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Russia and China in Space: Security and Defense Capabilities. Implications of Bilateral Cooperation.

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Διπλωματική Εργασία

Ρωσία και Κίνα στο Διάστημα: Ικανότητές στον Χώρο της Ασφάλειας και Άμυνας. Επιπτώσεις της Διμερούς Συνεργασίας τους.

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ABSTRACT

This thesis provides an in-depth analysis of the defense and security aspects of the Russian and Chinese space programs. It examines the countries' policies and priorities in space, their strategies for utilizing space assets, and their prospects for international collaboration. The study focuses on military applications of space technology including satellite defense systems and anti-satellites weapons. It also considers the geopolitical implications of the space programs of these two countries.

China is a rising power in geopolitics, economics, and technology, challenging the global dominance of the U.S. Its collaboration with Russia holds significant strategic importance. The invasion of Ukraine by Russia has shifted the geopolitical landscape, triggering changes in economic, military, and technological alliances.

This thesis examines these developments and their expected international implications for the space industry and collaboration among space organizations, particularly after the imposition of Western sanctions against Russia.

Subject Area: International space activities, Chinese space policy, Russian space policy, Space geopolitics, Security and defense in space, Russo-Ukrainian war

Keywords: Space technologies, Space applications, Space politics, Space warfare, Space security

ΠΕΡΙΛΗΨΗ

Η παρούσα διπλωματική εργασία παρέχει μια εις βάθος ανάλυση των πτυχών άμυνας και ασφάλειας των ρωσικών και κινεζικών διαστημικών προγραμμάτων. Εξετάζει τις πολιτικές και τις προτεραιότητες των δύο χωρών στο διάστημα, τις στρατηγικές τους για τη χρήση διαστημικών πόρων και τις προοπτικές τους για διεθνή συνεργασία. Η μελέτη επικεντρώνεται σε στρατιωτικές εφαρμογές της διαστημικής τεχνολογίας, συμπεριλαμβανομένων των δορυφορικών αμυντικών συστημάτων και των αντί-δορυφορικών όπλων. Λαμβάνει επίσης υπόψη τις γεωπολιτικές επιπτώσεις των διαστημικών προγραμμάτων αυτών των δύο χωρών.

Η Κίνα είναι μια ανερχόμενη δύναμη σε γεωπολιτικό, οικονομικό και τεχνολογικό επίπεδο, αμφισβητώντας την παγκόσμια κυριαρχία των ΗΠΑ. Η συνεργασία της με τη Ρωσία έχει καθοριστική στρατηγική σημασία. Η εισβολή της Ρωσίας στην Ουκρανία έχει αλλάξει το γεωπολιτικό τοπίο, προκαλώντας μετατοπίσεις στις διεθνείς οικονομικές, στρατιωτικές και τεχνολογικές συμμαχίες.

Η παρούσα εργασία εξετάζει αυτές τις εξελίξεις και τις αναμενόμενες διεθνείς επιπτώσεις τους για τη διαστημική βιομηχανία και τη συνεργασία μεταξύ διαστημικών οργανισμών, ιδιαίτερα μετά την επιβολή των δυτικών κυρώσεων κατά της Ρωσίας.

ΘΕΜΑΤΙΚΗ ΠΕΡΙΟΧΗ: Διεθνείς διαστημικές δραστηριότητες, Κινεζική διαστημική πολιτική, Ρωσική διαστημική πολιτική, Γεωπολιτική διαστήματος, Άμυνα και ασφάλεια στο διάστημα, Ρώσο-Ουκρανικός πόλεμος

ΛΕΞΕΙΣ ΚΛΕΙΔΙΑ: Διαστημικές τεχνολογίες, Διαστημικές εφαρμογές, Διαστημικές πολιτικές, Πόλεμος στο διάστημα, Διάστημα και Ασφάλεια

"The cosmos is within us. We are made of star-stuff. We are a way for the universe to know itself."

— Carl Sagan

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PREFACE

THESIS STRUCTURE

This Thesis is structured in ten (10) chapters. The first chapter is a brief introduction to the variety of existing satellite types, the connection between space and security, the current status of Chinese and Russian space industries and the role of international cooperation in space exploration. The second chapter provides a description of the historical background of the Chinese space sector from its dawn until the early 21st century. It focuses on the main policies and the evolution of China's space activities throughout the 21st century, with a specific analysis of its capabilities on all the main space fields (launch vehicles, satellites, launching sites, manned space missions, TT&C, outer-space exploration, space science and space debris). In the third chapter the international space cooperation projects of China in bilateral, regional and multilateral levels are presented and its results on global geopolitics are analyzed. The fourth chapter provides an insight on China's military-space accomplishments, structure and technologies, as well as an overview of the threats posed into the U.S.'s security from these defense capabilities. In chapters five, six, seven and eight the same format (as in chapters two to five) is followed for the Russian space sector respectively. In chapter seven the historical background of the Russian space industry is not including the Soviet era but solely its evolution throughout the years of the Federation. The ninth chapter analyzes the bilateral cooperation between the Chinese and Russian space sectors. It begins with a historical presentation of the U.S.'s space-threats towards the two nations and an analysis of their current geopolitical triangle of balance. Through constructed maps and charts, a comparative analysis of the global space arena follows, focusing on the three main space-powers' capabilities. Various comparative distributions are presented regarding the different types of satellites according to their missions (e.g. communication, navigation, etc.) and their entity of ownership (e.g. commercial, military etc.). The main collaborative technological projects and joint diplomatic/political efforts between China and Russia are then analyzed. Finally, the tenth chapter focuses on the connection between the ongoing Russo-Ukrainian war and the space industry. The use of space-technologies during the conflict, the effects the war and the western sanctions towards Russia have had on both its national and the global space industry, and China's posture towards the current crisis are all presented and analyzed.

1. INTRODUCTION

Space has always fascinated humanity's curiosity and imagination and the pursuit of exploring and understanding the cosmos has led our civilization to the most life-changing discoveries through the development of extraordinary technologies. Space utilization has become an essential part of everyday life and it can be traced in many aspects of our daily routines. From the GPS trackers on our smart-phones to dental health preservation, space technologies are everywhere. The final frontier has been humanity's last stand and the evolution of space industries has been immense in less than 70 years. From the first spacecraft in orbit, the Soviet Sputnik-1, and the Apollo programs, to the most advanced robots exploring the Martian surface, rockets returning on their launch pads for reusability purposes, mining of asteroids and highly sensitive space-based telescopes unraveling the mysteries of cosmic birth, the greatest achievements of our species are measured in correlation to space exploration.

One of the most important achievements in space technologies development is the design, construction, launch and in-orbit operation of satellites. There are many types of satellites orbiting the Earth in different attitudes and fulfilling different purposes. At the beginning of our thesis we wish to present the different types of satellites in orbit since there shall be a constant reference to its uses by different states. Along with that, we wish to present the importance of space-technologies on military operations, a synopsis of China's and Russia's current space-status (the two superpowers our thesis is focusing on), the importance of international space cooperation and the correlation between space and the Russo-Ukrainian war.

Different types of satellites based on their orbital paths

The main types of satellites according to their orbital planes are:

- Geostationary Earth Orbit (GEO) Satellites: These are placed in orbit at an altitude of about 36,000 km above the equator and remain in a fixed position relative to the Earth's surface. They are commonly used for telecommunications, television broadcasting, and weather forecasting.
- Low Earth Orbit (LEO) Satellites: These are placed in orbit at an altitude of between 160 and 2,000 km above the Earth's surface. They are used for a variety of purposes, including remote sensing, scientific research, and communication.
- Medium Earth Orbit (MEO) Satellites: These are placed in orbit at an altitude of between 2,000 and 36,000 km above the Earth's surface. They are used for navigation purposes, such as the GPS system.
- Polar Orbiting Satellites: These satellites orbit the Earth from pole to pole and provide global coverage. They are used for remote sensing, scientific research, and weather forecasting.
- Sun-Synchronous Satellites: These satellites orbit the Earth in a polar orbit that is synchronized with the position of the Sun. They are used for remote sensing and scientific research.

- Molniya Orbit Satellites: These are elliptical orbit satellites with a very high apogee that is above the Northern Hemisphere. They are used for communication and remote sensing over high latitudes. Each type of satellite has its own specific applications and advantages, and the choice of satellite type depends on the intended use and requirements of the mission.

Classification of satellites based on their function

The main types of satellites according to their payloads are:

1. Earth observation satellites: These satellites are designed to collect data about the Earth's surface, atmosphere, and oceans. They have a wide range of applications and are used for various purposes, including:

    - Environmental Monitoring: Earth observation satellites are used to monitor changes in the environment, including climate change, deforestation, and natural disasters. They can provide data on temperature, precipitation, sea level rise, and other environmental factors.
    - Agriculture: Earth observation satellites can provide information on crop health, soil moisture, and other factors that affect agriculture. This information can help farmers improve crop yields, reduce water usage, and increase efficiency.
    - Natural Resource Management: Earth observation satellites can be used to monitor natural resources such as forests, water resources, and mineral deposits. This information can be used to manage these resources more effectively and sustainably.
    - Urban Planning: Earth observation satellites can provide data on urban growth, infrastructure development, and traffic patterns. This information can be used to plan cities and transportation systems more effectively.
    - Disaster Response: Earth observation satellites can provide data on natural disasters such as hurricanes, earthquakes, and floods. This information can be used to coordinate response efforts and assist in rescue and recovery operations.
    - Military and Intelligence: Earth observation satellites can be used for military and intelligence purposes, including surveillance and reconnaissance.
    - Scientific Research: Earth observation satellites are used for scientific research in a wide range of fields, including atmospheric science, geology, and oceanography.

Overall, earth observation satellites are a critical tool for monitoring and understanding our planet and its environment. They provide a wealth of data that can be used to make informed decisions about how we manage our natural resources and respond to environmental challenges.

2. Communication satellites: These satellites are designed to relay signals between two or more locations on the Earth. They are used for various purposes, including:

    - Television Broadcasting: Communication satellites are used to transmit television signals to millions of viewers around the world. This allows broadcasters to reach audiences in remote areas and enables viewers to access a wide range of programming.
    - Internet Connectivity: Communication satellites are used to provide internet connectivity in remote and rural areas where traditional wired infrastructure is not available. They can also be used to provide backup connectivity in the event of a network outage.
    - Telephone and Data Services: Communication satellites are used to provide telephone and data services in areas where traditional infrastructure is not available. This is particularly important in developing countries where access to these services can be limited.
    - Navigation: Communication satellites are used in conjunction with ground-based receivers to provide navigation services such as GPS. This allows users to determine their location and navigate to a destination with accuracy.
    - Military and Government Communications: Communication satellites are used for military and government communications, including secure voice and data transmission. They are also used for reconnaissance and surveillance purposes.
    - Emergency Communications: Communication satellites can be used to provide emergency communications in the event of a natural disaster or other emergency situation. They can also be used to coordinate relief efforts and provide information to affected populations.

Overall, communication satellites are a critical tool for connecting people and enabling the flow of information around the world. They play a vital role in our modern communication infrastructure and are essential for many aspects of modern life.

3. Navigation satellites: These satellites are designed to provide global positioning and navigation services to users around the world. They are used for various purposes, including:

    - Navigation: Navigation satellites are used to provide accurate positioning information to users, allowing them to determine their location, velocity, and direction of travel. This is particularly important in the aviation, maritime, and transportation industries, as well as for outdoor enthusiasts such as hikers and campers.
    - Timing: Navigation satellites are also used for precise timing, which is essential for many industries, including telecommunications, finance, and scientific research.
    - Surveying and Mapping: Navigation satellites can be used for surveying and mapping purposes, providing accurate positioning data that can be used to create detailed maps and models of the Earth's surface.

- Agriculture: Navigation satellites can be used in precision agriculture to guide farming equipment and ensure accurate application of fertilizers and other inputs, leading to improved crop yields and reduced waste.
- Disaster Management: Navigation satellites can be used in disaster management and response efforts, providing accurate location data to emergency responders and aiding in search and rescue efforts.
- Military and Defense: Navigation satellites are used for military and defense purposes, including reconnaissance, surveillance, and targeting.

Overall, navigation satellites are a critical tool for providing accurate positioning and timing information to users around the world. They play a vital role in many aspects of modern life and are essential for a wide range of industries and applications.

4. Scientific satellites: These satellites are designed to conduct scientific research and observation of various aspects of the Earth and the universe. They are used for various purposes, including:

    - Astronomy: Scientific satellites are used to observe the universe and study the stars, galaxies, and other celestial bodies. They are equipped with specialized instruments, such as telescopes and spectrographs, which allow scientists to study the electromagnetic radiation emitted by these objects.
    - Earth Science: Scientific satellites are used to study the Earth's atmosphere, oceans, land surface, and geology. They are equipped with instruments that measure various parameters such as temperature, precipitation, ocean currents, and the Earth's magnetic field.
    - Space Physics: Scientific satellites are used to study the physical properties of space, including the magnetic and electric fields, plasma, and cosmic rays.
    - Climate Science: Scientific satellites are used to study the Earth's climate and monitor changes in the environment, including temperature, sea level rise, and deforestation.
    - Planetary Exploration: Scientific satellites are used to explore other planets and their moons. They are equipped with instruments that can detect the composition of the surface, atmosphere, and magnetic field of these bodies.
    - Fundamental Physics: Scientific satellites are used to study fundamental physics, including the behavior of matter and energy in extreme environments such as black holes and neutron stars.

Overall, scientific satellites are a critical tool for advancing our understanding of the universe and the Earth. They provide a wealth of data that can be used to make informed decisions about how we manage our planet and explore the cosmos.

5. Technology demonstration: These satellites are designed to test and validate new technologies for space applications. They are used for various purposes, including:

- Testing New Technologies: Technology demonstration satellites are used to test and validate new technologies for space applications. This includes new propulsion systems, power generation and storage systems, communication systems, and imaging and sensing technologies.
- Developing New Capabilities: Technology demonstration satellites can be used to develop new capabilities for space exploration and commercial applications. For example, they can be used to develop new ways of manufacturing in space, or to test new concepts for space habitats and transportation systems.
- Improving Efficiency and Reliability: Technology demonstration satellites can be used to improve the efficiency and reliability of existing technologies. For example, they can be used to test new methods of spacecraft propulsion or new materials for spacecraft construction.
- Enhancing Safety and Security: Technology demonstration satellites can be used to enhance safety and security in space. For example, they can be used to test new ways of detecting and mitigating space debris, or to develop new technologies for monitoring and responding to space weather events.
- Supporting Education and Outreach: Technology demonstration satellites can be used to support education and outreach efforts, by providing opportunities for students and researchers to participate in space-related projects and experiments.

Overall, technology demonstration satellites play a critical role in advancing the state of the art in space technology and enabling new capabilities for space exploration and commercial applications. They provide opportunities for innovation and experimentation, and help to ensure the safety, efficiency, and reliability of space systems.

As we can observe many of the different usage-types of satellites are overlapping, thus a satellite's mission could be fulfilling more than one purposes.

The role of space in security and defense

As with every aspect of our lives, the utilization of space is influenced by the world's geopolitical order, the various national interests, the economical and political antagonism between states and their resulting military conflicts. In fact, a valid point would be that the exploration of space was established on the basis of the Cold-War's space-race between the Soviet Union and the United States. Despite their motives this procedure led to a fast evolving and widely expanding international space environment. However, in the 21^{st} century there are still many concerns which can be raised regarding the military extensions of space technologies and their importance in global dominance. Thus, the correlation between evolving space-industries and defense & security issues is an important domain of analysis for geopolitical analysts and strategic research institutions.

According to the book "Space and International Security: Political and Strategical Dimensions" by Associate Professor Alexandros Kolovos, the military strength of a nation remains the fundamental mean for safekeeping national security. However the evolution of technology has created new data in the definition of power relations, leading to a crossroad regarding the traditional security environment in the new era. Space is part of the new domains that can alter sensitive regional balances and highlight existing asymmetries in a state's military strength. Many analysts characterize space as the fourth dimension of strategic operations, along with ground, sea and air military capabilities. Space utilization is no longer monopolized by the world's main superpowers and its commercialization has led a variety of countries and private enterprises to share a piece of the market.

Due to global geopolitical instability, military satellites have been developed to support a wide range of defense and security operations. These satellites are designed and operated by the military for various purposes, including:

- Intelligence, Surveillance, and Reconnaissance (ISR): Military satellites are used for intelligence gathering, surveillance, and reconnaissance purposes. They are equipped with sensors and cameras that can provide high-resolution imagery of the Earth's surface, detect electromagnetic signals, and intercept communications.
- Communication: Military satellites are used for secure communication purposes, including voice, data, and video transmissions. They are designed to operate in a wide range of frequencies, and can provide connectivity to remote or inaccessible areas.
- Navigation: Military satellites are used for navigation purposes, including providing accurate positioning information for military vehicles, aircraft, and ships.
- Weather Monitoring: Military satellites can be used for weather monitoring and forecasting, providing critical information for military operations and planning.
- Missile Warning: Military satellites are used to detect and track missile launches, providing early warning of potential threats.
- Space Situational Awareness: Military satellites are used to monitor the space environment, including tracking other satellites and space debris, and providing information on potential threats to space assets.

Overall, military satellites play a critical role in supporting military and defense applications, including intelligence gathering, communication, navigation, weather monitoring, and missile warning. They provide key capabilities for military operations and national security, and are designed to operate in challenging and hostile environments. Especially regarding the Russo-Ukrainian war military satellites have played an important role in the opposing sides' capabilities during the conflict and have affected in multiple ways its continuation and its results. [160]

1.1. The role of Russia and China in Space

The People's Republic of China and the Russian Federation are two of the most advanced space fairing nations in the world and follow a significantly interconnected path regarding the future development of their space sectors. The evolution of their space industries have been different throughout the evolution of the space age and despite initial cooperation many decades have passed until new collaborative processes began to reemerge.

China has invested a lot in the autonomous development of its national space program and, at the same time, it has shown impressive resilience in capitalizing the most out of foreign transferred technologies and cooperative bilateral and international programs, thus leading its industry in a fast-evolving, high-tech, exponential growth through the 21st century. China currently acquires 34% of the global space launches and 10% of the world's satellites in orbit. It has the second biggest budget (after the U.S.) spent on its space industry (~12 billion dollars) and has established four space-launch sites across its territory. China has been on the forefront of space experiments, new scientific discoveries and cutting-edge technology developments (from dark matter research to quantum communications). It has constructed, lifted and operated its autonomous national space station and has achieved great progress in both lunar and interplanetary space exploration, being the first country to land a spacecraft on the far side of the Moon and the second country to explore the Martian surface with a rover. Regarding its military, China has developed all types of satellite systems that can be used for military purposes such as Command & Control (C2), Intelligence-Surveillance-Reconnaissance (ISR), Positioning-Navigation-Timing (PNT), Ballistic Missile Early Warning, as well as the latest technologies for deploying electronic and cyber-warfare, ASAT, jamming and kinetic kill counter-measures.

Russia on the other hand has been facing a long period of decline in its space industry. The once space-pioneering country, which has achieved the most firsts in every space field, is facing a great risk of falling significantly behind its two main competitors. With its space-research budgets constantly reducing, its in-orbit satellites degrading (or even malfunctioning) as they reach their end-of-life cycles, its shear of global space-launches significantly dropping after western commercial alternatives emerged, its economic losses and production rate instabilities due to western sanctions and interruption of supply chains, Russia has been setting goals that cannot be easily achieved in the current turmoil that the Ukrainian war has formed. Russia currently acquires 12% of the global space launches and 3% of the world's satellites in orbit. It has the fifth biggest budget (after the U.S., China, Japan and France) spent on its space industry (~3.4 billion dollars) and has established two space-launch sites across its territory and one in lease from Kazakhstan. Russia has fallen behind on the field of scientific discoveries and new technologies development, but is still benefiting from the space-experiments conducted on board of the ISS. It has initiated plans for constructing its own national space station combining some of its already operating ISS modules, but due to the war's effects on its industry it is rather unlikely to produce rapid developments. Regarding lunar and interplanetary space exploration Russia has been stuck in a state of no-result efforts, with many of its missions failing. However, its military space-assets account for an important percentage (~18%) of all military-oriented spacecrafts in orbit and contain all types of operations. There are communicational systems enhancing Command & Control (C2), optical and radar satellites used for Intelligence-Surveillance-Reconnaissance (ISR), the GLONASS satellites that are used for Positioning-Navigation-Timing (PNT), many defensive mechanisms for Ballistic Missile Early Warning, as well as many technologies for counter-attacks, such as jamming, interfering, blinding or destroying hostile satellites, through electronic & cyber warfare, ASAT and other kinetic kill systems.

1.2. International cooperation in the space sector

Bilateral and multinational cooperation projects in space are crucial for advancing our understanding of the universe, for developing new technologies that benefit humanity, for enhancing the peaceful usage of space and for strengthening international relations in general. Some of the key reasons why such cooperation is important are:

- Sharing knowledge and resources: By collaborating on space projects, countries can share their knowledge, resources, and expertise. This allows them to pool their resources and achieve more than they would be able to on their own.
- Cost sharing: Space projects are often very expensive, and by working together, countries can share the costs and reduce the financial burden on each individual partner. This can help make space exploration and research more feasible and sustainable in the long term.
- Advancing scientific research: Space exploration and research require advanced technologies and specialized equipment that can be expensive and difficult to develop. By pooling their resources, countries can develop and use more advanced equipment and technologies, which can lead to breakthroughs in scientific research.
- Enhancing international relations: Space cooperation projects can also help build trust and cooperation between countries. By working together on a common goal, countries can develop stronger relationships and build bridges between different cultures and societies.
- Promoting peaceful uses of outer space: Space cooperation projects can help promote the peaceful use of outer space. By collaborating on space projects, countries can develop a shared understanding of the importance of peaceful exploration and research in space, which can help prevent conflict and promote international cooperation.

Despite these essential prospects of international space cooperation another crucial reason for which different nations promote bilateral and multinational cooperation exists, and this is the effort to broaden geopolitical influence. Since the world is divided into spheres of political influence the main antagonizing superpowers are trying through cooperation and promotion of their space technologies to attract other nations under the “umbrella” of their interests and to join their side in the global-power chessboard. For Russia and China this procedure has proven to be extremely important in their efforts to alter the world’s status-quo as established by western dominance, especially after the war in Ukraine has began.

2. CHINESE SPACE SECTOR – HISTORICAL BACKGROUND

2.1. China's entry into the international space arena

The People's Republic of China is the world's most populous country and number two of the global economy. The world's third largest superpower in military capabilities and second in space investment has had a slow, autonomous and steady development in the exploration and exploitation of space, for both commercial and military purposes.

It should be noted that in 1971, the United States encouraged China to develop its own satellite reconnaissance program. Henry Kissinger's secret trip to China in 1971 was a significant diplomatic event that helped to establish relations between the U.S. and China. CIA suggested making it easy for China to acquire the necessary information and equipment to develop a useful but not very high-quality capability. [161]

China's space program has its foundations in the early years after the victory of the Chinese Revolution, but it began concerning the international community substantially after 1986 for two main reasons. The first is that it was then when the Chinese state decided to offer the Long March rocket launching system for commercial programs, thus rendering China as one of the main competitors in international space services. The second is that, for the first time, information about the operations and achievements of its space program became widely public. Innovation, manufacturing capabilities, and launch facilities opened up to foreign researchers. [1]

The Chinese space program has demonstrated admirable resilience over the years regardless of the specific political, economic, and social forces that mobilized and competed against each other. In essence, its development concerns four separate periods. The beginning of the space program in the midst of the Anti-Rightist Campaign and the Great Leap Forward during 1956-1966, its maintenance through the Cultural Revolution during 1966-1976, its continuation in the years of reconstruction and reorganization during 1976-1986 and its peak development from 1986 to the present day. [1]

In the period after 1986 the country's space program got back on track. Firstly, the upcoming missions were fully defined and given absolute priority over any other science and technology program. Secondly, as in all previous phases, there was, once again, clear support from the highest levels of political leadership. Thirdly, China had finally gathered a critical mass of scientific and technological capabilities so that the space program was now ready to produce practical results. Finally, China had established an international credibility regarding the provision of space services. In this field, it was even favored by the Challenger accident in 1986 and a series of failed launches of the Ariane program that made the Long March rocket a viable alternative to the services provided by major space powers. [1]

Three were the long run goals that were set for space progress. The construction of a space station, the production of heavy launch vehicles and the development of a space transportation system. In 1989, China successfully launched 25 satellites, 11 of which were recoverable, and placed them in Low-Earth (LEO), geosynchronous, and sun-synchronous orbits. The main services were related to meteorological monitoring, telecommunications and remote viewing of natural resources, maritime navigation, satellite television channels, material processing and biotechnology. China entered the international market in August 1987 with the launch of a French cargo, followed by German and American payloads in the following years. International contracts with American, Brazilian and Australian companies were made. After the Tiananmen Square events, doubts were cast internationally about the future of China's commercial space programs, but the state's leadership soon reaffirmed its commitment to space services. [1]

An examination of China’s history reveals that its space program has remained remarkably strong from its inception due to three key factors. The first is the unwavering support from top political leaders. The second is the symbolic significance of space achievements. The third is the dedication and hard work of the personnel in the field. As a result, the program was able to retain state funding even during uncertain times and continually adapt and evolve. This progress would not have been possible without the backbone of China’s space program - the skilled experts who built world-class launch capabilities and satellite systems from scratch. [1]

2.2. Current phase – China’s space activities

The current situation finds Beijing in a period of rapid development of both its civil and military capabilities. China has been able to fill the gaps that exist in all kinds of space applications, mainly based on the technological knowledge it has acquired through commercial partnerships with foreign companies, organizations and states. Cooperation with Russia, Brazil, the European Space Agency and international space companies have contributed significantly to this process. Based on its highly talented engineers who combined gained knowledge from international collaborations with strong national capabilities, especially in the last decade, significant achievements in the space field were performed. The management of companies and facilities based on modern international experience, standardization, quality control and the development of mass production brought a new florescence to Chinese space policy. [2]

A prime example of China’s space program is the development of dual use satellites, for both commercial-scientific and for military purposes. In its attempt to imitate Western methods of reducing cost by upgrading quality and reliability, China proceeded to the standardization of the structural backbone (chassis) of various satellites. The entire future satellite program is based on this procedure, especially regarding the microsatellite systems which constitute a growing worldwide trend. Due to the multi-year experience and the capabilities China has demonstrated in the past, it is no exaggeration to assume that it will soon be a more skilled, flexible and equipped country in both human and technical resources than the traditional players of the space arena. China, in recent years, has exploited both the economic and geostrategic profitability of selling remote sensing and communications satellites, as well as providing components, launches and training to developing countries such as Venezuela, Nigeria and Laos. [2]

At the present time China uses about 50 BeiDou satellites for global coverage of navigational needs, being one of the 4 world powers to have such technology along with the US (GPS), Russia (GLONASS) and the EU (Galileo). BeiDou is the largest-scale, most complex, technically demanding and widely deployed space system built in the Chinese aerospace history. It has also made significant progress in developing high-definition earth observation systems and a national satellite remote sensing network. China’s plans, until 2030, include the deployment of base stations in overseas regions at the North and South Poles, as well as in Brazil via the "Earth Digital Science Platform" program. [2]

2.2.1. Official Documents related to Space

China has released a total of five white papers on its space activities. The first one was released in 2000, followed by others in 2006, 2011, 2016, and the most recent in 2022 titled "China's Space Program: A 2021 Perspective" released from the State Council of the People's Republic of China [7].

In the beginning of the 21st century China released the first White Paper concerning principles, details and future plans of its space activities. Up to this day, four more White Papers have been released to the public, helping us to understand the giant leap that has taken place in the space industry of China in just two decades. These White Papers have proven to be a great asset both in quantifying the efficiency of China's space planning and in comparing its growth rhythms with those of other space agencies.

The basic template of these White Papers has remained the same throughout the years. Firstly, the aims and principles of development are being stated. Secondly, there is an analysis of the progress made during the past five years. Thirdly, the development targets and major tasks for the forthcoming five years are being analyzed. Then, the development policies and measures are defined. Finally, the international exchanges and cooperation between China and foreign countries or organizations is being presented.

At this point, we shall take a deeper look on these papers focusing on the milestones covered in every aspect of the space technologies China has harvested.

2.2.1.1. Principles

The aims of China's space activities are referred in every paper as follows and haven't significantly changed through the last two decades: "to explore outer space, and enhance understanding of the Earth and the cosmos; to utilize outer space for peaceful purposes, promote human civilization and social progress, and benefit the whole of mankind; to meet the demands of economic construction, scientific and technological development, national security and social progress; and to raise the scientific quality of the Chinese people, protect China's national interests and rights, and build up the comprehensive national strength." [3]

It is important to note that the first White Paper released in 2000 states that "As a developing country, China's fundamental tasks are developing its economy and continuously pushing forward its modernization drive" [3]. In the paper published in 2011, a decade afterwards, we can observe a more ambitious view of the future steps as it is referred that "The next five years will be a crucial period for China in building a moderately prosperous society, deepening reform and opening-up, and accelerating the transformation of the country's pattern of economic development. This will bring new opportunities to China's space industry." [4]

In 2006, China published its second White Paper on its space activities. This document, titled "China's Space Activities in 2006," provided a detailed overview of the country's space program and outlined its goals and guiding principles. The White Paper also highlighted China's accomplishments in the fields of space science, technology, and application and presented its plans for future development. [4]

In 2016, China released a government White Paper titled "China's Space Activities in 2016" which outlined its fourth five-year plan for the space sector. This White Paper was considered the most comprehensive document on China's space activities and provided a strong policy foundation and clear guidelines for the development of space activities in China over the next five years. [6]

The basic principles of the above space policies can be summed up as follows [3], [4]:

- Long-term, stable and sustainable development. Making the development of space activities cater to and serve the state's comprehensive development strategy.
- Independence, self-reliance and self-renovation, while actively promoting international exchanges and cooperation.
- Limited number of targets and making breakthroughs in key areas of vital significance to the national economy.
- Enhance social and economic returns of space activities. Explore an economical and efficient development.
- Integrated planning combining long-term and short-term development.

While they haven't change, in the second decade of the century these principles have been redefined in a more specific way, clarifying the basis in which the Chinese space industry is built on [5], [6], [7]:

- **Innovative development.** China has relied on its own strength from the beginning of its space industry and has achieved great technological and scientific goals through innovation. So this principle proves to be a key factor for the development of China's space activities and has offered prestige (both to its people and the international markets), autonomy, innovation and cost savings.
- **Coordinated development.** Through an overall plan, the mobilization and contribution of different sectors and parts of the industry, the state and the academy, have proven a cornerstone on the way China's space activities have flourished.
- **Peaceful development.** Although the peaceful use of space and its resources, along with the assurance of a space debris avoidance/removal, has been declared in all of China's space policies, we need to comment that a much clearer and stricter reference has been expressed after 2011. This may have been a result of the international pressure that China faced after the test of its ASAT technology in 2007, which has created a vast number of space debris in low earth orbit. However, the contrast to a space-arms race may also come as a response to both Americas 2012 public law 112-55 of no-cooperation between NASA and Chinese companies/organizations, and the United Stated Space Force Act signed into law in 2019.
- **Open development.** As stated China "actively engages in international exchanges and cooperation on the basis of equality and mutual benefit, peaceful utilization, and inclusive development, striving to promote progress of space industry for mankind as a whole and its long-term sustainable development".

In 2022, the State Council Information Office of the People's Republic of China published the most recent White Paper entitled "China's Space Program: A 2021

Perspective" [7]. This document provided an overview of China's space activities since 2016 and its plans for the next five years. It stated that China's space program serves its major strategic needs and targets cutting-edge technology that leads the world. Spearheaded by major space projects, the country has accelerated research into core technologies and stepped up their application to develop space technology and systems.

2.2.1.2. Major Developments

In the White Paper released in 2000 the situation of China's space industry could be summarized in the following reference:

"China's space industry was developed on the basis of weak infrastructure industries and a relatively backward scientific and technological level, under special national and historical conditions. In the process of carrying out space activities independently, China has opened a road of development unique to its national situation and scored a series of important achievements with relatively small input and within a relatively short span of time. Now, China ranks among the most advanced countries in the world in many important technological fields, such as satellite recovery, multi-satellite launch with a single rocket, rockets with cryogenic fuel, strap-on rockets, launch of geo-stationary satellites and TT&C. Significant achievements have also been gained in the development and application of remote-sensing satellites and telecommunications satellites, and in manned spacecraft testing and space micro-gravity experiments." [3]

Twenty years later the present situation is summarized as follows:

"China's space industry serves its major strategic needs, and targets cutting-edge technology that leads the world. Spearheaded by the major space projects, the country has accelerated research into core technologies, stepped up their application, and redoubled its efforts to develop space technology and systems. As a result, China's capacity to enter and return from space and its ability to engage in space exploration, utilization and governance have grown markedly along a sustainable path." [7]

China has achieved great leaps in many different fields of space activities, through the last decades. Presenting those that the state considers as the most significant in its public releases can help us understand the overall capabilities of the Chinese space sector.

- **Launch Vehicles**

In the beginning of the 21st century China had constructed an armada of space launch vehicles, the "Long-March" rocket group. At that point it contained 12 types of rockets capable of launching satellites to near-earth, geo-stationary and sun-synchronous orbits. 1985 was the year when the Chinese government announced that the "Long March" vehicles would be conceded for commercial use in the international market. Through the 15 years that followed, China had launched 27 foreign-made satellites into space. The overall launching capabilities of the "Long March" fleet were summed up to 63 launches, with a number of 21 consecutive successes from 1996 to 2000. [3]

From 2000 to 2006, "Long March" rockets made 24 consecutive successful flights, followed by many technological improvements and reliability measures, reaching a total of 45 consecutive successful flights from 1996 to the end of 2005. R&D at that point was focused on the 120-ton thrust liquid-oxygen/kerosene engine and the 50-ton thrust hydrogen-oxygen engine. [4]

From 2006 to 2011, 67 successful launches had been performed via the Long March launch vehicles, sending 79 spacecrafts into orbit, demonstrating important improvements in China's rockets' reliability. [5]

From 2011 to 2016, the Long March carriers accomplished 86 launch missions, and over a hundred spacecrafts were sent into target orbits, achieving a success rate of 97.67 percent. This percentage came to prove the increasing effectiveness of China's launching capabilities. "The Long March 5 (CZ-5), China's newest generation of carrier rockets with a maximum carrying capacity, made its maiden flight, and increased the diameter of liquid fuel rocket from 3.35 m to 5 m, with a maximum payload capacity of about 25 tons to low earth orbit and about 14 tons to geostationary transfer orbit, significantly improving the carrying capacity of the Long March rocket family and becoming a symbol of the upgrading of China's carrier rockets. The development of the 120-ton liquid oxygen and kerosene engine was test fired, which powered Long March 6 and Long March 7 on their maiden flights" [6]. The successful launching of the Kuaizhou-1 and Kuaizhou-2, which adopted an integrated design of the carried satellite and its launch vehicle, has improved China's emergency response capability in space. Finally, a solid-fuel rocket, the Long March 11, was developed and accomplished a successful maiden launch.

Through the past five years, from 2016 to December 2021, 207 launch missions from different rocket carriers were completed. 183 of them were performed by the Long March series. The total launch attempts exceeded 400. A non-toxic and pollution-free launch policy is being established for the Long March rockets. Smart boosting systems through modular technology were achieved. Long March-5 and 5B vehicles were deployed for regular launches. Long March-8 and Long March-7A have made their maiden flights, providing increased payload capacity. Long March-11 carrier rocket has achieved commercial launch from the sea. The Smart Dragon-1, Kuaizhou-1A, Hyperbola-1, Chongqing SQX, Zhogke (Lijian), CERES-1 and other vehicles have been successfully launched for commercial use. Demonstration flight tests of reusable rocket technologies have been performed. [7]

Below are two charts: one showing the number of space launches conducted by China each year since the beginning of the space age, and another comparing the number of launches by the three main space powers – the U.S., Russia, and China. As we can observe through the first diagram, China has been having an exponential growth in its yearly space launches. The data used by the Aerospace organization which created the graph are retrieved from three databases. The Gunter's Space Page, the Space-Track database and Jonathan MacDowell's Space Activities. [162], [163], [164]

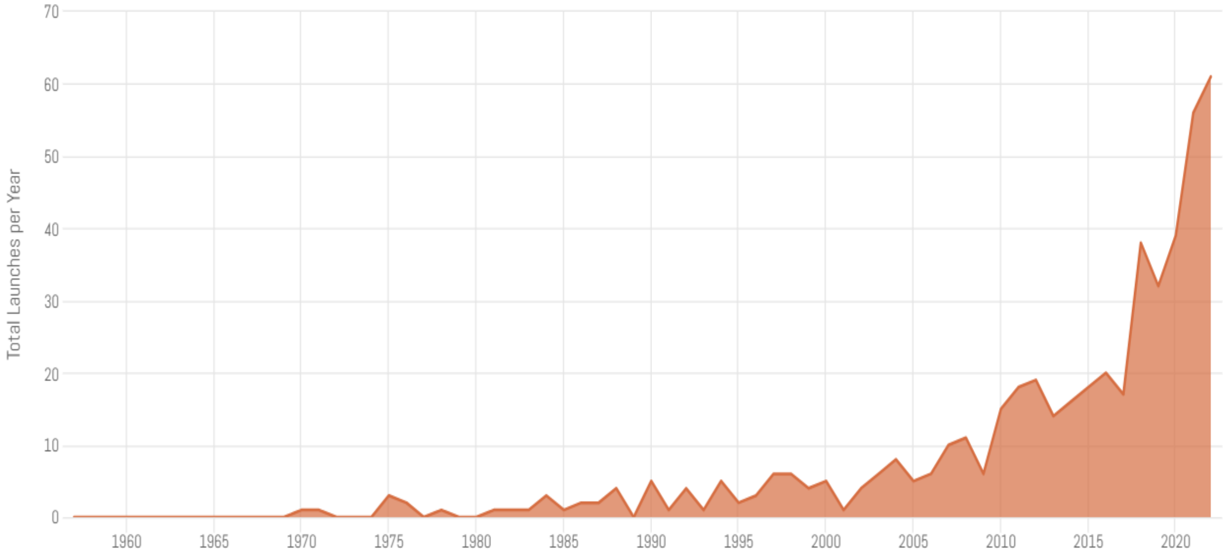


Fig. 1: China's total space launches per year [158]

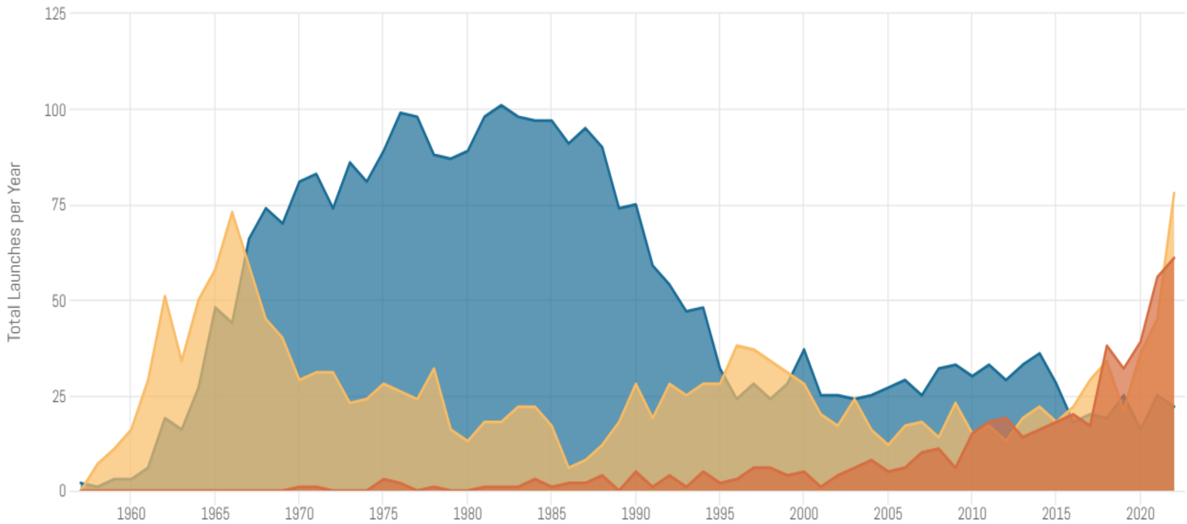


Fig. 2: U.S., Russian and Chinese total space launches per year [158]

Over the next five years, China plans to further improve and upgrade its space transportation systems. Key goals include expanding its carrier rockets, developing new-generation manned vehicles, advancing high-thrust solid-fuel engines, and accelerating research and development of heavy-lift launchers. Research on key technologies for reusable rockets, and implementation regarding test flights will be performed. "In response to the growing need for regular launches, China will develop new rocket engines, combined cycle propulsion, and upper stage technologies to improve its capacity to enter and return from space, and make space entry and exit more efficient" [7].

To sum up, China has produced the following families of space launching vehicles: the Long March (Chang Zeng – CZ), the Feng Bao (FB) and new solid-fuel rockets. The FB series was abandoned at some point. The CZ series followed a path of constant evolution throughout the years, as discussed. CZ-1 was discontinued after the first two missions, whereas CZ-2, CZ-3 and CZ-4 operate up to today. In the begging of the century, a replacement process was decided introducing a new generation of Long March carriers, the CZ-5, CZ-6 and CZ-7. All of them started operating after 2015. Some of the basic differences between launching vehicles refer to the type of engines used, the means of propulsion and the number of stages the rocket comprises. Rockets may use either solid fuel or liquid fuel, and the liquid fuels may be divided into storable, non-storable or a combination of both. China has favored the use of storable propellants for the main stages, with small solid-rocket boosters for the final kick to 24-hour orbit. [8]

An overview of core technical characteristics and differences of China's space rockets' series is presented in the following tables:

Table 1: CZ-2 rocket series (*52.03m for Tiangong) [8]

	CZ-2C	CZ-2D	CZ-2F
Height	40m	38.3m	58.34m*
Diameter	3.35m		
Weight	213 tonnes	237 tonnes	479.8 tonnes
Thrust	2,960kN	2,962kN	5,923kN
Strap-ons			Engines: 4 x YF-20 B Length: 15.33m Mass: 41 tonnes
First stage	Engine: 4 x YF-20A Length: 23.72m Mass: 151.55 tonnes Thrust: 284 tonnes Burn: 130 seconds	Engine: 4 x YF-20B Length: 24.92m Mass: 187.7 tonnes Thrust: 302 tonnes Burn: 154 seconds	Engine: 4 x YF-20B Length: 23.7m Mass: 196 tonnes Thrust: 326 tonnes Burn: 166 seconds
Second stage	Engine: YF-22A, 24 Length: 8.387m Mass: 38.5 tonnes Thrust: 73.2 tonnes	Engine: YF-24B Length: 7.92m Mass: 38.5 tonnes Thrust: 80 tonnes	Engine: YF-22 Length: 15.52m Mass: 91.5 tonnes Burn: 295 seconds
Capability	2,800kg to 300km orbit	3,400kg to 200km	8,100kg (Shenzhou) 8,600kg (Tiangong)

Table 2: CZ-3 rocket series [8]

	CZ-3A	CZ-3B	CZ-3C
Height	52.52m	54.838m	54.838m
Diameter	3.35m		
Weight	241 tonnes	427.3 tonnes	345 tonnes
Thrust	2,962kN	5,923kN	4,440kN
Strap-ons		Engine: 4 x YF-20B Length: 15.326m Mass: 41.2 tonnes Thrust: 305 tonnes Burn: 125 seconds	Engine: 2 x YF-25 Length: 15.326m Mass: 41 tonnes Thrust: 302 tonnes Burn: 127 seconds
First stage	Engine: 4 x YF-21B Length: 26.972m Mass: 182.83 tonnes Thrust: 296.16 tonnes Burn: 146 seconds	Engine: 4 x YF-21B Length: 23.272m Mass: 180.3 tonnes Thrust: 302 tonnes Burn: 146 seconds	Engine: 4 x YF-21B Length: 26.972m Mass: 179 tonnes Thrust: 326 tonnes Burn: 155 seconds
Second stage	Engine: 4 x YF-24B Length: 7.826m Mass: 34.963 tonnes Thrust: 73.2 tonnes Burn: 110 seconds	Engine: YF-24B Length: 9.943m Mass: 55.6 tonnes Thrust: 73.2 tonnes Burn: 185 seconds	Engine: YF-22 Length: 9.47m Mass: 55 tonnes Thrust: 76 tonnes Burn: 190 seconds
Third stage	Engine: 2 x YF-75 Length: 8.835m Mass: 21.257 tonnes Thrust: 8 tonnes Burn: 480 seconds	Engine: 2 x YF-75 Length: 12.375m Mass: 21.7 tonnes Thrust: 16 tonnes Burn: 470 seconds	Engine: 2 x YF-75 Length: 12.38m Mass: 21.257 tonnes Thrust: 15.6 tonnes Burn: 480 seconds
Capability	2.6 tonnes to GTO	5.5 tonnes to GTO	3.9 tonnes to GTO

Table 3 CZ-4 rocket series [8]

	CZ-4B	CZ-4C
Height	44.1m	45.8m
Diameter	3.35m	
Weight	248.5 tonnes	250 tonnes
Thrust	2,962kN	2,960kN
First stage	Engine: 4 x YF-21B Length: 24.66m Mass: 192.2 tonnes Thrust: 302.8 tonnes Burn: 156 seconds	Engine: 4 x YF-21B Length: 24.66m Mass: 192.2 tonnes Thrust: 302.8 tonnes Burn: 156 seconds
Second stage	Engine: 4 x YF-24B Length: 10.407m Mass: 40.05 tonnes Thrust: 73.6 tonnes Burn: 127 seconds	Engine: 4 x YF-24B Length: 10.407m Mass: 40.05 tonnes Thrust: 73.6 tonnes Burn: 127 seconds
Third stage	Engine: 2 x YF-40 Length: 1.92m Mass: 15.5 tonnes Thrust: 10.2 tonnes Burn: 321 seconds	Engine: 2 x YF-40 Length: 1.92m Mass: 15.5 tonnes Thrust: 10.2 tonnes Burn: 321 seconds
Capability	4.2 tonnes	4.8 tonnes

Table 4: CZ-5, 6 & 7 rocket series [8]

	CZ-5	CZ-6	CZ-7
Height	57m	29m	53.1m
Diameter	5m	3.35m	3.35m
Weight	878 tonnes	103 tonnes	597 tonnes
Thrust	10,572kN	1,200kN	7,200kN
Strap-ons	Engine: 4x YF-100 (RP1) Length: 26m Diameter: 3.25m Weight: 147 tonnes Thrust: 6,680kN		Engine: 4x YF-100 (RP1) Length: 29.9m Diameter: 2.25m Thrust: 1,200kN
First stage	Engine: 2x YF-77 LH Length: 31m Diameter: 5m Mass:176 tonnes Thrust: 1,400kN	Engine: YF-100 (RP1) Thrust: 1,340kN	Engine: 2x YF-100 (RP1) Length: 25m Diameter: 3.35m Thrust: 2,400kN Burn: 178 seconds
Second stage	Engine: 2x YF-75D LH Length: 12m Mass: 26 tonnes Thrust: 156kN	Engine: YF-115 (RP1) Diameter: 2.25m Thrust: 176kN	Engine: 4x YF-115 RP1 Length: 15.4m Burn: 400 seconds
Third stage		Engine: YF-86 (hydrogen peroxide) Diameter: 2.25m	
Capability	14 tonnes to GTO 22 tonnes LEO	1,080kg to 700km	7 tonnes to GTO 13.5 tonnes LEO

❖ Chinese Satellites

China is the fifth country in the world that accomplished developing and launching a satellite in orbit. Its first successful mission was that of “Dongfanghong-I” (The East is Red) and it took place in April 24, 1970. By the end of 2000, China had launched 47 satellites, with a success rate of over 90%. Four satellite types were produced up to that point. There were recoverable remote-sensing satellites, the “DFH” (Dongfanghong) telecommunications and broadcasting satellites, the “FY” (Fengyun) meteorological satellites and the “SJ” (Shijian) scientific research and technological experiment satellites. The “ZY” (Ziyuan) earth resource satellite series was under construction at the beginning of the century. China became the 3rd country in the world to master satellite recovery technologies and the 5th country to place a satellite in geostationary orbit. [3]

From 2000 to 2006, China launched 22 different satellites. There was an upgrade to the satellites series, since along with the “ZY” type, the “Beidou” navigation and positioning satellite was introduced. At this point, the first oceanic satellites were under development and a plan for “a constellation of small satellites for environment and disaster monitoring and forecasting” had been on the way. The FY-1 and FY-2 meteorological satellites had been “listed by the World Meteorological Organization in the international series for meteo-services” and important breakthroughs had been achieved in the platforms for big GEO-sats and the development of large capacity Tele-sats along with Small-sats. [4]

By the release of 2011's White Paper and on, there has been a distinguished presentation of achievements on each of the different satellite types. For each type we have created a graph presenting the different assets (commercial, civil, military and governmental) that China currently owns, along with their number of in-orbit operational hardware. The data we have used were retrieved by the "UCS Satellite Database", published by the Union of Concerned Scientists, and which has been lastly updated on the 1st of May, 2022. [136]

Remote Sensing (Earth Observation)

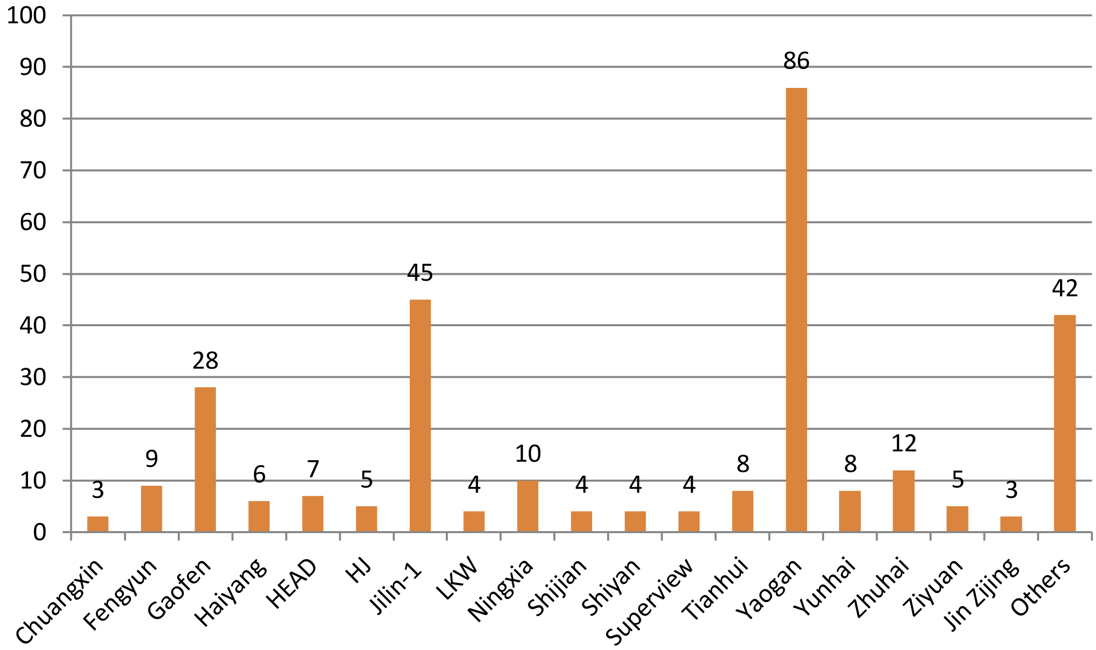
Since 2011 China had developed Fengyun (Wind and Cloud), Haiyang (Ocean), Ziyuan (Resources), Yaogan (Remote-Sensing) and Tianhui (Space Mapping) satellite series, plus a constellation of small satellites for environmental and disaster monitoring and forecasting. The first Haiyang dynamics environmental satellite had been launched in August, 2011. In 2010, China formally initiated the development of an important special project - a high-resolution Earth observation system. [5]

From 2011 to 2016, China had fully implemented the aforementioned High-resolution Earth Observation System program, introducing the Gaofen (High Resolution) satellite type. The technological breakthroughs inserted by these satellites are of great importance since they present capabilities of great value for both military and scientific purposes. "The Gaofen-2 is capable of sub-meter optical remote-sensing observation, the Gaofen-3 has a Synthetic Aperture Radar (SAR) imaging instrument that is accurate to one meter and the Gaofen-4 is China's first geosynchronous-orbital high-resolution earth-observation satellite" [6].

Also, the Jilin-1 satellite had been launched, offering high-resolution remote-sensing data for commercial use. The Jilin-1 satellite is part of China's first self-developed commercial remote sensing satellite systems, operated by Chang Guang Satellite Technology Corporation. The Jilin-1 constellation was designed to have 138 satellites at an altitude of 535 km to achieve a global revisit time of about 10 minutes. [165]

In the past five years, China's space-based section of the High-resolution Earth Observation System has been improved, providing high-spatial, high-temporal and high-spectrum resolution earth observation. [7]

In the following graph, the main different types of Chinese Earth-Observation Satellites are presented. China currently owns 50 different models of these satellites but we have narrowed are sample down to 19, including only those with at least 3 orbital assets, while the types ranging from 1 to 2 orbital asset have been summed up under the "Others" label. [136]



Graph 1: Main types of Chinese Earth-Observation Satellites and their respective numbers [136]

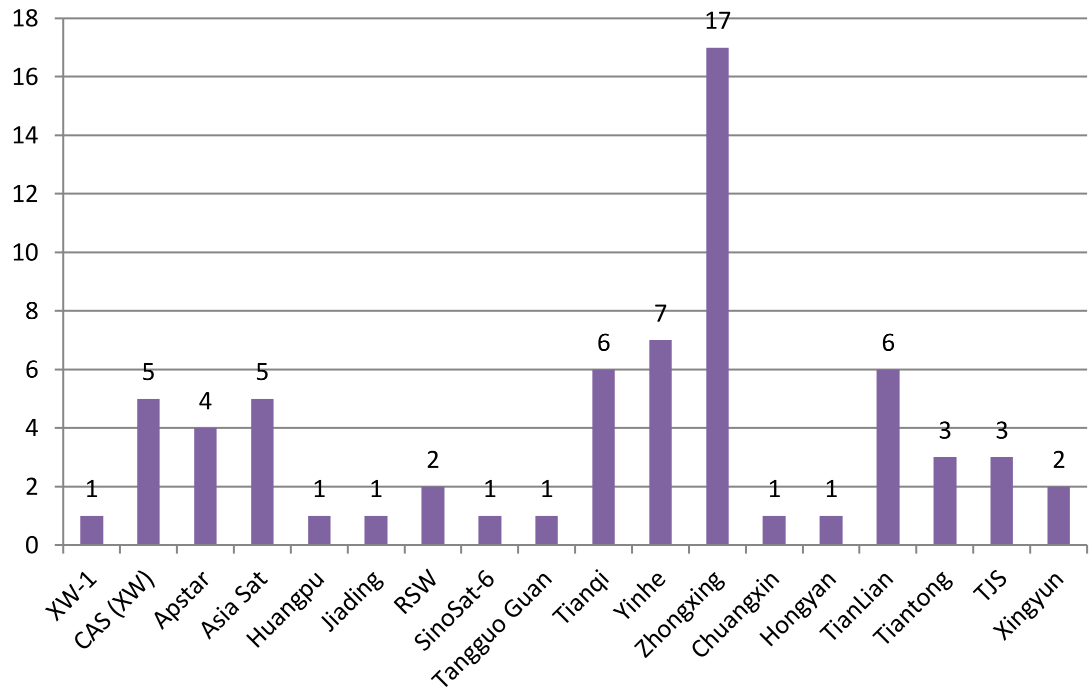
Communications and broadcasting

Since 2011, China had achieved significant progress in voice, data and television communications by improving its high-capacity GEO satellite platform, space-based data relays, telemetry and command (TT&C). A major step was the successful deployment of the Zhongxing-10 satellite, increasing power and capacity of communications and broadcasting technologies, along with the Tianlian-1 (Space Chain) satellite which supported both data relays and TT&C. [5]

From 2011 to 2016, the successful launch of communication satellites, such as Yatai and Zhongxing, upgraded China’s communication services since a full cover of all its territory, as well as major areas of the world, could be provided through a fixed communications’ satellite support system. The Tiantong-1, China’s first mobile communications satellite, had been deployed. As mentioned in the report: “The first-generation data relay satellite system composed of three Tianlian-1 satellites has been completed, and high-speed communication test of satellite-ground laser link has been crowned with success”. The development of the DFH-5 super communications satellite platform was in process. [6]

From 2016 to 2021, through the Zhongxing satellites China ensured the uninterrupted, stable operation of broadcasting and television services. Zhongxing-16 and APSTAR-6D satellites, provided a 50Gbps capacity, reaching the stage of high-capacity service. The mobile communications and broadcasting satellite network has expanded, providing voice, short message and data services for hand-held terminal users in both China, and its neighboring areas, and certain parts of the Asia-Pacific. The relay satellite system had been improved. The satellite communications and broadcasting ground system has been upgraded, forming a space-ground integrated network that covers a wide range of applications, such as satellite communications and broadcasting, internet, Internet of Things, and information services around the globe. [7]

The graph below shows the main types of Chinese communication satellites. China currently owns 18 different models of these satellites. [136]

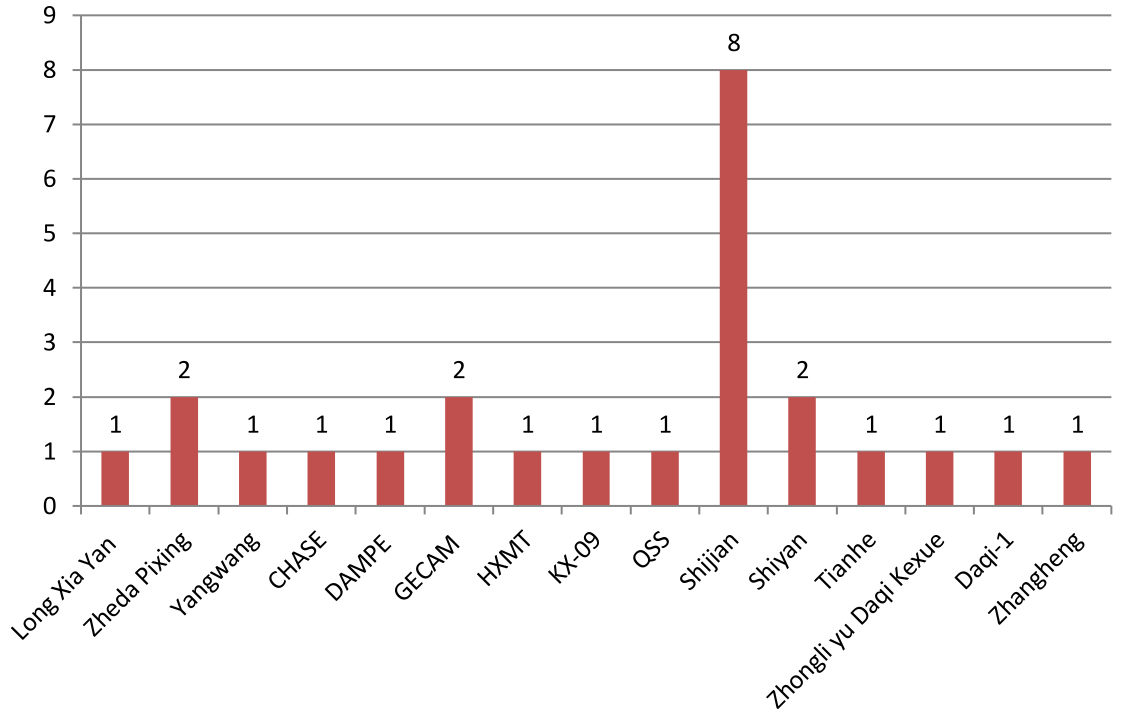


Graph 2: Main types of Chinese Communication Satellites and their respective numbers [136]

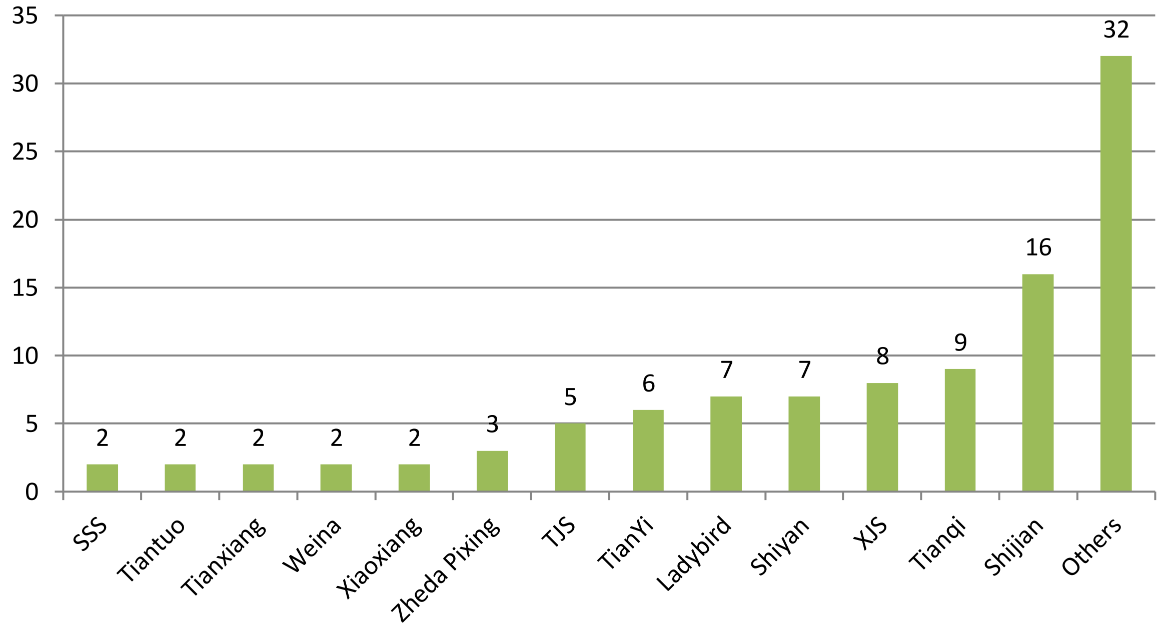
<u>Scientific and technological tests</u>

Many successful Shijian (Practice) and small and micro satellites have been set in orbit up to date, supporting space environment exploration, scientific tests and new technology demonstration.

In the graphs below, the main different types of Chinese Scientific and Technology Demonstration Satellites are presented. China currently owns 15 different models of scientific satellites and 45 for technology demonstration. In the graph presenting the latter we have included all types with more than 1 orbital asset while the rest have been summed up under the “Others” label, thus presenting an overall of 15 different types. [136]



Graph 3: Main types of Chinese Scientific Satellites and their respective numbers [136]



Graph 4: Main types of Chinese Technology Demonstration Satellites and their respective numbers [136]

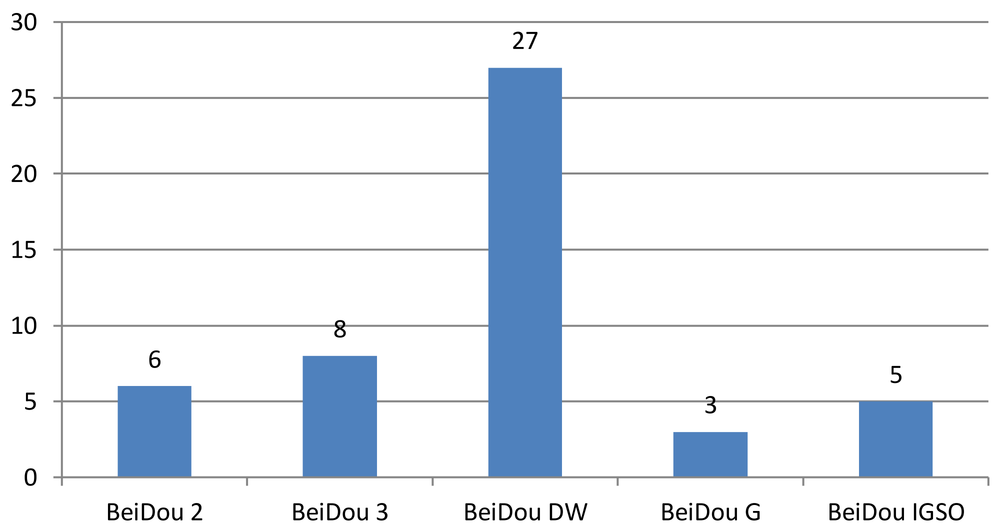
Navigation and positioning

Since 2007, China had launched four BeiDou (Bid Dipper) satellites. The goal for a fully operational navigation and positioning constellation of satellites included five GEO-sats, five IGSO-sats (Inclined Geosynchronous Orbit) and four MEO-sats (Medium Earth Orbit). Ten out of these fourteen satellites had been operating since 2011 providing trial services in the Asia-Pacific region. [5]

Since 2016, the BeiDou Navigation Satellite System had been completed, offering “positioning, velocity measurement, timing, wide area difference and short-message communication services” to customers. [6]

In 2021, the BeiDou system consisted of 30 satellites and had enhanced its services with “regional and global short-message communication, global search and rescue, ground-based and satellite-based augmentation, and precise point positioning” capabilities [7]. China became the fourth space power to provide global navigational capabilities after the United States of America (GPS), Russia (Glonass) and the European Union (Galileo). Japan (Quazi-Zenith Satellite System - QZSS) and India (Indian Regional Navigation Satellite System - IRNSS) have also implemented navigation satellites and applications but are still operating in a regional basis.

In the following graph, the number of the main different types of Chinese Navigation Satellites is presented. China currently owns 5 different models of these satellites. [136]



Graph 5: Main types of Chinese Navigation Satellites and their respective numbers [136]

According to the 2021 Space Policy released by the CNSA, “the next five years plan for man-made satellites consists of the following steps:

• Upgrade its spatial information services featuring extensive connection, precise timing and positioning, and all dimension sensoring;

• Develop satellites for geostationary microwave monitoring, new-type ocean color observation, carbon monitoring of the territorial ecosystem, and atmospheric environmental monitoring;

• Develop dual-antenna X-band interferometric synthetic aperture radar (InSAR), land water resources and other satellite technology, for efficient, comprehensive earth observation and data acquisition across the globe;

• Build a satellite communications network with high and low orbit coordination, test new communications satellites for commercial application, and build a second-generation data relay satellite system;

• Study and research navigation-communications integration, low-orbit augmentation and other key technologies for the next-generation BeiDou Navigation Satellite System, and develop a more extensive, more integrated and smarter national positioning, navigation and timing (PNT) system;

• Continue to improve the ground systems for remote-sensing, communications and navigation satellites." [7]

Guo Wang

A specific mention must be made regarding China's plan to build a mega-constellation of satellites called Guo Wang (State Network), which aims to provide widespread internet coverage. According to an article by Juliana Suess on RUSI, the project is led by the company SatNet, created by China's State-Owned Assets Supervision and Administration Commission (SASAC), and it is expected to consist of 13,000 satellites. The motivations behind China's investment in this project, include the success of Space-X's Starlink and the need for reliable internet access in various regions of the world. Starlink has gained 1 million global subscribers and showcased the commercial potential of satellite-enabled internet services. Starlink also highlighted the dual-use capabilities of such an infrastructure, offering C2, communications and UAV's enhancement during a military conflict, such as in Ukraine. However, Starlink still faces limitations in terms of global coverage, and there is a growing demand for more affordable alternatives, which Guo Wang could potentially fulfill. Taiwan has also expressed interest for a Starlink-like program since it could support internet access (and thus a huge amount of state operations and civil information) during a military intervention. The island is dependent on the use of undersea cables and those being targeted could result in isolation. [179]

The article also highlights China's focus on soft power, particularly in Africa, where the country has signed numerous space cooperation agreements and established infrastructure through the Belt and Road Initiative. This existing presence and infrastructure could lead African countries to choose the Chinese internet constellation over Western providers, further strengthening China's soft power in the region. Moreover, the article discusses the potential challenges of operating mega-constellations in Low Earth Orbit (LEO), including concerns about collision risks and the environmental impact of satellite debris. These factors could motivate China to launch Guo Wang sooner rather than later, as restrictions on mega-constellations might become more stringent in the future. In conclusion, China's investment in a satellite-enabled internet constellation aligns with its pursuit of economic opportunities, soft power expansion, and addressing the limitations of existing services. While Starlink currently holds a competitive edge, the success of Guo Wang will depend on its ability to provide affordable and accessible internet coverage, especially in regions where connectivity remains a challenge. [179]

❖ Launching Sites

In the beginning of the 21st century, three launching sites - Jiuquan, Xichang and Taiyuan - were operating in China, offering a variety of space launches for both domestic and international missions. Through the second decade, a fourth space launch site had been under construction in Hainan province for accommodating new-generation rockets. In 2016, this launch site began operating in Wenchang. Both coastal and inland areas, high and low geographical attitudes and different types of trajectories have been covered through this complex of launching sites. [6]

According to the 2021 Space Policy released by the CNSA, “in the next five years China shall:

• Further adapt the existing launch site system to better serve most launch missions, and make launch sites smarter, more reliable and more cost-effective to support high-intensity and diversified launch missions;

• Build commercial launch pads and launch sites to meet different commercial launch needs”. [7]

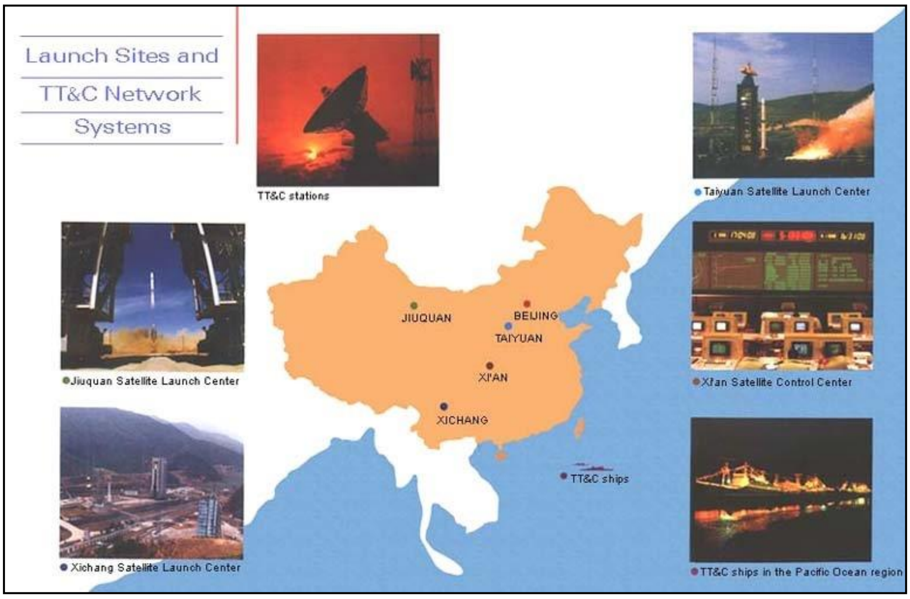


Fig. 3: Chinese space facilities [15]

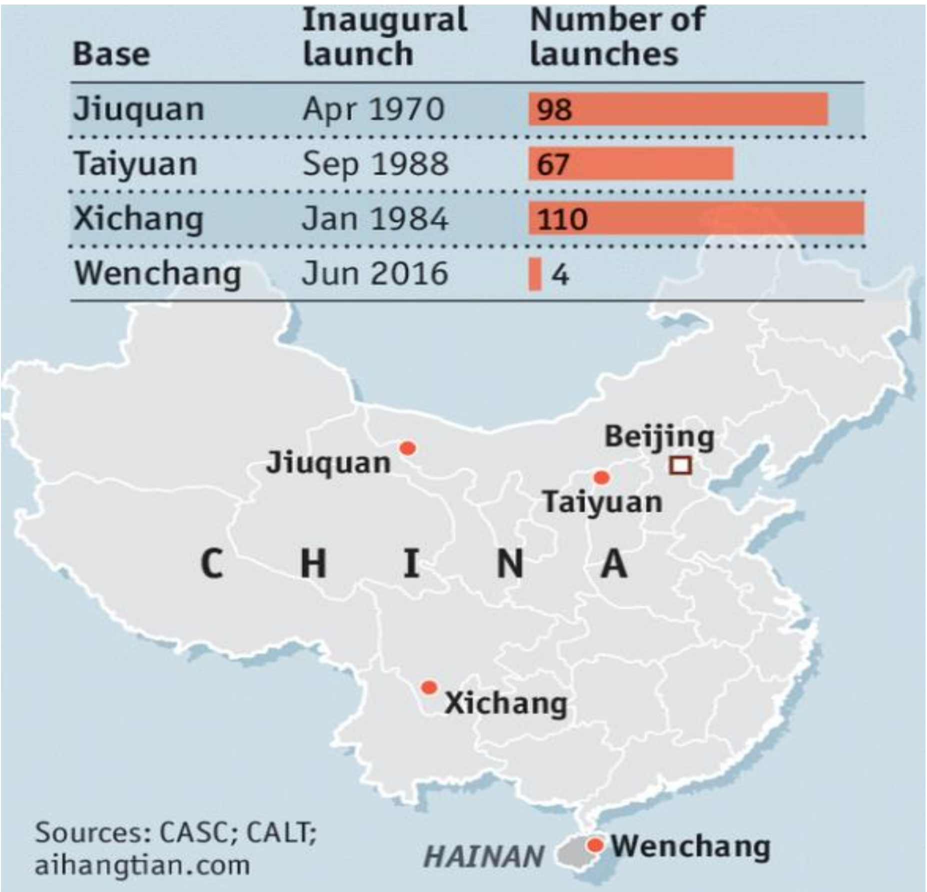


Fig. 4: Chinese Space Facilities and Number of Launches per Site (2018) [16]

❖ TT&C

Since 2000, China's Telemetry Tracking & Command network has been combining ground stations and ships of internationally advanced level capabilities. Since 2011, "a very long baseline interferometry (VLBI) network comprising four observation stations and a data processing center" has been operating. China's TT&C network had been expanding from ground to space and from geo-space TT&C to deep-space TT&C. Up to 2016, a spacecraft tracking ship – Yuanwang-7 – had started operating and the overall TT&C network has been offering space, ground and marine TT&C connections. In the last five years, a leap from cislunar to interplanetary TT&C communications has been achieved. "TT&C missions of the Shenzhou and Tianzhou spacecraft series, Tianhe core module, Chang'e lunar probe series, and Tianwen-1 Mars probe have been completed successfully". [7]

According to the 2021 Space Policy released by the CNSA, “in the next five years China will strengthen unified technical standard-setting for its space products and on this basis will:

• Improve the space TT&C network in terms of organization, technology and methodology, grow the capacity to utilize and integrate space- and ground-based TT&C resources, and build a space TT&C network providing ubiquitous coverage and connections;

• Coordinate the operation and management of the national space system for greater efficiency;

• Strengthen the deep-space TT&C communications network to support missions probing the moon and Mars.” [7]

❖ Manned Spaceflight

China’s history of manned missions to space has its roots in 1992. Back in the beginning of the 21st century China had developed a manned spacecraft and an according high-reliability launching vehicle. Studies were focused in aerospace medicine and life science, first astronauts’ reserves were chosen and equipment for remote sensing and scientific experiments on a manned flight were developed. A significant milestone for China’s manned space program was accomplished when its first unmanned experimental spacecraft Shenzhou (Divine-Ship) was set in orbit and recovered on November 20-21, 1999. [3]

After three more experimental spacecrafts and eleven years since the beginning of the program, China’s great leap forward was made in October 15-16, 2003. The Shenzhou-V manned spacecraft was launched. By this successful mission China became the third country in the world to ever send independently humans in space orbit (after the USSR and the USA). [4]

Up to 2011 China continued its successful manned spacecraft launches, while becoming the third country in the world to achieve astronaut space extravehicular activity. In September and November 2011, China successively launched the Tiangong-1 (Space Palace-1) and Shenzhou-8 spaceship, and accomplished their first space rendezvous and docking test, laying the foundation for the construction of future space laboratories and space stations [5]. In June 2012 and 2013, through the Shenzhou-9 and Shenzou-10 manned spacecraft’s docking to the target spacecraft Tiangong-1, China achieved new milestones concerning rendezvous, automatic and manual operations, and manned space transportation technologies. “In September and October 2016 the Tiangong-2 space laboratory and Shenzhou-11 manned spacecraft were launched and formed an assembly that operates steadily, with the mission of carrying out science and technology experiments in space, indicating that China has mastered technologies concerning astronauts’ mid-term stay in orbit, and long-term ground mission support” [6].

China accomplished another important milestone on its space station’s construction program with the successful docking of the Tianzhou-1 cargo spacecraft onto the earth-orbiting Tiangong-2 space laboratory. This achievement provided significant breakthroughs in key technologies for cargo transport and in-orbit propellant replenishment, thus completing China’s second phase of its manned spaceflight project.

On April 29, 2021 the Tianhe core module launched marking another solid step in the deployment of a modulated fully operational Tiangong space station. “The Tianzhou-2 and Tianzhou-3 cargo spacecraft and the Shenzhou-12 and Shenzhou-13 manned spacecraft, together with the Tianhe core module to which they have docked, form an assembly in steady operation. Six astronauts have worked in China's space station, performing extravehicular activities, in-orbit maintenance, and scientific experiments”. [7]

According to the 2021 Space Policy released by the CNSA, “in the next five years China will continue to implement its manned spaceflight project. It plans to:

• Launch the Wentian and Mengtian experimental modules, the Xuntian space telescope, the Shenzhou manned spacecraft, and the Tianzhou cargo spacecraft;

• Complete China's space station and continue operations, build a space laboratory on board, and have astronauts on long-term assignments performing large-scale scientific experiments and maintenance;

• Continue studies and research on the plan for a human lunar landing, develop new generation manned spacecraft, and research key technologies to lay a foundation for exploring and developing cislunar space.” [7]

❖ Deep Space Exploration

Following its successes in developing man-made satellites and conducting human spaceflights, China has performed great achievements in the field of deep space exploration. On October 24, 2007, China successfully launched its first lunar probe, Chang'e-1. The main accomplishments of the PRC’s lunar and planetary exploration missions up to today are being presented below.

<u>Lunar exploration</u>

- Chang'e-1: i) successful launch on October 24, 2007, ii) accurate orbital transfer, iii) successful orbiting, iv) retrieval of a variety of important scientific data, v) production of a complete map of the moon, vi) successful implementation of a controlled crash onto the lunar surface. [5]
- Chang'e-2: i) successful launch on October 1, 2010, ii) production of a full higher-resolution map of the moon, iii) retrieving a high-definition image of Sinus Iridium, iv) several extended tests, including circling the Lagrangian Point L2, which laid the foundation for future deep-space exploration tasks. [5] v) successful observation trip over asteroid 4179 (Toutatis), on December 2012. [6]
- Chang’e-3: i) first soft landing on the surface of an extraterrestrial body by a Chinese spacecraft, on December 2013, ii) completing patrol and exploration on the surface of the moon. [6]
- In November 2014 China achieved success in the reentry and return flight test of the third-phase lunar exploration engineering, indicating that China has mastered the key technology of spacecraft reentry and return flight in a speed close to second cosmic velocity. [6]

- Chang'e-4: i) performed humanity's first soft landing on the far side of the moon, achieving relay communications through the Queqiao satellite, ii) conducted roving exploration.
- Chang'e-5: i) brought back 1,731 g of samples from the moon, marking China's first successful extraterrestrial sampling and return, and the completion of its three-step lunar exploration program of orbiting, landing and return. [7]

Planetary exploration

The Tianwen-1 Mars probe launched on 23 July, 2020 and has achieved orbital transfer, Mars orbiting and successful deployment of its landing mechanism. The Zhurong Mars rover is exploring the planet and left China's first mark there. China has achieved a leap from cislunar to interplanetary exploration. [7]

According to the 2021 Space Policy released by the CNSA, “in the next five years China will continue with lunar and planetary exploration. It will:

• Launch the Chang'e-6 lunar probe to collect and bring back samples from the polar regions of the moon;

• Launch the Chang'e-7 lunar probe to perform a precise landing in the moon's polar regions and a hopping detection in lunar shadowed area;

• Complete R&D on the key technology of Chang'e-8, and work with other countries, international organizations and partners to build an international research station on the moon;

• Launch asteroid probes to sample near-earth asteroids and probe main-belt comets;

• Complete key technological research on Mars sampling and return, exploration of the Jupiter system, and so forth;

• Study plans for boundary exploration of the solar system”. [7]

2.2.2. Space Science

China began studying the upper atmosphere through rockets and balloons in the ‘60s. During the ‘70s, the PRC performed its first scientific explorations in space using the Shijian satellites. Throughout the following decades many different satellites and spacecrafts have been launched and operated for scientific purposes, and a wide variety of international joint programs have been conducted. Some of the main fields of space science that China has studied are: [3], [4], [5], [6], [7]

- Space weather forecasting, charged particles detection and analysis of Earth’s magnetosphere.
- Sun-Earth exploration through the Double Star Satellite Exploration in collaboration with ESA.
- Micro-gravity and strong radiation experiments focusing on life science, space materials, fluid mechanics and crop breeding, using the Shenzou spacecraft, the Shijian and other recoverable satellites.
- High-power astronomical observation in space.
- Observation and monitoring of space debris.

- Study of Lunar morphology, structure, surface matter composition, microwave properties and near-moon space environment.
- Research on complicated and challenging scientific fields, through the successful launches of the Dark Matter Particle Explorer, the Shijian-10 and the Quantum Science Experiment Satellite.

2.2.3. Space Debris

Regarding safety of space assets and governance of space environment, China has developed many systems for space debris monitoring. Focusing on space event prediction, collision warning and avoidance, China has effectively complied with the Space Debris Mitigation Guidelines and the Guidelines for the Long-Term Sustainability of Outer Space Activities. Through upper stage passivation of its space launchers, de-orbiting of satellites reaching their end-of-life cycles (both in LEO and GEO), search and tracking of near-earth objects, data analysis, production of manned spacecrafts protection systems, China has developed a basic active space climate service system.

According to the 2021 Space Policy released by the CNSA, "in the next five years China will continue to expand its space environment governance system. It will:

• Strengthen space traffic control;

• Improve its space debris monitoring system, cataloguing database, and early warning services;

• Conduct in-orbit maintenance of spacecraft, collision avoidance and control, and space debris mitigation, to ensure the safe, stable and orderly operation of the space system;

• Strengthen the protection of its space activities, assets and other interests by boosting capacity in disaster backup and information protection, and increasing invulnerability and survivability;

• Study plans for building a near-earth object defense system, and increase the capacity of near-earth object monitoring, cataloguing, early warning, and response;

• Build an integrated space-ground space climate monitoring system, and continue to improve relevant services to effectively respond to catastrophic space climate events". [7]

3. CHINA'S INTERNATIONAL COOPERATION IN SPACE

China's international activities in the space field are of great value for this research since they provide important data for the PRC's geopolitical aspirations and its established influence, both in regional and global perspectives. As referred in the State Council's public releases "China persistently supports activities involving the peaceful use of outer space, and maintains that international space cooperation shall be promoted and strengthened on the basis of equality and mutual benefit, mutual complementarity and common development." [3]

3.1. Guiding Principles

China's philosophy regarding its international space cooperation is established on the fundamental principles listed in the "Declaration on International Cooperation on Exploring and Utilizing Outer Space for the Benefits and Interests of All Countries, Especially in Consideration of Developing Countries' Demands" which was approved by the 51st General Assembly of the United Nations in 1996. According to the publicly released White Papers, China adheres to the following principles while carrying out international space cooperation:

- The aim of international space cooperation is to peacefully develop and use space resources for the benefit of all mankind.
- International space cooperation should be carried out on the basis of equality and mutual benefit, mutual complementarity and common development, and the generally accepted principles of international law.
- The priority aim of international space cooperation is to simultaneously increase the capability of space development of all countries, particularly the developing countries, and enable all countries to enjoy the benefits of space technology.
- Necessary measures should be adopted to protect the space environment and space resources in the course of international space cooperation.
- The function of the United Nations Office of Outer Space Affairs (OOSA) should be consolidated and the outer space application programs of the United Nations should be backed up.
- Safeguarding the central role of the United Nations in managing outer space affairs; abiding by the "Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies"; upholding the guiding role of relevant UN principles, declarations and resolutions; actively participating in the formulation of international rules regarding outer space; and promoting greater sustainability of space activities.

3.2. Fundamental Policies

In the first three public White Papers released (2000, 2006 and 2011), the policies adopted by the Chinese government concerning the development of international space cooperation are summarized as follows [3], [4], [5]:

- Persisting in the independence and self-reliance policy, carrying out active and pragmatic international space cooperation to meet the needs of the national modernization drive and the demands of the domestic and international markets for space science and technology.
- Supporting multilateral international cooperation on the peaceful use of outer space within the framework of the United Nations. Supporting all intergovernmental and nongovernmental space organizations' activities that promote development of the space industry;
- Attaching importance to the Asian-Pacific regional space cooperation and supporting space cooperation in other regions of the world.
- Attaching importance to space cooperation with both developed and developing countries.
- Enhancing and supporting research institutions, industrial enterprises, universities and colleges to develop international space exchanges and cooperation in different forms and at different levels under the guidance of relevant state policies, laws and regulations.

The reference to non-governmental organizations and enterprises added in the 2006 White Paper is providing a view on China's turn in the "New Space" era, where the private sector's involvement is rearranging national and international space activities.

In the 2016 and 2021 White Papers the basic policies concerning international cooperation have been readapted. Keeping the core philosophy of cooperation for the peaceful use of outer space and exchanging technologies in the scope of United Nations agreements, with regard to both independence and national development, some important points have been added clarifying China's international and regional goals in the space sector. These guidelines are important since they are connected to China's broader international geopolitical strategies. The policies added, and which shall be analyzed further in the following paragraphs, are [6], [7]:

- Strengthening bilateral and multilateral cooperation which is based on common goals and serves the Belt and Road Initiative, and ensuring that the space industry benefits the Initiative's participating countries, especially developing countries;
- Supporting the Asia-Pacific Space Cooperation Organization to play an important role in regional space cooperation, and attaching importance to space cooperation under the BRICS and Group 20 cooperation mechanisms and within the framework of the Shanghai Cooperation Organization;

3.3. Important Events

China's space program has been in-line with international exchanges and collaboration processes since the mid-'70s. China has been involved in all types of space cooperation concerning bilateral, regional, multilateral and international agreements. An important milestone has been the initialization of commercial launching services and China's subsequent entrance into the global rocket-services' market.

Along with the dozens of space cooperation agreements with multiple countries, space agencies and international organizations in a bilateral level, China has established multilateral cooperation in space technologies and application through the

Asia-Pacific region and has, also, joined relevant activities sponsored by the United Nations and other international organizations

Bilateral Cooperation

Through the years, China has signed many inter-governmental agreements and memorandums, has established long-term cooperative relations, and has engaged in multilateral and regional space coordination forums. China is coordinating its space activities in an intercontinental way, spreading its influence and know-how in countries all over the world, but also receiving substantial aid in several fields of space technologies and applications. China has cooperated with the United States, Canada, Italy, Germany, Britain, France, Sweden, Russia, Ukraine, Japan, Malaysia, Pakistan, India, Algeria, Argentina, Brazil, Peru, Chile, ESA, the European Union Committee and other countries. "Bilateral space cooperation is implemented in various forms, from making reciprocal space programs and exchanges of scholars and specialists, and sponsoring symposiums, to jointly developing satellite or satellite parts, and providing satellite piggyback service and commercial launching service".

In the following paragraphs we refer to China's most substantial bilateral collaborations as presented in the White Papers of its space activities and literature concerning every different geographical area of cooperation.

3.3.1. South America

The cooperation between China and Latin America in the space sector can prove to be a powerful interpretational guide towards understanding China's global political scopes and the struggle of emerging economies and underdeveloped nations for rearranging the current U.S. global dominance into a multi-polar world order. According to Julie Michelle Klinger in the article "A Brief History of Outer Space Cooperation between Latin America and China" [18] the bilateral and multinational space collaboration projects must be studied through the perspective of "the geopolitical implications that these relationships cause to the U.S.-dominated post-Cold War era". The relationships between space agencies and organizations of China and a variety of Latin American nations emerged through the struggle of Global South countries to establish their rights in the space arena and in resource geopolitics, thus affecting global political economy.

Most of the space capabilities developed through international cooperation have been established on the basis of the treaties concerning the peaceful use of outer space, "most of which have been shaped and drafted from Latin American countries" [18]. Although, these peaceful global treaties have served the development of many countries' space industries, they are characterized by inequalities concerning the actual assurance of equity in national and multilateral deployment of space activities, and carry many limits originating from international competition.

Klinger states that "as envisioned during the Cold War in a series of conferences among newly or nearly independent states, South-South cooperation would consist of mutual support and solidarity among Third World, developing, or nonaligned states. By sharing technology, expertise and capital, delegates from these countries envisioned a world in which formerly subjugated nations would build modern and prosperous societies”. [18] A country’s space strategy is not independent from its position in the global complex and its political goals, both national and bilateral. The development of space technology, policies, agreements and infrastructure are a projection of a state’s geopolitical and economical plans. Furthermore, terrestrial inequalities and political struggles are depicted in the international space race. Since space utilization plays an important role in “resources exploitation, technological development and scientific research” it is turned into an arena of confrontation, establishment and reproduction of political economies, international prestige, cultural export and global dominance after all. So despite the fact that space is characterized as a “province of all mankind” in the Outer Space Treaty, it actually “reflects unequal power relations in Earth”. Especially, if we consider how vital space applications are to contemporary life we can understand that not only are space policies influenced by geopolitical processes but they affect them vice versa. From “capital accumulation” to “military strategies”, ownership and evolution of space technologies & applications have widened and affect vital sectors of a state’s economical, structural and social reproduction. As Klinger points “The behavior of markets, states, social movements, and scientists is mediated through outer space-based technologies. These technologies link local, national, and international actors and institutions to their enabling infrastructures in outer space”. [18]

According to Klinger “the ideals of South-South solidarity continue to motivate space relations between Latin American countries and China”. [18] This strategy has been implemented in various fields outside the space sector too, such as military cooperation. Trade of arms and defense systems with China became an attractive option due to the political proximity that many governments in Latin America have developed in the turn of the century, and the consequent less-strict regulations. Those governments mostly refer to the “pink-tide” political wave that brought many left-wing political parties to authority. Some of the most prominent political leaders of the “pink-tide” wave are Chavez & Maduro in Venezuela, Morales & Arce in Bolivia, Lula in Brazil, Fernandez in Argentina, Castillo in Peru, Castro in Honduras, Boris in Chile, Petro in Colombia, Ortega in Nicaragua and others.

The development of space technologies has proved vital for both China and Latin American nations since it contributes in the enhancement of technological-scientific strength and the “projection of sovereignty” of those states inside the frame of a “more pluralistic space”. As a result this procedure affects the international geopolitical, scientific and technological arenas in a way that favors both China, as the primal antagonist of the United States, and the emerging economies of Latin America, into their common goal of “democratizing” the global political consensus towards a multi-polar world. Bilateral collaborations have been achieved between China and Bolivia, Venezuela, Peru, Argentina, Ecuador, Mexico, Uruguay.

In their effort to develop their autonomous and independent space programs outside U.S. restrictions and influence, China and Brazil have formed a joint cooperation strategy in the space segment since the 90’s. A project of an earth resources satellite was developed and the first of a longstanding series, satellite CBERS-01 (China-Brazil-Earth-Resources-Satellite) was launched by China on October 14, 1999. Research through collaboration had, also, been implemented in the fields of satellite technology, satellite application and satellite components. “The cooperation between China and Brazil in the space sector has set a good example for the developing countries in "South-South Cooperation" in the high-tech field”. [3] The aforementioned reference is indicative of how, from as far back as the beginning of the century, bilateral and multinational collaborations including underdeveloped or emerging economies of the world have been established, how the BRICS initiative started taking shape and how terms such as "Global South" emerged in the international geopolitical agenda. Throughout the years, China and Brazil have successfully launched CBERS-2, CBERS-2B, CBERS-3, CBERS-4 and CBERS-4A. They have established the Sino-Brazilian High-level Coordination Commission and signed a variety of protocols, such as Cooperation Agreement of China and Brazil on Remote-Sensing Satellite Data and Application, concerning the use of the received data, while expanding its application in a regional and global manner. The two countries have, also, worked together to set up the China-Brazil Joint Laboratory for Space Weather.

The tables below present some of the most important agreements and cooperation schemes concerning space activities between China and Latin American countries:

Table 5: Space Activities between Latin America and China vol.1 [18]

Country	Date	Event
Argentina	2004	Bilateral agreement under which China will provide commercial launch services, satellite components, and other space-related technology
	2005	Argentina becomes observer to Asia-Pacific Space Cooperation Organization San Juan University collaborates with China National Astronomical Observatories and China National Academy of Science to develop a satellite laser ranging facility
	2015	Joint Argentina-China defense and weapons sales agreement that also authorizes construction of Chinese satellite tracking and control center in Neuquén Province; base is considered sovereign Chinese territory
Bolivia	2010	Bolivia signs $300 billion contract with China Great Wall Industry Corporation to build the Bolivia's first communications satellite; China funds 85 percent of costs
	2013	China launches second Chinese-built satellite for a Latin American partner state from Xichang Satellite Launch Center in Sichuan, China; operated by Beijing-trained Bolivian personnel
Brazil	1984	Joint agreement to develop the China-Brazil Earth Resources Satellite program
	1988	Protocols established for joint research and production of satellites
	1999	First China-Brazil Earth Resources Satellite (CBERS-1) launched from Taiyuan Satellite Launch center in Shanxi, China
	2003	Second China-Brazil Earth Resources Satellite (CBERS-2) launched from Taiyuan Satellite Launch center in Shanxi, China
	2005	Brazil invited to be observer to Asia-Pacific Space Cooperation Organization
	2007	Third China-Brazil Earth Resources Satellite (CBERS-2B) launched from Taiyuan Satellite Launch center in Shanxi, China
	2013	Launch failure of CBERS-3 due to Chinese rocket malfunction
	2014	Fourth successful China-Brazil Earth Resources Satellite (CBERS-4) launched from Taiyuan Satellite Launch center in Shanxi, China

Table 6: Space Activities between Latin America and China vol.2 [18]

Chile	**2005**	Chile invited to be observer to Asia-Pacific Space Cooperation Organization
	2011	China makes unsuccessful bid to build and launch Chilean Earth observation satellite
Ecuador	**2013**	Following delays at Russian launch site, Ecuadorian satellite NEE-1 launched from Jiuquan Satellite Launch Center in Inner Mongolia Autonomous Region, China
Mexico	**2015**	Mexico joins the Asia-Pacific Space Cooperation Organization
Peru	**2005**	Peru is a founding member of Asia-Pacific Space Cooperation Organization
Venezuela	**2005**	Venezuela Science and Technology Ministry signs joint satellite launch agreement with China Great Wall Industry Corporation
	2008	VeneSat-1 launched from China; first Chinese-built satellite launched for Latin American partner state
	2011	Venezuela signs $144.8 million contract with China to build and launch Venezuelan Remote Sensing Satellite (VRSS-1)
	2012	VRSS-1 launched from Jiuquan Launch Center, Inner Mongolia Autonomous Region, China
	2014	Second agreement for China to build and launch Venezuelan Remote Sensing Satellite (VRSS-2)
	2017	VRSS-2 launched from Jiuquan Launch Center, Inner Mongolia Autonomous Region, China

3.3.2. Europe

As far as European countries are concerned China has achieved many important collaboration agreements both with the European Space Agency and through independent cooperation with many states in a bilateral way.

- Regarding ESA, the Sino-ESA Double Star Satellite Exploration of the Earth's Space Plan project has been conducted and operating. The "Dragon Program" has been implemented, “involving cooperation in Earth observation satellites, having so far conducted 16 remote-sensing application projects in the fields of agriculture, forestry, water conservancy, meteorology, oceanography and disasters” [4]. The "Status Quo of China-Europe Space Cooperation and the Cooperation Plan Protocol" has been signed under the mechanism of the China-Europe Joint Commission on Space Cooperation. The two sides cooperated closely during the lunar exploration missions of Chang'e-1 and Chang'e-2, and signed the "Agreement on Mutual Support for the TT&C Network and Operation" in September 2011. China and the European Space Agency signed the Outline of China-ESA Space Cooperation from 2015 to 2020 within the mechanism of the China-Europe Joint Commission on Space Cooperation. The two sides have declared their determination to cooperate in deep space exploration, space science, earth observation, TT&C services, space debris, and space-related education and training, and launched the panoramic imaging satellite for solar wind and magnetosphere interaction. The two sides have completed cooperation on the Dragon 3 cooperation program. China has signed the "Cooperation Agreement on the Application, Exchange and Distribution of Meteorological Satellite Data" with the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT), to promote the sharing in and application of meteorological satellite data.

- The Sinosat-1 was developed and manufactured through cooperation with DASA and Aerospatiale in 1995, and was successfully launched in 1998. This satellite was the first collaborative project between the Chinese and European aerospace industries (including both French and German).
- China’s collaborative satellite programs with France have been mainly concerning scientific purposes. Under the mechanism of the Sino-French Joint Commission on Space Cooperation, they have developed joint progress in the fields of Earth science, life science, satellite application, and satellite TT&C. They have signed a cooperation framework agreement on space and marine science and technology, aiming at developing bilateral cooperation on astronomic satellite, ocean satellite and other satellite programs. An example of this cooperation is the China-France Oceanography Satellite (CFOSAT). This joint satellite mission is designed for monitoring the surface winds and waves of the global oceans. They have, also, signed a letter of intent on space and climate change, and worked to promote the application of space technology in global climate change governance.
- Relationships with Germany in the space field have been evolving since 1993, when a Sino-German joint venture - EurasSpace GmbH - was established. China, in the former decade, signed a framework agreement with Germany concerning bilateral collaboration in the field of human spaceflight. The two countries have carried out a cooperative experiment project on the Shenzhou-8 concerning space life science. Since 2016, they have strengthened coordination in high-end space manufacturing.
- China and the United Kingdom have established a joint laboratory on space science and technology, exchanged know-how on space science and technology, and conducted common research on many fields, such as lunar exploration, Earth observation and remote sensing, space experiments, personnel training and other areas.
- China and Italy set up the Sino-Italian Joint Commission on Space Cooperation, and have steadily carried forward research and development of the China-Italy Electromagnetic Monitoring Experiment Satellite Program.
- China and the Netherlands signed a memorandum of understanding on space cooperation, promoting cooperation in remote-sensing applications in agriculture, water resources and atmospheric environment. Furthermore, Chang’e-4 carried a Dutch payload on its mission, the Netherlands-China Low-Frequency Explorer (NCLE).

3.3.3. North America

In 2006, the director of the U.S. National Aeronautical and Space Administration (NASA) - Michael Griffin - visited China supposedly commencing a new era in the dialogue between the two superpowers, regarding the space field. [5] China and the United States, within the framework of the China-US Strategic and Economic Dialogue, have carried out a civil space dialogue in the last ten years, stating that the two countries would strengthen cooperation in space debris, space weather, response to global climate change, and related areas. However, the relationship between China and the United States in the context of space is largely defined by competition and tension. This topic will be explored in Chapter 6 of our thesis. [6]

Regional and Multilateral Cooperation

One of China's main targets in space cooperation is the Asia-Pacific region. The purpose of spreading its geopolitical influence through collaboration with underdeveloped or non-aligned (towards North-Atlantic hegemony) regional states has led China to strengthen its exchanges of space technology, manpower, know-how, launch services, ground station infrastructure, satellite buses and data management applications with many countries in the Asia-Pacific, as well as coordinating a number of space cooperation initiatives.

Beside regional influence, China aims highly in globalizing its influence and trade transactions (both exports and imports) by entering a variety of markets far away from a regional basis, such as East-European and Middle-East. The Belt and Road Initiative is the main project serving this purpose that China has been promoting through the last decade and space transactions are an important part of this international strategy.

The main two space associations that China has established in this process are the APSCO (Asian Pacific Space Cooperation Organization) and the BRI-SIC (Belt and Road Initiative – Space Information Corridor). We will examine the fundamental policies that govern these cooperative projects, as well as their primary development plans and current achievements.

3.3.4. APSCO

Through the last couple of decades space science, satellite applications and their according industrial production have proven to be not only a way to acquire international prestige but also a backbone of a state's economical flourish, crisis management capabilities, social improvements and technological innovations. The amount of financial and human resources that must be devoted to achieve space technologies and infrastructure is enormous. As a result, for developing countries international cooperation and exchanges of manpower, knowledge and equipment can prove of vital importance in the path of space utilization.

The Asian-Pacific Space Cooperation Organization (APSCO) is headquartered in Beijing and was established in 2008 as an inter-governmental organization. APSCO "provides a cooperative mechanism for developing countries in the region" and aims to emphasize in the use of space as "a drive of development". By resource and know-how sharing in all the domains of the space industry and its applications, APSCO promotes multilateral cooperation to enhance the space-based capabilities of its Members, which include: Bangladesh, China, Iran, Mongolia, Pakistan, Peru, Thailand and Turkey. Indonesia has also joined as a Signatory State and Mexico as an Observer State. [9]

The main purpose of APSCO is "to enable its Member States in the development of space capabilities by pooling up financial, technological and human resources in order to harness the maximal benefits from exploration and exploitation of outer space through peaceful uses of space science, space technology and its applications in support of sustainable socio-economic development of the peoples in the Asia-Pacific region, in particular, and the world, in general." [9]

Its main objective has been the development of a variety of collaborative space programs aiming at the peaceful application of space science and technology through the enhancement of cooperative potentials in the Asia-Pacific region. APSCO has taken effective actions to assist its Member States in space research, technological development, industrial progress and use of space-based applications through the implementation of national and regional space policies and the creation of cooperative networks between enterprises and institutions. It, also, aims in boosting international collaboration projects and widening the field of its activities on a global scale. [10]

The main cooperative activities in which APSCO has been involved are programs of space-technology applications and space-science research concerning Earth observation, disaster management, environmental protection, satellite communications and satellite navigation and positioning. Education, training and exchange of scientists, students and engineers have been the backbone of the organization's collaboration since its establishment, with more than 150 trainees from Member States being involved in this process every year. The development of a central data bank for the organization has, also, been a significant step in enabling common approaches, activities and future plans. [9], [10]

To optimize the utilization of its Member States' overall capabilities and their tremendous geographic distribution advantage, APSCO has established a number of networks which we present as published in the organization's website:

Data Sharing Network: APSCO initiated the Data Sharing Service Platform (DSSP) for jointly accessing and using a wide range of satellite remote sensing data in 2012. These data are mainly retrieved from China's existing databases and satellite resources but will be enhanced by other Member-States. Meteorological satellite data are also provided through this platform. [9]

In the beginning of this project four proposals were chosen to demonstrate application pilot projects. These were:

- Strengthening of Satellite Based Crop Monitoring and Estimation System for Food Security Application in Bangladesh proposed by Bangladesh.
- Remote Sensing Monitoring of Dust and its Applicative Demonstration in the Arid and Semi-Arid Areas proposed by China.
- Evaluation of different Remote Sensing Techniques for Drought Study proposed by Pakistan.

• Estimation of Rice Field using Multiple Satellite Sensors proposed by Thailand.

Space Segment Network and Interconnection of Ground Systems: Three in-orbit remote sensing satellites provided by China and eight new satellites which are planned to jointly develop by all Member States construct APSCO's joint Small Multi-Mission Satellites (SMMS) constellation. The goal of allocating and interconnecting ground stations in all participating countries will enhance the network's benefits. [9]

Ground-Based Space Object Observation (APOSOS) Network: APSCO aims to offer space observation capabilities through a network of ground-based space observation system for space object detection, tracking, and identifying capability building. "Three telescopes have been installed in Iran, Pakistan and Peru, and a data center was established for data sharing and joint observation operating". Tracking of objects and space debris in LEO is the main focus of the network. Further plans for extending its capabilities in MEO and GEO are under track. Collision avoidance early warning systems shall also be developed. [9]

Disaster Monitoring Network: APSCO "jointly conducted studies on remote sensing data application for drought, flood and landslide, compatible GNSS for emergency use, earthquake prediction based on ground Ionospheric Sounding and Electromagnetic Satellites" in order to confront climate crisis results and enhance disaster management and rescue capabilities in the Asia-Pacific region. All of these processes aim in the development of a regional CHARTER-like mechanism. [9]

The Charter is a worldwide collaboration, through which satellite data are made available for the benefit of disaster management. By combining Earth observation assets from different space agencies, the Charter allows resources and expertise to be coordinated for rapid response to major disaster situations; thereby helping civil protection authorities and the international humanitarian community. [167]

Space Application Network: APSCO has initiated many other networks for joint utilization of space assets, ground infrastructures and space technologies, such as tele-medicine, GNSS applications, space sensors' development, monitoring of atmospheric effects and research on near-earth space environment. [9]

Education and Training Centre/ Network: APSCO has constructed a wide network providing online training programs and know-how exchange for educating scientists and students of all Member-States in space operation, design, technologies and research.

Knowledge-sharing Platforms: APSCO has based knowledge exchange between its Members through 'International Symposiums' and 'Space Law & Policy Workshops/Forums', providing access to the latest research conclusions and inviting space-experts to share their professional experience and their nation's space-heritage background.

Finally, "APSCO attaches great importance to its cooperative relationship with UN-OOSA and all space-faring nations and international organizations and establishes close cooperation with IAF, UN-ESCAP, UN-SPIDER, ESA, etc. APSCO is an Observer of ICG and GEO and participates in IAC and space activities towards realizing SPACE2030 Agenda and thematic priorities of UNISPACE+50. APSCO commemorates a decade of excellent space cooperation and strong support with its Members and acknowledges an excellent cooperation with all partners, who contributed to APSCO's success". [9]

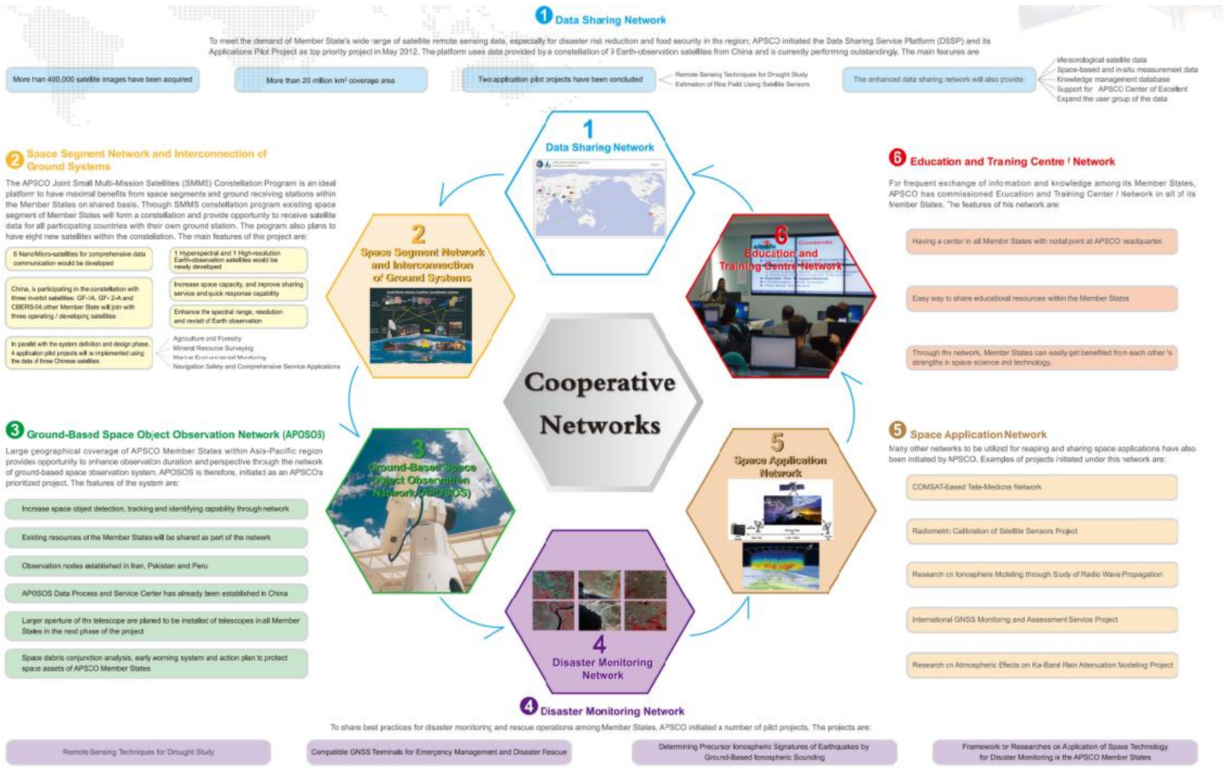


Fig. 5: APSCO's Cooperative Networks [10]

In general many countries that did not obtain space capabilities have demonstrated enormous progress through international cooperative space programs. Probably the most notable example is China itself if we focus on the beginning of its space industry and the exchanges with the USSR. However, in the frame of APSCO there is still an obvious gap between the state members. Bangladesh, Mongolia and Thailand are still processing the means to develop their own satellites. In an action plan of the United Nations, called Agenda 21, a capacity-building methodology for space operations is described including four main aspects: development of scientific and technological capacities, human resources, policy and law, and organizational development for space. For achieving equity, the capacity in the exploration and use of outer space of non space-faring nations must be developed in a quick and enhanced way. The gap between space-faring and non-space-faring countries will only widen without the support and assistance of the former, via international cooperation. With the exception of China, other member states of APSCO are all emerging space-faring nations with limited technological capacity.

According to Yongliang Yan in the paper "Capacity building in regional space cooperation: Asia-pacific space cooperation organization" a model for the space development assessment of evolving APSCO nations can be summed up to the following capabilities: 1) putting into place a basic national space authority, human resources, space policy or law as well as relevant facilities; 2) capability of operating satellites and applying satellite data; 3) capability of building satellites locally and independently; 4) capability of launching satellites independently; 5) capability of conducting manned space flights or operating space stations; and 6) capability of conducting extraterrestrial exploration. According to his frame a country can develop a space program with following the exact order of steps he refers as crucial or even by excluding some of them through its course. So regarding the APSCO Members: “Bangladesh, Mongolia and Thailand are proceeding to the tasks in the third category, Pakistan and Turkey are already in the third category, and Peru is on the way to the fourth category since it has successfully conducted a sounding rocket launch in 2013. Iran is proceeding to the fifth category as it has successfully sent a living monkey into the Earth’s orbit in 2013 and is planning to carry out its manned spaceflight in the foreseeing future. China is already in the sixth category”. Yan states that despite the fact that a nation’s space-law could be developed on a later stage of its space industry establishment, it could prove extremely important to regulate its space governance early. This perception is based on the fact that national space policies and laws are crucial in forwarding cooperation with other space-faring nations and enhancing international exchanges in all types of space-related issues. Yan notes that “while none of the APSCO member states had a comprehensive national space policy at the start, some of them indeed made an initial policy that provided direction for the development of their space affairs”. [19]

Space capacity of APSCO member states.

APSCO member states	Bangladesh	China	Iran	Mongolia	Pakistan	Peru	Thailand	Turkey
National space agency	Space Research and Remote Sensing Organization (1980)	China National Space Administration (1993)	Iranian Space Agency (2004)	Communication and Information Technology Authority (1987)	Space and Upper Atmosphere Research Commission (1961)	National Commission on Aerospace Research and Development (1974)	The Office of National Digital Economy and Society Commission (2002)	Turkish Space Agency (2018)
National space law								
National space policy		Yes (2000)	Yes (2005)	Yes (2012)	Yes (2011)	Yes (2009)	Yes (2016)	Yes (1993)
LEO satellite		Yes (1970)	Yes (2005)	Yes (2017)	Yes (1990)	Yes (2013)	Yes (1998)	Yes (2003)
GEO satellite	Yes (2018)	Yes (1984)			Yes (2011)		Yes (1993)	Yes (1994)
Local satellite building capacity	Yes? (2017)	Yes (1969)	Yes (2009)	Yes? (2017)	Yes (1990)	Yes (2013)		Yes (2011)
Satellite launch capacity		Yes (1970)	Yes (2009)		A rocket launch with America’s support (1962)	A sounding rocket launch (2013)		
Manned space flight		Yes (2003)	Animal space flight (2013)					
Moon probe landing		Yes (2013)						
Space station		Yes (2011)						

Fig. 6: Space Capacity of APSCO member states [19]

Furthermore, a report on APSCO’s activities is given by Yan along with a comparison between its evolving space capacity and that of other regional institutions and space organizations. Of particular importance is the analysis concerning the capacity building comparison between APSCO and APRSAF (Asia-Pacific Regional Space Agency Forum) where Japan plays a dominant role. There have been overlaps between the two foundations leading to waste of resources and competition, impacting on APSCO’s evolution. APSCO tends to have a more time-consuming methodology in the development of the state members’ space capabilities in both technological and human resources. In comparison some of APRSAF’s achievements have proven to be of interest to the least developed states (Mongolia, Bangladesh, Pakistan and Thailand) of APSCO, due to their most prompt practical use and return of hands-on experience. Yan states that “the small size of its membership, combined with limited economic and technological resources of its member states, which are primarily emerging space-faring nations, with the exception of China, makes APSCO focus more on addressing some urgent issues associated with sustainable development on Earth. Such financial and technological limitations might have presented an obstacle for the implementation of some ambitious space projects”. [19] He also claims that the way APSCO is structured, organized and coordinated proves to be an obstacle in the involvement of new members and along with the hierarchy which supposedly comes under the leadership of China, some doubts seem to have appeared concerning the ability of APSCO to retain its independency without the involvement of other advanced regional space-faring nations such as India, Japan and South Korea. China as the host country should be in the position to assist other APSCO member states to enhance their scientific and technological capacities for space, in particular in the fields of design, manufacture, launch, operation and disposal of both manned and unmanned spacecraft, as well as satellite data analysis and application. However, APSCO has played a much greater role in the development of human resources in the areas of space science, technology and their application for its member states in comparison to APRSAF, and this must be recognized as the backbone for a state to advance its space capabilities through an autonomous and independent way. China’s space program after all was built in a, more or less, similar way. The transaction of technologies and infrastructure from the USSR played a vital role, but if it hadn’t been for the in-depth education of the future space scientists and the home-coming of scientists from abroad, its space program might have had a completely different progress rate.

3.3.5. Belt and Road Initiative – Space Information Corridor

The Belt and Road Initiative is considered one of the most ambitious global development strategies ever proposed by a country, with some comparing it to the scale of the Marshall Plan. It is the backbone of president’s Xi Jinping foreign policy and has been approved by the CCP and the Chinese government back in 2013. It concerns enormous infrastructure plans and investments aiming to facilitate new trade and transport routes both overland, from Eastern Asia to Central Europe, and through Indo-Pacific sea routes, connecting South-East Asia to South Asia, the Middle East and Africa.

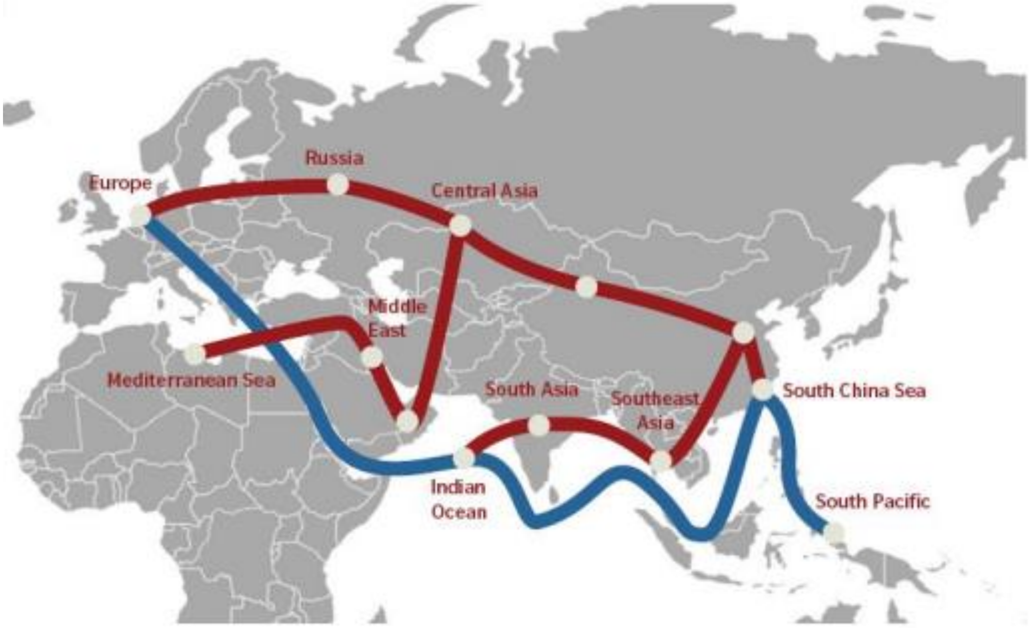


Fig. 7: The blue route is the "21st Century Maritime Silk Road", and the red routes are the "Silk Road Economic Belt" [19]

147 countries have signed a Memorandum of Understanding (MoU) with China, since March 2022, in order to join the Belt and Road Initiative (BRI). [11]

The countries of the BRI are spread across all continents:

- 43 countries are in Sub-Saharan Africa
- 35 BRI countries are in Europe & Central Asia (including 18 countries of the European Union (EU) that are part of the BRI)
- 25 BRI countries are in East Asia & pacific
- 20 BRI countries are in Latin America & Caribbean
- 18 BRI countries in Middle East & North Africa
- 6 countries are in South East Asia

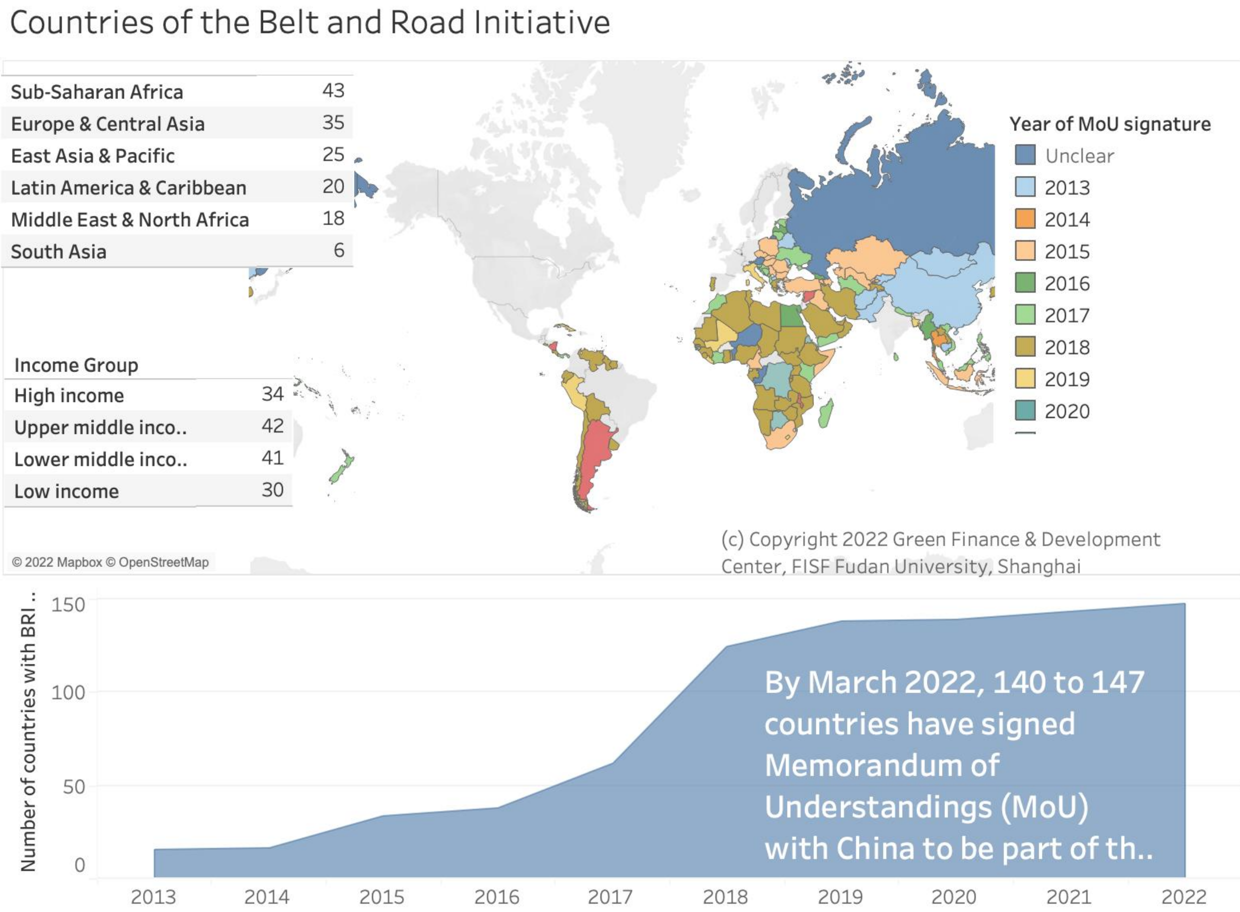


Fig. 8: Countries of the BRI [11]

We have to note that for some of the countries that are listed above the availability of independent information are contradictory. For example, the seven countries of Austria, Benin, Comoros, Congo D.R., Dominica, Niger and Russian Federation have not published a confirmation of signing a full MoU or even denied it.

Program and Development of the "Belt and Road" Space Information Corridor [12], [13]

The Belt and Road Initiative - Space Information Corridor mainly aims in providing information services along the BRI and its construction is based on the use of navigational, remote-sensing and telecommunication satellites, which will serve as the core for combining space based gathered data and resources with a wide ground sharing information network. The goal is to share knowledge and infrastructure on both construction of space based assets and the use of its application services in the BRI regions.

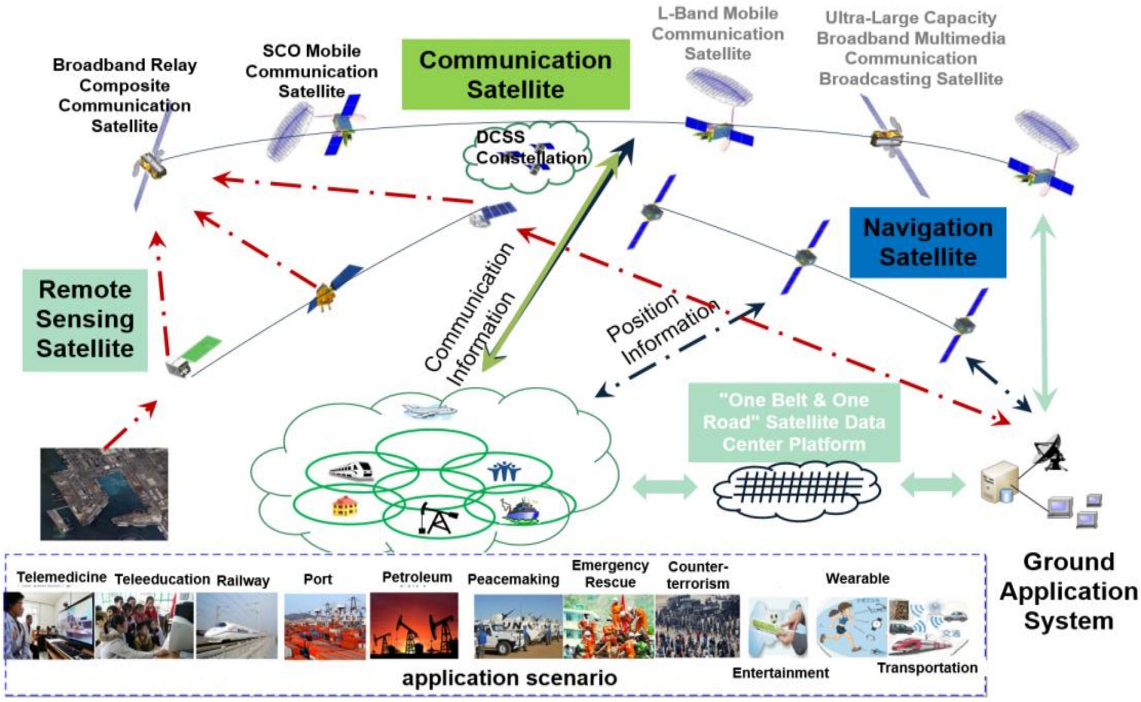


Fig. 9: Spatial Information Corridor [20]

In order to develop intercommunication and interconnection networks covering countries in this vast geographical territory of the BRI initiative the BRI-SIC is based on a “four-in-one” method of providing space data and applications: i) sense, ii) transmission, iii) knowledge and iv) use. [12]

The goal of establishing a communication satellite network will be based and supported by mobile, multifunctional and broadband Telecom satellites. China’s aim to export telecom-sats in order to support the connectivity in the Belt and Road area will strengthen the BRI’s development overall plan along with China’s international relationships and the dependency of other state’s use of advanced space technologies and applications from the People’s Republic. Furthermore it shall provide new markets for exports of space infrastructure and application services. [12]

On the field of space navigation and positioning the Beidou System expanded from regional to global scale on December 27, 2018 providing to its users multi-system compatibility and interoperability. The BRI gives China the chance to export its Beidou program not only in terms of positioning ground stations in many different continents but also in terms of updating its client users and improving China’s place in the competition between the four global satellite navigation systems (GPS, GLONASS, BeiDou, Galileo). According to the State’s Council of the PRC more than 120 countries and regions now use the BeiDou system. [12]

According to Millner, Maksim and Huhmann in “BeiDou: China’s GPS Challenger Takes Its Place on the World Stage” the BeiDou system does not pose a security threat for American users since the United States will not allow its ground stations to be deployed regionally. However, for nations participating in the BRI and taking advantage of the additional capability that ground stations offer, security might come as a concern if they need to sacrifice privacy for gaining access to superior services. Geopolitically, China has already sold access to its military-only signal to Pakistan and Saudi Arabia, allowing these countries to use BeiDou-enabled precision-guided munitions, which need not rely on other foreign GNSS, thus complicating any U.S. effort to deny these nations military-grade PNT capabilities directly through GPS. [21]

Regarding Remote Sensing Satellites, China provides to the Belt and Road its Fengyun meteorological satellite for service, and has adjusted its orbital position so as to monitor and acquire global meteorological data with more precision and integrity to fulfill each collaborating nations' needs. China has provided its Fengyun data to 121 countries and regions, including 85 along the BRI. [166]

According to the Office for Outer Space Affairs UN-SPIDER Knowledge Portal, "China has established an emergency mechanism using its meteorological satellites to help countries involved in the Belt and Road Initiative to combat extreme weather and disasters. Countries along the Belt and Road Initiative, which are suffering from meteorological disasters such as typhoons, rainstorms, wildfires and sandstorms, may apply to China to activate the mechanism. These countries will then receive high-frequency satellite data from China's Fengyun satellites via the China Meteorological Administration (CMA)". The availability of receiving such satellite data, timely and accurately, in order to assist in providing disaster relief could particularly benefit countries which do not currently have access to such information. From 8 May, 2018 the Fengyun-4A satellite started to serve users in the Asia-Pacific region providing data and products to the customers in Southeast Asia, East Asia and Oceania besides China itself.

China also contributes to the Belt and Road Initiative the Gaofen-5 hyperspectral imaging satellite that can monitor air pollution and provide a comprehensive observation of atmosphere and land. Gaofen-5 also detects inland water and land surface environment, providing reliable data for environmental monitoring, resource exploration, as well as disaster prevention and mitigation. GF satellite data have been broadly used by 16 government departments in over 20 industries including agriculture, land and resource, water resources, environmental protection and marine. [12]

The super-view series, a constellation of Chinese commercial remote sensing satellites, including Triplesat and Changguang, provide commercial data services for countries along Belt and Road, to support data application evaluation based on national characteristics. Two important examples of China's satellite exports in remote sensing satellites towards countries of the BRI are PRSS-1 (Pakistan) and VRSS-2 (Venezuela). These satellites were delivered to contribute to the enhancement of data observation capacity and provide data services for regional and global sustainable development for the two countries. [12]

Furthermore, the corridor provides remote sensing monitoring, navigation and positioning, communication services for infrastructure construction such as railways, ports and energy distribution along the "Belt and Road". There are several Chinese satellites that joined the CHARTER mechanism [167] and played an important role in dealing with major international disasters to provide remote sensing images, emergency communication, navigation and positioning for early warning of natural disasters, international humanitarian public affairs. Depending on the environmental monitoring satellites, communication satellites and BeiDou navigation satellites, a three-dimensional maritime search and rescue system will be established. China will probably become the country with the largest number of remote sensing satellites, and is willing to provide to all the countries along the route marine information services, such as: • Maritime rights enforcement • Safety of sea lanes • Maritime search and rescue •

Offshore resource development • Marine disaster prevention and mitigation • Coastal zone environmental monitoring [12]

Along the “Belt and Road”, China is focused on building remote sensing data and application centers, communication satellite information ports and BeiDou navigation ground enhancement systems, along with several distributed satellite application and service platforms. In this way a comprehensive service network shall be formed and developed throughout the “Belt and Road”. [12]

Finally, the Northwestern Polytechnic University (NPU) has established the Belt and Road Aerospace Innovation Alliance, by uniting 51 members (universities, research institutes and enterprises) from 14 countries and building platforms and mechanisms for all in and beyond the Alliance. Students from member countries are the people who are benefited mostly by attending the activities organized by the Alliance. [12]

<u>BRI-SIC and the New Silk Road strategy</u> [14]

Lucie Senechal-Perrouault in her paper, entitled “Chinese commercial space – A policies crossroad” analyzes the importance of the BRI-SIC for the New Silk Road Chinese strategy. She highlights that “the New Silk Road (NSR) Initiative or Belt and Road Initiative (BRI) is an intercontinental economic and trade development strategy of the Chinese government unveiled to the public by Xi Jinping in 2013. It initially involves massive projected investments for the construction and operation of transportation, energy and industrial infrastructure around two axes. One is land, the “belt” on six corridors; the other is maritime, the “road”, consisting of a port network. While the BRI intends to bridge the “industrial gap”, one side of the NSR called the Information Silk Road, launched in 2016 with the aim to link regional information and communication networks, comes to bridge the “digital gap” and infiltrate the corresponding markets. Most of the new programs that are being communicated abroad are now in the development stage. The Belt and Road “brand” is above all a means for China to promote its cooperation programs in an area of diplomatic tension with the United States. It is anchored in China’s positioning on space issues in various international bodies: UN, ASEAN, BRICS, APSCO.”

According to Senechal-Perrouault based on documents from PRC executive levels that have not been officially translated to date, Chinese commercial space is enshrined within three policies: economic reform, the Belt and Road initiative, and civil military integration. Concerning the BRI she is analyzing a 2016 *Guiding Opinion* issued by the State Administration for Science, Technology and Industry of National Defense (SASTIND) and the National Development and Reform Commission (NDRC). In the definition of BRI-SIC given in this *Guiding Opinion* a large scope of applications is covered as mentioned in the previous paragraphs. The main two opportunities for China’s space industry sums up in “mobilization of satellite space assets and ground stations in three areas with high commercial potential (telecommunications, remote sensing and geo-location) with the primary objective of providing “spatial information services” based on data from Chinese national programs in collaboration with those of the countries located along the road” and “launches for third countries”. Thus, BRI-SIC opens the prospective of new markets and commercial opportunities, contributing to the “globalization” of Chinese space companies and enhances launching services for third countries and larger state cooperations, a form of exchange that China has already established for decades. According to Senechal-Perrouault, in the *Guiding Opinion* the "main tasks" of BRI-SIC are divided into seven categories that organize its objectives. Specifically:

1. Improving the spatial information coverage capacity of the "New Silk Roads".
2. Supporting the internationalization of Chinese companies.
3. Providing public services.
4. Boosting the export of spatial data equipment and services.
5. Strengthening regional cooperation in the spatial information industry.
6. Significantly improving the level of marketing and internationalization.
7. Promoting exchange and cooperation in space information science and technology.

Regarding the internationalization of space launching and satellite technology, the *Guiding Opinion* proposes to "actively support the export of complete satellites" and "promote the export of satellite-related products and standards". Also, a future methodological plan is stated regarding the "Strive to build a Chinese satellite "brand", promote the export of satellite technology standards and support joint development of satellites' design, development and operation management". As Senechal-Perrouault mentions, this plan is related to "the fact that certain components of geostationary telecom satellites are subject to US export control regulations, notably International Traffic in Arms Regulations (ITAR) with respect to which China is subject to restrictions. As a result, China cannot launch satellites incorporating US components, which excludes most of the traditional market. Existing partnerships for telecommunications satellite launches account for nearly all of the commercial launches carried out by China for third countries. The customers correspond to different types: many are "new entrants", sometimes also subject to international limitations (Pakistan, Belarus, Nigeria); developing countries with an active space program (Indonesia, Algeria); South American countries (Brazil, Nicaragua, Bolivia, Venezuela). In this respect, the Space Information Corridor in telecommunications satellites corresponds rather to a "labeling" of existing bilateral exchanges to make them more visible, possibly to find other partners in a competitive field than to the setting up of new exchanges".

3.3.6. BRICS

Concerning China's global politics strategy and international space cooperation one needs to focus in the BRICS initiative and Klinger's "A Brief History of Outer Space Cooperation between Latin America and China" provides a valuable insight concerning the evolution of its space domain capabilities. Head figures of Russia's, Brazil's, India's, China's and South Africa's space agencies have begun since 2016 discussing on the construction of a joint remote sensing satellites constellation system for earth observation. On May 2022, a joint committee for BRICS' Cooperation on Remote Sensing Satellite Constellation was established with China's officials stating that despite the changes in global politics (presumably referring to the Ukrainian war and the international restrictions towards Russia) and the post-pandemic era, China shall persist in international cooperation and technological exchanges in the space (and other) sectors with regard to its peaceful use and the mutual benefits for all nations collaborating. This space program shall be based on the use of satellites already in orbit and ground stations covering a wide terrestrial area. Four out of the five participants have operating satellites that can contribute in this joint project. Brazil's CBERS-4 (which was constructed, deployed and operated along with China) shall provide earth observation data. Russia's Kanopus-V1 is used for environmental, disaster mitigation and agricultural purposes. India's Resourcesat-2 is observing land usage in South Asia. China's Gaofen-1 and Ziyuan-3 are also used for disaster mitigation, through fast-track detection and warning. These satellites' remote sensing capabilities can provide data for a variety of uses such as scientific, environmental and military. The telemetry and communication network that shall be established by this constellation and its subsequent applications shall provide the BRICS - New Development Bank with data important for the design, development and protection of many cooperative projects inside the BRICS' affected global territory (Klinger, A Brief History of Outer Space Cooperation between Latin America and China). South Africa does not currently own an Earth Observation satellite but shall provide both its ground stations and a variety of space data and imagery of the African continent handled by its space agency. [17

4. CHINESE MILITARY SPACE CAPABILITIES

4.1. Anti-satellite testing mission 2007

On January 11, 2007 a missile was fired from Xi Chang on an intercept trajectory aiming the Fengyun 1-3 satellite which had stopped operating. When the missile hit its target, with remarkable accuracy, it produced hundreds of tiny pieces of space debris. Those pieces started travelling with a velocity of up to 2,000 km/h, and according to NASA they make up for about 17% of the total orbital debris circling Earth. The interception has been an admirable showcase of tracking technologies, sensors use and computer systems operation. [8]

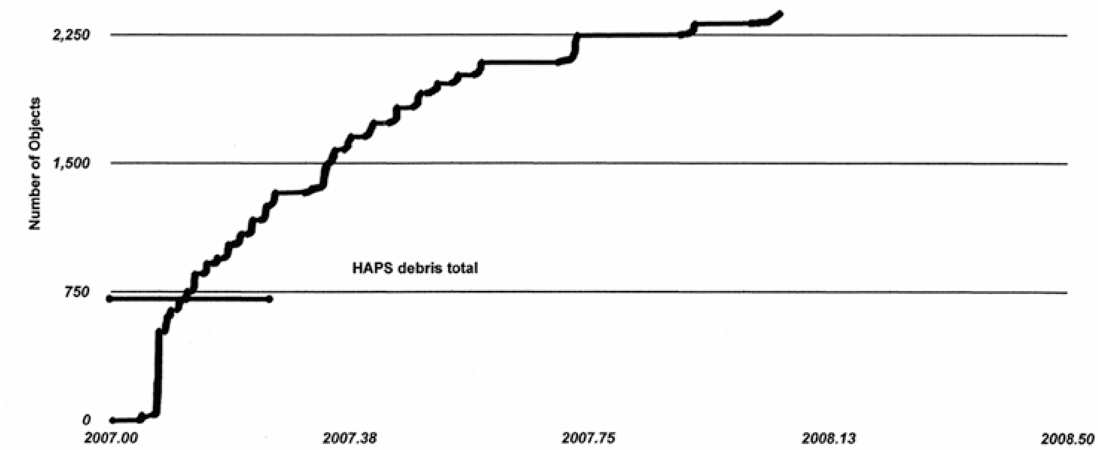


Fig. 10: Debris generated by the interception, with over 2,250 objects identified by 2008. [8]

This event rose large criticism towards China in the international press and inside the scientific community especially. PRC's political leadership was troubled and from this point on, China prioritized greatly Space Debris Mitigation in the development plans of its publicly released Space Activities White Papers and begun evolving new technologies concerning space debris targeting and removal.

In 2002 China and Russia submitted to the Conference on Disarmament in Geneva a joint working paper on "Possible Elements for a Future International Legal Agreement on the Prevention of the Deployment of Weapons in Outer Space, the Threat or Use of Force against Outer Space Objects". The draft treaty aimed to define and prohibit certain capabilities, specifically 'weapons in space'. However, it did not reach desired ends because of lack of consensus of member-states. The Conference of Disarmament (CD) is the world's sole standing multilateral disarmament negotiating body.

As Mark Hilborne states in "China's rise in space and US policy responses: A collision course?" [22], the US didn't sign this proposal, thus generating mistrust on the scopes of its national space strategy concerning military operations and the avoidance of a space based arms race. He argued that this situation formed a "moral high–ground" for the US's main counterparts, but also pushed them in developing advanced technologies concerning space-military actions, in order to ensure equity in the means of defense and counterattack regarding a future space-based warfare. This resulted on the 2007 ASAT test, which deprived China of its “moral-high ground”. It raises the question of whether the production of space debris in 2007 could have been avoided if the U.S. had joined conversations on Geneva.

One could argue that the U.S. not signing the proposal submitted by China and Russia to the Conference on Disarmament in Geneva in 2002 did not necessarily push other countries to develop advanced space-military technologies. Countries may have pursued the development of such technologies regardless of the U.S.’s decision to sign or not sign the proposal.

According to some analysts the 2007 ASAT might have been the result of bad coordination between different agencies. The People’s Liberation Army (PLA) might have planned and launched the test missile with some autonomy from both political and scientific consultation, thus resulting to the huge amount of space debris production and the according international outcry. PLA is the armed forces of People’s Republic of China and the Communist Party of China. It consists of five professional service branches: the Ground Force, Navy, Air Force, Rocket Force and the Strategic Support Force.

Despite the apparent contradiction with its own ASAT test in 2007, China, along with Russia, continued to advocate for the formal initiation of arms control talks in Conference on Disarmament (CD). In 2008, the two countries presented a revised draft treaty to this effect.

4.2. Space Military Accomplishments

Hilborne in his article above presented a number of China’s most significant space military actions that have had US intelligence concerned. Along with the ASAT technologies demonstrated on the 2007 incident China has produced a dual-use satellite program, the Yaogan Weixing, which can demonstrate both scientific and military capabilities in orbit. Officially these satellites’ payloads are used for “scientific experiments, land survey, crop yield assessment, and disaster monitoring” [23], but their enhanced Synthetic-Aperture Radar (SAR) and Electro-Optical (EO) cameras can both be used into military or reconnaissance operations, for intelligence and targeting purposes. [22]

Hilborne stated that the Shenzou program has been used too for testing possible anti-satellite technologies. In 2008, the Shenzou-7 spacecraft released the CubeSat BX-1 (Ban Xing-1, “companion satellite-1”), which carried a payload of high resolution imaging technology and demonstrated maneuvering capabilities around its mother-ship. It was justified as a maneuver testing technology that shall help in the development and completion of the Tiangong space station, but can, clearly, be catalogued as an example of dual-use satellite since it provides both observational and in-space re-orbital capabilities that could be used to attack an enemy satellite. Also mentioned is the launch and operation of a microsatellite testing maneuvering, rendezvous and docking capabilities. These technologies do not directly present military purposes but can be viewed through the scope of possible offensive use. [22]

Attached to military strategy are also the BeiDou satellites. Navigational satellites can prove to be extremely important during military operations and this applies to the global navigational systems of the US and Russia too (GPS and GLONASS respectively). [22]

China has also conducted a series of anti-ballistic missile tests, intercepting InterContinental Ballistic Missiles (ICBMs) in their mid-course phase. There have been seven such successful tests according to PLA announcements, from 2010 until today. This technology can be used for both IBMs interception and for targeting satellites in orbit. [22], [168]

The ASAT and ICBM-interception tests that China has conducted brought the state to a contradictory point where its actions couldn't align to the PPWT and its public announcements regarding the peaceful use of outer space. So in 2010, both China and Russia stated, in the Conference of Disarmament, that "the PPWT does not prohibit interceptors of ground-based, sea-based or air-based ABM systems or ballistic missiles and their re-entry vehicles. This is because such weapons are not placed in space" [25].

US space cooperation policy with China is mainly defined by the fact that the PLA has a strong involvement in the Chinese space program and the fact that many of China's space activities are not followed by an adequate demonstration of means and purposes, thus enhancing, from a US perspective, the belief that any collaboration with China's civilian space program inevitably ends up aiding its military. [24]

In his paper Hilborne has included an interesting comment from General Xu Qiliang, commander of the People's Liberation Army air force (PLAAF) which supported concerns that strategic competition with the US is inevitable. In November 2009 General Xu stated that the PLAAF 'would refocus from defense of national territory to a partly offensive stance.' Furthermore, he said 'Competition between military forces is developing towards the sky and space, it is extending beyond the atmosphere and even into outer space. This development is a historical inevitability and cannot be undone'. Despite the fact that this announcement might serve personal or other interests, such as budgetary competition between agencies, as Hilborne refers, it, also, provides a greater insight in the way that some Chinese military officials have been preparing their space strategy for over a decade, or at least the way they choose to provoke their counterpart's intelligence. [29]

4.3. Challenges to US Security in Space regarding China

In March 2022 the "Challenges to Security in Space: Space Reliance in an Era of Competition and Expansion" report was released by the Defense Intelligence Agency of the United States. In the analysis of the Chinese Military Strategic Guidelines conducted the report mentions that "The PLA uses 'informatized warfare' to describe the process of acquiring, transmitting, processing, and using information to conduct joint military operations across the land, sea, air, space, and cyberspace domains and the electromagnetic spectrum during a conflict" and that "PLA writings highlight the benefit of near-real-time shared awareness of the battlefield in enabling quick, unified efforts to seize tactical opportunities" [31]. In this process developing technologies, infrastructure and joint operations in the fields of space, cyberspace and electronic warfare has emerged as a crucial turn point in modern military doctrines. [30]

Access to information and communications for command and control has become a critical component in modern warfare. Nowadays, space has become a domain of great value not only for supporting and accelerating one's abilities in intelligence and real-time guidance of troops, artillery, aircraft, maritime equipment and missiles but also for making one's military operations more vulnerable, due to its dependence on the constant non-disruptive function of satellites. Most of space related military operations, equipment and testing competition has to do with dominance in the "space-enabled information sphere" and the ability to "deny adversaries their own space-based information gathering and communication capabilities" [32], [33], [34], [35]. The PLA has dedicated, throughout the last two decades, most of its efforts concerning the space arena in evolving such technologies.

4.4. Space and Counter-Space Organizations

In this section we present two mind-maps that illustrate the structure and main operations of the space departments within the People's Liberation Army (PLA), as well as a flowchart that outlines the structure of China's civil space program.

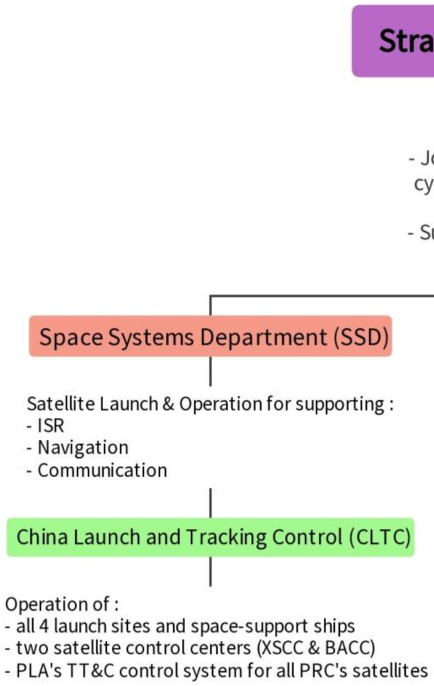


Fig. 11: Structure as analyzed in the 2022 report (graph created using GitMind) [30]

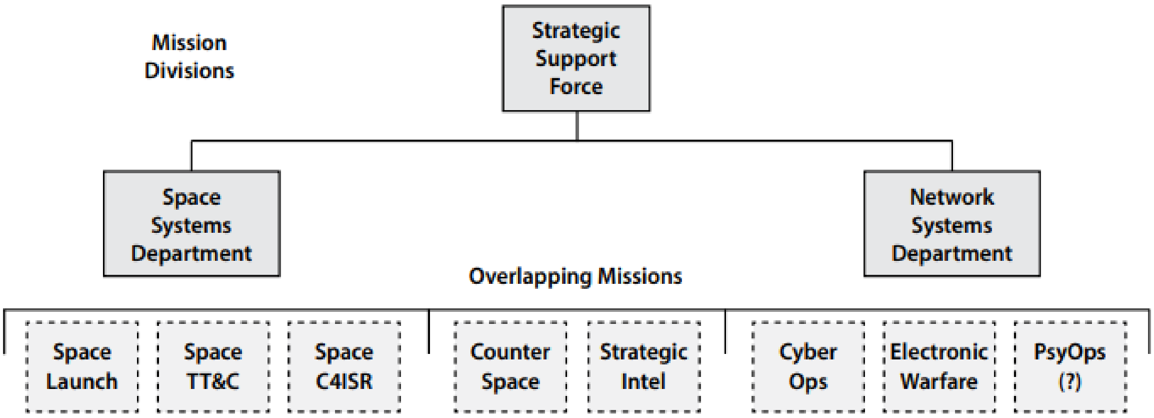


Fig. 12: SSF's Missions [28]

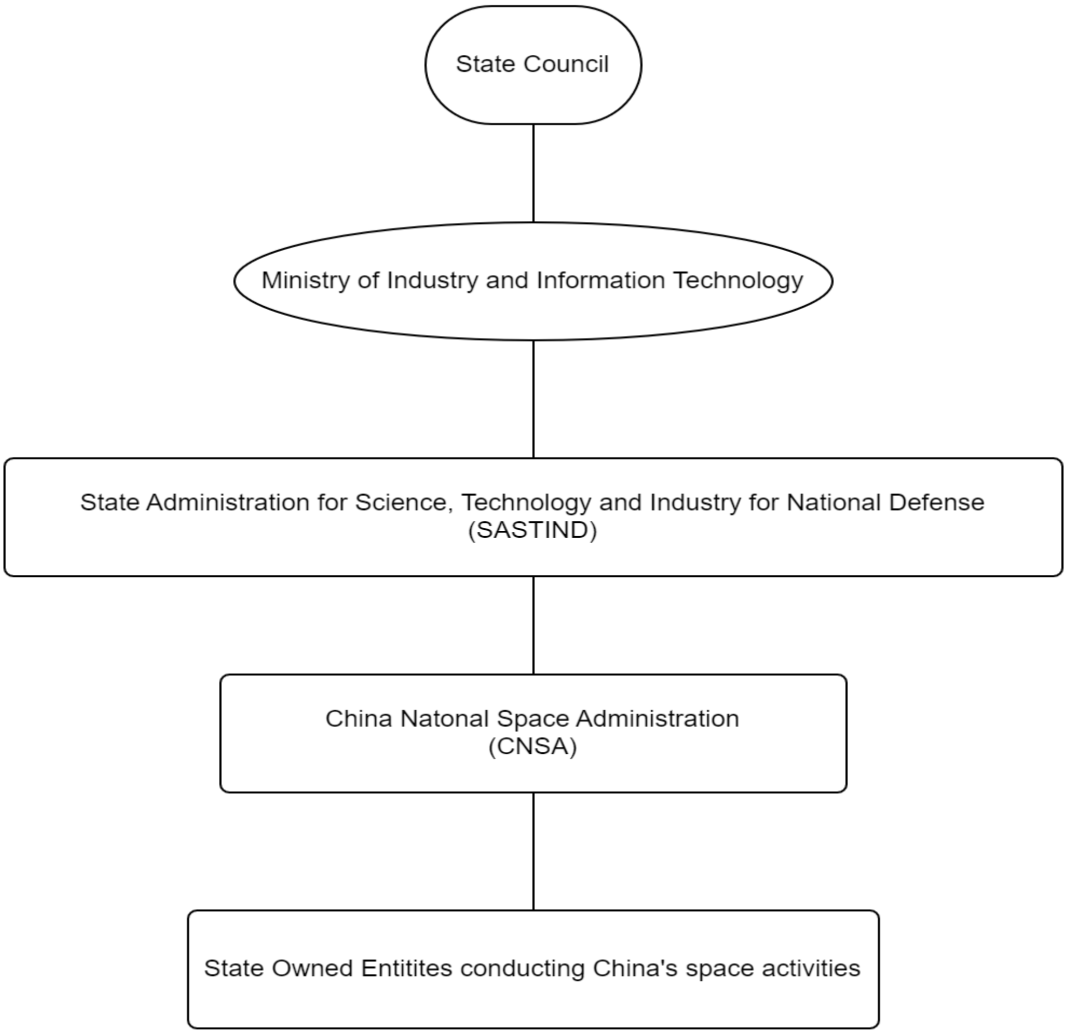


Fig. 13: Civil Space Program Structure (graph created using GitMind) [30]

4.5. Chinese Military Space Technologies

The U.S. Defense Intelligence Agency's 2022 "Challenges to Security in Space" report analyzes a variety of military capabilities that China has developed in the space sector.

- ISR (Intelligence-Surveillance-Reconnaissance)

China has the second largest ISR satellite fleet in the world after the US [36], [37]. This provides the PLA with monitoring, tracking and targeting capabilities against its adversaries, especially regarding the Indo-Pacific region. The main targets of interest are the Korean Peninsula, Taiwan, Indian Ocean and South China Sea [38], [39], [40].The indo-pacific region has been an area of conflict and geopolitical competition between many different countries for the last two decades and is, also, one of the main fields where adversarial interests between China and the US are being unfolded. For example, the AUKUS agreement between USA, UK and Australia for acquiring nuclear submarines in the region, and the recent visit by Nancy Pelosi (the Speaker of the United States' House of Representatives) in Taiwan, (despite the disapproval and warnings from the PRC and PLA) are only two, out of many, reasons why not only political and economical contradiction but also military heat has risen between the two global superpowers, and a new "cold-war" shadow has been unfolding in the region.

ISR satellite technologies include space-based radars (Synthetic Aperture Radars – SAR), as well as electro-optical imagery through digital cameras, which can provide a 24-hour, all-weather-type coverage of their targets. Despite from monitoring disputed land, they can serve the PLA for surveillance of military targets and movement of opponent troops, artillery, aircrafts and aircraft carriers. They can also aid the PLA in any out-of-sight warfare operation, far away from China's mainland. [41], [42], [43]

- Satellite Communications

We live in an age of Big Data where vast amount of data are generated, processed, and analyzed every day in all aspects of our lives. Data acquisition and data relay systems, for transmitting valuable information, has become a cornerstone not only for a state's economical and social growth, but also for maintaining its military dominance against its adversaries. Satellite communication systems play an extremely important role for both intelligence services and targeting, command & control of armed operations. According to the 2022 Challenges in Space report, "China owns and operates more than 60 communications satellites, at least 4 of which are dedicated to military use". [44]

An important milestone achieved by the PRC's space program regarding communicational satellites has been the development, deployment and operation of the Quantum Experimentation at Space Scale (QUESS) communications satellite. According to the aforementioned report, "In June 2020, a team of Chinese scientists claimed to achieve quantum supremacy, reporting successful satellite-based distributions of entangled photon pairs at a distance of more than 1,200 km and that the photon pairs' integrity remained intact after traveling such distances" [45], [46]. This satellite's research field is related with "hack-proof" communications between a satellite and its interlinked ground station. This technology would be highly valuable for any military force. By achieving transmission of entangled photons, one acquires the ability of immediate warning against any effort of hacking, along with a simultaneous destruction of the targeted information. If such a technology matures and becomes integrated into military satellite services it can provide prevention from any action of intercepting, deciphering, decoding and, in the end, interpreting Chinese space-based data [26].

- PNT Capabilities

The BeiDou system assists military operations through enabling force movements, command and control, and precision-guided munitions delivery [47], [48]. China has suffered the cost of its past dependence from the Global Positioning System (GPS), from an operational aspect, during the 1996 Taiwan crisis, where interference and jamming of its missiles' launch was detected [26]. It was suggested that this glitch was caused by deliberate disruption of the GPS by the U.S. military. This incident is considered to have spurred China's development of its own satellite navigation system. Thus, the deployment and operation of the BeiDou satellites' constellation, which provides global coverage since 2020, is an important milestone for both commercial and military purposes.

- Launching Capabilities

China has developed a variety of Small Launch Vehicles - SLVs (such as the Kuaizhou-1, LM-6, and LM-11) that can help to "rapidly reconstitute LEO space capabilities during a conflict". These SLVs are based on ICBM and MRBM technologies, they are transportable through road or rail, and can be stored launch-ready since they use solid-fuel boosters instead of liquid-fuel. [27], [30]

Fig. 14: Chinese Space Launch, SSA, Satellite Control Centers, Command and Control, and Data Reception Stations [49], [50]

As the aforementioned U.S. DIA's "Challenges to Security in Space" report states "China has four fixed launch sites. The newest, Wenchang on Hainan Island, has a launch latitude closer to the Equator, which provides a more efficient path to launch satellites into GEO. In 2020, China launched an LM-11 from a barge based in Haiyang Port. China's main satellite control center is in Xian, and its primary control center for human space flight and lunar missions is in Beijing. The PLA operates four large phased array radars (LPAR) most likely used for missile warning and SSA. Additionally, there are at least six ground stations used for satellite C2 - including one in Neuquén, Argentina, and five for receiving remote sensing data from satellites - including one located in Kiruna, Sweden." [30]

- <u>Space Situational Awareness</u>

According to the 2022 report china has developed "a robust network of space surveillance sensors and radars" that provides capabilities of tracking satellite type and orbital parameters. This technology is vital for early warning against any offensive action (space warfare, missile launch etc.) and can be used for counter-space retaliation. [51], [52]

- <u>Electronic Warfare and Cyber-threats</u>

EW is a crucial part of modern warfare. Despite the fact that basic military strategies have not changed regarding the use of armed troops, heavy artillery, naval and aircraft support - as the recent war in Ukraine proves -, electronic components, command and control, missile targeting, navigation, communication, surveillance and espionage are just some aspects of modern warfare that are almost completely dependent on electronic applications, digital technologies and space-based systems. Jamming or destroying those technologies in the early stages of one's offensive strategy can define the outcome of an armed conflict. The PLA has tested such technologies regarding the interruption of space communications, GPS navigation and the use of radar systems. As the 2022 report refers, interfering and intercepting military high frequencies for denying or altering communications, as well as scraping the payloads of reconnaissance satellites to disable imagery and targeting of important ground infrastructures is part of the counter-space operations that shall be used if the US engages into military operations against the PRC's interests [53], [54], [56], [57]. In the field of cyber-threats the report provides the following example: "the PLA could employ its cyber-attack elements to establish information dominance in the early stages of a conflict to constrain an adversary's actions or slow its mobilization and deployment by targeting network-based command, control, communications, computers, intelligence, surveillance, and reconnaissance (C4ISR); logistics; and commercial activities." [58], [59]

- Direct Energy Weapons

Except for kinetic assault weapons, such as ASAT missiles, or in-orbit maneuverable satellites that can damage the enemy's satellite systems (via robotic arms used for experiments or spears, nets and other equipment used for debris collection), China has developed terrestrial laser weapons that can target and disable satellite sensors or other electronic components. [30]

- ASAT

Along with the ASAT capabilities that we have already referred to, in 13 May 2013 China launched a rocket which was considered to have the ability to reach high-altitude orbits, above 20.000 km. It was reported as part of a scientific project to study space weather parameters, but as other new space-technology demonstrations, it has troubled US's military agencies. The possibility of supporting ASAT operations in MEO and GEO trajectories was considered, since such a capability puts at risk both navigational satellites, such as GPS, and Earth Observation and Communication satellites. [59], [60]

5. HISTORICAL BACKGROUND – RUSSIAN FEDERATION SPACE ACTIVITIES

The Russian Federation is a major player on the global geopolitical stage. It is the largest country in the world and has a strong military. In terms of space spending Russia ranked fifth in 2022, behind the United States, China, Japan and France [169]. Russia has a long history of space exploration and has made significant contributions to humanity's journey into space. The Space science and technological innovation it has brought about, the design and implementation of magnificent space programs, the utilization of thousands of applications opened up by the exploration and exploitation of the 'final frontier', owe a lot to the Soviet and Russian space programs. These programs were developed, to a significant extent in the aftermath of World War II and during the competition for global dominance that arose during the Cold War. This assumption contributes in understanding the inextricable link that existed and continues to exist between space and war industry. Entire books have been written to compile the experience and analyze the evolution of the Soviet and Russian space programs. We here seek to simply review some of the historical elements that played a critical role in its post-Cold War course and development.

5.1. Post-Soviet Era

After the dissolution of the Soviet Union, the newly formed Russian Federation faced numerous challenges. These included political instability, the need to reorganize state structures, the transition to a new economic and administrative system, changes in monetary policy, the redrawing of borders, and the task of maintaining national unity and social cohesion. Against this vast backdrop, the space industry, like other sectors of the economy, faced the risk of obsolescence and decline. In order to understand the causes of this situation we must refer to the four main objectives of the Russian reform that was taking place at that period. Macroeconomic stabilization, price liberalization, privatization-industrial restructuring and transition from the model of state-planned production to the market economy sum up the basic aspects of the Russian post Cold-War policy. The attempt to create a stable economy around the Ruble by balancing the state budget led to dramatic reductions in resources in the space sector. The industrial reconstruction policies created a significant dependence of space institutions on the "political winds" prevailing at the time. Thus critical investments in the sector were frozen and the main core of workforce left the industry for more lucrative professional alternatives with more stable prospects. [61]

The attempt to convert the Ruble into a stable currency and to limit state interference in economic activity led to restructuring, reduction and even termination of many oversized subsidies to the industry. Thus 'non vital' activities such as space were hit hard. In the five-year period 1990-1995 the Russian civilian space program suffered a reduction in the state budget of up to 80% and the military space programs up to 90%. In order to sustain themselves, space institutions, such as the Russian Space Agency, have often had to take advantage of the crisis situation, presenting a permanent "marginal" condition to government staffs in order to secure the maximum possible funds (e.g. an essential tripling of the budget that if not succeeded would result in inability to correspond Russia's obligations towards the International Space Station).

Thus, in 1996 50% of the satellite systems in use were obsolete and the stock of rockets and satellites was practically exhausted. In 1998 the head of the RSA (Russian Space Agency) Yuri Koptev announced an increase of this percentage to 72%, referring to all civilian and military satellites. The Chief of the General Staff of the Russian Army in early 1997 stated that the capability of Russia’s missile-launch surveillance around the world had been seriously degraded, since 60% of the surveillance satellites had exceeded their life cycle. New designs to replace them were not available since production in previous years had been frozen. Of course, as far as budgetary policy was concerned, a major negative factor for space programs was the fact that there did not seem to be significant support for this sector in public opinion, as it was mainly considered as a remnant of the past superpower’s lost status. [61]

It was therefore in the context of the aforementioned cutbacks that the impact on space missions began to emerge. Launch rates showed a significant annual decline, primarily, due to economic and industrial problems and, secondarily, to the increase in the life cycle of aircraft or changes in military requirements with the end of the Cold War. Launch failures were likely to multiply due to the financial inability of missile manufacturers to carry out the necessary checks. Priority was given to space systems, but also to all areas of the war industry that could be activated and exploited in the near future. This condition was directly linked to the fact that funding for R&D had been drastically reduced. The Russian Academy of Sciences, which in Soviet times had devoted 60% of its operations to developing innovations for military programs, had suffered a 20-fold reduction in resources within a decade. Finally, the mass exodus of skilled personnel from the space program and the brain-drain itself had led to a reduction of engineers and technicians by up to 50% by 1991. [61]

A key aspect of Russian economic reform was the attempt to convert large amounts of state-controlled property into private ownership. However, this was not the case for the defense and space industries as they involve activities vital to national security. With a few exceptions (e.g. Energiya) most space agencies were brought under the control of the RSA, which together with the Ministry of Finance presented a plan in late 1997 for a substantial reorganization of the industry. In this context, by decision of President Yeltsin, the RSA was given approval to create a “unified policy” for the civil and military activities of the aerospace industry. Thus, the RSA was given the authority to create strategic military missiles, early warning systems, space reconnaissance, space navigation and other space equipment. The continuation of the space program, from an economic point of view, rested on two main pillars during this difficult period; international ties and the exploitation of the stock of hardware and research from the Soviet period. A small fraction of large space companies managed to triumph based on funding from the provision of commercial launch services on the international market, but also through joint ventures with Western companies that were quick to take advantage of the cheap liberated labor and technology. [61]

5.2. Recovery and Redesign

After the "ruble crisis" of 1998, Russia's economy experienced an impressive recovery thanks mainly to the energy sector and oil and gas exports. From 1999 onwards there has been a gradual economic improvement as shown in the following graphs [62]:

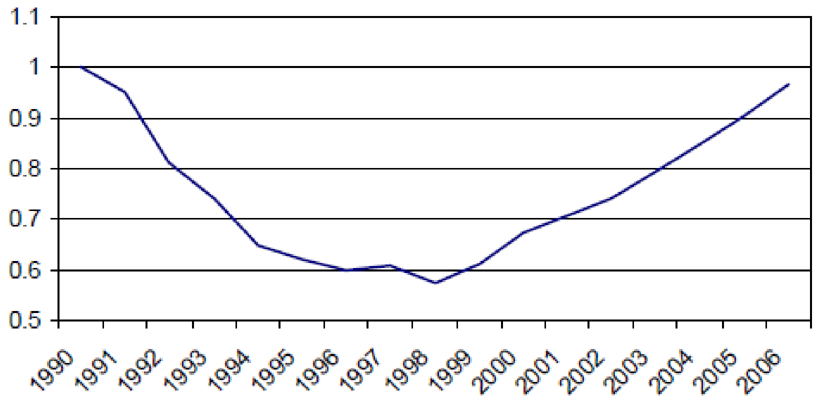


Fig. 15: Russia's GDP evolution proportionally to the 1998 levels [62]

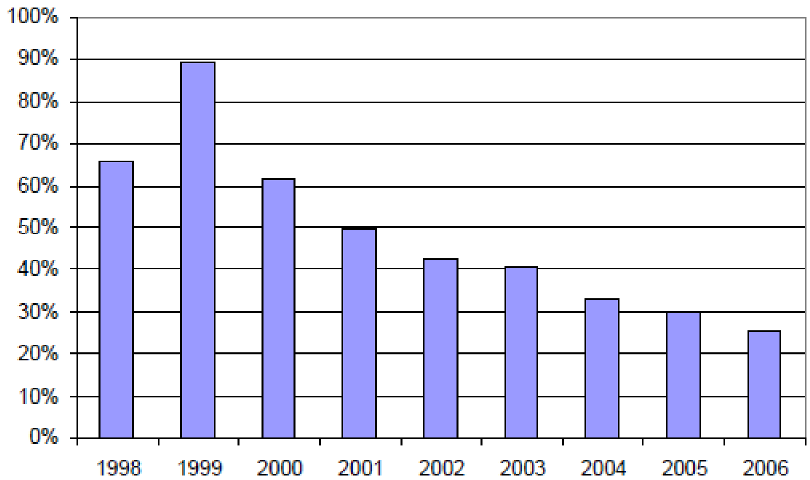


Fig. 16: Total foreign debt (as a GDP percentage) [62]

Russia's transformation into an "energy superpower" led to the re-nationalization of the energy sector during Vladimir Putin's second presidency, with tighter control over foreign investment. Moscow sought to use the funds flowing in from energy to expand the economy, diversifying it and investing in other sectors. The country has benefited from domestic political stability and, taking advantage of the economic recovery, has sought to demonstrate that it has regained foreign policy independence based on its national interests. [62]

The space policy situation discussed above had brought Russia in the early 00's with decommissioned civilian space systems, Western capital acquisition of rocket launchers and intercontinental ballistic missiles (ICBMs), dismantling of the GLONASS satellite navigation fleet and lack of operational weather satellites. After a decade of marginal survival and depreciation, the space program began to revert to a strategic sector, with the distinction that technological superiority was no longer an ideological and political end in itself. There were both political and economic reasons surrounding the renewed interest in the space sector and the assets that went with it. The Russian leadership reconnected sovereignty, independence, national security strength, economic growth, and international prestige with space. Russia has always been a key player in the space sector, especially in human spaceflight and rocket launchers. It has therefore sought to make the most of its unique heritage and improve the competitiveness of the sector in order to increase the valorization of its technological capabilities and the resulting profits. President Putin has shown a keen interest in the space sector, placing it at the core of industrial priority alongside shipbuilding and aerospace. [62]

The increase in resources (6% per year since 2007) has laid the foundations for further development of both civil and military space activities. Three main programs formed the backbone of the new effort. The Federal Space Program 2006-2015, the Federal Program for the Development of Russian Cosmodromes 2006-2015, and the Federal Program for GLONASS 2002-2011. The Russian Space Agency, at the time, had one of the highest budgets, as a percentage of GDP, after NASA. [62]

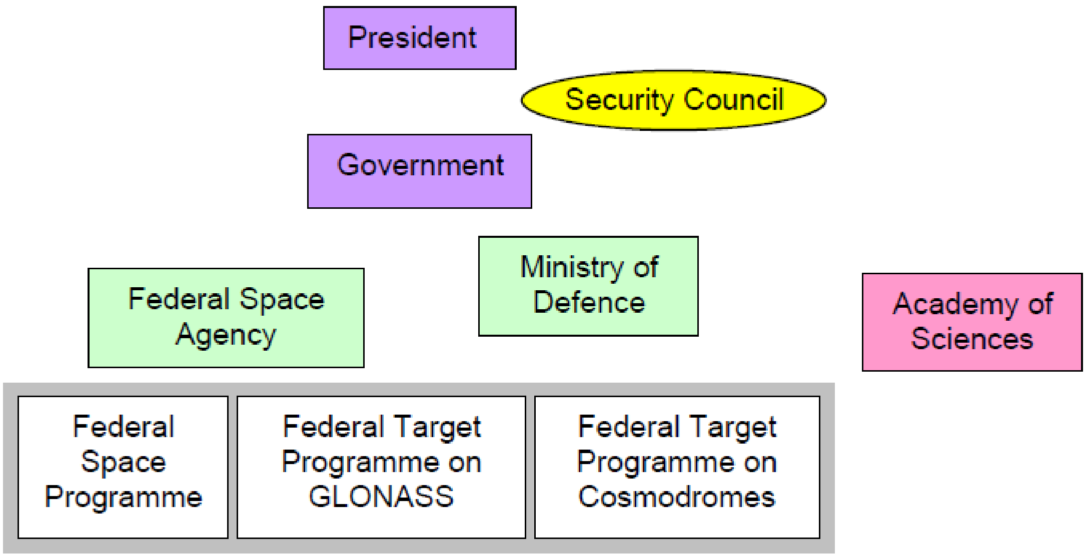


Fig. 17: Structure of space shareholders and federal programs. [62]

Country – Space Agency	2007 Budget of the Agency (in billion €)	Budget (in % of GDP)
USA - NASA	12	0.12%
Europe - ESA	2.9	0,02%
France - CNES	1.8*	0.09%
Japan - JAXA	1.1	0.05%
Germany - DLR	1*	0.04%
Russia - Roscosmos	0.9	0.12%
Italy - ASI	0.8*	0.05%

** including contribution to ESA*

Fig. 18: 2007 space agencies' budgets. [62]

In this context, structural changes were made within the organization. One of the difficulties faced was the lack of state-of-the-art technologies, especially in the field of Earth Observation and Telecommunications. This situation made Russia a weak supplier for the commercial satellite market, especially compared to the rocket launcher market. In addition, the lack of human resources due to the brain drain had to be stemmed. [62]

Russia remained very open and successful in its international partnerships and commitments to space programs, as shown especially by the example of the ISS. Cooperation, in addition to cost-sharing, offered greater stability, commitment of national resources and a degree of stable continuity of activities. It also offered a way of gaining experience and covering technological gaps. As the space sector regained credibility, the Russian leadership was seeking to ensure that its international partnerships reflect its national interests and priorities. Thus space started to gain an additional use as a foreign policy tool in order to reassert its reestablished sovereignty, power and influence. [62]

So, while the US remained a primary partner, especially in the commercial sector, and relations with Europe continued to prove vital in international space cooperation, Russia began to seek new markets for its products. It developed programs with Belarus and Kazakhstan, built and launched the first Iranian satellite, helped the Republic of Korea acquire its national space policy, facilities and launchers, built Angola's first telecommunications satellite, sent the first South Korean spaceman to the ISS, and supported India in this sector, be it launching its first satellite, Aryabhata, or enabling the first Indian to reach orbit. As Russia was effectively using space as a foreign policy tool, the most important objective was to strengthen relations with the growing space powers of China, India, Brazil and South Africa. These countries have proven to be key-partners for technology and know-how transfer as well as for establishing transnational joint ventures. [62]

5.3. Challenges for the Russian Space Sector

Vladimir Putin's third presidential term in March 2012 marked the beginning of efforts to expand the country's civilian space program. The ten-year, $70 billion plan targeted a range of new launchers, a human landing on the Moon, and an ambitious program of deep-space science research. There were high expectations for a resurgence of Russian dominance in space with new commercial and heavy-lift launchers, extensive lunar research, manned spaceflights, and a structures array of deep-space probes, but these expectations were not met due to several factors. Falling oil and gas prices were a blow to the Russian state’s budget. The successes of the American space-launch start-up company, Space-X, resulted in the construction of the heavy-lift Falcon 9 rocket booster at very low cost. This progress, combined with Western sanctions on Russia for its intervention in Crimea and Eastern Ukraine led to a gradual decline in its space momentum. [63]

Putin committed a very large amount of capital to the construction of the Vostochny Cosmodrome in the Russian Far East and in 2016 decided to launch the state space-agency Roscosmos, but the problems continued. The rupture with the West and NATO prompted a further development of all the above-mentioned anti-satellite defense systems. In 2018 the economic downturn and low energy prices led Putin to reduce the

10-year plan budget from $70 billion to $20 billion which signaled drastic cuts to the Roscosmos budget. [63]

While in 2013 Russia held 50% of the global commercial space launch market, by 2018 this percentage had dropped to a share of 10%. In 2019 it carried out just 2 of the world's 22 commercial launches. At the same time, while continuing to benefit from the monopoly of providing access to the ISS (established after the U.S. Space Shuttle program was terminated in 2011), the two successful manned missions of Space-X's Crew Dragon capsule from U.S. soil in 2020 suggested that the $70 million in fees to transport each foreign astronaut to the Station would soon disappear. [63]

A number of problems underscore the challenges faced by Russia. First, the current rocket collection uses old technology and lacks the ability to land and reuse the various stages, as introduced by Space-X, thus dramatically reducing launch costs. Second, many of the new technologies that are defining the global space services market are coming from small commercial start-up companies. But Russia has a significant shortage of viable private capital, and Roscosmos competes with such companies for state resources, actively blocking their development. Finally, Western sanctions have ended the ability of Russian space companies to buy high-quality components for their satellites. Thus, due to this, abruptly frozen, dependency relationship, Russia was driven both to seek alternative suppliers and to invest in a process of restructuring its production lines. The later proved to be an economically damaging and time-consuming process that has so far failed to produce the required results. [63]

Russia's current strategy at the United Nations and elsewhere appears to be mostly aimed at blocking and discrediting the growing US commercial and military role in space. This effort goes through the building of a coalition of nations with converging interests and a series of initiatives that appear to be aimed at deterring military armaments in space. [63]

6. CURRENT PHASE – RUSSIA'S SPACE ACTIVITIES

6.1. Russian Space Governance

According to the official website of Roscosmos, the main institutions involved in Russia's space policy-making and development are the President of the Russian Federation, the Government of the Russian Federation (including the Ministry of Defense and the Ministry of Finance), and the Roscosmos State Corporation. These institutions work together to develop and implement Russia's space policy and activities. [170]

On April 11, 2008, at a meeting at the Kremlin Russian President Vladimir Putin gave opening remarks at a meeting with the Security Council on Russia's space exploration policy for the period through to 2020 and beyond [171]. The meeting focused on establishing priorities and setting concrete goals for space exploration, rebuilding the sector's human resource potential, and carrying out thorough technological modernization. At the meeting, President Putin emphasized the importance of space exploration for Russia's defense, communications, navigation, and scientific research. President Putin highlighted five key goals: securing access to space; developing a clear plan to increase Russia's potential for orbiting constellations; increasing Russian market share for space equipment; modernizing its technology and developing a more dynamic human resource potential; and effectively utilizing the resource potentials of related scientific programs.

It is worth noting that since 2008, Russia has continued to prioritize its space program, particularly in terms of its military applications. In 2015, the Russian government established the Russian Aerospace Forces (VKS), which consolidated the country's air and space forces into a single branch of the military. This move reflected Russia's increasing emphasis on space as a critical component of its national defense strategy. Also, the goal of creating the Roscosmos State Corporation in 2015 was to speed up the space industry's transition, which was lagging.

The space forces' areas of responsibility include space situational awareness, early warning of ballistic missile attack, satellite launches and operations, and maintaining all elements of the space infrastructure at a high degree of readiness. One of the tasks assigned to the space forces is the detection of "threats to Russia in space and from space, and, if necessary, fending off these threats. [172]

According to the "Russia's Posture in Space" research, conducted by the European Space Policy Institute in 2019 the Russian space-policy is implemented through various long-term Federal Target Programmes (FTP) and through Sub-Programmes (SB). These programs are financed through the state's budget but also through non-governmental funds, such as foreign commercial launches, international joint ventures and projects. These programs and funding sources have been instrumental in shaping Russia's space activities over the years. [64]

The following graph illustrates the structure of Russia's coordination mechanisms for space-policy.

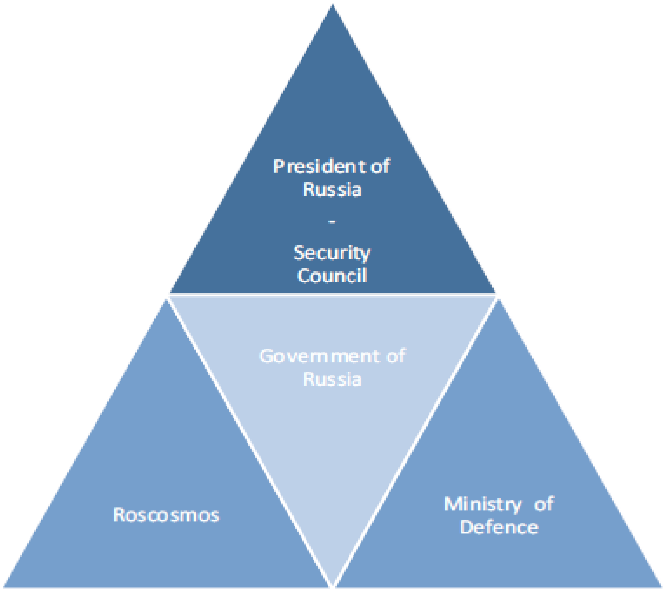


Fig. 19: Space policy-making structure in Russia [64]

Throughout the last decade Russia's space-activities backbone has been comprised by five main programs (three FTPs and two SBs) [64]:

- The FTP on Development, Utilization and Maintenance of the GLONASS System for 2012-2020 (GLONASS-2020)
- The FTP on Development of Russia's Cosmodromes for 217-2025
- The FTP on the Federal Space Program of Russia for 2016-2025 (FSP-2025)
- The SB on Support of the State Program Implementation
- The SB on Priority Innovation Projects of Rocket and Space Industry

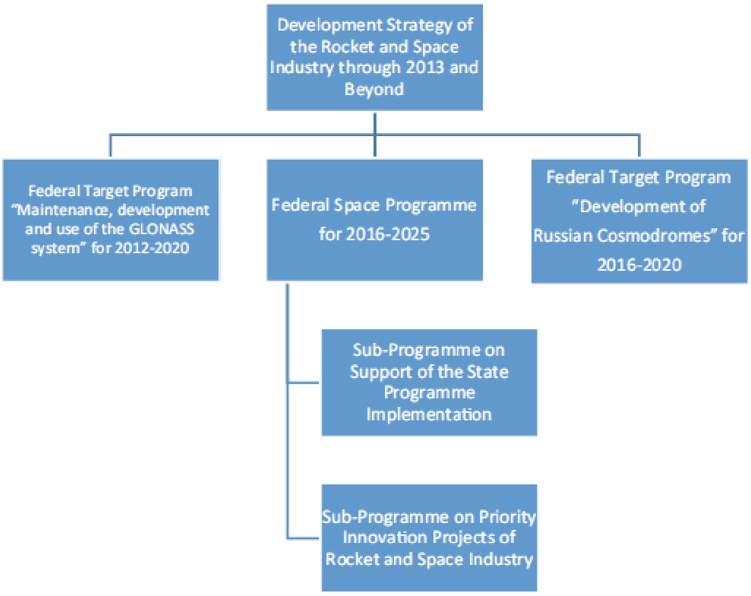


Fig. 20: Space policies in Russia [64]

The FSP-2025 program includes a plan for manned spaceflight, satellite navigation, and the development of new rockets and spacecraft. It is considered as the most important as it defines the basis of Russian space policy, along with the accomplishments, throwbacks and future plans of its space-industry, regarding a period of time larger than a decade.

Regarding the budgetary analysis of the FSP-2025 ESPI's "Russia's Posture in Space" provides an overview of the budgetary breakdown [64]:

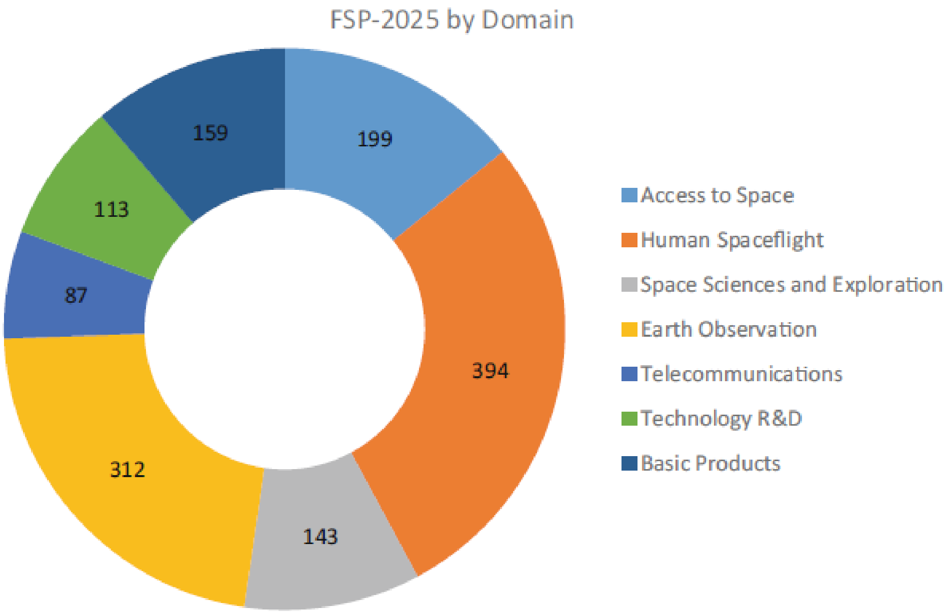


Fig. 21: Budget Breakdown of the FSP 2025 [64]

To accurately represent the current state of Russia's space-budget, it can be observed that a significant portion of it is allocated towards human spaceflight. This is due to Russia's historical leadership in providing manned spaceflights to the International Space Station, until the introduction of the Space-X Crew Dragon mission in 2020. However, recent trends suggest a prioritization of application missions, such as Earth Observation and telecommunications, over traditional areas of investment in Russia's space economy. This is reflected in the greater budget allocation towards application missions, as compared to human spaceflight.

According to the ESPI's "Russia's Posture in Space" report, "the range of priorities identified by the FSP-2025 document itself, clearly highlights the effort by the current leadership of Roscosmos to steer the industry toward more pragmatic goals rather than the prestige-oriented projects inherited from the Soviet period". Access to space launching programs (rockets, propellants and launching sites) come next in line. Finally, it is interesting that basic space products (applications and industrial extensions) have a greater share than space science and R&D. [64]

The programmatic priorities contained in the FSP-2025 and other FTPs are presented below:

Launchers

- Reduce operational launcher families from 8 to 2 (Angara and Soyuz)
- Reduce launcher versions from 12 to 6
- Develop a new medium-lift launcher (Phoenix)
- Expand Vostochny launch infrastructure

Human Spaceflight

- Support operation of the ISS until at least 2024
- Launch three Russian modules to the ISS
- Introduce a new manned launch vehicle “Federation”

Space Science and Exploration

- Implement 3 astronomy missions
- Implement 2 Mars missions
- Implement 5 lunar missions
- Develop critical technologies for a manned lunar landing in 2030

Satellite Systems

- Expand the E.O. constellation from 8 to 23
- Expand communication satellites from 32 to 41
- Maintain and expand the GLONASS system from 24 to 30 satellites and improve performance
- Improve the exploitation of data and development of (commercial) applications.

6.2. Current Capabilities and Future Programs

Russia's budgetary planning for civilian and military space programs was presumed to have changed compared with previous years due to the breakdown in space cooperation with the United States and Europe (with the exception of the International Space Station), the failures of Russia’s military space assets during Moscow’s invasion of Ukraine, and the economic troubles of the space corporation Roscosmos. [173]

The Russian military's share of total space spending has become harder to determine in recent years, but it is estimated to be no less than 110-120 billion rubles in

2023. This estimate is based on official documents and the differences between openly declared space spending and the total space budget in the previous decade. Minor fluctuations in spending have been observed annually compared to previous and current levels of expenditures. It is important to note that the estimated budget does not include dual-use programs and projects in the development of satellites and launch vehicles, which are financed within the civil space program. It should be noted that the following presentation of Russian space assets is based on ESPI's "Russia's Posture in Space" research and regards solely the commercial sector and not its military space capabilities and the according hardware.

6.2.1. Space Launchers

One of Russia's most vital space capabilities is its rocket infrastructure and the launching services they provide both domestically and internationally. This technology harnessing goes back to the Soviet Union era. Russian space-rocketry managed to persist throughout the years of reconstruction and remains up to today an important fund-supplying subsector of the industry. However, a number of factors have threatened the functional stability and prosperity of this sector, such as "quality assurance and reliability issues, increase in prices (affected by domestic and non-domestic influences), perceived reduced autonomy in access to space" [64]. Of course the most determining factors are the following two. The expansion of space-launch services from Western soil, mainly supported by NewSpace private industries such as Space-X, and the Western sanctions towards the Russian Federation concerning the Ukrainian conflict, established in 2014 with the annexation of Crimea and currently evolving after the invasion of Ukraine. The latter one shall be analyzed in the following chapters of this thesis.

Russia has been conducting an effort in modernizing its launcher vehicles. Production of the Angara space fleet has been the first target, since it shall provide "a streamline of manufacturing processes, exploitation of flexibility and modularity, capability of launching a complete range of small-to-large payloads", and use of some series-models to replace the Rockor and Dnepr rockets [64]. Along with Angara the production of the mid-class Phoenix rocket family, for eventual replacement of Soyuz and Zenit space-carriers, is the second goal. A production plan of reusable-first-stage rockets has been on track so as to compete the Falcon rockets. R&D in propulsion technologies (methane engines, new liquid propellant engines, engines based on composite materials) was supported [64].

However, "the economic recession of falling oil prices and western sanctions has forced substantial budget cuts" [64], leading to an alteration of the initial plans. No reusable-stages would be introduced, the size of a new heavy-lift-launcher would have to be cut down and a reduction in the number of foreseen Angara launch pads in Vostochny Cosmodrome would have to be decreased in half.

Development of the Soyuz-5, a.k.a Phoenix, space-launcher was prioritized and has come to be the "next best thing" for the Russian space-industry. The Angara series ranges from a small-launcher model A1.2 to a heavy-lift-launcher A7, with the intermediate A3 supposedly being the rocket that would gradually replace Soyuz and the A5 the one to replace Proton. The A7 model's design was considered to support manned spaceflights but due to the economic recessions the heavy-launcher was resized to an A5V rocket. However, this plan was also abandoned for piloted flights, giving its place to the Phoenix launcher. Phoenix (Soyuz-5) is developed by RKK Energia to support a New Generation Piloted Transport Ship (PTK NP), providing considerable cost-savings in placing humans into near-earth orbit (ISS) comparable to the Falcon and Zenit spacecrafts. Regarding future plans for manned missions to the Moon the plans are to produce a super heavy-lift rocket consisting of a five-stage Soyuz-5 rocket. [64]

In the following tables we can compare current and future (under-development) space-launchers.

Table 7: Russia's current launch vehicles [64]

Launch vehicle	Launch service provider	Performance range (kg)				Launch site
		LEO	SSO	GTO	GEO	
National						
Proton M/Block DM	Khrunichev	19,800		4400	1900	Baikonur
Angara 1.2	Khrunichev	3800				Plesetsk, Vostochny
Angara 5	Khrunichev	24,500		7500	4600	Plesetsk, Vostochny
Soyuz 2-1.a/b	GV Launch Services	7000–8300				Baikonur, Plesetsk Vostochny
Soyuz 2-1.v	TsSKB Progress	2800	2600			Plesetsk, Vostochny
Soyuz FG	TsSKB Progress	7130				Baikonur
(Ex-) Multinational						
Zenit-3SL	Sea Launch/Energia	7300		6200		Odyssey Platform
Zenit-3SLBU	SIS/Yuzhhnoye			4900	1900	Baikonur
Rockot	Eurockot	2100	1600			Plesetsk
Dnepr-1	ISC Kosmotras	3700	2300			Yasny, Baikonur
Proton M	ILS	23,000				Baikonur
Proton M/Breeze M	ILS			6900	3300	Baikonur

Table 8: Launch Vehicles under development [64]

Launch vehicle	Performance range (Kg)				Launch site	First flight
	LEO	GTO	GEO	Lunar Orbit		
Angara 1.2 (updated)	3000				Plesetsk, Vostochny	>2019
Angara A5P	18,000	6600	4000		Plesetsk, Vostochny	>2019
Angara A5V (proposed)	40,000	13,300	7600		Plesetsk, Vostochny	>n.a
Soyuz-5	17,000	4500	2300		Baikonur, Sea Launch	>2022
Energia-5VK (proposed)	105,000	43,300		20,500	Vostochny	>2028

6.2.2. Launching Sites

Russia's launching sites consist of three main Cosmodromes in Plesetsk, Baikonur and Vostochny. Since the Baikonur Cosmodrome is located in Kazakhstan, a need to ensure that all types of space-launches could be supported from national soil emerged after the collapse of the USSR. Thus, the development of the Vostochny Cosmodrome was approved by President Putin in 2007 and it has been operating since 2016. [64]

Table 9: Russia's launch infrastructure [64]

Name	Location	Operator	Main launch vehicle
Plesetsk Cosmodrome	Mirnyi, Arkhangelsk, Russia	RSC	Angara, Soyuz, Cosmos, Cyclone 3, Rockot, Soyuz 2-1.v, Start-1
Baikonur Cosmodrome	Kzyl-Ordinsk, Kazakhstan	RSC	Proton, Soyuz, Cosmos, Cyclone 2, Dnepr, Strela
Vostochny Cosmodrome	Amurskaya, Russia	RSC	All Russian upcoming manned and unmanned LV
Sea Launch Platform	Long Beach, CA, United States	S7 Group	Zenit (assembled in the U.S.) from 2019, Soyuz-5 from 2022
Yasny	Dombarovsky, Orenburg, Russia	RSC	Dnepr
Barents Launch Area	Barents Sea, Russia	VMF	Shtil, Volna

6.2.3. Operational Satellite Programs

We have created a graph for each type of satellites that shows the number of operational in –orbit hardware currently owned by Russia, categorized by commercial, civil, military and governmental assets. The data we have used were retrieved by the "UCS Satellite Database", published by the Union of Concerned Scientists, and which has been lastly updated on the 1st of May, 2022. [136]

6.2.3.1. Earth Observation and Meteorological Systems

The main Earth Observation satellites of the Russian civil space sector and their capabilities are presented below.

- AIST-2D: Russia has been conducting experiments on a new small-satellite bus-standard to serve as a platform for future spacecrafts of multi-purpose remote sensing satellites. It carries a Compact multispectral camera, the Avrora, and a P-band UHF radar for ground penetrating data used in high-accuracy agricultural observations, construction of elevation maps, tomography of ionosphere, and surface changes monitoring of extremely high resolution (a few centimeters).

- Resurs-P: This satellite series is used for natural resources, pollution and degradation monitoring, surveillance of the global ice conditions and emergencies control. [64]

- Meteor-M: This group of satellites is based on the collection of hydro-meteorological and helio-geophysical data through global observation of Earth's atmosphere and underlying surface. The data obtained are being used for agricultural, forestry, natural and man-made environmental disasters monitoring. [64]

- Electro-L: This type of spacecrafts are placed on GEO and are focusing on hydro-meteorological imaging regarding cloud coverage and analysis of the earth's underlying surface, hellio-geophysical measurements, hydro-meteorological and housekeeping data collection and relay.

- Kanopus-V & V-IK: This constellation is responsible for a wide range of optical in orbit observations, mainly focusing on monitoring many of earth's characteristics such as its surface, atmosphere, ionosphere, magnetosphere and the probability of strong earthquake occurrence.

Table 10: Roscosmos Earth Observational and Meteorological missions in FSP-2025 [64]

	Hydrometeorology and oceanography	Natural resources and monitoring systems
2016	Meteor M2	Resurs-P Kanopus-V
2017	Meteor M2 Arctica-M Electro-L	Kanopus V × 2
2018	Meteor-M3 Arctica-M	Resurs-P Kanopus-V × 2 Kondor-FKA Smotr-V
2019	Meteor-M3 Elektro-L4 Arctica-M2	Resurs-P Obzor-R Kondor-FKA
2020	Elektro-L5 Arctica-M2	Resurs-PM
2021	Meteor-M × 2	Resurs-PM Obzor-R
2022	Meteor-M	
2023		Resurs-PM Ozbor-R × 2
2024	Electro-L Arctica-M Meteor-MP	Resurs-PM Obzor-R
2025	Electro-M Arctica-M	Obzor-O Smotr-V

In the FSP-2025 the Russian government emphasizes strongly the process of rebuilding its remote-sensing constellation by tripling the number of in-orbit according spacecrafts.

The Russian National Center for Remote Sensing of the Earth has been under development since 2020 and shall be operational until 2025. [65]

In the following graph, the main different types of Russian Earth-Observation Satellites are presented. Russia currently owns 16 different models of these satellites. Military operated ones are also included. [136]

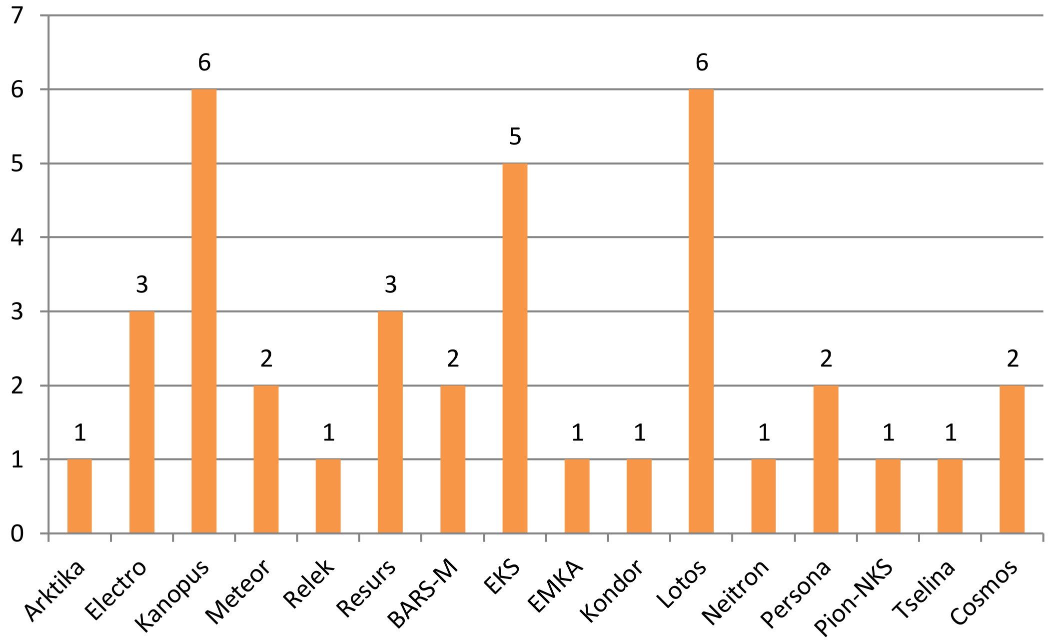


Fig. 22: : Main types of Russian Earth-Observation Satellites and their respective numbers [136]

6.2.3.2. Communication Satellites

Communication satellites are of vital importance for the Russian Federation both for military and civil operations. Russia is the largest country in the world, thus achieving communication links throughout its vast territory, covering multiple latitudes, has always been a challenge. Since 2016, 32 communication satellites have been operational and since 2025 an increase in numbers of up to 41 has been planned. [64]

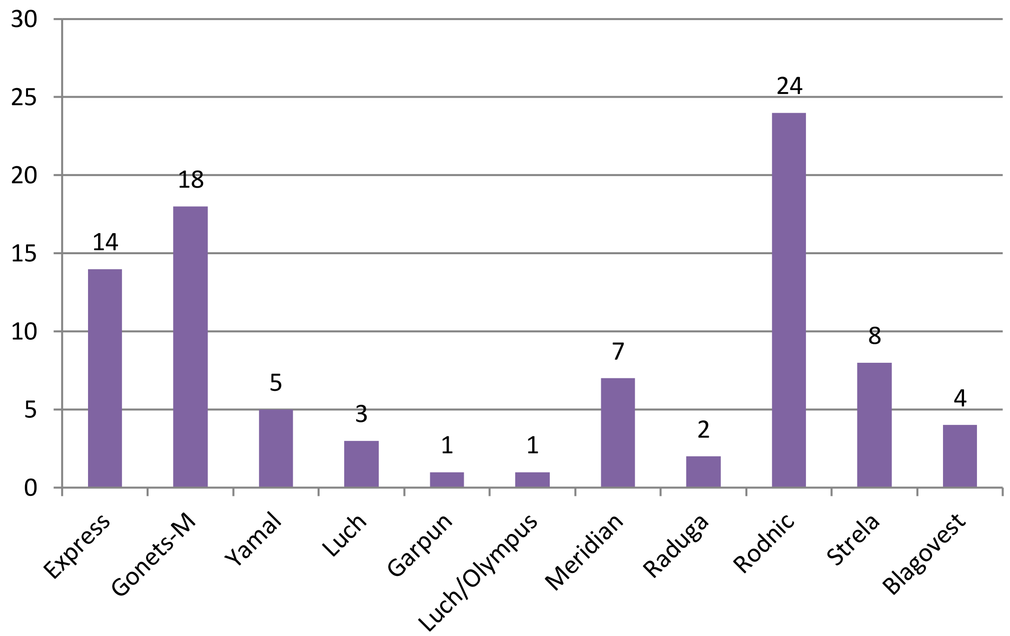
Table 11: ROSCOSMOS communication satellites as of 2016 [64]

Series	Function	Number	Orbit
Gonets-M	Telecom + Data Relay	9	LEO
Luch-5	Telecom + Data Relay	3	GSO
Ekspress	Telecom + Broadcasting	12	GSO
Yamal (Gazprom SS)	Telecom + Broadcasting	4	GSO

Table 12: ROSCOSMOS communication satellites as of 2016 [64]

	2016–2020	2021–2025	2026–2030
Satellite network	31	43	46
Active lifetime, years	10–15	15	>15

In the following graph, the main different types of Russian Communication Satellites are presented. Russia currently owns 11 different models of these satellites. Military operated ones are also included. [136]



Graph 6: Main types of Russian Communication Satellites and their respective numbers [136]

In 2018 Vladimir Putin announced the launch of the Sfera satellite system. It is planned to include 542 spacecraft and team deployment is expected from 2024 to 2028. According to Roscosmos, only the rockets to launch all the satellites will need about 150 pieces, the construction of which will cost over 300 billion rubles. It is believed that "Sphere" will become a competitor to the foreign systems OneWeb and Starlink, which are designed to provide communication and Internet access, but have also a significant role in space warfare.

6.2.3.3. Navigation Satellites

The Russian navigational satellite system has its roots back in the 70's, with the first launches being conducted during the mid 80's. GLONASS offers global coverage of real-time position and velocity determination for both military and civilian users and can achieve accuracy of 4.5 – 7.4 m. The fulfillment of the program has faced many ups-and-downs due to economic recession and political instability, but since 2012 it reached the full-fleet composition of 21 satellites. According to the GLONASS-2020 program, main targets regarding GLONASS concern the constellation's maintenance and exploitation for commercial purposes and the replacement of older GLONASS-K models from the GLONASS-K2 and GLONASS-VKK satellites, which offer higher accuracy and greater lifetime. Russia's ground network system is composed of 14 stations located on CIS (Commonwealth of Independent States), Antarctica and Brazil, and there is a development plan for expansion through Cuba, Iran, Vietnam, Spain, Indonesia, Nicaragua and Australia. [64]

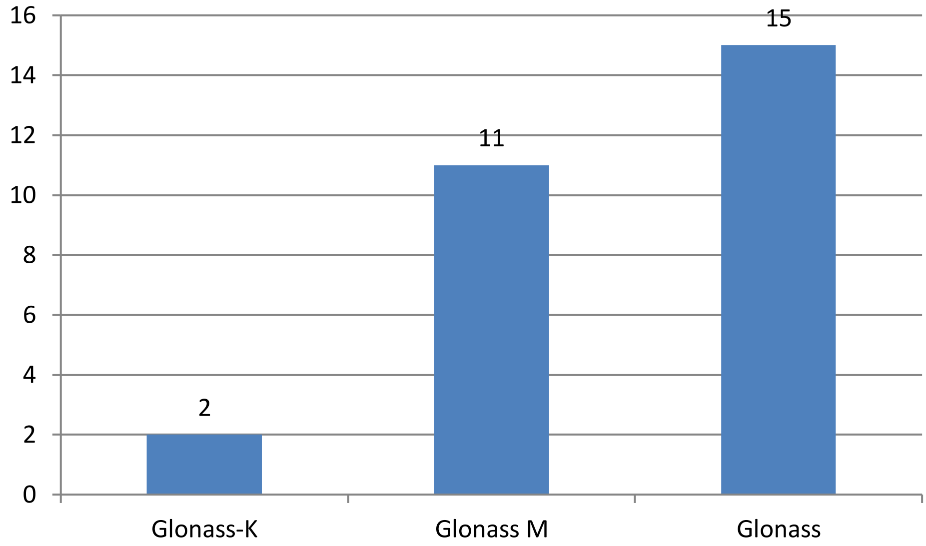
Table 13: Future GLONASS systems [64]

	No. of spacecraft	Series	Accuracy
2016–2020	24	GLONASS-K+K2	0.6 m
2021–2025	30	GLONASS-K+K2+VKK	0.3 m
2026–2030	30	GLONASS-K2+VKK	0.1

total satellites in constellation	25
In operation	22
In commissioning phase	one
In maintenance	0
Under check by the Satellite Prime Contractor	0
Spares	one
In-flight tests	one

Fig. 23: Current GLONASS satellites status [66]

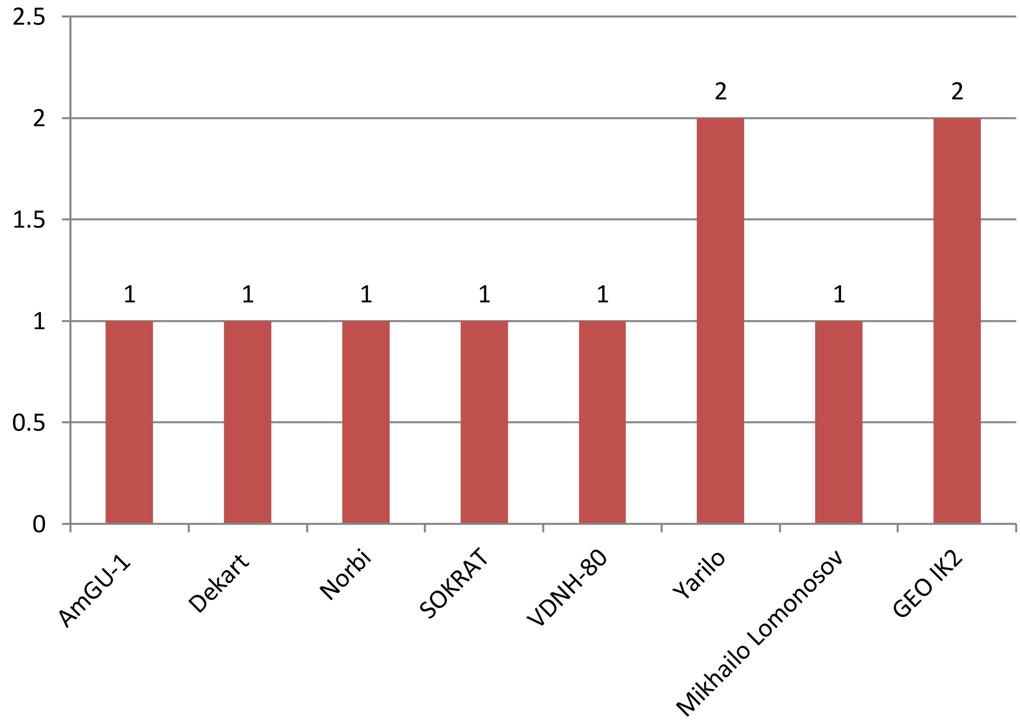
In the following graph, the number of the main different types of Russian Navigation Satellites is presented. Russia currently owns 3 different models of these satellites (if we consider those that do not belong on the -K and -M models as one category). Military operated ones are also included [136]. The planned investment in the GLONASS program for the period running from 2021 to 2030 is set at 484 billion rubles ($6.6 billion), as compared with 270 billion rubles ($5 billion) in 2012-2020. [174]



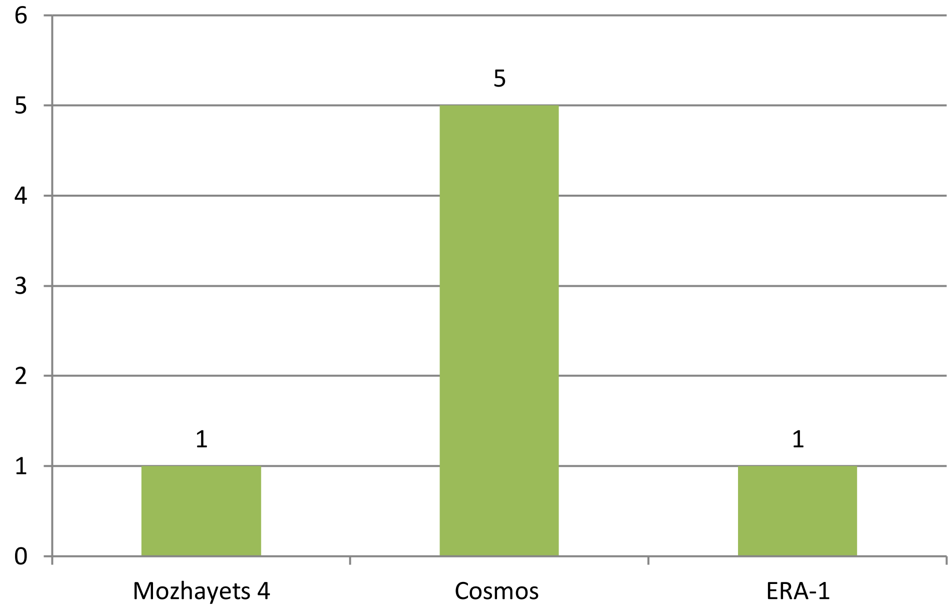
Graph 7: Main types of Russian Navigation Satellites and their respective numbers [136]

6.2.3.4. Science and Technology

We have also included two graphs with the main different types of Russian Scientific and Technology Demonstration Satellites currently in orbit. Russia owns 8 different models of Scientific Satellites and 3 main models for Technology Development satellite projects. Military operated ones are also included. [136]



Graph 8: Main types of Russian Scientific Satellites and their respective numbers [136]



Graph 9: Main types of Russian Technology Demonstration Satellites and their respective numbers [136]

6.2.4. Human Spaceflight

Human spaceflight has been consuming almost 50% of the Federal space budget. Russia has contributed a lot to the International Space Station, throughout all its years of operation. Although ambitious plans, such as lunar landing and manned Mars exploration, had been discussed in the beginning of the century, the economic recession pushed the agency, around 2013, to rearrange its future goals, focusing on the expansion of ISS's lifetime (achieved until 2024) and the construction of a habitable outpost at one of the Lagrangian points near the Moon. [64]

Roscosmos started developing three extra modules for the Russian segment of the ISS that could be detached and used to build a Russian Orbital Station after the ISS's decommissioning. Although the first two have been launched, docked and operating, the NEM module, which is the most promising for an individual ROS, has fell behind schedule and it remains uncertain when shall it be ready for deployment. [64]

Table 14: ISS's latest Russian modules [64]

Element	Launch Date	Mass	Note
Nauka—Multipurpose Laboratory Module (MLM)	2018–2019	20.3 tons	It will be docked to the ISS instead of the Pirs module and will be used for science experiments, docking and cargo. The European Robotic Arm is planned to be launched together with MLM
Pricahl—Node Module-1 (UM-1)	2019–2020	4.0 tons	A module with 6 hybrid docking ports intended to support deep space manned exploration. Can be used for the Russian OPSEK station
NEM—Science-Power Module-1 (SPM-1)	2019–2020	20.0 tons	It will be docked to Prichal and is meant to be part of the OPSEK station. It will be the most advanced component of the Russian segment including large power-generation solar arrays, laboratory facilities, living quarters, and new flight control systems

6.2.5. Space Science

In the space science sector Russia has not been conducting remarkable achievements for the last couple of years. Despite of the once remarkable USSR space-science past, this particular field has been coming second in comparison to other most applicable and prosperous commercial space activities. The last interplanetary mission Phobos-Grunt sample return mission proved to be an absolute failure, thus resulting in a pushback to similar missions aiming at other celestial bodies of our planet system [64]. However, in 2012 a new plan for planetary exploration and general scientific research has been discussed and many missions have been under preliminary - or more advanced - design stages. [66]

Table 15: FSP 2025 science missions [64]

	Budget	Name	Date	Details
Lunar exploration	38 bn RUB	Luna-Resurs-1	2019	Lunar polar orbiter
		Luna-Resurs-1 (×2)	2021	Lunar lander and rover
		Luna-Globe	2022	
		Luna-Grunt	2025	Sample return mission/search for water
Mars exploration	29 bn RUB	Exo-Mars (×2)	2016, 2020	Mars lander and rover/cooperation with ESA
		Expedition-M	2024	
Astrophysics	27 bn RUB	Spektr-RG	2017	Astrophysical labs
		Spektr-UF	2021	Astrophysical labs
		Spektr-R	–	Astrophysical labs
Heliophysics	19 bn RUB	Interheliozond		Heliosphere and sun at close range
		ARKA	2024	Stereoscopic study of the sun
		Resonans	2021	Solar corona
Biophysics	20 bn RUB	Bion-M	2021	

The most promising mission, the Exo-Mars, which was developed in cooperation with ESA was postponed after the beginning of the Ukrainian war and the western sanctions against Russia.

7. INTERNATIONAL SPACE COOPERATION

7.1. Motives of Cooperation

International space cooperation has always been an important factor of Russia's space activities. Despite economical difficulties, budgetary cuts or rearrangements on the space program, Russia has maintained its place as a core-member of the ISS and never failed to offer expected deliverables, either regarding cargo and new modules or launching services towards its partners. Also, trade in the space industry has proved vital for the Federation for a number of reasons, such as providing insights on the scientific and technological accomplishments of other space powers, serving as an important economical pillar for the self-preservation of its space program and enhancing geopolitical schemes through collaborative projects implemented on a bilateral or multinational level.

For Russia international cooperation provides a stability of its space program and ensures national funding in order to achieve effectiveness and by extension prestige [62]. Technology transfers and supply of products on the international market are exploited both as a means of income and as a way to advance "know-how" in many fields [64]. As Aliberti and Lisitsyna observe "In the eternally perceived need to 'catch-up' to the economic achievements of its counterparts, cooperation has been used to serve the objectives of technology-led macro-economic development and modernization. International partnerships, with the West in particular, have been seen as a way to gain know-how and to stimulate the overall development of the industrial base, but also as a way to maximize the benefits of investments in the space industry." [64]. Furthermore, space cooperation has always been used as a way to achieve particular political interests in a process of broadening Russia's geopolitical influence.

However, the aforementioned general motives have altered regarding the West after the 2014 Ukrainian Maidan riots, the changes in the political regime of Ukraine and the resulting intensity of rivalry between the Euro-Atlantic and Russian sides, along with the annexation of Crimea by the Russian Federation. These factors drove Russia in rearranging the basic principles for international cooperation regarding exchange of technology, economic stability and independence, as well as, finding new markets for trade and new countries for widening its geopolitical alliances.

The events of 2014 had a significant impact on Russia's approach to international cooperation and prompted the country to seek out new partnerships and alliances. According to Aliberti and Lisitsyna two are the main directions which shaped the international space relations of Russia from that point on.

- Gradual reduction of cooperation with former partners such as US, Ukraine and EU in order to enhance autonomy to foreign sources by relocating funds from joint ventures to Russian organizations, abandoning the use of non-domestically built launchers (such as Russo-Ukraine Zenit and Dnepr rockets) and initiating the construction of critical non-domestic space components. [64]
- Support of cooperation with new space faring nations such as Brazil, South Korea and antagonists of the Western status-quo such as China, India and Iran through technology transfers (e.g. electronic components from China), joint activities via the BRICS collaboration and funding acquisition through exports of

technologies and expertise that Russia's space industry possesses and are rapidly needed by these countries. [64]

7.2. Main Types of Cooperation

According to Aliberti and Lisitsyna "the main types of cooperation undertaken by Russia are: Technology transfer, Joint ventures, Joint programs, Exchange of data, Policy dialogue." [64]

In the first field of technology transfers Russia has engaged in multiple ways, such as selling entire Scud missiles to the Democratic People's Republic of Korea, cryogenic engines to India, liquid upper stage to Brazil, designing South Korea's KLSV-1 first stage and forwarding engine technologies to the US [64].

Table 16: Technology transfers in the field of launch vehicles [64]

Country of destination	Manufacturer	Component	Purpose
U.S.	Energomash	RD-180 engine	Atlas V
U.S.	Energomash	RD-181 engine	Antares
U.S.	Kuznetov DB	NK-33 engine	Antares
India	Glavkosmos	C-12 engine	GSLV Mk-I
North Korea	Korolyev OKB	Scud Missile plans	No-Dong
South Korea	Khrunichev	Angara technology	KSLV-I
Ukraine	Energomash	RD-251/2	Cyclone
Brazil	Energomash	Unspecified upper stage	VLS-1

Regarding the exploitation of Russian space rocket launchers many bilateral joint ventures have been established through the 90's as presented in the table below:

Table 17: Russia's international joint ventures for launch services [64]

Name	Year	Original composition	Service product
Sea Launch	1995	Boeing (U.S.) RSC-Energia, (Russia) Aker Solutions ASA, Yuzhnoye SDO (Ukraine) Yuzhmash PO (Ukraine)	Zenit-3SL Zenit-3M
International Launch Services (ILS)	1995	Lockheed Martin (U.S.) Khrunichev (Russia) RSC-Energia (Russia)	Proton, Angara
Space International Services (SIS)	1996	RSC Energia (Russia) UGMK (Russia) Yuzhnoye SDO (Ukraine) Yuzhmash PO (Ukraine) TsENKI (Russia)	Zenit-2SLB Zenit-2SLB Zenit-3F
International Space Company (ISC)	1997	Roscosmos (Russia) Ukranian Space Agency (Ukraine) Garysh Sapary (Kazakhstan)	Dnepr-1
Starsem	1996	EADS Astrium (Germany) Roscosmos (Russia) TsSKB-Progress (Russia) Arianespace (France)	Soyuz
Eurocktot Launch Services	1995	EADS Astrium (Germany) Khrunichev (Russia)	Rockot

The International Space Station (ISS) is one of the most successful collaborative space programs involving Russia. It has been in operation for nearly 25 years and has yielded numerous important scientific and technological achievements. In interplanetary science Russia has provided a scientific instrument in NASA's Mars Science Laboratory, marking the first successful collaboration with the US on extraterrestrial soil, and the development of the ExoMars program with ESA, had been a much promising cooperation, disrupted however by the Cosmodrome with Kazakhstan sanctions against Russia due to the Russo-Ukrainian war. Furthermore, many joint programs regard space launching activities, such as the use of the Baikonur and the Guyana Space Center for Soyuz-ST rocket launching. [64]

Regarding the exchange of data, Russia has been offering to the European Organization of Meteorological Satellites (EUMETSAT) data from its meteorological satellites, Earth Observation data to the International Charter on Space and Major Disasters, Navigational data on the COSPAS-SARSAT International System for Search and Rescue, along with object and debris detection data and infrastructure (telescopes and ground stations) for the International Scientific Optical Network (ISON). [64]

Finally, on the policy dialogue aspect Russia was conducting meetings with US space policy officials for discussing issues of Transparency and Confidence-Building Measures (TCBMs) in outer space after a 2009 satellites' collision, and has submitted with China in the Conference of Disarmament two "Draft Treaties on the Prevention of the Placement of Weapons in Outer Space" in 2008 and 2014. [64]

7.3. Russia's Bilateral Cooperation

7.3.1. U.S.A.

Russia and the United States have had many successful cooperative space endeavors since the dissolution of the Soviet Union. Despite political rivalry, both countries have benefited from each other's expertise. The International Space Station (ISS) is the most significant joint space program between the two countries and has continued to operate even after the Russo-Ukrainian war and Western sanctions against Russia. After the end of the Space Shuttle program in 2011, NASA relied on Russian Soyuz launchers to transport astronauts to the ISS. This created a partial monopoly for Roscosmos in providing launch services to the ISS and allowed Russia to increase prices accordingly, resulting in significant economic revenue for Roscosmos. [64]

Table 18: Total cost of Soyuz seat per year [64]

Launch year	Number of seats	Total cost ($ million)
2006	2	$50.200
2007	1	$21.800
2008	1	$21.800
2009	6	$150.997
2010	6	$158.550
2011	6	$224.426
2012	6	$306.000
2013	6	$335.070
2014	6	$361.875
2015	6	$364.869
2016	6	$424.045
2017	5	$381.641
2018	7	$567.500
Total	64	$3368.774

The two countries have also cooperated in the fields of outer space with the participation of Roscosmos in the Martian rover Curiosity (MSL) and in the Lunar Reconnaissance Orbiter projects, by offering scientific payloads to both missions for the detection of water.

An important joint program that had its roots back in the 90's was the transfer of Russian rocket engines, the RD-180, to be used on the Atlas V first stage and its strap-on boosters. This specific program, led to the creation of a 50-50 joint company, the RD AMROSS LLC, between Energomash and Pratt & Whitney Rocketdyne and to the transfer and coproduction of more than 100 RD engines. However, the program faced many challenges and was eventually abandoned, largely due to geopolitical conflicts.

Regarding navigational systems the US refused to permit GLONASS ground station to be placed over its territory due to security considerations. This policy pushed Russia to disable all active GPS stations over Russian soil. [175]

Regarding the missile defense a joint missile defense development effort between the United States and Russia, was developed at the end of the 1990s. The so called Russian-American Observation Satellites (RAMOS) program was a bilateral technology program that engages Russian early warning satellite developers in the joint definition and execution of space experiments. [176]

The program originally planned for one American-built satellite (AOS) and one Russian-built satellite (ROS) to work together. However, during the concept phase, the plan was changed to have two Russian-built and launched satellites carrying both American and Russian instruments. In 2004, the American side unilaterally cancelled the RAMOS initiative.

7.3.2. INDIA

India’s space cooperation with Russia roots back to the mid-70’s when it launched its first satellite, Aryabhata, through the Soviet Kosmos launcher. A decade later the first and only Indian astronaut was put in orbit through the Soviet Intercosmos mission. Despite this promising initiation of bilateral activities the two state’s collaboration has been in decline through recent years. After the dissolution of the USSR joint activities were mostly limited to the transfer of cryogenic engines for rocket assembly and technical guidance that would provide India with the capability of developing autonomously launching systems for placing its satellites in GEO. However, the US where strictly against such a cooperative plan since they considered that if India acquired this “know-how”, a nuclear threat would emerge due to the rivalry with Pakistan (both of which posses nuclear technology). With sanctions imposed on both ISRO and Glavkosmos, Russia held back the extraction of such critical technology to India and provided it with the boosters assembled and ready for use [64], [68], [69]. India decided to develop its own cryogenic-engines program after this turn of events and after a slow paced procedure this plan was accomplished in 2017 after 25 years of delay due to US sanctions.

In the 2000’s cooperation between India and Russia was focused on navigational satellites, manned missions and robotic outer space exploration. On the first field two agreements on launching GLONASS-M models through India’s GSLV and co-developing GLONASS-K satellites with ISRO were signed. India was eager for this procedure since it would acquire core technological abilities concerning navigational satellites and gain access in data that could prove useful in various ways, while Russia would reduce the cost of launching its necessary satellites for the construction of the GLONASS constellation and would promote its system against GPS expansion. However, once more, as in China’s case, Russia preferred not disclosing important designs and “know-how” that could result in undermining its technological advantage over new space faring nations. India once again decided to follow an autonomous path although in 2011 an agreement was reached in providing PNT data for India’s military [64], [70].

Furthermore, in space exploration two programs were supposed to involve cooperation. On the one hand an Indian scientific payload was placed on-board of the Coronas-Photon mission in 2009, and on the other a Russian landing module on the Chandrayaan-2 lunar mission. The first mission failed a year after its launch and the second was marked by a long-time delivery delay of the Russian module due to fears resulting from the failed Phobos-Grunt mission in 2011, which led once again to a successful, autonomously developed, launched and controlled mission from India’s side.

In the field of human spaceflight Russia and India agreed in 2008 that ISRO would base its design of a spacecraft for manned missions on the corresponding Soyuz vehicle, the possibility of an Indian astronaut to be set in orbit via Russian spacecraft and providing aid in the construction of a new Russian vehicle were considered. However, due to all of the above failed cooperation procedures these prospects were also abandoned. [64]

As Aliberti and Lisitsyna mention all the aforementioned disappointing collaborative experiences have not only grown the two countries apart but also brought them under competition, especially in commercial launches. India gradually evolved its space industry and overall space capabilities throughout the years. In the space launching sector India has accomplished about 385 foreign commercial launches up to 2022. From a political perspective it is important to note that although Russia invested in increased cooperation so as to expand its allies and to affect India's international policies towards a multi-polar more democratic world against the US's global hegemony, it failed to restrain Western influence. India has become an important partner for both the US and Europe regarding space launches, especially after the beginning of the Russo-Ukrainian war and Russia's ban on western astronauts traveling via its rockets. [64]

However, there is one field where cooperation seems to be blooming and this is the defense and security sector. "BrahMos Aerospace, a company owned by the Indian Defense Research Development Organization (DRDO) and partly by the Russian NPO Mashinostroyeniya, has been chosen to be India's commercial arm for Indian defense products sold abroad. India successfully test launched the BrahMos Extended Range supersonic missile off its eastern coast. Considered a milestone step for Indian defense, it now extends India's striking capability well beyond its current 180 miles (around 290 km). Complete with a guidance and stealth technology, the two-stage missile reached 2.8 Mach during the test flight. Touting BrahMos' as the global pinnacle of supersonic cruise missile system providers, great optimism and confidence seems to be spreading throughout the Indian defense industry in light of recent achievements" [64], [71].

7.3.3. Ukraine

As part of the former Soviet Union, after its dissolution Ukraine inherited a share of its space industry somewhere between 15 and 30%, as Aliberti and Lisitsyna mention. This infrastructure, mainly consisting of testing facilities and production plants for space hardware development, had been the cornerstone of its autonomous national space program. A key example referred in the Springer report was Yuzhnoye, a production facility for ballistic missiles and launch vehicles. Up to 2013, regarding the fact that Ukraine was not a political rival to Russia but a close partner in many fields, there had been many important space cooperation projects. The most promising had been the Dnepr and Zenit launch vehicles' production. Cooperation in hardware exchange, satellite programs and scientific research had been implemented. After the 2014 crisis in Ukraine and Crimea began, Russia strived to develop on its own all the necessary equipment provided by Ukrainian factories, a process nether cheap nor easy. Ukrainian vehicles were abandoned by the Russian space program, resulting in a suspension of the Zenit and Dnepr space launchers.

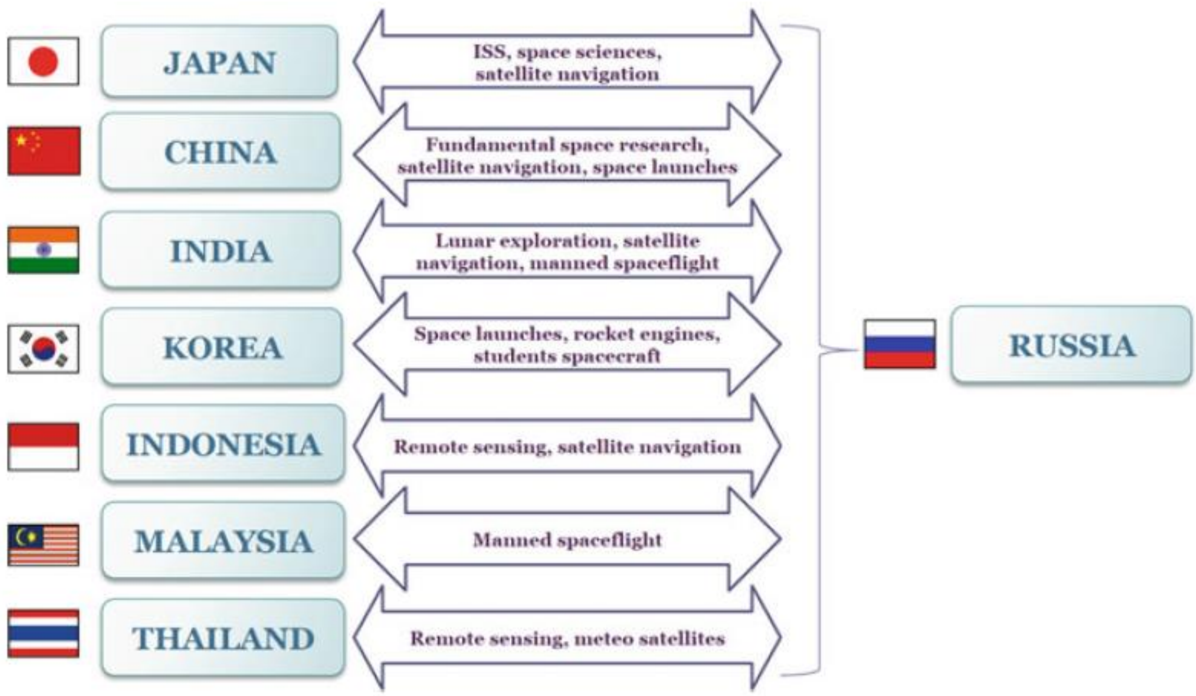
7.3.4. Kazakhstan

The main sector of cooperation between Russia and Kazakhstan has been the exploitation of the Baikonur Cosmodrome which was the main launching facility of the Soviet Union but was brought under Kazakhstan's control after the post-Soviet borders were defined. Astana and Moscow signed an agreement for a "long-term lease at an annual fee of 115 million $ until 2050". Kazakhstan's government often questioned the agreement, making it difficult for the Russian space agency to acquire the necessary authorization and permissions for launch. After Russia's plan for a new Cosmodrome on national territory and the development of the Vostochny launching facility began, Kazakhstan eased up its posture and in 2016 the two states agreed that Baikonur would be used for commercial launches.

7.3.5. East Asia

Russia has conducted a number of joint space activities with many countries of the East-Asian complex as presented in the figure below.

Table 1: Russia's regional space cooperation in Asia [72]



7.3.6. Iran

Iran has been an important ally to the Russian Federation throughout recent decades. Its geopolitical rivalry with western strategies regarding the Middle East region has shaped its cooperation with Russia in many fields, including scientific research and space activities. Iran has become an important export market for Russian technologies, both for civil and military applications. In 2005 the first Iranian satellite, Sina-1 Earth Observation Satellite, was developed and launched from Russia. In 2014 a cooperation agreement in space activities was signed including training of Iranian astronauts, construction of Earth observation and telecommunication satellites, provision of Russian E.O. data from the Resurs satellites and construction of ground stations for monitoring satellites of the GLONASS navigational system. Iran's National Remote Sensing Satellite was launched in October 2022 by a Russian Soyuz missile. In 2016 Russia delivered S-300 missiles to Iran despite concerns from the US and Israel. [64]

7.3.7. Brazil

Russia's space cooperation with Brazil has been going on for many years and has always been a field of unfolding political schemes along with mere scientific collaboration prospects. Half the GLONASS ground stations located outside Russian territory are established in Brazil. In 2015 space collaboration between Brazil and Ukraine for developing the Cyclone-4 carrier rocket was interrupted due to delays from the Ukrainian side and to an effort of establishing closer ties with Russia in the frame of BRICS. In 2017 there had seemingly been an agreement between the presidents of the two states regarding the use of the Alcantara Launch Center for joint space launches along with the provision of Russian assistance in the development of the SLV rockets for placing Brazilian satellites into orbit. This was an important milestone for Russia's expanding influence in South America, especially regarding the fact that the US were strongly competing to avoid such a turn-point. However, these plans were interrupted by the coming in Brazilian presidency of Jair Bolsonaro. [64]

7.3.8. BRICS

We have mentioned the activities of this international coalition regarding space operations in the analysis of the Chinese multilateral relationships. However, it is important to highlight that for the Russian side the value of the organization, when it comes to geopolitical prospects, is summarized on the following mention from Aliberti and Lisitsyna: "As the Kremlin visualizes it, in light of their combined political, economic and demographic weight, the BRICS countries have enough power to promote a "more democratic" and multi-polar international order where the hegemonic interests of the U.S. are constrained." [64]

7.3.9. EU

Cooperation between the European Union and Russia has always been affected by political ties and global geopolitics. This tidal relationship, from the Cold War era rivalry to collaboration with the post-USSR state in the early 00's, has once again fallen into confrontation since the initiation of the Ukrainian crisis and the resulting annexation of Crimea. In this section we shall refer mainly to previous collaboration space activities while the evolution of the relationship between EU and Russia and the results of economic sanctions shall be analyzed further in a later chapter.

Since ESA, who is Europe's main space organization, has been detached from political matters the cooperation between it and the Roscosmos has maintained a relatively stable course despite the differences in international politics. Along with ESA, the other two basic organizations concerning space in the European Union, the European Commission (EC) and the EUMETSAT, have also cooperated with Roscosmos throughout the years. The main fields of cooperation have been manned spaceflight, space launches, space sciences and satellite applications.

In manned spaceflight collaboration began with the MIR space station and the placement of European astronauts on-board, back in the mid-90's. After the ISS was constructed a large part of joint space activities have been concerning its use, maintenance, engineering and technological enhancement (e.g. Automated Transfer Vehicle and European Robotic Arm), training and transportation to the Russian module of European astronauts and conduction of microgravity scientific experiments.

In the field of space launchers joint Euro-Russian ventures were created in the mid-90's for common exploitation of Russia's heritage in space rocketry. Eurockot and Starsem were enterprises created for the commercialization or Rockot and Soyuz respectively. Also, collaborative research was conducted regarding new launchers, liquid-propulsion engines and reusable vehicles. The exploitation of the European French Guyana Space Port for launches of the Soyuz vehicle has been another important milestone in the collaboration between ESA and Roscosmos. The Soyuz-ST model entered the European space-fleet in 2005 allowing ESA to use extra launching vehicles besides Ariane and Vega. At the same time this procedure allowed Russia to expand its share in commercial markets and provided improved capabilities to the Soyuz rockets, since they launched from a location closer to the equator. The Soyuz technology would allow ESA to reach medium-range orbits, MEO and GTO, for placing communication, navigation and earth observation satellites. The first successful Soyuz-ST technology was launched in 2011 from Kourou [64]. However, Europe from the beginning of this cooperation did not want to depend on the Soyuz aircraft for strategic missions of political importance, since it is not an actual European vehicle [73].

In space research there has been a number of missions regarding scientific and outer space exploration. Rosetta, Cluster, Mars Express, Venus Express, Integral and Bepi Colombo are some of the programs worth mentioning. However the most notable ones are the Martian exploration ExoMars mission, the JUICE and LaPlace-P Ganymede mission for the exploration of the Jovian system and the Lunar Resource Lander and Lunar Polar Sample Return missions for Moon exploration [64]. All of these missions' future is uncertain regarding their collaborative prospects due to the western sanctions and Russia's counter-actions that took place after the beginning of the Ruso-Ukrainian war. [64]

Finally, regarding cooperation on satellite programs, electrical propulsion (plasma thrusters) and telecommunications have been the main fields of exchanging know-how and supportive technologies. Many companies on both sides (Airbus, Khrunichev, Thales Alenia Space, Gazprom, NPO PM etc.) have been cooperating on communication satellites with the European parts usually forwarding "payloads and systems" for satellites' buses in the Russia market, whilst the Russian side was responsible for launching them into orbit. [64]

8. RUSSIA'S MILITARY SPACE PROGRAM

8.1. Space Military Accomplishments

Over the past years, Russia has made constant efforts to increase its stockpile of nuclear ballistic missiles and strategic equipment. This procedure, combined with recent military operations in Ukraine and Syria, have highlighted during the last decade the prominent role that military superiority has played in Russia's foreign and defense strategies. Regarding space, Russia has been committed in investing to improve its reconnaissance satellites, so as to achieve a resolution equivalent to U.S.'s satellite systems. It reportedly plans to launch three Razdan satellites, which are technologically more developed from the existing Persona that achieve up to 31cm of resolution. The use of surveillance satellites for military operations lies in battlefield reconnaissance, mapping and preparation, as well as supporting remote troop deployment (as in Syria). The satellites also provide important targeting data that can be exploited by Russian bombers and cruise missiles. [26]

Moscow has invested in space-control applications and the enhancement of its space-warfare capabilities, in order to contain and counterattack enemy actions. The leadership of the armed forces appears to recognize three key-threats arising from the use of space; a generalized "global strike," the "intent to place weapons in space," and "strategically precise non-nuclear weapons". The ASAT program and counter-space technologies have been revived in recent years. The Russian armed forces have anti-satellite kinetic weapons, lasers, jammers, new cyber-technologies and are conducting strategic anti-satellite research. [26]

At the same time S-300 surface-to-air missiles (SAM) are considered capable of targeting "near space" objects. The S-400 and S-500 SAM systems with a range of up to 600km can shoot down low-orbit satellites and orbital space weapons. In December 2008 Russia tested a direct-attack anti-satellite missile called Nudol, which is likely to target satellites passing over Moscow. In 2014, four satellites were put into orbit with one of them achieving orbital maneuvers. The US assessed that the purpose of this mission was to test satellite systems capable of changing orbital paths for tracking and interference or even to deposit objects in a destructive path towards "rival" satellites. [26]

Furthermore, tests have been carried out on various airborne ASAT weapon systems. These can be missiles launched from an MiG-31BM aircraft, laser systems on board of an A-60 aircraft to implement counter-space warfare by "blinding" the sensors of enemy satellites or even EMP (Electro Magnetic Pulse) weapons tested at high altitudes to paralyze any system (ground and space) that does not have the required EMP-defense technology. Finally, Russia is developing technologies to detect and track orbiting space objects, thus increasing the ability of the armed forces to sabotage opposing systems. This is being achieved through the construction of new phased array radars and laser optical technology radars. [26]

The Russian space offensive force as of now is based on ICBMs and various types of re-entry vehicles. It continues to develop its very capable ballistic missiles - in both ground and sea-based platforms - which travel through space to their targets. It is estimated that Russia possess around 1200 nuclear warheads on-board various carrier vehicles. In 2012 they tested the SS-27 Mod 1 ICBM which contains countermeasures against ballistic missile defense systems and is already deployed in silos and launchers. Also, a number of supersonic glide vehicle technologies related to ICBMs have been tested to evade missile defense systems. Finally a number of Fractional Orbital Bombardment systems, which were banned by the START treaty (but not by the new version of it) have been tested and could be exploited to strike the US from the South Pole. In fact, if rumors of testing nuclear warhead launch systems from space are true, this would allow a strike in 1 to 2 hours anywhere on Earth. [26]

The Russian leadership clearly sees space as a critical area for both deterrence and warfare practice and therefore tends to increase the number of operational satellites to 150 by 2025. Since 2014 it had doubled its most advanced space assets in orbit, namely early warning satellites and geosynchronous signal intelligence collection platforms. It has remained a leader in space launch, specialized in sending large-capacity payloads into geosynchronous orbits, and in manned spaceflight, the facilities of which are deployed within Russian territory. [26]

According to the "2022 Challenges to Security in Space" report, released by the Defense Intelligence Agency, Russia's Space Strategy and Doctrine prioritizes support of all actions on space arms control. Despite the fact that it develops counter attack and presumably offensive strategies, Russia understands that the space sector shall be of critical importance in any major war-fighting future scenario. Thus, with awareness of the strength of its adversaries it has expressed concerns over the weaponization of space while also pursuing legal binding agreements. At the same time Russia has a slightly different approach than China and the US regarding the use of space assets for warfare actions. Overreliance on space is considered a potential vulnerability by the Russian Armed Forces and has led to a development of terrestrial redundancies for use in case space-based war-critical systems are jammed or destroyed during conflict. Also it has led Army agencies to focus on the production of counter-space and anti-satellite weapons so as to deny, degrade and disrupt the US's Armed Forces space capabilities. [30], [74], [75]

8.2. Space and Counter-space Organizations

The overall plans of the Russian Federation regarding space, the difficulties it faced after the western sanctions, the need to reestablish its production in many fields (e.g. microelectronics) due to the industrial disruption caused by rivalry with Ukraine and the loss of former Soviet production enterprises, led to a reorganization of its civil space program. The Russian space sector is almost entirely state owned. According to the 2022 Report "the state-owned corporation Roscosmos is the executive body responsible for overall management of the space industry and for carrying out Russia's civilian space program. The space industry primarily comprises 75 design bureaus, enterprises, and companies that carry out research, engineering development, and production of Russia's space technologies, satellites and SLVs for both civilian and military purposes." [30], [76]

On the following graph we present Russia's main space-military structure according to the 2015 reform.

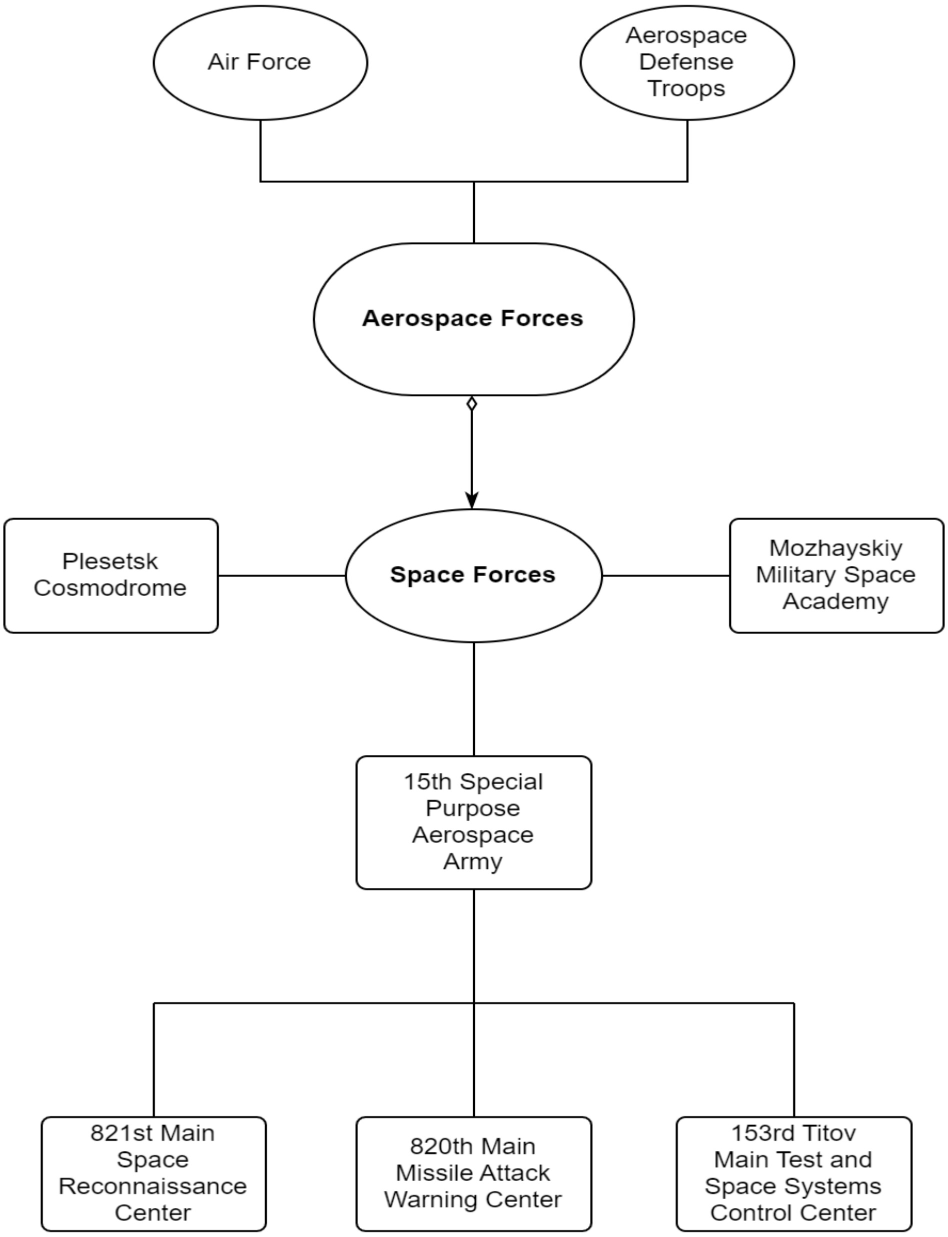


Fig. 24: Russian Space Military Structure [30] (graph created using GitMind)

8.3. Russian Space Military Technologies

The 2022 report analyzes a variety of military capabilities that Russia has developed in the space sector.

- ISR (Intelligence-Surveillance-Reconnaissance)

Russia has developed cutting edge technologies in this sector and currently owns more than 30 satellites in orbit "providing electro-optical imagery, a new radar observation platform, missile warning and electronic and signals intelligence. (…) Space-based sensors provide Russia strategic warning of ballistic missile launches, support targeting of Russian anti-ship cruise missiles, and support electro-optical imagery requirements for Russian military operations (as in Syria).” Due to the disrupted production of space-assets Russia has been also using commercial earth observation satellites for military purposes. [30], [77], [78], [79], [80], [81], [82], [83]

- Satellite Communications

Russia’s constellation of satellites in multiple orbits provides capabilities of autonomous SAT-COM operations that can support military actions and secure command and control of its troops, with new, enhanced and more capable satellites replacing old technologies. [30], [84], [85], [86], [87], [88], [89], [90], [91], [92]

- PNT Capabilities

Regarding the use of navigational satellites, the GLONASS system can prove to be crucial for position, navigation and tracking regarding military deployment, troops’ movement and for providing precision-guided munitions. [93], [94], [95]

- Human Spaceflight – Space Exploration

Regarding human missions in space, Russia has developed an autonomous communication protocol to connect with the Russian module of the ISS via the Luch relay satellites, ensuring independency from NASA. [96]

- Space Launch Capabilities

Russia, contrary to China, prefers to fund improvements of its medium and heavy lift space launchers rather than develop light-lift SLVs. Russia’s strategy regarding the future of its space-rockets consist of modular SLVs, multi-payload launches on larger rockets and designs for a new super heavy-lift SLV (similar to U.S. Saturn-V and SLS models) for manned missions in outer space. [30], [97]

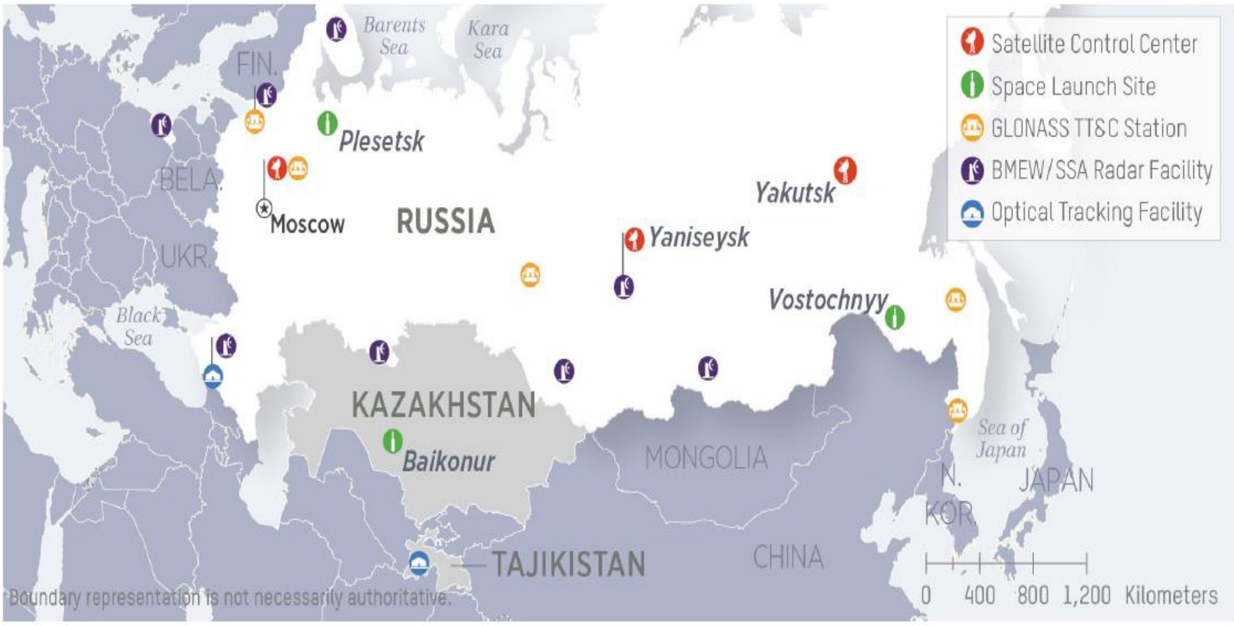


Fig. 25: Russian Space Launch, SSA, Satellite Control Centers and Command & Control Stations [30]

As the 2022 report mentions “Russia owns two of its launch sites and leases one from Kazakhstan. The European Space Agency has contracted Russia to conduct launches from Kourou, French Guiana. Inactive spaceports include Kapustin Yar and Svobodny Spaceports. Russia’s space control sites are spread across Russia to enable effective satellite C2. GLONASS TT&C stations are similarly spread across Russia to ensure timely control of the navigation constellation. Moscow has spread nine radars at eight locations of various types across its landmass to enable a dual-role BMEW and SSA mission.” [30].

- Space Situational Awareness

Russia owns a wide variety of infrastructures that provide the capability of space surveillance. Its network that is controlled by the 821st Main Space Reconnaissance Center consists of telescopes, radars, and multiple sensors, which can track and characterize satellites in all Earth orbits. Harnessing these abilities is of particular importance for intelligence and counter-space actions, but also for non-military purposes such as safe spaceflights, debris tracking and satellite malfunctions monitoring. [30], [98]

- Electronic Warfare Capabilities

EW is one of the main sectors that Russia has thrived throughout the years. Since its space military doctrine is based on disrupting enemy space technologies EW is an important part of its defense strategies. Intelligence and espionage, hacking and disarraying of C4ISR capabilities and weapons guidance systems are based on EW. Both ground-based EW systems and mobile jammers provide the ability to target and counter GPS systems, SAT-COMs and radars. In February 2020 Russia has confirmed using such technologies in Syria for disruption of GPS systems used in drones. [30], [99], [100], [101], [102], [103], [104], [105],

- Cyber-threats

Whether we are talking about superpower’s antagonism in a global scale or for any nation facing safety issues from its neighboring countries, information superiority has always been of ultimate importance in military strategy. Russia considers space-based information collection a critical asset and is constantly improving its systems for both acquisition and disruption of rival capabilities. [30], [106]

- Directed Energy Weapons

Ground based laser weapons can be used for blinding the optical payloads and sensors of satellites. Russia has deployed the Peresvet ASAT laser weapon system in five strategic missile divisions and shall use it in order to provide coverage from space detection to its missile systems. [30], [107]

- ASAT Missile Threats

Russia has developed and tested a range of ASAT systems capable of destroying satellites in LEO (mainly communication and ISR). These systems are supposed to serve antiballistic missile purposes but could also attack LEO space assets. The Nudol mobile missile and the Burevestnik air-launched missile could both be deployed for anti-satellite attacks. Nudol has produced, in one of its tests, tens of thousands of both trackable and untrackable pieces of space debris that could harm satellites in LEO, the ISS and the Tiangong space station. [30]

- Orbital Threats

Finally, regarding in-orbit counter-space activities Russia has deployed a number of dual-use satellites. Constructed to fulfill service purposes some Russian satellites (Nivelir and Cosmos programs) have been used for following U.S. security satellites, performing in orbit maneuverable approximation and inspection, ejection of objects in orbit that could prove to be ASAT weapons and other capabilities that could be used for kinetic-kill of rival systems. Roscosmos intends to create orbital servicing satellites for Geosynchronous Orbits as well, advancing further its dual-use technologies. [30], [108]

9. ANALYSIS OF THE RUSSO-CHINESE BILATERAL RELATIONSHIP

9.1. China, Russia and the U.S.'s threat in space

In this chapter of our research we shall analyze the correlation between U.S. actions, regarding commercial and military uses of space, how they are interpreted by China and Russia and how they affect their space activities accordingly. In a publication by RAND-Corporation entitled "Chinese and Russian Perceptions of and Responses to U.S. Military Activities in the Space Domain" the way that China and Russia have historically perceived U.S. actions in space is analyzed based on primary sources (papers, articles, military archives) originating from the two countries. In the last 5 years there have been plenty initiatives from the U.S.'s side that can justify not only China's and Russia's mistrust but their counteractions as well. Trump administration's National Space Strategy (2018) and National Space Policy (2020), the reestablishment of U.S. Space Command (2019), the launch of U.S. Space Force (2019) and many documents from the Department of Defense and the Joint Staff are indicative of the U.S.'s strategy regarding a space-arms race. China accuses the U.S. of sticking to a Cold War mentality, thus leading to the militarization of space, while Russia is increasingly concerned about maintaining its national interests in the presence of a space warfare arena. [109]

According to RAND's publication, the main past U.S. policies and strategic actions regarding the use of space for military purposes that have contributed in bilateral space antagonism and deployment of ASAT weaponry can be summed up as follows:

• <u>Strategic Defense Initiative (SDI) (1983) and U.S. Space Command creation (1985)</u>: The Reagan administration's SDI was a space-based missile defensive program for early-tracking and attacking incoming offensive nuclear weapons. U.S. Space Command was in charge of the SDI program. It is considered (especially by the Chinese) as the beginning of militarization of space and space arms race [109].

• <u>President Bill Clinton's National Space Policy (1996)</u>: Despite the fact that Clinton's administration emphasized more on the use of space for peaceful purposes, its space strategy is characterized by the acknowledgement that the U.S. are extremely space-dependant for both commercial and military purposes, thus regarded space as a critical arena for safeguarding national security and civil interests. [109]

• <u>Mid-Infrared Advanced Chemical Laser (MIRACL) test (1997)</u>: Presumably a scientific mission for understanding the vulnerability of satellite imaging sensors to laser beams, the MIRACL test was conceived by China and Russia as a ground-based ASAT technology demonstration. It has been the first laser targeting test of a spacecraft by the U.S. [109]

• <u>Commission to Assess United States National Security Space Management and Organization ("Rumsfeld Commission") (2001)</u>: Under the Bush administration a special committee was established to assess vulnerability issues on national defense that could be created from U.S.'s space dependence. The probability of a "Space Pearl Harbor" was highlighted along with the need for greater coordination between the CIA and the DoD regarding military strategies on the space field. China and Russia both perceived the reports produced by the committee as a statement for advancing space arms' technologies to ensure U.S.'s strategic superiority. [109]

• U.S.'s withdrawal from Anti-Ballistic Missile (ABM) Treaty (2002): The withdrawal of the U.S. from the 1972 ABM Treaty which banned Soviet Union and the United States from deploying ABM defense systems was perceived as an act that would lead in the deployment of missile defensive systems to support offensive actions. This action would, also, allow the U.S. to launch its military space operations' plans creating concerns to both Russia and China for the initiation of space weaponization. [109]

• U.S. Air Force (USAF) *Counter-space Operations* doctrine (2004): This particular document appears to be a more specific and clarified plan on how the United States developed their space military strategy. The importance of counter-space operations was declared and plans on space situational awareness, defensive and offensive operations were conducted, aiming at both safeguarding freedom of operations and denying adversaries' capabilities. [109], [110]

• President George W. Bush's National Space Policy (2006): The Bush administration strengthened the U.S. space sector and emphasized the connection between space and national defense. The policy rejected future arms-control agreements and emphasized the importance of freedom of action in space. It also asserted the U.S.'s right to deny access to space to any actor hostile to U.S. national interests. China and Russia perceived this policy as an attempt by the U.S. to dominate space and achieve space hegemony. [109], [111]

• Operation Burnt Frost (2008): This operation regarded the missile strike of a malfunctioned U.S.'s satellite that was orbiting back to Earth. The satellite was successfully destroyed creating no permanent debris. This was conceived by Russia and China as an ASAT mission aiming to demonstrate U.S.'s kinetic counter-space abilities and a further escalation point in the space arms race. It is important to note that this operation took place a year after China's 2007 ASAT test. [109]

• President Barack Obama's National Security Space Policy (2011): The Obama's administration space policy was considered as a step forward into international space coordination and cooperation, smoothening the rather offensive aspects of the Bush administration. A peaceful shift regarding space affairs, talks for international regulations and a hope for ceasing space militarization were most welcome by the Russian side. China also viewed a positive progress by the U.S., but both countries maintained some skepticism. [109]

• Remarks of General William Shelton (Commander, USAF Space Command) regarding the Geosynchronous Space Situational Awareness Program (GSSAP) (2014): This type of GEO satellites was presented by the U.S. as a technology that would assist the enhancement of orbital predictions, GEO space environment surveillance and space-based assets collision avoidance. Both China and Russia considered this program to have clear military operational prospects focusing on maneuvering, interception, striking, reconnaissance and surveillance. [109], [112]

• Trump Administration's National Space Strategy: The Trump Administration's 2018 National Space Strategy aimed to achieve "Peace through Strength" by protecting the US's vital interest in space and ensuring unfettered access to and freedom to operate in space. The strategy set a goal to strengthen the safety, stability, and sustainability of US space activities and stated that any harmful interference or attack on critical components of the US space architecture would be met with a deliberate response. The strategy accused US competitors of turning space into a warfighting domain and stated that while the US would prefer that space remain free of conflict, it would overcome any challenge to deter, counter, and defeat threats hostile to the national interests of the US and its allies. [113], [114]

• Trump Administration's National Space Policy: In 2020 Trump administration released its new National Space Policy and directions to increase support to space defense and add more funding to counter-space threats were given. It was stated that the U.S. shall develop technologies to maintain continuity of services, enhance the protection, cyber-security, and resilience of its assets and conduct operationally-focused exercises. [115], [116]

• Biden Administration's Space Policies: The Biden Administration released a US Space Priorities Framework in 2021 that states that access to and use of space is a vital national interest. The framework highlights the importance of space in collecting information for monitoring threats and supporting US military operations. Addressing space and counter-space threats is a priority for the US, and strategic competitors are accused of militarizing space and advancing counter-space capabilities. However, confrontation or conflict is not considered inevitable. The US aims to achieve stability in outer space through diplomatic engagement with strategic competitors, developing defensive means to protect US and allies' interests in space, and exploiting new commercial space capabilities and services. In April 2022, Vice President Kamala Harris announced that the US commits not to conduct destructive direct-ascent anti-satellite (ASAT) missile testing and seeks to establish this as a new international norm for responsible behavior in space. [117], [118]

• Restrictions in Space Technology Exports: Regarding space technology in general (rocket launchers, satellite components, space related hardware etc.) it is important to mention that two regulation policies regarding exchanges between U.S. and China have affected the relationships between the two states throughout the years. Firstly, the ITAR (International Traffic in Arms Regulation) policy poses control on exports regarding technologies that could be exploited for military use and, thus, could pose a danger to U.S.'s national security. Following the failed launches of the Apstar 2 and Intelsat 708 satellites by Long March vehicles in 1995 and 1996 accordingly, along with the exchange of information and know-how regarding space systems between the CNSA and American companies, satellites were reclassified as munitions and returned into ITAR regulations under strict policies regarding exports. Since 1996 no satellite technologies have been exported to China. The ITAR defense articles contain launch vehicles, rockets, spacecrafts, and associated equipment as protected items. The subjection of space technologies to ITAR is assumed to have costed the U.S. a large share of the global satellites' market. In 2011 the Wolf Amendment was passed hardening further space technology transfers between NASA and Chinese space corporations. According to Public Law 112–10, Sec. 1340: (a) None of the funds made available by this division may be used for the National Aeronautics and Space Administration or the Office of Science and Technology Policy to develop, design, plan, promulgate, implement, or execute a bilateral policy, program, order, or contract of any kind to participate, collaborate, or coordinate bilaterally in any way with China or any Chinese-owned company unless such activities are specifically authorized by a law enacted after the date of enactment of this division. [119]

• ISS vs Tiangong: Through the beginning of its operation the ISS has been visited by more than 200 astronauts and individuals from 20 countries. None of them however were of Chinese nationality. Due to the ITAR and Wolf Amendment restrictions and the general geopolitical rivalry between China and the U.S., China has been one of the few space fairing nations in the world that hasn't had access to the ISS. This situation led the Chinese state to construct and deploy its own space station, the Tiangong, which soon enough shall be fully operational. Along with the fact that the ISS will be decommissioned some time during the next two years, the Tiangong shall become the only space station capable of hosting a wide variety of experiments and space-based operations. China has called other nations to participate in the Tiangong station, with ESA's astronauts having already conducted common exercises with their Chinese counterparts. [120], [121]

• Lunar Gateway: Around 2017 talks between Russia and the U.S. began regarding the construction of an orbital space station around the moon. The project, called the Deep Space Gateway, was planned to serve as the first step for travels into the outer solar system. Emerging as part of the U.S.'s initiative to send a manned mission to Mars, the lunar-orbiting base would resemble to a spaceport for deep space missions. The project was initially presented as a cooperational plan between NASA and Roscosmos, which would combine their abilities and knowledge regarding space-station technologies, docking systems and interoperability of powerful space launchers [64], [122]. However, in 2020 Dmitry Rogozin, head of Roscosmos, referred to the Lunar Gateway program as a "U.S.-centric" scheme that prohibited his agency from participating in, despite the fact that other ISS partners (Canada, Europe, Japan) had stated their positive intents. Russia started moving away from the Gateway plans once it considered them to drift away from the ISS's policies. The U.S. supported that the gateway program would be based on the intergovernmental agreements that have been in practice to the ISS, but the Russian side seemed to be skeptical regarding the true purposes of the so called "Artemis Accords" (of which the Lunar Gateway would be a part) [123].

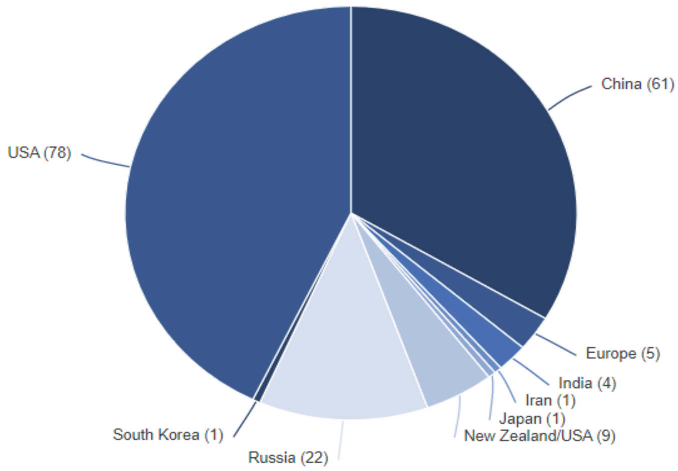
• Artemis accords - Privatization of outer space: The Artemis accords are multilateral agreements that form norms regarding the "peaceful" exploration of space bodies, such as the Moon and Mars, asteroids and comets of the solar system, and the exploitation of their resources. Russia has compared the agreements with the "U.S. invasions in the Middle East" and the willing members' alliance with the NATO organization. It has expressed deep concerns regarding the complete lack of legislations in space mining and has declared its non-participation. In addition, China has not even been asked to participate in the accords, resulting in an even more skeptical attitude towards the Artemis program. The Chinese consider these agreements to initiate a plan of colonizing celestial bodies, providing the "right" to claim sovereignty over their resources through economical "free zones" and through targeting any nation interfering with such activities as hostile to national interests. Both countries accuse the U.S. of maintaining a new Cold War status, whilst undermining the 1967 Outer Space Treaty and the United Nations. By bypassing the U.N., the United States have been signing bilateral agreements, legislating for space through the alliance of "like-minded" states and might, presumably, demand compliance to their own interests and guidelines. It was via the Trump administration that the director of the US National Space Council stated "It bears repeating: Outer space is not a 'global commons,' not the 'common heritage of mankind,' not 'res communis,' nor is it a public good". [124], [125], [126], [128]

An example of space resources mining could regard extraction of oxygen and hydrogen from the surface of the Moon. These elements could be used for sustaining habitable environments through the production of breathable air conditions and water, as well as for propellant manufacturing. In the Outer Space Treaty ones space operations must be implemented "in due regard" to other nations activities and there is no reference in "safety zones". Furthermore, the "preservation of space heritage" introduced could lead in the use of significant outer space achievements, such as the manned landing missions on the Moon or rover traverses, to claim ownership on specific landscapes of celestial bodies. There are fears that amidst the rapid privatization of space the Artemis Accords shall be used for legalizing "exclusive" areas for resource extraction. This might prove a valid point if we take into account the fact that the owners of some of the most successful, or rising, private space enterprises are amongst the wealthiest billionaires on Earth. All of the above reveal a violation of international agreements, where space is regarded as a global common, and an "unjust" act of unfair competition, if we consider the dominance that shall be imposed by technologically-ready space-faring companies, when at the same time most of the world's nations, let alone enterprises, don't acquire space capabilities. [127]

It is common in international law that particular actions implementing a "status quo" may lead in acceptance of specific behaviors as having the value of law. Since more than 20 countries have signed the accords there is a great chance they'll become widely approved by the international community, especially since the 1979 Moon Agreement had been signed by less [127]. This procedure has led China and Russia to a cooperative plan for their own lunar base on the South Hemisphere of the Moon, where an abundance of water seems to lay under the surface. The threat of space dominance rises and along with it rises the threat of space militarization and conflict.

9.2. Comparative Analysis on Space Launches

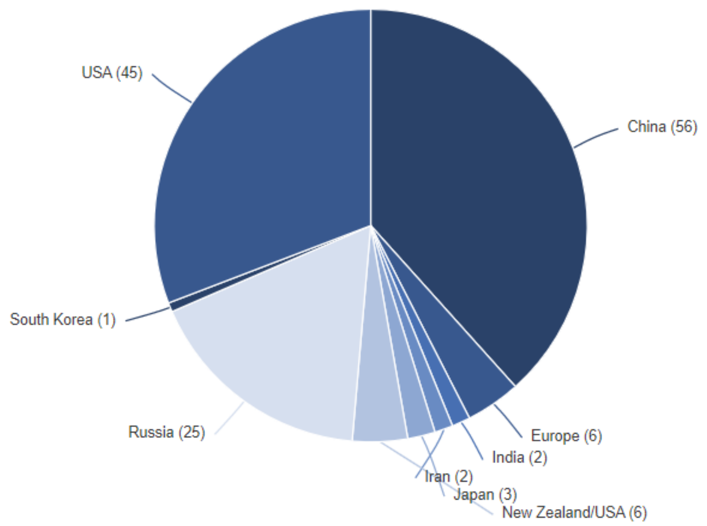
According to statistics retrieved from Gunter's Space Page, in the beginning of the last decade Russia was the main player in the space launch industry. From 2010 until 2016 it surpassed both the U.S. and China in the number of annual orbital launches. In 2016 China's launches tied to those of the U.S. and they both surpassed Russia. The U.S. took the lead only in 2017 to lose it for four consecutive years from China between 2018 and 2021. It was 2022 that would once again find the U.S. on the highest rank of orbital launches, after the astonishing achievement of Space-X doubling its Falcon-9 launches from 31 to 61 in a year.



Graph 10: Orbital launches by country in 2022 [129]

Table 2: Russian, Chinese and U.S.'s launch-percentages in 2022 [129]

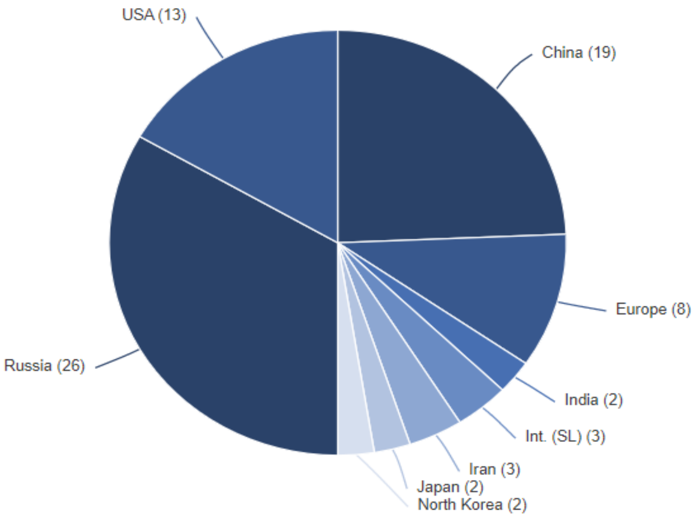
Total Launches in 2022	**182**
Country	*Percentage*
U.S.	43%
China	33,5%
Russia	12%



Graph 11: Orbital launches by country in 2021 [130]

Table 3 : Russian, Chinese and U.S.'s launch-percentages in 2021 [130]

Total Launches in 2021	**146**
Country	*Percentage*
U.S.	31%
China	38%
Russia	17%



Graph 12: Orbital launches by country in 2012 [132]

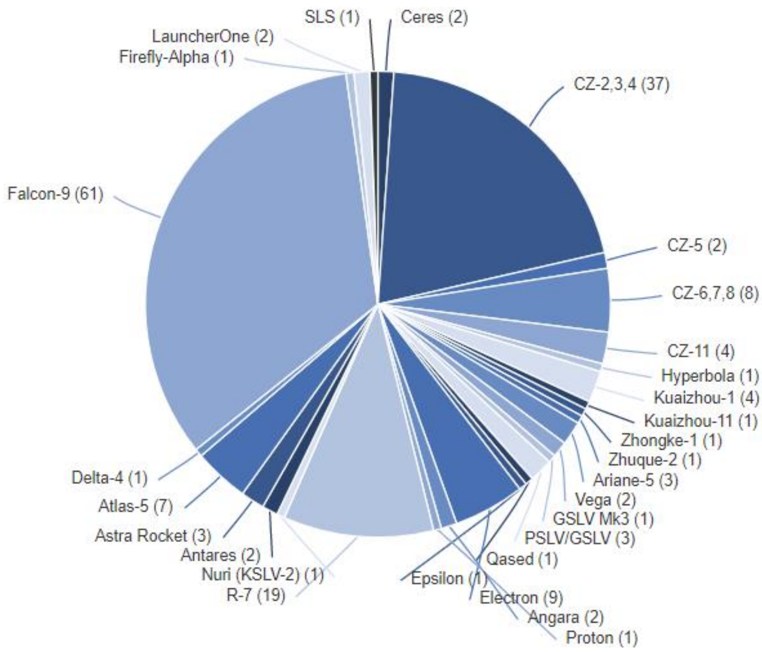
Table 4 : Russian, Chinese and U.S.'s launch-percentages in 2012 [132]

Total Launches in 2012	**78**
Country	*Percentage*
U.S.	16,6%
China	24,3%
Russia	33,3%

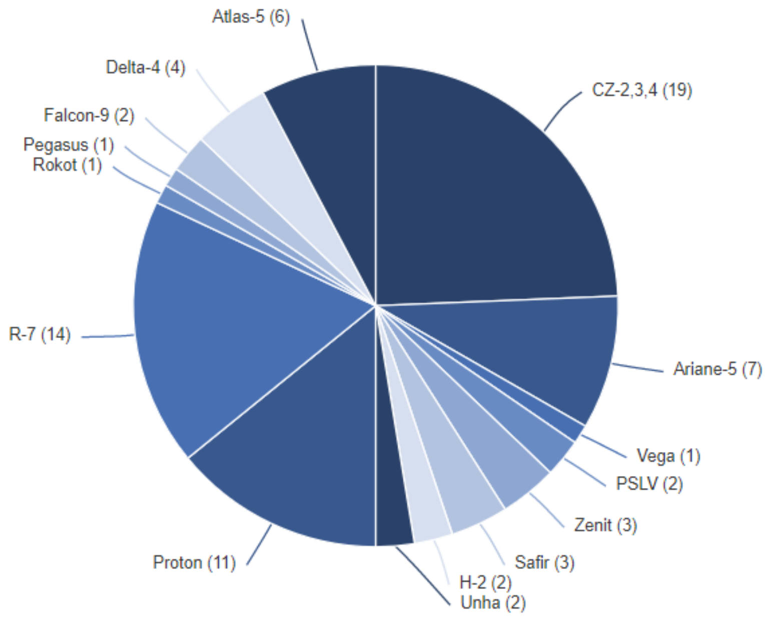
From the figures and tables presented above some crucial results about the evolution of the global space-launch industry can be extracted. During the last ten years orbital launches have increased by a percentage of approximately 43%. Russia conducted an average of 25 launches per year, whilst the U.S. jumped from 13 launches in 2012 to 78 in 2022, and China from 19 to 61 during the same period. These numbers indicate that the U.S. have increased their space launches by a factor of 6 through the last decade (which is mainly a result of the vast growth of its commercial space launching sector and Space-X's accomplishments in it), while China by a factor of 3.

Ten years ago Russia owned one third of the global launch market while today it owns slightly above 10% of it. However we need to clarify that this drop in percentage is not caused by some significant reduction in absolute numbers of Russian space launches but by the immense increase of launching capabilities that the other two global superpowers have achieved. The world's economical bipolarization can be summed up in the space launches industry since China and the U.S. currently own more than three quarters of the global market.

In the following two figures we can observe the rapid growth that has been achieved through the last decade in the different kinds of space launchers globally, as well as the constantly evolving share that private enterprises own.



Graph 13: Orbital launches by launch vehicle family in 2022 [129]

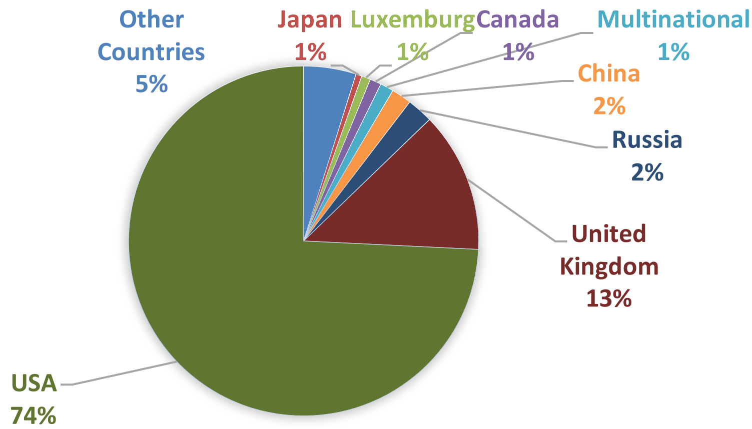


Graph 14: Orbital launches by launch vehicle family in 2012 [132]

9.3. Comparative Analysis on Global Satellites' Distribution

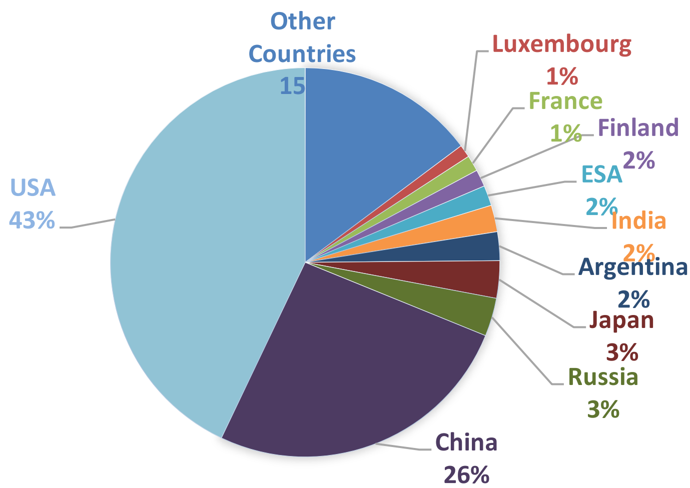
At this point, we shall present some charts and maps we produced regarding the global distribution of satellites. The data we used were received by the free satellites' database published by the Union of Concerned Scientists in January 1st 2022, and which was last updated in 30th of April 2022 [136]. We have taken in account solely the five main types of satellites (communication, navigation, earth observation, scientific and technology development) and not all the available types given in the database (such as amateur radio, educational, etc.). Also, regarding the type of user of each satellite we present some valuable data focusing only in those operated by each country's military, without any specific reference in other users (civil, government, universities, commercial, etc.). The tables we created using the primal datasheet, in order to construct the following charts and maps, are included in the Appendix.

Communication Satellites



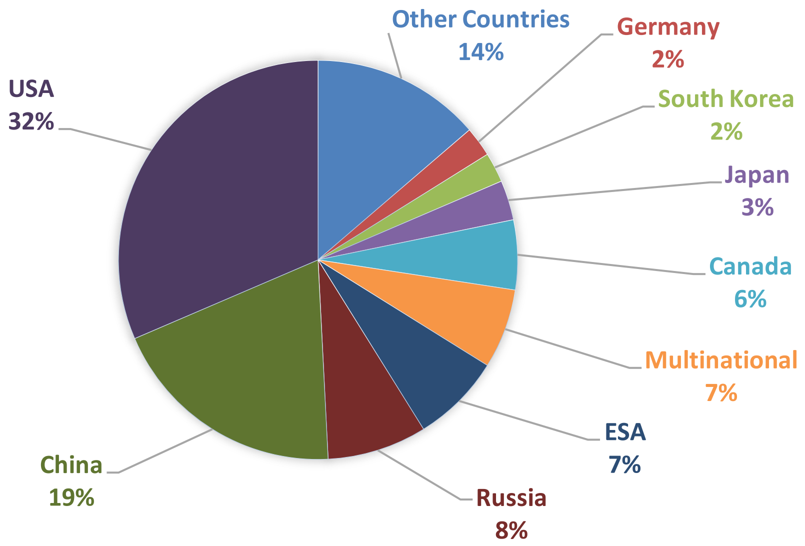
Graph 15: Global percentage distribution of communication satellites [136]

Earth Observation Satellites



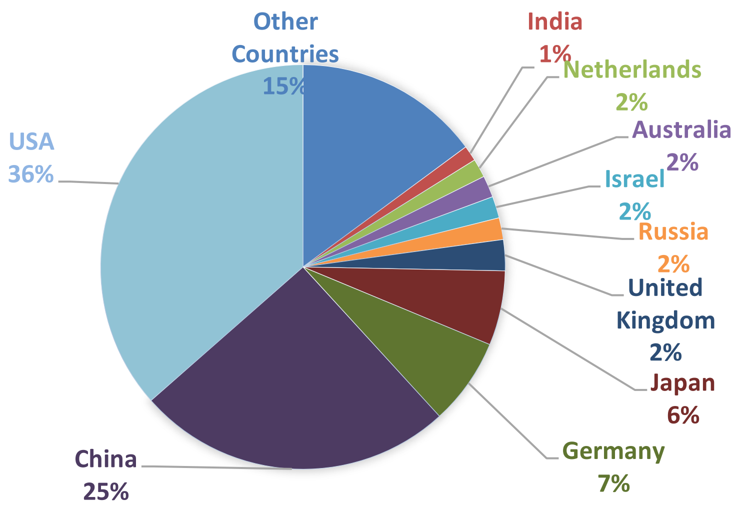
Graph 16: Global percentage distribution of earth observation satellites [136]

Space & Earth Science Satellites



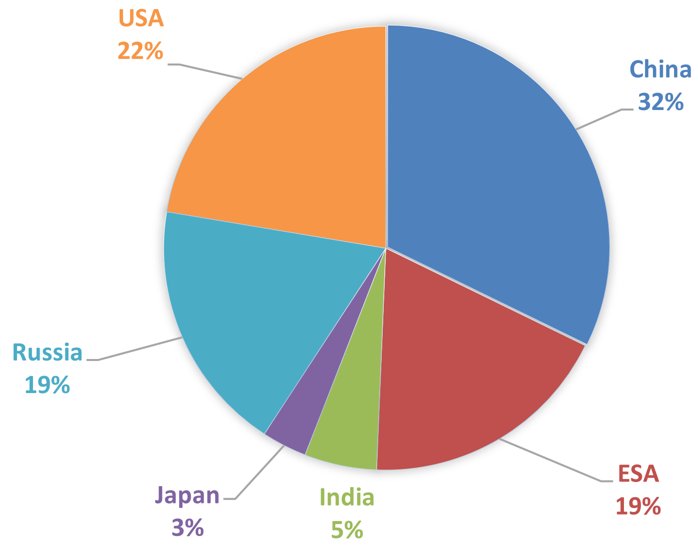
Graph 17: Global percentage distribution of space & earth science satellites [136]

Technology Development & Demonstration Satellites



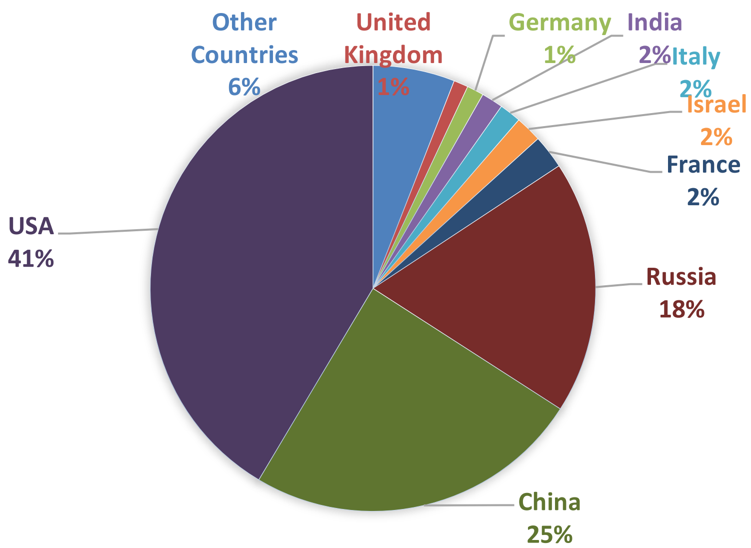
Graph 18: Global percentage distribution of technology demonstration & development satellites [136]

Navigation Satellites



Graph 19: Global percentage distribution of navigation satellites [136]

Military Satellites



Graph 20: percentage distribution of satellites used by the military [136]

We have also created a map which presents the global distribution of military satellites.

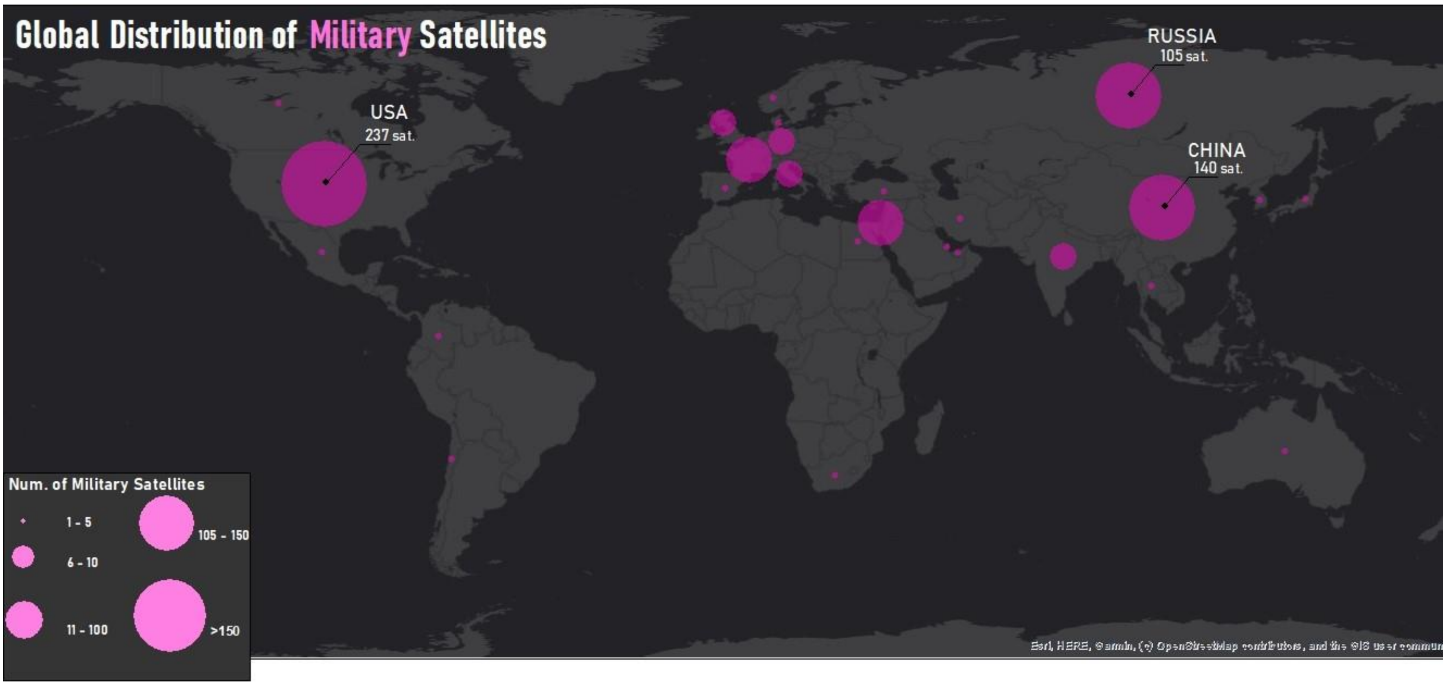
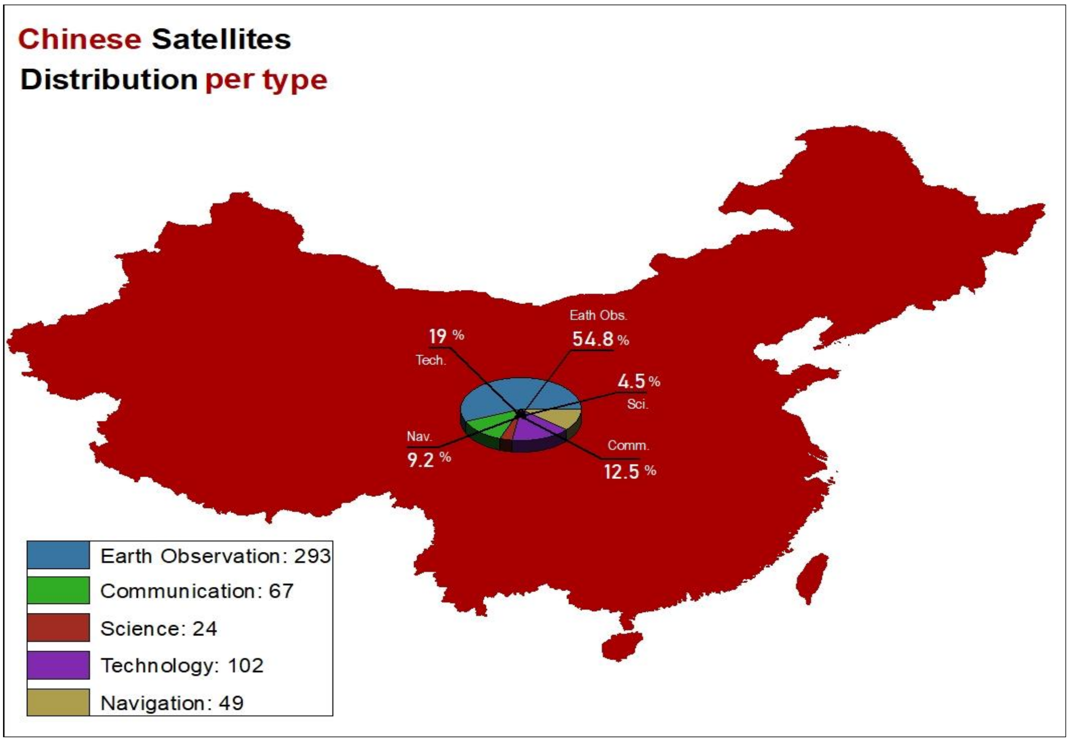


Fig. 26: Global Distribution of Military Satellites [136]

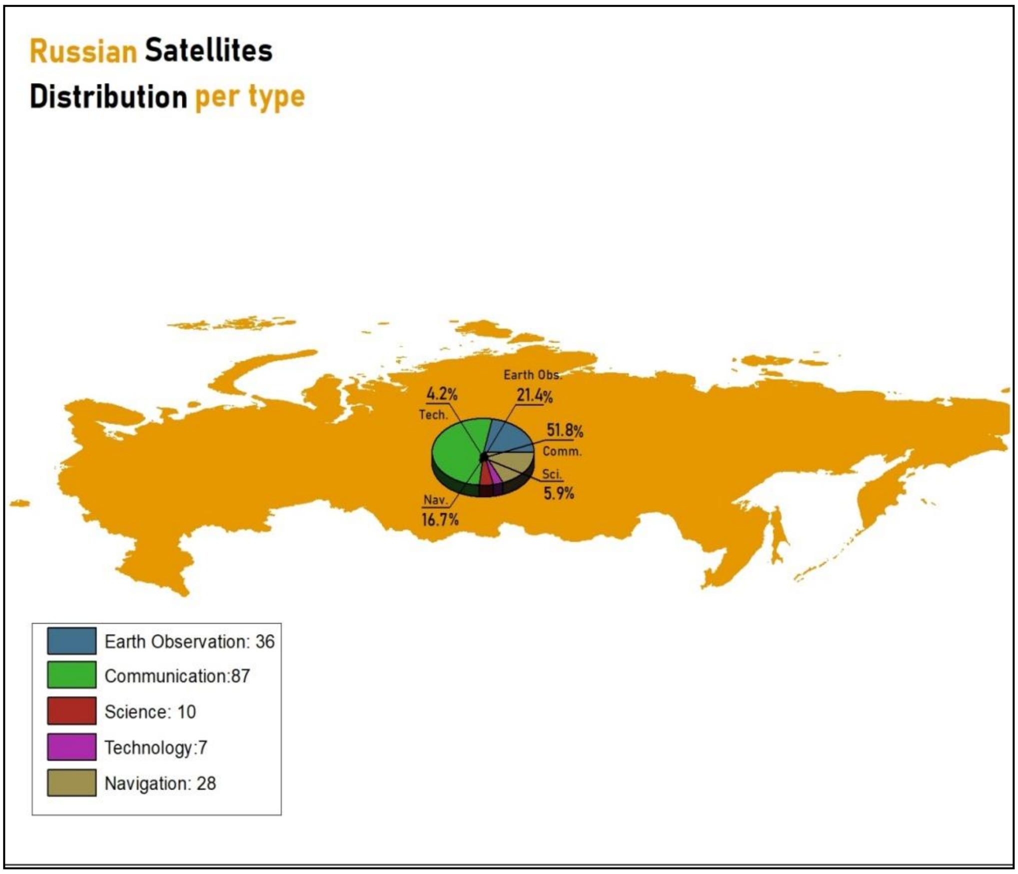
As we can observe from all of the above charts the U.S. dominates the space environment. In all types of satellites, except navigational, the U.S. poses a percentage of more than 30-40%, with an immense share of 75% regarding the communicational ones. It is private commercial satellites (especially Space-X's Starlink constellation) which create this huge gap from other stakeholders in this specific market.

In the case of satellites that can be used for military purposes the distribution percentages reveal the global space-military status. The U.S.'s share is 41%, while China's and Russia's combined 43% (25% and 18% respectively) merely exceeds that percentage. It is interesting to note how despite the fact that Russia owns a comparatively small percentage of the various satellite types, on the military sector it poses a rather respected share. Military satellites' data are not referred to the ones solely used by armed forces but also to dual use satellites (such as navigational ones).

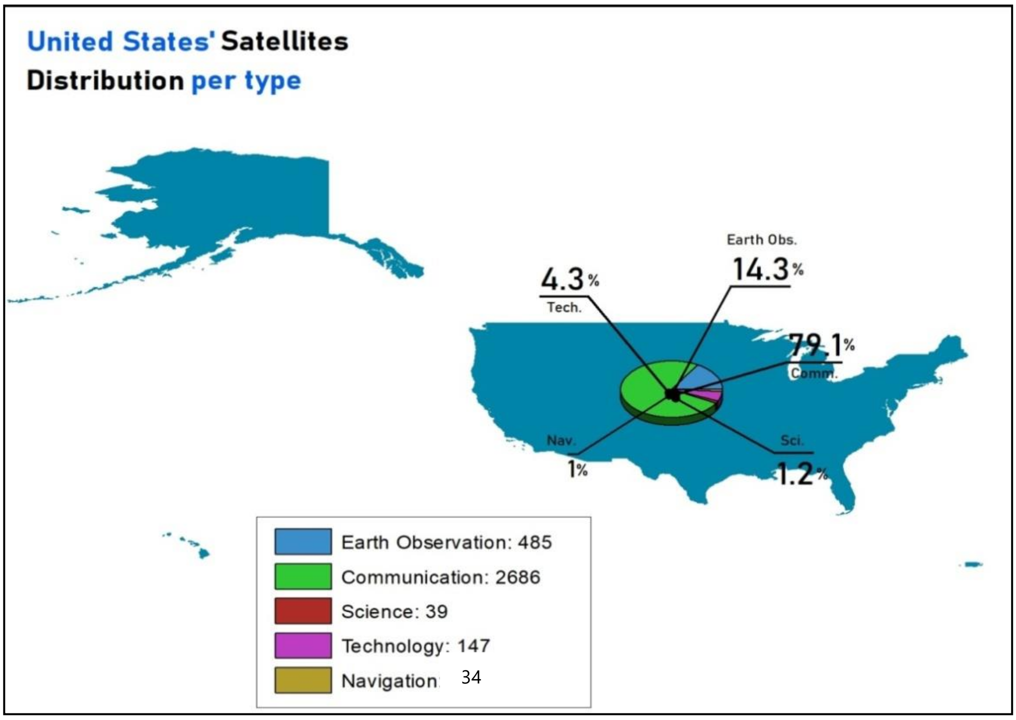
The following maps were created using the ArcMap 10.3.1 software and present the distribution of satellites per type for China, Russia and the United States.



Graph 21 : Map of Chinese satellite distribution per type [136]



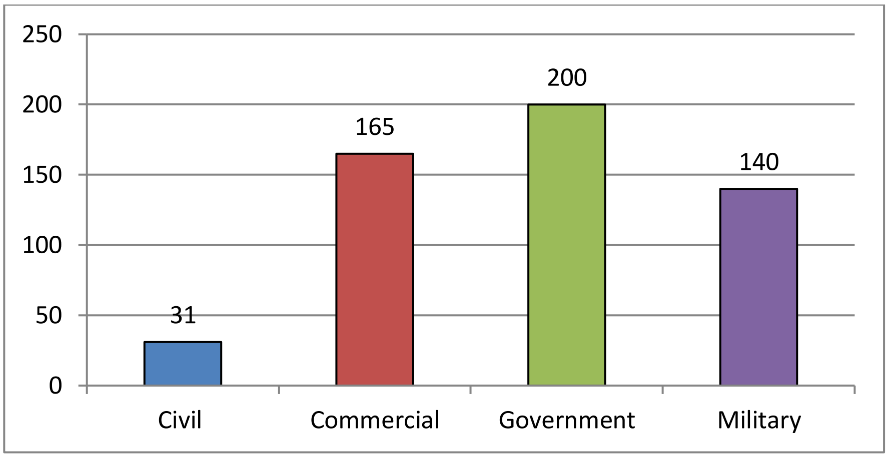
Graph 22 : Map of Russian satellite distribution per type [136]



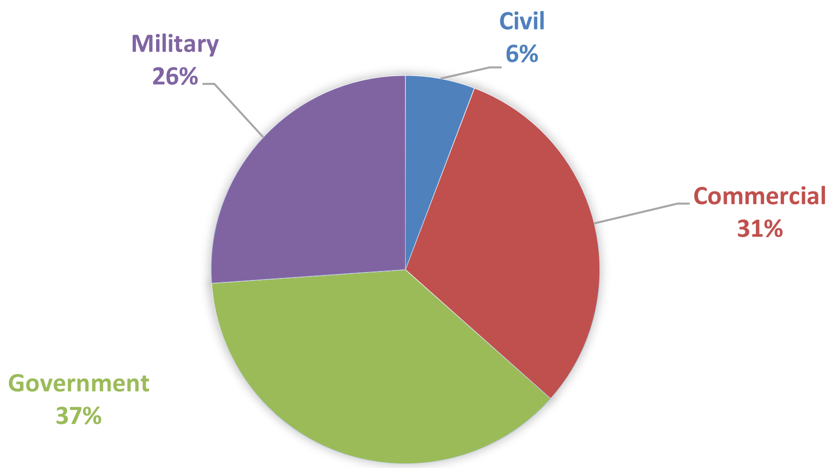
Graph 23 : Map of U.S.'s satellite distribution per type [136]

These maps help us understand the main investments of each of these countries' space budgets and the current trends on their space-industries' production. First of all, the U.S.'s undoubted dominance in numbers is clear given the absolute values presented. In Science and Technology Demonstration, China is stepping up its pace towards the U.S.'s orbital assets, but in Earth Observation and Communications it remains significantly behind. For Russia and the U.S., Communicational satellites are the highest in numbers, whilst China prioritizes Earth Observation ones. In fact, it is important to note that for China Communicational satellites come third after those of Technology Demonstration.

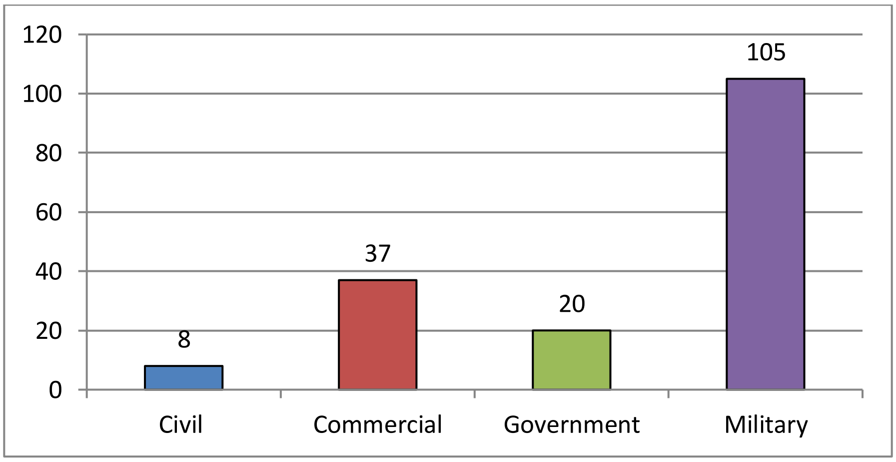
At this point we, also, provide some charts regarding the distribution of national satellites per user for the three main space-powers. In the military type we have included satellites which may not have been constructed solely for this usage but are undoubtedly serving ones military during a conflict, such as navigational.



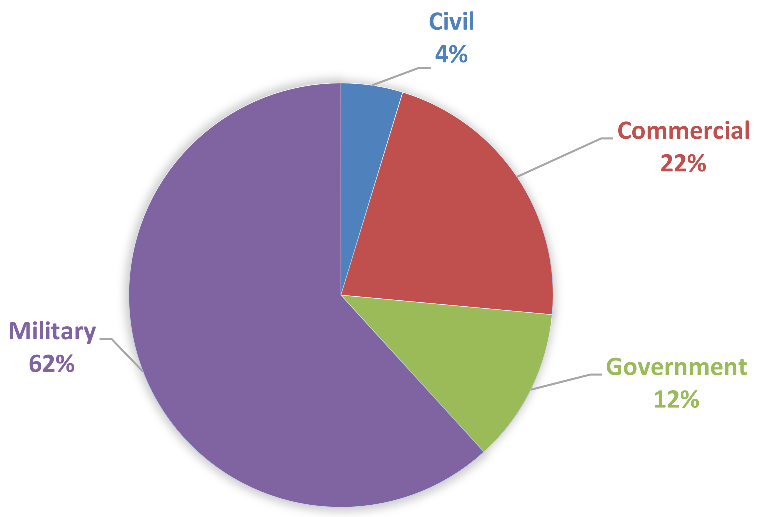
Graph 24 : Distribution of Chinese satellites per user [136]



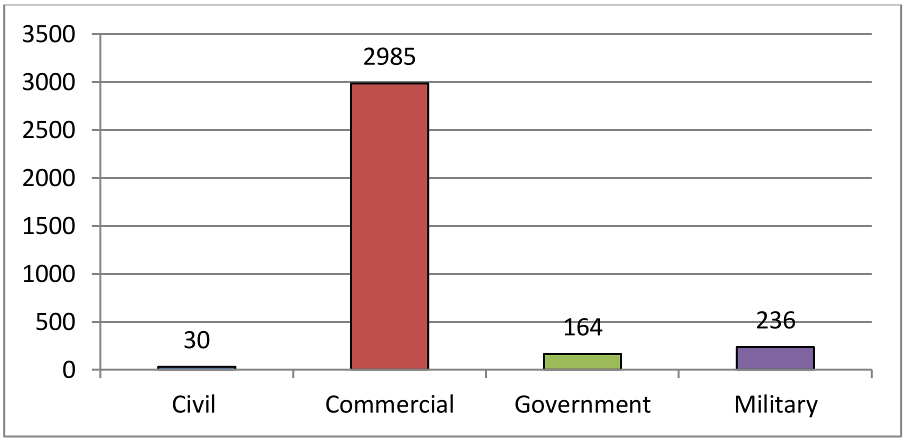
Graph 25 : Percentage distribution of Chinese satellites per user [136]



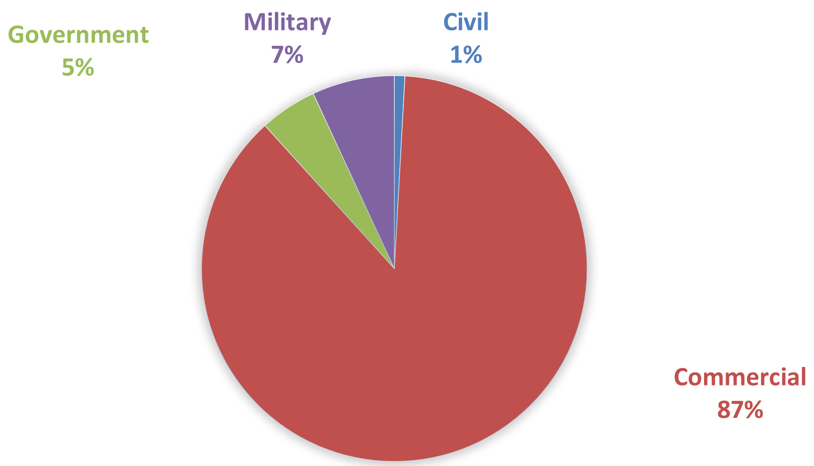
Graph 26 : Distribution of Russian satellites per user [136]



Graph 27 : Percentage distribution of Russian satellites per user [136]



Graph 28 : Distribution of U.S.'s satellites per user [136]



Graph 29 : Percentage distribution of U.S.'s satellites per user [136]

From the above charts we can observe that China owns the most equally distributed number of satellites per type. Its percentages of governmental, commercial and military satellites account for 37%, 31% and 26% respectively, out of the overall number. These numbers confirm how the Chinese space sector has been based on its state-agencies and military prospects (a reasonable point considering China's political system and the role of both the Communist Party and the PLA in it), but also reveal China's current turn in developing its commercial sector and into the New Space age.

For Russia, military satellites account for 62% of the total percentage, with commercial and governmental ones following with 22% and 12% respectively. These numbers reveal not only the high interconnection between Russia's military and space operations but also the decline of its governmental space program and the underdevelopment of its commercial space sector.

9.4. Bilateral Space Collaboration

Cooperation between China and Russia has its roots back in the 1950's when the USSR helped the early revolutionary Chinese state to construct the backbone of its space program. Providing two R-1 missiles, along with personnel and knowledge transfer, China developed its space technologies on the basis of the Soviet achievements and the return to Chinese mainland of many scientists that were working abroad, thriving in their respected fields. In the '60s however the Sino-Soviet split resulted in tensions between the two countries and led to a pause in space technology exports to China from the USSR's side. Relationships were not restored until the fall of the Soviet Union.

In 1992 a 10-year intergovernmental agreement on space cooperation was signed giving access to Chinese scientists in many of the most important space technologies of Russia, such as "the Soyuz rockets, ground infrastructures, tracking facilities and environmental control systems for manned spacecrafts". In 1995 another agreement provided crucial help to the development of China's manned space program since the Russians provided a "Soyuz capsule (without integrated electronic hardware), a Kurs rendezvous system, a docking module, a Sokol spacesuit and entire life support systems". The Chinese also bought RD-120 rocket engines, an exchange important for both nations since China needed this technology transfer to enhance its rocket capabilities and Russia was eager to ensure economical revenues from exports such as this and to safeguard trade corridors after the dissolution of the Soviet Union. Astronauts and observers were also transferred from China to Russia to receive training. [64], [133]

In 2000 the Space Cooperation Sub-Committee between the two nations was funded and has played, since then, a crucial role in coordinating exchanges between the respective industries. Collaboration has been achieved in many fields including Earth Observation, Space Science, Space Debris, Deep Space Exploration (especially lunar programs), Manned Flights and Space Stations. In the field of satellite navigation systems, at first, Russia was reluctant in providing technologies that would help China build its own constellation of BeiDou satellites, considering the concealment of according technologies as important both for military purposes and for maintaining an advantage towards the fast growing Chinese space sector. However, after China started developing space-based navigational capabilities on its own and the U.S. denied the expansion of the Glonass system on its territory, Russia changed its posture estimating that there were more to gain from cooperation. Generally, during the last decade Russia invested greatly in the industrial production of China, especially after the posture of the Western sanctions, and the space cooperation has expanded also in the fields of electronic parts and hardware components. [64]

Geopolitical implications with the West have had a strong impact on the evolution of Sino-Russian cooperation. With the Wolf amendment banning the collaboration between NASA and China and the 2014 Crimea annexation sanctions prohibiting NASA and Russia from cooperating in many fields, partnership between China and Russia came almost as a forced alternative. Besides space, Russia has become the core provider of energy supplies to the Chinese state, regarding oil and gas extraction, and has been exporting a wide range of strategic military technologies. China has been supportive towards the strategy of a multi-polar world order that would halt the Euro-Atlantic superiority and expansion. Thus, their bilateral ties strengthened through the last decade, forming a stable strategic alliance in both economic, political and security affairs. [64]

The 2015 Defense Authorization Act which banned the purchase of Russian engines for the U.S.'s National Security Space Launch program, former Evolved Expandable Launch Vehicles, led Russia in a shift in export policies regarding the RD-180 to China. Since then Russia provided the Chinese industry solely with older less high-tech models, such as the RD-120, but once the embargo from the west was imposed, announcements were made that new space technologies' exports would advance including this type of engines and micro-electronic components from China's side. [64]

A crucial share of the evolving space collaboration focuses on outer space exploration, manned spaceflight and launch vehicles. First of all, regarding lunar exploration China and Russia have initiated the ILRS program. According to official reports "The International Lunar Research Station (ILRS) is a set of complex research facilities to be constructed with the possible involvement of international partners on the surface and/or in the orbit of the Moon. It is designed for multi-purpose scientific research activities, including exploration and use of the Moon, moon-based observation, fundamental research experiments and technology verification, with the capability of long-term unmanned operation with the prospect of subsequent human presence" [134].

The Milestones of the ILRS include the China and Russia MoU regarding cooperation for the construction of the International Lunar Research Stations singed in March 9 2021, the joint statement of the CNSA and Roscosmos regarding "Cooperation for the Construction of the International Lunar Research Stations" in April 23 2021 at the side event of STSC and the jointly released "Roadmap of ILRS (V1.0)" and the "Guide for Partnership of ILRS (V1.0)" at the GLEX 2021 in June 16.

The scientific objective of this joint operation focuses on:

- Lunar topography geomorphology and geological structure
- Lunar physics and internal structure
- Lunar chemistry (materials and geochronology)
- Cislunar space environment
- Lunar based astronomical observation
- Lunar based Earth observation

• Lunar based biological and medical experiments

• Lunar resources in situ utilization

Regarding outer space, talks on cooperation between the space agencies of the two countries have included plans for joint efforts on China's Mars sample return mission and Russia's Venera-D mission for returning to Venus. On the rocket launchers' sector, China's material resources and Russia's expertise shall help in common approaches regarding the construction of heavy-lift launch vehicles (such as the Russian Yenisei and the Chinese Long March 9). Development of unified standards for manufacturing space technologies, docking units and electrical connectors that shall be especially used in lunar missions and space stations are under configuration. Joint development and use of spacecrafts, common data centers for deep space exploration and exchanges of Earth observation and space debris detection data are also some of the future plans.

According to the article "Analysis of Space Cooperation between China and Russia" published by He Qisong and Ye Nishan, up to now many Universities, Enterprises and Research Institutions have collaborated and their main progress includes [159]:

- A laboratory focusing on space cable systems' studies.
- A laboratory focusing on manufacturing processes for Russian-Chinese engines.
- A project for research on the use of nano-composites in space.
- Development of a highly-accurate selenocentric navigation network.
- An institute focusing on space materials' research.

During the first two decades of the 21st century the main collaborative agreements that the two states have signed regarding space can be summed up as follows [159]:

- "Draft Treaty on the Prevention of the Placement of Weapons in Outer Space, the Threat or Use of Force against Outer Space Objects" (PPWT). February 2008.
- "Outline of China-Russia Space Cooperation for 2010-2012". October 2009.
- "Agreement on Mutual Notification of Ballistic Missile and Space Launch Vehicle Launches". October 2009.
- Agreement on facilitating the exchange of space information on an academic level. December 2009.
- "Russia-China Project Committee on Important Strategic Cooperation in Satellite Navigation". January 2014.
- Agreement on the protection of intellectual property rights in the field of space technology. June 2016.
- "Outline of China-Russia Space Cooperation for 2018-2022". September 2017.
- Agreement to establish a data center for lunar and deep space exploration to share relevant information, including on the Moon and Mars. 2019.
- Agreement on jointly developing a roadmap for the construction of an international lunar research station. March 2021.

Regarding the political and military aspects of the two nations' space cooperation Qisong and Nishan state that space diplomacy between the two nations has been crucial in order to maintain national security and development in both space and the international strategic landscape. Geopolitics have shaped space cooperation and according to the authors' opinion: "The space development dynamics of China and

Russia, as well as the U.S. strategy of space hegemony (including space weaponization policies and practices) are the key variables in space technology cooperation between the two sides. The expansion and deepening of China-Russia space cooperation dovetails the development of political relations between the two countries in response to changes in space geopolitics, and also has an impact on the shaping of space geopolitics". [159]

As we have observed their relationship has been characterized not only by trade of components, but also by a constantly evolving cooperation in the fields of space science and technology, launch vehicle engines and global navigation systems, manned and interplanetary exploration, while it has also led to its expansion into the space security sector recently. This constant upgrade in their bilateral space coordination and joint-policy planning has, also, contributed in safeguarding a balanced (according to their interests) space-landscape and its strategic stability. [159]

Another important point made by Qisong and Nishan concerns the fact that space cooperation between the two countries will strengthen the "space production chains of both sides". Both "economic structural transformation" and "industrial structure upgrading" can be pursued from the scientific and technological developments that joint space research will provide, especially since this procedure comes as a necessity towards the West's "scientific and technological blockade". Thus, as the authors underline: China and Russia can mutually enhance their "comparative advantages, expand and extend production chains, form a new division of labor system, drive the development of technology overall, and enhance their ability to resist Western sanctions". [159]

Regarding military space operations, Qisong and Nishan state that the cooperation between China and Russia has had western officials worried since "space systems are closely related to strategic nuclear deterrence capability, and provide the 'eyes and ears' of nuclear forces, enabling them to strike with precision". The development of joint early-warning systems and their know-how and implementation of anti-missile and anti-satellite technologies combined seem to pose a significant amount of pressure on the U.S.'s satellite fleet. [159]

9.5. 2022 Joint Statement of the Russian Federation and the People's Republic of China

On February 4, 2022 President Vladimir Putin visited China after invitation from President Xi Jinping. The talks that took place were followed by a joint statement between the Russian Federation and the People's Republic of China entitled "Joint Statement of the Russian Federation and the People's Republic of China on the International Relations entering a New Era and the Global Sustainable Development" [135]. The statement regards many fields of political, economical and societal importance and represents the basis of common approaches and coordination between the two nations in bilateral, regional and international matters. From the understanding of global phenomena, such as multi-polarity, economic globalization, international governance, cultural diversity, information society, interdependence, redistribution of power, growing demands on peaceful development, to the opposition towards unilateral approaches that tend to interfere with internal affairs and force entire nations to align with specific interests and ideological perspectives in order to maintain the existing world order, the two states share common beliefs.

Firstly, the joint statement refers in democracy issues analyzing the need to respect specific cultural and ethnical characteristics of each civilization, as well as, the universal nature of human rights and the need to protect them in an internationally coordinated way. It strongly opposes the strategy of enforcing one's own "democratic standards" in order to achieve ideological hegemony and broaden political influence while undermining worldwide peace and stability, obviously referring to the U.S. and its allied nations' international policies and military acts. Subsequently, fields of cooperation are analyzed prioritizing the Eurasian Economic Union and the Belt and Road Initiative. In all plans of coordination the United Nations are viewed as a crucial mechanism of achievement. Coordination in macro-policy and strengthening ties with developing countries, exchanges in scientific and technological development, production of sustainable transport systems, countering climate change, protecting biological diversity and green transformation, fight against the COVID-19 pandemic and opposing the politicization of this issue, are some of the basic fields of cooperation for the two nations. Also, a common attitude in fields such as governance in the sector of Artificial Intelligence, international information security, development of an open, secure, sustainable and accessible ICT environment is stated.

Furthermore, the two sides underline their concerns on issues of security challenges and "believe that the fates of all nations are interconnected. No State can or should ensure its own security separately from the security of the rest of the world and at the expense of the security of other States. The international community should actively engage in global governance to ensure universal, comprehensive, indivisible and lasting security". Russia supports the Chinese view regarding Taiwan as a national territory and opposes its independence. Both countries stand against color revolutions and regard them as influenced by U.S.'s plans to undermine political regimes that do not align to its interests. They stand in favor of a single global anti-terrorism front with the U.N. as the core mechanism of action. They refer to the NATO coalition and the North Atlantic Alliance as responsible for maintaining cold-war approaches and for advancing actions which "seek to obtain, directly or indirectly, unilateral military advantages to the detriment of the security of others, including by employing unfair competition practices, intensify geopolitical rivalry, fuel antagonism and confrontation, and seriously undermine the international security order and global strategic stability". They express concerns regarding the issue of nuclear warfare and the threats imposed by the AUKUS partnership between U.S., U.K. and Australia, while reaffirming the importance of the Treaty on the Non-Proliferation of Nuclear Weapons. They accuse the U.S. for withdrawing from the Treaty on the Elimination of Intermediate-Range and Shorter-Range Missiles and causing deterrence in world peace and stability prospects by insisting in R&D and development of those missiles, efforts of deployment in Asia-Pacific and European regions and transfer to allies.

Regarding space, the two sides "stress the importance of the peaceful uses of outer space, strongly support the central role of the UN Committee on the Peaceful Uses of Outer Space in promoting international cooperation, maintaining and developing international space law and regulation in the field of space activities". Cooperation in space activities and the use of space resources is stated and the opposition towards the weaponization of space which could lead in armed conflict is highlighted. The two countries will jointly "counteract activities aimed at achieving military superiority in space and using it for combat operations". Legal measures for binding the international community on a common approach towards the peaceful use of outer space are promoted on the basis of the "Russian-Chinese draft treaty on the prevention of placement of weapons in outer space". Russia and China consider that the commitment of "not being the first to place weapons in space" can enhance the development of international strategic governing rules for space.

Finally, the two states emphasize on the importance of multilateral and regional institutions such as the United Nations (and its Security Council in particular), the G20 format, the BRICS alliance, the Shangai Cooperation Organization, the Asia Pacific Economic Cooperation and the ASEAN Regional Forum. Russia notes the significance of China's vision for a "community of common destiny for mankind" and China supports Russia's strategy on establishing a just multi-polar system of international relations. As referred "Friendship between the two States has no limits, there are no "forbidden" areas of cooperation, strengthening of bilateral strategic cooperation is neither aimed against third countries nor affected by the changing international environment and circumstantial changes in third countries".

From all of the above we can understand that a year ago, and before Russia's invasion in Ukraine, the two states were enhancing their close coordination on all the critical aspects of today's life. All of the aforementioned fields of cooperation such as science, technology and innovation, national security and international collaboration, human rights and democracy perspectives, regional and global governance, disarmament and peace-treaties development, inclusiveness of underdeveloped nations, economic globalization and trade, confronting the climate crisis and establishing sustainable environments, solving humanitarian crises such as the pandemic, are commonly viewed as opportunities of broader international cooperation. We note that the main political backbone of the joint statement appears to be the opposition towards interventionism by the U.S. and allied nations on the basis of its ideological, geopolitical and economical interests. The two states not only defend their unilateral and mutual interests and rights, but also seem to converge on the strategic views regarding the current geopolitical world order. A multi-polar world and a shift in the global power balance appear to be a common goal and shaking Euro-Atlantic dominance can be achieved through various manners. Russia, in fact, has chosen perhaps the most aggressive path through its military involvement in Ukraine.

10. RUSSO-UKRAINIAN WAR

10.1. Space and the Russo-Ukrainian war

Space technologies have played an important role in both military and civilian operations during the Russo-Ukrainian war. Some of the main ways in which space technologies have been used during the conflict are:

- Satellite imagery: Both sides have used satellite imagery to monitor troop movements and to gather intelligence on enemy positions. Satellite imagery has also been used to assess damage from airstrikes and to monitor the movement of refugees.
- Communications: Satellites have played a critical role in providing communications infrastructure for military and civilian operations. Satellites have been used to establish secure communications links for military units and to provide internet and telephone services for civilians in areas where terrestrial infrastructure has been destroyed.
- Navigation and positioning: Satellites have also been used for navigation and positioning, which has been critical for both military and civilian operations. GPS and other satellite-based positioning systems have been used to guide military vehicles and to coordinate relief efforts.
- Weather monitoring: Satellites have been used to monitor weather conditions, which has been important for planning military operations and for assessing the impact of natural disasters on civilian populations.

The Russo-Ukrainian war has had several impacts on the space industry. Here are some of the ways in which the conflict has affected the space industry:

- Disruptions to supply chains: The conflict has disrupted the supply chains of critical components and materials needed for the space industry. This has caused delays and increased costs for space projects.
- Loss of cooperation: The conflict has strained the relationship between Russia and many western nations and has hindered bilateral cooperation in the space industry. This has limited opportunities for joint projects and reduced the sharing of knowledge and resources.
- Sanctions and export controls: The conflict has resulted in the imposition of sanctions and export controls by Western countries against Russia. These restrictions have affected Russia's ability to import and export space-related technologies and materials, which has slowed down its space program.

Overall, the Russo-Ukrainian war has had a negative impact on the space industry. All of the above are addressed with details in the following paragraphs.

10.2. Pre-Invasion Effects of the Russo-Ukrainian Conflict on the Space Sector

We have mentioned on several parts of our research how the sanctions imposed on Russia by the West following the 2014’s annexation of Crimea have affected the space sector. However, it is important to note once again some of the core implications that have emerged through this process in the last decade and have formulated today's worldwide space industry.

It was Russia's threats that they would forward suspension of U.S. astronauts from launching via the Soyuz capsule, along with exports of the RD-180 rocket engines, that seemed to alter U.S. space policy. Since the U.S. had, at the time being, no other way to send manned missions to the ISS this dependence from Russia's space launching systems forced the Congress to fund its own launching capabilities through the Commercial Crew Program. This action led in the fast development of Space-X's Crew Dragon capsule which achieved the first manned spaceflight launch from U.S. soil in 2020, almost a decade after the discontinuation of the Space Shuttle program. Other similar vehicles have been under development since then, such as Boeing's Starliner CST-100, revealing the milestones the commercial sector has achieved for ensuring U.S.'s fully autonomous manned-spaceflight activities. [137]

Regarding the RD-180 rocket engines, the U.S. followed a similar path enhancing the United Launch Alliance in the development of alternative propulsion means, while Space-X also demanded a piece of the market, supporting actions for enhancement of commercial competition. Despite decrease from imports of RD-180 engines, both the existing stack and the experience gained by its multiple years' usage in the Atlas launchers have provided the ULA not only with a seemingly sufficient in-house backup for future missions but also much expertise for domestic rocket-systems' production, such as the Vulcan launch vehicle. [137]

10.3. Use of space technologies

Before the war began Ukraine did not own any national military space equipment but, as it was proven during the past year, sometimes what matters most is having access to the output products of a satellite rather than the satellite itself. Ukraine's space enhanced military capabilities were mostly based on Euro-Atlantic aid. Many western foreign satellites and radar ground stations, both governmental and commercial, have been used to assist the Ukrainian side throughout the conflict. Space ISR (Intelligence Surveillance Reconnaissance) technologies were used even before the beginning of the Ukrainian invasion to track Russian armed forces' deployment on the Ukrainian borders. The initial build-up of Russian forces was identified and it was made clear that Russian troops were not withdrawing despite official announcements. Also, the construction of a bridge for machinery and military transportation on the Belarusian borders was detected. The movement of troops, artillery and warships in the Black Sea has been under satellite surveillance ever since. Early warning radars, like the one owned by the British RAF Fylingdales, have been tracking the use of ballistic missiles during the conflict. Ukraine has enhanced its rocket capabilities by US-supplied precision weapons. Himars rockets and Excalibur artillery shells have upgraded both the precision and the range of their attacks. These rockets are guided by GPS satellites. [143]

Privately-owned space assets have been largely involved in the conflict in many different ways. Many commercial remote sensing industries, such as ICEYE, Planet, HawkEye 360, Maxar and BlackSky, have contributed to the support of Ukraine through their advanced imaging systems, which in cases surpass the capabilities of respective military spy satellites. Especially for the ones acquiring radio imaging payloads, an important advantage is they can “pierce” through clouds; a capability that in the case of Ukraine’s weather conditions can prove vital for tracking military operations. One example is the SAR (Synthetic Aperture Radar) satellite of the Finnish ICEYE company, which has been offered under contract to the Ukrainian government and uses the most innovative worldwide radio imaging payload technologies, providing high-resolution images during daylight, nighttime and through cloud covers. [142], [143]

Even if their sensors appear to be of lowest resolution or accuracy, commercial satellites acquire another benefit. The data retrieved from their payloads can be shared in public without being subjected to strict security restrictions and bureaucratic processes. Thus, remote sensing images from commercial companies have revealed troops’ build-up, battle damages and evidence of warfare actions in such small timeframes that they actually provide a constant feed of military expansion and operation. Most of these data have been publicly released, contributing in the shape of global opinion. Some companies have even provided satellite images directly to the Ukrainian military helping on its defense mechanisms. [142]

A specific mention must be made regarding the involvement of Elon Musk on the Russo-Ukrainian conflict. Space-X’s CEO has played a significant role in the war by providing Ukraine with tens of thousands of uplink terminals for connection with the Starlink satellite constellation, thus ensuring the country’s internet connection against targeting and destruction of critical communication ground facilities. Elon Musk moved forward with this rather “offensive” action of involvement after a tweeted request from Ukraine’s president Volodymyr Zelenski on the eve of the war. The Starlink constellation consists of private corporation satellites beaming communication-enabling internet services. According to Musk there have been several attempts of hacking and jamming the Starlink satellites by Russia. He stated that, indeed, some terminals near operations were affected for several hours at a time, but up to this point countermeasures have been effective resulting in the continuation of operations. [177]

Last March, Musk announced on Twitter that his company would be “focusing on cyber defense and overcoming signal jamming of its Starlink internet satellites amid Russia's ongoing invasion of Ukraine”, prioritizing the development of hack-proof technologies over other major programs of Space-X (e.g. the Starship and the Version 2 of Starlink satellites). Besides Russian cyber-attacks, another issue has emerged regarding the billionaire’s support to the Ukrainian defense and this is funding. Musk has asked the U.S. government to economically support Space-X’s free transfer of terminals and stable internet connection, announcing that his company cannot provide funds for these operations indefinitely. This turn came after a heated debate on Twitter that he had with Ukrainian officials regarding some controversial comments he made. In October, he suggested through a poll that: i) Crimea should be considered Russian territory, ii) the regions recently annexed by Russia should hold referendums under the United Nation’s supervision so that the people can decide in which territory they want to belong, and iii) Ukraine should remain a neutral country. However, some days afterwards he withdrew his funding demands, through the following tweet: “The hell with it, even though Starlink is still losing money & other companies are getting billions of taxpayer $, we’ll just keep funding Ukraine govt for free”. [142], [151], [152], [153]

What is more, Ukraine has been using satellite links to share data for the GIS Arta software which “is an android app that collects target information from drones, US and NATO intelligence feeds, and conventional forward observers, then distributes orders to fire among multiple artillery units to make counter-battery fire more difficult”. GIS Arta has improved identification and verification of targets, thus enhancing quick response and striking accuracy, while also offering a gun-selection system with automatic feed of targeting coordinates. It seems to be one of the most innovative and accurate artillery systems currently developed in the West. [149]

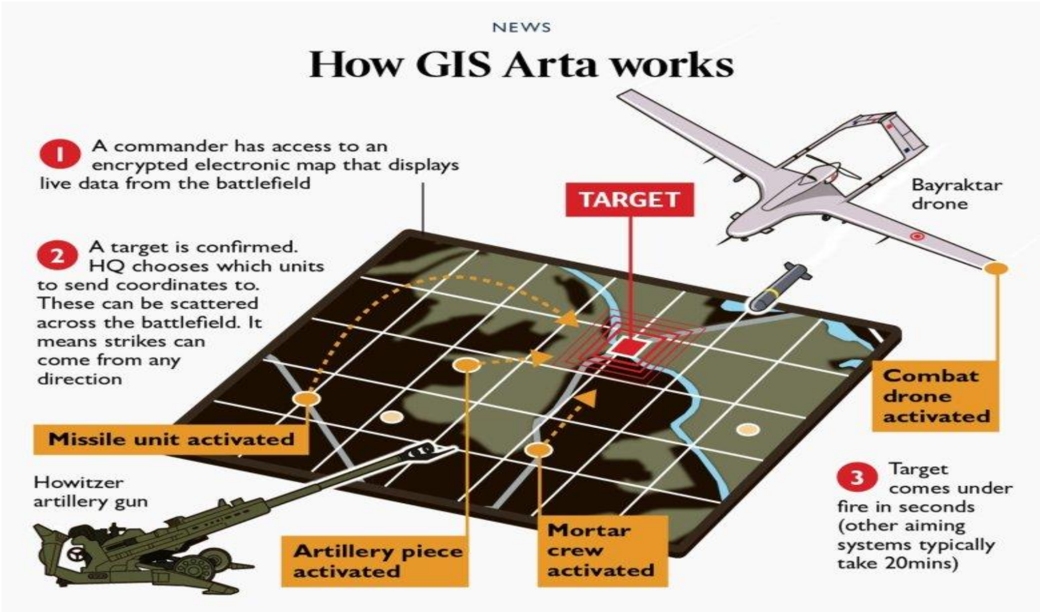


Fig. 27 : GIS ARTA operation [149]

Regarding the Russian side, domestic space military assets have mostly been used in the duration of the war. According to an article released on the Atlantic View, “on the first day of the conflict, a Russian operation used destructive malware to disable tens of thousands of user terminals of ViaSat, a US-based commercial network, requiring factory repair of the devices before they could function again. The Ukrainian military was a heavy ViaSat user and the obvious target. Russia’s successful ViaSat attack caused significant property damage to civilians in NATO nations, requiring tens of thousands of terminals to be replaced and causing disruptions, such as knocking thousands of wind turbines off the European electric grid for days. Satellite operators have been asking governments for more assistance in securing their systems and for more clarity about what governments will do to protect them”. This first critical strike revealed that Russia had invested in hacking, jamming and cyber-warfare technologies in order to degrade Ukraine’s military early in the war’s beginning. The damage caused to ViaSat’s terminal hardware and satellite services paved the way for offensive tactics that were applied in the efforts of the Russian military to undermine Navster and Starllink connectivity. However, those jamming techniques have not yet managed to breach and permanently destroy Starlink’s terminals. Targeting and destroying Starlink-satellites through ASAT missile operations would not prove effective, since their fleet consists of thousands of small satellites and they are, also, developed with an exceptionally large production rate which makes them easily replaceable. [150]

During the last year Russian cruise missiles have been using the Glonass positioning satellites to find their targets. A variety of satellites have also offered military-aid operations. However, Russia’s communication and surveillance satellite-fleet is comparatively small and uses systems that either are outdated or consist of foreign acquired parts which are not easily accessible after Western sanctions. Russia has two

Persona optical reconnaissance satellites in orbit, but since they operate for almost a decade they might be reaching their end-of-life cycle. Furthermore, the maximum resolution of these satellites is presumably around 50 centimeters per pixel, at the same time that the most enhanced American spy satellites, called Keyhole, are supposed to reach a resolution of about 5 centimeters per pixel, and commercial satellites owned by private enterprises, such as Maxar, usually have a maximum resolution of around 15 centimeters. Russia's civil satellites that could assist military operations are the Kanopus-V and Resurs-P optical-imaging earth-observation satellites. The first fleet is characterized by a large revisit period (more than 10 days per satellite) and offer relatively small resolution data, while the second one has a revisit period of 3 to 6 days. They could assist in the surveillance of massive targets, planning of bombardments and monitoring warfare damage. [144], [145]

The Russian military satellite fleet also lacks in remote-sensing radar payloads. With only one such spacecraft confirmed operating, the Kondor, Russia's cloud-penetrating surveillance abilities are weaker than the ones acquired by Ukraine through the aforementioned cooperation with western commercial companies. The Kondor was launched in 2014 and has a targeted life-cycle of five years, thus creating doubts regarding its operational capabilities after a decade in orbit. A new satellite, the Kosmos-2553 or Neitron, was launched in 2022, supposedly containing a radar payload that could be in use during the current military conflict. [144]

According to an article from the Jamestown Foundation, "Russia operates a satellite electronic intelligence system – Liana – which consists of five Lotos and one Pion-NKS satellites. The system is used mostly for naval intelligence. Lotos satellites are equipped with passive radar surveillance systems, but the Pion-NKS (Cosmos 2550) has an active radar system. In orbit since June 2021, Pion-NKS represents the most advanced satellite of the Liana constellation, and Russia could theoretically be using it in the war against Ukraine. Yet, like in the case of the Kondor satellite, the lone Pion-NKS's contribution to Russian combat activity in Ukraine is presumably low". [145]

It is important to note that according to defense ministry officials, Russia has used a hypersonic missile to attack a large base in southwestern Ukraine last March. The Kinzhal hypersonic missile reaches speeds of up to 5 Mach making anti-missile systems difficult to detect and shoot it down. It is carried by a MiG-31K fighter jet and has a range of 2,000 kilometers. Many hypersonic missiles are travelling through low space orbits in order to achieve longer flight ranges and required maneuvering. [146]

10.4. The Effects of Western Sanctions on Russia's Space Sector

The Western sanctions on Russia target a wide variety of fields, such as exports, imports, banks, economical assets, technological items, oil and gas supplies, aircraft operations, impoundment of ships and many more. The main purpose of these sanctions is to prevent Russian military and intelligence from developing new capabilities that could be used in the war with Ukraine and to degrade existing ones. Also, the embargo posed to Russia aims in economical strangling, which could lead to internal sociopolitical impacts on the Russian government and could force a change of posture in the armed conflict. Through the new sanctions many items used for civil purposes are being examined before exporting to Russia. Regarding space, U.S.'s items that serve "civil space cooperation activities with Russia" and "commercial space launches" are examined through a "case-to-case" and "policy of denial" procedure. Since many components that are used in the space industry can be of dual-use, for both commercial and military operations, the sanctions that are imposed by the west have had a great impact on this domain. Furthermore, the West's reliance on Russian rockets has lessened, since many alternatives have been developed in the West, and the anti-Kremlin political spirit has led to a strict embargo of imports regarding products and applications produced by Russian space enterprises. [138], [141]

Russia is already suffering from a shortage of vital technological components through the high-tech imports-exports sanctions, such as semi-conductors, circuits, sensors and other critical hardware, which not only affect the space field but also many Russian industries, such as car production. Since the begging of the war some of Russia's biggest car factories were forced to close due to lack of electronics' imports. According to some estimates, Russia has suffered about $10 billion import loses from Europe and $500 million from the United States. As a consequence this has resulted into significant economic losses for western providers in reverse. Russia is seeking alternative sources for components regarding high-tech, aerospace and military technologies. However, a tendency towards supporting Russia's industries through international cooperation has not yet emerged. Even countries which have kept a neutral stance towards the Russian invasion in Ukraine, such as India, have not offered alternatives that could help Russia counterbalance its total losses. This comes as a result of two factors. These nations are, for the time being, reluctant on bypassing the western sanctions due to the effects this may have on their own economies, as such decisions pave the danger to make them targets too. On the other hand, on a regional geopolitical scale, there may be opposing interests and antagonism, resulting on policies that will leverage from the weakening of the Russian economy and its dependency towards their exports. [139], [140], [141]

Russia's satellite industry faces several challenges. The production of satellites that can match, let alone exceed, the quality of western ones is far from close, and usually result in operational problems. Along with that, Moscow still lacks an effective data collection, distribution and analysis system combing orbital-assets, ground stations and software capabilities. Thus, the following question rises. Can Russia overcome the imposed sanctions and reestablish itself in a rapidly evolving industry? However, regardless of the outcome, considering its current capabilities and future trends, Russia appears to lack the ability to engage in large-scale warfare relying solely on its satellites, especially in the military sector. [145]

According to an article in Aerospace Technologies: "The war in Ukraine has negatively affected the global space industry in general, largely due to the war's broader economic impact; it is expected that the growth of the industry will slow for 1-2 years, before accelerating again. In general, the war in Ukraine has highlighted the general trend away from international cooperation in space, towards national programs". [141]

10.5. The effects of the war on the Space Industry

- <u>International Space Station</u>

The ISS remains the only technological field where Russia and Western countries kept cooperating after the invasion of Ukraine. Political tensions were transferred in the rhetoric of space-agencies' officials, mostly focused on the present and future plans each country has for the ISS, but the current operations were never disrupted. Former Roscosmos head, Dmitry Rogozin, stated multiple times during the past year that Russia would end its membership on the ISS, an action well regarded as a pressure mechanism towards western sanctions. The fact is that the current mission agreement reaches up to 2024 and Russia will then supposedly withdraw from the program, aiming at the construction of an autonomous space station partially developed using some of the ISS's modules owned by Russia. The Russian Orbital Service Station (ROSS), which will allow high-frequency observations and easier access for Russian cosmonauts, will be constructed on top of a spacecraft named the Science Power Module-1. This part was scheduled to be launched in 2024, following Russia's departure from the ISS. However, due to redesign delays, its launch is not going to proceed prior to 2025, let alone that the war-related sanctions will most probably pose difficulties to R&D, thus rendering this schedule even more uncertain. [141], [147]

NASA on the other hand had long expressed its will to extend the ISS's lifetime until 2030. This posture is undoubtedly in line with the fact that if the station stops operating in a year or so, the only in-orbit alternative for the international community shall be the Chinese Tiangong space station. Such a prospect shall undermine NASA's global lead in space science and micro-gravity experiments, technology development and demonstration of capabilities, manned space missions of prolonged duration, international partnerships and global influence, as well as, future plans for human spaceflight to Mars. Regarding the fact that U.S.'s space companies are prohibited by state-laws to cooperate and exchange technologies and know-how with the PRC, such a turn will also affect its commercial sector. For example, Space-X has gained a lot, both in recognition and funding, from offering crewed space launches to the ISS. Losing this ability will have a great cost for the industry in multiple ways. Thus, In August 2022 the U.S. Congress signed an authorization bill for permitting NASA's participation to the ISS up to September 2030 [148]. However, the other members have to agree in prolonging the life-cycle of the station, but Canada, Europe and Japan will probably give a "green light" to this process. It remains uncertain whether Russia will agree to such an extension regarding both its hostility towards its ISS partners and its independent plans for a national space station. However, considering the fact that such a milestone is not expected to be shortly achieved, especially with the effect the war has had on Russian industries, Russia might have more than one reason to remain an ISS partner until the end of the decade. [147]

On a mere operational point-of-view Russia's withdrawal could cause a variety of difficulties for the ISS. Russian and Western modules are highly interconnected and the smooth performance of multiple tasks leans on combined procedures between the different parts of the station. Perhaps the most important ones are the energy production and storage, which is almost completely developed by the U.S.'s modules, and the flight-control orbital maneuvers, which rely on the Russian systems. The latter is of great significance in order to ensure that the station's orbit doesn't degrade, leading it, within a year, into entering the Earth's atmosphere and burning up. NASA can turn to a variety of alternatives for replacing Russian systems, such as using the Cygnus spacecraft which is under development by Northrop Grumman, but they are all costly and time-consuming. Thus, a fast-coming withdrawal of Russian modules would cause many problems to NASA's plans regarding the continuation of the program. However, such a decision will have a cost for the Russian space industry as well. From a political perspective, its cosmonauts program would in fact freeze, leading to the loss of one of the most powerful means of propaganda and long-lasting paradigm of national excellence. What is more, the ISS can always serve as a diplomatic tool in negotiations between the cooperating superpowers. Finally, as is the case for the commercial space-launch companies of the U.S., the discontinuation of the ISS would also pose a drastic harm to Russia's space launch industry, which as we have mentioned in the comparative analysis of national space capabilities is currently degrading. [147]

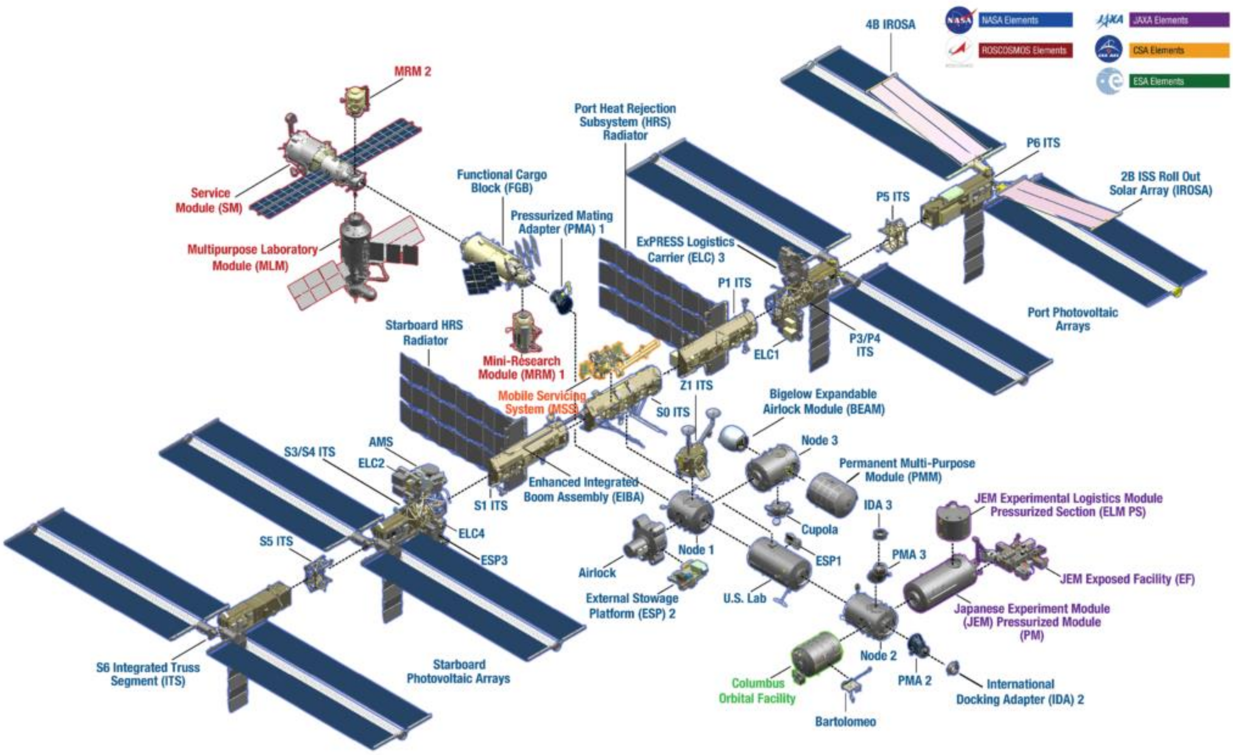


Fig. 28 : Scheme of the ISS [147]

- <u>Russo-European Space Cooperation</u>

The main effects of the war in space coordination between Russia and Europe can be summed up as follows [139]:

i. The Soyuz rockets halted launches from the European spaceport in French Guiana freezing many scheduled launches of commercial satellites.
ii. The ExoMars rover remained without launcher and lander, leading to a discontinuation of the Mars oriented mission. The rover was planned to launch in September 2022 through a Russian Proton rocket, but ESA cancelled its lift-off after the war began. A launch is not expected prior to 2028.
iii. The suspension of European satellites' launches applies also to those scheduled to launch from Russian soil (Baikonur Kosmodrome) instead of Kourou spaceport. The most striking example is that of OneWeb's constellation satellites, 36 of which were "stranded" at the launch pad, in an unsuccessful attempt to extort concessions from the United Kingdom.
iv. ESA furthered from joint lunar missions, Luna 26 and Luna 27, with Roscocmos.

v. A supply shortage has been created in Europe's rocket industry since its Vega launchers use Ukrainian engines. The disrupted factories' production has resulted in a limited stockpile of engines.

Since the war began, and especially due to its continuance throughout the whole year, Europe's vulnerabilities from its dependence to Russia have emerged on a large scale in great many levels. Russia undeniably takes advantage of its superiority in many fields and of the backfire-results the sanctions are having to Europe, depending on the fact that the pressure to Europe's economies and its results to people's life-standards will force European governments to change their posture. Europe was not ready for supporting strategic autonomy and this will probably reveal more clearly on a later time. Regarding space, difficulties to deliver on time orbital flights even for its most sensitive satellites (such as a scientific satellite looking for dark matter-energy evidence, earth observation Copernicus satellites, Galileo's constellation parts, and other spacecrafts involved in national security applications) has been a critical hit to both the status and the operational capabilities of Europe. The current situation has pushed European officials to adopt a more "hostile" point-of-view when it comes to space, since the war led them to realize that space operations shall be highly integrated to security and defense in the new era of geopolitical tensions. Improving the military uses of its satellite fleets (e.g. Copernicus and Galileo), enhancing the use of spacecrafts and satellite payloads for surveillance, crisis management, undisrupted connection and protection of critical infrastructures, improving the resilience of its space-assets and ground-bases to cyber-attacks are just some of the main concerns that Europe is focusing on for the near future. According to an ESPI brief "Overall, a convergence of unrelated factors challenge some historical positions of Europe in space: from the advent of the "New Space" economy and its consequences on space business, to the current crisis which marks yet another milestone urging European stakeholders to reconsider the way they "think" and "do" space internationally. As a matter of fact, European decision-makers have demonstrated their readiness to use space as a geopolitical tool". [140]

- <u>Civil Space Enterprises: The Short Term Winners of the War</u>

As the war has proven, commercial space companies are not only capable of taking part in a military conflict but may also prove to be short-term winners from the rising tensions. In 2022 nearly all available commercial space launches were booked shortly after the Soyuz rockets were suspended from launching commercial western satellites. As we have pointed, the forming environment in the space launch sector became highly strained, since a significant number of satellites were caught stranded in warehouses expecting available launch services. At the same time, an overwhelming rise in launch demands is continuing to occur. Some of the companies that have been severely affected started turning into other space-launch entities. OneWeb for example signed contracts with the Indian Space Research Organization and with Space-X. There are many national and commercial enterprises that proved to be eager in filling the gap created in the space-launch market by the Soyuz embargo. Both evolving space-faring nations, such as India, Brazil and Japan, and commercial western companies (some obtaining a multiyear flight heritage, such as Space-X, Arianespace, Northrop Grumman, United Launch Alliance and others with evolving capabilities, such as Blue Origin) will likely push forward their development plans and "expand their launching schedules to accommodate these additional missions". This procedure may result in even further losses for the Russian launching industry, with Roscosmos already being "cash-strapped". Even if at some point the conflict pauses and a diplomatic solution is reached, the question of whether Russia will face immense difficulties in reentering the market remains.

- Commercial Space Warfare

The Gulf War is considered as the "first space war" but it is the Ukrainian one that has emphatically proven not only the dual-use of space technologies, but in fact their military extensions regardless of ownership (civil, governmental, military etc.) [178]. During the past year there have been many references to the Russo-Ukrainian conflict as "the first commercial space war". All the actions of private space entities that we have analyzed in the former sections raise concerns regarding security issues for the space technologies of private enterprises. Since commercial entities have taken part in the war, it is possible they will be targeted as military assets, regardless the intensity of their involvement. Even if these companies do not seem to presently face counteractions of degradation, interference, cyber-attacks or destruction, the current situation paves the way for future conflicts. And there is no guarantee that besides the specific satellites or payloads contributing to the warfare, the personnel of civil companies won't be targeted as well. All of the above create an environment where a variety of commercial systems could be characterized as military equipments, thus demanding corresponding security enhancements to avoid offensive actions. Of course, such a procedure can prove to be highly cost-inefficient since insurance and protection, let alone replacement, of hardware in space is very expensive. From developing methods for attacks mitigation to deploying counter-measures against any type of interference, the "collateral" militarization of commercial products in orbit could not only "reduce profitability" but also "prevent new entrants from joining the market". However, many of these space companies are, in fact, scoping on a greater involvement of their products in military operations and have already started developing corresponding technologies for security and defense. For example, Space-X is trying to "extend its branches" into military contracts, furthering from sole commercial applications, imitating enterprises with a long history of space-military interconnection such as Northrop Grumman and Lockheed Martin. Elon Musk has proceeded in "government contracts for launching military satellites and building missile-tracking satellites and is exploring a Pentagon partnership for the space transportation of military supplies". [154]

10.6. China's Posture on the Russo-Ukrainian War

On December 2022 a report was released from the Center for Strategic & International Studies (CSIS) entitled "Understanding the Broader Transatlantic Security Implications of Greater Sino-Russian Military Alignment". In this report four main sectors of cooperation between China and Russia are being examined: Arms sales and military technology transfers, joint military exercises, space & cyber warfare, and hybrid tactics concerning armed conflicts. The findings are based on translated primary-source materials retrieved from strategic thinkers of the two states and focuses on a number of alternatives regarding the future relationship of the two nations. Despite the fact that the main research was conducted prior to Russia's invasion in Ukraine, the report is referring to the results of the conflict on those different fields examined and on the environment the war has shaped. It is stated that, despite what Western officials have expected, the bilateral relationships between the two superpowers have not been undermined by the sanctions imposed to Russia neither by the informational-war that western media have unleashed in order to form a global anti-Russian opinion. [155]

China's posture towards the war is characteristic of its foreign policies and its broader stance towards the global order of power. It has not helped extensively Russia with military enhancement during the conflict and has kept a relatively neutral position towards bypassing western sanctions. However, the PRC has not condemned Russia's invasion and instead blames the U.S. and NATO's aimed enlargement for the ongoing warfare. Trade between the two states has evolved impressively since the war began, there has been a 34.3 percent raise in 2022 leading to a record high of $190 billion according to the Global Times, and joint military exercises have not been paused. [155]

According to the report, Russian and Chinese strategic thinkers share a common perception that the global power distribution is shaped as a "strategic triangle", between their nations and the United States. This triangle currently seems "out of balance". They regard the Euro-Atlantic coalition as responsible for this status, since its will of global dominance and its efforts of constant power-shear enlargement have been provocatively undermining other evolving nations' capabilities. By setting international norms and legal frameworks (or bypassing others) according to their interests, by taking advantage of their military and technological dominance, by launching propaganda warfare against their geopolitical adversaries, by destabilizing governments of non like-minded states, and in some cases through mere armed intervention, western countries have not only shaped global order but are also considered by the Sino-Russian alliance as the ones responsible for its current crisis. Both states consider that undermining the status-quo formed by western dominance is essential for creating a multi-polar, just and sustainable future world. Thus, the political extensions of the Sino-Russian cooperation are overcoming these of mere technological and operational enhancement. [155]

Military and space cooperation serve the purpose of improving mutual trust on the basis of the aforementioned bilateral trend. The goal of competing towards western military capabilities has led to the provision of greater access into one-another's military technologies. Thus, arms-sales are constantly evolving, despite the fact that China's industry has "reduced its need of external imports" and that Russian officials have been reluctant on providing sensitive-technologies due to China's past "reverse-engineering" efforts which have led in "property-theft" accusations. Deepening cooperation can be expected even in advanced systems, such as missile defense. Joint military exercises have increased after the 2014 Russian annexation of Crimea and the fact that they have continued after the 2022 Ukraine's invasion is currently sending a message that in the Asia-Pacific region a strategic alliance is strongly founded. Exposure of each others' strength and weaknesses characterizing troops' deployment, military tactics, armed operations, warfare strategies and equipments' capacity, are enhancing their bilateral trust and sets the basis for "forces' interoperability". Furthermore, China has not taken part in a military conflict for decades so it can leverage through joint exercises with Russian troops which have operational experience against western arms and tactics. [155]

Regarding the war on Ukraine, the report focuses on two possible alternative future paths as far as the alliance is concerned. On the one hand, if the war results in some kind of Russian defeat, Chinese officials shall have to reassess their point-of-view towards the Federation's operational military performance, the gains derived from joint strategies, the efficiency of imported technologies and, after all, its partner's ability to ensure strategic interests in a global changing environment. On the other hand, if Russia manages to endure, adapt and overcome the funding restrains and supply-chain interruptions caused by western sanctions and media propaganda, the lessons learned could prove to be of great value for the PRC leadership regarding a future possible Asian-Pacific conflict followed by U.S. intervention. According to a statement in July 2022 by the CIA's director William Burns, China is, already, learning from the Russo-Ukrainian war and the effects it has had on Russia. Thus, the PRC shall be in a better position to face western hostility in case it engages into a military invasion of Taiwan. Some of the most important strategic lessons can be summed up in three points. China shall need: i) an initial overwhelming force for a decisive victory, ii) control over the information space, and iii) a shore up of its domestic economy against sanctions. [155], [156]

Bilateral coordination on the space sector is, also, affected by the Ukrainian war. Russia's space industry is suffering from "shrinking budgets, imports' restrictions, aging equipment and personnel", thus raising questions as to whether it shall manage to deliver the expected results in great projects and cutting-edge technologies, such as the joint Lunar Research Station. Cooperation, however, is de-facto pursued in terms of shaping international legal guidelines in order to halt space militarization by the U.S. and to counter the legislation of frameworks, such as the Artemis Accords, that shall undermine outer space's common wealth resources and other similar activities raising sovereignty issues. Western sanctions have led in deepening collaboration in the space sector especially in the fields of outer-space. Regarding trade, China's exports of printed circuits, microelectronic components and integrated chips has increased impressively and along with raw materials, such as aluminum oxide used for making metal aluminum, western thinkers claim that China actually supports both Russia's aerospace industry and its weapons production, since most of these products can be of dual-use. [155], [157]

China is taking advantage of Russia's multiyear space heritage whilst Russia is apparently in great need of Chinese resources. This procedure raises concerns for the West, regarding not only grave technological leaps that could occur but also safety issues focused on its ability to counter Sino-Russian bilateral space-based military equipment. Developing advanced integrated systems through joint projects, such as the BeiDou and Glonass navigation satellites' compatibility, and enhancing their common strategic military capabilities troubles western officials. Some examples concerning these critical strategic fields are Russia's aid in the production of China's "space-based missile early warning systems" (which up to now were developed solely by them and the U.S.), the joint exercises on computer-simulated ballistic missile interception that have been conducted for three consecutive years and the provision of ballistic missile defense software. [155]

In the possibility of a space war an attack on a space asset which integrates jointly-developed technologies and payloads could be considered as an act of war against both states. What is more, if we take into consideration: i) the rising heat in global geopolitical "temperatures", ii) the progress of joint exercises between the two corresponding military departments and iii) the involvement of satellites (both commercial and governmental) in war-related actions, we can presume that if the bilateral ties between China and Russia strengthen even more, joint counter-space technologies and operations could be pursued. [155]

It is anticipated that in the future, China will become a more powerful military space-player than Russia. When comparing the military space assets and capabilities of both countries, Beijing is far ahead of Moscow. Unlike Russia, China has launched numerous military ISR satellites for earth observation and surveillance. China's space industry is characterized by an "emerging commercial space sector" and a "sophisticated domestic electronics industry that can supply components for advanced military satellites". Russia's lack of these capabilities was evident during the war with Ukraine, especially compared to the satellite capabilities Ukraine acquired through foreign contributions. Although Russia currently posses more ASAT missiles than China, China has evolved both in terms of quantity and technological advancements in many aspects of space-military capabilities, surpassing Russia. [150], [155]

However, there are some negative side-effects which complicate operational coordination and technology exchanges between the two states. Russia has to take into account the fact that China is thriving in every technological sector and, through cooperation, shall probably surpass Russia's capabilities, lessening the mutual benefits of their joint-activities. In addition, China might suffer too from the western world's hostility towards Russia, leading various nations and companies into furthering from exchanges with its industries due to their collaboration with Russian entities. This process could result into a counterbalance of the benefits-to-losses scale from China's perspective. China is undeniably in pursuit of multilateral cooperation space programs with western space agencies, since this procedure will have positive effects in both funding of large space projects and in raising its status and recognition as a leading space-power in the global arena. For example, ESA's change of posture regarding its involvement on the Tiangong space station causes damage to the world's perception of the Chinese project as a space-base which could serve international progress. [155]

11. CONCLUSIONS

In conclusion, both China and Russia are two of the main space-faring nations in the world. Our analysis reveals that both countries have made significant contributions to the international space arena. These two countries have demonstrated remarkable determination and success in the global space field, from launching spacecraft and operating satellites to exploring other planets and conducting manned space missions. China's space industry has produced a rapid development throughout the last two decades and is currently presenting an exponential growth in most of the space-sector's fields, while the Russian one has a long-lasting space-heritage, being a pioneer of space exploration for almost 70 years, but is currently facing a decline on its overall progress. Despite both nations' autonomous capabilities, their space strategies have become significantly interconnected, as a result of a variety of industrial, political and military reasons.

Regarding bilateral and international space cooperation, the two states have been involved in a wide variety of intercontinental collaboration projects. For both countries the global geopolitical consensus has played an important role on the prospects of space-oriented alliances. Their current strategies are based on a mutual perception regarding global order and on the prospect of a multi-polar world through reforming the post-cold war era and western dominance.

China, having been banned from U.S. space-exchanges since the end of the 20th century, has mostly focused on five sectors: Establishing multinational space organizations in a regional basis (APSCO), developing the Space Information Corridor for its Belt and Road Initiative, participating on the United Nations' space-oriented programs, improving the BRICS alliance's space capabilities and strengthening its bilateral relations with a variety of countries worldwide. China has played an important role in providing developing countries, in Central and Eastern Asia and in South America, with space technologies and investing in the development of their space capabilities. It has supported like-minded nations which are opposing the Euro-Atlantic coalition's geopolitical strategies (e.g. Iran), has enhanced states which tend to overcome their economic and political dependence from the U.S. (e.g. South America) and has assisted many countries, which were viewed by western interests mostly as vast areas of cheap labor and industrial production facilities, to send satellites and astronauts in orbit. Nonetheless, China is trying to establish advanced relations with both ESA and the U.S., mainly regarding space-sciences, orbital debris removal policies and peaceful uses of outer-space.

Russia, on the other hand, has had a long-lasting cooperation with its current rivals. Especially in the case of ESA, technology transfers, launching services and scientific know-how exchanges have played a vital role for Russia's space sector. In the case of the U.S. the post-cold war mentality of the two nations can be characterized as mostly collaborative, despite the differences in strategic interests. The turn-point for Russia has been the 2014 Ukrainian crisis and the posture of western countries towards it. Russia has suffered from the sanctions imposed after the annexation of Crimea, thus being led to a reprioritization of its space partnerships. Russia has supported the BRICS alliance and its prospects, has focused greater in trade with Asian countries (e.g. Korea and Iran), has developed significant collaboration processes with India (although not always successful) and has invested greatly in the bilateral space coordination with China.

The two nations' cooperation was initially characterized by some mistrust since Russia didn't want to provide to China technologies that would further enhance its exponential economic and technological development, along with its geopolitical status on the East-Asia region. However, the effects the western sanctions have had on Russian industries, trade and overall economy have accelerated the closer approach between the two superpowers. Their overall relations (military joint operations and strategic technologies exchanges, microelectronics trade, energy supplies, industrial support, international policies, information world, crisis management, etc.) have been thriving through the past years and the Ukrainian war has not put them on-hold. In the space-field there have been some substantial achievements and future plans mainly concerning lunar and interplanetary exploration, rocket-engines' and micro-electronic components' trade, manned spaceflight systems, heavy-lift launchers' production, ground stations expansion for navigational satellites, earth-observation, meteorological and climate-surveillance data exchanges, LEO satellite communications, and development of interconnected and interoperable space-systems.

The two countries have also had a common approach regarding space diplomacy, especially when it comes to the militarization of space. Their common treaty that was proposed in the United Nations Conference on Disarmament in 2008, known as PPWT, was the first joint action revealing their mutual distrust towards the U.S.'s posture on the placement of weapons in orbit. Both states accuse Washington for depending on a new cold-war era in order to secure its global power share and are trying to overcome western barriers in the international community. We are living through a period where the U.S. seeks to ensure its space hegemony and dominate the space-chessboard through militarization, while, also, raising sovereignty issues on celestial bodies through the Artemis Accords and through bypassing international agreements.

At the same time, space has become a strategic environment for nuclear forces, serving as their "eyes and ears", leading to a transformation of satellites into military force "multipliers" and "enablers". Despite the fact that both China and Russia have developed a wide variety of space-based military projects, dual-use satellites and counter space-warfare measures, they are aware that they cannot separately outmatch the military space-capabilities of the U.S. Thus they are forced to adopt a more collaborative approach on the matter and promote peaceful solutions. The space-cooperation between China and Russia promotes the development of space technology, enhances mutual political trust between the two countries, deepens their strategic partnership, helps to maintain a status of multi-polar "global-commons" space and assists in facing the current instabilities on the three space-powers' triangular balance. It is of vital importance for both China and Russia to construct just and inclusive regulations regarding both orbital assets and celestial bodies' governance. The two states have great interest in defending "a community of human destiny in space" based on "negotiation, joint construction and sharing" and their joint ILRS project serves all of the above purposes.

Finally, regarding the Russo-Ukrainian war we can summarize the following results of our research. Space-based technologies have been used widely and from both sides since the beginning of the war. Ukraine has been relying on western rockets and artillery shells using the GPS system for navigation and precision, and on western commercial satellites for ISR, Communications and Internet Connectivity. Western earth-observation space-firms have offered to Ukraine the ability to track Russian troops' deployment, tactics and war-damage, and have also played an important part on influencing the global opinion against Russia's intervention. Space-X's Starlink constellation has played a crucial role in safeguarding satellite links for communications and stable internet access throughout the country.

Russia has been using its satellites for ISR, C2 and PNT operations on the battleground and until today has used countermeasures, such as radio-interference and cyber-warfare, to jam and interrupt the western satellites' aid to the Ukrainian military. Russia's space-military capabilities are not so advanced and accurate compared to some of the cutting-edge technologies that western companies have provided to Ukraine but its army is nonetheless relying mostly on its ground based military tactics for dominance on the field. The Russian space sector has suffered in many aspects since the war began with the most notable results being the losses of income, through the decrease of space launches, and the interruptions in supply chains connected with its industry (e.g. micro-electronics and raw-materials).

The international space community has also suffered from the war since many planned missions have been strapped to the ground for long periods due to the discontinuation of space launches (e.g. the Rosetta Martian Rover). Furthermore, the future of the ISS remains uncertain. Commercial space enterprises have proven to be the short-term winners of the war since they have acquired both national funds and largest shares on the global-space-market through the gap created by Russia's isolation, but are currently facing retaliation dangers. The "First Commercial Space War" resembles to Science-Fiction scenarios, where commercial enterprises' and national interests align, military enhancement of civil assets has become a prospect so as to protect them from counter-measures, and manipulation of public view for private interests has risen significantly. The fact that the wealthiest man in the world has been directly involved in the confrontation between two states raises concerns.

China, up to this point, has held a neutral stance towards the war and has concentrated its "fires" towards the western responsibilities for the current situation and its continuance. The PRC has not aided Russia directly regarding military operations and according technologies but their cooperation and trade have excelled throughout the past year and the two nations have formed a strong bond towards the establishment of a multi-polar world order both on Earth and in Space. However, it is anticipated that in the future, China will become a more powerful military space player than Russia.

ABBREVIATIONS - ACRONYMS

TT&C	Telemetry Tracking & Command
GPS	Global Positioning System
GEO	Geostationary Equatorial Orbit
LEO	Low Earth Orbit
MEO	Medium Earth Orbit
GTO	Geostationary Transfer Orbit
IGSO	Inclined Geosynchronous Orbit
ISR	Intelligence Surveillance Reconnaissance
C2	Command & Control
PNT	Positioning Navigation Timing
ASAT	Anti-Satellite
U.S.	United States
ISS	International Space Station
PRC	People’s Republic of China
LM	Long March
BeiDou	Big Dipper
QZSS	Quazi-Zenith Satellite System
IRNSS	Indian Regional Navigation Satellite System
GLONASS	Globalnaya Navigazionnaya Sputnikovaya Sistema
NASA	National Aeronautics and Space Administration
CNSA	China National Space Administration
ESA	European Space Agency
DASA	Deutsche Aerospace AG
R&D	Research and Development
CZ	Chang Zeng
FB	Feng Bao
DFH	Dongfanghong
FY	Fengyun
SJ	Shijian
ZY	Ziyuan
UCS	Union of Concerned Scientists
SAR	Synthetic Aperture Radar
InSAR	Interferometric Synthetic Aperture Radar
VLBI	Very Long Baseline Interferometry

USSR	Union of Soviet Socialist Republics
USA	United States of America
UN	United Nations
OOSA	Office of Outer Space Affairs
CBERS	China Brazil Earth Resource Satellite
EUMETSAT	European Organization for the Exploitation of Meteorological Satellites
NCLE	Netherlands China Low Frequency Explorer
APSCO	Asia Pacific Space Cooperation Organization
BRI	Belt and Road Initiative
BRI – SIC	Belt and Road Initiative – Space Information Corridor
DSSP	Data Sharing Service Platform
SMMS	Small Multi-Mission Satellites
APOSOS	Asian-Pacific ground-based Optical Space object Observation System
GNSS	Global Navigation Satellite System
IAF	International Astronautical Federation
UN-ESCAP	United Nations Economic and Social Commission for Asia and the Pacific
UN-SPIDER	United Nations Platform for Space-based Information for Disaster Management and Emergency Response
ICG	International Committee on Global Navigation Satellite Systems
IAC	International Astronautical Congress
SMMS	Small Multi-Mission Satellite
CCD	Charge-Coupled Device
APRSAF	Asia-Pacific Regional Space Agency Forum
CCP	Chinese Communist Party
MoU	Memorandum of Understanding
EU	European Union
CMA	China Meteorological Administration
PRSS	Pakistan Remote Sensing Satellite
VRSS	Venezuelan Remote Sensing Satellite
NPU	Northwestern Polytechnic University
NSR	New Silk Road
BRICS	Brazil Russia India China South-Africa
ASEAN	Association of Southeast Asian Nations
SASTIND	Stated Administration for Science, Technology and

	Industry of National Defense
NDRC	National Development and Reform Commission
ITAR	International Traffic in Arms Regulations
PLA	People's Liberation Army
EO	Electro-Optical
IBM	Intercontinental Ballistic Missile
PPWT	Draft Treaty on the Prevention of the Placement of Weapons in Outer Space
ABM	Anti-Ballistic Missile
PLAAF	People's Liberation Army Air Force
DIA	Defense Intelligence Agency
AUKUS	Australia United Kingdom United States
SSF	Strategic Support Force
SSD	Space Systems Department
CLTC	China Launch and Tracking Control
NSD	Network System Department
QUESS	Quantum Experimentation at Space Scale
SLVs	Small Launch Vehicles
ICBM	Intercontinental Ballistic Missile
MRBM	Medium-Range Ballistic Missile
LPAR	Large Phased Array Radars
SSA	Space Situational Awareness
EW	Electronic-Warfare
RSA	Russian Space Agency
GDP	Gross Domestic Product
FTP	Federal Target Program
FSP	Federal Space Program
SB	Sub-Program
EO	Earth Observation
PTK NP	New Generation Piloted Transport Ship
RKK Energia	Korolev Rocket and Space Corporation Energia
ROSS	Russian Orbital Service Station
NEM	Science and Power Module
KSLV	Korea Space Launch Vehicle
COSPAS	Space System for the Search of Vessels in Distress
SARSAT	Search and Rescue Satellite-Aided Tracking
ISON	International Scientific Optical Network

TCBM	Transparency and Confidence-Building Measures
MSL	Martian Science Laboratory
ISRO	Indian Space Research Organization
DRDO	Defense Research Development Organization
JUICE	Jupiter Icy moons Explorer
ExoMars	Exobiology on Mars
SAM	Surface to Air Missiles
EMP	Electro-Magnetic Pulse
START	Strategic Arms Reduction Treaty
SAT-COM	Satellite Communications
SLS	Space Launch System
C4ISR	Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance
RAND	Research and Development
SDI	Strategic Defense Initiative
MIRACL	Mid-Infrared Advanced Chemical Laser
CIA	Central Intelligence Agency
DoD	Department of Defense
USAF	United States Air Force
ILRS	International Lunar Research Station
GLEX	Global Space Exploration Conference
S&T	Science & Technology
ICT	Information and Communications Technology
G20	Group of Twenty
CEO	Chief Executive Officer
GIS	Geographic Information System
NATO	North Atlantic Treaty Organization
ESPI	European Space Policy Institute
CSIS	Center for Strategic and International Studies

12. Appendix

Table 1 : Global distribution of communication satellites

Country	No. of Satellites	%
Algeria	1	0,027678
Bangladesh	1	0,027678
Belarus	1	0,027678
Bolivia	1	0,027678
Bulgaria	1	0,027678
Czech Republic	1	0,027678
Greece/United Kingdom	1	0,027678
Japan/Singapore	1	0,027678
Jordan	1	0,027678
Kuwait	1	0,027678
Laos	1	0,027678
Nepal	1	0,027678
Nigeria	1	0,027678
Pakistan	1	0,027678
Qatar	1	0,027678
Singapore/Taiwan	1	0,027678
Sweden	1	0,027678
Turkmenistan/Monaco	1	0,027678
United Kingdom/ESA	1	0,027678
United Kingdom/Netherlands	1	0,027678
USA/Canada	1	0,027678
Azerbaijan	2	0,055356
Egypt	2	0,055356
ESA	2	0,055356
France/Italy	2	0,055356
Greece	2	0,055356
Kazakhstan	2	0,055356
Malaysia	2	0,055356
Russia/USA	2	0,055356
Vietnam	2	0,055356
France	3	0,083033
Germany	3	0,083033
Israel	3	0,083033
Italy	3	0,083033
Mexico	3	0,083033
USA/Japan	3	0,083033
Indonesia	4	0,110711
Thailand	4	0,110711
USA/Argentina	4	0,110711
Norway	4	0,110711
South Korea	5	0,138389

Turkey	5	0,138389
Saudi Arabia	6	0,166067
United Arab Emirates	6	0,166067
Argentina	7	0,193745
Netherlands	7	0,193745
Australia	8	0,221423
Brazil	9	0,2491
Switzerland	12	0,332134
Spain	18	0,498201
India	19	0,525879
Other Countries	175	4,84362
Japan	20	0,553557
Luxemburg	30	0,830335
Canada	38	1,051758
Multinational	45	1,245502
China	67	1,854415
Russia	87	2,407971
United Kingdom	469	12,9809
USA	2682	74,23194
Total	**3613**	**100**

Table 2 : Global distribution of earth observation satellites

Country	No. of Satellites	%
Belarus	1	0,0884956
Belgium	1	0,0884956
Chile	1	0,0884956
China/France	1	0,0884956
Colombia	1	0,0884956
Egypt	1	0,0884956
Estonia	1	0,0884956
France/Israel	1	0,0884956
France/Italy	1	0,0884956
India/Canada	1	0,0884956
Iran	1	0,0884956
Iraq	1	0,0884956
Peru	1	0,0884956
Slovenia	1	0,0884956
Sri Lanka	1	0,0884956
Sudan	1	0,0884956
Sweden	1	0,0884956
Taiwan	1	0,0884956
Ukraine	1	0,0884956
USA/Canada/Japan	1	0,0884956
USA/France	1	0,0884956
USA/Japan/Brazil	1	0,0884956

China/Brazil	2	0,1769912
Denmark	2	0,1769912
Ethiopia	2	0,1769912
France/Belgium/Sweden	2	0,1769912
France/Italy/Belgium/Spain/Greece	2	0,1769912
India/France	2	0,1769912
Morocco	2	0,1769912
Nigeria	2	0,1769912
Norway	2	0,1769912
Pakistan	2	0,1769912
USA/Germany	2	0,1769912
USA/Japan	2	0,1769912
Venezuela	2	0,1769912
Vietnam	2	0,1769912
Algeria	3	0,2654867
Indonesia	3	0,2654867
Kazakhstan	3	0,2654867
Mexico	3	0,2654867
Singapore	3	0,2654867
Thailand	3	0,2654867
Brazil	4	0,3539823
Saudi Arabia	4	0,3539823
Turkey	4	0,3539823
Canada	5	0,4424779
Poland	5	0,4424779
South Africa	5	0,4424779
Spain	6	0,5309735
United Arab Emirates	6	0,5309735
United Kingdom	6	0,5309735
Multinational	7	0,619469
Israel	8	0,7079646
South Korea	8	0,7079646
Italy	9	0,7964602
Germany	11	0,9734513
Taiwan/USA	11	0,9734513
Other Countries	167	14,778761
Luxembourg	12	1,0619469
France	15	1,3274336
Finland	16	1,4159292
ESA	19	1,6814159
India	25	2,2123894
Argentina	27	2,3893805
Japan	35	3,0973451
Russia	36	3,1858407
China	293	25,929204
USA	485	42,920354
Total	**1130**	**100**

Table 3 : Global distribution of Space & Earth Science satellites

Country of Operator/Owner	No. of Satellites	%
Belgium	1	0,806451613
China/Italy	1	0,806451613
ESA/USA	1	0,806451613
ESA/USA/Russia	1	0,806451613
France	1	0,806451613
France/USA	1	0,806451613
Israel	1	0,806451613
Italy	1	0,806451613
Norway	1	0,806451613
Paraguay	1	0,806451613
Switzerland	1	0,806451613
USA/India/Singapore/Taiwan	1	0,806451613
USA/United Kingdom/Italy	1	0,806451613
Chile	2	1,612903226
India	2	1,612903226
Other Countries	17	13,70967742
Germany	3	2,419354839
South Korea	3	2,419354839
Japan	4	3,225806452
Canada	7	5,64516129
Multinational	8	6,451612903
ESA	9	7,258064516
Russia	10	8,064516129
China	24	19,35483871
USA	39	31,4516129
Total	**124**	**100**

Table 4 : Global distribution of technology development & demonstration satellites

Country of Operator/Owner	No. of Satellites	%
Algeria	1	0,248138958
Brazil	1	0,248138958
Bulgaria	1	0,248138958
Chile	1	0,248138958
China/France	1	0,248138958
Ecuador	1	0,248138958
Egypt	1	0,248138958
Hungary	1	0,248138958
Japan/Singapore	1	0,248138958
Kazakhstan	1	0,248138958
Malaysia	1	0,248138958
Mexico	1	0,248138958
Morocco/Germany	1	0,248138958
New Zealand	1	0,248138958
Norway	1	0,248138958

Poland/UK	1	0,248138958
Slovenia	1	0,248138958
South Africa	1	0,248138958
South Korea	1	0,248138958
Tunisia	1	0,248138958
Turkey	1	0,248138958
Ukraine	1	0,248138958
United Arab Emirates	1	0,248138958
USA/Sweden	1	0,248138958
Vietnam	1	0,248138958
Argentina	2	0,496277916
Denmark	2	0,496277916
Finland	2	0,496277916
Italy	2	0,496277916
Lithuania	2	0,496277916
Spain	2	0,496277916
Switzerland	2	0,496277916
Czech Republic	3	0,744416873
France	3	0,744416873
Saudi Arabia	3	0,744416873
Canada	4	0,992555831
ESA	4	0,992555831
Singapore	4	0,992555831
Other Countries	60	14,88833747
India	5	1,240694789
Netherlands	6	1,488833747
Australia	7	1,736972705
Israel	7	1,736972705
Russia	7	1,736972705
United Kingdom	10	2,481389578
Japan	24	5,955334988
Germany	28	6,947890819
China	102	25,3101737
USA	147	36,4764268
Total	**403**	**100**

Table 5 : Global distribution of navigation satellites

Country	No. of Satellites	%
China	49	32,23684
ESA	28	18,42105
India	8	5,263158
Japan	5	3,289474
Russia	28	18,42105
USA	34	22,36842
Total	**152**	**100**

Table 6 : Global distribution of military satellites

Country	No. of Satellites	%
Canada	1	0,17482517
Chile	1	0,17482517
Colombia	1	0,17482517
Denmark	1	0,17482517
Egypt	1	0,17482517
Iran	1	0,17482517
Japan	1	0,17482517
Luxembourg	1	0,17482517
Norway	1	0,17482517
Qatar	1	0,17482517
South Africa	1	0,17482517
USA/Sweden	1	0,17482517
Australia	2	0,34965035
France/Italy	2	0,34965035
France/Italy/Belgium/Spain/Greece	2	0,34965035
Southe Korea	2	0,34965035
Thailand	2	0,34965035
Turkey	2	0,34965035
Mexico	3	0,52447552
United Arab Emirates	3	0,52447552
Spain	4	0,6993007
Other Countries	34	5,94405594
United Kingdom	6	1,04895105
Germany	7	1,22377622
India	9	1,57342657
Italy	9	1,57342657
Israel	11	1,92307692
France	14	2,44755245
Russia	105	18,3566434
China	140	24,4755245
USA	237	41,4335664
Total	**572**	**100**

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