endeavors. The first space-related legislation, the Aerospace Industry Development Promotion Act, was enacted in 1987, and the Korea Aerospace Research Institute (KARI) was founded in 1989 to further advance space capabilities. In 1992, South Korea launched its first satellite, KISAT-1, in collaboration with a UK university, and in 1993, it launched its first scientific sounding rocket, KSR-1. The country's first comprehensive space plan, the Basic Plan on Mid-to-Long-Term National Space Development, was introduced in 1996, setting the goal of placing South Korea among the world's top ten space industries by 2010. This ambitious plan aimed for the independent development and launch of a rocket and satellite from South Korean soil. Over the years, South Korea achieved key milestones, including sending its first astronaut to the International Space Station (ISS) and building a spaceport. In 2013, the country launched the Naro-1 rocket, marking another significant achievement. Since 2018, South Korea's space activities have increasingly focused on the socio-economic benefits generated by space technology, alongside industrial development and national defense. A key shift in space priorities has been the acknowledgment of space as a strategic domain, with significant emphasis on improving military capabilities. In 2020, South Korea launched its first military communications satellite, highlighting the growing importance of space for defense.

South Korea's space policies in the medium-term emphasizes two primary goals: generating socio-economic benefits and enhancing national security. South Korea's long-term space vision, known as Future Vision 2050, focuses on four key areas: space transportation, space exploration for science and research, aerospace capabilities to address environmental challenges, and the use of space for socio-economic development. According to the OECD, South Korea has capabilities in nearly all segments of the space industry, including satellite manufacturing, launch vehicle development, satellite operations, and downstream applications. By 2016, the South Korean space industry employed over 6,000 people and generated USD 2.4 billion in revenue, increasing to USD 2.9 billion by 2018. The government has formulated a Space Industry Strategy to foster the growth of the private sector, create new industries, and enhance competitiveness. In 2020, the government allocated approximately USD 537 million to space activities, increasing to USD 553 million in 2021.

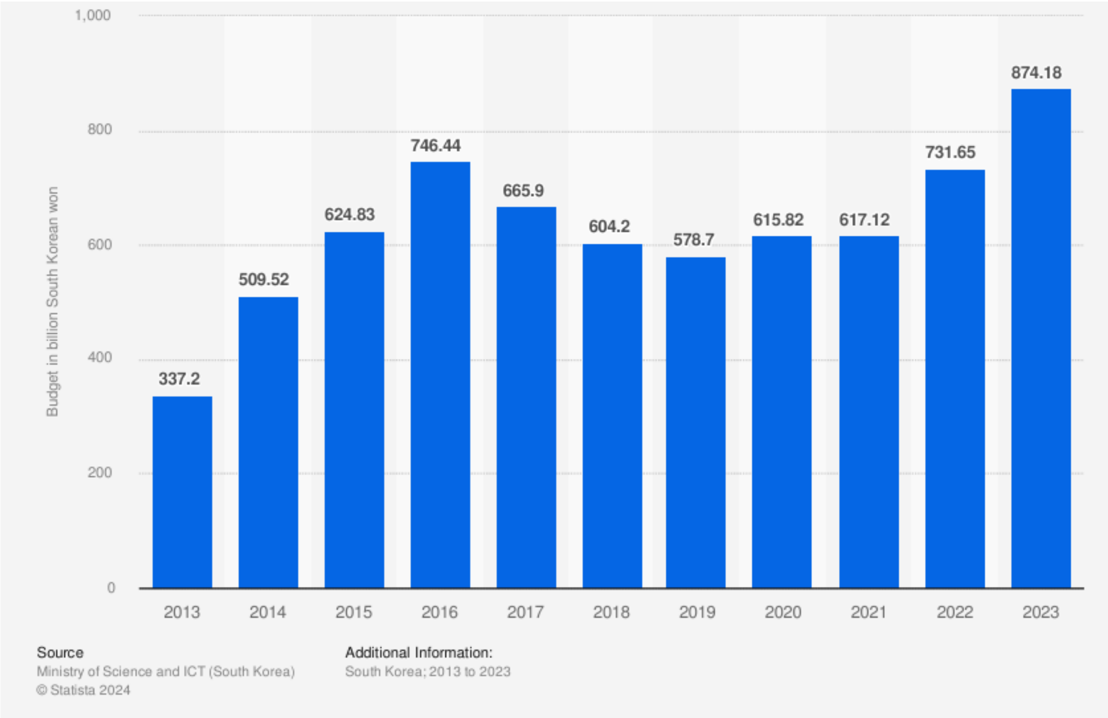

Figure 2.5: Space development budget of South Korean from 2013 to 2023 (in billion South Korea won)

In 2023, the development budget for the space industry in South Korea was approximately 874.2 billion. This was a large increase from the previous year, with the budget showing continuous growth since 2019.

The defense sector is also a central component of South Korea's space strategy. In 2018, the country released its Defense White Paper, which introduced Defense Reform 2.0, aimed at creating a military capable of proactively responding to diverse security threats. As part of this, space-related technologies have become more integral to defense planning. Two key priorities are the development of space defense capabilities (the creation of a space force and an operational space defense system) and increasing cooperation with the United States, particularly through the ROK-US alliance. In 2014, South Korea and the U.S. signed agreements on Space Situational Awareness (SSA) and information sharing, leading to the establishment of a Space Intelligence Center in 2015. This collaboration was further strengthened with military exercises to assess space risks on the Korean Peninsula.

Although South Korea did not initially view outer space as a warfare domain on par with land, sea, air, and cyber, the White Paper outlines plans to reorganize the Air Force to include capabilities for strategic deterrence and aerospace operations. The development of South Korea's space capabilities must be understood in the context of regional geopolitical tensions. The rising tensions between China and the U.S., territorial disputes in Northeast Asia, and North Korea's continuing development of nuclear and missile technologies have all contributed to the strategic importance of space. North Korea's space ambitions are closely linked to its missile program, heightening concerns in the region. In 2021, at the United Nations Committee on the Peaceful Uses of Outer Space (UNCOPUOS), South Korea acknowledged that space is "becoming increasingly congested, contested, and competed by numerous actors," and warned of a potential arms race and the weaponization of space.

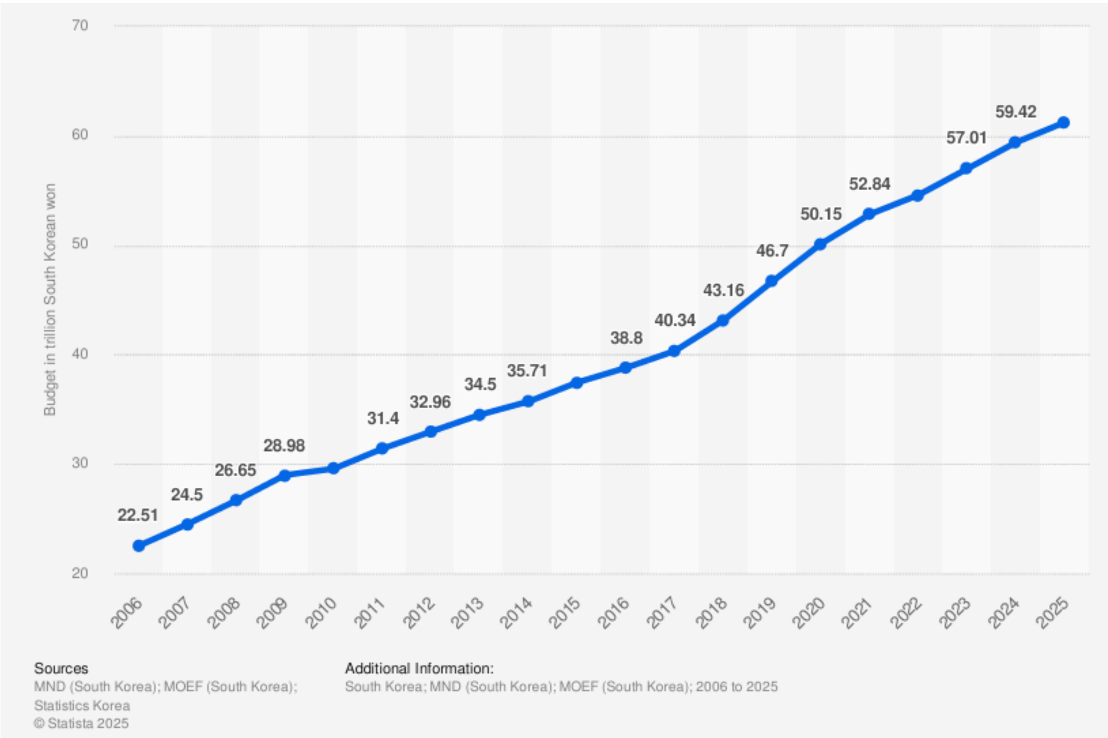

Figure 2.6: South Korea's national defense budget from 2006 to 2025 (in trillion South Korean won)

In 2025, South Korea allocated approximately 61.25 trillion South Korean to its national defense budget. This was an increase compared to the previous year. South Korea's defense budget has steadily increased throughout the surveyed period.

2.4.5 Takeaways of these examples

There are some similarities and we take some conclusions from the analysis of these spacefaring nations. The militarization of space emerges as a direct consequence of geopolitical tensions: someone like Argentina started its space development for these reasons, while someone else like Korea has to implement its defence and security as a consequence of it. The common view of space is a contested and congested landscape, with nations increasingly viewing space as a crucial domain for maintaining security and asserting power. Today, space systems provide critical early-warning capabilities and strategic advantages, reflecting a shift in how states approach security. Instead of some years ago, when nuclear programs act as a deterrence for war, now this role is covered by space technologies that act as a deterrence to conflict.

The socio-economic benefits derived from space programs are a shared priority for all these nations, reflecting a broader understanding of how space can serve as a tool for national development. Emergent countries like UAE started his space development precisely to increase communications to improve the quality of life of its citizens, but also Argentina, which has a lot of rural areas, emphasizes bridging the digital divide through satellite technologies, which improves access to ICT services, particularly in underserved rural areas. South Korea's comprehensive Future Vision 2050 similarly integrates socio-economic goals, focusing on satellite-based solutions to address environmental challenges, enhance communications, and drive industrial development. These initiatives illustrate how space programs are not only about technological prestige but also about delivering tangible improvements in quality of life and national economic resilience, space is viewed as a common heritage of humanity.

Collaboration remains a cornerstone of space efforts for all these nations, emphasizing the importance of pooling resources, sharing expertise, and fostering partnerships, but also for political reasons. South Korea's partnerships with the United States and regional allies demonstrate how collaboration can strengthen both technological capabilities and strategic security. Argentina has worked closely with Brazil on initiatives like the SABIAMAR Earth observation satellite, highlighting how regional alliances can advance shared scientific and environmental objectives. These examples reflect a collective recognition that space exploration and development are global endeavors, requiring cooperation to address shared challenges and capitalize on the opportunities space offers.

Chapter 3

Space as a new strategic domain

3.1 Crucial role of space for world's power

NATO officially designated outer space as a new operational domain in November 2019. However, as early as 1961, the astronomical community had already recognized that outer space contained strategic locations comparable in importance to terrestrial chokepoints such as the Panama Canal. Over the past three decades, the perception and utilization of the space domain by military forces worldwide have undergone gradual yet profound transformations. From the launch of Sputnik in 1957 through the 1980s, the United States and the Soviet Union primarily employed military space systems to support strategic missions, including missile warning, strategic intelligence, and nuclear command and control. By contrast, the use of space systems to support conventional military operations was of lesser priority.

However, beginning in the 1990s, conflicts such as the First Gulf War and the wars in Bosnia and Kosovo underscored the critical role of space systems as force multipliers in conventional military operations. By the late 1990s, space-based capabilities had become indispensable to military forces across the entire spectrum of conflict. A 1997 United States Space Command publication stated that, "So important are space systems to military operations that it is unrealistic to imagine that they will never become targets. Just as land dominance, sea control, and air superiority have become critical elements of current military strategy, space superiority is emerging as an essential element of battlefield success and future warfare."[14]

Recognizing the growing significance of space to U.S. military operations, other nations began developing similar capabilities and counterspace weapons aimed at neutralizing the U.S. advantage. In 2004, the Air Force produced its first doctrine publication on counterspace operations to provide "operational guidance in the use of air and space power to ensure space superiority"[15]. Importantly, this document defined space superiority as the ability to ensure "the freedom to operate in the space medium while denying the same to an adversary"[16]. Since then, senior military and civilian leaders in the United States have increasingly referred to space as a "warfighting domain." This rhetorical shift has sparked concerns that space could become weaponized, potentially triggering an arms race. While debates continue over whether space should or inevitably will be militarized, much of the discourse remains ambiguous.

In this context, space technologies and applications play a crucial role in national security and defense, both in times of peace and during armed conflict. Remote sensing satellites, for instance, fulfill military and intelligence-gathering functions without violating another nation's sovereignty or endangering human lives. Space-based information is extensively used for target tracking, precision guidance, positioning, and communication between combat forces and weapon systems.

Indeed, space technology has become one of the central pillars of modern warfare, underpinning the Revolution in Military Affairs (RMA), which emphasizes information and knowledge superiority. Space-based assets provide vital Command, Control, Communications, and Intelligence (C3I) capabilities, as well as other forms of mission support. Given space's pivotal role in contemporary warfare, denying an adversary access to space-based resources is considered a decisive factor in securing victory. Control over space-based information enhances situational awareness and warfighting effectiveness, allowing military forces to conduct long-range operations and cross-domain attacks while leaving adversaries disoriented, disorganized, and vulnerable to defeat. To conclude, space power, which is defined as the ability to exert rapid and sustained influence from or in space during peace, crises, or war, becomes fundamental in state policies. As national power reflects a country's ability to influence others through diplomacy, economy, information, and military tools, space power is considered a subset of this broader concept.

3.2 Space as a Domain of Warfare

The militarization of space is driven by three primary factors: the pursuit of solutions to military challenges, advancements in technology, and international competition. These dynamics have transformed outer space into a critical operational domain. Although official documents from major powers such as the United States, China, Russia, and India continue to advocate for the peaceful use of space, the operational reality demonstrates its increasing integration into joint military operations.

Militarization refers to the use of space to support military operations on Earth, such as employing satellites for communication and precision-guided weaponry. In contrast, weaponization involves the deployment of weapons capable of operating in various configurations: Earth-to-space, space-to-Earth, or within space itself. If space assets are utilized primarily for data collection and intelligence gathering to support land, air, and sea military operations, this constitutes the militarization of space. Conversely, actions such as damaging or destroying another state's space assets, using space-based weapons against ground targets, or targeting missiles in orbit fall under the category of weaponization. Space is already heavily militarized, with satellites maneuvered to support navigation and enhance national security. Since the latter half of the 20th century, space has been militarized and, according to some perspectives, even partially weaponized due to the dual-use nature of many space systems. Presently, space assets are employed for a wide range of purposes, including navigation, reconnaissance, surveillance, imagery collection, communication, early missile warning, meteorology, ocean surveillance, disaster management, commercial applications, and anti-satellite (ASAT) operations. Emerging trends among major space powers (namely the United States, Russia, and China) indicate a growing inclination toward the development of warfighting capabilities in space. In terms of military technology, these nations have intensified efforts to develop advanced capabilities, including electronic warfare, directed energy weapons, and cyberattack systems. Additionally, they have deployed space-based weapons and counter-space capabilities, such as ASAT technology, that could potentially be used in future conflicts.

A key turning point occurred in 2007 when China conducted an anti-satellite weapon (ASAT) test, destroying one of its own weather satellites and generating a significant amount of space debris in Earth's orbit. This event highlighted the potential dangers of space warfare, as even the destruction of a relatively insignificant satellite could severely disrupt a state's activities in outer space. Many analysts consider this test a defining moment, marking the beginning of a new era in the understanding of space as a warfighting domain. India also demonstrated its ASAT capabilities in March 2019 through Mission Shakti, an anti-satellite weapons test. Russia, meanwhile, conducted three ASAT tests in 2020 and is regarded as one of the most advanced countries in the field. As U.S. Army General James Dickinson, commander of the U.S. Space Command, stated in 2020: "Russia publicly claims it is working to prevent the transformation of outer space into a battlefield, yet at the same time, Moscow continues to weaponize space by developing and fielding on-orbit and ground-based capabilities that seek to exploit U.S. reliance on space-based systems."[17]

He further emphasized that: "Russia has made space a warfighting domain by testing space-based and ground-based weapons intended to target and destroy satellites."[18] The increasing instability of space as an operational environment is driven by rapid advancements in weapon technology, coupled with states' strategic ambitions for power and dominance. The development of offensive military capabilities has outpaced defensive measures, particularly ballistic missile defense systems, further exacerbating the militarization of space and raising concerns about its long-term stability.

3.3 The era of dual-use technologies

Until the end of the Cold War, space exploration and technology development were almost exclusively the domain of government agencies. In recent years, however, the inherently dual-use nature of space technologies (serving both civilian and military purposes) has become increasingly evident. This characteristic has significantly influenced global space policies, particularly since the 1990s, fostering growing collaboration between the public and private sectors. A pivotal moment in this evolution was the Gulf War of 1991, which demonstrated the strategic value of dual-use space technologies. During the conflict, commercial satellites were employed for military communication, navigation, and operational planning. Satellite-based communication networks facilitated the rapid deployment of over 400,000 soldiers within weeks, enabling an uninterrupted exchange of vast amounts of data. Additionally, navigation systems provided U.S. forces with precise targeting information for combat operations involving missiles, tanks, aircraft, and naval assets. These satellites also supplied reconnaissance imagery of Iraqi troop movements, significantly enhancing Allied operational effectiveness. As a result, the Gulf War became the first major battlefield demonstration of a Revolution in Military Affairs (RMA).

The integration of commercial space technologies into military operations contributed to a swift and decisive victory with minimal allied casualties, underscoring the strategic importance of space assets. This success highlighted the potential benefits of public-private cooperation in space. Consequently, Public-Private Partnerships (PPPs) emerged as a key framework for leveraging private sector capabilities to meet governmental needs. These partnerships offer mutual advantages: governments gain access to advanced technologies while reducing costs, and private companies benefit from funding opportunities, market expansion, and cutting-edge expertise. This evolving dynamic has transformed space into a critical domain for both economic development and global security, positioning the private sector as an indispensable partner in the modern space ecosystem, and space technologies, often initially developed for military applications, have found widespread use in civilian domains.

A notable example of this transformation is the Global Positioning System (GPS). Originally developed for military applications, GPS signals for civilian use were initially degraded through a system known as Selective Availability. However, by 2000, the U.S. government recognized that enhancing the accuracy of civilian GPS would yield significantly greater economic and commercial benefits than maintaining a degraded signal for military advantage. As a result, Selective Availability was discontinued, leading to the widespread civilian adoption of GPS technology. Initially designed to guide military vehicles, GPS has since become an integral component of global transportation and logistics systems.

3.3.1 The development of own capabilities

The role of satellites in this transformation has been fundamental. Their functions have expanded beyond their initial purposes to encompass a wide range of military applications, including communications, command and control, optical and radar reconnaissance, cartography, signals intelligence, meteorology, navigation, and global positioning. Over time, technological advancements and cost reductions have accelerated this trend, enabling more countries to integrate space-based capabilities into their military strategies. Satellites have evolved from supportive tools into indispensable assets for advanced militaries, allowing them to fully deploy and enhance their operational capabilities. As technology has progressed, the distinction between military and civilian applications has become increasingly blurred, as the same infrastructure now serves both sectors.

In the past decade, certain satellite-based features, such as high-resolution imagery and GPS, have become critical assets, prompting many nations to develop their own independent capabilities. For instance, in 2009, China relied primarily on satellite imagery acquired from Europe and the United States. However, in recent years, China has made significant efforts to establish an autonomous capability in this domain, aiming to reduce its dependence on foreign providers. Similarly, Japan has pursued greater self-reliance in space-based technologies, strengthening its indigenous capabilities primarily to support national security objectives.

A particularly relevant example of this trend is the development of national Global Navigation Satellite Systems (GNSS). While GNSS provides free global services, these systems are considered critical national infrastructures and are therefore developed and operated at the national level. Despite their extensive civilian and commercial applications, they continue to receive substantial defense funding for technological advancements and maintenance. For instance, the GPS system remains sponsored, maintained, and controlled by the United States Air Force and GLONASS is operated by the Russian Aerospace Defense Forces. This strategic significance has driven other spacefaring nations to establish their own national satellite navigation systems, seeking autonomy in this crucial domain. Russia has been actively reinforcing and improving GLONASS, expanding its network of ground stations beyond its national borders and establishing facilities

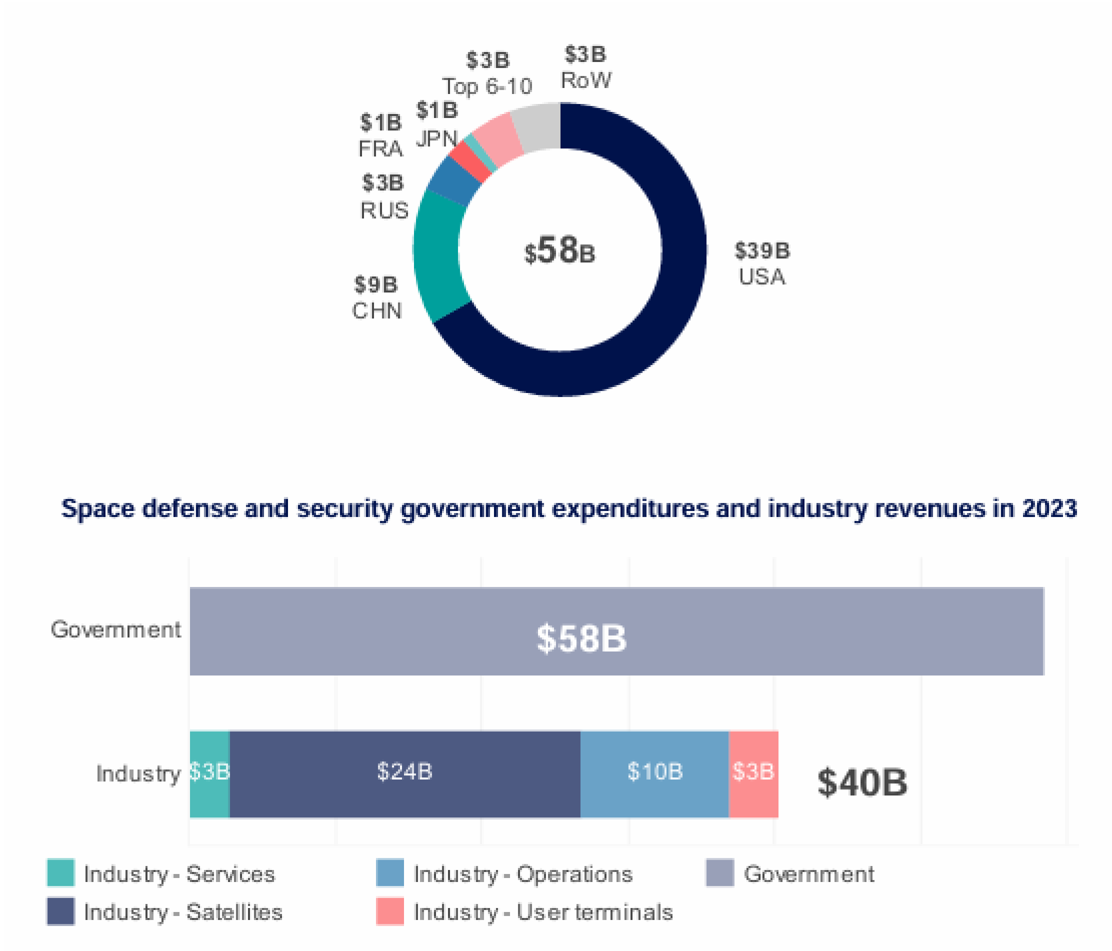

Figure 3.1: Space defense and security expenditures in 2023 by country

Source: Space Defense and Security, Euroconsult report, 2024

In 2023, global government spending on space defense and security (SDS) reached an estimated $58.3 billion, representing 2.6% of total global military expenditures and around half of all government space budgets. This investment is primarily driven by concerns over national sovereignty, the growing geopolitical fragmentation, and renewed great power competition. Spending is highly concentrated: the United States alone accounted for two-thirds of the total, with $39 billion, followed by China ($8.8B), Russia ($2.6B), France ($1.3B), and Japan ($716M). Collectively, the sixth to tenth highest-spending countries contributed $2.7B, while over 40 additional nations accounted for the remaining $3.2B, averaging $74M each. The European Union also plays a role through its investment in dual-use systems like Galileo and IRIS2. Approximately 70% of SDS spending is directed to the private sector, mainly for the procurement and launch of satellites, user terminals, and commercial data and services. The remaining $18 billion is retained by governments for internal activities, such as RD, system operation, program management, and strategic analysis. 70% of government expenditures, representing a total of $40.2 billion in 2023, are contracted to industry to provide the space defense and security capabilities required by governments and their militaries. Of this $40.2 billion, $24 billion (60%) are for the manufacture and launch of defense and dual-use satellites; $3.3 billion (8%) for the provision of user terminals; $10.2 billion (25%) for industry operating government systems as well as the sale of raw data and bandwidth; and $2.7 billion (7%) for the provision of managed services.

in more than 35 countries. China, likewise, has developed its own BeiDou satellite navigation system, which became operational in 2013. The system continues to expand, with the ultimate goal of achieving global coverage. The desire to establish an alternative to the U.S.-controlled GPS has also encouraged strategic cooperation between China and Russia. In July 2014, the two countries signed a partnership agreement to collaborate on the development of navigation satellites and monitoring stations within each other's territories, aiming to integrate and enhance their respective satellite navigation systems.

In addition to Russia and China, other nations have also prioritized independent GNSS development. The European Space Agency (ESA) has been advancing the Galileo satellite navigation system, while India has developed and deployed the seven-satellite Indian Regional Navigation Satellite System (IRNSS). Similarly, Japan has been working on a regional space navigation system to support its strategic and economic interests.

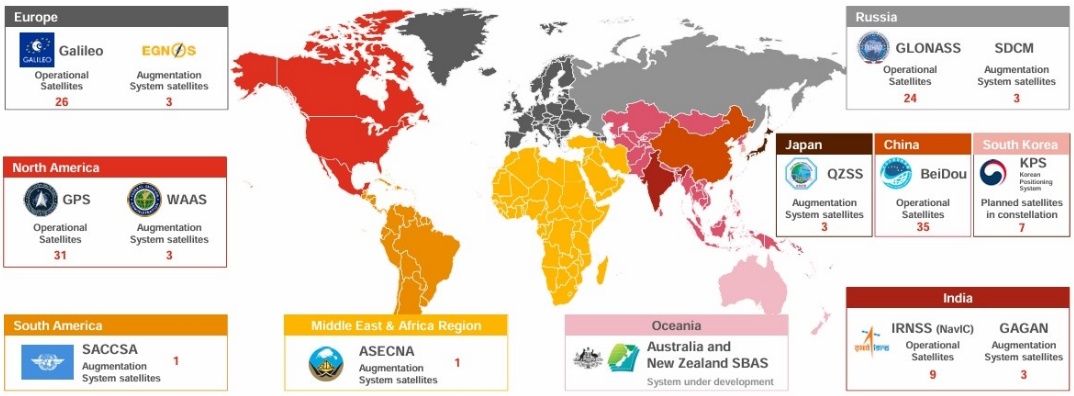

Figure 3.2: Main GNSS and augmentation systems across the globe

Source: Main Trends and Challenges in the Space Sector, by PWC, 2020

This map illustrates the global distribution of major GNSS constellations and regional augmentation systems, highlighting their strategic importance in positioning, navigation, and timing (PNT) applications. With over 120 operational satellites worldwide, GNSS powers essential services.

3.3.2 Dual-use technologies

The active militarization of space primarily entails the use of navigation, communication, and surveillance systems for military purposes. While not all satellites are designed for military applications, their integration into modern defense strategies has become so fundamental that contemporary military operations would be nearly inconceivable without these technologies.

According to Johnson-Freese, approximately 98% of space technologies possess both military and civilian applications. The inherently dual-use nature of these technologies complicates efforts to curb the proliferation of space weapons and raises significant concerns regarding their deployment. Any technology with dual-use potential presents regulatory challenges, as it becomes increasingly difficult to restrict its use exclusively to civilian purposes. A parallel can be drawn with nuclear fission, which serves as a major source of energy while simultaneously posing an existential threat through its application in nuclear warfare. Similarly, existing space assets can be leveraged for both civilian and military functions.

Some dual-use capabilities are easily identifiable, such as military rockets, where the technological foundations of launch vehicles and ballistic missiles overlap with those utilized in space exploration. However, in other cases, the distinction between civilian and military applications is less apparent, further complicating regulatory and security frameworks.

- **GNSS:** As previously mentioned, Global Navigation Satellite Systems (GNSS) were initially developed for military use during the Cold War and remain strategic dual-use assets. Navigation satellites provide essential services for both civilian aviation and precision-guided munitions, acting as force multipliers in ground military operations.

  In any terrestrial conflict, satellites can support ground forces, including infantry units, land vehicles, naval and riverine forces, as well as manned and unmanned aircraft. Positioning satellites facilitate location tracking, navigation, and the identification of optimal routes, allowing obstacles to be bypassed while enabling the guidance of autonomous systems such as Remotely Piloted Aircraft Systems (RPAS) and precision-guided weaponry deployed from aircraft or ground-based installations. Similarly, telecommunications satellites ensure uninterrupted communication for ground troops, regardless of the operational environment or terrain conditions.

- **Earth Observation (EO):** The commercial market for Earth Observation (EO) data and services plays a critical dual role, supporting both civilian applications (discussed in the first chapter) and military operations.

  Military satellites can be used to survey enemy ground installations, and can be equipped with advanced optical systems capable of capturing high-resolution imagery with centimeter-level precision. For example, companies such as the U.S.-based Maxar captures high-resolution images of conflict zones using space-based visual, infrared, radar, and electromagnetic sensors. These surveillance satellites play a vital role in detecting enemy movements, identifying strategic activities, and alerting ground forces to potential threats, thereby enhancing situational awareness and operational effectiveness. These capabilities are often enhanced by machine learning algorithms, which improve both the speed and accuracy of image analysis. However, EO services are also leveraged by global media and non-governmental organizations to monitor human rights violations and war crimes. For example, during the war in Ukraine, EO data provided crucial evidence of attacks on civilian infrastructure and helped verify military positions along the frontlines.

- **Space launch vehicles:** The launch of vehicles for the transportation of satellites and other payloads in orbit are the major potential threat to other systems since they have many in common with ballistic missiles and missile defense interceptors that can be modified into kinetic ASAT (anti satellite weapons). Space launches may serve as a delivery system for space weapons.

- **Small satellites, on orbiting service (OOS) and rendezvous and proximity operations (RPO):** Military use of these technologies has been increasing in recent years, offering new capabilities for both peaceful operations and warfare. These technologies are inherently dual-use; the same features that make them effective for civilian missions also enable their deployment in potentially hostile operations. The anticipated expansion of the commercial on-orbit sector will likely accelerate the proliferation of these technologies beyond traditional military and governmental control, increasing security risks and potentially exacerbating geopolitical tensions. A key concern is that such systems possess the fundamental capabilities required to function as co-orbital anti-satellite weapons (ASATs) while being developed and deployed under the guise of entirely peaceful, non-military missions. Additionally, they introduce new operational capabilities, including maneuverability, close approach, rendezvous and proximity operations (RPO), imaging, docking, and object manipulation.

  Manoeuvrability: Similar to co-orbital ASATs, certain satellites must be capable of frequent orbital adjustments to approach and interact with other spacecraft. The majority of satellites currently in orbit lack the capacity for such significant maneuvers. This issue is particularly relevant in the geostationary (GEO) belt, which hosts a high concentration of commercial and military communication satellites, meteorological satellites, and intelligence assets. Most satellites in this region perform only minor orbital corrections to maintain their designated positions. However, satellites equipped with advanced maneuvering capabilities can traverse the GEO belt with relative ease, potentially accessing and surveilling a broad range of high-value commercial and strategic space assets.

  This concern is not merely theoretical. In 2015, a Russian satellite demonstrated extensive maneuverability within the GEO belt, approaching two commercial satellites operated by Intelsat. Despite formal complaints from the company, the Russian spacecraft remained in their vicinity for three months before shifting its focus to a UK military satellite, as well as U.S. and European meteorological satellites. Similarly, between 2016 and 2018, the Chinese SJ-17 satellite exhibited comparable maneuvering behavior, although it primarily interacted with other Chinese satellites.

The implications of such activities are substantial. These maneuvers pose national security risks, as classified satellites may be subjected to espionage or interference. Furthermore, they may serve as demonstrations of ASAT capabilities, heightening concerns that such techniques could be employed in future conflicts to disable critical space assets. The growing prevalence of close-proximity operations also increases the likelihood of accidental collisions, potentially generating hazardous space debris that threatens both commercial and military infrastructure. *Close approach, Rendezvous and proximity opera-*

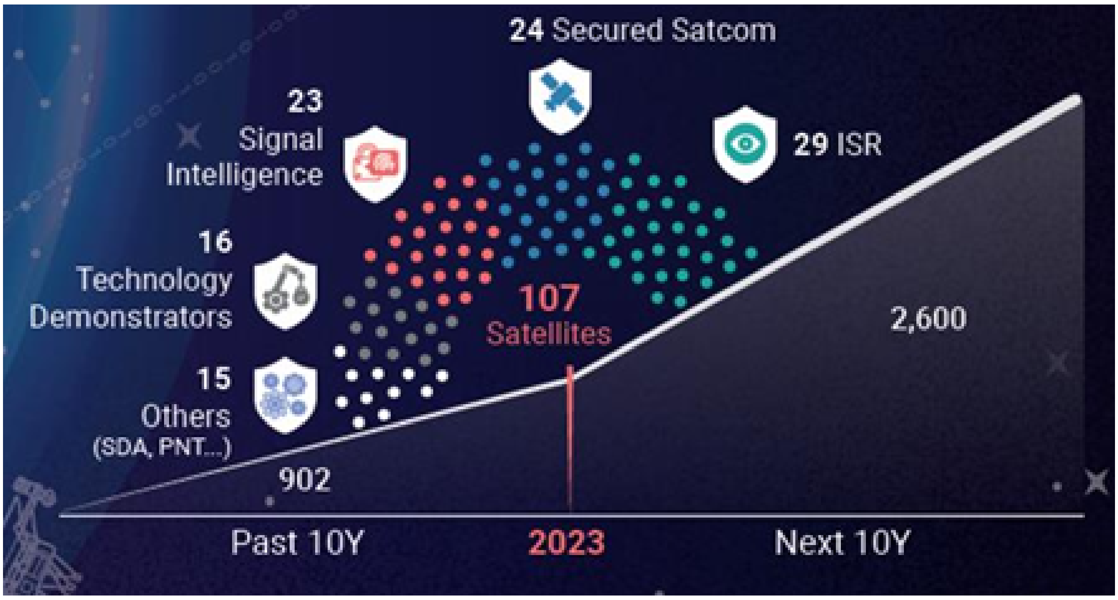

Figure 3.3: More than 100 defense satellites launched in 2023

Source: Space Defense and Security, Euroconsult report, 2024

107 defense satellites were launched by 17 countries in 2023, up 40% from 2022. Top launchers were the US (44), China (30) and Russia (11), with other countries collectively launching 22 satellites.

tion: Instead of normal satellites, on-orbit servicing spacecraft rely upon highly capable onboard sensors to acquire their targets and ultimately enable close approach, docking/grappling, and conducting/monitoring servicing missions. On-orbit servicing satellites are not operating with kilometers of margin, but with centimeters or less. If there is an error in calculation or a system anomaly, the two objects could collide, and, given that these objects are moving at tens of thousands of kilometers per hour, even glancing collisions could be fatal to both spacecraft, and the resulting debris could threaten many others in orbit. OOS spacecraft possess all the qualities of co-orbital ASATs and are even more capable weapons in some regards. Many modern spacecraft that are capable of close approach and docking can perform these functions autonomously. With spacecraft that can track targets and dock autonomously and which also carry a significant amount of fuel and feature highly capable thrusters, the ability to escape an attack is greatly diminished. Defensive options for target spacecraft, thereby, are reduced.

Imaging, docking, manipulating: RPO spacecraft, once near a satellite, typically have some additional mission to carry out. This mission might be an information gathering initiative, in which a spacecraft takes high-resolution imagery of another spacecraft to diagnose the source of an issue.

Certainly, the benefit to repair or refuel satellites, which have tremendous military and commercial value, is the reason why on-orbit servicing spacecraft are being developed. However, RPO satellites can also approach the adversary's satellites, using the same imaging, docking, and manipulation capabilities for more damaging purposes. The design and operations of military and intelligence satellites are typically highly classified. The ability to collect high-resolution imagery and other data about these satellites after they are already in space could compromise efforts to maintain secrecy. In 2014, General William Shelton, then-Commander of Air Force Space Command, stated, "We can see literally what that satellite looks like and you can effectively reverse engineer and understand what the capabilities are."[19]

In 2014, the U.S. airmen observed that a Russian satellite (previously deemed as space debris) was unexpectedly spotted actively conducting advanced proximity manoeuvre to inspect the rocket booster. Lately, in January 2020, two Russian satellites with likely inspection capability, were spotted at a short distance from the American reconnaissance satellite. Also China is known to have been testing such satellites; a dual-use technology that could be used for docking operations at the future station. In 2013, during a China scientific experiment on space-keeping technologies, U.S. officials reported that one of the Chinese satellites was equipped with a robotic arm that tested its ability to grip and capture another satellite. Moreover, American micro satellites are constructed for advanced RPOs and could serve as potential co-orbital weapons.

The scope of small satellites capabilities may be more extensive, and it is difficult to distinguish which RPOs and satellites are tested for peaceful, offensive, or both purposes. It is a matter of fact that all the United States, Russia and China conducted various rendezvous and proximity operations. These types of equipment are launched for the purpose of testing the technologies needed to collect and put space debris out of orbit, but space security experts debate the true purpose of these tests. It is interesting to point out that commercial on-orbit servicing systems use the same types of technologies as their military counterparts. They must be able to conduct robust and precise maneuvers to reach customers in different orbits, perform close-approach and docking maneuvers, and conduct physical repairs. Any satellite able to do these things can also be used as a weapon. Additionally, by enabling modifications after launch, the ability to weaponize existing spacecraft or alter their capabilities in other meaningful ways creates a greater need for continuous and improved space surveillance.

- **Active debris removal:** Active debris removal (ADR) systems are the example of a new emerging space technology that is vital for maintaining access to outer space. ADR systems aim to dislocate a dysfunctional system from orbit disregarding previous consideration about their removal. However, at the same time, it is also an example of a potential space weapon in case of removal of functional systems. The main advantage of ADR systems as space weapons rests upon their dual-use capability and uncertain intentions. Unlike traditional anti-satellite (ASAT) weapons, ADR-based attacks would be difficult to detect in advance, leaving the target with no opportunity to evade. Additionally, ADR systems offer a strategic advantage in space warfare by eliminating enemy satellites without generating excessive debris, thereby avoiding the collateral risks associated with kinetic ASAT strikes. Furthermore, ADR technologies could be employed in hybrid operations involving rendezvous and proximity maneuvers, operating below the threshold of open military conflict while still exerting strategic pressure on adversaries.

3.3.3 Ethics problems with dual-use

Space launch vehicles, small satellites, satellites as weapon platforms, information technology and active debris removal systems have broad dual-use consequences that can eventually lead to the weaponization of space. The concern is that some of these systems possess all of the requisite technology to serve as co-orbital ASATs, but can be developed and employed under the auspices of an entirely peaceful, non-military (and legitimately useful) mission. The challenge of distinguishability could provide ample room for misperception and escalation.

One of the most pressing ethical concerns is the increasing entanglement of military and civilian space infrastructure. As experts point out, "[m]uch of the U.S. military's current communication system also runs through commercial satellite systems."[20]

This reliance on commercial satellites for military operations not only complicates the traditional distinction between civilian and military assets but also raises significant ethical and legal questions in times of conflict. As the Pentagon and other government agencies become more dependent on information from commercial satellites, the boundary between military and civilian targets in space becomes increasingly indistinct. This blurring of lines has grave ethical implications.

Civilian-operated satellite systems, which support essential services such as global communication, navigation, and disaster response, may inadvertently become legitimate military targets during conflicts. Any attack on these systems, whether intentional or accidental, could have devastating consequences for civilian populations, disrupting critical infrastructure, financial systems, and humanitarian operations.

Beyond the immediate operational risks, dual-use space technologies contribute to broader geopolitical instability. The deployment of satellites with maneuvering capabilities, rendezvous and proximity operations (RPOs), and on-orbit servicing functionalities can easily be misinterpreted by rival states as aggressive military actions. This misperception could trigger retaliatory measures, leading to a dangerous cycle of escalation and counter-escalation. The ethical challenges posed by dual-use space technologies necessitate urgent attention from the international community. Clearer guidelines and transparency measures are essential to mitigate the risks associated with the militarization of space.

3.4 The case of Ukrainian war

The conflict in Ukraine serves as a clear example highlighting the critical role of dual-use technologies in modern military strategies. This war has underscored the essential nature of satellite communication (SATCOM), positioning, navigation, and timing (PNT), as well as Earth observation and intelligence, surveillance, and reconnaissance (EO/ISR) services for maintaining situational awareness and command and control (C2) on today's battlefield. Moreover, the conflict has revealed how competition in space is deeply intertwined with the race to gain an informational and decision-making edge. Since the beginning of hostilities, Russian forces have actively attempted to jam, spoof, and hack satellite networks supporting the Ukrainian military.

One notable incident occurred in February 2022, just an hour before the invasion, when a cyberattack targeted the ground infrastructure of ViaSat's KA-SAT network. This assault caused widespread disruption affecting thousands of users across Europe, including the Ukrainian government and armed forces. Despite the initial setback, Ukraine, aided by Western support, quickly adapted. This event foreshadowed the pivotal role that commercial space systems would assume in bolstering Ukraine's early war efforts.

Only five to ten years ago, access to space capabilities was largely restricted to the world's most powerful states—primarily the US, China, and Russia. Even major global players such as the UK, France, Germany, and Japan maintained only limited military satellite assets. Since the invasion in February 2022, however, Ukraine has managed to compensate for its lack of sovereign space assets by procuring commercial data and services from an expanding market, predominantly provided by private US companies.

The growth and sophistication of commercial space services offer Ukraine significant advantages, enabling it to operate within and through the space domain. Commercial satellite providers deliver critical geospatial intelligence, allowing Ukrainian forces to track the deployment and movements of Russian troops. Companies such as ICEYE, Umbra Space, and MDA employ privately owned synthetic aperture radar (SAR) satellites to collect and analyze imagery, granting decision-makers constant surveillance of strategically important areas. Additionally, SpaceX's Starlink terminals connect military units via a reliable network of low Earth orbit satellites, linking sensors and data processors across the battlefield. Private firms have also demonstrated greater agility than governments in deploying new services. Within days of the invasion, SpaceX shipped 5,000 Starlink terminal kits to Ukraine, enabling off-grid internet access and vital communications amid disrupted infrastructure caused by fighting and Russian attacks. By June 2022, the number of active terminals had grown to 15,000, at one point accounting for approximately 58% of global Starlink downloads.

The critical importance of this distributed infrastructure has led Ukrainian civilian volunteers to repair heavily damaged terminals, whether impacted by shelling, weather, or electrical surges. Overall, the Ukrainian government's ability to blur the lines between military and civilian technologies illustrates a new model of rapid acquisition, conflict response, and infrastructure resilience. However, Ukraine's dependence on Starlink also reveals risks tied to relying on a limited number of private providers. On several occasions, Elon Musk, SpaceX's CEO, reportedly restricted the use of Starlink to limit Ukrainian unmanned operations targeting Russia's naval forces in the Black Sea. According to the Wall Street Journal, Russian Foreign Ministry official Konstantin Vorontsov stated that "if U.S. satellites were used to aid Kyiv, they could be a legitimate target for a retaliatory strike"[21]. Vorontsov added: "We are talking about the use by the United States and its allies of civilian infrastructure components in space, including commercial ones, in armed conflicts"[22].

Recent reports also suggest Russia is now using Starlink terminals in its own offensive , seemingly circumventing the geofencing technology designed to limit use in unauthorised locations, even as it also seeks to jam the service over Ukrainian territory. Though the terminals may have been procured through third parties to bypass sanctions, and Starlink has not provided these directly, it remains to be seen whether the company will take proactive steps to prevent further use by Russian forces. An article notes the importance of Starlink in this war: “The United States and NATO improved the situation for the Armed Forces of Ukraine not only by mass deliveries of modern weapons, but also by deploying Starlink satellite internet terminals there in March 2022. Their delivery allowed the Armed Forces of Ukraine to be relatively independent from the effects of electronic warfare and have reliable closed communications in their units up to the battalion level."[23].

The Ukraine conflict has involved commercial satellite services so extensively that observers have dubbed it the “first commercial space war.” Broadly speaking, it is not just the Ukrainian military that increasingly relies upon space capabilities; the U.S. and other modern militaries are also dependent upon them. The U.S. Defense Intelligence Agency (DIA) says: “On the national security front, space-based capabilities afford the United States and our allies the crucial ability to project combat power to areas of conflict and instability. They enable our armed forces to collect vital intelligence on foreign threats, navigate and maneuver rapidly, and communicate with one another to support global military and humanitarian crises”. [24]

Dependence on commercial satellite services in international conflicts is poised to increase almost inevitably. In 2022, the U.S. Government Accountability Office observed that commercial remote sensing satellites and the data they generate have fundamentally changed how the United States addresses critical national security challenges. Given current trends, the commercial space sector is projected to expand substantially in the coming years, potentially fulfilling a greater portion of the imagery requirements of both the Intelligence Community (IC) and the Department of Defense (DOD). As a result, while the conflict in Ukraine may be considered the first “commercial space war,” it is unlikely to remain unique. In future conflicts, the U.S. must anticipate that its commercially owned dual-use satellites will face attacks. Even if adversaries abide by the Law of War (LoW), losses affecting both military operations and civilian users should be expected.

Today’s exploitation of space is increasingly propelled by private-sector space technologies that serve dual purposes—civilian and military alike. Recent wars, including the one in Ukraine, have underscored the shifting character of warfare in the digital era. The adoption of open-source commercial satellite intelligence is becoming widespread, with commercial space enterprises playing a growing and influential role in shaping military strategies.

The involvement of commercial space entities will resemble, in some respects, the role commercial actors have historically played in traditional warfare domains such as the maritime arena. However, important differences will distinguish this new era. Innovations like large constellations of satellites—exemplified by Starlink—and more efficient launch capabilities offered by companies like SpaceX are already transforming the space domain with military implications, akin to how steam engines, gunpowder, and sonar revolutionized naval warfare in the past. Just as commercial vessels became prime targets during maritime conflicts, it is only a matter of time before commercial satellites or civilian ground infrastructure become deliberate targets of modern military forces.

3.5 Space weapons

The increasing importance of satellites has led them to perform a wide range of functions, from enabling communications, navigation, and weather forecasting, essential to daily life and the global economy, to supporting nearly all modern military operations. These assets are critical, and their loss could result in severe economic consequences while significantly delaying or impairing military capabilities. For instance, the United States is considered particularly vulnerable to space-based attacks due to its heavy dependence on satellite infrastructure. A potential adversary could exploit this reliance by targeting space systems, creating an asymmetric disadvantage for the U.S. military.

From this example we can understand the growing importance of space weapons. Space weapons encompass a broad range of technologies capable of disabling or destroying spacecraft. While some of these systems are ground-based, such as high-powered lasers or electronic jammers, perhaps the most well-known are direct-ascent and co-orbital anti-satellite (ASAT) weapons. There are multiple definitions of space weapons. Karl Hebert defines them as “any asset, Earth-based or space-based, designed to attack targets in space (Earth-to-space and space-to-space). Space weapons also include space-based assets designed to attack targets on Earth. For this definition, space-based weapons include weapons placed on celestial bodies”.

Types of space weapons can be categorized in several ways. One classification is based on operational domain, distinguishing between Earth-to-space systems such as ground-based ASATs, space-to-space systems such as co-orbital ASATs, and space-to-Earth systems such as orbital bombardment technologies. Another categorization is based on the method of attack, differentiating between kinetic weapons, which physically damage or destroy their targets, and non-kinetic weapons, which disable or disrupt a target without direct physical harm. Electronic warfare and cyberattacks fall into this category. However, some non-kinetic weapons can still cause physical damage depending on their mechanism of action.

3.5.1 Kinetic weapons

Kinetic attacks aim to physically damage or destroy space assets and are typically categorized into direct-ascent and co-orbital ASATs. The nature of these attacks makes them easier to attribute, allowing the attacker to confirm success with greater certainty. Examples include bullets, missiles, bombs, and artillery shells.

- **Direct-ascent ASAT:**Direct-ascent anti-satellite missiles (DA-ASAT) represent one of the most extreme counter-space capabilities due to the military escalation they provoke and their impact on outer space. These weapons generate large amounts of space debris, which can endanger other space systems. A DA-ASAT attack typically involves launching a medium- or long-range missile from Earth to intercept and destroy a satellite in orbit, classifying it as an Earth-to-space weapon. Since missile launches are easily detectable, these attacks are generally attributable. The physical nature of such attacks makes them irreversible, providing the attacker with near real-time confirmation of success. Despite the risks associated with space debris, major space-faring nations have conducted real-world ASAT missile tests since 1985. As of January 2022, more than 25,000 cataloged space debris objects larger than 10 cm have been identified, with approximately half originating from three major incidents: China's 2007 ASAT test, the accidental collision between a U.S. communications satellite and a defunct Russian satellite in 2009, and Russia's 2021 ASAT test of the Nudol system.

- **Co-orbital ASAT:** Satellites are also vulnerable to co-orbital ASAT attacks, in which an attacker places a satellite in orbit and later maneuvers it to intercept a target. This makes it a space-to-space weapon. A co-orbital ASAT requires advanced onboard guidance systems to successfully reach and disable its target. One form of co-orbital attack involves space mines, small explosives that follow the orbital path of a target satellite and detonate upon close proximity. Another method involves using a robotic arm to physically manipulate or de-orbit the targeted satellite. Co-orbital attacks can often be attributed by analyzing the orbital parameters of the attacking satellite before the event. Depending on the method used, these attacks can be either reversible or irreversible. The first known example of co-orbital ASAT systems dates back to the Cold War. Between the 1960s and 1980s, the Soviet Union developed and tested co-orbital ASAT weapons capable of tracking and maneuvering toward a target before detonating an explosive charge that propelled shrapnel into the target satellite. After nearly a decade of testing, the system was declared operational in 1973.

3.5.2 Non kinetic weapons with physical impacts

Unlike kinetic weapons, non-kinetic weapons operate without direct physical impact, instead utilizing energy, electromagnetic waves, cyber attacks, or psychological tactics to disrupt, disable, or manipulate targets. Examples include electronic warfare, lasers, and cyber attacks. Non-kinetic weapons are gaining significance in modern warfare because they allow adversaries to incapacitate an enemy without causing direct physical destruction, thereby reducing collateral damage.

- **Electronic warfare:** Electronic warfare (EW) focuses on controlling the electromagnetic spectrum and can be challenging to attribute or distinguish from unintended interference. This category includes spoofing and jamming.

  Jamming is an electronic attack that uses radio frequency signals to interfere with communications. A jammer must operate within the same frequency band and within the field of view of the antenna it is targeting. Unlike physical attacks, jamming is reversible: once the jammer is disengaged, communications are restored. Attribution of jamming can be difficult because the source can be small, highly mobile, and difficult to trace. Additionally, operating on the wrong frequency or targeting the wrong satellite can result in unintentional jamming of friendly communications. An uplink jammer interferes with signals sent from ground stations to satellites by creating noise that prevents the satellite from distinguishing between the real signal and the noise. Uplink jamming can block commands from being sent to a satellite. However, since the jammer must be within the field of view of the satellite's antenna, it must be physically located within proximity to the command station. Downlink jammers target satellite users by creating noise in the same frequency as the downlink signal. A downlink jammer needs to be as powerful as the signal received on the ground and must be within the field of view of the receiving terminal's antenna. This limits the number of users affected by a single jammer. Ground terminals with directional antennas are typically less vulnerable to downlink jamming, while those with omnidirectional antennas, such as many GPS receivers, are more susceptible. The U.S. military encountered jamming in Iraq well after the fall of Saddam Hussein's government, with at least five documented instances of hostile jamming of commercial SATCOM links. In recent years, Iran has used jamming to interfere with satellite signals from Persian-language broadcasters.

  Spoofing involves an attacker mimicking a legitimate radio frequency signal to deceive the target into locking onto the fake signal. An attacker can spoof a satellite's downlink, causing users to lock onto a false signal and inject misleading data. Spoofing can also target the command and control uplink signal, potentially taking control of the satellite. While spoofing is generally reversible, the consequences may not be. If an attacker takes control of a satellite and it is subsequently damaged or destroyed, the attack is irreversible. Encryption is the best defense against command and control uplink spoofing, as an attacker would need to break the encryption to make the signal appear legitimate. Omnidirectional antennas are more vulnerable to spoofing attacks due to their wide field of view. Directional antennas, which block signals from other directions, can reduce the likelihood of spoofing. An important example of this trend comes from the Ukrainian war. Russia heavily relies on GPS jamming to disrupt Ukraine's precision-guided weapons, drones, and other systems dependent on space-based PNT. This electronic warfare tactic reduces the range and accuracy of GPS-guided munitions, increasing the risk of missed targets and collateral damage. To counter this, efforts are underway to develop alternative PNT solutions and target Russian EW systems directly.

- **Cyber:**"cyberspace pervades all other warfighting domains, including space, and many space operations depend on cyberspace and vice versa. With sophisticated knowledge of satellite and data distribution networks, actors can use offensive cyberspace capabilities to enable a range of reversible to irreversible effects against space systems, associated ground infrastructure, users, and the links connecting them"[25].

  The commercialization of space and the development of new generations of satellites are closely tied to advancements in communications, transmissions, electronics, computing, and artificial intelligence, all of which process vast amounts of data. As space systems become more interconnected, cyberattacks have become a preferred offensive strategy for intercepting data, corrupting it, or taking control of systems for malicious purposes. Unlike electronic attacks, which disrupt data transmission through radio frequency signals, cyberattacks target the data itself and the systems that process this data. Any point of data exchange in the system, such as antennas on satellites or ground stations, or landlines connecting terrestrial networks, could be a potential point of intrusion. An advanced persistent threat (APT) attack seeks extended, undetected access to a system, enabling attackers to steal information or even take control of a system. The effects of cyberattacks on space systems can range from data loss to widespread disruptions, potentially resulting in the permanent loss of a satellite.

  Data intercept/monitoring: A cyberattack that seeks to collect or monitor data as it is transmitted through a satellite system is a form of interception. This attack is difficult to attribute, as hackers often use proxy servers and other methods to hide their identities. A satellite operator may not be aware of the attack when it occurs or afterward, but the attacker will receive near real-time confirmation of its success. In 2009, it was reported that insurgents in Iraq intercepted and decoded video from U.S. surveillance aircraft via commercially available software. The lack of encryption on some video feeds allowed the insurgents to view live footage, enabling them to monitor U.S. military operations.

  Data corruption: This cyberattack occurs when an attacker infiltrates a system and alters data to present false information. Like data interception, such attacks are difficult to attribute and may be fully reversible. However, the satellite operator may remain unaware of the attack when it occurs, potentially allowing false information to be acted upon before the attack is detected.

Seize control of a satellite: Cyberattacks can also seize control of a satellite, allowing the attacker to execute commands on the satellite. This type of cyberattack is difficult to attribute and can be irreversible if the attacker gains full control and carries out irreversible actions. The satellite operator may be aware of the attack but unable to stop it until it is too late, potentially causing collateral damage if the satellite is disabled or left to drift uncontrollably. The U.S.-China Economic and Security Review Commission has cited instances of cyberattacks targeting the command and control systems of U.S. government satellites. In 2008, hackers gained control of NASA's Terra EOS satellite on two occasions, holding it for 2 minutes and 9 minutes, respectively, though no commands were executed.

The proliferation of cyberweapons has led NATO to recognize cyberspace as an independent strategic domain that requires protection. The U.S. cyber strategy emphasizes the importance of securing the ability to fight and win wars in any domain, including cyberspace, in the context of long-term strategic competition with China and Russia. The power of cyberweapons lies in their flexibility, low cost, and difficult attribution. The commercial space sector, which is not sufficiently hardened against cyber threats, presents an additional vulnerability. While the military sector has taken steps to protect against cyber threats, many startups and academic missions are not designed with these risks in mind and are thus more easily compromised.

3.5.3 Non-kinetic physical attack

A non-kinetic physical attack involves damaging a satellite without direct contact. These types of attacks include electromagnetic pulses, high-powered lasers, and high-powered microwaves. These attacks have medium attribution levels and often provide limited evidence of success for the attacker.

- **Electromagnetic pulse attack:** A high-altitude nuclear detonation is an indiscriminate form of attack in space. A nuclear detonation in space generates an electromagnetic pulse (EMP), which has immediate consequences for satellites within range. The EMP disrupts satellite electronics and communications, and the detonation creates a high radiation environment that accelerates the degradation of satellite components in affected orbits.
- **High-powered laser:** A high-powered laser can be used to permanently or temporarily damage critical satellite components, such as solar arrays

or optical centers. When directed at a satellite's optical center, the attack is referred to as blinding or dazzling. Blinding causes permanent damage to the satellite's optics, while dazzling temporarily disables the satellite's ability to see. Although the location of the laser's origin can be tracked at the time of the attack, the mobile nature of the lasers used in these attacks can make attribution difficult. The attacker does not need to be in their own country or even continent to carry out such an attack, complicating identification. Only the satellite operator will know whether the attack was successful, and an attacked nation may not announce the attack for strategic reasons. High-powered laser attacks can also leave satellites disabled and uncontrollable, leading to potential collateral damage if the satellite begins to drift. More powerful lasers can cause permanent damage by overheating satellite components such as structures, thermal control panels, and solar panels. In 2005, China claimed to have successfully blinded a satellite using a mounted laser gun in Xinjiang province, although this claim has not been confirmed. In 2006, reports emerged of American satellites being dazzled while passing over China. While the attack did not impair the satellites' ability to gather data, it demonstrated China's ability to carry out dazzling attacks. Although China's ability to blind satellites is not fully operational, it is a capability that could be perfected over time.

- **High-powered microwave:** High-powered microwave (HPM) weapons can disrupt or destroy a satellite's electronics. A "front-door" HPM attack targets a satellite's own antennas, using them as an entry point, while a "back-door" attack exploits small seams or gaps in the satellite's electrical connections and shielding. A front-door attack is simpler to execute as long as the HPM is positioned within the antenna's field of view, but it can be mitigated if the satellite has circuits designed to detect and block surges of energy entering through the antenna. In contrast, a back-door attack is more complex, as it requires exploiting design or manufacturing flaws but can be conducted from many angles relative to the satellite. Both types of HPM attacks can be either reversible or irreversible, depending on the severity of the damage. However, the attacker may not be able to control the extent of the damage. Like laser attacks, HPM attacks are difficult to attribute, and the attacker may not know whether the attack has been successful. A successful HPM attack may disable the satellite, making it uncontrollable and causing it to drift into other satellites, resulting in further collateral damage.

3.6 Modern warfare

After analyzing the dual-use capabilities of space and the various types of space weapons, it is essential to contextualize these developments within contemporary warfare models. Technological advancements and the integration of new operational domains, such as space and cyberspace, have profoundly influenced how military powers plan and conduct operations. Strategic concepts like the Revolution in Military Affairs (RMA), Anti-Access/Area Denial (A2/AD) strategies, and multi-domain approaches such as Multi-Domain Operations (MDO) and Joint All-Domain Operations (JADO) reflect this transformation. Examining these models provides a deeper understanding of the growing role of space capabilities in modern warfare and their impact on global strategic balances.

3.6.1 The example of Ukrainian war

As we mentioned above, the conflict in Ukraine is showing the potential of new technologies in the war, and is a good example of how the new technologies can affect the war in 2025. The war in Ukraine has highlighted how modern conflicts are increasingly shaped by the integration of digital, space, and artificial intelligence (AI) technologies. Space operations have played a crucial role in supporting Ukraine's resistance, providing essential capabilities in communication, navigation, surveillance, and targeting. The battlefield is evolving through the convergence of innovations in AI, robotics, telecommunications, sensors, and advanced computing, expanding the range of tools available for command and control (C2) and military intelligence (C5ISTAR). Global powers like the US, China, Russia, and European NATO allies are competing to gain a decisive edge by leveraging data, connectivity, and real-time analytics. Russia's invasion has accelerated this push for digital innovation, turning Ukraine into a testing ground for AI-driven warfare. The Ukrainian Armed Forces have shown remarkable adaptability, integrating intelligence sources and AI tools to optimize "kill chains" and engage Russian targets more efficiently. New digital technologies have been deployed for various purposes, including:

- Automated analysis for real-time battle damage assessment (BDA);
- Facial recognition to detect infiltrators, identify casualties, counter disinformation, and reunite families;
- Satellite imagery analysis for geospatial (GEOINT) and open-source intelligence (OSINT);
- Voice transcription and translation using large language models (LLMs) to intercept and analyze Russian communications;
- The use of drones and loitering munitions for strikes, ISR, and logistics.

3.6.2 C5ISTAR

C5ISTAR (Command, Control, Computers, Communications, Cyber, Intelligence, Surveillance, Target Acquisition, Analysis, and Reconnaissance) is an advanced military concept that represents the evolution of modern command, control, and intelligence systems. It is an integrated system that enables military forces to collect, analyze, and utilize real-time information to enhance decision-making. This model builds upon its predecessors by incorporating cyber capabilities and advanced data analysis, both of which are essential in modern warfare.

C5ISTAR serves as the brain of modern military operations, combining advanced technology, data analysis, and cybersecurity to provide a strategic advantage. Contemporary military strategies such as MDO (Multi-Domain Operations) and JADO (Joint All-Domain Operations) rely on it, as it allows seamless integration of military forces through real-time data sharing.

Unsurprisingly, Russia and China are developing similar systems to counter Western military effectiveness, investing heavily in electronic and cyber warfare to disrupt C5ISTAR's information flow.

The primary objective of C5ISTAR is to establish a secure and continuous information network, enabling military forces to gather intelligence from satellites, drones, and sensors, protect communications, leverage AI and big data for rapid analysis, ensure effective command and control between military units, and increase the precision of strikes. Space is a key element in this system, as it relies heavily on satellites for communication, surveillance, and navigation. Without space-based assets, the efficiency of C5ISTAR would be significantly reduced, making space dominance a critical factor in future military operations.

External actors, including the US, NATO, and China, are closely studying the war in Ukraine to shape future operational concepts and military capabilities. This is evident in initiatives like NATO's Multi-Domain Operations (MDO), designed to make military forces more integrated, connected, and responsive.

The convergence of space and AI has become a defining feature of modern warfare, with satellite communications (SATCOM), positioning, navigation, and timing (PNT), and Earth observation (EO) playing a strategic role. This digital transformation was already underway before the war, but the conflict has accelerated the testing and refinement of emerging technologies. At the same time, growing reliance on interconnected space-based infrastructure has created new vulnerabilities, making space an increasingly contested domain. The war in Ukraine has underscored the critical role of SATCOM, PNT, and EO/ISR services in battlefield awareness and command and control. It has also demonstrated how competition in space is now closely tied to the battle for information and decision dominance. Russian attempts to jam, spoof, or hack Ukraine's satellite networks have been a consistent feature of the conflict. One striking example was the February 2022 cyberattack on ViaSat's KA-SAT network, launched just an hour before the invasion, which disrupted services for thousands of European users, including Ukraine's government and military. Ultimately, the war in Ukraine is a turning point for the future of warfare, proving that technological superiority, digital warfare, and cross-domain integration (spanning land, space, and cyberspace) are now essential for gaining operational advantage.

3.6.3 MDO and RMA

MDO and RMA were the first modern warfare concepts that integrated multiple domains to create superiority over the enemy.

MDO (Multi-Domain Operations) refers to joint military operations conducted across multiple domains, including space (both terrestrial and outer space), to overcome an adversary's Anti-Access/Area Denial (A2/AD) capabilities. It focuses on maneuvering across all domains and connecting all elements of the battlefield within a digital infrastructure. Space plays a crucial role in synchronizing and integrating these elements through Positioning, Navigation, and Timing (PNT) services, Earth Observation (EO) for situational awareness, and Satellite Communications (SATCOM) for real-time communications between strategic, operational, and tactical levels, as well as across multiple battlefields. The U.S. developed this doctrine to regain freedom of action and counter near-peer adversaries such as China and Russia. Over time, this doctrine (or equivalent) has been progressively adopted by other countries.

RMA (Revolution in Military Affairs) is a warfare concept developed in the 1980s and early 1990s in the United States, based on four main components: information warfare, dominant maneuver, precision strike (precise and guided attack capability), and space control. The goal of RMA is to synchronize all four components into a single, cohesive system. Space technologies such as GPS satellites, surveillance and reconnaissance satellites, and communication satellites play a fundamental role in achieving this objective. A document published by the U.S. military titled "Joint Vision 2020" describes that the key elements of RMA are information-led warfare, precise strike capability, and dominant maneuverability. Full spectrum dominance is the primary constituent of modern warfare. The document describes future warfare of the U.S. as "The strategic concepts of decisive force, power projection, overseas presence, and strategic agility will continue to govern our efforts to fulfill those responsibilities and meet the challenges of the future"[26].

3.6.4 A2/AD

Anti-Access/Area Denial (A2/AD) is a military strategy designed to prevent an enemy from entering or operating effectively within a strategic area, primarily implemented by Russia and China to counter the military superiority of NATO and the United States, aiming to create an environment where access is extremely difficult and where, even if an enemy manages to enter, operating efficiently becomes nearly impossible.

A2/AD consists of two complementary phases: Anti-Access (A2), which focuses on denying the enemy entry into the area through long-range strikes and other deterrent measures, and Area Denial (AD), which restricts the enemy's ability to function effectively within the contested space once they have entered. This strategy relies on a combination of long-range missiles to strike bases and airfields preemptively, advanced air defense systems to neutralize incoming enemy forces, electronic and cyber warfare to disrupt GPS, communications, and radar systems, hypersonic weapons to bypass traditional missile defenses, and naval assets, such as warships and submarines, to enforce maritime control.

For the United States, A2/AD strategies pose a significant challenge to its ability to project power, particularly in the Asia-Pacific region, where China is establishing A2/AD zones within the First Island Chain, stretching from the Kuril Islands to the Malay Peninsula, threatening U.S. bases in Japan, South Korea, the Philippines, and even Guam in the Second Island Chain, complicating carrier strike group operations and limiting U.S. military flexibility in the region.

Beyond its military implications, A2/AD also serves a political function by significantly increasing the costs and risks of a potential military response from adversaries, creating a powerful deterrent effect that reduces the likelihood of direct intervention in contested regions and shaping strategic decision-making and power dynamics.

3.6.5 JADO

Over the past decade, the U.S. Armed Forces have been developing various concepts to address a central challenge: how to prevail over adversaries equipped with long-range precision-guided weapons systems. While the Revolution in Military Affairs (RMA) proved highly effective against conventional adversaries, it was insufficient in Iraq and Afghanistan, where insurgencies relied on asymmetric tactics and where decisive factors were fundamentally different. Against a conventional military opponent, U.S. military dominance remained overwhelming. However, the last decade has witnessed a shift in the balance of power due to China's economic and military rise and Russia's modernization of key capabilities, combined with Moscow's increasingly aggressive policies.

Joint All-Domain Operations (JADO) is an advanced military concept developed by the United States to integrate and synchronize operations across all military domains. While similar to Multi-Domain Operations (MDO), JADO represents an evolution, offering a higher level of coordination between forces and extensive use of AI, big data, and advanced communications technologies. The increased speed, automation, and seamless integration of capabilities make military operations more efficient and effective compared to MDO. The primary objective of JADO is to create a strategic advantage by rapidly combining capabilities across multiple domains. The core principle is that simultaneous and coordinated attacks across land, air, sea, cyber, and space can overwhelm an adversary, disrupting their ability to respond effectively.

What distinguishes JADO from previous approaches is the role of AI, which enables real-time analysis of vast amounts of data, facilitating rapid and informed decision-making. By leveraging big data and machine learning, JADO can identify patterns in enemy tactics and anticipate their next moves. Additionally, military cloud computing and secure communication networks ensure seamless data sharing across all forces, enhancing operational efficiency.

JADO was developed in response to the growing success of Anti-Access/Area Denial (A2/AD) strategies implemented by Russia and China to counter U.S. military power. By integrating AI-driven decision-making and advanced cross-domain coordination, JADO provides the capability to penetrate and neutralize A2/AD defenses. Furthermore, its ability to enhance cooperation among allied forces helps overcome challenges typically associated with multinational operations.

Unlike previous doctrines that sought long-term dominance in a single domain, such as air superiority, JADO assumes no permanent superiority in any domain. Instead, it focuses on achieving temporary superiority in specific domains, leveraging effects from others to enable decisive action at critical moments.

The space domain is essential for JADO to function effectively. Satellites provide vital support in data transmission across multiple domains, geolocation of friendly forces and enemy targets, precision guidance for munitions and control of unmanned systems and command and control operations for strategic coordination. At the same time, JADO strategies aim to deny adversaries access to their space assets, recognizing that modern warfare is increasingly dependent on space-based capabilities. As both an enabler and a target, space remains at the heart of 21st-century military operations.

3.7 Dilemmas

The growing complexity of space dynamics is turning outer space into an increasingly vulnerable domain marked by misunderstanding, competition, and potential conflict. Advanced technologies such as maneuverable satellites, On-Orbit Servicing (OOS) operations, and high-resolution surveillance systems offer new opportunities, but they also raise serious concerns regarding security, mutual trust, and strategic stability.

- **Attribution and Escalation:** Even though satellites typically travel in predictable orbits, collisions can still happen. Maneuvering in orbit is complex, and any miscalculation in trajectory, or anomalies, could lead to unintentional collisions. Space-domain awareness systems that track satellites and debris in orbit rely on these factors to predict the future location of space objects and forecast potential collisions, allowing those in danger to maneuver. If spacecraft are maneuvering in and across different orbital regimes, these predictions become less accurate, which could result in unintentional collisions in orbit. The possibility of such collisions leaves room for malicious space actors to intentionally destroy a satellite and attribute the event to an error or accident. Awareness of this possibility may lead to mistrust and inadvertent escalation, even if a collision is truly accidental, nations may perceive it as intentional.

- **Security Dilemma:** The United States, Russia, and China describe their military RPO (Relative-Positioning Operations) satellites as benign. For example, the official factsheet on the U.S. GSSAP satellites describes them as "enabling space flight safety" by providing better knowledge of the space environment. However, historical actions by these states raise concerns about their true intentions. Russia's maneuvers of satellites in the GEO belt, or China's controversial experiment testing an imaging system for identifying space debris at high altitudes, may serve purposes beyond scientific endeavors. The development of On-Orbit Servicing (OOS) spacecraft similarly raises concerns. Moreover, space weapons are more effective when their capabilities are not easily countered by the potential adversary. To achieve this, Anti-Satellite Weapons (ASATs) must remain secret, as revealing their capabilities could prompt the enemy to develop countermeasures. An ASAT maneuvering near a national security satellite could create the potential for escalation. Even OOS spacecraft, though intended for peaceful use, can be openly developed by both military and commercial entities, and will be employed in large numbers throughout many orbital regimes. The fact that the technology used for OOS spacecraft is nearly indistinguishable from that used for ASATs exacerbates these concerns, generating fear. As a result, the United States, China, and Russia all view each other's development of such systems as threatening. States have increased efforts to advance their proximity and rendezvous capabilities to ensure their own security, which could destabilize space security and lead to mistrust. This, in turn, triggers the security dilemma: "Striving to attain security from such attacks, they are driven to acquire more and more power in order to escape the impact of the power of others. This, in turn, renders the others more insecure and compels them to prepare for the worst. Since none can ever feel entirely secure in such a world of competing units, power competition ensues, and the vicious circle of security and power accumulation is on"[27]. The perceived security of space actors is crucial, as counter-space developments in their space programs are based on this perception. Unfortunately, a security dilemma is already unfolding: in an attempt to defend themselves from perceived threats, states are continuously improving their arsenals, thus increasing the fear of other states and prompting them to build up their own military capabilities even further.

- **Erosion of Secrecy:** Capabilities Exposed. The ability to collect high-resolution imagery and radio-frequency (RF) surveillance of objects in space could diminish all but the most sophisticated methods of deception and concealment. Through high-resolution imaging and the characterization of space systems, adversaries or competitors could determine the true capabilities of these systems. Once exposed, adversaries could then develop countermeasures to neutralize, degrade, or defeat these capabilities. This is particularly true for intelligence, surveillance, and reconnaissance (ISR) satellites. Imaging and surveillance of these systems could reveal the resolution and sensitivity of their payloads, the signals they collect, and the methods of collection.

  In the past, the United States and other nations have successfully used national security satellites, in part because they were able to protect the specific details of these systems. Once the capabilities of intelligence collection systems are revealed, even the most unsophisticated adversary could devise methods to mitigate the surveillance of their activities. This could severely hamper the global intelligence reach of many superpowers. It is unclear how states will respond once they can determine the actual capabilities of classified systems, or once the true capabilities of these systems are made public.

- **Lowering Barriers to Conflict:** The development and deployment of On-Orbit Servicing (OOS) systems could significantly alter the dynamics of space competition by lowering the barriers to conflict. Deterrence in space relies heavily on the essential role that space plays in modern life and commerce, and on the understanding that kinetic attacks on space assets could have far-reaching consequences, not just for the target nation but for everyone. Furthermore, states are deeply dependent on their space assets for crucial military functions and strategic decision-making. Many of the most vital satellites are low-density, meaning that states cannot quickly build and launch replacements. Consequently, an attack on these systems could lead to massive retaliation, or at least the threat of it, due to the crippling effects such attacks would have. However, if satellites can be easily repaired and debris removed from orbit, targeting space assets could become more attractive to adversaries. The development of OOS technologies could, therefore, make space warfare more likely simply by altering the cost-benefit analysis for deterrence, making it seem less risky to attack space assets.

These dilemmas are exacerbated by the proliferation of commercial activities in space, which poses several additional challenges and dilemmas for the future. Since the technology used for civil and commercial RPO/OOS is the same as that used for military applications, nations might use the commercial development of these systems as a cover to advance their weapons capabilities. Even if these systems are intended for civil or commercial purposes, they could be exploited for military use. In such cases, attribution becomes incredibly difficult, and as these technologies proliferate in the civil and commercial sectors, they become more accessible to those who might wish to acquire them for use as weapons. This could create an even greater urgency for states to develop their own military on-orbit servicing systems to minimize the risks posed by potentially less secure commercial providers. Moreover, escalation could become easier for two reasons. First, even though these systems are officially commercial, they could easily be repurposed as weapons, and the development of these systems could unintentionally trigger an arms race as countries build military capabilities to counter what are officially (and in reality) commercial/civil technologies. Second, as maneuvering systems proliferate, the likelihood of accidental collisions increases. Such collisions would not only increase the chances of one nation passing off a deliberate attack as an accident but also heighten the incentive for nations to do so. Knowing these possibilities, nations might become more suspicious when accidents occur and may mistakenly attribute a genuine accidental collision to a purposeful attack, leading to unintended escalation.

Chapter 4

What's the world's situation?

4.1 The world's Space powers: China, Usa, Russia

4.1.1 Outer Space as a Strategic Domain: Global Militarization and the Rise of Counter Space Capabilities

Outer space is becoming an increasingly critical domain for both civilian and military purposes. The exponential growth of actors and assets operating in orbit, along with the growing reliance on space-based services, has elevated space to a central role in national security strategies. Many governments now consider outer space not just a scientific or commercial frontier, but a potential domain of warfare.

This shift is occurring in parallel with intensifying geopolitical tensions and a renewed era of great power competition, with space emerging as a critical arena in this global struggle. The desire of states to safeguard their space infrastructure is reflected in their national policies and strategic reorganizations. In recent years, several spacefaring nations have either created or restructured dedicated military space organizations, doctrines, and strategies.

The growing vulnerability of space systems in a volatile international environment has prompted major powers to revise their strategic postures and military doctrines. China and Russia for example justify their military space reorganizations as necessary steps to improve efficiency and preparedness for future conflicts. Meanwhile, countries like France, India, and Japan cite the need to protect their space assets from potential attacks in future wars. France has announced plans to develop national counter space capabilities, and Japan is actively evaluating whether to do the same. Japan is historically opposed to the militarization of space, but now has begun to address it as an operational warfighting domain, aligning with broader strategic shifts seen in other countries. Iran and North Korea, although more limited in resources, are advancing non-destructive counterspace tools such as jamming and spoofing, which, alongside cyberattacks, represent less sophisticated but potentially disruptive threats.

Among the most controversial developments is the establishment of the U.S. Space Force, introduced by former President Donald Trump and presented as "absolutely vital" for maintaining American dominance in space. This decision, coupled with the reactivation of U.S. Space Command, marked a profound shift in U.S. defense strategy.

However, America's military-technological superiority in space is now increasingly contested. Both China and Russia are rapidly expanding their capabilities in electronic warfare, directed-energy weapons, and cyber operations. All three possess kinetic anti-satellite (ASAT) weapons and space-based counterspace assets designed to target adversary satellites in the event of conflict. India, too, has demonstrated successful ASAT capabilities, though its broader counter space policy remains ambiguous.

Despite the development of these capabilities, no state has yet employed kinetic weapons against another country's space assets. Nevertheless, the dual-use nature of many technologies makes it difficult to determine their true intent. This technological ambiguity fuels mutual distrust and heightens tensions among space powers.

Overall, the data suggest that most major spacefaring nations are now approaching space from a security-oriented perspective. While some countries are primarily focused on defending their space-based infrastructure, others are openly pursuing space dominance through advanced armament and counterspace systems.

Beyond military considerations, outer space is vital to modern society. Satellite-based systems enable global communication, real-time environmental monitoring, precision navigation, and high-resolution Earth observation. These technologies also enhance both offensive and defensive military capabilities, reinforcing space's status as a crucial geopolitical resource. In this context, space is no longer a purely civilian domain but a contested arena with far-reaching implications for international security and stability.

4.1.2 The Strategic Role of the United States in Space

The U.S. government, along with its top military and national security officials, views space supremacy as a key element in maintaining global leadership in defense. While Washington had already recognized the strategic value of space by the late 1990s, it wasn't until 2014 that space security and the potential for armed conflict in orbit became a clear political priority.

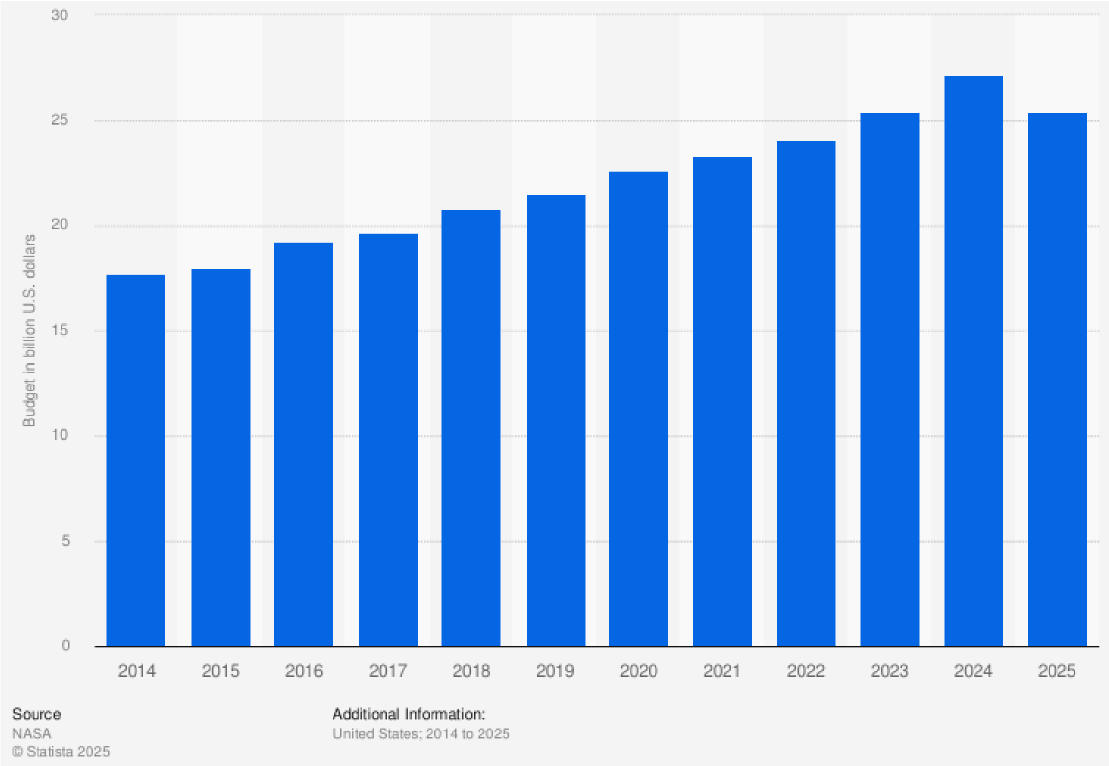

Figure 4.1: NASA's budget request from 2014 to 2025 (billion $)

NASA's annual budget request has followed a consistent upward trend, rising from under $18 billion in 2014 to over $27 billion in 2024, illustrating increased national investment in space research, exploration, and technology.

Between 1999 and 2006, a growing perception emerged in the U.S. Congress that China represented a strategic challenge in space. These concerns deepened in 2012, when China intensified its efforts to compete with the U.S., sparking fears that it could eventually displace Washington from its dominant position.

In response, the U.S. unveiled in 2020 an ambitious plan to overhaul its military space architecture, the most significant restructuring in over six decades. This included the establishment of the U.S. Space Command and, most notably, the creation of the U.S. Space Force as a separate branch of the armed forces. The Space Force, now on par with the Army, Navy, Air Force, and Marine Corps, is responsible for developing, managing, and operating the Department of Defense's space systems. Its official doctrine "Spacepower: Doctrine for Space Forces" (published in August 2020), outlines a vision of space as a warfighting domain.

The Space Force is tasked with organizing, training, and equipping personnel for global space operations. Its roles include maintaining space superiority, providing space domain awareness, enabling offensive and defensive space control, command and control of space forces, satellite operations, missile defense, and early warning

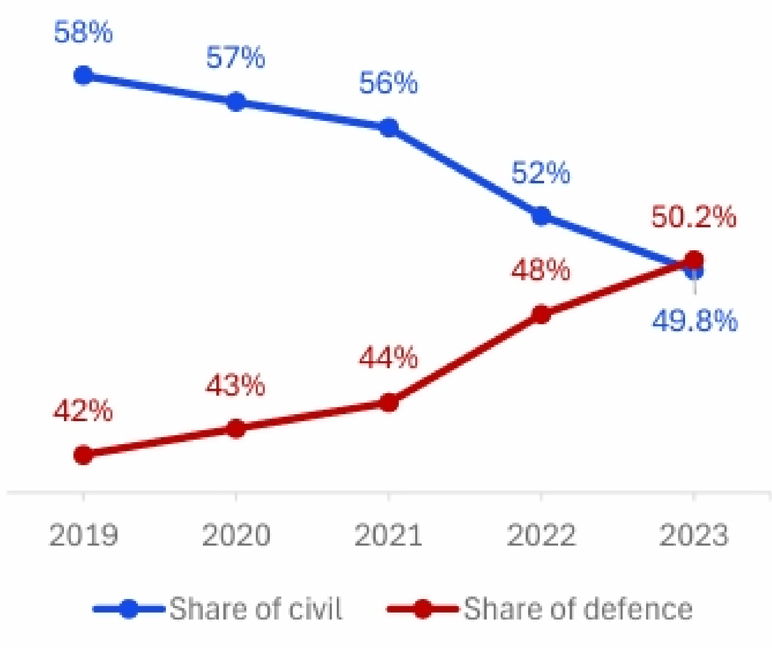

Figure 4.2: Evolution of civil and defence share of global space budgets, 2019–2023

Source: Euroconsult, Government Space Programs, 23rd Edition, December 2023

The chart highlights the growing importance of the space defence sector, which surpassed the civil share of space investment for the first time in 2023, reaching 50.2%. This shift reflects an increasing focus on national security, satellite resilience, and strategic capabilities in orbit—underlining how space is becoming a critical domain for defence policy and geopolitical competition.

systems. In parallel, the U.S. Space Command (SPACECOM) was reactivated in 2019 after being decommissioned in 2002. SPACECOM is now one of the eleven unified combatant commands within the Department of Defense. Its mission is to "conduct operations in, from, and to space to deter conflict, and if necessary, defeat aggression, deliver space combat power for the Joint Force, and defend U.S. vital interests with allies and partners."[28]

The importance of space is further underscored by three key strategic documents: the National Strategy for Space (2018), the National Defense Strategy (2018), and the Defense Space Strategy (2020). The DDS, in particular, identifies China and Russia (as well as Iran and North Korea to a lesser extent) as adversaries seeking to erode U.S. advantages in space through emerging technologies and military doctrines. The DDS outlines four strategic lines of effort: first, achieving comprehensive military advantage through innovation, doctrine development, and organizational reform; second, integrating space power into joint all-domain military operations alongside allies; third, shaping the strategic environment by promoting responsible behavior in space; and fourth, enhancing collaboration with other U.S.

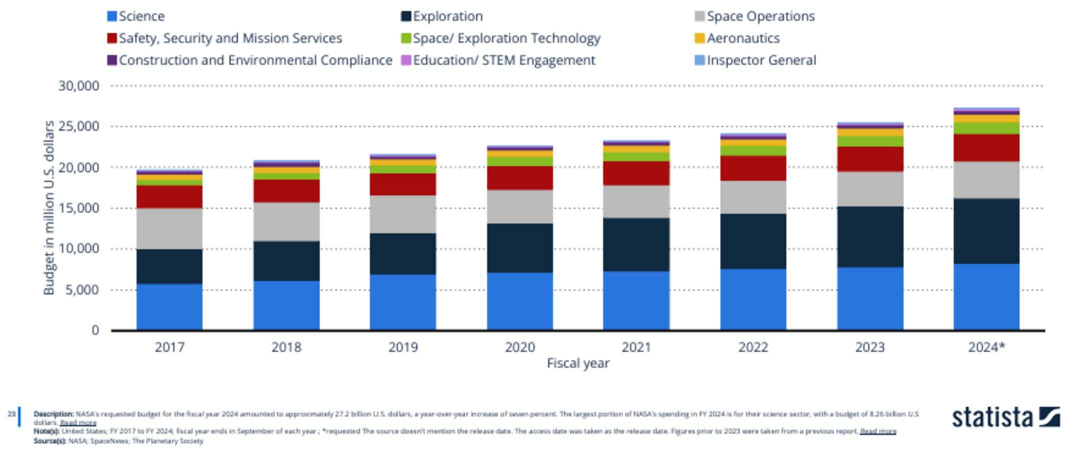

Figure 4.3: NASA's approved budget from FY 2017 to FY 2024 by sector (million $)

NASA's approved budget shows steady growth across all mission sectors, with science, exploration, and space operations receiving the largest shares. In FY2024, total funding exceeded $27 billion, reflecting continued U.S. commitment to space leadership and innovation.

agencies, international partners, and the private sector.

The U.S. possesses the world's most advanced constellation of satellites for intelligence, surveillance, reconnaissance, and secure military communications. These include systems capable of detecting missile launches, intercepting signals, and producing optical and radar imagery. The Advanced Extremely High Frequency (AEHF) satellites, for example, operate in geostationary orbit and provide secure, jam-resistant communications for military use.

In terms of counter-space capabilities, the United States has demonstrated multiple forms of ASAT potential. Right after Sputnik, the U.S. jumped headfirst into developing direct-ascent ASAT missiles, but it quickly became clear the technology of the day wasn't up to the challenge. So, the USA turned to what seemed more feasible at the time: nuclear detonations in space. This led to a testing program which culminated with Starfish Prime in 1962, where the USA detonated a nuclear weapon in space, with tremendous results. Some years later, in 1985, it destroyed an obsolete satellite using an ASM-135 missile launched from an F-15A. In 2008, it used an SM-3 missile launched from the USS Lake Erie to destroy a defunct Earth observation satellite. These demonstrations highlighted the latent kinetic capabilities of the U.S., even without a formally declared direct-ascent ASAT program.

The U.S. arsenal for space defense includes not only kinetic ASAT weapons, but also cyber tools, electronic warfare systems, and directed-energy weapons. Investments in these capabilities have grown significantly in recent years. Not only, since 2010 the U.S. has operated the experimental X-37B spacecraft, launched by the Air Force, which serves various classified functions and has proven useful in scenarios involving ASAT threat simulation. Given its success, the program is set to expand: future plans call for the development of 13 to 16 new X-37C spacecraft, two upgraded X-37B models, and the continuous presence of at least 10 spacecraft in orbit at any time. Their main role will be to support and enhance space-based missile defense operations. Ultimately, the U.S. strategy aims to ensure a secure, stable, and accessible space domain, one that remains open and protected for use by the United States and its allies. As former Secretary of Defense Mark Esper warned, "the next big fight may very well start in space, and the United States military must be ready." General Mark Milley echoed this sentiment, stating that "space is critical to the nation's economic interests, national security, and way of life," and emphasizing that "in military operations, space is not just a place from which we support other domains, but a warfighting domain in and of itself."

4.1.3 Russia's Militarization of Outer Space

Unlike the United States, where the space program emerged from a collaborative effort between the military and civilian agencies such as NASA, Russia has historically treated outer space primarily as a military domain. Since the inception of its space program, Russia (and previously the Soviet Union) has regarded space as an arena for strategic and defense operations.

Russia's modern space era began after the geopolitical collapse of the Soviet Union. On February 25, 1992, the Russian Space Agency was established. It became the Federal Space Agency (Roscosmos) in 2004, and later transformed into the Roscosmos State Corporation in 2015 through a merger with the United Rockets and Space Corporation. Simultaneously, the Russian Ministry of Defense founded the world's first dedicated space force on August 10, 1992, with responsibilities ranging from launching military satellites and managing orbital assets to monitoring space traffic and detecting potential threats from space.

Russia's military doctrine identifies the deployment of weapons in space as one of the primary external military threats. It advocates for the creation of an international legal regime that would prohibit the placement of any weapons in outer space. Furthermore, Russia openly acknowledges the militarization of space as a main external military danger and sees potential strategic advantage in exploiting other nations' dependency on space infrastructure in times of conflict.

Driven by this perspective, Russia views space as a key domain of warfare and believes that future military superiority will depend on achieving dominance in this domain. Reflecting this belief, Russia has reorganized its space-related defense structure by merging its air force and aerospace defense troops into a unified branch, the Aerospace Forces (VKS). This integration is intended to improve coordination and efficiency across space, air defense, and missile defense operations. Militarily, space remains one of Moscow's top strategic priorities: this is reflected also looking the Russia's total space spending in 2020, that amounted to approximately $4 billion (over 0.21% of its GDP, second only to the U.S), only around $1 billion of that is estimated to be allocated to military applications, a fraction of the U.S. space defense budget.

Russia has maintained a space defense strategy since the 1960s, with a strong focus on active defense measures, such as missile and satellite destruction. This legacy continues today, with modern emphasis on electronic warfare, the survivability of space communication systems, and the development of offensive measures targeting adversaries' ground infrastructure.

Currently, Russia operates approximately 24 intelligence, surveillance, and reconnaissance (ISR) satellites, with roughly half under military control. The primary mission of its space forces remains missile defense, but their electronic warfare capabilities (such as GPS signal jamming) have been demonstrated in conflicts in Syria and Ukraine. Russia is also capable of launching cyberattacks against satellite command, control, and communication systems. Notably, in February 2022, just before the invasion of Ukraine, a cyberattack disrupted the satellite communications company Viasat, affecting the Ukrainian military and thousands of European users. While attribution remains difficult, the U.S. and EU publicly accused Russia of the attack. Elon Musk also reported increased attempts to disrupt Starlink systems in Ukraine, although the network remained functional. However, the Ukraine war has revealed key shortcomings in Russia's space capabilities, including weaknesses in satellite intelligence, limitations of GLONASS-guided munitions, and a lack of reliable satellite communications. These challenges are compounded by budget constraints, corruption, and difficulties accessing Western technology (issues exacerbated by international sanctions imposed after the annexation of Crimea in 2014 and further tightened after the 2022 invasion of Ukraine). These sanctions have, in turn, accelerated strategic space cooperation between Russia and China, deepening the geopolitical divide with the West. Since 2018, Russia has deployed directed-energy systems such as the Peresvet laser, designed to temporarily or permanently blind the optical sensors of Earth observation satellites. These systems have been assigned to mobile intercontinental ballistic missile (ICBM) units to conceal their deployment and movement.

Russia has also inherited the Soviet Union's interest in developing anti-satellite (ASAT) capabilities. Several Soviet-era programs have been revived to enhance the counter space functions of the Aerospace Forces (VKS). Among the known kinetic counterspace programs is the ground-based Nudol missile system (PL-19), under development since 2009. The system was successfully tested in 2021, creating over 1,500 pieces of orbital debris in low Earth orbit (LEO). While it's unclear whether Nudol is a dedicated direct-ascent ASAT (DA-ASAT) weapon, it is believed to be capable of targeting both LEO satellites and ballistic missiles at altitudes exceeding 1,000 km.

Another emerging capability is the S-500 air defense system, still under development, which has been described as potentially capable of ASAT missions. According to Russian media and statements from military leadership, including General Sergei Surovikin, the S-500 is expected to intercept ballistic missiles exo-atmospherically at altitudes up to 200 km and may form the first generation of Russian counter space defense systems capable of targeting low-orbit satellites and space-based weapons.

4.1.4 China's Capabilities, Doctrine, and Geostrategic Ambitions

China's space program has its origins in the development of ballistic missile systems, which eventually served as the foundation for its space launch vehicles. In the mid-1950s, China's missile industry received substantial assistance from Soviet engineers, underpinned by shared Marxist ideology. This collaboration laid the groundwork for what would become one of the most advanced and strategically significant space programs in the world.

China now possesses robust capabilities in space, including its own independent satellite systems and a fully functioning national space station: the final satellite of the BeiDou-3 constellation was launched on June 23, 2020, and on July 31, 2020, President Xi Jinping officially declared the BeiDou Navigation Satellite System (BDS-3) operational. In terms of human spaceflight, China launched its first space station prototype, Tiangong-1, on September 29, 2011, which was followed by Tiangong-2 in 2016. On April 29, 2021, China successfully launched Tianhe, the 22-ton core module of the permanent Tiangong space station into low Earth orbit, demonstrating a clear ambition to establish a long-term national presence in space.

Although official Chinese discourse traditionally emphasizes the peaceful use of outer space, recent years have revealed a growing interest in space defense. In 2015, China explicitly recognized space as a military domain, and space security was formally listed as a key national strategic interest in the "Chinese Defense White Paper." That same year, the People's Liberation Army (PLA) was restructured to create the Strategic Support Force (SSF), an entity tasked with integrating space, cyber, and electronic warfare (EW) capabilities. As noted by the European Space Policy Institute, this reorganization aims "to enhance the military power of China and make the country better prepared than the United States to use space assets in wartime." The SSF is now considered the fifth pillar of China's armed forces, charged with conducting space, cyber, psychological, electronic, and strategic intelligence operations.

China's evolving space doctrine has been shaped by the growing competition between the U.S. and Russia, and by lessons drawn from past conflicts, particularly the 1991 Gulf War. In 2019, China's Defense White Paper officially designated outer space, electromagnetic space, and cyberspace as unified domains of national defense. It emphasized that "space security provides strategic security for national and social development"[29]. China sees space as a vital part of its military strategy, driven by three main goals.

First, as the PLA expands its naval reach beyond coastal defense, especially within the First Island Chain, it depends heavily on space-based systems for surveillance and command capabilities needed for modern maritime operations. Second, China is preparing for "informatized warfare," where controlling and using information across all domains is key. Space-based C4ISTAR systems are central to this, especially for supporting its Anti-Access/Area Denial (A2/AD) strategies with missiles like the DF-21D and DF-26.

Finally, China aims to weaken its adversaries by targeting their use of space. In particular, it seeks to undermine the U.S.'s space-based military systems, reducing its ability to operate effectively in the Asia-Pacific and shifting the strategic balance in China's favor.

Militarily, China has significantly expanded its space assets. It possesses over 40 satellites dedicated to electronic and signals intelligence (ELINT and SIGINT), and about 25 ISR satellites. It also maintains at least nine dedicated military communication satellites and likely uses over 60 dual-use civilian satellites for strategic communication purposes. Beijing is investing heavily in its national satellite communications industry, including quantum communication technologies aimed at securing high levels of encryption. The BeiDou constellation, operational since 2018, offers global positioning with standard accuracy of ten meters globally and five meters within the Asia-Pacific region.

China's space arms race visibly escalated in January 2007 with the successful destruction of one of its own satellites using a ground-launched ASAT missile. Since then, President Xi Jinping has made the development of anti-satellite (ASAT) capabilities a strategic priority. In February 2018, China tested the Dong Neng-3 (DN-3), a long-range interceptor missile capable of targeting objects in orbit. China is believed to possess a wide range of counter-space tools, including kinetic ASAT weapons, cyberattack capabilities, and high-powered lasers.

"China has embarked on a sustained national effort to develop a broad spectrum of space capabilities across the civil, national security, and commercial sectors"[30], these developments suggest a long-term strategic investment in counter-space warfare.

China, alongside Russia, continues to pursue both destructive and non-destructive ASAT technologies for future conflicts. U.S. intelligence agencies estimate that several Chinese counter-space capabilities are nearing operational readiness, with the PLA reportedly conducting training exercises using ground-based ASAT systems.

While not yet evidence of permanent space weaponization, notable tests underscore China's potential. For instance, in July 2021, China conducted a test involving a hypersonic glide vehicle (HGV) launched from a fractional orbital bombardment system (FOBS). This combination, difficult to detect and intercept, introduces new complexities for missile defense systems.

From a Chinese perspective, future warfare will be shaped by space dominance. Beijing integrates ASAT weapons, ballistic missile defense (BMD) systems, and satellite miniaturization into its broader strategy for military modernization. Some Chinese analysts even consider space weaponization as the third military revolution, positioning space as the linchpin of national security and global military power.

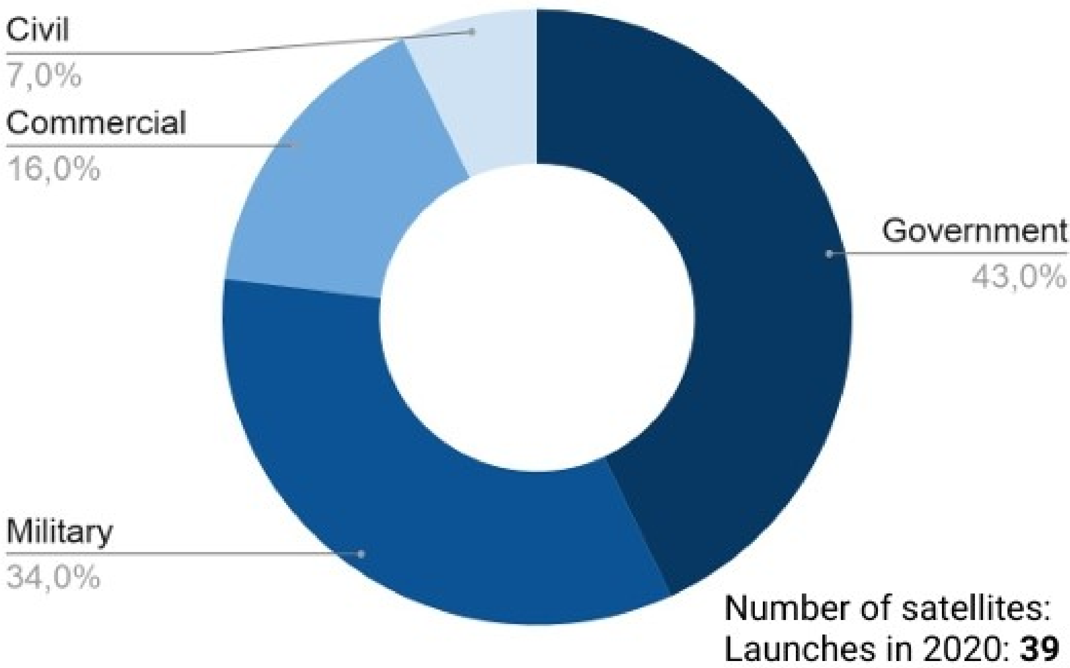

Figure 4.4: Total satellites launched in China till 31.03.19

Source: SpaceTech Industry, SpaceTech Analytics, 2021

China's satellite launch profile reveals a strong strategic focus on military and government space capabilities. As of March 2019, military satellites accounted for a substantial 34% of total launches, second only to government missions at 43%. This high proportion highlights the central role of space-based assets in national defense, surveillance, and strategic autonomy. With 39 satellites launched in 2020 alone, China's rapidly growing space program reflects its ambition to expand both civilian and security-related operations in orbit.

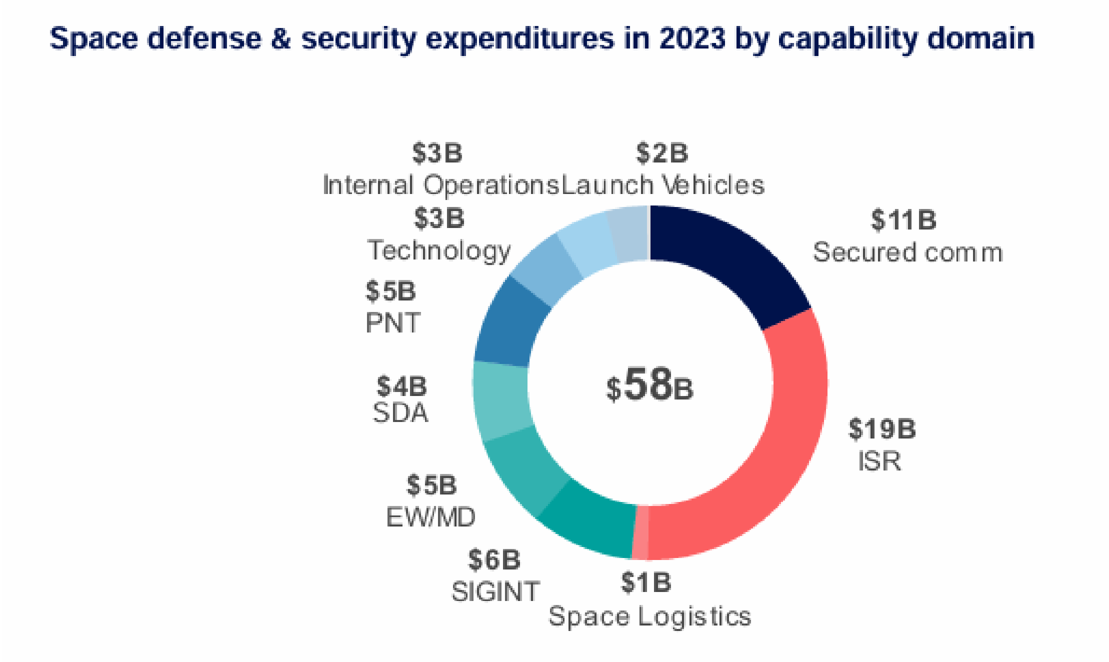

Figure 4.5: Space defense and security expenditures in 2023 by capability domain

Source: Space Defense and Security, Euroconsult report, 2024

In 2023, nearly 50% of the $58 billion in government space defense spending was concentrated in two key capability domains: Intelligence, Surveillance and Reconnaissance (ISR) with $18.8 billion and Secured Satellite Communications (Satcom) with $10.6 billion, reflecting their critical role in enabling modern warfare, intelligence superiority and force projection. Other major areas of spending included Positioning, Navigation and Timing (PNT) at $5 billion, limited to four GNSS-operating powers (US, EU, Russia, China) with partial civil co-funding, Signal Intelligence (SIGINT), Early Warning and Missile Detection (EW/MD), and Space Domain Awareness (SDA) received between $4 and $6 billion each, with investment concentrated in a smaller number of countries.

4.2 The case of India, France and Japan

In addition to the major space powers several other states are developing military space capabilities at lower levels of intensity. Notably, India, Japan, and France have all established modest yet strategically significant military satellite constellations. As of the most recent data, India operates approximately 21 military satellites, Japan maintains 11, and France has a fleet of around 9. While these figures are relatively modest compared to the space superpowers, they nonetheless indicate a clear recognition of the growing strategic utility of space.

These countries emphasize the enhancement of national security, communications, surveillance, and strategic autonomy, while avoiding an overtly competitive or hegemonic approach to the space domain. Moreover, their space strategies are deeply embedded in alliance frameworks, particularly with the United States. Japan and France, both formal allies of the U.S., place considerable emphasis on

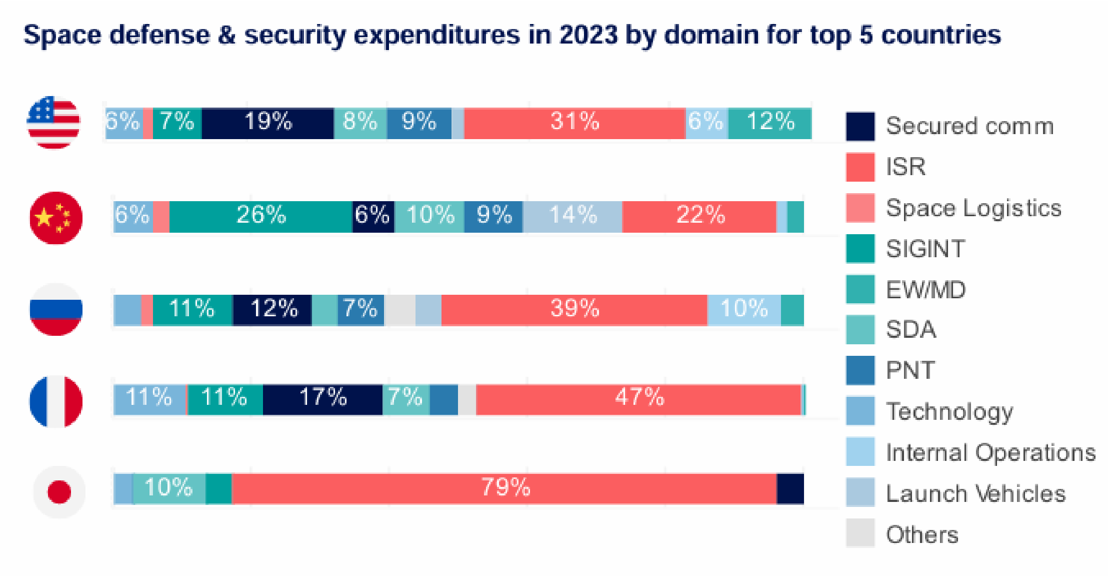

Figure 4.6: Space defence and security expenditures by domain for top 5 countries

Source: Space Defense and Security, Euroconsult report, 2024

The distribution of expenditures by capability domain varies among the top five countries. ISR is dominant across all except Russia, where other priorities prevail. Japan and France have focused on deploying new ISR systems such as IGS and CSO, respectively. The relatively low Japanese investment in Satcom is due to a public-private cost sharing model. Satcom holds greater weight in the US and France, where new military communication satellites like the Transport Layer and Syracuse are being deployed. SIGINT appears to be the leading capability in China, accounting for 26 percent of its total space defense spending. Space Domain Awareness (SDA) is emerging as a key area of interest for all five leading space powers.

the scientific, economic, and security benefits that cooperation with Washington provides. These partnerships reinforce their space capabilities while also aligning them with broader Western security architectures, such as NATO and the U.S.-Japan alliance.

India, though not a formal treaty ally of the United States, has also moved progressively toward closer security collaboration with Washington, particularly since 2011. This evolving relationship is marked by increasing interoperability, joint military exercises, and intelligence sharing. India views cooperation with the U.S. as a means to bolster its technological capacity, access space situational awareness data, and ensure regional stability in the Indo-Pacific, particularly in light of China's assertive behavior. All three states perceive their contributions as adding strategic value to U.S. interests, and by extension, to the alliances and partnerships in which they participate. Their involvement in space security reflects a converging understanding of the importance of resilient space infrastructure, while also signaling a commitment to a rules-based international order in outer space.

4.2.1 India: From Civilian Space Pioneer to Emerging Military Space Power

India's institutional space journey began in 1962 with the establishment of the Indian National Committee for Space Research (INCOSPAR) under the Department of Atomic Energy. This organization evolved into the Indian Space Research Organisation (ISRO) in 1969, and by 1972, it was brought under the newly created Department of Space and Space Commission, positioning space exploration as a national priority. Despite historically modest financial investment in its space sector compared to major powers, India has made substantial progress over the past two decades, emerging as one of the world's leading space-faring nations. ISRO has concentrated on leveraging space technologies for socio-economic development, developing indigenous launch vehicles and a broad range of satellite systems to serve domestic needs, such as telemedicine, agriculture, and distance education. Today, ISRO ranks among the top six space agencies globally, underlining India's ability to deliver cost-effective and reliable space solutions.

During the Cold War, India adopted a non-aligned policy and was a vocal opponent of space militarization. This stance was rooted in India's focus on commercial and developmental space benefits rather than geopolitical competition. However, this approach began to shift in the post-Cold War period. The 2007 Chinese ASAT test in particular marked a turning point, prompting Indian defense planners to reassess the vulnerability of their space assets and the strategic necessity of deterrence capabilities in space.

As a response, India established the Integrated Space Cell in 2008 within the Ministry of Defence to coordinate civilian and military space interests. This was followed in 2019 by the creation of two dedicated organizations: the Defence Space Research Agency (DSRA) and the Defence Space Agency (DSA). The DSRA focuses on developing dual-use technologies and enhancing military utilization of ISRO's capabilities, while the DSA is designed to serve as the military's dedicated space command, laying the groundwork for a potential future 'Aerospace Command'.

India's space militarization trajectory is largely underpinned by the development of dual-use technologies. Many of its earth observation satellites, such as the Cartosat (optical) and RISAT (radar) series, are civilian in origin but serve military reconnaissance functions. Similarly, communication satellites like GSAT-7 and GSAT-7A are explicitly military, while others provide dual-use services. The government further institutionalized the military space architecture in 2018 with the creation of the Defence Space Agency, incorporating existing satellite control and imagery analysis units under a unified command.

India has also made notable progress in ballistic missile defense (BMD), aiming to counter nuclear threats from Pakistan and China. However, unlike the U.S. or Russia, India still relies heavily on ground-based early warning systems, lacking geostationary satellites with infrared sensors capable of real-time missile launch detection.

The most significant milestone in India's military space program came in 2019, when it became the fourth nation to demonstrate an Earth-to-space kinetic anti-satellite (ASAT) weapon. On March 27, 2019, India used a Prithvi Delivery Vehicle Mark-II (PDV MK-II) to destroy its own Microsat-R satellite at an altitude of 282 km. Although the first attempt on February 12 failed, the second succeeded in showcasing India's counter-space capabilities. Following the test, Prime Minister Narendra Modi emphasized that India remained opposed to the weaponization of space, a nuanced stance suggesting that the ASAT capability is perceived as a deterrent rather than an offensive tool.

Supporting this view, Dr. Satheesh Reddy, head of the Defence Research and Development Organisation (DRDO), noted that India was exploring advanced technologies such as directed energy weapons (DEWs), lasers, electromagnetic pulse (EMP) systems, and co-orbital weapons as part of a broader deterrence-based strategy. This marked a clear evolution from India's traditionally civilian-led program to a more militarized and security-conscious approach to space.

In July 2019, India further demonstrated its strategic thinking in space by conducting its first simulated space warfare exercise, IndSpaceEx, designed to assess threats to Indian space assets and evaluate the nation's preparedness for space conflict scenarios.

Thus, while India's space program originated with peaceful, developmental aims, it has undergone a strategic transformation. India now views space militarization as essential to its national security architecture and its emerging great power status, particularly in the context of regional threats and the broader global shift toward contested space domains.

4.2.2 Japan: From Pacifism to Defensive Space Preparedness

Japan's space program has roots extending back to the 1950s, initially focused on scientific and peaceful uses of space. Institutional consolidation came in 2003, with the unification of the Institute of Space and Astronautical Sciences (ISAS), the Japan National Space Development Agency (NASDA), and the National Aerospace Laboratory (NAL) into the Japan Aerospace Exploration Agency (JAXA). This merger aimed to streamline Japan's civilian space efforts under a single national entity. Historically, Japan maintained a pacifist orientation toward space, however, geopolitical developments (most notably China's 2007 ASAT test) prompted a shift in Japan's strategic outlook. In 2008, Japan passed the Basic Space Law, marking a watershed moment by legally permitting national security-related activities in space. This law laid the foundation for Japan's gradual but significant turn toward military utilization of space capabilities.

Japan's 2019 Defense White Paper underscores the evolving threat landscape. It explicitly references China's pursuit of anti-access/area denial (A2/AD) capabilities, including direct-ascent ASATs, co-orbital weapons, jammers, and lasers. The paper identifies these as "critical security challenges" that threaten the stable use of outer space. In response, Japan has committed to improving its space situational awareness (SSA), developing passive defense mechanisms, and investing in the means to disrupt adversarial command and control systems. A central component of this effort is the creation of the Space Domain Mission Unit (SDMU) in 2019, a branch of the Air Self-Defense Force tasked with defending Japan's space assets. The SDMU is responsible for tracking threats, coordinating with JAXA and international partners, and managing counter-space operations. It also supports Japan's increasing emphasis on multi-domain operations, integrating space with cyber, electromagnetic, land, air, and maritime capabilities. While Japan has not formally adopted offensive space capabilities, official statements have not ruled them out. Former Prime Minister Shinzo Abe emphasized that Japan must "adapt to new modes of warfare", and explore the development of active counter-space tools if necessary. The SDMU works closely with both U.S. Space Command and the United States Space Force, highlighting the strategic value Japan places on its alliance with the U.S. as a cornerstone of its space security architecture.

Japan's approach to military space activities remains defensive and deterrent in nature, but the institutional and doctrinal changes since 2008 reflect a decisive pivot towards preparedness in the face of increasing threats in the space domain.

4.2.3 France: Space as a Sovereign Strategic Domain

France operates the third oldest national space program in the world, dating back to 1946, and currently holds the distinction of being the largest space power in Europe. For decades, French space activities focused on civil and scientific objectives, but by the early 2000s, strategic concerns began to shape a more military-oriented perspective. In 2006, France officially declared space a "sector of vital importance" for national security. This marked the start of a doctrinal and structural evolution, culminating in the 2019 Space Defense Strategy. This strategy outlined France's intent to defend itself "in space and through space", leading to the establishment of a Space Command under the Air Force, which was subsequently renamed the Air and Space Force. The 2019 strategy focuses on two primary objectives: Enhancing space situational awareness around French assets, and actively protecting satellites against hostile actions. The policy document makes it clear that France reserves the right to retaliate against acts of aggression in space, asserting its right to self-defense. This represents one of the most explicit commitments by any state to military countermeasures in the space domain.

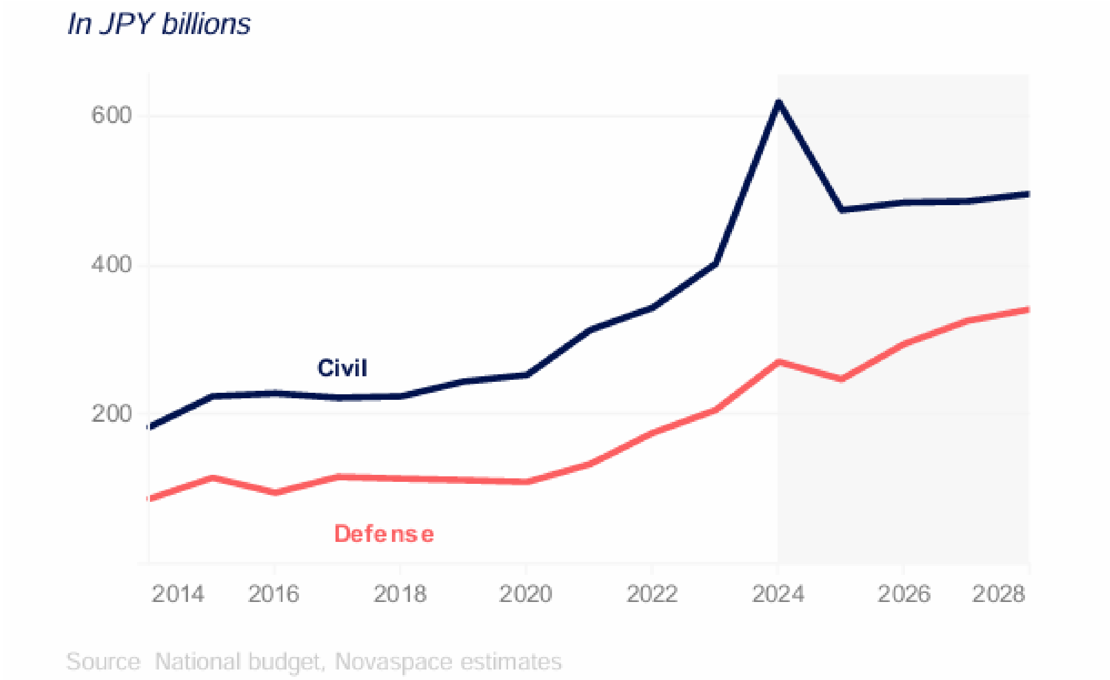

Figure 4.7: Japan governments space expendituresSpace defense and security expenditures in 2023 by capability domain

Source: Space Defense and Security, Euroconsult report, 2024

In 2024, Japan significantly increased its space-related expenditures, allocating ¥894 billion ($6.8 billion), a 46% rise from the previous year. This growth was largely driven by the launch of the Space Strategy Fund, which pledged ¥1 trillion ($7.6 billion), with ¥300 billion already invested across civil and defense sectors. The civil space budget reached ¥621 billion ($4.7 billion), led by a sharp increase in technology spending (¥306 billion, +431%). Other key areas included Earth Observation (ALOS-4, AMSR3), launches, navigation, and meteorology (Himawari program). On the defense side, Japan committed to spending ¥43 trillion over five years, aiming for 2% of GDP in military investment by 2027. For 2024 alone, space defense spending reached ¥272 billion ($2.1 billion), with major allocations to Earth Observation, X-band military communications, and Space Situational Awareness (SSA) initiatives.

Furthermore, Defense Minister Florence Parly publicly confirmed France's intent to develop active defenses, including anti-satellite laser weapons. She stated unequivocally: "If our satellites are threatened, we intend to be able to blind those of our adversaries."[31] France has allocated 4.1 billion euros to its space defense program through 2030, which includes the following key developments: Syracuse satellites equipped with optical sensors for threat identification, laser- and gun-armed satellites capable of disabling adversarial spacecraft, a constellation of nanosatellites designed for rapid threat response and orbital maneuvering. In 2021, France hosted 'AsterX 2021', the first European space-defense exercise involving Germany, Italy, and the U.S., underscoring its leadership role in European military space cooperation.

Notably, France is the only European country to have announced the development of armed nanosatellites for space patrols and has taken a proactive stance on counter-space operations, emphasizing sovereign control and autonomous protection of its orbital assets.

Through its doctrine, investment, and innovation, France is consolidating its position as a leading military space power, uniquely bridging the civil-military divide and affirming space as a strategic domain of national sovereignty.

4.3 The increasing importance of the Moon

At the time of writing, the Moon remains the only celestial body beyond Earth on which human beings have ever set foot. Although American astronauts placed U.S. flags on the lunar surface during the Apollo missions, a gesture often symbolically interpreted as a territorial claim, no nation has formally asserted sovereignty over any part of the Moon. This restraint is rooted in the legal framework established by the 1967 Outer Space Treaty, which explicitly prohibits any national appropriation of outer space, including the Moon, by claim of sovereignty, use, occupation, or any other means. For decades following the conclusion of the Cold War space race and the end of the Apollo program, this principle has remained largely uncontested. However, recent developments suggest that the consensus surrounding the Moon as a domain free from geopolitical rivalry may no longer be assured. The renewed interest in lunar exploration, most notably through the United States' Artemis program, signals a broader shift in how space, in particular the Moon, is being integrated into strategic and geopolitical thinking.

Alongside traditional civilian and scientific motives for space activity, new discourses have emerged that consider the Moon not merely as a site of exploration but as a potentially valuable geopolitical asset. While military interest in near-Earth space is already well established, attention is now expanding toward the Moon itself. Unlike low Earth orbit, where space assets primarily serve terrestrial conflicts through surveillance, communication, and positioning systems, military interest in the Moon is predicated on the assumption that the lunar environment may hold intrinsic strategic value. Despite the continuing legal prohibition of territorial claims under current international space law, a future in which such norms are revised, circumvented, or ignored cannot be excluded. In that scenario, establishing a presence on the Moon may become an instrument for asserting control over valuable zones and resources.

The prospect of militarization on the Moon is not new. As early as 1959, the United States Army conducted Project Horizon, a study evaluating the feasibility of constructing a lunar base that, while ostensibly scientific, would also be capable of supporting military operations. Although the Eisenhower administration ultimately shelved the project, its conceptual legacy persisted, and the idea of a lunar outpost with dual-use capabilities has resurfaced in the context of modern space programs. While the Cold War ended without such projects coming to fruition, the Artemis program has contributed to reviving these strategic imaginaries. Beyond Artemis itself, the United States has announced plans for over a hundred lunar missions by 2030, many driven by commercial actors, yet interwoven with broader national space priorities. In 2022, this trend took on an explicitly strategic dimension when the U.S. Congress allocated funds for lunar-related projects under the auspices of the U.S. Space Force. Although the initial sum of $61 million is modest in comparison to either civilian space budgets or military expenditures, it marks a shift in institutional focus. As emphasized by Space Force Colonel Eric Felt in an interview with Politico, the U.S. military "clearly envisions" a future in which operations in lunar space will become increasingly relevant.

In this evolving context, the Moon appears less as a neutral celestial body and more as a potential arena for great-power competition. The Artemis Accords, initiated by the United States to foster a cooperative legal and normative framework for lunar exploration, have yet to receive endorsement from several key spacefaring nations, most notably China and Russia. The hesitancy or outright refusal to adhere to these accords raises fundamental questions about the future of space governance and the principle of res communis: the idea that space is the province of all humankind. The re-emergence of the Moon as a focal point of international interest, and the potential erosion of legal norms surrounding non-appropriation, suggest that decisions made in the next decade will be decisive. Whether the Moon becomes a platform for peaceful cooperation and shared scientific progress or a contested zone marked by unilateral interests and military footholds remains to be seen.

What is clear, however, is that major space powers, including the United States, Russia, China, and increasingly India, are directing significant attention and resources toward the Moon. A particularly coveted target is the lunar south pole, an area of heightened interest due to the likely presence of water ice in permanently shadowed regions and its potential for providing continuous solar energy. These characteristics make the south pole a prime candidate not only for scientific research and human settlement but also for geopolitical maneuvering. NASA has publicly expressed concerns regarding China's lunar ambitions, specifically the possibility that ostensibly peaceful missions could be used to justify the deployment of strategic infrastructure on the Moon.

At present, only four nations have successfully landed spacecraft on the Moon: the United States through the Apollo missions, the Soviet Union with its Luna program, China with the Chang'e program, and more recently India through its Chandrayaan missions. The race to the Moon has thus re-emerged not simply as a pursuit of knowledge or a symbolic return to humanity's most distant physical frontier, but as a multi-dimensional competition with significant consequences. The Moon offers not only scientific and technological benefits but also strategic, commercial, and even ideological opportunities. In this context, lunar exploration is becoming a key indicator of spacepower. The choices made in relation to the Moon will, therefore, define not only the future of space exploration but also the norms and power dynamics of the coming space age.

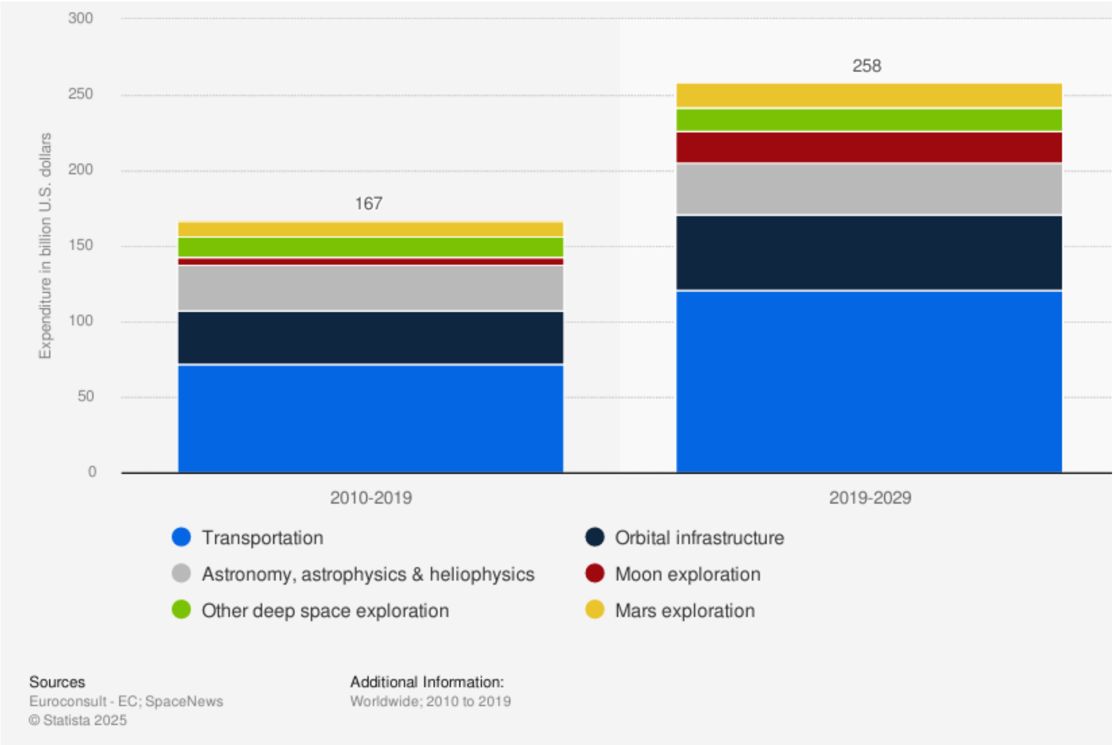

Figure 4.8: Government investments on space exploration worldwide from 2010 to 2029 by type

The chart shows a general increase in government investment, rising from $167 billion during 2010–2019 to a projected $258 billion for 2019–2029. Government investments will increase in this decade in all sectors, but the interesting fact is the growing funding for Moon and Mars exploration (in red and yellow). Moon's exploratgion budget exceeds also the budget allocated to other deep space exploration, highlighting how these celestial bodies are becoming increasingly central to national space agendas, both from scientific and geopolitical standpoints.

4.3.1 The importance of partnership

We can assume the USA as an example, but also other space powers can gain the same benefits of Usa through collaborations.

Through the Artemis Accords and a range of international collaborations regarding the Artemis program, the United States is strategically reinforcing its ties with partner nations in the space domain. This approach enables the U.S. to distribute key responsibilities among allies, allowing domestic efforts to focus on specific high-priority areas. This model of cooperation brings with it both geopolitical advantages and vulnerabilities. On the one hand, pooling resources enhances efficiency and strengthens political and technological bonds among participants, collectively sharing the burden of complex projects such as a lunar landing. On the other hand, it creates a degree of strategic dependence on foreign actors, whose contributions may not be easily or quickly replaceable in the event of diplomatic friction. A historical example of this vulnerability occurred between 2011 and 2020, when the retirement of the Space Shuttle left the United States without an independent means of crewed access to space. During this period, the U.S. had to rely entirely on Russian Soyuz launches. Had this still been the case in 2023, given the significant deterioration in U.S.–Russia relations following the war in Ukraine, U.S. human spaceflight efforts could have faced serious jeopardy.

For international partners, participation in the Artemis program offers a rare and prestigious opportunity. Very few countries possess the capability to conduct crewed spaceflight independently, and even fewer have the technical and financial capacity to undertake lunar missions. Through Artemis, nations with more modest space programs gain access not only to lunar exploration infrastructure but also the potential to send their own astronauts into lunar orbit or to the Moon's surface. Beyond the scientific returns, such involvement carries considerable symbolic and geopolitical value. Nevertheless, these partner nations must accept a framework defined by the Artemis Accords, which often entails a degree of strategic alignment with U.S. space policy. As a result, access to the Moon and participation in future lunar missions may become increasingly tied to U.S. leadership and vision, potentially reinforcing a form of asymmetrical dependence in the emerging space order.

Meanwhile, alternative models of cooperation are also taking shape. In 2021, China and Russia announced the joint development of the International Lunar Research Station (ILRS), envisioned as a long-term base for scientific exploration near the Moon's south pole. This program is explicitly positioned as a multilateral initiative outside the scope of the Artemis Accords and is open to participation from countries that prefer a non-Western approach to space governance. China, in particular, has already demonstrated its capacity for independent lunar exploration through its Chang'e missions, while Russia brings decades of experience in robotic and human spaceflight. The ILRS aims to rival Artemis both technologically and diplomatically, offering an alternative space bloc for countries that may be unwilling or unable to align with the United States.

In a world that is becoming progressively more multipolar, there is also the possibility that major space actors such as China will propose competing lunar programs. These initiatives may require exclusive participation, effectively forcing states to choose between rival blocs. In this context, space policy is no longer a purely scientific or technological domain, but is closely intertwined with broader geopolitical dynamics. As space infrastructure becomes more central to global power projection, states will need to adopt carefully calibrated strategies to manage both the opportunities and constraints of international space cooperation.

4.3.2 The importance of commercialization

A key benefit for space powers in pursuing a sustained presence on the Moon lies in the integration of commercial actors into lunar missions. This strategy serves multiple objectives: it promotes cost-efficiency through domestic market competition, expands opportunities for private sector involvement in space exploration, and ultimately enhances a nation's overall capacity to access and utilise the lunar environment.

The use of commercial enterprises fosters innovation and technical advancement, as competition among private contractors is widely seen as a catalyst for both creativity and efficiency. This model, now increasingly adopted by major spacefaring nations, mirrors previous initiatives aimed at reducing the cost of access to low-Earth orbit and is being extended to lunar exploration. Should these cost reductions succeed, the Moon would become significantly more accessible not only to states but also to non-governmental entities, thereby accelerating scientific, technological, and even economic activity on the lunar surface.

Moreover, by enabling private actors to deliver payloads to the Moon, a space power effectively multiplies the number of missions, technologies, and experiments being deployed, including those beyond traditional government-led initiatives. This diversification contributes to a more robust and sustainable presence on the Moon and enhances the scientific return of lunar exploration.

However, such commercial involvement also introduces legal and geopolitical complexities. Under international frameworks such as the Outer Space Treaty, the state remains legally responsible for the activities of its commercial entities in space. Thus, a space power must ensure that its private sector complies with international norms, especially regarding resource extraction and non-appropriation principles. While current interpretations of lunar resource use strive to remain within legal bounds, some critics suggest that increased commercial exploitation may eventually challenge existing space law, potentially prompting shifts in the international regulatory regime.

Ultimately, the commercialization of lunar access represents a powerful tool for space powers, not only to enhance their strategic and scientific footprint on the Moon, but also to shape the future norms and structures governing lunar activities. If successful, it may establish long-term technological leadership, economic benefit, and geopolitical influence in the emerging lunar domain.

4.3.3 Long-term implications

Profitable exploitation of lunar resources is unlikely to become viable in the near term; however, laying the groundwork through extensive infrastructure development is essential for any future success. Establishing reliable access to the Moon, and, by extension, to other celestial bodies, requires a robust network of launch vehicles, habitable platforms, lunar landers, and associated technologies. Programs such as Artemis, together with its complementary initiatives represent substantial investments in building this critical infrastructure.

Should the Moon become materially profitable, the states that have laid early groundwork may enjoy significant first-mover advantages. This could lead to increased geopolitical competition, possibly evolving into a "scramble for the Moon," where space powers seek to secure key lunar sites or resources. Scholars such as Everett Dolman and Daniel Deudney have theorised that such competition could escalate into political or military tensions, particularly in the absence of robust legal frameworks to manage territorial and resource disputes on the lunar surface.

Moreover, the infrastructures developed for lunar exploitation are inherently dual-use: while designed for peaceful purposes, they can also support military posturing or serve as a strategic buffer in broader geopolitical contexts. A permanent or semi-autonomous presence beyond Earth could help spacefaring states secure access to critical domains, respond to threats more flexibly, and potentially gain asymmetric strategic leverage over rivals. In more speculative terms, the ability to control extraterrestrial resources could even be militarised, as Deudney warns, through mechanisms such as kinetic strikes or strategic positioning of orbital assets, underscoring the potential for outer space to become an extension of terrestrial power politics.

Although current programs are not explicitly intended to establish unilateral dominion or to turn the Moon into a profit center, the long-term consequences of these investments raise critical policy questions. For instance, new international legislation may be required to ensure an orderly and peaceful regime for resource distribution in outer space. At the same time, there is a risk that control over deep-space resources could eventually be weaponized, as warned by theorists who discuss the possibility of "planetoid bombs" or other forms of resource-based strategic coercion.

In essence, while the Artemis program is not a deliberate attempt to monopolize outer space, the maturation of these infrastructure investments could eventually redefine the global balance of power. Whether outer space continues to be managed as a res communis dedicated solely to peaceful and scientific purposes or evolves into a competitive arena for resource extraction (res nullius) will depend on how these early initiatives develop. Ultimately, if humanity establishes a long-term, self-sustaining presence on the Moon then the strategic, economic, and geopolitical concerns raised by such endeavors will need to be addressed with increasing urgency.

4.4 China, Usa, India and Russia programs on the moon

The motivations driving national space programs have historically ranged from demonstrating technological capability and strategic power to fostering national prestige and morale. In recent years, however, new priorities have emerged, particularly the pursuit of sustainability and cost efficiency. These objectives not only facilitate continued political support by containing budgets, but also increase a state's operational capacity in space by enabling more missions at lower cost.

In parallel, the development of infrastructure to support future space expansion suggests that some space powers are motivated not solely by exploration or scientific goals, but also by the prospect of eventual economic return. Technologies such as In-Situ Resource Utilization (ISRU) and surface habitats indicate a clear intention to prepare for potential exploitation of extraterrestrial resources. While such ambitions are speculative and may not be economically viable in the near term, the investments being made today may give early participants a considerable advantage in the future. These developments also raise questions about the legal and normative frameworks governing outer space. If the commercial exploitation of the Moon or other celestial bodies becomes profitable, existing principles like res communis may be challenged in favor of more competitive, resource-driven interpretations.

In this light, current lunar programs are not just scientific or diplomatic ventures, they are strategic investments in future capabilities. Whether framed by cooperation or competition, the long-term impacts of these efforts will shape the trajectory of human activity in space for decades to come.

4.4.1 Artemis program

China's growing ambitions in space were one of the key drivers behind the 2017 decision by then-President Donald Trump to launch a new lunar program, now known as Artemis. While the program formally set the goal of landing humans on the Moon by 2024, its deeper origins can be traced back over two decades of planning to replace the Space Shuttle and continue the legacy of Apollo.

Artemis centers on sending humans back to the Moon, but this time with a broader vision: to lay the foundation for sustained lunar presence and to prepare for future crewed missions to Mars. It brings together efforts from NASA, the

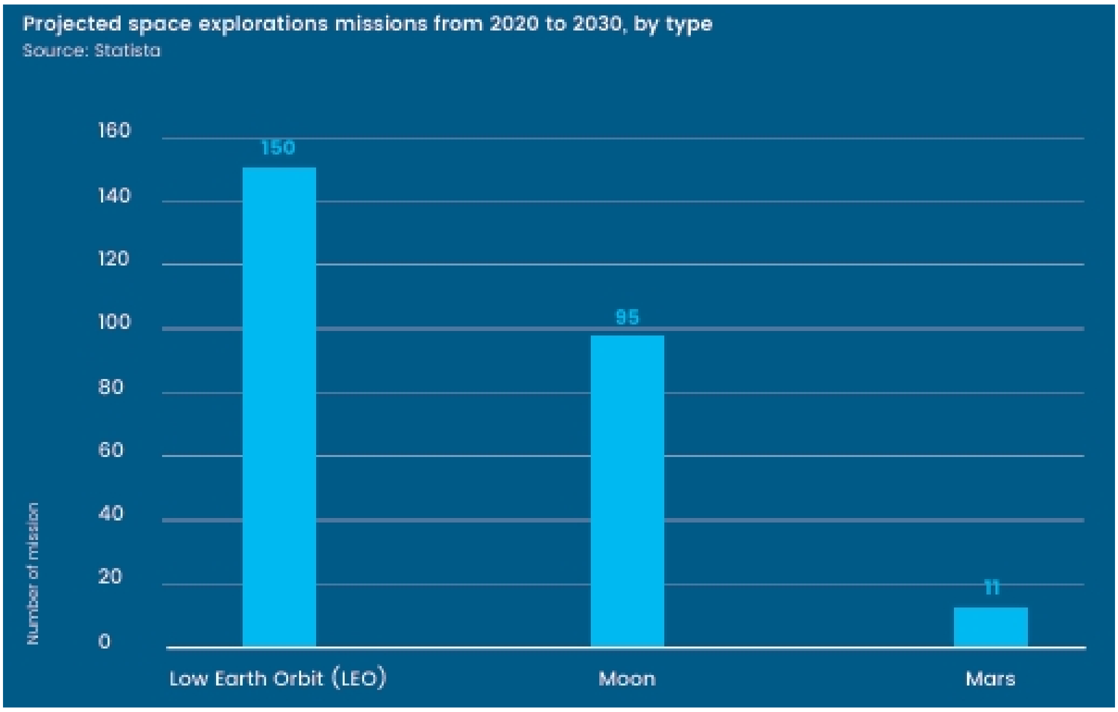

Figure 4.9: Projected space exploration missions from 2020 to 2030 by type

The projected space exploration missions from 2020 to 2030 are primarily focused on Low Earth Orbit (LEO), with 150 missions, compared to 95 targeting the Moon and 11 headed to Mars. Despite their lower numbers, lunar and Martian missions account for a substantial portion of global space exploration budgets due to their high technological complexity and scientific ambition. At the same time, the high volume of LEO missions reflects the rising demand for satellite infrastructure supporting GNSS (Global Navigation Satellite Systems) and Earth Observation (EO)

U.S. Space Force, private aerospace companies, and international partners in a large-scale initiative that blends science, strategy, and diplomacy.

Unlike Apollo, Artemis is not about planting a flag and returning home. Its aim is to establish a sustainable and long-term human presence on the Moon. The vision includes creating a cislunar economy supported by scientific infrastructure, international cooperation, and the ability to use local resources (such as water ice) for life support and fuel production. The Moon is seen as a proving ground for technologies, systems, and human survival strategies that will later be used on Mars. This concept, often called "Moon to Mars," is central to NASA's long-term roadmap, with crewed Mars missions tentatively envisioned for the 2030s. The motivations behind Artemis are both scientific and geopolitical. On the one hand, the program seeks to test advanced systems for deep space exploration (life support, resource extraction (ISRU), mobility, and transportation) that are crucial for longer, more complex missions. The Moon offers a nearby and relatively controlled environment to train for the far more challenging Martian surface. On the other hand, Artemis plays a key geopolitical role. In a new era of global competition, especially with China and Russia actively advancing their own lunar ambitions, the United States aims to reaffirm its leadership in space exploration. This strategic vision is also reflected in the Artemis Accords: Artemis is not just a space program, it's also a tool of soft power, shaping the norms and values that will govern the future of space activity.

Artemis is structured into several key phases. Artemis I, launched in November 2022, was an uncrewed mission that successfully tested the new Space Launch System (SLS) and Orion spacecraft on a lunar flyby, paving the way for human flights. Artemis II, expected in 2025, will be the first crewed mission to orbit the Moon in over 50 years. While astronauts will not land, they will perform a fly-by and test all systems in real spaceflight conditions. Artemis III, tentatively scheduled for 2026 or later, will mark the return of humans to the lunar surface. Two astronauts are expected to land near the Moon's south pole, a region of high scientific interest due to the presence of water ice, which could be crucial for future missions. Artemis IV, currently planned for 2028, will deliver the first major components of the Lunar Gateway (a small, modular space station in lunar orbit) using the more powerful Block 1B version of the SLS rocket. The crew will dock at the Gateway and continue testing long-duration systems in preparation for sustained lunar presence. Artemis V, projected for no earlier than 2029, will combine the use of the Gateway and a lunar landing with new hardware and international contributions, such as the ESA-built ESPRIT module. This mission will deliver additional components to the Gateway and conduct further exploration on the Moon's surface. Artemis VI and VII, scheduled for the early 2030s, aim to expand lunar infrastructure and test technologies essential for Mars missions, including more frequent surface stays, resource utilization, and habitat construction. These later missions represent the transition from short-term exploration to the establishment of a sustained lunar presence.

In parallel, NASA and its partners are developing the Lunar Gateway, a space station that will orbit the Moon and serve as a staging point for future missions. Plans are also underway for surface habitats to support increasingly long stays. The Artemis program is designed to kickstart a new space era, not just of exploration, but of permanence. It seeks to create a lasting space ecosystem that can support missions to Mars and eventually even deeper into the solar system. At the same time, Artemis drives innovation in areas like robotics, AI, energy systems, and miniaturization, with dual-use applications that will benefit Earth's economy as well. From a geopolitical perspective, the success or failure of Artemis may determine who sets the rules and reaps the benefits of the 21st-century space economy. In a world increasingly shaped by multipolar power dynamics, the Moon has become a symbolic and strategic frontier. Whoever gets there first, not just physically, but with lasting infrastructure, will hold a decisive advantage in shaping the next phase of human space activity

4.4.2 Chandrayaan program

India's growing involvement in space exploration reflects a broader ambition to establish itself as a leading space power on the global stage. Through the Indian Space Research Organisation (ISRO), the country has developed and successfully carried out a series of ambitious programs that cover multiple domains of space exploration: lunar exploration (Chandrayaan), human spaceflight (Gaganyaan), and interplanetary missions (Mangalyaan). Each of these programs showcases not only India's scientific and technological prowess, but also its strategic intent to build long-term capabilities in space.

The Chandrayaan program marks India's contribution to lunar exploration. The first mission, Chandrayaan-1, launched in 2008, aimed to map the Moon in three dimensions and conduct high-resolution chemical and mineralogical surveys. Among its most notable achievements was the discovery of water molecules and hydroxyl groups on the lunar surface, as well as confirmation of ice deposits in the lunar north pole. Though communication with the spacecraft was lost earlier than expected, the mission was hailed as a major scientific success. Building on this, Chandrayaan-2, launched in 2019, featured a more complex mission profile including an orbiter, a lander (Vikram), and a rover (Pragyan). While the lander failed to execute a soft landing due to a last-minute anomaly, the orbiter has remained fully functional and continues to send back valuable data, most notably confirming the widespread presence of water molecules across all lunar latitudes. This mission, though only partially successful, significantly advanced India's technological expertise in lunar operations. The third and most recent installment, Chandrayaan-3, launched in 2023, marked a major milestone: India became the first country to achieve a successful soft landing near the lunar South Pole. This region holds great scientific interest due to its potential reserves of water ice, a crucial resource for future space missions. The lander and rover operated for one lunar day (about 14 Earth days), completing their scientific objectives, including thermal measurements, seismic activity analysis, and environmental studies. With Chandrayaan-3, India not only demonstrated its growing technical competence but also positioned itself as a serious contender in the new era of lunar exploration.

Looking ahead, ISRO has expressed intentions to move toward lunar sample return missions, which would represent a substantial leap in mission complexity and capability. Moreover, India is collaborating with Japan on the upcoming LUPEX mission (Lunar Polar Exploration), set for launch between 2026 and 2028. The mission will further investigate the South Pole's ice deposits, with India providing the lander and Japan contributing the rover and launcher. These developments underline India's growing role in international space partnerships and its interest in future in-situ resource utilization (ISRU), an approach that could eventually support a sustainable human presence on the Moon.

Parallel to its lunar ambitions, ISRO is actively developing the Gaganyaan program, India's first human spaceflight initiative. The program is expected to carry out its first uncrewed test flight in 2025, followed by a crewed mission potentially as early as 2026. Gaganyaan signifies an important step toward building sovereign human spaceflight capabilities, and may eventually tie into lunar or even interplanetary missions in the longer term.

India has also made its mark beyond Earth and Moon. In 2013, it launched the Mars Orbiter Mission, also known as Mangalyaan, becoming the first Asian country to reach Mars and the first nation in the world to do so on its first attempt. Operated for nearly eight years, Mangalyaan became a symbol of India's ingenuity and cost-efficiency in space exploration. Although the mission officially ended in 2022, its legacy continues to influence India's planetary science endeavors. Together, the Chandrayaan, Gaganyaan, and Mangalyaan programs demonstrate how India has transitioned from a spacefaring newcomer to an increasingly central actor in global space activities. These programs are not only driven by scientific curiosity but are also tightly connected to geopolitical strategy, economic opportunity, and national prestige. With these advancements, India is paving its own path in the broader narrative of space exploration and shaping its future role in the off-world frontier.

4.4.3 Chang'e program

China's Chang'e lunar program represents one of the most structured and ambitious efforts in the contemporary landscape of space exploration. Officially approved in 2004 by the Chinese government and developed under the coordination of the China National Space Administration (CNSA), the Chang'e program embodies a phased, incremental approach aimed at gradually mastering the scientific, technological, and operational challenges of lunar exploration. From its earliest missions, China has adopted a methodical path, starting with orbital observations before advancing to surface operations, sample returns, and preparations for a long-term human presence on the Moon.

Chang'e-1 and Chang'e-2, launched respectively in 2007 and 2010, were focused on obtaining detailed topographic and mineralogical data of the lunar surface, which not only enriched our understanding of the Moon but also laid the foundation for future landings.

Chang'e-2 also served as a stepping stone for interplanetary missions, performing a flyby of the asteroid 4179 Toutatis and demonstrating China's growing technical capabilities beyond cislunar space. With Chang'e-3 in 2013, China achieved its first soft landing on the Moon, joining the ranks of the United States and the former

Soviet Union. This mission successfully deployed the Yutu (Jade Rabbit) rover, which conducted surface analyses, despite encountering early mechanical issues.

The 2018 Chang'e-4 mission marked a global milestone as the first spacecraft to soft-land on the far side of the Moon, a feat made possible by the deployment of the Queqiao relay satellite to maintain communication with Earth. Its rover, Yutu-2, remains operational well beyond initial expectations and continues to return valuable scientific data. In 2020, the Chang'e-5 mission carried out the first lunar sample return in over four decades, collecting 1.73 kilograms of lunar soil and demonstrating China's proficiency in complex maneuvers such as automated drilling, surface ascent, and Earth re-entry. Most recently, in 2024, Chang'e-6 achieved the first-ever sample return from the far side of the Moon, specifically the South Pole–Aitken Basin, once again relying on a relay satellite (Queqiao-2) to maintain continuous communication. Future missions, including Chang'e-7 and Chang'e-8, are already in development and aim to search for water ice, test in-situ resource utilization technologies, and lay the technological and infrastructural groundwork for the construction of a robotic lunar base at the South Pole. These efforts are linked to the larger international project known as the International Lunar Research Station (ILRS), which China is co-developing with Russia. This long-term strategy reveals that China does not view the Moon solely as a site for scientific inquiry, but rather as a multifaceted platform for asserting technological leadership, gaining strategic advantage, and pursuing potential commercial opportunities.

China's vision for the Moon is deeply interwoven with geopolitical ambitions. The Chang'e program is part of a broader framework through which Beijing seeks to establish itself as a dominant actor in the emerging multipolar space order. Unlike the United States and its allies, who promote inclusive and multilateral initiatives such as the Artemis Accords, China has opted for a model of selective cooperation, cultivating bilateral relationships with countries outside the Western sphere.

The decision to reject participation in the Artemis program and instead advance its own cooperative model through ILRS highlights China's intent to consolidate a distinct space bloc composed primarily of non-Western nations. This approach serves not only to showcase China's technological independence but also to challenge existing norms and governance structures in outer space.

The Moon, in this context, is perceived as both a critical resource frontier and a symbolic battleground for influence, particularly its South Pole, which is considered essential for future sustainable presence due to the presence of water ice in shadowed craters and regions of prolonged sunlight ideal for solar power generation.

China's ambitions also extend beyond the Moon. Although its first attempt at a Mars mission (Yinghuo-1, launched in collaboration with Russia in 2011) failed, the experience contributed to the eventual success of Tianwen-1 in 2020.

This mission, which included an orbiter, lander, and rover, culminated in China becoming the third country to land a spacecraft on Mars and successfully operate it on the surface. This demonstrates a long-term strategic alignment between lunar exploration and interplanetary expansion. Just as the United States and India see the Moon as a stepping stone to Mars, so too does China envision it as a launchpad for deeper ventures into the solar system.

Ultimately, the Chang'e program should be interpreted not simply as a scientific initiative, but as a key pillar in China's broader project of geopolitical positioning and international leadership. By combining technological prowess with an alternative vision of international cooperation, China is asserting itself as a central actor in shaping the future of lunar and deep space exploration.

4.4.4 Luna program

The Luna program represents Russia's ongoing commitment, first as the Soviet Union and now as the Russian Federation, to maintain a significant presence in lunar exploration. Its origins date back to the 1950s and 1960s, when the USSR was a pioneer in early robotic lunar missions. After decades of dormancy, Russia has revived the program with the goal of reaffirming its position in the global space landscape and contributing to the future of human lunar exploration. During the Soviet era, the Luna program was at the forefront of space exploration: between 1959 and 1976, 24 robotic missions were launched with varying degrees of success. The Soviet program achieved numerous historic firsts, including the first controlled impact on the Moon (Luna 2, 1959), the first images of the far side of the Moon (Luna 3, 1959), and the first probes to make soft landings and return lunar samples to Earth (Luna 9, Luna 16, Luna 24). These missions made significant contributions to early lunar science and laid the groundwork for increasingly complex operations. Following the collapse of the Soviet Union in 1991, Russia's space programs faced severe funding and priority constraints. However, since the 2000s, Roscosmos has relaunched the Luna program as part of a long-term strategy to return to the Moon systematically. This revival comes in the context of renewed international competition in space and growing strategic interest in lunar resources, particularly those located near the Moon's south pole.

The first mission of the new generation, Luna 25, was launched in 2023 after several delays. The lander was designed to perform a soft landing near the Boguslawsky crater, but due to a control system anomaly during descent, the mission ended in a crash landing. Despite the failure, Luna 25 represented a symbolic step forward for Russia, marking its return to lunar missions after nearly fifty years. Looking ahead, Roscosmos plans several more missions under the Luna program. Luna 26, expected around 2027, will be an orbiter designed to map the lunar surface and identify potential landing sites for future missions. Following that, Luna 27, in collaboration with the European Space Agency (ESA), will attempt another landing to test drilling and soil sampling technologies, with the goal of studying the presence of water and volatile materials in the lunar subsurface. Luna 28 (sometimes called Luna-Grunt) is envisioned as a sample return mission that would bring lunar material back to Earth, further solidifying Russia's operational capabilities.

These missions are part of a broader strategic vision that includes the creation of an automated base at the Moon's south pole by the 2030s, potentially supporting human missions in the future. Russia has also discussed cooperation with China in the framework of the International Lunar Research Station (ILRS), a joint project aimed at building a permanent scientific infrastructure on the lunar surface. The Luna program is not merely a scientific initiative but also a tool of geopolitical projection. In an era of major power competition in space, Russia aims to demonstrate its technological independence and the continuity of its space legacy. Although economic challenges and international sanctions have slowed progress, Moscow continues to view the Moon as a key element in its long-term strategy, scientifically, strategically, and symbolically.

Through the Luna program, Russia seeks to revive its space heritage and actively participate in the new chapter of lunar exploration, aiming for a central role in future international missions and sustainable access to the Moon's natural resources.

4.4.5 Analysis of differences and similarities between programs

Lunar exploration is essential for all four space powers. While the programs share similar objectives, they stem from different strategic, technological, and geopolitical backgrounds. We can analyze their differences and similarities across five key dimensions: political ambitions, technology, international cooperation, military relevance, and commercial development. All of them converge on one point: the increasing importance of a new lunar era.

- **Political Ambitions:**Chang'e and Artemis represent two contrasting visions. Chang'e reflects China's ambition to become a dominant space power and assert its leadership, particularly within the Asian sphere. In response, the Artemis program was launched with the intent of countering China's expansion. Artemis aims to consolidate U.S. leadership in space, which has been increasingly challenged by rising powers like India and China.

  The Luna and Chandrayaan programs operate on a different level. Chandrayaan mirrors India's strategy to emerge as a key space power, with growing political ambition, but without adopting a confrontational stance. India's goals center on prestige, soft power, and scientific credibility on the global stage. Russia, on the other hand, is seeking to reclaim lost ground following the collapse of the USSR and its recent geopolitical isolation due to the war in Ukraine. The Luna program represents an attempt to reassert Russia's role in space exploration.

- **Technological and Scientific Approach:**From a technological standpoint, Chang'e and Artemis are the most advanced. Chang'e is focused on building autonomous lunar infrastructure, aiming for long-term sustainability and self-reliance. Artemis, meanwhile, emphasizes human presence both on the Moon and in lunar orbit, through projects like the Lunar Gateway and partnerships with commercial landers. Both programs are technologically complex and highly ambitious.

  Chandrayaan, while operating with more limited resources, has achieved significant results. Its approach is cost-effective and focused on incremental progress, moving step by step toward more complex missions.

  Russia's Luna program lags behind in comparison. After decades of inactivity in lunar exploration, Luna represents a return to the Moon with the intent of rebuilding lost technological expertise and re-establishing scientific capabilities.

- **International Cooperation:**China promotes a geopolitically selective form of cooperation, focusing on partnerships with Russia and countries of the Global South that are generally outside Western influence. Unlike Russia, which has fewer space partners and mostly relies on China, China is attempting to shape an alternative governance model for space through initiatives like the International Lunar Research Station (ILRS), a joint lunar base project with Russia that serves as a counterproposal to the U.S.-led Artemis Accords.

  The United States, with Artemis, is building a broad coalition of partners including ESA (Europe), JAXA (Japan), CSA (Canada), Brazil, Australia, and others. Artemis aims not only to return humans to the Moon, but to define the future rules of space governance. The U.S. envisions itself as the leader of this new lunar order.

  India, through Chandrayaan, maintains a non-aligned strategy. It collaborates bilaterally with several countries, including Japan, France, and the United States, while preserving strategic autonomy and avoiding alignment with any specific political bloc.

- **Military Dimension:**From a military perspective, the Luna program is closely tied to the Russian state and military. Roscosmos maintains strong links with the armed forces, and the lunar program is part of a broader strategic vision that includes control over orbital infrastructure and future lunar outposts.

Chang'e is formally managed by the civilian China National Space Administration (CNSA), but it also cooperates with the People's Liberation Army (PLA). The lunar infrastructure being developed could have dual-use capabilities, blending civilian and military applications.

Similarly, while Artemis is led by NASA and officially civilian in nature, it includes strategic collaborations with the U.S. Space Force. Critical infrastructure development, protection of lunar assets, and deterrence strategies indicate a growing defense component in the program.

Chandrayaan has a less explicit military dimension, but there is a degree of civilian-military overlap. ISRO collaborates with the Defence Research and Development Organisation (DRDO), and the development of advanced orbital capabilities has clear strategic implications.

- **Commercial Dimension:**Chang'e, Luna, and Chandrayaan all show limited but growing engagement with private industry. China maintains a highly centralized state model but is gradually encouraging private sector involvement. In Russia, international sanctions have severely restricted the development of a private lunar economy. India has recently introduced reforms aimed at liberalizing its space sector and attracting private investment.

  Artemis stands out as the most commercially open and dynamic program. NASA contracts key components (such as landers, cargo delivery systems, and scientific payloads) to private companies including SpaceX, Blue Origin, and Astrobotic. Artemis is designed not only as an exploration initiative but as a catalyst for the emerging lunar economy.

Chapter 5

Implications of the space militarization

5.1 Geopolitics of the space world

The space race, which began in the 1950s, had a strong political and ideological connotation. Throughout the Cold War, each success achieved by the political-military blocs was celebrated as a victory of one ideology over the other. Over the past forty years, the international community has increasingly recognized that geopolitics significantly influences and can even pose risks to global space activities. This awareness stems from the crucial role that space technology plays in modern military strategies. To counter the space-based advantages of potential adversaries, countries are investing in capabilities designed to disrupt, disable, or even destroy satellites.

Today, geopolitical tensions on Earth are reflected in space, raising the possibility of hostile actions targeting space systems. On one side stands the Russian-Chinese technological alliance, which recently consolidated the foundation for a future permanent lunar station, extending an invitation to India to join. On the other side are NASA and the Artemis Accords, with their principles for cooperation in the peaceful exploration and utilization of the Moon, Mars, comets, and asteroids. Initiated in 2020 with the support of space agencies from Australia, Canada, Italy, Japan, Luxembourg, the United Arab Emirates, and the United Kingdom, the agreements have since been signed by agencies from Ukraine, South Korea, New Zealand, Brazil, Poland, Mexico, and Israel. While the European Space Agency (ESA) has only signed a memorandum of understanding with NASA regarding the agreements, it still participates in the Artemis Program.

This dynamic indicates the emergence of two space blocs, marking a shift towards a new global power structure. On one side, a continental bloc unites Russia, China, and potentially India; on the other, a maritime bloc led by the United States, the United Kingdom, and Japan, with partial European participation. This division reflects a broader power competition, justified by political leaders as necessary to protect space assets from potential threats or attacks. A clear example is the security dilemma involving India and Japan, which officially began using space for military purposes after China conducted an anti-satellite (ASAT) test. Both countries felt threatened by Beijing's actions and sought to bolster their security. Conversely, China justified its military space development as essential to counter potential U.S. actions, while the U.S. itself established the Space Force partly out of concern about being outpaced by Russia and China.

Deterrence strategies are increasingly present within this international landscape. Countries investing in kinetic weapons, directed energy weapons, or electronic warfare argue that these measures are meant to dissuade adversaries by demonstrating that the cost of attack would outweigh the potential gains. The United States, for instance, aims to convince potential opponents that any attack on American space assets would be futile. Similarly, North Korea's pursuit of such capabilities appears motivated by the desire to deter U.S. aggression, while Russia has explicitly warned Washington of reciprocal measures to balance American space superiority. In this context, we are entering a new era of power competition, shaped by escalating geopolitical tensions and the emergence of new spheres of influence beyond the United States. China and Russia challenge U.S. space supremacy by advancing their own counter-space capabilities, seeking to strengthen national power, extend influence, and establish alliances akin to those formed over terrestrial geopolitics. Japan, meanwhile, values its alliance with the United States and prioritizes securing its space systems. The political and technological rivalry between major space powers underscores the notion that space dominance is increasingly critical not only for economic and military power but also for securing strategic advantages on Earth. Therefore, the United States remains committed to maintaining its leadership in space, seeing it as vital to safeguarding national interests and projecting power on the global stage.

5.2 Asat problem

Militarization and weaponization of space are often used interchangeably, but they have distinct meanings. The militarization of space refers to the use of space-based assets for military purposes without necessarily deploying weapons into orbit. This process began with the launch of the first communication satellites, which military forces worldwide have utilized for command and control, communication, surveillance, early warning, and navigation through systems like GPS. In this sense, space has been militarized for decades, as armed forces have integrated space-based technology to enhance their operational capabilities. In contrast, weaponization of space involves placing actual weapons in space or developing systems designed to destroy or incapacitate space assets. This includes anti-satellite (ASAT) weapons and other technologies capable of targeting satellites or disrupting space systems. Although such weapons have not yet been routinely used against enemy satellites, their existence raises concerns about space becoming a new battlefield. Both militarization and weaponization pose significant risks to space security and global stability, as they increase the potential for conflict in an environment traditionally viewed as a global commons.

5.2.1 The Development of Anti-Satellite (ASAT) Weapons

The earliest ASAT tests began during the Cold War, following the launch of Sputnik I in 1957, which ignited American fears of Soviet nuclear-armed satellites. In response, the United States developed Bold Orion, an air-launched ballistic missile designed to intercept satellites. Shortly afterward, the Soviet Union created co-orbital ASAT systems in the 1960s and 1970s. These systems were engineered to synchronize with target satellites before detonating, thereby neutralizing the threat.

During the 1980s, the United States introduced the ASM-135, a hit-to-kill ASAT weapon that relied on collision energy rather than explosives. This system successfully destroyed a satellite in 1985, marking a significant technological advancement.

Approximately 30 years later, China entered the space race. In 2007, China conducted a successful test of a kinetic-energy ASAT (KE-ASAT), using a ballistic missile to destroy an old weather satellite. More recently, in 2019, India demonstrated its ASAT capabilities through Mission Shakti, successfully intercepting a satellite in low Earth orbit. As of 2018, both Russia and China continue to advance their non-kinetic ASAT technologies. Russia, in particular, is developing the Nudol system, which operates in low Earth orbit and can maneuver between orbital paths, posing a greater threat than ASAT weapons limited to a single orbit. Despite the end of the Cold War, more nations are joining the space arms race, leading to the rapid proliferation of sophisticated space weaponry.

5.2.2 A Global Obsession with Anti-Satellite Weapons

A global fixation on anti-satellite (ASAT) weapons is arguably the logical end result of the primary American project of the late 20th and early 21st century: the transition to digital communications. Through the development of telephones, computers, and eventually the internet, the United States pioneered the use of space-based communications for both civilian and military functions. However,

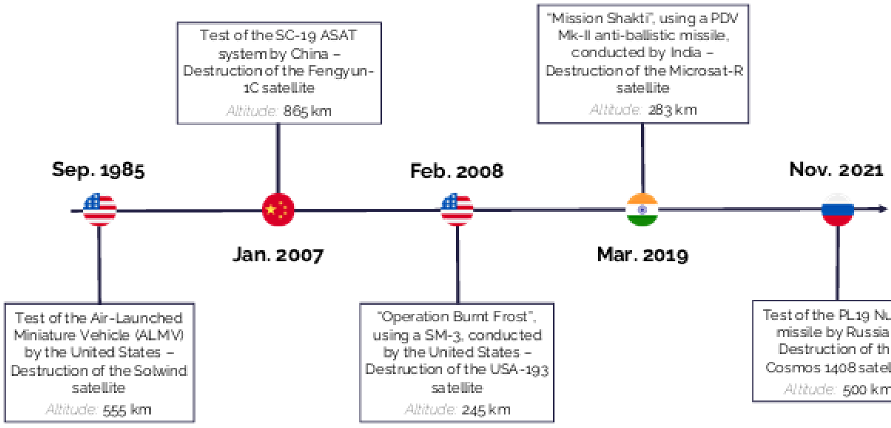

Figure 5.1: Timeline of direct-ascent kinetic ASAT tests resulting in the destruction of a spacecraft

Source: What's Next for Europe in Multilateral Engagement on Space Security?, Espi report

this leadership in the shift to space-based systems also posed a vulnerability: relying on satellites for military applications more than any other nation created an asymmetric dependency. In other words, an unexpected denial of space-enabled information or capabilities would be more crippling to the United States than to any other country, as no other nation is as reliant on satellite communications.

In an era marked by U.S. hegemony, countries like Russia, China, and India are actively seeking domains where they can maximize their strategic gains against a conventionally superior opponent. The space race exhibits an inherently asymmetric nature: the more the United States develops its space infrastructure, the more it stands to lose. Thus, space warfare becomes a field where emerging powers can gain a relative strategic advantage over the United States.

More broadly, ASATs are also attractive because they can function as deterrents. In the event of a conflict, countries may hesitate to escalate if they believe their opponents can effectively incapacitate their military capabilities. Just as two nuclear-armed opponents risk mutually assured destruction (MAD), two ASAT-armed nations risk mutual military paralysis. If both can potentially "turn off" each other's militaries, or deny access to the satellites upon which conventional and nuclear forces depend, both parties become almost defenseless, making the decision to initiate conflict significantly riskier. Moreover, the development of non-kinetic ASAT technologies, such as cyber or electronic warfare methods, is becoming increasingly attractive as they offer reversible or less detectable disruptions to space systems, further complicating strategic calculations.

5.2.3 The Dangerousness of ASATs

Despite their intended role as a deterrent, ASATs carry a high risk of conflict escalation, particularly because they threaten critical early warning satellites used in U.S. ballistic missile defense. These satellites play a crucial role in detecting missile launches in real time and tracking their trajectories. If one of these satellites were to be suddenly disabled, it could be interpreted as either a technical malfunction or a deliberate attack. In a global environment where other nations possess ASAT capabilities, the latter interpretation could provoke a crisis.

A delay of up to twelve hours in restoring satellite functionality is especially problematic, as this window is far too long for the U.S. to coordinate a nuclear counterstrike. Consequently, the United States might feel compelled to initiate a nuclear response against Russia or China, even if the satellite outage was caused by something as innocuous as space debris.

This inherent uncertainty not only escalates the risk of conflict but also pressures nations to maintain high alert statuses, further straining global stability.

Space is generally considered offense-dominant, as it is easier and more cost-effective to develop destructive ASAT systems than to create robust defensive measures. Building effective defenses is technically challenging due to the high speed and mobility of satellites. This imbalance between offensive and defensive capabilities increases the risk of strategic miscalculations and unintended warfare.

In regions like the South China Sea, ASATs pose additional risks. China's Anti-Access/Area Denial (A2/AD) strategy heavily depends on maritime surveillance, which could be compromised by ASAT attacks, thereby undermining the entire system. This is particularly concerning for China, given the critical importance of territorial sovereignty under President Xi Jinping. Should a Chinese satellite malfunction, Beijing might perceive it as a targeted U.S. ASAT strike, potentially leading to conventional military escalation.

The dual-use nature of many satellites, serving both civilian and military purposes, adds another layer of complexity, as a strike against a military asset could inadvertently disrupt vital civilian functions.

5.2.4 The debris problem

A major issue with ASAT testing is the exponential growth of space debris, which poses a significant threat to operational satellites and space activities. Kinetic energy ASATs (KE-ASATs) operate by smashing satellites into thousands of fragments, creating vast amounts of debris. For example, China's 2007 KE-ASAT test alone increased the number of orbital objects by 20%, generating the largest debris cloud ever recorded, with over 3,000 trackable fragments according to the Space Surveillance Network.

After the test, 97% of the debris remained in orbit between altitudes of 175 km and 3,600 km. By 2017, only 6% of the debris had decayed, and it is estimated that around 79% will still be in orbit by 2108, posing a long-term threat to numerous space systems. If we imagine the scenario of hundreds of rocket attacks in space, the resulting massive cloud of particles would not only destroy additional satellites but could also lead to operational inefficiencies. Even minuscule debris particles, traveling at speeds exceeding 15,000 miles per hour, can cause catastrophic damage.

This cascade of collisions is known as the Kessler Syndrome, where the density of debris in orbit could reach a critical point, causing chain reactions that render entire orbital paths unusable. Compared to the minimal debris generated by commercial space launches, ASAT tests significantly accelerate the approach toward this critical mass, threatening the long-term sustainability of space operations.

The risk of triggering the Kessler Syndrome underscores the urgent need for comprehensive international agreements to regulate ASAT testing and minimize debris creation.

5.2.5 Solutions

There are two opposing approaches to mitigating the detrimental effects of an ASAT arms race. The first, proposed by former U.S. Secretary of Defense Donald H. Rumsfeld in 2001, is relatively straightforward: since space militarization is inevitable, the United States should aim to achieve and maintain superior capabilities to deter conflicts, essentially ending the arms race by decisively winning it. This approach aligns with the classic escalation dominance theory, where sustainable deterrence is achieved by escalating the conflict to a level the adversary cannot match. However, the inherent nature of an arms race makes such advantages temporary. The progress made by Russia and China since Rumsfeld's report demonstrates that relying on U.S. space superiority alone may be strategically flawed. Achieving escalation dominance would also necessitate continuous weapons testing, exacerbating the space debris issue. The second approach advocates for ending the arms race through comprehensive space arms control agreements. Although historically challenging, such treaties could offer a more sustainable solution than the indefinite proliferation of space weapons.

Efforts like the proposed Prevention of an Arms Race in Outer Space (PAROS) treaty, supported by many UN member states, reflect a collective recognition of the risks associated with space weaponization and the need for preventive measures.

5.3 Problems on space law

The first wave of arms control in space emerged in the 1960s. The 1963 Partial Test Ban Treaty (PTBT) prohibited nuclear weapons tests in outer space, and the more comprehensive 1967 Outer Space Treaty (OST) laid the foundation for space law.

5.3.1 Partial Test Ban Treaty and Outer Space Treaty

In 1963, the Treaty Banning Nuclear Weapon Tests in the Atmosphere, in Outer Space, and Under Water came into force. This treaty was a response to increased nuclear testing that also took place in outer space starting in 1958 by the United States. Notably, in 1962, the U.S. conducted the Starfish Prime nuclear test at an altitude of 400 km, with a yield of 1.4 megatons. The resulting electromagnetic pulse affected satellites, disrupted communications, and even blew fuses in Hawaii. Although the treaty banned nuclear weapon testing in outer space, it did not directly regulate space weapons. A major milestone in space law was the adoption in 1967 of the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies, commonly called the Outer Space Treaty (OST). This treaty established basic norms of international space law and provided a framework for subsequent agreements. It requires states to conduct activities to avoid harmful contamination of the space environment or harmful interference with other states' activities. Importantly, it prohibits the stationing of weapons of mass destruction (WMD) in Earth orbit or on celestial bodies and forbids military activities on celestial bodies.

Article IV of the OST can be seen as the first formal effort at arms control in outer space: "States Parties undertake 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. The Moon and other celestial bodies shall be used exclusively for peaceful purposes. The establishment of military bases, installations, and fortifications, the testing of any type of weapons, and the conduct of military maneuvers on celestial bodies shall be forbidden. The use of military personnel for scientific research or other peaceful purposes, as well as any equipment or facility necessary for peaceful exploration, shall not be prohibited."

However, the treaty's wording has significant drawbacks. It does not define "peaceful" or clarify what constitutes WMD. Generally, WMD includes nuclear, radiological, biological, and chemical weapons, thus, other types of space weapons remain permitted. The term "peaceful" is similarly vague: some countries interpret "peaceful purposes" strictly as "non-military," while others, such as the U.S., adopt a "non-aggressive" interpretation that allows self-defense against threats in outer space. Moreover, the treaty refers to the Moon and other celestial bodies but does not explicitly address near-Earth orbit where satellites operate. The launch of the first artificial satellite was decisive in highlighting the potential of space applications and prompted the United States to support an interpretation of "peaceful uses" that would entail only a partial demilitarization of space. The Western superpower, therefore, chose to condemn "only aggressive uses, rather than generically non-military ones."

According to current regulations, military uses of space are currently permitted only in passive forms, limited to implications of the process of space militarization. Weaponization of space, instead, would represent a qualitative leap toward active military uses, inherently destructive. Since the 1980s, numerous treaty proposals have been advanced to curb space weaponization, perceived by the international community as a fundamental threat to humanity's existence. The most recent relevant attempt to ban ASAT weapons dates back to 2014, proposed by Russia and China.

5.3.2 Prevention of the Placement of Weapons in Outer Space (PPWT)

The latest significant proposal to regulate space weapons is the 2008 draft Treaty on Prevention of the Placement of Weapons in Outer Space (PPWT), promoted by China and Russia. This treaty would have defined and prohibited the proliferation of space weapons, also providing definitions of prohibited weapons, use of force, and threat of force in space. However, the PPWT was rejected and criticized mainly by the United States, which considers it difficult to enforce and suspects it is a strategy by Russia and China to gain military advantages.

The treaty did not include effective verification tools and did not regulate terrestrial weapons, thus leaving room for the development of ground-based ASAT systems. Russia, while supporting the treaty, continues to invest in the development of terrestrial ASAT armaments, such as the PL-19 Nudol missile, capable of ASAT operations in low Earth orbit. In 2014, an updated version was proposed to address criticisms, but the lack of a legally binding verification mechanism and the absence of a ban on terrestrial ASAT weapons remained significant obstacles.

As UNIDIR (2018) points out, the PPWT focuses on prohibiting specific behaviors (namely, the placement of weapons in space and the threat or use of force against space objects), rather than specific weapons. However, without verification tools and with limited scope, the United States maintained opposing positions.

From a geopolitical perspective, Russian military doctrine considers space the "Achilles' heel" of the United States and aims to exploit it, while China urgently calls for a binding agreement for peace in space. These contrasts reflect current geopolitical tensions.

In conclusion, the regulation of space weapons only concerns weapons of mass destruction and does not ban other forms of armaments in space. The use of nuclear weapons in space would also be impractical because it would destroy allied systems. The French initiative for satellites with offensive capabilities highlights the lack of an updated legal framework in relation to modern technological development. In this sense, initiatives like Woomera and MILAMOS 6 are trying to formulate clearer rules on military use of space. A significant quote from Nadelman (1990), still relevant in 2025, states: "One reason for the lack of an adequate prohibition regime in space is the relatively insufficient technological capacity of states to dominate outer space." Although there is no comprehensive and effective international mechanism to ban militarization and weaponization of space, this does not mean the field is entirely unregulated. The most important treaty remains the Outer Space Treaty of 1967. We are witnessing extensive militarization of Earth orbit, involving the seven major space powers in a spiral of space armaments. This is particularly worrying because current regulations are outdated and new proposals are not universally accepted, partly due to geopolitical tensions that reflect Cold War dynamics with the risk of "mutually assured destruction."

In an era of rapid technological development, the possibility of a global agreement banning all space weapons appears increasingly unrealistic. However, the absence of legal obstacles does not automatically imply a space arms race, as weaponization will also depend on technological advances. It is difficult to expect a treaty that prevents any nation from gaining military advantages in space.

5.3.3 Other lacunae of the OST

The OST presents other legal gaps and uncertainties, for example regarding extraction of raw materials and ownership of future space mining on celestial bodies. Current norms generically affirm the welfare of humanity and peaceful use of space, without clear rules on mining, which could become a business of enormous value (NASA estimates asteroids at $700 quintillion).

The treaty does not prohibit launching ballistic missiles from space and does not clearly define the boundary between atmospheric and outer space, nor regulate military activities in Earth orbit, issues destined to become more sensitive with the increasing number of space actors. Moreover, there is no consensus on how to manage close approach maneuvers near other states' satellites, potentially allowing risky actions without violating international agreements. Rendezvous and proximity operations can be used both for peaceful purposes (monitoring, maintenance) and for espionage or sabotage.

There are also no shared agreements to define armed attacks in space or to apply laws of armed conflict. No clear escalation thresholds exist, nor norms on irresponsible behavior in these proximity operations. The U.S. denunciation of Russian proximity maneuvers constitutes a first attempt at standards, but much remains to be done.

Besides the OST, there are four other important treaties: the Astronaut Rescue Agreement (1968), the Liability Convention (1972), the Registration Convention

(1976), and the Moon Treaty (1984). The latter prohibits commercial activities on the Moon and other celestial bodies, but it was not signed by major space nations (USA, Russia, China, Japan, India), rendering it practically unenforceable.

5.3.4 What now? Artemis accord

In recent decades, little has changed in international space regulation. As West points out, "the existing normative framework is no longer adequate to face current and future challenges in space" and "does not reflect the nature of modern counter-space capabilities."

New regulatory proposals such as the PPWT have been made, but neither has been universally accepted, partly due to geopolitical tensions reflecting terrestrial rivalries. With renewed interest in the Moon and the increasing importance of space as a geopolitical arena, the Artemis Accords, launched by the U.S. in 2020, represent much more than a technical cooperation framework. Originally conceived to support NASA's Artemis program, the Accords outline key principles for peaceful exploration of the Moon, Mars, and other celestial bodies, including transparency in space activities, international cooperation, protection of lunar heritage sites, and use of in-situ resources without sovereignty claims.

However, the Artemis Accords have broader political significance, acting as a tool to assert U.S. space leadership. Drafted outside traditional multilateral institutions like the United Nations, they establish a governance model where the U.S. sets the rules inviting other countries to join. This exercise of soft power aims to consolidate an allied bloc with similar views. For this reason, the Accords have drawn strong criticism from powers such as China and Russia, who see them as a unilateral attempt to dominate space governance, excluding the international community and bypassing multilateral mechanisms like COPUOS. One of the most contested clauses is the possibility of establishing "safety zones" around lunar sites, interpreted as a veiled attempt at territorial appropriation, contrary to the OST spirit forbidding sovereignty claims in space.

In this context, former Roscosmos director Dmitry Rogozin called the Artemis Accords a "lunar invasion," stressing that space governance cannot be decided by a single power bloc. This amplifies fears that space could become a field of exclusion and division, rather than true global cooperation. The most controversial issue concerns space resource extraction, regulated by Section 10 of the Accords, which states that the use of resources for sustainable activities does not constitute national appropriation, thus not violating OST Article II. This interpretation is criticized by legal experts as overly permissive, potentially turning space into a competitive market dominated by powerful states and corporations.

In response, China and Russia launched the International Lunar Research Station (ILRS), a joint project to establish a permanent lunar base for scientific research. This can also be seen as a geopolitical countermeasure to the Artemis Accords, marking a new chapter in space competition. The absence of an updated and universally accepted international legal framework on space weapons and military activities leaves room for growing tensions. Without shared multilateral governance, the risk of militarization and conflicts in space is real. However, technological interdependence and high operational costs may still favor some forms of cooperation.

The future of space regulation will depend on a complex balance among geopolitical interests, technological progress, and global political will to preserve space as a common good for humanity.

5.4 Risk for humanity

We may have flourishing futures, but no possible futures are free from high levels of risk. With respect to human activities in space, we may benefit considerably from scientific research into polar ice formation and changes on the Moon and Mars; from a greater understanding of ocean worlds (given that Earth itself is an ocean world); and likely from an enhanced understanding of atmospheric systems (given that our recognition of the greenhouse effect was itself strongly shaped by research on Mars and Venus and the prior recognition of a runaway version of global warming on Venus). The difficulty, however, lies in harnessing these research benefits without becoming overwhelmed by the strategic and societal downsides; a challenge compounded by the fact that robust science programs in space are likely to require, or at least be associated with, an increasing volume of broader space infrastructure, both commercial and military. Given that space is a shared global domain, managing these risks requires robust international cooperation. Establishing clear norms and frameworks can help prevent misunderstandings and manage conflicts peacefully. Without such multilateral agreements, strategic competition and commercial expansion risk escalating into conflicts, undermining both scientific progress and security.

Due to the growing interconnectedness of many commercial and military space assets and services, even temporary and reversible attacks on a single point of the chain can ripple through the entire network. The cascading effects of cyberattacks or electronic warfare (EW) against space services can also potentially affect neighboring or neutral countries. For instance, the February 2022 cyber attack against the “consumer-oriented partition of (Viasat’s) KA-SAT (telecommunications) network” impacted an American-owned, French-operated, and UK-subsidized satellite network. Besides affecting Ukrainian military users, the attack cut off tens of thousands of Europeans’ access to high-speed internet and disabled 5,800 German wind turbines for several months. This reflects a wider pattern of new security risks arising from the complex dependencies across many sectors and terrestrial space infrastructure areas. For example, the French Civil Aviation Authority reported that Russian military equipment designed to counter GPS-guided missiles inadvertently disrupted commercial satellite navigation in Finland, causing in-flight issues for pilots. Even Russia reportedly hesitates to conduct large-scale GPS jamming, given the risk of disrupting the connection of its own GLONASS receivers and thus undermining its own operations.

This example highlights the extreme vulnerability of space-based infrastructure and the interconnectedness that makes disruptions difficult to contain. Alongside these security concerns, the growth of space activities has led to a sharp increase in space debris. This debris poses a persistent threat to satellites, spacecraft, and human missions, increasing the risk of accidental collisions and potentially triggering cascading effects that could severely limit the usability of certain orbits.

Space is seen by most states as a focal point of both great-power political competition and emerging commercial activity, each of which needs to be regulated in some way. This is the setting in which the three great space powers (the US, Russia, and China) currently position their security interests, competition, and ambitions. The strategic significance of space operations depends primarily on the military uses (capabilities delivered) to which countries can put their space assets in a timely fashion.

At the same time, the increasing role of private companies adds complexity to space governance. Commercial actors drive innovation and reduce access costs but also complicate regulation and accountability. Effective frameworks must balance fostering commercial growth with maintaining security, transparency, and sustainable use of space.

The development of space weapons does not necessarily mean waging a space war. This is best illustrated by nuclear weapons, which were used only once in history, during the period of the United States' nuclear monopoly. Nuclear deterrence functioned almost flawlessly by preventing direct armed conflicts between the possessors of nuclear arsenals. Problems can arise if future space weapons (such as space-based defense missile systems) could neutralize an opponents ability for a second strike. This would lead to more unstable mutual relations between the most powerful countries in the world. Limited space wars would be difficult to imagine, and given that most spacefaring nations are nuclear powers, deterrence would still function. Only the emergence of a superior space weapon capable of preventing a nuclear strike could be used in a war as a "blitzkrieg" tool. No one can ignore the extreme vulnerability of existing space systems to attacks. Superior space weapons would have to develop effective self-defense mechanisms. From a technological standpoint, humanity is still far from creating such weapons, but that possibility must not be ruled out. Meanwhile, the race to develop space weapons will continue and most likely gain momentum.

This evolving arms race introduces serious risks to strategic stability. The prospect of weapons that could undermine nuclear deterrence threatens the delicate balance that has helped avoid great-power conflicts for decades. In addition, newer forms of threats such as directed-energy weapons and cyberattacks on space assets add further complexity to maintaining strategic stability.

In parallel, the militarization of space raises profound ethical and societal questions. Space has long been considered a domain for peaceful exploration and scientific advancement. Increasing weaponization and competition challenge this ideal, raising concerns about equitable access to space and the risk that space could become a theater of conflict detrimental to all humanity.

Despite these risks, direct combat encounters in space remain unlikely outside scenarios of imminent war among great powers. However, harassment operations such as jamming, satellite interference, or close-proximity maneuvers are expected to become more frequent. Both China and Russia are likely to avoid provocations that could escalate into full conflict, but the risk of miscalculation remains.

Finally, the next decade will be critical for diplomacy surrounding space governance. Issues like traffic management, space situational awareness, and transparency on civil and military uses will dominate international negotiations. Progress in these areas could help prevent accidents and misunderstandings, but ongoing weapon development and intelligence activities will continue to fuel mistrust.

Conclusion

This thesis has examined the growing importance of outer space, focusing on the dynamics of its militarization and weaponization from an economic, strategic, and geopolitical perspective.

As observed, the increasing relevance of space in technological and geopolitical terms is transforming the approach of states, directly influencing global economic trends. The mounting interest in space as a strategic domain has triggered a surge in both public and private investments across various economic sectors. Global positioning technologies and Earth observation systems have emerged as key drivers of this transition, increasingly shaping our future. Their versatility makes them applicable to a wide range of commercial fields, from logistics to precision agriculture. As highlighted, these technologies often originated in military contexts and were later commercialized. The fact that they are now strategic not only economically but also defensively compels a deeper reflection on the underlying geopolitical balance. It is telling, for instance, that the major global powers have independently developed their own positioning systems: China with BeiDou, the ESA with Galileo, and Russia with a reinforced GLONASS. Despite their civilian uses, these systems remain tightly controlled by defense agencies: GPS, for example, is still sponsored, maintained, and controlled by the United States Space Force, while GLONASS is managed by the Russian Aerospace Defense Forces.

The thesis also explored the increasing number of new actors in the space sector, often driven by motivations beyond mere profit: military and geopolitical concerns are now central. Space is now perceived as a "must-have" for international credibility. The role of space weaponry is also becoming increasingly decisive. Orbital weapons are not only functional but also serve as tools of deterrence and symbols of power projection.

Major powers are intensifying their investments in military space capabilities, also through the "new race to the Moon," which holds a much greater strategic significance than in the past. The Moon has now become the focal point of a challenge that redefines global leadership in space, with direct implications on the legal and diplomatic front, contributing to a growing legal fragmentation between opposing blocs. From an economic standpoint, the implications of space militarization are already visible through the rising share of public spending allocated to military space systems. Surveillance, encrypted communications, early warning systems, and anti-satellite weapons are increasingly consuming national defense budgets. This trend requires a reassessment of public spending priorities, influencing resource allocation mechanisms and industrial policy.

To assess the scale of this transformation, we refer to estimates by the OECD and NASA, which have calculated the economic multiplier of space investments: according to these analyses, each dollar invested in space technologies generates, on average, between 4 and 7 dollars in total economic return, considering direct, indirect, and induced effects. This supports the long-term sustainability of national space strategies and justifies public intervention in high-risk, high-potential sectors. Satellite demand is also set to surge. Satellites have evolved from simple support tools to essential assets for advanced military operations. Technological advancement and declining costs are accelerating this trend, encouraging the integration of space capabilities even into the strategic plans of emerging middle powers.

As discussed, the development of specialized space agencies such as the U.S. Space Force or the French Space Command has gone hand-in-hand with the growth of private industries supporting defense. Increasingly, private firms are securing contracts for launch systems, satellite components, cybersecurity software, and surveillance capabilities. This dynamic strengthens the role of Public-Private Partnerships (PPPs) in the space sector. However, it is essential to acknowledge the governance challenges tied to such models: these include dependency on private suppliers, concentration of know-how among a few monopolistic players, cybersecurity vulnerabilities, and, not least, difficulties in ensuring transparency and accountability in public spending. The model adopted varies by country: while China favors a highly centralized and vertically integrated system, the United States relies on a more dynamic and decentralized ecosystem, where companies like SpaceX and Blue Origin collaborate closely with public entities like NASA. This "network-based" approach fosters rapid innovation but also increases the complexity of contract management, strategic coordination, and critical asset protection. Alongside developments in the defense sector, civilian economies will also continue to benefit. Military competition acts as a catalyst for technological innovation, promoting knowledge transfer to areas such as low-latency satellite communications, artificial intelligence integration, and high-resolution Earth observation.

From a geopolitical perspective, space has now established itself as the fifth domain of warfare, alongside land, sea, air, and cyberspace. Control over space has become a prerequisite for the global projection of military power. The growing divide between the United States (and its allies) on one side and China and Russia on the other is also evident in the race for lunar resources, posing a risk of further regulatory fragmentation. The current legal framework is outdated, chaotic, and fragmented, with proposals often rejected or seen as biased toward one side. The Artemis Accords clearly exemplify the creation of a non-universal legal system, risking further legal and political divisions. The lack of clear legislation and binding agreements on military use of the Moon or cislunar space opens the door to potential legal and operational conflicts. The new Moon race, in fact, has far more strategic and less symbolic objectives than in the past. Goals such as the establishment of permanent bases, the extraction of resources (helium-3, water, rare earths), and the control of strategic areas like the lunar South Pole may become significant flashpoints. The economic consequences of this polarization are already taking shape: reduced international cooperation, barriers to technological access for emerging nations, potential space trade wars, and restrictions on the export of strategic components.

Space militarization is thus introducing new sources of strategic power, shifting the focus of major powers to new arenas of competition, with significant impacts on global stability. A particularly critical issue is the proliferation of anti-satellite weapons (ASATs), which could have devastating effects from both a military and environmental perspective. The real risk of orbital collisions and the so-called Kessler Syndrome already pose major challenges for global space security and sustainability policies. Although the probability of full-scale escalation remains low, the increasing number of space-armed nations introduces an element of uncertainty. The race to orbital armaments is a matter of grave concern for the international community. An intrinsic limitation of this thesis lies in the difficulty of accessing reliable and unbiased data, especially regarding military aspects and the comparison between powers. The global narrative is often polarized, and the distinction between "good" and "bad" actors rarely reflects the complexity of the strategic landscape.

In the future, it will be especially interesting to observe the evolution of the Moon race, as well as the advancement of missions toward Mars, which could redefine global space hierarchies. One of the most pressing challenges will be controlling the proliferation of ASATs and adopting binding rules on the military use of space.

Finally, it will be crucial to monitor the evolution of the strategies of emerging spacefaring nations, whose future orientation may have a decisive impact on global balances, both economically and politically.

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