SCIENCE & TECHNOLOGY POLICY INSTITUTE

Trends in Russian Space Development

Pavel Panko
Luba Katz
Dylan H. Cohen
Asha Balakrishnan, Project Leader

October 2024
Approved for public release; distribution is unlimited.
IDA Product 3001835

IDA SCIENCE & TECHNOLOGY POLICY INSTITUTE
1701 Pennsylvania Ave., NW, Suite 500
Washington, DC 20006-5805

About This Publication

This work was conducted by the IDA Science and Technology Policy Institute under contract NSFOIA-0408601, Project ET-20-5115, "Russian Space Development." The views, opinions, and findings should not be construed as representing the official positions of the National Science Foundation or the sponsoring agency.

Acknowledgments

The authors appreciate the contributions of Mr. Evan M. Wright, a former Science Policy Fellow, who conducted research in the initial phases of this study. The authors would also like to acknowledge Mr. Travis S. Cottom and Mr. Matthew A. Hallex, IDA Systems and Analyses Center; and Dr. Rebecca K. Miller, IDA Science and Technology Policy Institute, who served as technical reviewers for this work.

For More Information

Asha Balakrishnan, Project Leader
abalakri@ida.org, 202-419-5480

Kristen M. Kulinowski, Director, Science and Technology Policy Institute
kkulinow@ida.org, 202-419-5491

SCIENCE & TECHNOLOGY POLICY INSTITUTE

IDA Product 3001835

Trends in Russian Space Development

Pavel Panko
Luba Katz
Dylan H. Cohen
Asha Balakrishnan, Project Leader

Executive Summary

The former Soviet Union has a long and distinguished history in space exploration. As the first country to launch a satellite into orbit and send the first human into space, the space program is one of the country's proudest accomplishments. Since the collapse of the Soviet Union, the space program has been in transition. Russia remains a major space power despite recent economic hardships and technological challenges, and has publicly committed to maintaining its role as a global space leader. However, in recent years Russia has fallen behind other leading spacefaring nations that have adopted new concepts, such as reusable launch vehicles and proliferated small satellite constellations. Over the next decade, efforts to modernize Russia's space capabilities may help Russia maintain its stature as a global power, but it is not assured. This study, performed by the Science and Technology Policy Institute (STPI), attempted to assess how the Russian space program may evolve by examining its recent activities, public policy announcements, role of the commercial sector, challenges, and other key areas that are critical for a robust space program. Specifically, STPI addressed the following questions:

1. What space capabilities does Russia currently have and what capabilities does the country seek to preserve, develop, and acquire in the short term and longer term?
2. What are the biggest challenges facing the Russian space enterprise over the next decade?
3. Which Russian space companies are poised to emerge as industry leaders within Russia and in the world? Which companies may fail to maintain their current status as leaders?
4. To what extent is Russia extending the timelines and life of its systems in orbit?
5. How do these space capabilities and development efforts support military and national security objectives?

The study drew on several open sources in English and Russian languages. These included: (a) government documents, including priority statements regarding space (when available), annual reports from Roscosmos (Russia's state-owned space corporation), and budgets for the Federal space program; (b) analyses of satellites launched as well as launch vehicles based on Jonathon McDowell's *General Catalog of Artificial Space Objects* database (McDowell 2024); and (c) unstructured discussions with Russia space experts to contextualize the reporting and publications about the Russian space program. To characterize the commercial space actors, the study team compiled a list of companies from newspaper articles, reports, opinion pieces, and similar published literature, and TechSuccess documents (a rating scheme developed by the Western financial auditing firm PricewaterhouseCoopers to score domestic high-tech companies).

Conducting research on the Russian space sector comes with a number of challenges and limitations, including a dearth of credible information about Russia's space program.

As such, STPI was unable to gather suitable information with adequate confidence on Russia's space capabilities and development efforts that support military and national security objectives, rendering it challenging to answer the final study question.

Russia seeks to maintain or preserve a set of active satellite constellations, launch services, and some (limited) lunar exploration capabilities

Maintain existing constellations

After the annexation of Crimea in 2014, the lack of access to Western technology prompted the Russian space industry to begin transitioning to a domestic model of production for key systems, such as GLONASS (Russia's global navigation satellite system). The expanded international sanctions imposed on Russian companies in the wake of the invasion of Ukraine in 2022 have forced Roscosmos to shift to producing most spacecraft components domestically, which strongly affected satellite systems because most modern Russian satellites include microelectronics and other components produced by Western manufacturers. The shift in the production model has delayed the anticipated launch dates of most Russian satellites. In particular, GLONASS satellites had to be redesigned completely due to their heavy reliance on imported technologies and are now severely behind schedule when compared to the reported launch timeline prior to the war.

Launch services

Russia's launch services continue to be the most stable aspect of its space program. The Proton and Soyuz workhorse vehicles are highly reliable, and Roscosmos has extensive domestic expertise in producing successful launches. Despite the initial delays in production, Russia's relatively new cosmodrome, Vostochny, is now hosting launches and is being expanded to increase its capacity. That said, the competition between Roscosmos' subsidiaries, shortages of funding, constant changes in leadership, and lack of strategic consensus have produced an incoherent vision for Russia's future launch vehicles. Most tellingly, after being in development for decades, the most mature next-generation launch vehicle program, Angara, has only seen a handful of test flights. In addition, the status of the Baikonur cosmodrome based in Kazakhstan and currently leased to Russia is unclear. Despite these challenges, a reliable and trusted set of launch vehicles and its own spaceport enable Russia to maintain in-orbit presence through the use of domestic capabilities.

Lunar exploration

The launch of the Luna-25 lander in 2023 has signaled Russia's intention to continue the lunar exploration missions begun by the Soviet Union. However, the launch took much longer than expected based on public announcements, in part due to lack of resources assigned to the effort compared to the Soviet Luna missions. The timeline for the launch of Luna-25 was consistent with the deprioritization of scientific space missions by the Russian government, which has traditionally pursued more commercially aligned programs.

Russia seeks to develop a serial manufacturing capacity for satellite constellations, establish a new orbital space station, and build a stable workforce

Serial Manufacturing

As it searches for additional streams of revenue, Roscosmos has been attempting to reach parity with Western satellite services, focusing on large low-orbit small satellite constellations. Compared to the United States and China, Russia has yet to begin its transition to serial production methods to produce commercial constellations. Roscosmos leadership has repeatedly expressed the need for Russia to "catch up" to other major spacefaring nations in terms of satellite production.

Orbital Space Station

The sunsetting of the International Space Station (ISS) has accelerated the need for Roscosmos to transition to the next-generation space station. Roscosmos has announced the Russian Orbital Station (ROS) will be in service by 2027. ROS' expanded facilities seek to increase the range of possible applications, including facilitating production of materials for possible commercial use. Activating ROS by 2027 would require a new crewed spacecraft, a launcher for this new crewed vehicle, and the completion of a host of ground infrastructure projects, including monitoring stations and launch pads. Experts are dubious of Roscosmos' ability to achieve the intended plans for ROS by 2027, and public statements from Roscosmos current leadership suggest that it is likely to attempt to extend the lifetime of the ISS past the currently planned deorbiting date of 2031.

Economic Stability and a Sufficient Space Workforce

To carry out its future plans for the development of its space enterprise, Russia requires sufficient funding and highly skilled workers. The latest projections for the Russian economy in 2024 are favorable, suggesting that it will expand, due in part to the realignment of its trade partners and seemingly limited impact of the sanctions. However, if the Russian economy begins to decline, civil space programs may lose funding as the Russian government will likely shift its priorities to more critical necessities. In particular, civil satellite systems, experimental launch vehicles, and scientific missions are the most likely directions to be halted given historical trends.

Russia's space workforce is in a similarly precarious position. Roscosmos' workforce is aging, with many current specialists close to retirement. STPI's previous study found that Roscosmos may find it difficult to replace them and to maintain the necessary level of workers because the production of graduates in relevant fields is in decline, brain drain is high, and working in the space sector is no longer viewed as desirable.

Russia seeks to develop a domestic commercial space sector, regain its space services market share, and grow its partnerships

Seeking a Domestic Commercial Sector

Roscosmos' Director has gone on record of late in stating the need to develop the commercial space sector in order to assist Roscosmos in developing Russia's space services economy. Historically, Roscosmos has stifled competition from the commercial sector to the benefit of its subsidiary companies, many of which are holdovers from the Soviet Union. This shift is indicative of Russia's desire to capitalize on the *new space* trend observed in Western countries. At the same time, the barrier to entry for new space sector companies remains high due to the difficulties during the licensing process, shortage of components, and competition from Roscosmos-owned organizations. Consequently, the majority of new Russian entrants to the space sector are large private sector organizations for whom space services are a natural extension of their supply chain or products, and they have sufficient government contacts that can usher them through the licensing process.

Seeking to Regain a Substantial Share of the Space Services Market

Roscosmos is eager to regain the loss of launch revenue stemming from the war and the international competition. To increase its share of the domestic space services market, Roscosmos is expanding its pay-for-service capabilities—aimed at both government and private sector customers—and is attempting to monopolize the sale of Earth-observing data. Internationally, Roscosmos has engaged other BRICS countries with interest in prospective satellite constellations and the forthcoming Russian space station, attempted to market launch services to nations in the developing world, and is in the process of developing a new generation of launch vehicles that can feasibly compete in the international launch services market.

Strengthening Foreign Partnerships

Historically, Russia's partnerships with the United States have resulted in a number of highly successful space projects, most notably the ISS. Since the termination or pause of the ISS partnership, the Russian space program has not shown the capacity to carry on major space exploration projects independently. Moreover, the severance in relations with the West has brought Russia closer to China in terms of its strategic goals, which include the development of joint civil space capabilities and collaboration on military projects. Russia was the first partner with China on the International Lunar Research Station (ILRS). While China is a logical partner for Russia's deep space ambitions, the Russia-China space partnership has yielded few tangible results despite the strong rhetoric from both sides. China does not view Russia's contributions as critical to its strategic space projects, while Russia does not want to lose face by accepting a role as China's junior partner. The state of Russia's current capabilities suggests that it will have to accept China's leadership to realize its major deep space projects.

Russia has sought new foreign partners to offset its dependence on Western-produced technologies and loss of revenue from severed contracts with Western countries (Vedomosti 2023b; Zak n.d. dd). As part of this trend, Roscosmos is engaged in a marketing campaign across the developing world, seeking both customers for its space services and partners to collaborate with on space projects.

Russia lost significant revenue and production capacity due to the severance of partnerships after its invasion of Ukraine, and its historical posture makes the prospect of adapting to the current circumstances difficult

Prior to the conflict with Ukraine, Russia maintained a significant share of the international space services market, particularly in the area of launch services. In addition, Russia facilitated the majority of the crewed flights to the ISS, and sold RD-180 and RD-181 rocket engines to the United States for use on the Atlas V and Cygnus U.S. launch vehicles. STPI estimates that Russia's average revenue (adjusted in constant 2020 dollars) from 2006 to 2023 was approximately $1B per year for a total of $18.5B (Figure ES-1). The invasion of Ukraine severed these revenue streams, leaving Roscosmos with only a small proportion of its funding from sources other than the Russian government. STPI estimates that in 2021 the revenue from foreign sales and services accounted for an average of 30 percent of Roscosmos' total (with a peak of 57 percent in 2020) revenue from non-military projects.

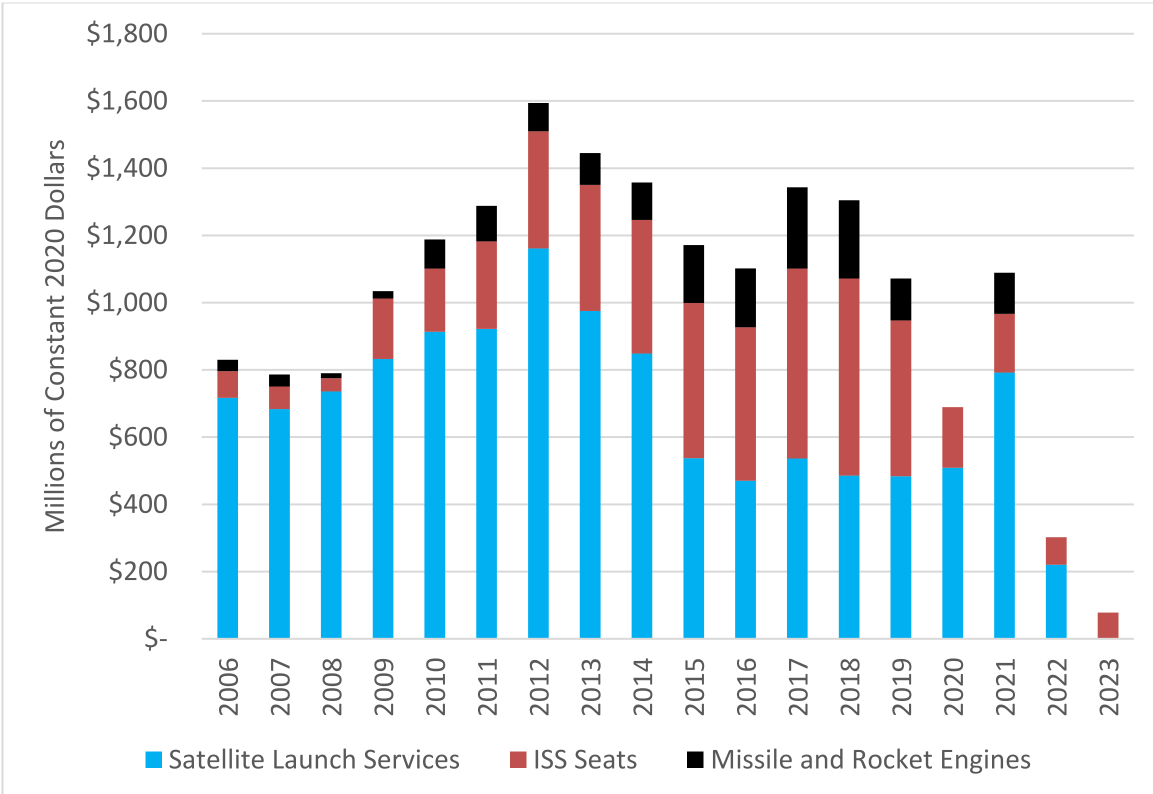


Figure ES-1. Combined Estimated Revenue from Rocket Engine Imports, Sale of ISS Seats, and Launch Costs of Foreign Payloads

STPI concluded that many aspects of Russia's civil space sector—its programs and priorities, manufacturing and production capabilities, supply of talent, funding, and partnerships—are facing challenges. The conditions for maintaining a leadership position remain unfavorable for Russia as its space sector is hampered by an obsolete industrial base, weak to nonexistent commercial sector, and loss of historical partnerships.

Sanctions placed on Russia from its invasion of Ukraine have created a shortage of key spacecraft components including microelectronics. While Russian manufacturers are capable of producing some of the required technologies, much of the software and microelectronics previously supplied by Western firms cannot be easily replaced by domestic substitutes, which has created further delays due to the need to redesign space systems across the board. Finally, Russia's commercial space sector is hampered by Roscosmos' historical priorities. Roscosmos is a regulator of commercial space companies overseeing their activities. At the same time, Roscosmos, a state-owned enterprise, is both a supplier to the Russian government as well as the biggest customer of space services in the Russian market. This dual role carries an inherent conflict of interest, which Roscosmos has exploited to its own financial advantage. First, its subsidiaries are prioritized in competitions for government contracts, stifling competition. Second, new ventures in the space sector are required to obtain permits from Roscosmos, giving it full control over any potential competitor. As a result, Russia's non-Roscosmos commercial space sector companies have struggled to compete with Roscosmos and its subsidiaries to the detriment of the space sector at large.

Russia has been unable to stimulate a vibrant commercial space sector and as a result no company or entity is poised to become an industrial leader

Roscosmos' role as both a regulator of the space industry and a corporation in its own right places constraints on the development of Russia's private space sector. Throughout the years, Roscosmos has guarded the interests of its subsidiaries against private sector competition, including in the development of launch vehicles, remote sensing services, and fulfillment of military contracts.

A picture of a relatively weak commercial space sector emerged from this study. Relative to other technology sectors in Russia, investments in space and space-adjacent companies are small by Russian technical industry standards. Of the 117 space and adjacent companies established within the different application areas between 2010 and 2020, 15 percent are on the path to bankruptcy based on absent revenue. Furthermore, the active space companies appeared to be more financially volatile and smaller in terms of revenue than other tech sectors. Companies specializing in launch services or products appeared to be more vulnerable, presumably due to a combination of the Ukraine war and competition from Roscosmos' subsidiaries.

STPI has not identified any Russian companies poised to emerge as a leader in the global space industry and to compete for the global market share.

The life expectancy of GLONASS satellites has increased over the decades demonstrating high quality engineering, but the pace of replacement has waned suggesting the full functionality of the GLONASS system may not be maintained in the future.

Two trends emerged from investigating lifetime performance of GLONASS satellites over time: (1) as new generations of GLONASS satellites were introduced, their expected lifetimes increased but Russia often relied upon those satellites beyond their planned life expectancy; and (2) given the longer lifetimes for subsequent programs, fewer satellites were launched each year resulting in a constellation that is past its prime. In addition, because of supply chain disruption due to international sanctions, Roscosmos is redesigning future GLONASS satellites to rely primarily on domestically produced components. These trends suggest that Russia is struggling to manufacture enough satellites to maintain full functionality of the GLONASS constellation and to replace GLONASS satellites in a timely manner, without relying on in-service satellites to overperform their expected lifetime.

Contents

1. Introduction

Russia has been the leader in many great achievements in space. It launched the first satellite into orbit in 1957, opened up the possibilities of human space exploration by sending the first cosmonaut to space in 1961, and placed a space station into orbit in 1971. Generations of Russians have looked to the space program as a source of inspiration and pride. After the fall of the Soviet Union, the Russian Federation and other partner nations collaborated and built off the Russian Mir module to construct the International Space Station (ISS). In the past 25 years, many spacefaring nations continued to rely on Russia's Soyuz vehicle to launch astronauts and payloads into orbit.

Russia remains a major space power despite recent economic hardships and technological challenges, and has publicly committed to maintaining its role as a global space leader. However, in recent years Russia has fallen behind other leading spacefaring nations that have adopted new concepts, such as reusable launch vehicles and proliferated small satellite constellations. Over the next decade, efforts to modernize Russia's space capabilities may help Russia maintain its stature as a global power, but it is not assured.

The Science and Technology Policy Institute (STPI) assessed Russia's current space capabilities, future challenges, and the presence and viability of the future Russian space enterprise guided by the following questions:

1. What space capabilities does Russia currently have and what capabilities do they seek to preserve, develop, and acquire in the short term and longer term?
2. What are the biggest challenges facing the Russian space enterprise over the next decade?
3. Which Russian space companies are poised to emerge as industry leaders within Russia and in the world? Which companies may fail to maintain their current status as leaders?
4. How do these space capabilities and development efforts support military and national security objectives?
5. To what extent is Russia extending the timelines and life of its systems in orbit?

A. Data Sources and Methodology

We drew on several open sources to address these research questions. These included government documents, such as priority statements regarding space (when available), annual reports for Roscosmos (Russia's state-owned space corporation), and budgets for the Federal space program. These documents provided valuable insights regarding the investments and priorities for space that the Russian government was publicly discussing. We also relied on Russian and English language reports, newspaper articles, and websites discussing Russian space activities.

Second, analyses of satellites launched as well as launch vehicles were based on Jonathon McDowell's *General Catalog of Artificial Space Objects* database (McDowell 2024). We used this source to analyze data on Russian rocket launches as well as the payloads carried on these rockets to understand the frequency, breadth, and scope of the Russian launch sector. Though McDowell categorizes the payloads into application areas, we refined and merged some categories.

Third, we had a small set of unstructured discussions with Russia space experts, when feasible. These conversations provided context on the reporting and publications about the Russian space program coming out of the Russia.

Fourth, to identify Russian commercial space companies, the study team drew on several sources of data to identify private companies including newspaper articles, reports, opinion pieces and similar published literature, and TechSuccess (ТехУспех).[1] TechSuccess is a rating scheme developed by the Western financial auditing firm PricewaterhouseCoopers (PwC) to score domestic high-tech companies. TechSuccess uses experts to rate companies for innovativeness, growth, and export potential based on financial data, technologies owned, leadership, number of employees, products/services, customers, and other indicators. From this source we obtained company names, main products/services, and revenue levels for 2018, 2019, and 2020—the most recent years available. We also obtained information about companies included in the "space and aviation" category from the Skolkovo innovation center, which maintains a database of companies it funded. Finally, we used data from the Russian Science Foundation, a research and development (R&D) funder similar to the National Science Foundation in the United States to find commercial recipients of grants on the topics related to space.

The list of companies gathered from these sources was reviewed to identify all companies that offered space or space-adjacent products. For these companies, we collected additional data, including their website addresses, whether the company was active, revenue over the most recent 3 years to the extent available, number of employees, evidence of partnerships or business relationships with Roscosmos and the Russian Ministry of Defense, and foreign customers.

---

[1] The rating was developed by PwC in 2013 (http://ratingtechup.ru/en/about/)

B. Limitations

Conducting research on the Russia space sector comes with a number of challenges and limitations. In October of 2021, the Russian government issued a decree that limited Russian nationals from sharing information on domestic space activities with foreign citizens (Reuters 2021). Consequently, STPI did not contact any Russian residents knowledgeable about the space sector to avoid putting them at risk. Furthermore, many Roscosmos websites and other information about the agency—including its financial status, annual reports, and plans—became inaccessible.

We had no way to validate the accuracy of information found on public Russian websites beyond a small number of interviews. The Russian government is protective of the reputation of its space sector and any negative data may be suppressed and positive data exaggerated. Similarly, we had no way to confirm the information reported in news articles or English-language websites. Finally, the space activities and the geopolitical situation are highly dynamic.

Regarding the Russian commercial companies, STPI could not verify the accuracy of information, other than to note whether the websites were working and if the revenue data were similar across TechSuccess, Skolkovo, and other public sources of financial information. For some companies, it was difficult to reconcile the names from different sources, due to the use of full names, acronyms, and transliterations. Therefore, it is possible that in some cases the same companies remain on the list under slightly different names.

C. Organization of Report

The report is organized into eight chapters. Chapter 2 contains a background of Russia's space history, national policies, space budgets, priorities, and challenges. Chapter 3 discusses Russia's launch sector; Chapter 4 focuses on Russia's civil space systems, and Chapter 5 briefly touches on the future of Russian space exploration. In Chapter 6, we turn our attention to Russia's commercial space sector. Chapter 7 provides a lifetime analysis Russia's global navigation satellite system—GLONASS. Chapter 8 is another analysis investigating the revenue from space services Russia has benefited from over the years. The report culminates in a final chapter that summarizes the findings from the study.

2. Space Priorities and Challenges

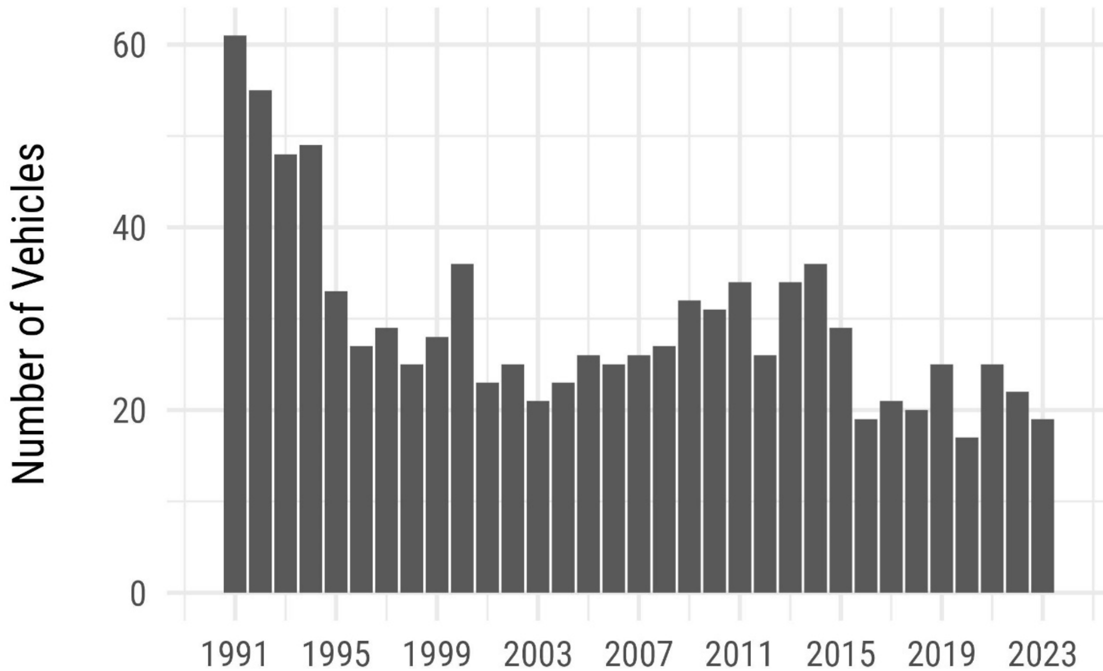
A. Background

On October 4, 1957, the Soviet Union shocked the world as it successfully launched the first artificial satellite, Sputnik 1, into Earth's orbit. For decades, the Soviet Union continued to maintain its leadership in space, becoming the first nation to launch and return a living organism into orbit, reach the surface of the Moon with a spacecraft, and most importantly, send the first human being into space (Aliberti and Lisitsyna 2019). Throughout its existence, the Soviet Union maintained space as a priority, devoting significant funds to the realization of its space program.

After the dissolution of the Soviet Union in 1991, the Russian space sector experienced a period of decline due to a steep drop in government funding (Zak n.d. x). The space sector trends are reflected in Figure 1, which describes the Russian launch activity from 1991 onward. Lack of funding led to delays or outright cancellations of space programs outside of launch and propulsion (Mathieu 2010), which resulted in the degradation of on-orbit capabilities and an exodus of experts from the space workforce (Aliberti and Lisitsyna 2019). Moreover, the fragmentation of the Soviet Union, which distributed its space industry among its constituent republics, resulted in Russia having to work across foreign borders to maintain ties with key organizations abroad (Mathieu 2010).

Consequently, the 1990s and early 2000s were a challenging period for the Russian satellite sector as developers struggled to maintain on-orbit capabilities by repurposing Soviet programs and developing novel customer bases (Zak n.d. t). In the early 1990s there was a great deal of activity, but that activity dipped later in the decade as cooperation with the United States and other allied partners gained traction, particularly with the ISS. Although certain companies within the Russian space industry, such as launch vehicle and propulsion manufacturers, fared better due to foreign commercial interest, satellite manufacturing was deprioritized. As the economic conditions improved in the mid-2000s, the Russian government renewed its interest in funding civil space programs, while protecting the struggling space sector organizations from foreign competition (Zak n.d. t). The launch trend picked up again in the early 2010s as the commercial satellite sector began flourishing with more missions and the United States lacked transportation for its astronauts to and from the ISS.

Figure 1 describes the number of launch vehicles Russia placed in orbit over time.



Source: McDowell (2024)

Figure 1. Number of Russian Launches Over Time, 1991–2023

During the 2010s and 2020s, expansion of the Russian civil space sector came into conflict with the ambitions of the Russian government. The war against Georgia and later Ukraine undermined Russia's geopolitical standing and resulted in economic losses for the space sector due to the international sanctions imposed by the United States and its allies (Aliberti and Lisitsyna 2019). Nevertheless, despite the military annexation of Crimea in 2014, Russia's launch services were still highly sought after in the West, and Russia was able to maintain a place in the international launch services market (Aliberti and Lisitsyna 2019).

The invasion of Ukraine in February 2022 precipitated a major shift in Russia's relationship with its most important international partners in space, including the United States, the European Union, and the United Kingdom. Russia's space program had to change their production models due to lack of access to Western space-grade components (de Selding 2023). The changes to the component base along with the steep drop in revenue from severed contracts with former Western partners has caused delays to many space programs (RIA Novosti 2023g).

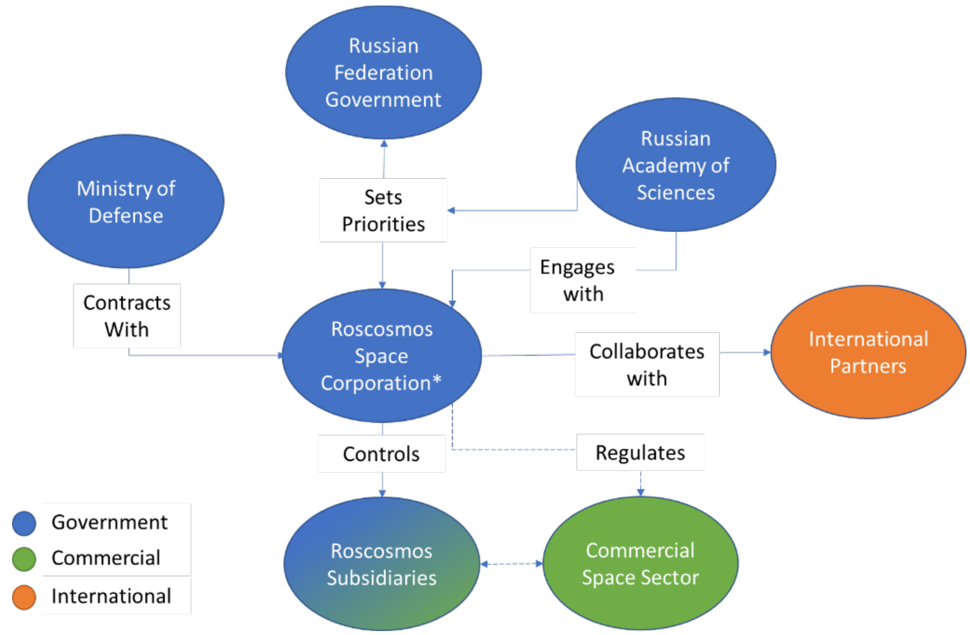
Russia's space agency, Roscosmos, has addressed its challenges and outlined a set of priorities, both through the media (Cordell 2022; RBK 2023a) and through action on the international stage (Interfax 2023b). Roscosmos' ability to accomplish its stated goals is best understood in the context of Russia's space enterprise and policy landscape. The following sections discuss the structure of Russia's space sector as well as the legislation and funding for space activities.

B. Russian Space Enterprise

The Russian space enterprise consists of two major components: (1) the civil program, overseen by the Prime Minister and centered around Roscosmos, and (2) the defense program, overseen by the Ministry of Defense and embedded within the armed forces. The focus of this report is on the civil arm of the Russian space sector.

Roscosmos is a state-owned corporation formed in 2015 through a merger of the Russian Federal Space Agency and the United Rocket Space Corporation. It controls all aspects of Russia's rocket and space industry, including strategic planning and policymaking, industrial production and launch of spacecraft, training of cosmonauts, collaboration with international space agencies, and operation of the ISS. Roscosmos also controls dozens of subsidiaries and (importantly) regulates the commercial space sector, including issuing licenses to start-up companies.

Roscosmos is organized around eight areas: (1) human space flight, (2) launch systems, (3) unmanned spacecraft, (4) rocket propulsion, (5) military missiles, (6) space avionics, (7) special military space systems, and (8) flight control systems (Aliberti and Lisitsyna 2019). Figure 2 notionally describes how Roscosmos' priorities are established and how it carries out those priorities. The central government establishes the priorities of Roscosmos through a central budgeting process, described in the next section. The development of priorities is done in collaboration with the Russian Academy of Science, which engages both with the budget process and directly with Roscosmos. Finally, the Ministry of Defense contracts with Roscosmos to execute some of its missions and, as a result, the lines between the civil and military space programs can be blurred.



Source: Aliberti and Lisitsyna (2019)

* Indicates that Roscosmos has reorganized and changed names a few times.

Figure 2. Roscosmos Space Corporation Governance, Oversight, and Partners

STPI used public sources (including the Roscosmos website that was accessible until the fall of 2022) to characterize the structure of the agency, which at the time was composed of 85 organizations. Of these, 74 appeared to be active, 6 had been liquidated or likely liquidated, and the status of the remaining 5 was either not available or contradictory depending on the source. The number of Roscosmos components differed depending on the year or the source, but whether these discrepancies were due to mergers and acquisitions or inaccuracies in the data could not be determined.

A review of the available information on the activities of each component revealed that 67 of 85 Roscosmos components were involved in research, development, and manufacturing. The remaining were service providers, training units, suppliers, and financial/management organizations. Table 1 presents the Roscosmos organizations by the focus areas, to the extent these could be determined.

Table 1. Roscosmos Organizations by Focus Area

Organization Focus Areas	Number of Organizations
Guidance, Navigation and Control	16
Propulsion	9
Economics, Policies, Management	7
Launch Vehicles	7
Missiles	6

Organization Focus Areas	Number of Organizations
Satellite Communications; Remote Sensing	6
Ground Infrastructure	5
Spacecraft Integrator	5
Materials	3
Test Infrastructure	3
Purchasing	3
Power supply and storage	2
Training	2
Prototypes	1
Transportation	1
Human Space Flight	1
Unknown	8

Note: STPI Coded these organizations by focus area based on limited information. Each organization was coded into a single focus area.

Source: Roscosmos Annual Report (2020)

STPI used an open source database to gather financial data on individual Roscosmos components for 2020, the most recent year available. According to the database, revenue for 79 components with data ranged from ₽33B to nearly ₽400B. The top 10 organizations by are shown in Table 2 and includes well-known entities such as Energia, Progress, and Reshetnev.

Table 2. Top 10 Roscosmos Organizations with the Highest Assumed Revenue, Average from 2011 to 2020

Short Name	Full Organization Name	Focus area	Average Revenue, billion Rubles - ₽
MITT	Corporation Moscow Institute of Thermal Engineering	Intercontinental missiles	56.7
Progress	Rocket and Space Center Progress	Launch vehicles, remote sensing and scientific spacecraft	33.9
TSENKI	Ground-based space infrastructure operation center	Cosmodromes	33.7
Energia	S.P. Korolev Rocket and Space Corporation Energia	Launch vehicles, satellites, automatic interplanetary stations, manned space vehicles, manned orbital stations, ballistic, cruise and other missiles	32.3

Short Name	Full Organization Name	Focus area	Average Revenue, billion Rubles - ₽
Khrunichev	Khrunichev State Space Research and Production Center	Launch vehicles, orbital modules	30.3
Votkinsk Plant	JSC Votkinsk Machine Building Plant	Missiles	30
Reshetnev	Academician M.F. Reshetnev Information Satellite Systems	Satellites	24.9
Titan-Barrikady	Federal Research and Production Center "Titan-Barrikady"	Missiles and weapons systems	20.8
Pilyugin	Academician N.A. Pilyugin Research and Production Center of Automatics and Instrument Engineering	Control systems	16.6
Lavochkin	Lavochkin Research and Production Association	Landers, scientific payloads, rocket upper stages	14.8

Note: Average revenue in raw Rubles between 2011–2020

Sources: E-Dossier, public websites of Roscosmos organizations, when available

Operating revenue for these subsidiaries comes from direct Roscosmos funding but also from other sources such as the Ministry of Defense, other Roscosmos subsidiaries, and other State-owned Enterprises (SOEs).

C. National Space Policies and Funding

In response to the new economic and geopolitical challenges that faced the Russian Federation after the collapse of the Soviet Union, the Russian government adopted new legislation to govern and regulate space activities. The first major piece of legislation adopted by the Russian government was the 1992 *Presidential Decree on Space Activities Administration Structure in the Russian Federation*, which formed the governmental organization responsible for regulating and administrating space activities: Roscosmos. The second major piece of legislation was the *Law of Space Activities* passed in 1993, which became the main federal law governing space activities conducted by Russia and defined the parameters for government financing for space activities.

The *Law on Space Activities* has been amended several times throughout the years and continues to serve as the main legislation regulating space activities in the Russian Federation (Buzko 2021). The *Law on Space Activities* includes provisions for empowering Roscosmos to draft long-term planning documents that lay out the Federal Space Program (FSP), which must be approved by the President of the Russian Federation, with input from government stakeholders from the Ministry of Defense, the Ministry of Finance, the

President’s Security Council, and the Russian Academy of Sciences (Aliberti 2019). FSP documents typically outline 10-year plans for development of the major components of Russia's space infrastructure, including the following (Roscosmos 2021):

- Development, expansion, and maintenance of the Russia's national satellite constellation;
- Development of launch systems;
- Development and maintenance of Russia’s spaceports;
- Scientific and technical aspects of Russia’s manned space flight program, including the training of cosmonauts and the use and development of modules for the ISS;
- Deep space exploration and other scientific missions in space; and
- National socioeconomic development with respect to space.

FSPs are funded through both the federal budget as well as extra-budgetary sources and profit from commercial activities such as launch services and satellite development provided to foreign customers (Aliberti 2019). Beyond the federal space program, several planning documents have been adopted to guide specific programs, called Federal Targeted Programs (FTPs).

As part of President Vladimir Putin's second term in office during 2004–2008, the space sector received additional stimulus, due in part to the growth of Russia's energy export business at the time (Aliberti 2019). During this period, the Russian government adopted the FTP on the Development of Russia’s Cosmodromes (2006–2015), which allocated funding specifically for developing ground infrastructure at the new Vostochny cosmodrome and the Dombarovsky launch site, as well as municipal enhancements and accommodations for the workforce in those regions; the FTP on the Development of Cosmodromes was renewed for 2017–2025 (The Government of Russia 2017). In addition, the GLONASS system, Russia's primary system for satellite navigation, had been severely depleted due to lack of funding in the 1990s (GLONASS Consumer Application Center n.d.; Mathieu 2010; Zak n.d. x). Given the necessity of a satellite navigation system for both civil and defense-related goals, the Russian government adopted an FTP on the Development of GLONASS (2002–2011), which was renewed for 2012–2020. Subsequent to the two FTPs on GLONASS, funding for development and maintenance of the system was folded into the federal budget.

Table 3 shows the total federal budget allocated to space activities during years 2014–2024, along with projected budgets for 2025–2026. The trend in federal funding over the years has been relatively stable, despite numerous cuts to spending on space. Data for 2023 to 2026 are speculative based on documents of expected budgets for space activities. The future GDP deflators and exchange rates are estimated based on data from 2022. It is important to be aware that the budget figures in Table 3 do not include military space programs, personnel, or maintenance for military space assets (e.g., Plesetsk cosmodrome), or extra-budgetary funding (Luzin 2021b).

Table 3. Total Federal Budget of Space Activities, 2014 to 2026

Year	Russian FSB Budget (Billions of Current Rubles)	GDP Deflator, World Bank Data, Base Year = 2016	Russian FSB Budget (Constant 2016 Rubles)	Exchange Rates Rubles to Dollars	Russian FSB (Billions of Constant 2016 Dollars)
2014	178	90.662	196.334	38.378	5.116
2015	166	97.234	170.721	60.938	2.802
2016	164	100.000	164.000	67.056	2.446
2017	173	105.350	164.215	58.343	2.815
2018	181	115.883	156.192	62.668	2.492
2019	195	119.664	162.956	64.738	2.517
2020	198	120.739	163.990	72.105	2.274
2021	203	143.668	141.298	73.654	1.918
2022	217	166.374	130.429	68.480	1.905
2023	258	*166.374*	*155.072*	*85.160*	*1.821*
2024	286	*166.374*	*171.902*	*85.160*	*2.019*
2025	272	*166.374*	*163.487*	*85.160*	*1.920*
2026	258	*166.374*	*155.072*	*85.160*	*1.821*

Note: Data in *italics* is future data and assumed.

Sources: Russian FSB budget taken from FCP economy website, GDP deflator from World Bank (NY.GDP.DEFL.ZS), Exchange rates taken from International Monetary Fund (ENDA_XDC_USD_RATE)

D. Priorities

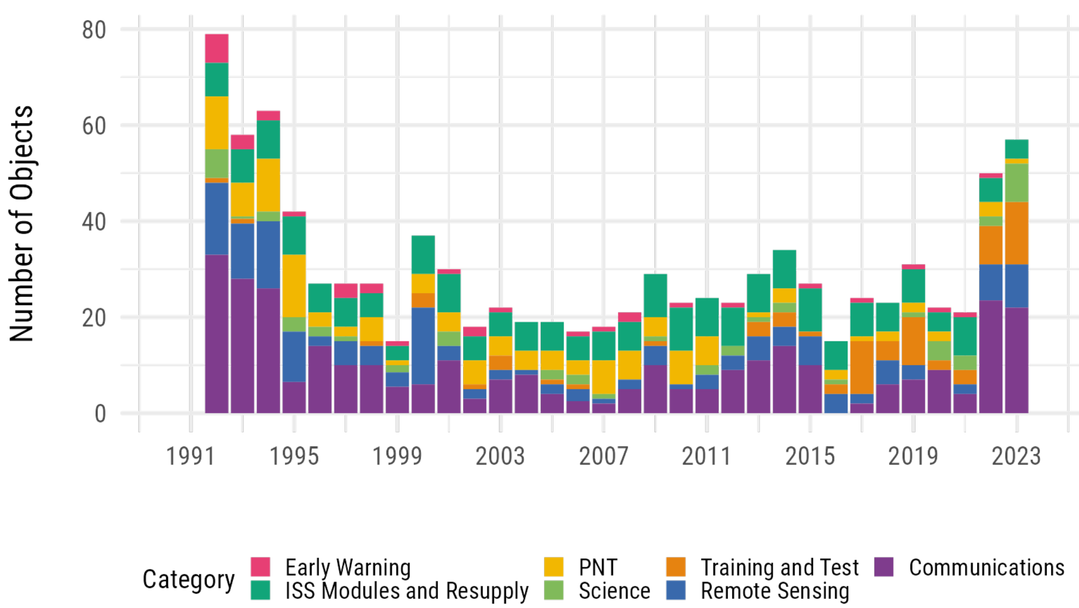
To understand the state of the space sector in Russia, STPI examined official policy documents describing space priorities as well as interpretation and evaluation of these priorities in published literature. In addition, STPI attempted to look beyond the official statements to validate and clarify the priorities by interviewing a few knowledgeable individuals originally from Russia but currently residing in Europe or the United States.

1. Launch Infrastructure and Vehicles

As a result of the current economic and geopolitical challenges facing Russia, the Russian government and Roscosmos are prioritizing the preservation of their launch capabilities, including both infrastructure and vehicle development. Historically, Russia has had a robust launch infrastructure for both domestic use and for providing access to space as a service to other countries. Russia seeks to preserve and maintain a launch program that is suitable to the needs of Roscosmos' main customers and is largely independent from foreign organizations or states (Zak n.d. z). It seeks to ensure uninterrupted deployment and maintenance of on-orbit space assets through the stable development and exploitation of launch vehicle programs that can perform light-, medium-, and heavy-lift operations (RIA Novosti 2023a; Pyadushkin and Klotz 2021; Lukin et al. 2021). Subsequent sections in this report will go into depth about Russia's intentions towards launch vehicle programs, launch sites, and their launch services programs.

2. Key Satellite Programs

Russia has a number of legacy programs that support its communication, remote sensing, and position, navigation, and timing (PNT) missions. Figure 3 describes the number of these payloads launched over time. Russian payloads are predominantly communication payloads followed by remote sensing, training, and test payloads (McDowell 2024). Chapter 4 will discuss the major programs Russia's civil space program continues to support as well as the current outlook for future programs.



Source: McDowell (2024)

Figure 3. Annual Number of Russian-Owned Payloads, by Payload Category, Launched by Russia, 1991 to 2023

3. Space Exploration

Russia boasts a series of firsts when it comes to human space flight (termed manned spaceflight in the Russia translation). Russia saw the first human in space, Yuri Gagarin, in 1961. Russia is also responsible for the first woman in space in 1963 and the first spacewalk or extravehicular activity (EVA) in 1965. In more modern times of the Russian

Federation, Russia joined the ISS, the most lauded international scientific partnership in this generation. Russia signed the International Governmental Agreement (IGA) on Space Station Cooperation with the United States, Japan, Canada and 11 participating European Space Agency (ESA) countries.

Since 2022, Russia's commitment to continue working with other nations on the ISS has been in question. In April 2022, the then head of Roscosmos, Dmitry Rogozin, threatened withdrawing from the ISS in response to sanctions from the West due to Russia's invasion of Ukraine (Wall 2022). In July 2022, Rogozin was dismissed from his position and his successor Yury Borisov seemingly confirmed Rogozin's plan to withdraw from the ISS "after 2024" and transition to Russia's own Orbital Space Station (Foust 2022). However, Russian space officials simultaneously informed the National Aeronautics and Space Administration (NASA) that the date of "after 2024" actually meant "not earlier than 2028." Luzin (2022b) suggested that Roscosmos was issuing conflicting and vague deadlines to stall for time to build its own space station, while trying to avoid antagonizing the Kremlin.

4. Space Services

Despite owning a major share of the Russian space sector, Roscosmos has struggled to turn a profit in recent years (Luzin 2021a). Prior to Russia's conflict with Ukraine, Roscosmos had a strong position in the launch services market, and was in the process of expanding its base of international customers. However, due to Russia's conflict with Ukraine and the incendiary rhetoric of its management, Roscosmos has lost the majority of its international revenue stream (Zak n.d. dd). Since his appointment in 2022, Roscosmos director Yuri Borisov has made repeated public overtures about creating a space services market with Roscosmos at its center. According to Borisov, this market would cater primarily to domestic government and private customers, providing services such as telephony, high-speed internet, and imaging of the Earth's surface (Luzin 2021c; RBK 2023a; RIA Novosti 2023a; Russian News Agency TASS 2023d). As part of this market, Borisov seeks to promote private space businesses that have been historically marginalized due to competition with Roscosmos and to develop cost-effective launch systems that would help Russia regain its position in the launch services market (RIA Novosti 2023e).

5. Satellite Production

Roscosmos intends to shift its satellite production model away from custom-built, large satellites to semi-automated small satellite assembly lines. This shift is due in part to Roscosmos' stated perception that Russia's share of in-orbit satellites is shrinking, as its foreign competitors and partners outpace its yearly satellite production capacity (RBK 2023a), as well as Roscosmos' desire to stay competitive in the satellite services market by modernizing its offerings. To do so, Roscosmos is encouraging both its subsidiaries and private space companies to invest in small satellite manufacturing and is building factories to increase its satellite manufacturing capacity (RBK 2023a; RIA Novosti 2023a). Roscosmos director Borisov has stated that modernizing Russia's satellite production model is coming "too late" and that Russia's private sector will need to contribute in order to reach Roscosmos' goals for the number of satellites in orbit (RBK 2022a).

6. Commercial Space Sector

Roscosmos acts as both a provider of space services, being the owner of the majority of Russia's major space companies, and a regulator of Russia's space sector. In this contradictory role, Roscosmos has treated its space subsidiaries preferentially, thereby creating an unfavorable climate for other commercial space companies (Vidal and Privalov 2023). Consequently, Russia's non-Roscosmos commercial space sector is relatively small and underdeveloped compared to that of the other major spacefaring nations (Vidal and Privalov 2023).

To offset the recent loss of foreign contracts, Roscosmos plans to outsource a subset of space services to the private sector (RIA Novosti 2023a; Russian News Agency TASS 2023d). To do so, Roscosmos now seeks to incentivize new and emerging Russian space companies without harming its subsidiaries (Luzin 2021c). Chapter 5 will describe the state of Russia's commercial space industry and characterize the types of services provided by private sector actors.

7. Partnerships

Due to its increasingly isolated position, Russia has sought new foreign partners to offset its dependence on Western-produced technologies and loss of revenue from severed contracts with Western countries (Vedomosti 2023b; Zak n.d. dd). As part of this trend, Roscosmos is engaged in a marketing campaign across the developing world, seeking both customers for its space services and partners to collaborate with on space projects (Interfax 2022b; Interfax 2023b; Russian News Agency TASS 2023o; Zak n.d. r).

Moreover, the severance in relations with the West has brought Russia closer to China in terms of its strategic goals, which include the development of joint civil space capabilities and collaboration on military projects (Harvey 2021; Jones 2021). However, despite frequent rhetoric about collaboration on major civil projects in space, the China-Russia partnership has not yet resulted in overt accomplishments. Experts interviewed by STPI suggested that any progress made on this front remains behind the scenes.

E. Challenges

A number of sources, both domestic and foreign, concluded that despite its successful past, the Russian space sector suffers from many deficiencies. These include poor management and corruption, obsolete industrial base and absence of healthy private sector, declining workforce, and lack of funding stemming from slashed government budgets and loss of commercial revenue.

1. Corruption

Roscosmos bureaucracy, top-down management, and low pay foster corruption (Moltz 2020), of which Vostochny is the most emblematic example because of its scale. According to an exposé in the Moscow Times published in 2018, 17,000 violations have been uncovered since construction had begun 4 years before, amounting to ₽10 billion ($152 million) in losses or 10 percent of the construction budget (The Moscow Times 2018a; Moiseev et al. 2021; The Moscow Times 2018b). More than 140 criminal cases have been brought against 1,000 officials and contractors (The Moscow Times 2018b). In 2019, the opposition leader Alexei Navalny also alleged widespread corruption across the Russian space enterprise, starting with personal enrichment of its then-director Rogozin (Berger 2021). In 2021, Russia's Federal Security Service declared nearly all information about Roscosmos off-limits to foreigners on national security grounds—probably at least in part as an effort to shield the agency plagued with corruption from scrutiny (The Moscow Times 2022).

2. Space Specific

a. Poor management

The Russian space sector remains a highly centralized bureaucracy, where programmatic and operational decisions are shrouded in secrecy (Vidal 2023) and funding for projects is decided based on politics. An enormous and questionable investment in building Vostochny—described as "a cosmodrome without a mission," and "a sacrifice to the political altar"—is an especially poignant example of failed government-driven decision-making (Bodner 2019; Zak n.d.a.). An effort to piece together space sector priorities unearthed a series of vaguely worded and constantly updated official policy documents, suggesting that the space sector lacks long-term vision and strategy. As noted in one Russian-language source, even space experts cannot identify Russia's space goals and priorities (Жданов 2022).

Government control of the space sector is also apparent in the choice of Roscosmos leadership. Anatoly Zak points out that as an R&D-focused agency with a technical workforce, Roscosmos should be led by "an intelligent technocrat and an experienced administrator" rather than "commands-barking military men" or the political hacks who ran Roscosmos for the past 20 years (Zak n.d.a; Varlamov.ru 1 июня 2020).

To illustrate his point, Zak describes how in 2009 Roscosmos leadership was rushing the launch of the unprepared and untested Phobos-Grunt spacecraft, and only the refusal of its own scientists and of the Russian Academy of Sciences to go along stopped Roscosmos from moving forward. However, even the most influential scientists could not prevent the disastrous launch of Phobos-Grunt 2 years later. A controversial restructuring of the Russian Academy of Sciences in the 2010s diminished its influence (Stone 2014) and ensured that its experts play a minimal role in steering the scientific direction of Roscosmos or evaluating its needs (Уваров 2021). In another clear example of questionable investment, Roscosmos has begun construction of new, lavish headquarters on the premises of the Khrunichev Space Center in Moscow (Vidal 2023).

Finally, a group of Russian industry experts said in published interviews that defense-related technologies are the strongest components of the space sector. However, placing military and civilian space programs within the same agency makes the structure of Roscosmos inflexible and unable to adapt to changing market conditions (Платформа 2019).

b. Obsolete industrial base

The Russian space sector suffers from many structural and technological deficits, prompting repeated but unmet modernization goals from every new head of Roscosmos over the past decade. In his analysis of the sector, Vidal notes that much of the space infrastructure was built during the Soviet times, in closed cities scattered throughout the vast territory (Vidal 2023). The operating facilities were organized around these entities and often had redundant tasks.

A Russian-language report of expert interviews conducted by authors also concluded that the space sector has a "technological culture" of the 20th century (Платформа 2019). Many tasks, such as grounding of engine blades, are still performed manually. The experts also reported that the space program lacked the capacity for serial production of satellites, which is required for orbital constellations. Finally, this and other reports concluded that Roscosmos has not been successful in developing alternative suppliers or establishing domestic production for vital parts embargoed in 2014 (Платформа 2019; Moltz 2020).

c. Workforce problems

A recently completed study by STPI (Katz 2023) concluded that Russia's scientific workforce is depleted and unlikely to meet the needs of the space sector, although recent public statements from Roscosmos leadership suggest that the agency is unlikely to maintain all of its programs. But the fact remains that low salaries, loss of Soviet-era prestige, onerous security requirements, absence of commercial companies, and oppressive climate make the space sector unattractive for the new generation of scientists, who instead seek jobs in IT, finance, and other more lucrative industries.

d. Funding shortages and emergence of new powers

While it is difficult to determine the amount of government funding for Russian space programs, recent literature suggests a downward trend. According to Russian-language sources, the state budget for space programs will be cut by 16 percent annually between 2022 and 2024. The 2022 budget, which is set to ₽210 billion ($2.9 billion), is also a significant reduction from the previous year, by ₽40.3 billion ($557 million; Berger 2021).

Ten years ago, Russian commercial launch services were more widely used, generating a considerable source of revenue for Roscosmos (Grunet 2022). One study estimated that in 2011 Russia generated $700 million in launch revenue, compared to none by the United States. However, over the past few years Russia lost its monopoly on launch services due to 2014 sanctions, failure to modernize its fleet, and entrance of new private launch providers such as SpaceX, which offered similar services at drastically lower prices (Moltz 2020). In addition, Roscosmos lost almost all of its revenue from the sales of RD-180 engines and seats on Soyuz spacecraft, which used to bring ₽15–20 billion a year (Vidal 2023). Within days of the invasion of Ukraine, Russia lost its only launch service contract with OneWeb (Zak 2022). The loss of commercial revenue is significant, as it was the sole source of funding for Roscosmos' human space flight programs and, to a lesser extent, science programs (Moltz 2020). The war in Ukraine and the resulting sanctions threaten to permanently push Russia out of the commercial space market (Grunet 2022).

Finally, even before the war the entry of new state actors was changing the geopolitical landscape. China, India, and Japan "have asserted their aspirations with the launch of national space programs." China is also making large investments in small satellite start-ups (Vidal 2023).

e. Absence of healthy private sector

Much of the innovation driving the global market in space technology comes from the private sector, in particular small commercial start-up companies (Moltz 2020). However, for Russian start-ups, entry into the space sector and integration with the government-run space enterprise is extremely difficult (Vidal 2023). Russia's intellectual property laws date back to the Soviet times; entrepreneurs are required to register with the Federal Security Service in order to compete for funding; and Roscosmos actively blocks start-ups it sees as potential competitors for government contracts (Moltz 2020) (Платформа 2019). The state remains the dominant force behind R&D spending, and there are few venture capital investors (Weiss 2021).

The investment of billions of rubles in the Skolkovo innovation center outside of Moscow and smaller tech incubators in other parts of the country was the signature initiative of Dmitri Medvedev's presidency 2008–2012 (Weiss 2021). However, these initiatives have not changed the trajectory of the Russian private sector. A few of the more promising start-ups have closed their doors (see Chapter 6), and even Russian malign influence operations, such as interference in the U.S. elections in 2020, were not technologically advanced. The Intellectual Property Organization ranked Russia 45th of 132 economies on the Global Innovation Index (United Nations 2021), and Russia's own experts concluded that the country's failure to develop advanced technologies (such as electronics, optoelectronic, and information and communication technology) may lead it to be "permanently left behind" in global markets (Стогова, E. 2021).

3. Evolution of the Launch Sector

A. Background

From the world's first successful space launch placing Sputnik 1 into orbit to its reliable Soyuz launches to the ISS, Russia's status as a major launch provider has persisted across many decades. In addition to launching payloads, Russia has consistently provided launch services cargo and crew to the ISS since 1999. However, its share in the number of launches began to decline in 2014–2015, mirroring a dramatic increase in launches worldwide (Figure 4). This chapter discusses the evolving landscape of Russia's launch sector.

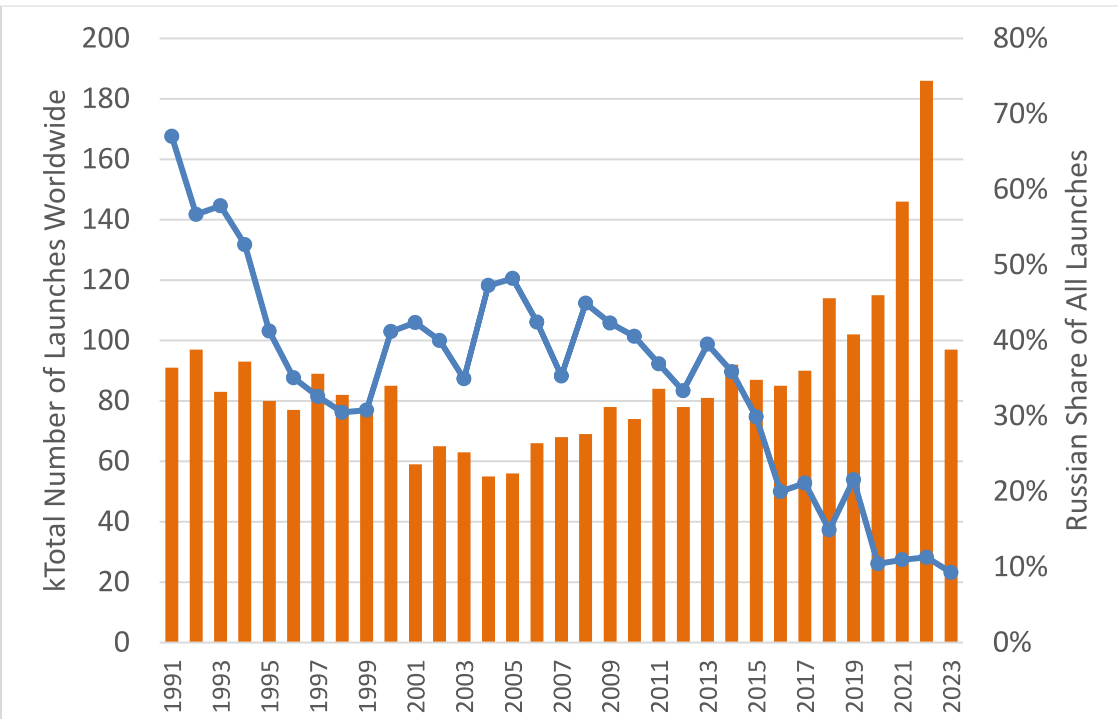
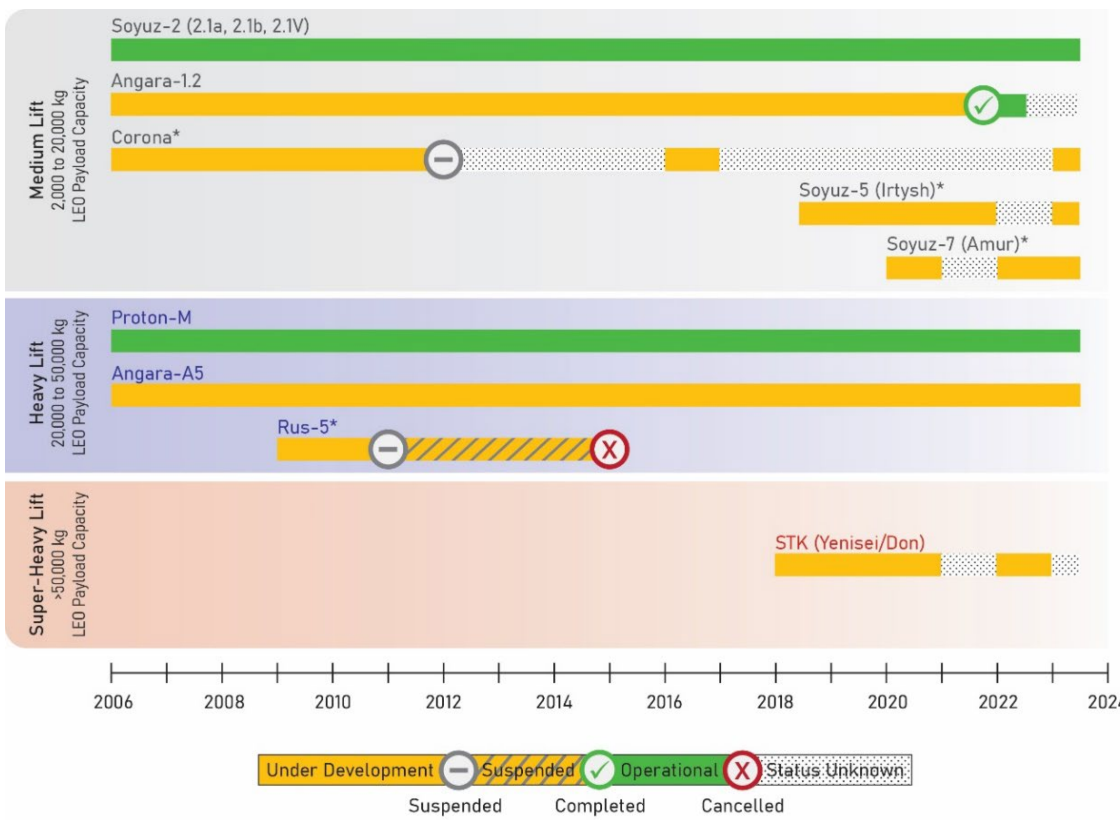


Figure 4. Total Number of Launches (orange); Russia's Share of All Launches (blue), 1991–2023

B. Launch Vehicle Programs

1. Launch Vehicles Currently in Use

Russia's access to space relies on two aging launch vehicle families, the heavy-lift Proton-M and medium-lift Soyuz-2. Several follow-on programs are currently in development, including the Angara launch vehicle family. While the Proton-M and Soyuz-2 are still functional, both designs are beginning to show their age. Consequently, Roscosmos maintains significant interest in developing the next generation of launch vehicles in order to maintain a stable launch rate and remain competitive in the global launch services market. However, balancing the political pressures from the Russian government with the needs of the launch vehicle developers under Roscosmos' management makes the task of executing a coherent development strategy challenging. The political expediency to maintain a steady space workforce and competition between launch vehicle developers has resulted in Roscosmos simultaneously producing several next-generation launch vehicles in various stages of development, many of which have overlapping intended uses. Figure 5 describes the status of the three launch vehicle families in recent years.



Sources: McDowell (2024), Zak (n.d.s)

Figure 5. Status of Russian Launch Vehicles, 2023

The Soyuz-2 family, developed as a predecessor to the successful Soviet-era Soyuz rocket series, is the primary medium-lift launch vehicle currently in use by Russia. Three main versions of the Soyuz-2 have been developed since the mid-1990s, including Soyuz-2.1a, Soyuz-2.1b, and Soyuz-2.1v (TASS 2015). The Soyuz-2 family can launch manned or unmanned payloads, but primarily carries satellites, spacecraft, and ISS supplies. Since

2006, the three Soyuz-2 variants have been launched approximately 108 times (McDowell 2024; Ryumin 2021).

The Proton rocket family originated as an intercontinental ballistic missile in the 1960s called the UR-500, but was repurposed as a launch vehicle during the development process (Howell 2018). The M variant of the Proton was first launched in 2001 and remains in use as Russia's commercial workhorse launcher, despite its relatively high rate of failure. It is expected that Proton will remain operational until 2025, at which point it will be replaced by the Angara-A5 (Zak 2019). The Proton-M rocket and its variants have launched approximately 100 times since 2006, with its most recent launch in 2023 (McDowell 2024).

The Angara family of launchers includes the medium-lift Angara 1.2 and the heavy-lift Angara-A5 (Mooney 2021; Zak 2023a). The development of the Angara family of vehicles, which began in the mid-90s, is behind schedule despite stable funding for at least a decade (Zak n.d. f). Despite the long development time, neither Angara vehicle sees regular use.

Angara 1.2 underwent an initial flight test in 2014, with its maiden flight occurring in April 2022 (Mooney 2022). Both the April 2022 flight and a subsequent October 2022 flight were reported as successful. At the same time, both Angara 1.2 launches resulted in suspected spacecraft failure: the satellite launched in April 2022 but decayed in orbit in May 2022 (Zak n.d. c) and the satellite launched in October 2022 reentered in December 2022 (Zak n.d. d); neither made any noticeable maneuvers. As of the publication of this report, the Angara 1.2 has had no other flights.

Angara-A5, which has only undergone three flight tests (Zak n.d. e), is slated to have a major role in Russia's long-term objectives, such as the ability to place geostationary satellites in orbit, and deliver modules of the planned Russian Orbital Station (ROS) and vehicles to ROS. The Angara-A5's first test flight was in 2014 (Zak n.d. e), and two subsequent test flights in 2020 and 2021 were successfully conducted from the Plesetsk cosmodrome (TASS 2023c). The third test flight failed to reach orbit due to an engine failure in its upper-stage booster (Rao 2021). Angara-A5 is intended to replace Proton-M on the global launch services market (Zak 2019), but is facing an uphill battle. Concerns remain about its high cost, making the vehicle uncompetitive in a market dominated by SpaceX, in addition to the lack of interest in Russia's products due to the political situation (Egorov 2018).

As of 2023, Roscosmos has not yet completed the Angara-A5 launch pad and assembly facility at the Vostochny cosmodrome, and currently relies on the secondary launch facilities at the Plesetsk cosmodrome for flight testing (Khrunichev State Research and Production Space Center n.d.). Vostochny is slated to be the main launch pad for

Angara-A5 (Russian News Agency TASS 2020d), signaling a major shift away from the main spaceport at Baikonur.

2. Prospective Launch Vehicles in Development

Beyond Soyuz, Proton, and Angara, several additional programs are currently being developed, namely Soyuz-5 (Irtysh), its super-heavy lift variants STK-1 "Yenisei" and STK-2 "Don," and the reusable vehicles Soyuz-7 (Amur) and CORONA (RIA Novosti 2023a; Pyadushkin and Klotz 2021; Lukin et al. 2021). These vehicles are in various stages of development and have faced problems with funding, making their future uncertain. The development timelines for both the in-use and prospective launch vehicles are shown in Figure 5.

a. Soyuz-5

The Soyuz-5 (Irtysh), originally written into the FKP 2016–2025 as project "Feniks," is an in-development heavy-lift vehicle with similar capabilities to Proton-M and Angara-5. Despite lagging behind the Angara-5 in development, the Soyuz-5 was initially selected to carry the next-generation crew vehicle based on the assessment of its prime developer RKK Energia (Zak n.d. s), which is also the company heading the manned spaceflight program. The reasoning given was that the Soyuz-5 is expected to be cheaper to produce than the Angara-5 (Zak n.d. s).

The development of the Soyuz-5 launch infrastructure is currently at an impasse. In 2017, RKK Energia signed an agreement with the Kazakh authorities to convert the now-defunct Zenit launch vehicle facilities at Baikonur into *Baiterek*, a launch complex intended for Soyuz-5 that would be developed jointly between Roscosmos and the Kazhcosmos, the national space agency of Kazakhstan (Russian News Agency TASS 2023q). However, in early 2023, due to a disagreement about the fulfillment of contractual obligations by Roscosmos, Kazakhstan impounded Russian space assets at Baikonur, seeking significant monetary reimbursement. The Kazakh authorities also have halted the construction of the Baiterek facility until 2025, delaying the schedule of the Soyuz-5 even further (Zak n.d. z).

The Soyuz-5 is intended to be developed as a modular base that can accommodate modifications suitable for heaver lift missions. In particular, STK-1 "Yenisei," a reconfigured Soyuz-5 with 6 boosters, would accommodate a payload weighing over 100 tons to low-Earth orbit (LEO; Russian News Agency TASS 2023r). A further modification, STK-2 "Don," would increase the possible weight to 130 tons (RIA Novosti 2019b). However, the STK program has faced a number of challenges, primarily related to lack of funding (Vedneeva 2021). Moreover, a number of analysts have indicated that a heavy-lift vehicle is unnecessary for Russia given the lack of achievable near-to-midterm goals for deep space exploration and prospective customers for the system in the near term (Zak 2018; BFM.ru 2021; Vedneeva 2021).

b. Amur

The original idea for the launch vehicle that would become the Amur rocket (first called Soyuz-5, then Soyuz-7) was conceived by TsKB Progress in 2013 (Vorontsov 2013), as a future methane-powered replacement for the Soyuz-2 (Russian News Agency TASS 2020a). According to the director of TsKB Progress, the impetus for the concept was the necessity to develop a modern alternative to the aging Soyuz-2 design; the proposed vehicle would be an entirely new design, focused on limiting the number of necessary parts, thereby reducing the burden of assembly and manual labor, which would consequently result in cost savings (RIA Novosti 2015b; Russian News Agency TASS 2020b). Representatives of TsKB Progress argued that in comparison to the Soyuz-2, the new launcher would be able to deliver payloads to a greater range of orbits, and feature an engine powered by a propellant with a broader raw material base and more eco-friendly properties than the kerosene-based fuel traditionally used for Soyuz launchers (RIA Novosti 2015b).

Initially, the development of the Amur vehicle was internally funded by TsKB Progress, with assistance from NPO Energomash (Interfax 2018). In 2020, Roscosmos placed an open request for tenders for the development of the "Amur-SPG" and the associated launch pad at Vostochny (Zakupki.gov n.d.). The open request entailed an initial award of ₽407 million for the development of a launch platform with a reusable first stage and a methane-based engine that could support a minimum of 10 launches, with the total launch service cost not exceeding $22 million per launch.

Despite competition from a private sector company that reportedly offered to complete the work for half the initial award, TsKB Progress won the bid for the development of Amur-SPG (Interfax 2020a; Russian News Agency TASS 2020b). The bid called for the completion of the schematic design for Amur by the end of 2020, but the schematics were not finalized until 2022 (RIA Novosti 2021a). In 2023, TsKB Progress secured a government contract to continue the technical development of Amur, stipulating completion by the end of 2024 (Russian News Agency TASS 2023p). However, the development of the RD-0169 methane-powered engine for Amur, currently under development by the Chemical Automatics Design Bureau (KBKhA), has been delayed. The first engine was planned to completed in 2023, but the date has since been extended to 2025 (RIA Novosti 2021c). While Roscosmos continues to tout Amur, with its director Yuri Borisov boasting that each first stage could be reused 50 or 100 times (RIA Novosti 2023e), the test flight of the vehicle is not planned until 2028–2029 (Russian News Agency TASS 2023i).

c. CORONA

The CORONA launch vehicle is a prospective single-stage-to-orbit fully reusable launcher currently being developed by Makeev rocket design bureau. Although CORONA has been in development since the 1990s (Fishman 2017), information about the launcher is not readily available. The lack of funding for CORONA has resulted in little progress beyond the technical design stage and multiple pauses to the development of the launcher (RIA Novosti 2017b).

In 2017, Makeev announced the intention to continue the development of CORONA (RIA Novosti 2017b) and has engaged a number of Roscosmos' subsidiaries and educational institutions as partners (Russian News Agency TASS 2023t). As of 2023, CORONA is in the technical design stage (Russian News Agency TASS 2023u).

From the perspective of its designers, the selling points of CORONA are its cost-effectiveness and versatility. CORONA is intended to be fully reusable, without the need to refurbish expendable components, thereby making launch cheaper (estimated at ₽2 billion as of 2017; Fishman 2017) and faster. Given its reusable design, CORONA would also be able to both place payloads in orbit and to repair and refuel or return in-orbit spacecraft (Russian News Agency TASS 2023t). However, CORONA's unique design requires an appropriate propulsion system: Makeev is currently working with NPO Energomash on a prototype engine for CORONA as there is no existing equivalent that can support CORONA's intended missions (Russian News Agency TASS 2023u).

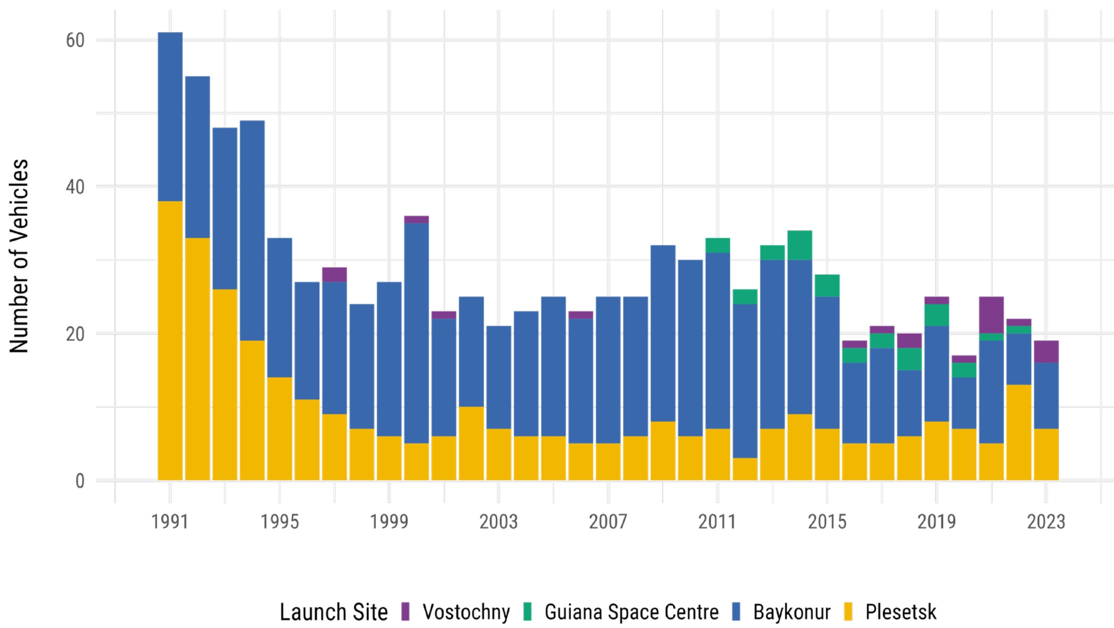
C. Spaceports

A major aspect of a vibrant launch sector is access to launch sites. Russia operates two civil cosmodromes, Baikonur and Vostochny, and performs select civil and test launches from its military base in Plesetsk. Baikonur, originally the Soviet Union's flagship cosmodrome, is located on the territory of neighboring Kazakhstan, and is currently leased to Russia until 2050 for approximately $115M annually (RIA Novosti 2021b). The Russian government, unable to extricate its space assets from Baikonur after the Soviet Union's collapse, has continued to use Baikonur as its primary cosmodrome while attempting to build its own modernized cosmodrome concurrently. These efforts started in the early 2000s at the Svobodny missile test site, which was later renamed Vostochny.

The Vostochny cosmodrome, long in development, has only begun to host space flights in 2016, and is only capable of accommodating Soyuz-2 unmanned launches (Zak n.d. bb). Plesetsk is Russia's primary launch site in Europe, and has been used to launch military and dual-use satellites as well as to perform flight tests for prospective launch vehicles such as Angara 1.2 and Angara-A5 (Khrunichev State Research and Production Space Center n.d.). Figure 6, adapted from an online document created by the Center for Strategic and International Studies, shows the location of each launch site (CSIS 2023). Figure 7 describes the number and volume of launches from the various Russian-operated spaceports.

Source: CSIS (2023)

Figure 6. Adapted from Spaceports of the World (1957–2022)



Source: J. McDowell (2024)

Figure 7. Number of Russian Launches by Spaceport, 1992–2022

A transition from Vostochny to Baikonur has been rocky for Roscosmos. The ecological impact of hosting a cosmodrome is often a sticking point in Kazakh politics (Abdrazak and Musa 2015; McGuire 2024), and the recent geopolitical ramifications Russia has faced since the invasion of Ukraine in 2022 have incentivized the Kazakh government to negotiate for a more favorable agreement. By contrast, Vostochny is not yet ready to serve as Russia's primary space port and is still missing functionality as compared to Baikonur, such as a launch facility for previous-generation launch vehicles (i.e., Proton-M) and manned launch vehicles (i.e., Soyuz-2.1a; Zak n.d. bb). The launch pad for new Angara-A5 rockets is currently under construction at Vostochny (Bodner 2019). While

Russia and Kazakhstan publicly downplay the seriousness of the disagreement, Roscosmos will remain at the mercy of the Kazakh government until its new cosmodrome is fully functional.

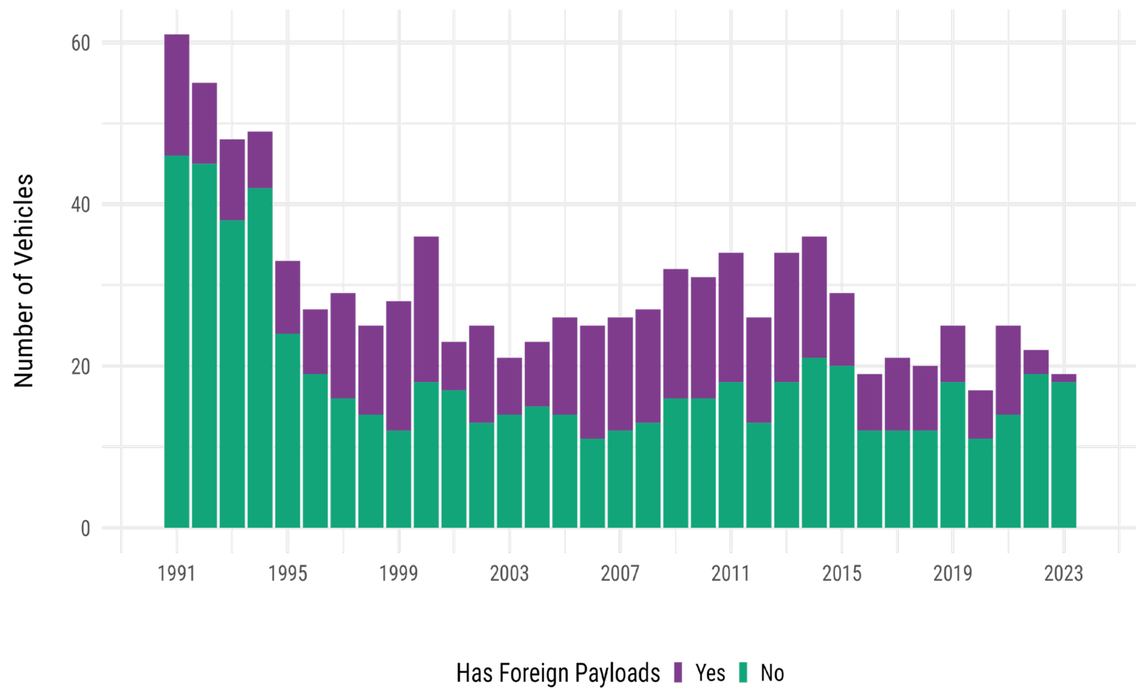
To further exacerbate the issue, in 2023, the Kazakh authorities seized Roscosmos' assets due to unfulfilled contractual stipulations (Putz 2023). The Kazakh authorities alleged that Roscosmos' main operator at Baykonur, TsENKI, the Center for Utilization of Ground-based Space Infrastructure, owes approximately $29 million in debt to the Joint Kazakh-Russian Enterprise *Baiterek* JSC (Putz 2023). In retaliation for the infringement, Kazakhstan impounded TsENKI assets and has barred Roscosmos from exporting those assets outside Kazakh borders, until the lawsuit filed against TsENKI by the Government of Kazakhstan is resolved (Katin 2023). Although both sides downplay the seriousness of the situation and the cadence of Russia's launches has not been impacted, this event serves as yet another reminder of the tenuous nature of maintaining launch facilities in a foreign country for the Kremlin.

Finally, Russia had also maintained the Soyuz Launch Complex (SLC) at the Guiana Space Center in Kourou, French Guiana, which was constructed as part of an agreement with ESA in 2002 (Via Satellite 2002). SLC hosted 27 Soyuz launches of ESA and commercial payloads (e.g., OneWeb) before 2022. Roscosmos' director at that time, Dmitriy Rogozin, announced the suspension of Soyuz operations and discontinuation of its partnership in Guiana with ESA in response to European Union sanctions implemented after the invasion of Ukraine in early 2022 (Foust 2022; RIA Novosti 2022d).

D. Launches of Foreign Payloads

Over the past 20 years, Russia has built up its commercial service launch sector. In the mid- and late 1990s, it launched modules and cargo to the ISS, followed by crew. From 2007 to 2021, between 30 and 50 percent of Russia's launches contained at least 1 foreign payload (McDowell 2024). Due to constellations and multiple satellites being launched, an equally healthy share of the payloads Russia launched into space were non-Russian. However, demand for payload delivery services fluctuated because of Russia's domestic and international conflicts (Figure 8). For example, Russia experienced a decrease in foreign payload launches in the year after the invasion of Crimea in 2014 and again after the invasion of Ukraine in 2022. However, in most years the number of launches was less than half of its peak in the early 1990s.

STPI also examined the data on what foreign countries used Russia's delivery services and what was being delivered. The U.K. (469), U.S. (262), Germany (55), ESA (26), and France (25) have historically been Russia's top customers, representing approximately 41 percent of all foreign payloads launched by Russia from 1992–2022. Figure 8 describes the share and totals of Russia's launch vehicles providing launches to foreign payloads.



Source: McDowell (2024)

Figure 8. Russian Launch Vehicles with at Least One Foreign Payload

4. Civil and Dual-Use Satellite Programs

The origins of Russia's major civil satellite programs can be traced back to the Soviet military and dual-use programs of the 1970s (Fedorov 2018; Podvig 2002; Bihovskiy and Dyachkova 2008), as several of Russia's mainstay satellite families are successors to Soviet precursors. The gains in satellite capabilities lapsed in the wake of the collapse of the Soviet Union in 1991, as budgets for Russia's non-critical space programs shrank dramatically (Mathieu 2010). After the downturn of the 1990s and early 2000s, Russia's government and private space companies expanded investment in civil applications due the influx of oil revenue and the perceived commercial interest in space applications (Aliberti and Lisitsyna 2019). This period marked the inception of many of Russia's space communication and Earth observation satellite programs aimed at telecommunications, broadcasting, and data transmission services, including those intended for cartography, weather forecasting, and monitoring natural resources as well for the GLONASS satellite navigation system.

Former Soviet space institutions, such as NPO Prikladnoi Mehaniki (NPO PM; now ISS Reshetnev), NPO Lavochkin, and NPO Energia (now RKK Energia), played a key role in preserving and developing Russia's space communications capacity. These organizations, particularly NPO PM, were initially struggling to maintain Russia's orbital group, but over time began attracting funding from domestic government and a few foreign sponsors. NPO PM and other domestic stakeholders in Russia's satellite sector began relying on foreign organizations to develop payloads for communications satellites (RIA Novosti 2022a; Zak n.d. y).

Russia's space industry is attempting to both onshore the manufacture of space technologies necessary for constructing satellites and to modernize its own existing satellite constellation (Vedomosti 2023b). Specific efforts include streamlining satellite production through the use of domestic or ally-produced technologies (Vedomosti 2023b), serializing the production of certain satellite families (Rossiyskaya Gazeta 2023), and broadening the range of satellite services offered, including expanding access to high-definition television (HDTV) broadband satellite internet (Aviasat 2023) and broadening Earth-observing (EO) capabilities. However, these efforts face a plethora of challenges, including the necessity to redesign existing assets (Lenta 2023a; Interfax 2023a), delayed launch schedules, reduction of on-orbit capacity, and, critically, a lack of investment from both domestic and international sources (Vedomosti 2023b). The following sections describe more details about Russia's satellite communications, remote sensing, PNT, and partnerships.

A. Satellite Communications

1. Overview

Russia maintains a multifaceted network of civil satellite constellations to address communication requirements across its vast territory. With a landmass spanning multiple time zones, including remote and sparsely populated areas, Russia relies on its space communications assets to ensure efficient and reliable communication services across the country. The space communications assets facilitate access to a variety of services for individuals as well as private and governmental organizations; these services include personal communications, public broadcasting, internet connectivity, and telephony.

Although Russia's domestic satellite manufacturers showed the capacity to produce communications satellites independently during the 1990s (ISS Reshetnev 2009), during the 2000s and 2010s, Russian satellite operators have relied heavily on Western manufacturers for the procurement of satellite components, such as communications payloads (Henry 2016; Hajiyeva 2018) and advanced components (RBK 2019b). Russia's invasion of Crimea in 2014 strained relationships with Western manufacturers and prospective clients, while the 2022 invasion of Ukraine severed many of those ties completely. Consequently, Russian companies have experienced limited access to Western expertise, investment, and technologies, resulting in delays in both ongoing and planned satellite programs.

2. Satellite Communications Programs

a. Gonets system

In 1989, NPO PM began the development of a civil equivalent of the Strela military satellite called Gonets-D, the first member of the Gonets (meaning *courier*) satellite series. The Gonets satellites were designed for personal communications and data transfer functions in low orbit, and used for tasks such as passing messages across secure channels or to remote sites. The satellites perform "store-dump" communications, recording messages when in proximity of the sender and later transmitting the information to the intended receiver when in range (Zak n.d. j). These satellites facilitate the Gonets communications system, which includes both the satellite constellation and the ground infrastructure. The Gonets system performs a number of critical functions, including process monitoring as well as remote tracking and control. The customer base of the Gonets system is primarily government, but also includes companies in several private sector industries such as transportation, meteorology, and forestry (Roscosmos n.d.).

The first two satellites of the Gonets series (Gonets-D) were successfully launched in 1992 as a demonstration, and the system was picked up by Roscosmos. By 1994, the funding for the Gonets system was incorporated into the Russian Federal Space Program

1992–2000, with NPO PM named as developer of the satellite constellation (Kuzovnikov n.d.). The operation of the Gonets system was given to AO Gonets, now part of Roscosmos. Nine Gonets-D satellites were launched by 2001 (McDowell 2024).

The Russian Space Program 2006–2015 approved the development of a successor satellite series, the Gonets-M1 with the objective to provide faster data transmission than the Gonets-D (Zak n.d. j). The first Gonets-M1 satellites were launched in 2011, along with a newly developed military equivalent called Rodnik. As of 2024, the Gonets satellite constellation consists of 20 satellites (McDowell 2024).

Despite the relatively large size of the Gonets constellation, several of its member satellites are reaching their end of life and are currently being replaced with Gonets-M satellites that were first put into service in 2010. The follow-on generation, Gonets-M1, has been redesigned to only include domestically manufactured components (Chupov 2022), and while the design phase for this generation of satellites was reportedly completed in 2022, the flight tests are not scheduled until 2028 (Chupov 2022). Additionally, given the smaller size of the Gonets family, ISS Reshetnev plans to produce the Gonets-M1s serially (Russian News Agency TASS 2023c).

b. Ekspress

By the early 1990s, the Gorizont telecommunications constellation, initially developed in the 1970s, was rapidly aging. NPO PM saw an opportunity to develop a series of state-of-the-art telecommunications satellites for the Russian Satellite Communications Company (RSCC), Russia’s primary civil telecommunications satellite operator (Federal Communications Agency 2010). This led to the development of the Ekspress series, which was intended to provide transmission of television channels, supporting direct-to-home broadcasting. The first two satellites in this series were developed domestically under the leadership of NPO PM, and launched in 1994 and 1996 respectively (Lantratov and Kamentsev 1999).

Following the successful deployment of the first Ekspress satellites, NPO PM sought to incorporate cutting-edge technology into its next family of satellites. Without the ability to develop the desired technologies domestically, NPO PM subcontracted the development of the communications payload for Ekspress-A1, launched in 1999, to a foreign manufacturer, Alcatel (Zak n.d. g). The outsourcing of communications payloads became a staple of the Ekspress family—all Ekspress satellites developed after 1996 either include a payload developed by a foreign manufacturer (e.g., Thales Alenia, Airbus) or were manufactured abroad entirely (Airbus Defense Space. n.d.; Ustinova 2018; Zak n.d. g).

Future satellites in the Ekspress series are reportedly being developed exclusively by ISS Reshetnev (Russian News Agency TASS 2022b). Based on statements by an RSCC spokesperson, the next Ekspress satellite is to be launched in 2026, with two more planned after 2028 (RIA Novosti 2022c). The delay is ascribed to the influence of international sanctions as future Ekspress satellites are being developed using primarily domestically produced components (Russian News Agency TASS 2022b).

c. Yamal

During the late 1990s, Gazprom, a large Russian oil and gas company, recognized the need for reliable communication infrastructure to support its operations in remote regions (Zak n.d. aa). Gazprom created a subsidiary, Gazprom Space Systems (GSS), to establish and operate a satellite communication system that would service Gazprom's operational needs and provide spare satellite communications capacity as a service to other private or government organizations (Zak n.d. aa). GSS engaged RKK Energia, formerly a major satellite communications manufacturer that was then looking to regain its position in the satellite services market (Zak n.d. aa), to act as the developer of a series of satellites named *Yamal*, after a peninsula featuring a prominent site of Gazprom operations.

RKK Energia began the development of the first Yamal satellites in 1996, contracting with Space Systems/Loral for the development of the communications payload (Semenov 2001, 801–806). These satellites featured a hermetically sealed design that provided an in-orbit lifespan of up to 12–15 years. Yamal-101 and Yamal-102 were launched into geostationary orbit in 1999, but Yamal-101 was lost soon after launch. GSS ordered another two satellites from RKK Energia in 2001, which were launched in 2003.

Although RKK Energia planned to continue the development of the Yamal series, disagreements about the contract led GSS to seek a new developer (Finmarket 2008). In 2009, GSS contracted with ISS Reshetnev to develop Yamal-300 and with the French company Thales Alenia Space to develop Yamal-401 and 402. GSS continued contracting with Thales Alenia, despite the pressure to offer the contract to a Russian developer (Zak n.d. n), resulting in a total of three Thales Alenia-developed satellites in orbit by 2019.

Building on their relationship, GSS and Thales Alenia signed an agreement in 2019 to develop a capacity for producing market-competitive spacecraft on Russian territory "using advanced European technologies" (National Association of Oil and Gas Services 2019). The agreement included a proposal for Thales Alenia to assist with the development of a spacecraft assembly facility near Moscow, potentially providing GSS with the ability to produce Yamal satellites independently (Aerospace Technology 2019). However, the assembly facility was still in development during the start of Russia's invasion of Ukraine, and due to the limits placed by the resulting sanctions, Thales Alenia chose to temporarily halt the work (Russian News Agency TASS 2022a). In 2023, Roscosmos signed an agreement to assist GSS in creating production capacity for spacecraft technologies (Russian News Agency TASS 2023g). It is unclear to what degree Roscosmos will incorporate or continue the construction started by Thales Alenia.

Given the reliance on Thales Alenia, the planned replacement of the Yamal satellites has gone off schedule. Reportedly, Yamal-501 was scheduled to be launched in 2024 to replace Yamal-402, which will be out of fuel by that time, but the launch of Yamal-501 has been delayed until 2026 (Gazprom Space Systems n.d.). Nevertheless, Gazprom Space Systems plans to launch eight Yamal satellites by 2035 (Interfax 2020b).

d. Luch

In the 1980s and early 1990s, the Soviet Union undertook several ambitious projects in the field of manned spaceflight, including the crewed space stations of the Salyut series, Mir, and the Buran spaceplane (Zak n.d. cc). To ensure the success of these projects, NPO PM was tasked with developing a data-relay system responsible for two-way communications between ground control and the space-based assets. Beginning its development in the late 1970s, the first satellite of the Luch constellation, based on the earlier KAUR-4 platform, was launched in 1985 (Zak n.d. cc). Four additional satellites were launched in the first generation of the Luch constellation, but due to their 3-year lifespan and inability to replace retired satellites due to lack of funding (Zak n.d. cc), the constellation stopped operating by 1998.

Renewed by increased government funding and recognizing the need for a long-term solution for data-relay needs, Roscosmos contracted with NPO PM for the development of a modern variant of the Luch constellation in 2005, which would be included as part of a Multifunctional Space Relay System (MSRS), funded through the Russian Space Program 2006–2016 (Roscosmos 2015) and operated by AO Gonets (AO Gonets n.d.). The orbital calibration testing of the new Luch satellites was completed in 2015, and the MSRS became operational. Facilitated by Luch satellites with a 15-year lifespan, the MSRS boasted enhanced capabilities compared to its previous instantiation, including the ability to monitor and control space objects (launch vehicles, rocket stages, spacecraft) and retransmit telemetry information, meteorological readings, signals from COSPAS-SARSAT beacons, differential corrections for GLONASS, and data transmission of television channels and video conferencing services (ISS Reshetnev 2009).

The second-generation Luch satellites are quickly reaching their expected end of life, and Roscosmos plans to add two satellites modeled after Luch-5B to the constellation in 2024 and 2025, respectively, as a way to bridge the gap between the second-generation series and the forthcoming third series (RIA Novosti 2019c). Luch-5X was launched in March 2023, but it is unclear whether this satellite is one of the two planned replacement satellites (Izvestiya 2023b).

B. Satellite Remote Sensing

1. Overview

Russia's on-orbit assets include satellite systems intended for Earth observation and remote sensing. These systems provide a variety of services, including digital imaging of the Earth's surface, tracking climate patterns, disaster response, and management. EO satellites also have a dual-use purpose for Russia; several satellite series, such as Meteor-M and Kondor-FKA are contracted by the Ministry of Defense. In addition, many civil satellite series have been developed based on a precursor intended for military use. Apart from the Ministry of Defense, a number of government and private organizations rely on space Earth observation, including the Ministry of Agriculture, the Ministry for Natural Resources and Ecology, and the Russian Service for Hydrometeorology and Environmental Monitoring (ROSHYDROMET).

The current model for developing EO satellites for Russian manufacturers is similar to that of the communication satellites manufacturers, focusing on large custom-built satellites. Much like the communication satellite sector, the effect of Western sanctions has placed constraints on the productions of EO satellites, and programs are facing across-the-board delays. Unlike communications satellite programs, the manufacture of EO satellites and their major components is not typically outsourced to foreign companies, but it is unclear to what extent this will insulate Russia's EO satellite producers.

2. Earth Observation Programs

a. Arktika

The Arctic is a key area of economic interest for the Russian Federation given the abundance of natural resources in the region and the growing accessibility of those resources due to climate change. Since the 2000s, the Russian government has recognized that the utilization of those natural resources requires expanded infrastructure in the region, including space-based assets (Paradiso 2023). Consequently, Roscosmos began planning for the development of a satellite constellation, called the Arktika project, that would provide services including space communication, remote sensing, and weather monitoring in the Arctic.

Under the direction of Roscosmos, NPO Lavochkin began the development of the Arktika satellites in 2012, using the Electro-L satellites as a base. The initial Arktika-M configuration was equipped with a multi-spectral imager and a transponder for emergency communications (eoPortal 2022; Krebs n.d. a). The Arktika satellites would be launched into a "Molniya" orbit, a highly elliptical orbit that would allow the satellites to provide better coverage of the northern hemisphere (Zak n.d. p).

Roscosmos had intended to partially fund the development of the Arktika system through extrabudgetary means. Statements made by NPO Lavochkin and other Roscosmos officials in 2013–2014 indicated foreign interest in the Arktika program by Finland and Canada, among others (Cheberko 2015). However, foreign partners withdrew after Russia's invasion of Crimea. Consequently, the development of Arktika was entirely funded by the Russian government and faced delays as a result of foreign sanctions. Initially, the first pair of Arktika satellites was scheduled to be launched in 2013, but due to the delays in obtaining the necessary components, the launch had to be moved several times (Borisov 2016; Cheberko 2015).

The first Arktika-M satellite was launched in 2021, followed by a second in 2023 (Russian News Agency TASS 2023b). Three more Arktika-M satellites are scheduled to launch in 2024–2025 (Krebs n.d. a). Statements from Roscosmos officials outlined plans to develop additional configurations of Arktika satellites to facilitate communication. These include Arktika-MS1, developed by Gazprom Space Systems (Borisov 2016; Zak n.d. p), and Arktika-MS2, developed by Roscosmos (Borisov 2016; Zak n.d. p). Arktika-R, also developed by Roscosmos, would perform environmental monitoring (Mapgroup 2016). In 2023, Roscosmos announced plans for the development of next-generation Arktika-MP satellites in 2026 (Interfax 2023d).

b. Electro-L

The Electro-L satellite constellation consists of a series of geostationary remote sensing satellites designed to provide meteorological information and facilitate weather forecasting (NPO Lavochkin 2015). The original Electro satellite series, developed in the Soviet Union, had a relatively short life: the final satellite was out of commission by 1998, only 4 years after the launch of the first Electro satellite in 1994. The loss of the Electro constellation severely weakened Russia's weather satellite network, necessitating a follow-on project (Zak n.d. h).

In 2001, the Russian government awarded the contract for the Electro successor series, Electro-L, to NPO Lavochkin—the first of which was launched in 2011 (Zak n.d. h). The Electro-L satellite was designed to provide hydro-meteorological data of the Earth's atmosphere and surface as well as to transmit collected data and KOSPAS-SARSAT signals to ground stations (eoPortal 2012a). The instruments onboard the Electro-L were developed in collaboration with Moscow State University, the Pilyugin center, and ROSHYDROMET, which is the main customer of the Electro-L (Zak n.d. h).

To date, four of five Electro-L satellites have been launched, three of which are operational (RBK 2016). The last Electro-L satellite is scheduled to be launched in 2025, after which NPO Lavochkin will begin producing an improved satellite series, the Electro-M (Russian News Agency TASS 2023h). The Electro-M would boast a higher resolution and additional spectral channels, but it is not scheduled to launch until after 2030 (Russian News Agency TASS 2023h).

c. Kanopus-V

The Kanopus-V constellation of EO satellites is intended for monitoring natural and human-made disasters, such as earthquakes and wildfires, as well as agricultural, aquatic, and coastal resources (VNIIEM 2016). The Kanopus-V series was developed by the All-Russian Scientific Research Institute of Electromechanics (VNIIEM) in collaboration with Surrey Satellite Technology Limited (SSTL), which assisted with satellite avionics, power management, data handling, and system design (eoPortal 2012b). The main customers of Kanopus-V are Ministry of Natural Resources and Ecology, the Ministry of Emergency Situations, ROSHYDROMET, and the Russian Academy of Sciences (Krebs n.d. b; Zak n.d. k).

The first Kanopus-V satellite was launched in 2012, with four additional satellites of the same configuration launched in 2018. In 2017, Roscosmos launched a modified Kanopus-V-IK satellite that included an additional module for greater capacity of detecting wildfires (Krebs n.d. b). Two additional Kanopus-V satellites are scheduled to be launched in 2024 and 2025, respectively (Russian News Agency TASS 2020c).

d. Kondor-FKA

The Kondor-FKA satellite series is a civilian version of the Kondor all-weather military reconnaissance satellites (Zak n.d. o). The design of the original Kondor satellite was presented to the Russian Ministry of Defense by NPO Mashinostroyenia (NPO Mash) in 1998. However, the space funding crisis of the 1990s prevented the project from proceeding until the mid-2000s (Zak n.d. o). The first domestic Kondor satellite did not launch until 2013 (NPO Mash 2024; RIA Novosti 2023c).

Despite the lengthy development, the Kondor program garnered international interest in the 2000s (Zak n.d. o). After a marketing campaign across Africa, Latin America, and the Middle East, NPO Mash secured a sale of an export version of the satellite to South Africa in 2006, designated Kondor-E (Zak n.d. o). However, the purchase of the satellite was unpopular within the South African government; national security concerns arose around Russia's level of access to the data gathered by Kondor-E (Zak n.d. o). These concerns, along with a stated lack of necessity (Zak n.d. o) for the project relative to its high cost, led the South African government to temporarily halt the project (Campbell 2014). Nevertheless, Kondor-E was launched in 2014 (NPO Mash 2024) and reportedly handed over to South Africa (RIA Novosti 2015a). Kondor-E was later reported to have had a partial failure (Interfax 2015), which may have been resolved; the current satellite operator and degree of functionality of Kondor-E are unknown.

In 2014, NPO Mash was reported to be working on a civilian version of the Kondor-E satellite, Kondor-FKA. In addition to the Ministry of Defense, the Ministry of Agriculture, and the Ministry of Emergency Situations would be the main customers of Kondor-FKA (Zak n.d. o). Subsidiaries of the Rostec State Corporation developed on-board instruments and the satellite body for Kondor-FKA (Rostec 2023a; Rostec 2023b).

The first Kondor-FKA was launched on May 27, 2023 (NTs OMZ 2023; Lenta 2023b), with a second currently scheduled to launch in 2024 (Russian News Agency TASS 2023s). Two additional Kondor-FKA satellites are promised in 2029 (Russian News Agency TASS 2023j). NPO Mash has stated that the follow-on Kondor-FKA-M satellite series will be built using domestically produced technologies, with a test flight planned for 2030 (Russian News Agency TASS 2023j).

C. Position, Navigation, and Timing

GLONASS, Russia's global navigation satellite system, is one of the primary components of Russia's on-orbit capabilities. Prior to GLONASS in the 1970s, the Soviet Union had developed several programs to support its military functions, such as the Tsiklon program that facilitated navigation for the Soviet navy (Dvorkin et al. 2009). Follow-on programs such as Parus and Tsikada (see Table 4) were developed following Tsiklon but were each intended for specific purposes, such as marine navigation. To achieve parity with the United States in terms of navigation, the Soviet government undertook the GLONASS program in the mid-1970s, intending to create a comprehensive system for PNT. The first GLONASS satellite, Uragan, was launched in 1982 (A. Kumar et al. 2021). Achieving and maintaining full functionality of the GLONASS system remains a high, albeit challenging, priority for Russia.

Table 4. Known Non-GLONASS PNT Satellites by Program, Quantity, and Timeline

Program	Number satellites launched	Number satellites active	Year of first launch^	Year of most recent launch	Last end of life
Parus	25	3	1992	2010	*NA*
Tsikada	3	0	1992	1995	2005
Nadezhda	5	0	1994	2000	2007

Note: ^The first launch occurred in 1974, but the 1990s was when it shifted to a non-classified system.
Source: McDowell (2024)

The GLONASS system quickly lost its full functionality after the reduction in space sector funding during the 1990s. By the end of the 1990s, the constellation dwindled to seven satellites with an expected life span of 3.5 years, which were insufficient for providing coverage across Russia (GLONASS Consumer Application Center n.d.). In 2002, the Russian government took steps to modernize the capabilities of GLONASS by adopting the *Global Navigation System for 2002–2011* federal program (Dvorkin et al. 2009). This program aimed to replenish the GLONASS constellation with modernized in-orbit and ground components. By 2011, the GLONASS constellation was restored to 24 satellites, which included the newly developed Uragan-M satellite (GLONASS Consumer Application Center n.d.; RBK 2010). The Russian government took additional steps to fund the development of GLONASS, adopting the *GLONASS Sustainment, Development and Use for 2012–2020*, and adding funding for GLONASS development to the *On Space Activities* legislation thereafter (The Government of Russia 2021).

To date, there have been three main generations of GLONASS satellites (Uragan, Uragan-M, and Uragan-K), all developed primarily by ISS Reshetnev. These programs, the number of satellites in each program, and the date of first launch are depicted in Table 5.

Table 5. GLONASS PNT Satellites by Program, Quantity, and Timeline

Program	Expected lifespan (years)	Number of satellites launched	Number of active satellites as of Jan 2024	Year of first launch	Year of most recent launch
Uragan	3	46	0	1982	2005
Uragan-M1 and M	7	46	22	2001	2022
Uragan-K1 and K2	10	5	4	2011	2022
Uragan-V	Unknown as of Aug 2024	0	0	Expected 2025	N/A

Sources: Expected lifespan taken from Krebs (n.d.) but verified through GLONASS Consumer Application Center (n.d.); McDowell (2023)

Full functionality of the GLONASS constellation requires 24 satellites (GLONASS Consumer Application Center n.d.). Occasionally the number of active satellites is higher due to test flights or replacements intended to replace satellites reaching their end of life. The Uragan program was the backbone of the constellation for the first 20 years, with a life span of 3 years and a total of 46 satellites launched (McDowell 2024). Since Uragan can only produce 2.6 satellites per year, on average, and the life span of a satellite is 3 years, Russia would struggle to maintain full functionality of GLONASS with this series alone.

Uragan-M1 was a prototype of the M program launched in 2001 with an expected lifespan of 7 years (GLONASS Consumer Application Center n.d.). The first mainline

Uragan-M satellite was launched in 2003. As with Uragan, there were 46 Uragan-M satellites launched in roughly 20 years, but with the extended lifespan they were more capable of sustaining presence in orbit. As of 2024, there are 22 active Uragan-M satellites (McDowell 2024). Chapter 7 of this report includes a more comprehensive analysis of the lifespan and cadence of the Uragan satellite series.

The Uragan-K program was the intended successor of the Uragan-M. In comparison to the Uragan-M1, the Uragan-K1 model featured a longer expected life span (an increase from 7 to 10 years) and improved components, including a stronger power supply and a new satellite bus (Zak n.d. i). The Uragan-K1 was also able to transmit additional navigation signals, which substantially increased the accuracy of civil navigation (Krebs n.d. c). Four Uragan-K1 satellites have been launched since 2011. An upgraded version of the Uragan-K1 satellite, Uragan-K2, was launched in 2023 (Zak n.d. q).

D. Partnerships

Russia's civil satellite sector is characterized by a range of both domestic and international partnerships. Domestically, the civil satellite sector is bolstered by Roscosmos' collaborations with various private, educational, and government organizations, including Russia's constituent regional governments and republics. Roscosmos relies on these partnerships as a means to obtain funding for services enabled by satellite constellation, such as access to broadcast media, internet, and data transmission. In the case of partnerships with educational institutions, Roscosmos primarily seeks to collaborate on scientific experiments, develop technologies, and provide opportunities for potential members of the space workforce. Roscosmos is also responsible for the development of satellites for the Russian defense and intelligence sector, including the Ministry of Defense, the Federal Security Bureau, the Ministry of Emergency Situations, and the Ministry of Internal Affairs (Aliberti and Lisitsyna 2019). The satellite systems Roscosmos develops provide the Russian government with access to secure communication channels to assist in functions such as law enforcement, emergency management, transportation, logistics, and national defense (Aliberti and Lisitsyna 2019).

Internationally, Russia's space companies have traditionally partnered with European, Japanese, and Canadian private space companies to procure cutting-edge technologies, such as transponders for communications satellites and avionics software. Thales Alenia Space, MDA, Airbus, Toshiba, and SSL have collaborated with Russian companies to develop and supply a large portion of Russia's civil communications satellites, including the Yamal and Ekspress series (Zak n.d. g; Zak n.d. aa). Russia has also sought partnerships with the governments and space agencies of countries in Africa, Central Asia, and Eastern Europe. These relationships have resulted in the development of several communications satellites for the benefit of the partner nation, such as the AngoSat communications satellite series for Angola (Interfax 2022b), the Kondor-E reconnaissance satellite for the South African military (Graham 2014), the BelKA remote sensing satellite for Belarus (News of Belarus 2011), and the KazSat communications satellite series for Kazakhstan (Zak n.d. l). Beyond pay-for-service, the purpose of these collaborations includes a marketing function, intended to demonstrate Roscosmos' capabilities to countries Russia views as potential customers.

However, it is unclear to what extent these partnerships will benefit Russia, as the partnering country would need to dedicate sizeable financial resources and obtain Russia's assistance to develop space capabilities. Given that many of the countries Roscosmos has sought to partner with do not have expertise in developing space-grade technology and do not have the requisite experienced space personnel, the prospect of collaborating with Roscosmos is a financially risky prospect. Furthermore, Roscosmos has a relatively poor track record developing satellites for foreign countries and lacks proven capabilities in space services other than launch. Moreover, these nations may be hesitant to face sanctions and international isolation for collaborating with the Russian government.

E. Future Prospects

Russia's future plans in the space communications sector include three directions: enhancing self-reliance by focusing on domestic production of telecommunications technologies, modernizing satellite manufacturing, and expanding the capabilities of the Russian satellite constellation to attract investment.

Through the 2010s, Russia's space industry has been highly dependent on Western-manufactured technologies, and although export controls have been impacting the ability of Russian satellite manufacturers to procure from Western suppliers since 2014, domestic manufacturing has not become a priority until recently (de Selding 2023). In the space communications sector, several major satellite families, including Yamal and Ekspress, have been developed with Western-manufactured communications payloads, and telecommunications operators continue to rely on Western components for ground infrastructure for lack of an alternative (Cherkasova 2023).

Because of concerns about future replacement and long-term viability of their products, satellite manufacturers such as ISS Reshetnev and NPO Mash, and operators such as GSS and RSCC, are structuring production plans around domestic components (de Selding 2023). These decisions have resulted in long-term delays to many of the satellite constellations described in this section; for example, satellites such as the next-generation Gonets-M1 are not scheduled to begin flight testing until the close of the decade. While domestic production ramps up, Russian space services providers will likely have to rely on a dwindling reserve of Western-manufactured components to replenish aging on-orbit assets.

Roscosmos and its constituent organizations have recognized that their current model for satellite manufacturing is in need of modernization. In a 2022 interview, Yuri Borisov addressed the growing gap in satellite production between Russia and the other spacefaring nations, calling for the serial production model of certain satellite series. Satellite developer ISS Reshetnev echoed this priority, stating an intention to develop a small satellite per day, a medium satellite per week, and at least 15 large satellites per year (Russian News Agency TASS 2023c). Importantly, the call for modernization is backed up by investment: in 2023, Borisov announced the sale of ₽50 billion worth of bonds to fund the construction of two factories for serial satellite production (Cordell 2022).

However, while Russian space companies do have the capacity to manufacture specific sophisticated components on a serial basis (e.g., rocket engines), they have yet to demonstrate the ability to produce whole satellites—and it will be especially difficult to do so while relying on untested domestically produced components. In particular, Russian firms have not been able to produce electronic components comparable to those produced by Western or Chinese manufacturers (Yanigin 2019), and have experienced quality control issues in producing such components in the past (Zak n.d. y).

1. Efir and Sfera

After the economic revival of the mid-2000s, the Russian government renewed its interest in developing a space services industry as part of a broader pursuit of a digital economy (Aliberti and Lisitsyna 2019). The success of foreign projects such as O3b, OneWeb, and later Starlink suggested a similar direction for the Russian space industry; expertise in developing satellites would naturally complement Russia's strong standing in the fields of launch services.

Consequently, Roscosmos proposed the Efir project in 2017 (RBK 2017), which aimed to create a multiple-orbit satellite constellation to provide communication services to the global market, directly challenging OneWeb. The plans for Efir centered on the development of 288 satellites between 2018–2025, intended to provide global telephony and internet access (RBK 2018). Efir would require ₽299 billion in funding through 2020 (RIA Novosti 2018a): ₽19 billion would be allocated to creating the infrastructure for the system, ₽30 billion to the design and planning, and ₽250 billion to the initial round of development work (RBK 2017). Of the initial ₽299 billion budget, ₽280 billion was reportedly sought from private investors (Korolev 2021; RBK 2019a), and the estimated amount rose to ₽534 billion by 2018. However, private sector investors were not interested (Noviy, Skorobagatko, and Dzhordzhevich 2018), judging the prospect of the Efir constellation too risky due to the presence of established international competitors (i.e., OneWeb and Starlink) along with the influence of international sanctions (RBK 2018) on both the development of the system and its potential market share.

Being unable to garner enough private sector interest, Roscosmos rebranded “Efir” as “Sfera” in 2018.[2] The rebranded program, which was endorsed by the government, would expand the number of satellites to be developed for the constellation to 638 and rely primarily on government subsidies (Zak n.d. r). Sfera would focus primarily on Russia and its neighbors and provide a more comprehensive list of services than Efir, spanning both telecommunication and remote sensing (Safronov 2018).

The negotiations for Sfera’s budgets, list of satellite systems included, and the number of satellites to be developed for each system have fluctuated over the years. In 2020, Roscosmos requested ₽1.5 trillion through 2028, ₽800 billion through 2028 in 2021, and ₽180 billion through 2030 in 2022 (Russian News Agency TASS 2021). It was later reported that Roscosmos initially estimated the cost of Sfera to be ₽3.3 trillion (RBK 2020). The initial number of satellites Roscosmos intended to develop for Sfera was 638, but that number dropped to a range of 319–392 satellites as of 2024 (Table 6). A 2020 report estimated that placing 638 satellites in orbit would require 148 rocket launches, which would total ₽300 billion for launch alone (RIA Novosti 2020). Between 2022–2026, the Russian government appropriated approximately ₽62 billion for the Sfera project (RIA Novosti 2022b), far less than the lowest estimates.

Table 6. Roster of Satellite Systems Included in the Sfera Project as of 2024

System	Planned Number	Primary Manufacturer	Operator	Application Type
Yamal	2	Gazkom	Gazkom	Communications
Ekspress	8	ISS Reshetnev		Communications
Ekspress-RV	4	ISS Reshetnev		Communications
Skif	6	ISS Reshetnev	Zond-Holding	Communications
Marafon-IoT	137	ISS Reshetnev		Communications
Smotr	3	Gazkom	Gazkom	Remote sensing
Berkut-O	4–40	Lavochkin		Remote sensing
Berkut-S	16	Lavochkin		Remote sensing
Berkut-VD	3–28	Lavochkin		Remote sensing
Berkut-X/XLP	2–12	Lavochkin		Remote sensing
Grifon	136	Novosibirsk State University		Remote sensing

Note: Blanks denote an unknown operator

Sources: Aviation Explorer (2023); Egorov (2022); Russian News Agency TASS (2023a); Russian News Agency TASS (2023l); Russian News Agency TASS (2023q); Zak (n.d. s.)

2 The Efir program was renamed by Roscosmos after President Vladimir Putin mistakenly referred to it as “Sfera” in 2018. https://arstechnica.com/space/2023/10/russia-renamed-its-ambitious-satellite-program-after-putin-misspoke-its-name/

As of 2024, Sfera contains 11 programs at various stages of development, including previously existing Yamal and Ekspress—and ostensibly new Berkut series or Marafon-IoT. Based on the reported number of satellites alone, the development of certain new programs, particularly Marafon-IoT, will necessitate a change in Roscosmos' mode of manufacturing from individual to serial production. Currently, ISS Reshetnev is developing facilities that would allow serial production of one Marafon-IoT satellite per 1.5 days and one Skif satellite per week (Russian News Agency TASS 2023c). As of 2024, no date has been provided for the completion of ISS Reshetnev's serial production facilities. Gazkom has also been working on a serial production facility, initially in cooperation with Thales Alenia and currently with Roscosmos (Russian News Agency TASS 2023g), but no timetable for the completion of these facilities has been released.

Despite being in development since 2017, the Sfera program is yet to produce major results. The launch of the Skif-D demonstrator satellite in 2022 was heralded as a new beginning for the Sfera constellation. However, according to reports, the satellite was launched primarily to preserve the radio frequencies of its operator, Zond-Holdings (Egorov 2022; Korolev 2023), registered with the International Telecommunications Union (ITU). Skif-D's capabilities do not match those of the production Skif satellites (Egorov 2022), furthering the notion that the Skif-D launch was primarily symbolic. The mainstay Skif satellites are not scheduled to be launched until 2026–2027 (Korolev 2023). The status of the other systems under the Sfera umbrella is similar. Berkut is (optimistically) scheduled to launch in 2025 (Russian News Agency TASS 2022d), pre-production Marafon-IoT satellites in 2025 (Russian News Agency TASS 2023k), Express-RV in 2025 (PortNews 2023), and Smotr satellites in 2026–2028 (Krestyahskiye Vedomosti 2023).

As Sfera begins to slowly take shape, Roscosmos continues to seek investors in order to expand the constellation and increase the rate of its rollout. Apart from engaging additional private and educational organizations domestically (Stavrogina 2023), Roscosmos is marketing Sfera to its international partners as an alternative to Starlink, and has garnered some interest from the BRICS block (Zak n.d. r). Moreover, the conflict in Ukraine may spur additional funding for Sfera from the military sector as the Russian military seeks to equalize the Ukrainian advantage in communication and UAV capabilities provided by Starlink (Zak n.d. r).

2. GLONASS

Prior to the conflict in Ukraine in 2014, the stated goal of Roscosmos was to continue the development of the GLONASS constellation by enhancing the capabilities of the Uragan-K satellites while relying on largely the same base satellite model. However, international sanctions imposed in 2014 had an outsized impact on Uragan satellites: according to Russian space industry sources, the base for Uragan-M satellites consisted of

75–80 percent imported components (RBK 2019b). During the mid-2010s, the ISS Reshetnev, the prime developer of the Uragan series, initiated a redesign process for the Uragan satellites to reduce the dependence on foreign parts. With the expansion of the conflict in Ukraine in 2022, ISS Reshetnev announced plans to use a component base that was predominantly produced domestically (RBK 2019b).

At a meeting of the Russian Academy of Sciences in December of 2023, Nikolay Testoyedov, the director of ISS Reshetnev, outlined future plans for GLONASS given the new reality of Russia's space sector operating under international sanctions imposed after February of 2022. According to Testoyedov, the primary limitation for the future development of the GLONASS constellation was a shortage of electronic components from foreign developers due to sanctions. His report suggested that prior to 2014, GLONASS satellites contained 6,000 electronic components produced abroad, making up about 42 percent of the total component base of each satellite. Testoyedov went on to state that the shift to 100 percent domestically produced satellites was estimated to take until the year 2030 (Herald GLONASS 2023a).

The near-term goal for the GLONASS constellation, according to Testoyedov, is to strive toward parity with other global navigation systems while continuing to replenish the GLONASS constellation using partially domestically produced Uragan-K2 satellites, the first of which is scheduled to launch in 2025 (Interfax 2023b). These retrofitted Uragan-K2 satellites would boast the ability to create "local zones of navigation" using a signal "100 times stronger than the standard," thereby protecting against interference. Currently, GLONASS can achieve an accuracy of up to 1.32 meters, paling in comparison to the accuracy attributed to the Global Positioning System (GPS) and BeiDou. According to Testoyedov, the stated goal is to increase the accuracy of GLONASS to 0.5 meters, commensurate with International Civil Aviation Organization (ICAO) standards (Vedneeva 2023). Testoyedov's statements seemingly respond to recent reports about the vulnerabilities of GLONASS, such as interference due to topography (e.g., forests, mountains, urban environments) and localized low-power signals (Herald GLONASS 2023b). However, satellites with improved signal strength are unlikely to offset the broader problems with the GLONASS constellation, including a systemic lack of coverage for precision and correction of signals (RBK 2019b), which are facilitated by ground stations and other on-orbit assets (i.e., Luch constellation).

Testoyedov further outlined long-term goals for the GLONASS constellation, which include developing additional capabilities and finding international partners (Vedneeva 2023). Upon completion of the domestically produced Uragan-K2 satellites, the development of GLONASS would shift to the creation of 6 high-orbit (36,000 km) satellites on 3 geosynchronous orbits. The goal would be to increase the availability of the GLONASS signal in cities and remote areas of Russia. In addition, Testoyedov reported ongoing talks about creating a low-orbit constellation supporting GLONASS: the current plan is to launch 300 satellites orbiting 100–500km above the Earth in order to amplify the GLONASS signal. Lastly, Testoyedov stated that the functionality of GLONASS is not solely dependent on electronic components but is also reliant on international services, such as the International Bureau of Weights and Measures and International Association of Geodesy. Testoyedov insinuated that the international organizations "may, and some of them already do" apply discriminatory measures against the GLONASS system. Testoyedov proposed that countries of the BRICS+ bloc should work together to replicate the products of the international services that allegedly discriminate against GLONASS to counteract the unilateral influence of certain countries.

5. Russian Space Exploration

A. Future of the Manned Spaceflight Program

The continuation of the manned spaceflight program is a key priority area for Russia. The current manned program relies highly on access to a LEO space station, as the main output of the manned program is scientific experimentation in a microgravity environment. The ability to send humans to space is a powerful propaganda tool domestically, and an instrument of foreign policy abroad.

Russia performed and continues to perform key crew and cargo launch services to the ISS. The first ISS module, Zarya*,* was launched by Russia in 1998 with several subsequent launches by Russia and the United States to successfully assemble the station. The vast majority of cargo flights to the ISS were on Russian or U.S. launch vehicles (NASA n.d. a). Russia and the United States were also the only countries that had vehicles certified to launch people to the ISS. From 1998 to 2011, the Russian and U.S. vehicles took crew members and space flight participants to the ISS (NPR 2012). After the Space Shuttle made its final flight in 2011 and until 2020 when SpaceX launched its first crew mission to the ISS, the United States had no transportation for its space flight participants to and from the ISS. Therefore, the United States and its allies and partners depended solely on Russian launch capabilities for human spaceflight. Despite Russia's military annexation of Crimea in 2014, the United States and U.S.-aligned states continued to maintain a strong space partnership with Russia. However, reliance on Russia for human spaceflight gradually declined after SpaceX successfully transported astronauts to the ISS in 2020. Since then, the United States has mostly, but not exclusively, relied on SpaceX launch vehicles to transport American astronauts to the ISS (NASA 2019). On occasion, Russia's flights to the ISS contain U.S. astronauts.

Beyond its ideological value, the ISS affords Russia with a valuable laboratory for experimentation in a microgravity environment applicable to a variety of questions with applications in cryogenics, high-energy processes, astrophysics, and biology. Authorities from Roscosmos regularly pay lip service to accomplishments in these areas as justification for funding the manned spaceflight program and suggest that the absence of a scientific environment (such as the one provided by the ISS) would result in a general degradation in the relevant scientific areas.

At the same time, the ISS has now passed its operational life span, as evidenced by a number of leaks and malfunction aboard the station (Berger 2021; Byrne 2023; Foust 2023; Roulette 2022). The geopolitical tensions between the signees of the ISS accord have complicated the exit strategy. After the start of the conflict in Ukraine and as a response to the resulting sanctions, Roscosmos authorities threatened to end cooperation (Interfax 2022a; Sauer 2022). Rogozin's replacement, Borisov, was at first coy about plans for the ISS (RBK 2022b; Smith 2022), but subsequently committed to extending its operations as long as possible (Russian News Agency TASS 2023e; Russian News Agency TASS 2023f), demonstrating the importance of the ISS to Russia's space strategy and underscoring the lack of alternatives. As of 2023, NASA has stated that the space station will be deorbited in 2031 (NASA n.d.), leaving Russia with few options to preserve its manned spaceflight program.

The sunsetting of the ISS has accelerated Russia's timetable to develop an alternative space station, resulting in a comprehensive push to produce the ROS, culminating in a proposal approved by the President of the Russian Federation in 2023 (Interfax 2021; RIA Novosti 2023d). The station would be placed in a polar orbit, which would present a novel environment for basic and applied research and facilitate launches to the station from Russia's major space ports. The cost of the project was estimated at ₽609 billion through 2032, ₽150 billion of which would be spent during 2024–2026 (RIA Novosti 2023h; Russian News Agency TASS 2023v).

Due to lack of available technical resources, time, and funding, Roscosmos chose to repurpose the Energy and Power Module (NEM; Zak n.d. m), originally designed as a component to the ISS, as the core module for ROS to be launched in 2027 (Russian News Agency TASS 2024). Similarly, several other systems intended for the ISS would be retrofitted for compatibility with ROS. While repurposing existing technology seems to speed up the instantiation of ROS on the surface, Roscosmos has yet to demonstrate the ability to pass other significant technical hurdles necessary to make ROS operational.

Critically, considering the intended orbit for ROS, Roscosmos requires a new heavy-lift launcher to place the station modules in orbit, a new crew vehicle, and a launcher for the crew vehicle (Zak n.d. v). Roscosmos has provided provisional but unrealistic responses to each of these components, often hinging on the expedited development of a yet-unrealized technology or vehicle, or the retrofitting of an existing vehicle. Given the uncertainties, a 2027 launch appears unrealistic, especially considering that much of the funding for the project has not been approved.

To offset ROS' apparent funding shortages, Roscosmos has taken steps to market the space station to prospective domestic and international customers. Around the approval of the ROS proposal in 2023, Roscosmos director Yuri Borisov had traveled to a number of countries in Africa, the Middle East, and Southeast Asia, offering prospective partners the opportunity to jointly develop a module for ROS (Russian News Agency TASS 2017; Russian News Agency TASS 2023n; Interfax 2023b; Russian News Agency TASS 2023o). Additionally, several mockups of a commercial module for ROS have been developed to interest private sector organizations in purchasing or renting space or mounting instruments on ROS (RIA Novosti 2023b). However, given ROS' schedule, the commercial module will likely be competing with several private space stations currently in development by Western companies (Zak n.d. w).

B. Lunar Exploration

1. The Luna Programs

On August 10, 2023, a Soyuz-2.1b launched from Vostochny cosmodrome carrying the Luna-25 lunar lander, the first lunar mission by the Russian Federation. The Luna-25 mission was intended to serve a dual purpose: to explore the southern polar regions of the Moon containing frozen water and to test landing technologies and scientific instruments (Russian Space Research Institute 2023).

The name of the lander was a nod to the previous Soviet lunar mission Luna-24 launched in 1976. Although scientific interest in lunar exploration continued after the collapse of the Soviet Union, the lunar program was deprioritized due to the space sector funding crisis of the 1990s (Egorov 2023b). During the 2000s, the funding for scientific missions did not improve dramatically, which necessitated the proponents of the lunar exploration program to compete against other scientific programs for what little funding was available (Egorov 2023b).

The first official funding for Luna-Glob was part of the Federal Space Program 2005–2015 strategic planning document, which called for a series of automated lunar landers (Egorov 2023a). In 2013, Roscosmos signed a contract with NPO Lavochkin to develop the first such lander, Luna-25, which was originally scheduled to launch in 2014 (RIA Novosti 2013b; Egorov 2023b).

The development of Luna-25 faced multiple delays after Russia's military annexation of Crimea in 2014, when international partners and contractors began withdrawing from the project. NPO Lavochkin faced challenges replacing Western technologies as well as changes in the contract with Roscosmos (Chereneva 2023). In consultation with the Russian Academy of Sciences, NPO Lavochkin moved the launch of Luna-25 to 2016 (RIA Novosti 2013a), then to 2019 (RIA Novosti 2017a), and finally to 2021 (RIA Novosti 2018b).

The delays were not received well by Roscosmos, which filed a number of lawsuits against NPO Lavochkin alleging a breach in contractual obligations by failing to deliver the lander and its various components on time (Chereneva 2024). The damages sought by Roscosmos ranged from several million to almost one billion rubles. Although most lawsuits were unsuccessful, NPO Lavochkin was found to have breached the contract for the development of Luna-25, repaying Roscosmos ₽252 million for a program costing a minimum of ₽12.6 billion (Izvestiya 2023a).

The Luna-25 lander was finally completed in 2022 and prepared for launch in 2023. However, 9 days after launch the lander collided with the lunar surface while attempting to enter a pre-landing orbit. Roscosmos reported that due to an onboard malfunction, the thrusters fired for 127 seconds instead of the planned 84 seconds (RBK 2023b).

Despite the failure of the Luna-25 mission, Roscosmos has reiterated a commitment to continuing the lunar program. During an interview in 2023, Roscosmos director Yuri Borisov cited lack of continuity in lunar exploration as the main reason for the failure, stating that the experience gained from the Soviet-era missions was now "practically lost" (Gazeta.ru. 2023). Borisov stated that the crash of Luna-25 was a valuable experience for future lunar programs, and that the development of follow-on missions Luna-26 and Luna-27 should be accelerated (Russian News Agency TASS 2023m).

Currently, Luna-26 and Luna-27 are scheduled for 2027 and 2028, respectively (Chereneva 2023). Future automated missions beyond Luna-27 are currently scheduled for after 2030. The first manned missions to the Moon, which depend on the completion of in-progress programs such as the Orel crewed spacecraft and the STK super heavy launch vehicle, are also scheduled for after 2030.

2. International Lunar Research Station (ILRS)

ILRS, announced in March 2021, is a multinational program led by China with Russia as a main partner. The vision statement of the ILRS is to "jointly build and share and operate the first extraterrestrial home in the solar system, serves the community of human destiny on the surface of the moon, used for long-term exploration and development of the universe, and contributes Chinese wisdom and strength" (UN 2023).

According to a recent article by Brian Harvey, Russia and China have been engaging in "working group dialogues on a range of space activities including space stations, lunar and interplanetary mission, supplemented by polite meetings at a senior level" since the fall of the Soviet Union in 1992 (Harvey 2021). In March 2021, China and Russia signed a memorandum of understanding on the ILRS composed of a set of reconnaissance, sample return, cargo delivery, and technology demonstration activities. It will also include a lunar orbiter, a Moon base, and multiple exploration rovers. In June 2021, Russia and China jointly released the ILRS partnership plan inviting other nations to join their efforts to develop a lunar presence. It has been reported that Russia has pondered exiting from the ISS in 2024 and developing ROS. Some sources also speculated that Russia may send cosmonauts to the Chinese Space Station (Jones 2021).

6. Russian Commercial Space

Under the Soviet system, the economy was fully planned and controlled by the government. As part of “perestroika” in the 1980s, Gorbachev championed a number of reforms that transferred some controlling rights from the government to the employees, ushering in the age of privatization. This chapter describes the commercial space sector, first providing an overview of roughly 100 companies that could be found in multiple sources and then focusing on a few better-known commercial entities to illustrate the hostile environment for private enterprise in the space sector.

A. Commercial Space Actors

1. Companies Registered in Russia

STPI used five sources of data to create a roster of Russian companies: databases from TechSuccess, Skolkovo, and the Russian Science Foundation; a participant list from the International Navigation Forum, and a literature review. Of these sources, TechSuccess is probably the most reliable in terms of financial status as it uses a ranking methodology developed by PwC. However, TechSuccess contains data only through 2020 and includes companies with a minimum of ₽100 million in revenue. To capture smaller companies, STPI used the data available from the Skolkovo incubator.

The full list of companies from all sources contained 374 unique entities. Of these, 43 were space companies, offering products or services directly applicable to the sector, and 74 were space-adjacent companies, offering products or services that either were relevant to the sector but used for other applications or for which applications could not be determined.

Table 7 shows the sources of data for all 374 companies and for 117 space and space-adjacent companies. A full list of the space and space-adjacent companies is in Appendix A. STPI found that while the “space and navigation” filter was used to find companies in the Skolkovo database, roughly 40 percent belonged to other sectors. The reason for this “contamination” could not be determined. It is possible that some companies misrepresented their portfolios to attract Roscosmos and other customers and/or that the Skolkovo database contains errors. It is worth noting that of all companies with ratings by TechSuccess, only 9 percent were in the space or adjacent sectors; for comparison, the number of companies in oil and gas sector was 14 percent.

Table 7. Sources of Data on Companies

	All companies	Space and adjacent companies
TechSuccess only	232	21 (9%)
Skolkovo only	85	53 (62%)
International Navigation Forum only	21	13 (62%)
Literature only	18	18 (100%)
Russian Science Foundation only	7	2 (29%)
TechSuccess and literature	6	6 (100%)
Skolkovo and literature	4	4 (100%)
TOTAL	**374**	**117**

Source: STPI database. The total includes both active and obsolete companies.

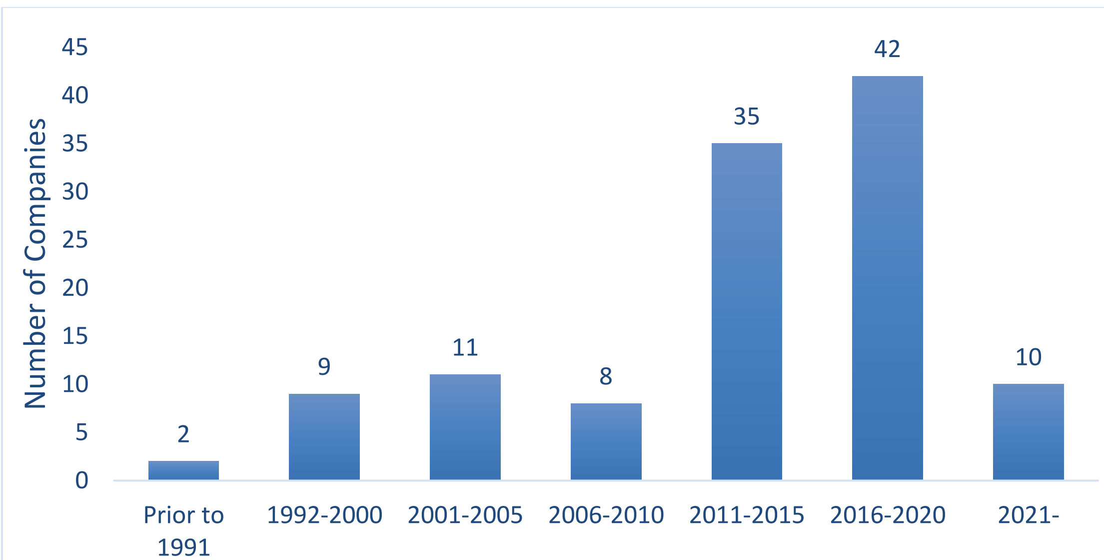
The number of space and space-adjacent companies by application area is shown in Table 8, ordered by the number of space companies. The three most common application areas of space companies were satellite communication (n=9), launch (n=9), and systems integrators (n=6). In contrast, most companies focusing on microelectronics, PNT, and UAV/UAS were space-adjacent. In total, the number of dedicated space companies (n=43) represented just over one-third of all companies.

Table 8. Space and Space-adjacent Companies by Application

Application	Space companies	Space-adjacent companies	All companies
Satellite communication	9		9
Launch	9		9
Systems Integrators for Satellites and Aircraft (Systems Integrator)	6	2	8
Power and propulsion	5	8	13
Materials	4	3	7
Software	3	2	5
Robotics	2	5	7
Microelectronics	2	10	12
Grounds stations	2		2
Position, navigation, and timing (PNT)	1	20	21
Unmanned aerial vehicle/Unmanned aircraft system (UAV/UAS)		24	24
TOTAL	**43**	**74**	**117**

Source: STPI database. The total includes both active and obsolete companies.

STPI examined the founding years for 117 companies using their year of registration. This analysis revealed a significant expansion of the sector between 2011 and 2020, with 77 companies (66 percent) launched during this period (Figure 9). These data are consistent with reports that the Russian government made a significant investment in the space industry in the early 2010s, after a series of embarrassing Roscosmos failures (Zak n.d. ee); the significant increase in the number of companies also coincides with the launch of Skolkovo in 2010. It is too early to determine the most recent trend in company formation, but the number of new companies appeared to have declined in 2021 and 2022, with the average of five new companies registered per year, compared to seven and eight in the previous 5-year intervals. While it seems unlikely that the growth in the commercial space and adjacent sectors will be sustained, the number of companies registered in the most recent years was still higher than in any 5-year period since the collapse of the Soviet Union.



Note: Bins are not consistent in the time period covered.

Sources: companies.rbc.ru; https://e-ecolog.ru; navigator.sk.ru

Figure 9. Registration Year for Space and Space-Adjacent Companies

STPI used open-source data to determine the status of space and space-adjacent companies. Of 117 companies in the set, 99 (85 percent) were determined to be active for 1 of 3 reasons: they had an active status in public databases (n=99), reported non-zero revenue in recent years (n=87), or reported zero revenue but were registered after 2020 (n=6). The last group were “benefit of the doubt” companies—recent start-ups that were assumed to be active but not yet revenue-generating. Of the remaining 18 companies, 7 were reported as having been liquidated and 10 reported no revenue over the past 3 years and were presumed bankrupt. The status of the remaining company, S7 Space, could not be determined, but this company is unlikely to have survived and was classified as bankrupt.

Table 9 shows the status of companies by application. Companies offering launch services were less likely to be active than average, at 56 percent versus 85 percent, but no other obvious relationships between application and operational status emerged from the data. However, the number of companies stratified by application was too low to identify trends.

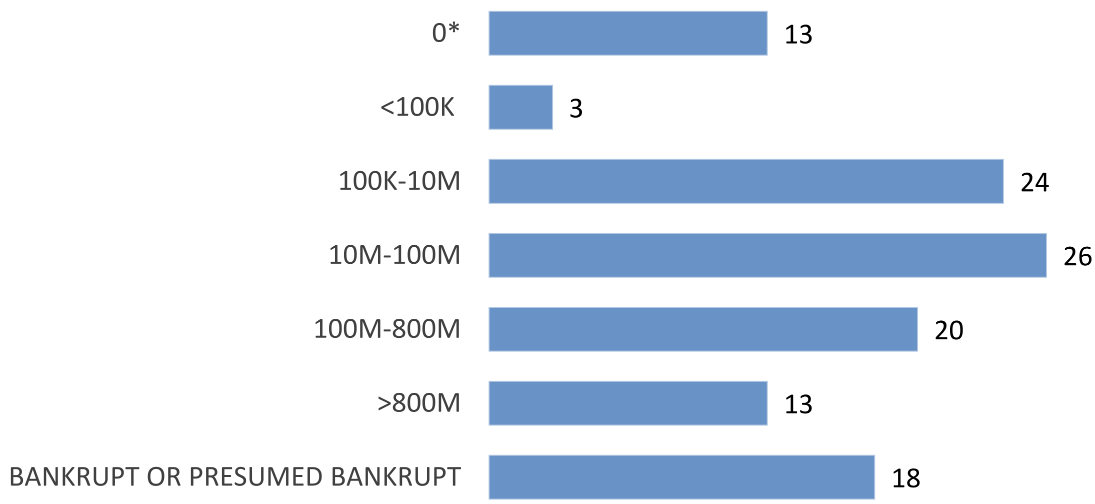
Table 9. Companies by Technical Domain with Operating Status

Application	Number of Companies	Number of Active Companies*
Unmanned aerial vehicle/Unmanned aircraft system (UAV/UAS)	24	21 (88%)
Position, navigation, and timing (PNT)	20	18 (90%)
Power and propulsion	13	10 (77%)
Microelectronics	12	11 (92%)
Launch	9	5 (56%)
Satellite communication	9	7 (78%)
Systems integrator including satellites and aircraft	8	6 (75%)
Materials	7	7 (100%)
Robotics	7	7 (100%)
Software	5	5 (100%)
Ground stations	2	2 (100%)
TOTAL	**117**	**99 (85%)**

Sources: companies.rbc.ru; https://e-ecolog.ru; navigator.sk.ru.

*Active companies as of September 2023, which include six start-ups registered after 2020 with zero reported revenue.

Figure 10 shows the distribution of companies by revenue based on the most recent year available at the time of research, generally 2021 or 2022. Of the 99 companies assumed to be active, 86 (87 percent) reported revenue of ₽800M or less. For comparison, only 64 percent of companies rated by TechSuccess in 2020 (the most recent year available) were in that revenue bracket, and this bracket was classified as “small” by TechSuccess. These data demonstrate that space and space-adjacent companies are small by the standards of the Russian tech industry and have lower revenue than companies in other sectors.



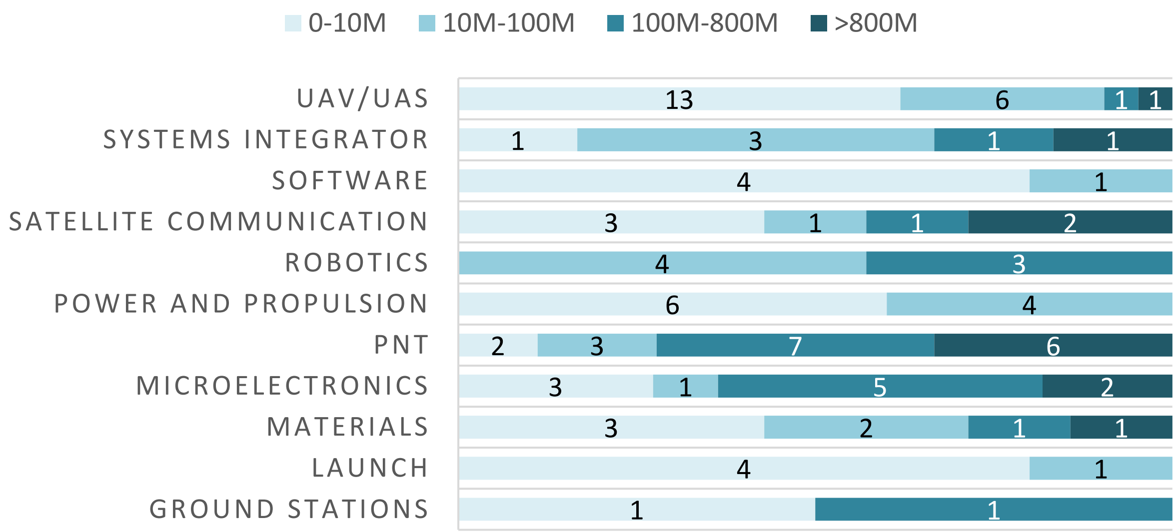
Note: N=117

Sources: companies.rbc.ru; https://e-ecolog.ru; navigator.sk.ru.

*Includes start-ups

Figure 10. Number of Companies by Revenue in Rubles

STPI found some differences in the revenue when companies were stratified by application. Software, power and propulsion, and launch companies tended to have lower annual revenue of ₽100M or less in the most recent available year, while satellite communication, PNT, and microelectronics companies tended to have revenue of more than ₽100M (Figure 11). Companies with revenue exceeding one billion rubles included AZIMUT (PNT), Inertial Technologies of Technokomplex or ITT (PNT), UNIKHIMTEK (materials), Milandre (microelectronics), Fort-Telecom (PNT), SpaceTeam (PNT), Special Technology Center (UAV/UAS and satellite communication), Perm Scientific and Production Instrument (PNT), PRIMA (PNT), and Gazprom Space Systems (satellite communication).



Note: N=99

Sources: companies.rbc.ru; https://e-ecolog.ru; navigator.sk.ru.

Figure 11. Number of Companies by Revenue in Rubles

STPI examined financial trends for companies with 3 years of revenue data (Table 10). Of 93 active non-start-ups, 58 percent were on the upward trend and 36 percent on the downward trend. For about half of the companies, the revenue fluctuated by two-fold or more in either direction (data not shown), suggesting that the data are unreliable, or the financial position of many companies is unstable, or both. For comparison, only 8 of 78 TechSuccess-rated companies had a change in revenue category, of which 7 moved to a higher bracket. Perhaps tellingly, the only company that moved down in revenue was space-adjacent.

Table 10. Revenue Trends for Space and Space-Adjacent Companies

Application	Upward	Flat	Downward	No data or start-up	Bankrupt
UAV/UAS	14		6	1	3
PNT	11		7		3
Power and propulsion	4	2	2	2	3
Microelectronics	4		7		1
Launch	2	1	1	1	4
Satellite communication	4	1	2		2
Systems integrator	5		1		2
Materials	4		2	1	

Application	Upward	Flat	Downward	No data or start-up	Bankrupt
Robotics	4		3		
Software	1		1	3	
Ground stations	1		1		
TOTAL	**54**	**4**	**33**	**8**	**18**

Sources: companies.rbc.ru; https://e-ecolog.ru; navigator.sk.ru.

STPI also studied the distribution of active companies by the number of employees. Of 99 companies, 78 (84 percent) reported less than 100 employees (Table 11), confirming that most space and space-adjacent companies are small. However, there were large discrepancies in the number of employees for several companies—so as with revenue, these data may be unreliable. Of the 20 companies with more than 100 employees, the distribution by technical domain was as follows: materials n=1, microelectronics n=4, PNT n=9, robotics n=2, satellite communication n=1, systems integrator n=1, and UAV/UAS n=2. All ground station, launch, power and propulsion, and software companies had fewer than 100 employees.

Table 11. Number of Employees at Space and Space-Adjacent Companies

Number of employees	Number of companies
<100	78
100–500	11
500–1,000	4
1,000–5,000	5
Unknown	1
TOTAL	**99**

Sources: companies.rbc.ru; https://e-ecolog.ru; navigator.sk.ru.

Websites of all space and space-adjacent companies were searched to determine whether they sold to or partnered with Roscosmos, Ministry of Defense, and/or foreign customers. Ten companies listed Roscosmos or one of its components as partners (Laser systems, Fort-Telecom, Astronomikon Lab, VISAT-TEL, Geyser-Telecom, ICC Severnaya Korona, Sputnix, Android Technology, NILAKT DOSAAF, and Orbital Express), and one company (Aerob) listed the Ministry of Defense. However, no information was available on the nature and extent of domestic partnerships with the exception of two companies: Astronomikon Lab (which has launched a satellite for Iran from Baikonur Cosmodrome) and Fort-Telecom (which participates in GLONASS). Eighteen companies listed foreign companies or countries as partners or stated that they had these relationships, but again minimal specific information was available. While lack of information is inconclusive, it is probable that such partnerships would be mentioned on company websites if they existed to attract new customers.

2. United States-Russia Joint Ventures

One company identified in the search, International Launch Services (ILS[3]), is registered in the United States (Reston, VA). ILS is a joint venture with the Khrunichev Space Center, a Roscosmos unit that is responsible for manufacturing Proton and Angara launch vehicles.

There may be other joint ventures with the Russian space sector that present as U.S. companies. For example, a story in *Reuters* described small Florida-based company RD Amross, which was a joint venture between Energomash and the U.S. conglomerate United Technologies (Grow 2014). According to this source, RD Amross was a "middle-man," skimming tens of millions of dollars from the sales of RD-180 rocket engines. The company's website is no longer accessible and it is likely defunct, but there may be similar "joint ventures" with Roscosmos that evaded detection (Swanson 2023). STPI considered these companies to be outside of the Russian commercial landscape and did not attempt to find them.

3. Case Studies of Seven Commercial Space Companies

STPI further examined seven companies operating in the space sector: Dauria Aerospace (Даурия Аэроспейс), Sputnix (Спутникс), SR Space (СР Спейс) also known as Success Rockets, S7 Space Transport Systems (С 7 космические транспортные системы), Gazprom Space Systems (Газпром космические системы), Lin Industrial (Лин Индастриал), and KosmoKurs (КосмоКурс). The basic information about these companies is summarized in Table 12.

With the exception of Gazprom Space Systems, all companies were established in 2010–2020, the peak years of Russian commercial space activity. Four of the companies (Dauria, KosmoKurs, Lin Industrial, and Sputnix) began in the Skolkovo incubator, and two (Gazprom Space Systems and S7 Space) were spin-offs of large corporations operating in a different sector (gas and airlines).

Two of seven companies had been liquidated (Dauria and KosmoKurs), and two have recently downsized (S7 Space and Lin Industrial). Of the remaining three, the revenue was flat for Gazprom Space Systems (from ₽4.4B in 2019 to ₽4.1B in 2020 and ₽4.3B in 2021) and fluctuated significantly for SR Space (from ₽9M in 2019 to ₽0 in 2020 to ₽23M in 2021). An expert interviewed for the study said that so far, SR Space has launched one

[3] https://www.ilslaunch.com/

rocket that flew 7 kilometers before crashing, and that their greatest accomplishment is public relations.

The only company that appeared to be doing reasonably well was Sputnix, which reported doubling in revenue from 2020 to 2022 (₽108M to ₽289M), although there was a dip in 2019 (96M). A review of the Sputnix website revealed that it had been recently acquired by or incorporated into SITRIONICS Group, an information technology conglomerate with international reach.[4] Possibly because of this merge, Sputnix appears to have shifted its products/services from development and launch of satellites to support systems and ground infrastructure. An expert interviewed believed that Sputnix was compelled into the sale and did not consider the company a serious commercial player.

The case study companies spanned a range of products and services, including development and manufacturing of small satellites, launchers, and other spacecraft (Dauria, Lin Industrial, Sputnix, SR Space); space tourism (KosmoKurs); operation of launch platform (S7 space); and satellite communication services (Gazprom Space Systems). Several companies reported some notable accomplishments, but these successes were mixed with failures. For example, in 2014, Dauria developed and launched three small commercial satellites (in Perseus-M family), which were sold to a U.S. company Aquila Space for $6M after initial problems.[5] Dauria was also the first private company in the space sector to secure a government contract to produce two spacecraft for Roscosmos, [6,7] as well as one of the first to successfully launch a satellite into orbit. However, after Dauria failed to launch satellites for Roscosmos in 2017, it was sued by the agency for full repayment and driven out of business. The owner, who promptly left the country, said in an interview that creating a space company in Russia "was the biggest mistake of his life," citing lack of government support compounded by international sanctions.

According to one expert, S7 Space was the most serious attempt to launch a private space business. The company was established to purchase and restore Sea Launch platform. Sea Launch was initially owned by a consortium of four companies from Russia, Ukraine, Norway, and the United States and managed by Boeing. It declared bankruptcy in 2009 and was acquired by RKK Energia (a Roscosmos subsidiary), which already had a 25 percent stake in the venture. In 2017, S7 Space purchased bankrupt Sea Launch from Energia for $100M, with an additional $470M estimated to be necessary to restore the platform. The reasons for the purchase by S7 are murky. One story claimed that S7 agreed to the purchase in return for protection of its airline business (Luzin 2021c). An expert

---

4 https://www.sitronics.com/company

5 https://www.rbc.ru/technology_and_media/11/04/2018/5acccbaa9a794767ffb6550b

6 https://www.rbc.ru/technology_and_media/11/04/2018/5acccbaa9a794767ffb6550b

7 https://pikabu.ru/story/konets_russkogo_chastnogo_kosmosa_6854364

interviewed thought that Roscosmos promised S7 that it would support Sea Launch, but reneged when it became clear that the company was a competitor for government contracts to develop rockets. The fate of S7 is unclear. Our interviewee said that S7 has no launch vehicles appropriate for its Sea Launch platform,[8] its own rockets are not ready, and it has no resources to modernize the platform. As only 1 year of revenue was available from public data, STPI could not determine its financial standing but it was recently reported that it is laying off staff. It is possible that Sea Launch will return to Roscosmos, making a full circle from privatization to nationalization (Nyrkov 2018).

Table 12. Essential Information on Seven Space Companies Selected for Case Studies

Company	Domain	Est.	Status	Key products	Revenue, rubles	Revenue trend
Bureau 1440	System integrator	2021	Active	Smallsats	1M (2022)	No data
Dauria	System integrator	2009	Liquidated	Smallsats	-	-
Gazprom Space systems	Satcom	1992	Active	Satellite operator	4.3B (2021)	Flat
KosmoKurs	Launch	2014	Liquidated	Space tourism	-	-
Lin Industrial	Launch	2014	Active	Ultra-light launch vehicle	0 (2022)	Flat
Sputnix	System integrator	2011	Active	Microsats, their services and systems	300M (2021)	Up
SR Space	Launch	2020	Active	Ultra-small launch vehicle, small spacecraft	23M (2022)	Up
S7 Space	Launch	2016	Unknown, presumed bankrupt	Operation of Sea Launch platform	156M (2021)	No data

Note: Revenue trend is based on 3 years of data. Only 1 year of data could be found for S7 Space and Bureau 1440.
Sources: companies.rbc.ru; https://e-ecolog.ru; navigator.sk.ru.

[8] Previously, the launch vehicles for Sea Launch used components manufactured by a Ukrainian company that terminated its relationship with its Russian partners after the invasion of Crimea in 2014.

In sum, a picture of a weak commercial space sector emerged in the study. Of the 117 space and space-adjacent companies in different application areas that had been launched between 2010 and 2020, 15 percent have been liquidated or are on the path to bankruptcy based on absent revenue (this number excludes 6 recent start-ups that may not survive in the current business environment). Of the active companies, most reported less than ₽800M in annual revenue, had fewer than 100 employees, and appear to be financially volatile. TechSuccess data showed that space and space-adjacent companies performed worse than other technology companies in Russia in terms of revenue.

Companies specializing in launch services or products appeared to be more vulnerable, presumably due to a combination of Ukraine war and heavy competition from Roscosmos' subsidiaries. An in-depth look at seven better-known (and presumably more successful) space companies revealed that only one, Sputnix, is doing reasonably well based on revenue data, but two experts interviewed were skeptical about its status as a serious space company. In addition, a potentially promising model for the Russian approach of creating a space-focused subsidiary of a large and stable company such as Gazprom or S7 Airlines so far has not produced a successful outcome.

Two individuals interviewed for the study confirmed that Russian companies involved in the space sector generally offer a limited set of products or services to Roscosmos or the Ministry of Defense. They also noted that the conditions for commercial space activities in Russia are even less favorable now than 10 years ago when many of the firms were registered. Potentially unsurmountable obstacles to a healthy commercial space sector include lack of private investment, shortage of electronic components, an obsolete industrial base, and loss of market position due to competition and sanctions. Importantly and as discussed in earlier chapters, a license from Roscosmos is required to launch a private space business, giving it the power to block, destroy, or acquire any company that threatens its monopoly on government contracts.

B. Future Role for Commercial Space Sector Articulated by Roscosmos Leadership

Roscosmos' role as both a regulator of the space industry and a corporation places constraints on the development of Russia's private space sector. Throughout the years, Roscosmos has guarded the interests of its subsidiaries against private sector competition, including primacy in the development of launch vehicles, remote sensing services, and fulfillment of military contracts. This strategy allowed many firms originating during the Soviet era to endure, at the expense of severely reducing the potential market share for non-Roscosmos companies (Vidal and Privalov 2023).

Despite cornering the space services market, Roscosmos itself is not profitable. Since its reorganization in 2015, Roscosmos' reported profit has been either small or negative (Luzin 2021a). Facing a sharp decline in foreign contracts after the invasion of Ukraine in

2022, Roscosmos finds itself needing additional cost savings and revenue streams to cover the growing deficit.

Since his appointment as the director of Roscosmos, Yuri Borisov has painted a sobering picture of Roscosmos' current position (RBK 2023a), going so far as to say that Roscosmos "owes" the Russian state due to its stagnant business model (RBK 2022a). To revive the space agency, Borisov has charted a vision for developing additional commercial services, modeled after the Western companies (RBK 2023a). The key priority for this vision is the development of mass-produced small satellite constellations in LEO, with success being measured by the number of satellites developed per year (RIA Novosti 2023f) and the number of in-orbit satellites reaching 1,700 by 2030 (RIA Novosti 2023a).

According to Borisov, Roscosmos will not be able to manufacture its target number of satellites without the help of private sector businesses (RIA Novosti 2023a). Both Roscosmos and the Russian government have expressed the urge to involve private business in space projects (Russian News Agency TASS 2023d), which has resulted in some policy changes. In 2023, the Russian government signed a roadmap for the development of the private space sector (The Government of Russia 2023a). The roadmap included favorable regulatory changes relating to licensing, lending, and use of existing infrastructure (Permyakov 2023; The Government of Russia 2023b).

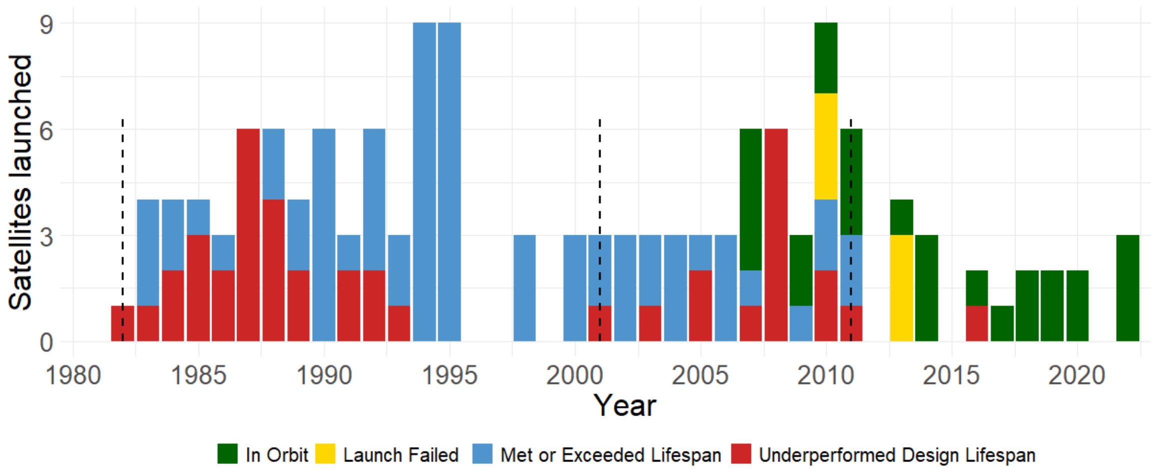
However, the efforts made by Borisov's administration to incentivize the private space sector seem to be primarily aimed at boosting Roscosmos' bottom line (Luzin 2021c). Borisov and other Roscosmos officials have described their intention to build a space services market where Roscosmos will connect private sector providers with potential customers. At the same time, the Russian government is currently considering Roscosmos-backed federal legislation that would make Roscosmos the sole-source provider for remote sensing data (Vedomosti 2023a), which according to some experts, is 90 percent of the space services market in Russia (Herald GLONASS 2024).

7. Lifetime Analysis of Russian Satellite Systems

For the satellite lifetime analyses, STPI looked only at the GLONASS system. This system had the most information and the most continuity across the fleet of satellites Russia has maintained over the years. GLONASS is a satellite navigation system similar to GPS in the United States. The GLONASS constellation has several key properties that make it a fruitful subject for lifetime analysis. The lifetime analysis investigates the extent to which the constellations are still functioning and operating past their intended lifespan.

As discussed in Chapter 4, maintaining GLONASS functionality is a high priority, meaning that gaps in functionality are a result of capacity rather than will on the part of Russia. Second, GLONASS satellites have been in orbit since 1982, providing a long dataset to examine. Finally, GLONASS is a civil constellation, so information about its capabilities, performance, and lifespan are all public. This combination of plentiful public data and the emphasis placed on the constellation make it an informative subject for a deeper dive into Russian space capabilities.

GLONASS requires 24 active satellites to be fully functional. Therefore, the success or failure of the GLONASS constellation is dependent on the relationship between the design lifespan of the Uragan satellites that make up the system and the observed lifespan. The initial lifespan of Uragan satellites was 3 years, and many of those satellites did not meet their expected lifespan. As a result, Russia struggled to reach a launch cadence capable of meeting or sustaining full functionality with the initial Uragan program. The introduction of Uragan-M in the 2000s improved GLONASS functionality by creating a constellation that required less frequent replacement given its longer lifespan. However, the success of the Uragan-M program led to the current situation in which Russia *requires* Uragan-M satellites to overperform in order to maintain full functionality of the constellation. Figure 12 describes the launch cadence of the GLONASS satellites and identifies the status of the satellite for each year it was launched. For example, in 2007 Russia launched six GLONASS satellites, of which four are still in orbit, one met or exceeded its lifespan, and one underperformed and deorbited before it met its expected lifespan.



Source: McDowell (2024)

Figure 12. GLONASS Satellites by Launch Year and Lifetime Performance

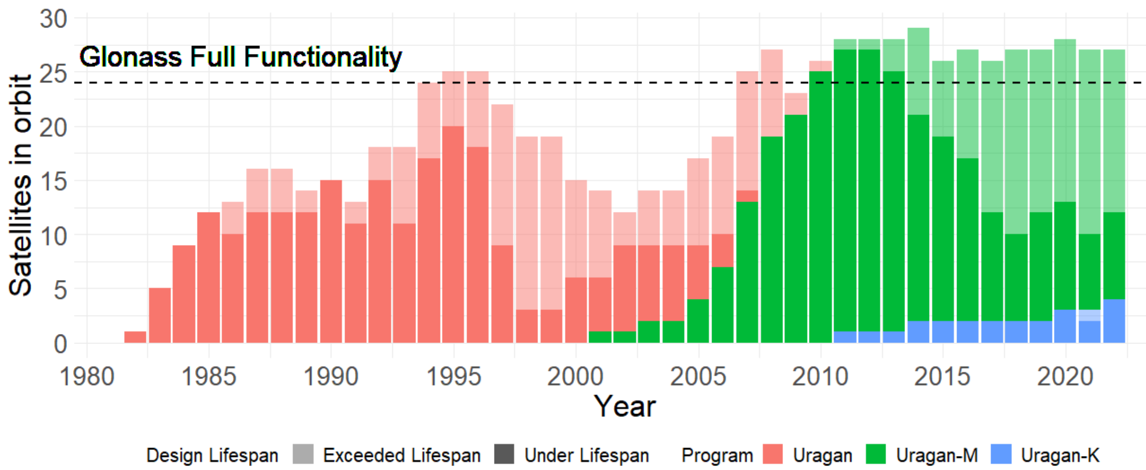
In theory, Uragan-M satellites have a lifespan of 7 years. However, as Figure 12 describes, Uragan-M satellites launched as early as 2007 are still functioning 16 years later (green bars). This drastically extended operational time allowed GLONASS to reach full functionality in 2007 and 2008, and to maintain it from 2010 onwards. This was possible despite the launch failure of rockets carrying Uragan-M satellites in 2010 and 2013 (Zak 2010; Graham 2013). The GLONASS constellation has only maintained full functionality while having no satellites that exceeded their lifespan from 2010 until 2013. Every other year at least one of the satellites in the constellation required to provide full functionality has been beyond design lifespan. Uragan-M exceeded its intended lifespan, which allowed Russia to have a functional fleet for longer than they may have expected. However, since many Uragan-M satellites are so far beyond their design lifespan, they may be subject to unpredictable failures in the near future.

Figure 12 also shows that the launch cadence of GLONASS satellites has been steadily decreasing over time. In the early 1990s it briefly reached a pace of nine satellites per year, but that was followed by multiple years with no launches and then a steady rate of three launches per year through the 2000s. When Russia attempted to increase the launch cadence in the late 2000s and early 2010s, the number of underperforming satellites increased and there were multiple failed launches. While it is not possible to directly attribute the failures to the attempted launch cadence increase, it is noteworthy that in the years following the failures, the launch cadence further declined to approximately two satellites per year. Launch failures and satellite underperformance also became less common from 2016 onward.

By looking at the lifetime performance of GLONASS satellites over time, two trends emerged:

1. As time progressed, satellites lasted longer—often beyond their life expectancy based on design.
2. As time progressed, fewer satellites were launched each year.

To gain the full picture of the GLONASS constellation it is also instructive to examine the programs that comprise the constellations over time.



Source: McDowell (2024)

Figure 13. GLONASS Satellites in Orbit by Program and Status

Figure 13 illustrates that the trend toward longer lifespans along with the launch cadence correspond with the transition between Uragan programs. The initial Uragan series had too short a lifespan and could not consistently reach full functionality despite frequent launches. It was gradually replaced by Uragan-M that became the backbone of GLONASS functionality for two decades, increasingly relying on satellites that outperformed expectations. However, this program is in the process of winding down as the new member of the series, Uragan-K, is emerging.

The transition to Uragan-K has presented its own challenges. The previous transition (from Uragan to Uragan-M) resulted in several years without full functionality, but it also was fairly quick, taking less than 10 years. By contrast, 10 years after the launch of the first Uragan-K satellite only 3 satellites appear to be in orbit. The launch data suggest that unless the longevity of the existing Uragan-M satellites significantly exceed expectations, Russia will not be able to ramp up Uragan-K fast enough to counter the close of the Uragan-M program and maintain full functionality of GLONASS.

8. Space Services Revenue

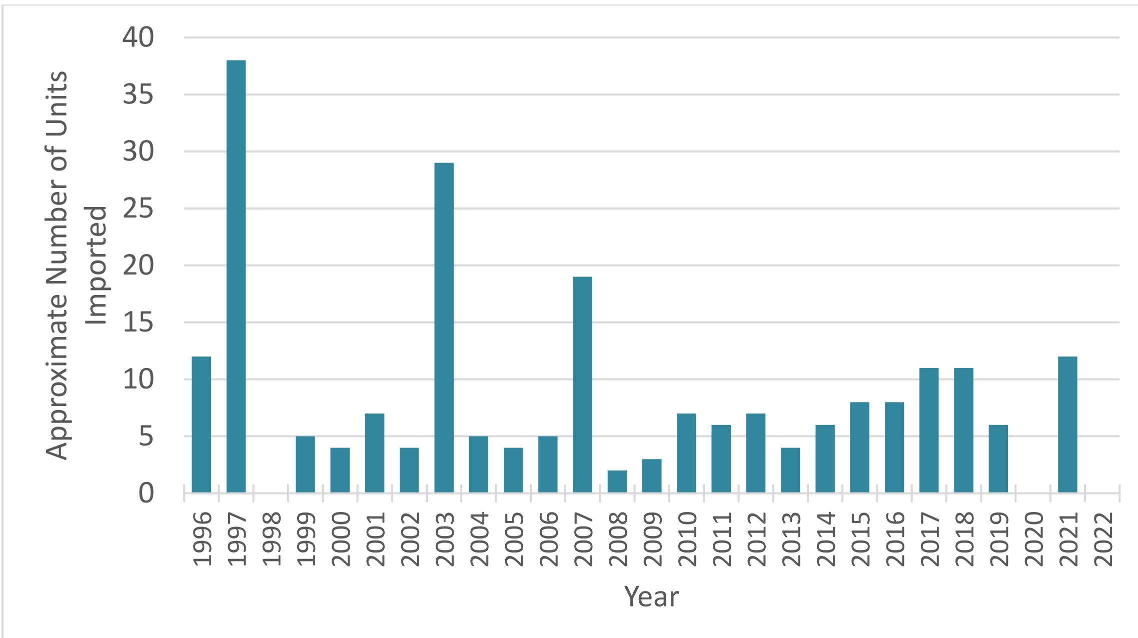
As discussed in Chapter 3, Russia is an integral player in the global launch enterprise. This chapter discusses the revenue Russia has received from 2006 to 2023 from the United States across three different dimensions: missile and rocket reaction engines, seats to the ISS, and launch services from Russian launches. The ultimate goal is to show the revenue originating from foreign partners, but this revenue analysis is in no way exhaustive. Specifically, for the rocket engine sales, it only considers those engines sold to and imported by the United States, and does not take into account other space technologies. The sale of seats to the ISS and the revenue estimate from providing launch services consider all activity, not just that from the United States.

A. Rocket Engine Sales

In the mid-1990s, the United States and other nations that had capabilities to build rockets sought out a unique liquid oxygen (LOx) combustion technology used by Russia (Mosely 2011). These engines offered an advantage in that they provided a reliable rocket design while also maintaining a high efficiency and performance profile. Consequently, a joint venture between Pratt and Whitney and Roscosmos' Energomash called RD Amross LLC was set up to import and sell the RD-180 engines to the U.S. market (Grow 2014). RD Amross purchased RD-180 engines for United Launch Alliance's (ULA) Atlas launch vehicle family, a series of launch vehicles used in U.S. national security missions (Mosely 2011). Other U.S. companies also made agreements to purchase RD-181 engines for the Antares launch system, originally purchased by Orbital Sciences Corporation, but now part of Northrop Grumman.

STPI analyzed a number of sources and determined that ULA purchased a total of 122 RD-180 engines through a number of block contracts from the late 1990s to 2022 (Maidenberg 2022). In 2014, Orbital Sciences Corporation purchased 30 RD-181 rocket engines from Roscosmos' Energomash subsidiary (de Selding 2015). While there was a contract option to purchase another 30 RD-181 options, it does not appear that it was exercised (de Selding 2015). STPI determined that the total number of RD-180 and RD-181 engines purchased from 1996 to 2002 was 152 engines, but these data are based on news reports and secondary publications, not primary sources (Maidenberg 2022; de Selding 2015).

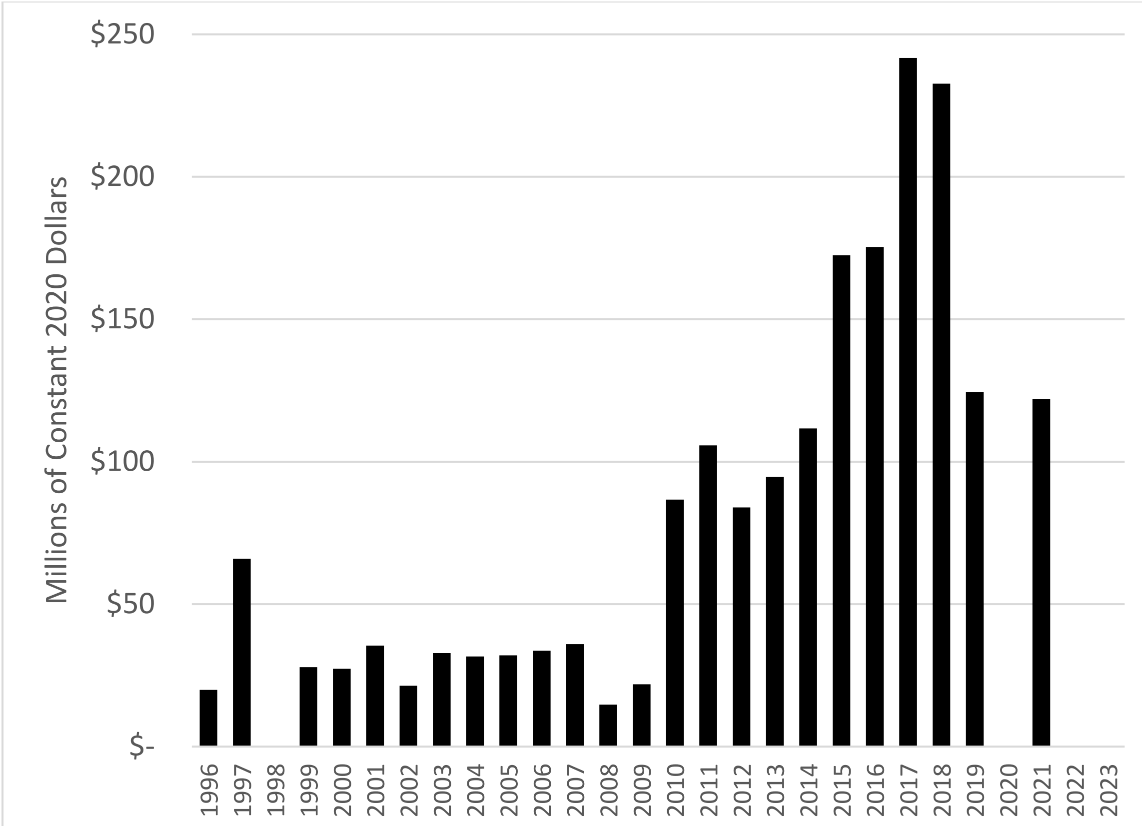
Given the challenges in determining the cost and dates for each block purchase, STPI turned to foreign trade data between the United States and Russia on rocket and missile commodities. We relied on the Schedule B Chapter 84 district-level trade data of imports from Russia, 1996–2022. Specifically, we used the 6-digit code 84.12.20 (Reaction Engines Other Than Turbojets) and its 10-digit sub-codes 8412.10.0010 (Missile and Rocket Reaction Engines). From 1996 to 2002, the United States imported 223 units under these codes at a value of $1.74B. Figure 14 describes the number of missile and rocket reaction engine units imported over time from Russia to the United States. The data do not specify the product name or indicate whether these are in fact RD-180s and RD-181s, but we assume a large majority of these units were the RD-180 and RD-181 engines.



Source: U.S. Census Bureau USA Trade Online Data, Schedule B Code 8412.10.0010: Missile and Rocket Reaction Engines

Figure 14. Number of Missile and Rocket Reaction Engines Imported from Russia to the United States, 1996 to 2022

Figure 14 is the imported value of these Missile and Rocket Reaction Engines from 1996 to 2022. The unit cost varied greatly over this time period, but the average unit cost between 2010 and 2020 was $17.6M. News reports and secondary sources confirm the trade data is on the order of the value of the RD-180 engines. For example, a 2014 Reuter's article reports that RD Amross paid Energomash between $17.9M and $20.2M on average for the engines. Given the completeness of the U.S. import data, we rely on these values and unit numbers to estimate the revenue made from the sale of the Russian rocket engines to the United States. The detailed data table can be found in Appendix Table B-1.



Source: U.S. Census Bureau USA Trade Online Data, Schedule B Code 8412.10.0010: Missile and Rocket Reaction Engines

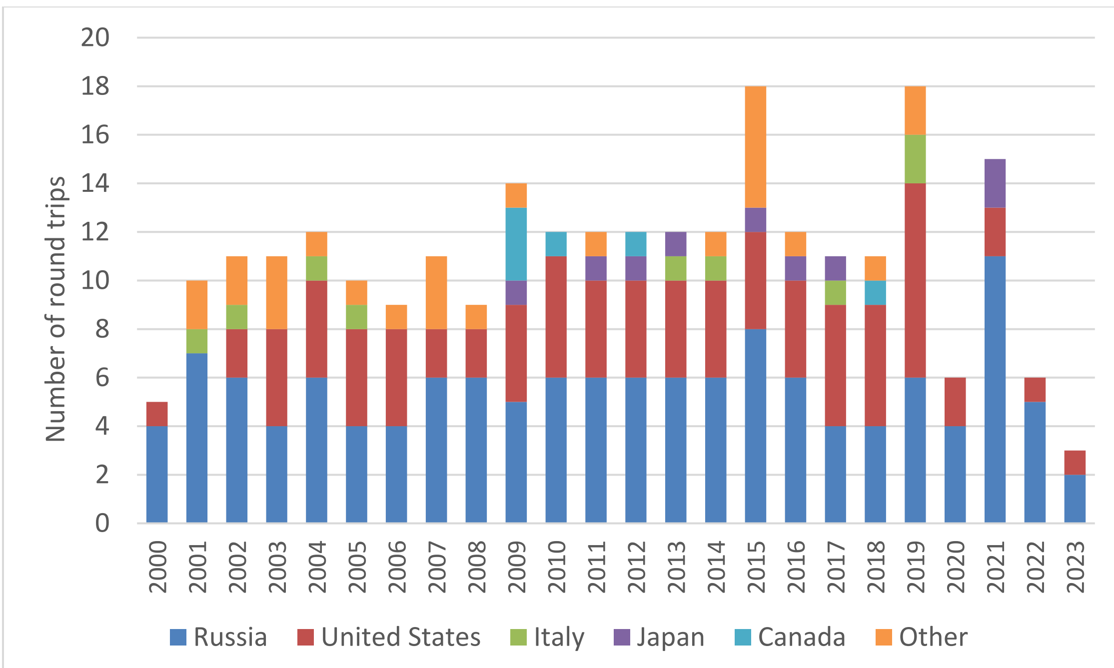
Figure 15. Customs Value of Number of Missile and Rocket Reaction Engines Imported from Russia to the United States, 1996 to 2023

We find that the value of imports from of rocket engines from 2010 to 2021 was much higher than the prior decade, with a peak of imports from 2015 to 2019 due to the higher per unit cost during that timeframe (Figure 15). This is likely because the United States relied on the RD-180 and RD-181s for their launch complex and at that time there were no engine alternatives for the Atlas V launch vehicle, in particular.

B. Seat Sales to the International Space Station

The next major revenue category we consider was the sale of seats for astronauts to the ISS on the Russian Soyuz launch vehicles. Using launch information from NASA and the NASA Inspector General report, we determined that 278 people were launched to the ISS on a Soyuz rocket from 2000 to 2023, including space tourists. Of that total, 47 percent were from Russia; 33 percent were from the United States; 3 percent were from Italy, Japan, and Canada each; and 10 percent from all other countries (NASA n.d. b; NASA 2019).

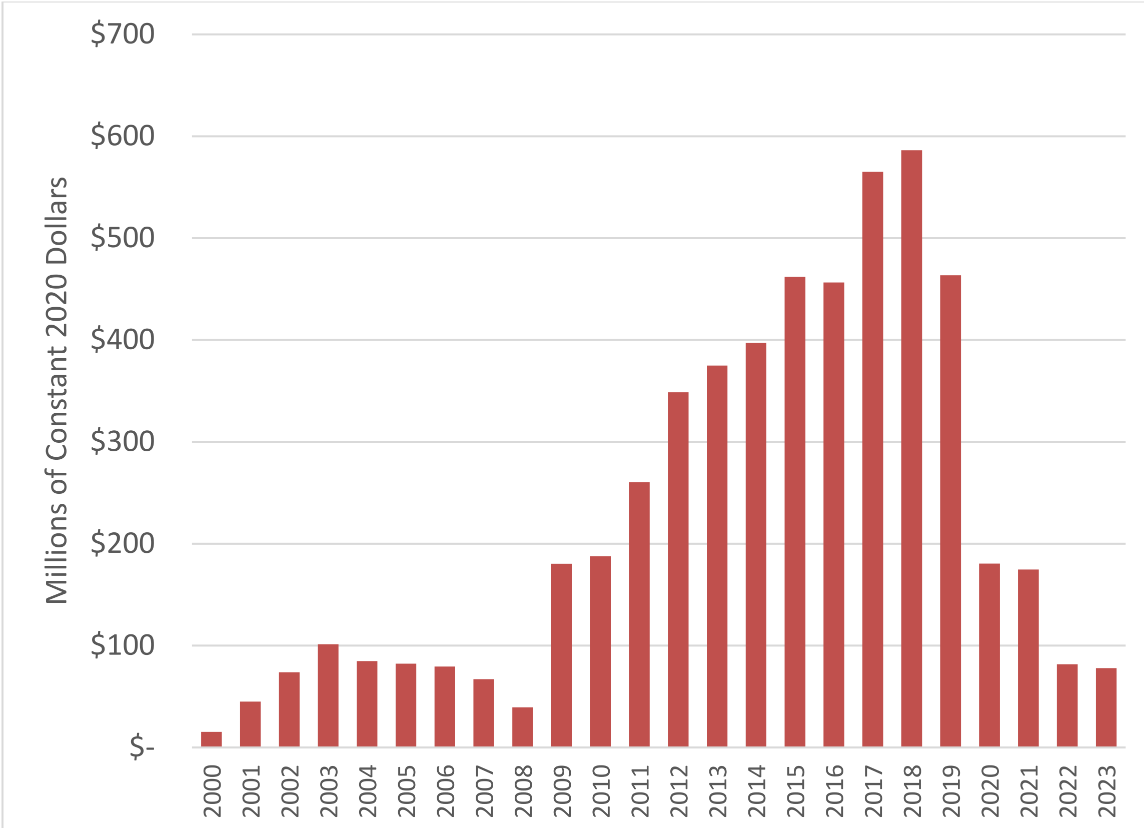
We estimated the total amount spent by non-Russians on seats to the ISS each year. We assumed that from 2000 to 2005, the cost per round-trip seat was $21M (Aliberti and Lisitsyna 2019), and from 2006 to 2019, we used early cost per seat data from NASA's Inspector General report (NASA 2019). In this calculation, we assume that the number of round-trip flights times the cost per seat estimates the total Russian revenue from ISS seat sales to foreign countries or individuals. The prices may have varied, and the exact sales process of seats, particularly to tourists, are not well known. Finally, we use reporting information on the cost of the seat sale in 2020 and assume that cost was the same from 2021–2023 (Bartels 2020). Table B-2 contains the data and assumptions used in the analysis.



Sources: NASA (n.d. b)

Figure 16. Number of Roundtrips to ISS on Russian Soyuz Launch Vehicle, 2000–2023

Figure 16 describes the estimated number of roundtrips to the ISS on the Soyuz launch vehicle from 2000 to 2023. The United States lacked viable transportation to the ISS between 2010 and 2020, and relied solely on the Soyuz to take U.S. astronauts to the ISS. Included in this analysis is also what tourists and others would have had to pay for seats to the ISS as a non-astronaut.



Sources: Aliberti (2019); NASA OIG Report (2019)

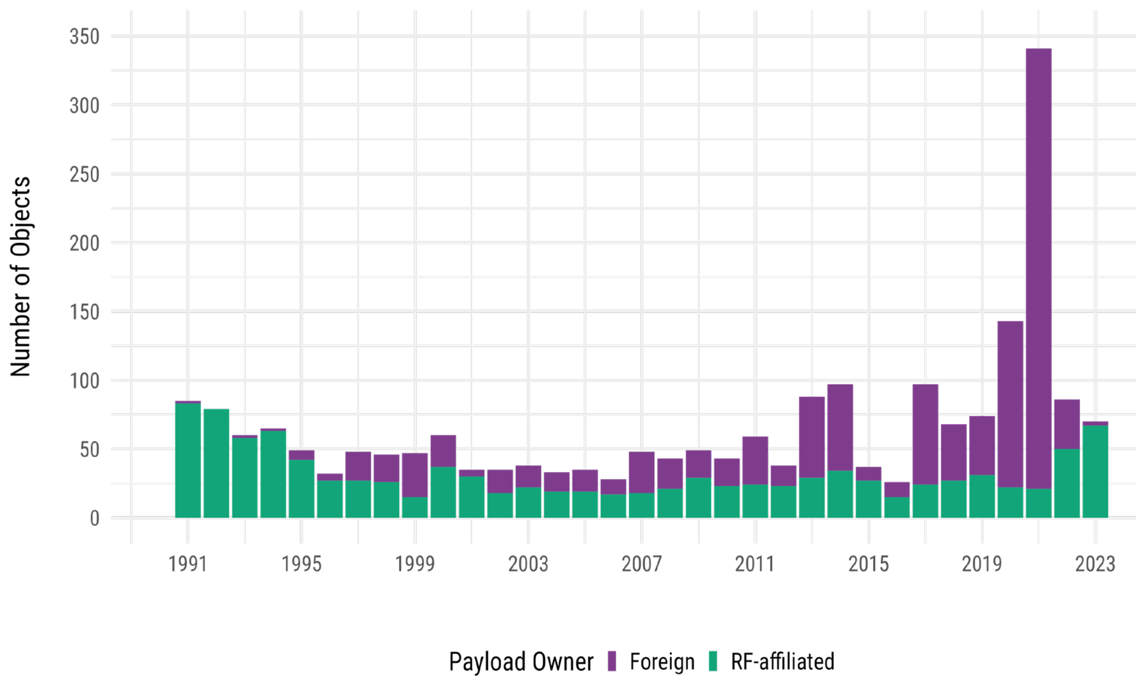
Figure 17. Estimated Russian Revenue from Sales of Seat to ISS

The cost per seat coupled with the data from Figure 16 provided the basis for the estimated revenue per year Russia gained from providing ISS transportation to all non-Russians. Figure 17 describes, in current dollars, the total revenue earned over time for Soyuz ISS transportation. In total, from 2000 to 2023, when deflating to 2020 constant dollars and summing, we estimate that $5.4B was paid to Russia for this service.

C. Launch Services

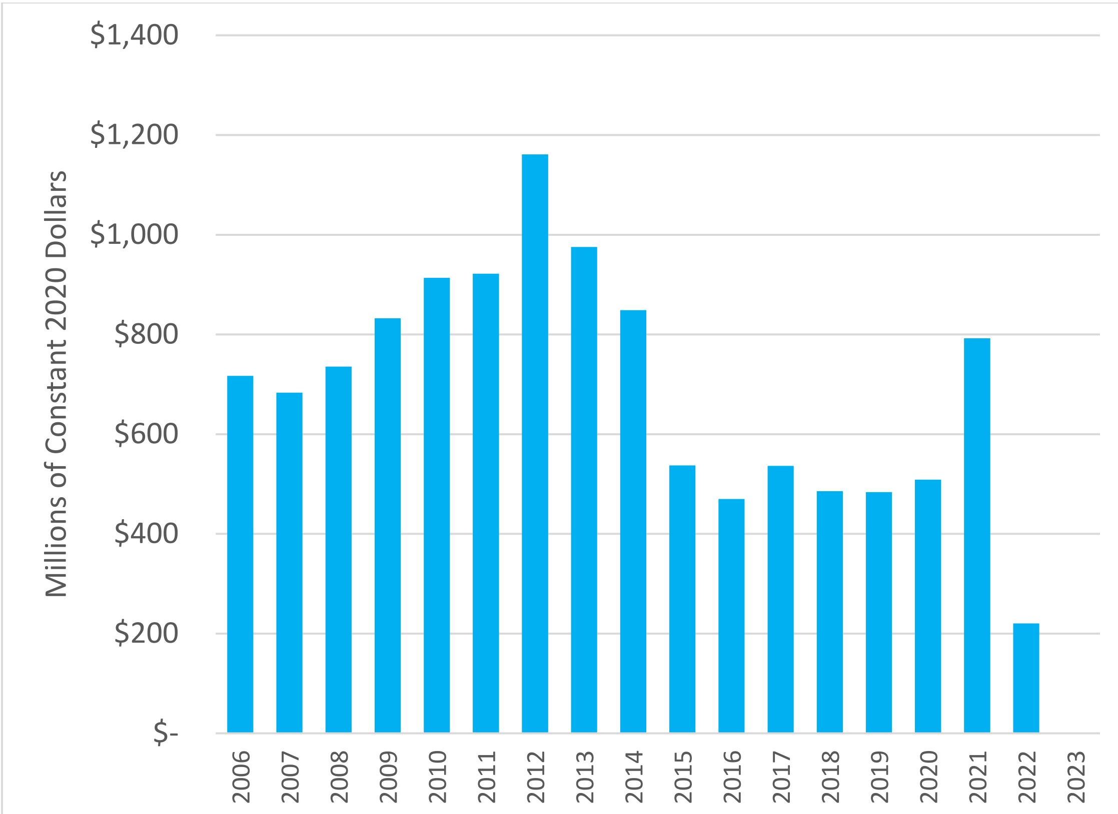
The final section of the revenue analysis considers the payments made to Russia for providing satellite launch services. The analysis is based on payload and launch data from the General Catalog of Artificial Space Objects (GCAT) complied by Jonathan McDowell. These data were cleaned and parsed to determine the yearly number of foreign payloads launched by launch vehicle by Russia. Figure 18 shows the number of payloads launched aboard Russian launch vehicle from 1991 to 2023. Since 2006, on average 40 to 60 percent of the payloads launched by Russia were foreign payloads. The spike in 2021 was due to Russia's launch of the OneWeb constellation prior to their invasion into Ukraine.

To estimate the cost of launch, we primarily relied on the Federal Aviation Administration's (FAA) Annual Compendium, which contains estimates for each of the relevant launch vehicles (Proton, Rokot, Soyuz-2.1, Soyuz-U; FAA 2012–2018). These four launch vehicles were responsible for all foreign payload launches. For most launches with foreign payloads, the entire launch vehicle was dedicated to launching the foreign payload. Given this, we attributed the full cost of launch to foreign payloads and assigned it as revenue Russia was receiving from selling launch services. For those few launches with both Russian and foreign payloads, we proportionally determined the foreign launch cost based on the mass of the foreign payloads. Figure 17 describes the yearly estimated price or revenue to Russia for providing satellite launch services.



Source: McDowell (2024)

Figure 18. Domestic and Foreign Payloads (objects) on Russian Launch Vehicles, 1991 to 2023

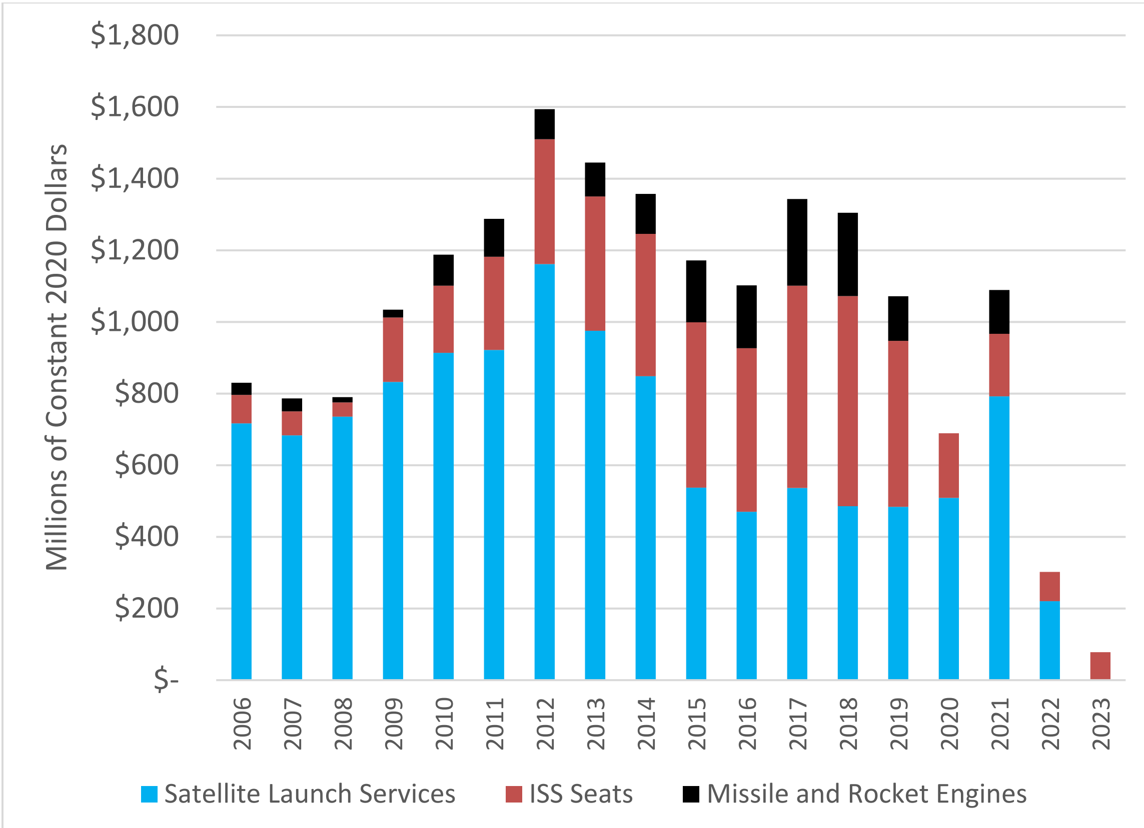


Sources: McDowell (2024); FAA (2012–2018)

Figure 19. Estimated Cost of Foreign Payloads on Russian Launch Vehicles

D. Combined Estimated Revenue

Russia has generated a significant amount of revenue from harnessing their launch and propulsion expertise and selling products and services to the rest of the world. The combined estimated total revenue from 2006 to 2023 for selling rocket engines to the United States, selling seats to the ISS, and providing launch services to foreign entities is $18.5B in constant 2020 dollars; the average revenue across the 18-year period is approximately $1B per year. Figure 20 describes the combined revenue over time and shows the relative share of the three sources of revenue with satellite launch services as generating the highest and most significant share of the total revenue assessed. After the invasion of Ukraine in February 2022, the revenue from foreign launches has significantly declined, and as a result the estimated revenue in 2023 is only $78M.



Sources: McDowell (2024); FAA (2012–2018); Aliberti (2019); NASA OIG Report (2019)

Figure 20. Combined Estimated Revenue from Rocket Engine Imports, Sale of ISS Seats, and Launch Costs of Foreign Payloads

9. Summary and Conclusions

Russia’s civil space enterprise is undergoing a transition. While Russia’s space sector benefits from legacy systems that are reliable and have demonstrated great capability in the past, the present and future pose major challenges.

A. Capabilities That Russia Seeks to Maintain

1. Active Satellite Constellations

After the annexation of Crimea in 2014, the lack of access to Western technology prompted the Russian space industry to begin transitioning to a domestic model of production for key systems, such as GLONASS. The expanded international sanctions imposed on Russian companies in the wake of the invasion of Ukraine in 2022 have forced Roscosmos to shift to producing most spacecraft domestically, which strongly affected satellite systems because of their heavy dependence on Western technology.

The shift in the production model has delayed the anticipated launch dates of most Russian satellites. In particular, GLONASS satellites had to be redesigned completely due to their heavy reliance on imported technologies and are now severely behind schedule when compared to the reported launch timeline prior to the war. While Russian manufacturers are capable of producing some of the required technologies, much of the software and microelectronics previously supplied by Western firms cannot be easily replaced by domestic substitutes, which has created further delays. It is likely that Roscosmos and its subsidiaries will attempt to extend the lifespans of their in-orbit assets in an effort to ease the transition to a domestic production model.

At the same time, STPI’s analysis concluded that the loss of access to Western-produced technologies may reduce Russia’s on-orbit capabilities, but is not likely to result in serious degradation of Russia’s critical satellite systems—GLONASS chief among them. The shift to domestic production for GLONASS started in 2014, and the first GLONASS satellite that was in part domestically produced was launched in 2023; the first fully domestically produced GLONASS satellite is currently scheduled for launch in 2030. These dates suggest that the transition is still in progress, and the consequent delay may result in the GLONASS constellation dropping below full capacity.

The lifetime analysis revealed that since 1980, when the GLONASS satellites were first launched, the satellites have struggled to maintain full functionality. While newer GLONASS families have an increased lifespan, between 1998 and 2007 GLONASS did not maintain a fully functioning system due to a decrease in launch frequency. More recently, Russia appears to be facing the same challenges, as it struggles to manufacture and launch its latest GLONASS program, Uragan-K, at a fast-enough rate to establish full functionality. Despite similar manufacturing challenges, Russia is also attempting to develop Uragan-V satellites to provide similar capabilities with fewer satellites through an atypical orbit.

However, given the necessity of GLONASS' navigation capabilities for Russia's military and the option of purchasing microelectronics from allied countries, such as China, the production of GLONASS satellites is unlikely to run out of funding or necessary components, despite the inevitable delays.

2. Launch Services

Russia's launch services continue to be the most stable aspect of its space program. The workhorse vehicles of Russia's space program are highly reliable, and Roscosmos has a high degree of collective expertise in producing successful launches. Despite the delays in its production, Russia's relatively new cosmodrome, Vostochny, is now hosting launches and is being expanded to increase its capacity.

The Proton and Soyuz families remain the main launch vehicles as Russia has struggled in developing and transitioning to a new generation of launch vehicles. The competition between Roscosmos' subsidiaries, issues with funding, and a lack of strategic consensus have produced an incoherent vision for Russia's future launch vehicles. With decades in development, the most mature next-generation launch vehicle program, Angara, has only seen a handful of test flights.

Russia has also seen its grasp on its primary spaceport, Baikonur, grow more tenuous. While Kazakhstan has leased Baikonur to Russia until 2050, recent actions of the Kazakh authorities aimed at keeping Roscosmos fiscally accountable seem to suggest dissatisfaction with the partnership. Ultimately, these actions may not threaten Russia's immediate future in Baikonur, but are nevertheless a signal; recent actions by Roscosmos suggest construction of new facilities at Baikonur are being deprioritized in favor of Vostochny.

Taken together, Russia's launch services remain a strong point of its space program. Regardless of future progress on next-generation launch vehicles or the status of Baikonur in the long term, Russia maintains a reliable and trusted set of launch vehicles as well as its own spaceport. These aspects ensure Russia's capacity for maintaining its in-orbit presence through the use of domestic capabilities.

3. Lunar Exploration

The recent launch of the Luna-25 lander in 2023 has signaled Russia's intention to continue the lunar exploration missions begun by the Soviet Union. The launch of Luna-25 took much longer than expected, in part due to lack of resources assigned to the effort compared to the prior Soviet Luna missions. This was largely reflective of the deprioritization of scientific space missions by the Russian government, which has traditionally pursued more commercially aligned programs.

The crash of Luna-25 has resulted in pessimism about follow-on lunar missions among experts, but this sentiment has not been echoed by Roscosmos leadership. The director of Roscosmos has suggested that the failure of the Luna-25 mission is a natural consequence of the loss of capacity for conducting lunar missions given the nearly 50-year lapse between Luna-24 and Luna-25, and that it is all the more reason to devote additional resources to the forthcoming Luna-26 and Luna-27 missions. This stance from Roscosmos leadership is not surprising, as an official announcement that Russia will abandon its lunar program would have negative political ramifications. Currently, the full ramifications of the Luna-25 failed mission are still coming into focus; the level of interest will be gauged by the amount of funding developed to lunar exploration in the space strategy document to be released leading up to 2025. Until then, historical trends suggest that lunar exploration programs will continue, but at a pace similar to or slower than Luna-25.

B. Capabilities That Russia Seeks to Develop

1. Serial Manufacturing Capacity for Satellites

As it searches for additional streams of revenue, Roscosmos has been attempting to reach parity with Western satellite services, focusing on large low-orbit small satellite constellations. However, Russia has yet to begin its transition to serial production methods such as those used to produce OneWeb and Starlink satellites. Most Russian satellites are still custom-made, requiring a lengthy labor-intensive manufacturing process, resulting in a production capacity of about 40 satellites per year. Consequently, much of the rhetoric from Roscosmos leadership concerns the need for Russia to "catch up" to other major spacefaring nations in terms of satellite production.

As part of this effort to catch up, Roscosmos has been marketing *Sfera*, a collection of satellite constellations offering broadband internet, HDTV, imaging, and remote sensing, focused on Russian customers and customers in neighboring friendly countries. To date, Sfera has not garnered sufficient funding or private sector interest in Russia, so Roscosmos has begun reaching out to partner countries in the BRICS bloc. Ultimately, Sfera may be successful, at least in part, if there is a lack of alternatives for Russian customers or sufficient interest from Russia's military, which seeks to gain an advantage in communications and EO capabilities in the war with Ukraine.

Roscosmos and its subsidiaries are currently transitioning to a serial manufacturing model but are still in the process of testing prototypes. The agency hopes to fund the construction of factories for satellite manufacturing, but likely has not yet secured funding to do so. Moreover, Roscosmos has realized that its subsidiaries are unlikely to reach the targeted goal for number of in-orbit satellites by themselves—as the director of Roscosmos has made overtures to the private Russian space sector, seeking to attract additional interest in satellite production.

Given the lack of expertise, funding, and slow transition to a new supply chain for components, it is unclear to what degree Roscosmos and the Russian private sector will be successful in developing small satellite constellations in the near future. Even if produced in sufficient numbers, instability in the component base may result in satellites with high failure rates or unreliable service. The Russian private space sector is weak and has not produced major players even in the more favorable commercial environment—so it is unlikely to be a significant contributor to the constellations envisioned by Roscosmos, at least in the near future. Furthermore, Russia has yet to find an international market for its satellite services.

2. New Orbital Space Station

Access to the ISS has been a central component of the Russian manned space flight program and is a key priority for the Russian government. The sunsetting of the ISS has accelerated the need for Roscosmos to transition to a follow-on space station, and Roscosmos has formulated a plan that includes bringing the new space station, ROS, into service by 2027.

ROS would provide several tangible benefits to Russia's space program. Primarily, ROS is intended as a space laboratory. Roscosmos plans to place the station in a polar orbit, which would allow for scientific experimentation in a novel space-based environment as compared to the ISS. Moreover, ROS' expanded facilities would increase the range of possible applications, including facilitating production of materials for commercial use. Finally, placing ROS in a polar orbit would allow for easier access from Russia's space stations, as well as the ability to observe Russia's territory and the Arctic.

Roscosmos' ability to carry out the plan for ROS hinges on retrofitting assets originally intended for the ISS and accelerating timetables of programs that are currently in development. Roscosmos' subsidiaries are currently refitting an ISS module to serve as the core module for ROS, and are testing the next-generation launch vehicle that would carry the components for ROS. Activating ROS by 2027 would also require a new crewed spacecraft, a launcher for the new crewed vehicle, and the completion of ground monitoring stations and launch pads. As experts are dubious of Roscosmos' ability to achieve the intended plans for ROS by 2027, Roscosmos is likely to attempt to extend the lifetime of the ISS past the currently planned deorbiting date of 2031.

C. Capabilities That Russia Seeks to Build or Acquire

1. Building a Domestic Private Space Sector

The Russian government has traditionally applied the *national champion* model to its space sector, incentivizing the survival and growth of large companies over which it can exercise direct control, to the detriment of the rest of the space sector. The majority of Russia's national champions in the space sector are former Soviet factories and design bureaus that are, in one way or another, investing their efforts in continuing or expanding Soviet-era programs. While many follow-on programs to Soviet precursors have been highly successful, the domination of the national champions over the Russian space sector and the inertia of their operations have left little space for both new entrants to the space sector and innovation.

Roscosmos, a state-owned corporation that currently controls most major space companies in Russia, is an exemplar of the strategy the Russian government has taken in managing the space sector. Roscosmos is both a regulator, overseeing and ensuring the health of space companies in Russia, and a potential supplier to the Russian government, which is the biggest customer of space services in the Russian market. Roscosmos' role includes an inherent conflict of interest, one that Roscosmos has exploited to its own financial advantage: its subsidiaries are prioritized in competitions for government contracts and the support for new companies, in terms of subsidies and licensing, is minimal. In this climate, the majority of new Russian entrants to the space sector are large private sector organizations for whom space services are a natural extension of their supply chain, and have sufficient government contacts that can usher them through the licensing process.

While the direct management strategy of the Russian government has allowed a greater degree of control over the space sector, it has also led to a stagnation of the Russian space sector as compared to the United States and China. Roscosmos has acknowledged that Russia has fallen behind its peers, particularly in terms of satellite production, and is interested in supporting private sector space businesses. However, the rhetoric of Roscosmos officials seems to suggest that the private sector push is ultimately intended to benefit the company's revenue stream, both in terms of cost savings and commission on services.

A picture of a relatively weak commercial space sector emerged from this study. Of the 117 space and adjacent companies launched in different application areas between 2010 and 2020, 15 percent are on the path to bankruptcy based on absent revenue. This is probably a conservative estimate, since it excludes recent start-ups with no revenue under the assumption that they need more time to succeed. Furthermore, even the active space companies found appeared to be more financially volatile and reported lower average revenue than other tech sectors. Case studies of the best-known and presumably most successful companies paint mostly a grim picture of failure. Companies specializing in launch services or products appeared to be more vulnerable, presumably due to a combination of the Ukraine war and heavy competition from Roscosmos' subsidiaries.

2. Seeking a Share of the Space Services Market

Prior to the conflict with Ukraine, Russia maintained a significant share of the international space services market, particular in the area of launch services. Besides providing satellite launch services to private space companies, Russia facilitated the majority of the crewed flights to the ISS, and sold rocket engines to the United States. The study estimated that Russia profited from an average revenue (adjusted in constant 2020 dollars) of approximately $1B per year from 2006 to 2023. The invasion of Ukraine severed these revenue streams, leaving Roscosmos with only a small proportion of its funding from sources other than the Russian government. Similarly, Russia lost all revenue from the sale of RD rocket engines, and is unlikely to regain this market even under a friendly government due to changes in technology.

Throughout its existence, Roscosmos has struggled to maintain profitability, depending in large part on Russian government contracts and subsidies. The heavy reliance on government funding has been a point of criticism often levied against Roscosmos; the Russian government has insisted that Roscosmos needs to find a path to solvency. However, the loss of lucrative foreign contracts leaves Roscosmos more dependent on government funding than ever.

Currently, Roscosmos is pursuing several paths to increasing its share of the domestic space services market and regaining a place in the international space services market. Domestically, Roscosmos is expanding its pay-for-service capabilities, aimed at both government and private sector customers, and is attempting to monopolize the sale of EO data. Internationally, Roscosmos has attempted to interest BRICS countries in satellite constellations, market its launch services to nations in the developing world, and is developing a stable of launch vehicles that can feasibly compete on the international launch services market.

3. Looking to Forge Major Foreign Partnerships

Historically, Russia's partnerships with the United States have resulted in a number of highly successful space projects. The funding provided by the United States during the 1990s supported Russia's space program after the collapse of the Soviet Union, which helped bring about the ISS, one of the most successful collaborative space projects to date. An expert interviewed for the study quipped that the United States saved the Russian space program. Russia's conflict in Ukraine that began with the annexation of Crimea in 2014 largely severed its space partnerships with the United States, leaving the ISS as the sole area of collaboration between the two countries.

In its current state, the Russian space program has not shown the capacity to organize major space exploration projects on its own. In recent years, Russia has been a junior partner in projects like ExoMars or has mounted small-scale deep space missions, several of which were unsuccessful. Despite the stated aim to construct a lunar base, Russia's space program does not seem to be on a trajectory to lead a project of that magnitude.

Given the severance of the partnership with the United States, China would seem to be a logical partner for Russia's deep space ambitions. However, despite the strong rhetoric on both sides, the Russia-China space partnership has yielded few tangible results. STPI's analysis found that Russia and China are largely incompatible as partners in space because China does not view Russia's contributions as critical to its strategic space projects and Russia does not want to lose face by accepting a role as China's junior partner. However, given STPI's assessment of Russia's capabilities and potential, it may have to accept China's leadership in order to realize its major deep space projects.

4. Economic Stability and a Sufficient Space Workforce

To carry out its future plans for the development of its space enterprise, Russia requires both highly skilled workers and sufficient funding for its ongoing space programs. Although experts have predicted that the Russian economy would quickly collapse as a result of international sanction after its invasion of Ukraine, the effects of these sanctions on the Russian economy is unclear. The latest projections of the Russian economy in 2024 are favorable, suggesting that it will expand, due in part to the realignment of its trade partners. However, if the Russian economy begins to decline, civil space programs may be the first to lose funding as the Russian government will likely shift its priorities to more critical necessities. In particular, civil satellite systems, experimental launch vehicles, and scientific missions have historically suffered due to the loss of government subsidies to the space sector.

Russia's space workforce is in a similarly precarious situation. Roscosmos' workforce is growing older, with many current specialists on track for retirement; STPI's findings suggest Roscosmos may find it difficult to replace them. The government space sector—that is Roscosmos and its subsidiaries—which makes up the major part of Russia's space workers, is seen as an undesirable prospect for young workers in Russia, even prior to the war. The perception of low wages, corruption, and organization stagnation are pervasive enough to deter many prospective workers. In addition, many qualified workers have left the country after the invasion of Ukraine. Due to these factors, Roscosmos may face serious challenges replenishing its workforce in the near future.

D. Challenges Facing Russian Space Enterprise

STPI concluded that many aspects of Russia's civil space sector—its programs and priorities, manufacturing and production capabilities, supply of talent, funding, and partnerships—are facing challenges. The conditions for maintaining a leadership position remain unfavorable for Russia as its space sector is hampered by an obsolete industrial base, weak to nonexistent commercial sector, and loss of historical partnerships.

Sanctions placed on Russia from its invasion of Ukraine have created a shortage of key spacecraft components including microelectronics. While Russian manufacturers are capable of producing some of the required technologies, much of the software and microelectronics previously supplied by Western firms cannot be easily replaced by domestic substitutes, which has created further delays due to the need to redesign space systems across the board. Finally, Russia's commercial space sector is hampered by Roscosmos' historical priorities. Roscosmos is a regulator of commercial space companies overseeing their activities. At the same time, Roscosmos, a state-owned enterprise, is both a supplier to the Russian government as well as the biggest customer of space services in the Russian market. This dual role carries an inherent conflict of interest, which Roscosmos has exploited to its own financial advantage. First, its subsidiaries are prioritized in competitions for government contracts, stifling competition. Second, new ventures in the space sector are required to obtain permits from Roscosmos, giving it full control over any potential competitor. As a result, Russia's non-Roscosmos commercial space sector companies have struggled to compete with Roscosmos and its subsidiaries to the detriment of the space sector at large.

Prior to the conflict with Ukraine, Russia maintained a significant share of the international space services market, particular in the area of launch services. In addition, Russia facilitated the majority of the crewed flights to the ISS, and sold RD-180 and RD-181 rocket engines to the United States for use on the Atlas V and Cygnus U.S. launch vehicles. STPI estimates that Russia's average revenue (adjusted in constant 2020 dollars) from 2006 to 2023 was approximately $1B per year for a total of $18.5B. The invasion of Ukraine severed these revenue streams, leaving Roscosmos with only a small proportion of its funding from sources other than the Russian government. STPI estimates that in 2021 the revenue from foreign sales and services accounted for an average of 30 percent of Roscosmos' total (with a peak of 57 percent in 2020) revenue from non-military projects.

E. Russian Commercial Space Sector

Roscosmos' role as both a regulator of the space industry and a corporation in its own right places constraints on the development of Russia's private space sector. Throughout the years, Roscosmos has guarded the interests of its subsidiaries against private sector competition, including in the development of launch vehicles, remote sensing services, and fulfillment of military contracts.

A picture of a relatively weak commercial space sector emerged from this study. Relative to other technology sectors in Russia, investments in space and space-adjacent companies are small by Russian technical industry standards. Of the 117 space and adjacent companies established within the different application areas between 2010 and 2020, 15 percent are on the path to bankruptcy based on absent revenue. Furthermore, the active space companies appeared to be more financially volatile and smaller in terms of revenue than other tech sectors. Companies specializing in launch services or products appeared to be more vulnerable, presumably due to a combination of the Ukraine war and competition from Roscosmos' subsidiaries.

STPI has not identified any Russian companies poised to emerge as a leader in the global space industry and to compete for the global market share.

F. Timelines and Life Expectancy of Russian Orbital Systems

In examining the life expectancy of Russia's orbital platforms, STPI looked only at the GLONASS satellite system. We learned that the life expectancy of GLONASS satellites has increased over the decades demonstrating high quality engineering, but the pace of replacement has waned suggesting the full functionality of the GLONASS system may not be maintained in the future.

As new generations of GLONASS satellites were introduced, their expected lifetimes increased, but Russia often relied upon those satellites beyond their planned life expectancy. Given the longer lifetimes for subsequent programs, fewer satellites were launched each year resulting in a constellation that is past its prime. Finally, due to the supply chain disruption from international sanctions, Roscosmos is redesigning future GLONASS satellites to rely primarily on domestically produced components. These trends suggest that Russia is struggling to manufacture enough satellites to maintain full functionality of the GLONASS constellation and to replace GLONASS satellites in a timely manner, without relying on in-service satellites to overperform their expected lifetime.

Appendix A.
Codebooks for Space Data

Commercial Companies

Space or Space-Adjacent

Two STPI researchers independently reviewed and reconciled the list to identify any companies operating in space or space-adjacent sectors using the following definitions:

Space—products and/or services directly related to the space industry, such as provision of launch services and infrastructure; design and manufacturing of satellites and other spacecraft or their components and materials; and satellite data processing software.

Space-adjacent—products and/or services relevant to space industry, but either used for other applications or for which applications could not be determined, including robotics, microelectronics, drones and other unmanned vehicles and aerial systems, airplane engines, and navigation and remote sensing software and hardware.

Appendix Table A-1. Space Companies Identified

Technical Domain	Company Name
Ground Stations	Galileoskay
	Nebo GK
Launch	Cosmolab
	Starsem
	International Space Company Kosmotrans
	Lin Industrial
	KosmoKurs
	S7 Space
	Rocket Technologies
	Orbital Express
	SR Space/SR Rockets
Materials	Termoran
	Cintez-Project
	Soluterm
	Techprom-AKS
Microelectronics	Transformo

Technical Domain	Company Name
	Sensor Spin Technologies
PNT	SpaceTeam
Power and Propulsion	Nauka-AT
	Advanced Propulsion
	Avant Space-Systems
	PL TM
	Spectralaser
Robotics	Android Technology
	NTLAB-SC
Satellite Communication	Lorette
	Vector-Arctic
	VISAT-TEL
	Geyser-Telecom
	ICC Severnaya Korona
	KuSpace Technologies
	Matrix Wave
	Gazprom Space Systems
	Internsputnik
Software	Tensor Lab
	MKS
	Space Systems
Systems Integrator including Sats and Aircraft	New Smart Systems
	Astronomikon Lab
	Sputnix
	Dauria Aerospace
	NILAKT DOSAAF
	Special Technology Center

Appendix Table A-2. Space Adjacent Companies Identified

Technical Domain	Company Name
Materials	Unikhimtek
	Aeroplatforms
	ACT
Microelectronics	About OKB-Planeta
	Elvis
	Milandre
	SuperOx
	Troitsk Engineering Center
	Svetlana-Rost
	Inversion-Sensor
	SIGNAL
	Specialized Electronic Systems
	Ten Flex Rnd
PNT	Laser Systems
	Laboratory Of Microdevices
	Azimut
	Inertial Technologies Of Technokomplex (Itt)
	Labsolut
	Lemz-T
	Fort-Telecom
	Hyrolab
	Cubi
	Agrostorman
	Ends-Orryol
	Topcon Positioning Systems
	Elmetro Group
	Rts
	Perm Scientific And Production Instrument
	Botlikh Radio Plant
	Stancoproekt
	Turboscan
	Prima
	Spirit Navigation
Power and Propulsion	Eme-Aero
	Iag
	Dda
	Reynolds

Technical Domain	Company Name
	Delmot
	Pdt
	Rtt
	Skyturbins
Robotics	Itsumma
	Promobot
	Ukam-Grup
	Robocv
	Smithec
Software	Pirss
	Quadriga
Systems Integrator including Sats and Aircraft	Aviasport
	Wasp Aircraft
UAV/UAS	Unmanned Systems
	Ada Aero
	Nic Aeroscript
	Industrial Drones
	Robolyot
	Dron Solutions
	Ics
	Technoveter
	Klevercopter
	Prosvet
	Morphing Technologies
	Hover
	Hypercopter
	Alticam
	Facc
	Aerial Photography
	Cusire
	Avianovations
	Virtus
	Communication Spetsprozaschita
	Aviation Solutions
	Aerob
	Kopter Express Technologies Ltd.
	Geoscan

Appendix B.
Revenue Analysis Estimates and Assumptions

Table B-1. Estimate of Value and Quantity of Russian Missile and Rocket Reaction Engine Imports to the U.S. from 1996–2022 in U.S. Dollars

Year	Customs Value (Gen) (Current $U.S.)	Customs Unit Value (Current $U.S. Gen)	Approximate Number of Units
1996	12,773,789	1,064,482	12
1997	43,093,169	1,134,031	38
1998	0	0	0
1999	18,674,116	3,734,823	5
2000	18,674,116	4,668,529	4
2001	24,846,532	3,549,505	7
2002	15,205,587	3,801,397	4
2003	23,806,889	820,927	29
2004	23,502,157	4,700,431	5
2005	24,503,595	6,125,899	4
2006	26,603,595	5,320,719	5
2007	29,183,565	1,535,977	19
2008	12,211,438	6,105,719	2
2009	18,317,157	6,105,719	3
2010	73,222,876	10,460,411	7
2011	91,138,000	15,189,667	6
2012	73,658,560	10,522,651	7
2013	84,619,188	21,154,797	4
2014	101,730,000	16,955,000	6
2015	158,892,000	19,861,500	8
2016	162,948,000	20,368,500	8
2017	228,568,500	20,778,955	11
2018	225,186,500	20,471,500	11
2019	122,829,000	20,471,500	6
2020	0	0	0
2021	126,168,714	10,514,060	12
2022	0	0	0
Total	**1,740,357,043**	**235,416,698**	**223**

Source: Census Bureau USA Trade Online Data, Schedule B Code 8412.10.0010: Missile and Rocket Reaction Engines

Table B-2. Estimated Russian Revenue from ISS Seat Sales to Foreign Countries

Year	One-way ISS trips (non-Russian/non-Tourists)	Roundtrip to ISS (non-Russian/non-Tourists)	Cost per seat estimates in millions of current dollars	Revenue in millions of current dollars	Revenue in millions of constant 2020 dollars
2000	1	0.5	$21.00	$10.50	$15.35
2001	3	1.5	$21.00	$31.50	$44.96
2002	5	2.5	$21.00	$52.50	$73.77
2003	7	3.5	$21.00	$73.50	$101.34
2004	6	3	$21.00	$63.00	$84.79
2005	6	3	$21.00	$63.00	$82.29
2006	5	2.5	$25.10	$62.75	$79.38
2007	5	2.5	$21.80	$54.50	$67.10
2008	3	1.5	$21.80	$32.70	$39.44
2009	12	6	$25.17	$151.00	$180.28
2010	12	6	$26.43	$158.55	$187.67
2011	12	6	$37.40	$224.42	$260.40
2012	12	6	$51.00	$306.00	$348.66
2013	12	6	$55.85	$335.07	$374.92
2014	12	6	$60.31	$361.88	$397.23
2015	14	7	$60.81	$425.68	$461.97
2016	12	6	$70.67	$424.04	$456.41
2017	14	7	$76.33	$534.30	$564.99
2018	14	7	$81.07	$567.50	$586.33
2019	12	6	$76.23	$457.38	$463.48
2020	4	2	$90.25	$180.50	$180.50
2021	6	2	$90.25	$180.50	$174.63
2022	2	1	$90.25	$90.25	$81.66
2023	2	1	$90.25	$90.25	$77.89

Source: ISS Trip estimates come from NASA's website

References

Abdrazak, P. Kh., and K. Sh. Musa. 2015. “The impact of the cosmodrome ‘Baikonur’ on the environment and human health.” *International Journal of Biology and Chemistry* 8 (1): 26–29. issn: 2409-370X. https://doi.org/10.26577/2218-7979-2015-8-1-26-29.

Aerospace Technology. 2019. “Gazprom and Thales to partner on spacecraft assembly project.” https: //www.aerospace-technology.com/news/gazprom-thales-spacecraft-assembly/.

Airbus Defense Space. n.d. “Express AM4R and Express AM7.” Accessed Feb 19, 2024. https://web.archive.org/web/20150701012815/http://www.space-airbusds.com/en/programme/expressam4r-and-express-am7.html.

Aliberti, M and K. Lisitsyna. 2019. *Russia’s Posture in Space: Prospects for Europe*. Vol. 18 of *Studies in Space Policy*. Cham, Switzerland: Springer International Publishing, 2019.

AO Gonets. n.d. “МКСР «Луч» [MSRS “Luch”].” Accessed Feb 19, 2024. https://gonets.ru/rus/ uslugi/sistema-retranslyacii-luch/.

Augustynowicz, P. 2014. *State-owned enterprises in Russia- The origin, importance and principles of operation.*

Aviasat. 2023. “В России создадут низкоорбитальную группировку спутников для обеспечения доступа в интернет [Russia will create a low-orbit constellation of satellites to provide Internet access].” https://www.aviastat.ru/news/264823news- v-rossii- sozdadut- nizkoorbitalnuyugruppirovku-sputnikov-dlya-obespecheniya-dostupa-v-internet.

Aviation Explorer. 2023. “В Новосибирске начали проектирование и сборку спутников “Грифон” [Design and assembly of Grifon satellites started in Novosibirsk].” https://www.aex.ru/news/ 2023/12/19/265440/.

Bartels, Meghan. 2020. “NASA to pay Russia $90 million for a Soyuz seat on a crew launch this fall.” May 13, 2020. https://www.space.com/nasa-pays-russia-90-million-for-soyuz-seat.html

Berger, E. 2021. “Russian module suddenly fires thrusters after docking with space station.” https: //arstechnica.com/science/2021/07/russian-module-suddenly-fires-thrusters-after-docking-withspace-station.

Bauman Moscow State Technical University. 2022. “МГТУ вошёл в «Созвездие Роскосмоса» [BMSTU joined the “Constellation of Roscosmos”].” https://bmstu.ru/news/mgtu-v-sozvezdieroskosmos.

BFM.ru. 2021. “В РАН назвали несвоевременной сверхтяжелую лунную ракету «Енисей» [The Russian Academy of Sciences called the super-heavy lunar rocket “Yenisei” untimely].” https: //www.bfm.ru/news/462633.

Bihovskiy, M.A., and M.N. Dyachkova. 2008. “История создания и развития отечественных систем спутниковой связи и вещания [History of creation and development of domestic satellite communication and broadcasting systems].” https://www.computer-museum.ru/connect/sputnik.htm.

Borisov, A. 2016. “Взгляд сверху: Зачем Россия решила наблюдать за Арктикой из космоса [View from above: Why Russia decided to observe the Arctic from space].” Lenta. https://lenta.ru/ articles/2016/12/11/arktika2/.

Buzko, R. 2021. *Regulation of Space Activities in Russia.* Buzko Legal. https://web.archive.org/web/ 20211205000530/https:/www.buzko.legal/content-eng/legal-regulation-of-space-activities-inrussia.

Byrne, B. 2023. “Another coolant leak on a Russian space vehicle docked to the ISS could delay plans.” https://www.npr.org/2023/02/16/1157635455/another-coolant-leak-on-a-russian-space-vehicledocked-to-the-iss-could-delay-pl.

Campbell, K. 2014. “SA spy satellite issue resurrected.” Engineering News. https://www.engineering news.co.za/print-version/sa-spy-satellite-issue-resurrected-2014-01-31.

Center for Strategic and International Studies. 2023. Spaceports of the World (1957–2022). Aerospace Security Project. Available online at https://aerospace.csis.org/data/spaceports-of-the-world/, updated on 1/31/2023, checked on 7/11/2023.

Cheberko, I. 2015. “«Арктика» попала под санкции Госдепартамента [Arktika has fallen under State Department sanctions].” Izvestiya. https://iz.ru/news/594603.

Chereneva, V. 2023. “Штурм Луны. Чем для космической отрасли обернётся потеря станции “Луна-25” [Siege of the Moon. How will the loss of the Luna-25 station turn out for the space industry?]” Mashnews. https://mashnews.ru/shturm-lunyi.-chem-dlya-kosmicheskoj-otrasliobernyotsya-poterya-stanczii-luna-25.html.

———. 2024. “«Луна» не укладывается в сроки. Роскосмос требует денег с разработчиков российской лунной программы [Luna does not meet the deadline. Roscosmos demands money from the developers of the Russian lunar program].” Mashnews. https://mashnews.ru/luna-ne-ukladyivaetsyav-sroki.-roskosmos-trebuet-deneg-s-razrabotchikov-rossijskoj-lunnoj-programmyi.html.

Cherkasova, N. 2023. “Космическое импортозамещение [Space import substitution].” https://rspectr.com/articles/kosmicheskoe-importozameshhenie.

Chupov, D. 2022. *Летные испытания спутников «Гонец М-1» начнутся в 2028 году [Flight tests of Gonets M-1 satellites will start in 2028].* https://telesputnik.ru/materials/tech/news/letnyeispytaniya-sputnikov-gonec-m-1-nachnutsya-v-2028-godu.

Cordell, J. 2022. “Russia’s space agency to issue bonds for satellite programme.” https://www.reuters.com/markets/rates-bonds/russias-space-agency-issue-bonds-satellite-programme-2022-12-21.

de Selding, P B. 2015. “Orbital Sciences: Russian Press Overstate RD-181 Contract Value.” January 26, 2015. https://spacenews.com/orbital-sciences-expects-rd-181-delivery/

———. 2023. “Russia’s Satellite Operators Assess How to Achieve the Self-Sufficiency Imposed by Sanctions.” https://www.kratosdefense.com/constellations/articles/russias-satellite-operatorsassess-how-to-achieve-the-self-sufficiency-imposed-by-sanctions.

Dvorkin, V.V., Yu. I. Nosenko, Yu. M. Urlichich, and A.M. Finkel’Shtein. 2009. “The Russian global navigation satellite program.” *Herald of the Russian Academy of Sciences* 79 (1): 7–13. https: //link.springer.com/article/10.1134/S101933160901002X.

Egorov, V. 2018. “Звездные войны: может ли ракета-носитель «Ангара» стать конкурентом Falcon 9 [Star Wars: Can the Angara launch vehicle become a competitor to Falcon 9].” https://www. forbes.ru/tehnologii/361545-zvezdnye-voyny-mozhet-li-raketa-nositel-angara-stat-konkurentomfalcon-9.

———. 2022. “Сферо-буро-малиновый [Sferaically-brownish-crimson].” Novaya Gazeta. https://nov ayagazeta.ru/articles/2022/11/08/sfero-buro-malinovyi-media.

———. 2023a. “Cosmic karma: Russia loses Moon race to India due to sanctions, underfunding and mismanagement.” The Insider. https://theins.ru/en/opinion/vitaly-yegorov/265079#:~:text=Originally%20named%20Luna%2DGlobe%2C%20it,Moon%20and%20develop%20subsequent%20missions.

———. 2023b. “How Russia’s Lunar Ambitions Came Crashing Down.” *The Moscow Times*. https: //www.themoscowtimes.com/2023/08/28/how-russias-lunar-ambitions-came-crashing-downa82246.

eoPortal. 2012a. “Electro-L / GOMS-2 (Geostationary Operational Meteorological Satellite-2).” https: //www.eoportal.org/satellite-missions/electro-l.

———. 2012b. “Kanopus-V 1 (Kanopus-Vulkan N1).” https://www.eoportal.org/satellite-missions/ arktika-m.

———. 2022. “Arktika-M.” https://www.eoportal.org/satellite-missions/arktika-m.

Erygina, L. V., and R. S. Serdyuk. 2014. “Состояние Российской Ракетно-Космической Промышленности и Тенденции ее Расвития [Growth Trends of Russian Space Industry].” *Vestnik SibGAU* 53 (1): 207–211. https://cyberleninka.ru/article/n/sostoyanie-rossiyskoy-raketno-kosmicheskoypromyshlennosti-i-tendentsii-eyo-razvitiya/viewer.

Federal Aviation Administration. 2012. “Commercial Space Transportation: 2011 Year in Review.” January 2012. https://www.faa.gov/sites/faa.gov/files/space/additional_information/2012_YearinReview.pdf

———. 2013. “The Annual Compendium of Commercial Space Transportation: 2012.” February 2013. https://www.faa.gov/sites/faa.gov/files/space/additional_information/Annual_Compendium_of_Commercial_Space_Transportation_2012_February_2013.pdf

———. 2014. “The Annual Compendium of Commercial Space Transportation: 2013.” February 2014. https://www.faa.gov/sites/faa.gov/files/space/additional_information/2014-02-04_FAA_2013_Compendium.pdf

———. 2015. “The Annual Compendium of Commercial Space Transportation: 2014.” February 2015. https://www.faa.gov/sites/faa.gov/files/space/additional_information/FAA_Annual_Compendium_2014.pdf

———. 2016. “The Annual Compendium of Commercial Space Transportation: 2016.” January 2016. https://www.faa.gov/sites/faa.gov/files/space/additional_information/2016_Compendium.pdf

———. 2017. “The Annual Compendium of Commercial Space Transportation: 2017.” January 2017. https://www.faa.gov/sites/faa.gov/files/space/additional_information/2017_AST_Compendium.pdf

———. 2018. “The Annual Compendium of Commercial Space Transportation: 2018.” January 2018. https://www.faa.gov/sites/faa.gov/files/space/additional_information/2018_AST_Compendium.pdf

Federal Communications Agency. 2010. “Федеральное государственное унитарное предприятие «Космическая связь» (ГПКС) [Federal State Unitary Enterprise “Space Communications” (RSCC)].” http:// rossvyaz.ru/about/organizations/rscc/.

Fedorov, E. 2018. “Навигационные спутниковые системы СССР, России и США. История вторая [Navigation satellite systems of the USSR, Russia and the USA. History two].” *Военное обозрение [Military Review],* https://topwar.ru/143637-navigacionnye-sputnikovye-sistemy-sssr-rossii-issha-istoriya-vtoraya.html.

Finmarket. 2008. ““Энергия” ставит под срыв телекоммуникационный выход “Газпрома” на новые географические рынки [Energia disrputs Gazprom’s telecom entry into new geographic markets].” https://www.finmarket.ru/news/818130.

Fishman, R. 2017. “От сложного к простому [From complex to simple].” Accessed February 19, 2024, Popular Mechanics, no. 4, https://epizodsspace.airbase.ru/bibl/popul-meh/2017/4/38-42.pdf.

Foust, J. 2023. “Russian ISS module experiences coolant leak.” https://spacenews.com/russian-issmodule-experiences-coolant-leak.

Gazeta.ru. 2022. “«Юра, удержи отрасль»: с чего начинался «Роскосмос» [“Yura, maintain the industry”: how Roscosmos began].” https://www.gazeta.ru/science/2022/02/25/14574145.shtml.

———. 2023. “«Не будем делать из неудачи трагедию». Россия собирается вернуться на Луну [“Let’s not make a tragedy out of failure.” Russia is going to return to the Moon].” https://www.gazeta.ru/science/2023/08/25/17481398.shtml?updated.

Gazprom Space Systems. 2020. “Текущий бизнес «Газпром космические системы» в современных условиях и перспективы развития компании представлены на конференции Satellite Russia CIS [Current business of Gazprom Space Systems in modern conditions and the company’s development prospects are presented at the Satellite Russia CIS conference].” https://kosmos.gazprom.ru/press/news/2020/07/528/.

———. n.d. “Космический Аппарат Ямал-501 [Yamal-501 Spacecraft].” Accessed Feb 19, 2024. https: //www.gazprom-spka.ru/ru/projects/kosmicheskie-apparaty/yamal-501/.

GLONASS Consumer Application Center. n.d. “История ГЛОНАСС [History of GLONASS].” Accessed March 13, 2024. https://glonass-iac.ru/guide/.

Graham, W. 2014. “Russian Strela rocket launches Kondor-E.” https://www.nasaspaceflight.com/ 2014/12/russian-strela-launch-kondor-e/.

Grow, B., S. Grey, R. Anin. 2014. “Special Report: In Pentagon deal with Russians, big profit for tiny Florida firm.” November 18, 2014. https://www.reuters.com/article/us-russia-capitalism-rockets-special-rep/special-report-in-pentagon-deal-with-russians-big-profit-for-tiny-florida-firm-idUSKCN0J22BQ20141118

Hajiyeva, G. 2018. “Russia Develops Payload Modules to Operate Home-Grown Satellites.” Caspian News. https://caspiannews.com/news-detail/russia-develops-payload-modules-to-operate-homegrown-satellites-2018-8-12-28.

Harvey, A. 2021. “Blue Moon lunar lander: Facts about Jeff Bezos’ spacecraft.” Space.com, Dec 23. Retrieved from https://www.space.com/blue-origin-lunar-lander, on Jan 28, 2022.

Henry, C. 2016. “RSCC pays Russian-European manufacturing team to build next two satellites.” SpaceNews. https://spacenews.com/rscc-pays-russian-european-manufacturing-team-to-buildnext-two-satellites.

Herald GLONASS. 2023a. “Ассоциация «ГЛОНАСС/ГНСС-Форум» о недостатках российской навигационной системы [GLONASS/GNSS-Forum Association on the shortcomings of the Russian navigation system].” http://vestnik-glonass.ru/news/tech/assotsiatsiya-glonassgnssforum-o-nedostatkakhrossiyskoy-navigatsionnoy-sistemy/.

———. 2023b. “Ожидать полностью отечественных спутников «Глонасс» раньше 2030 года не стоит [It is not worth expecting fully domestic Glonass satellites before 2030].” http://vestnikglonass.ru/news/tech/ozhidat-polnostyu-otechestvennykh-sputnikov-glonass-ranshe-2030-godane-stoit/.

———. 2024. “«И хочется, и колется»: Эксперт о сотрудничестве Роскосмоса с частниками [“Both want and need”: Expert on cooperation between Roscosmos and private companies].” http: //vestnik-glonass.ru/news/corp/i-khochetsya-i-koletsya-ekspert-o-sotrudnichestve-roskosmosas-chastnikami/.

Interfax. 2015. “Запущенный в интересах ЮАР спутник вышел из строя [A satellite launched in the interests of South Africa has malfunctioned].” https://www.interfax.ru/world/441630.

———. 2018. “Гендиректор НПО Энергомаш: марсианский метан в будущем можно использовать для заправки ракет.” https://web.archive.org/web/20180601211354/http://www.interfax.ru/interview/615149.

———. 2020a. “РКЦ “Прогресс” выиграл конкурс на разработку метановой ракеты “Амур-СПГ” [RSC Progress won the tender for the development of the Amur-LNG methane rocket].” https: //web.archive.org/web/20200928065036/https://www.interfax.ru/russia/728122.

———.2020b. “Шесть спутников “Смотр” и 8 аппаратов “Ямал” планируется запустить в космос к 2035 году - гендиректор “Газпром Космические Системы” [Six Smotr satellites and 8 Yamal satellites are planned to be launched into space by 2035 - Gazprom Space Systems CEO].” https://www.militarynews.ru/story.asp?rid=1&nid=534276&lang=RU.

———. 2021. “Одобрено создание новой российской орбитальной станции [The creation of a new Russian orbital station has been approved].” https://www.interfax.ru/russia/781858.

———. 2022a. ““Роскосмос” представил набсовету позицию по прекращению работы МКС [“Roscosmos” presented a position on the termination of the ISS operation to the supervisory board].” https://www.interfax.ru/russia/834223.

———. 2022b. “Angola’s Angosat-2 satellite put in operation in orbit - Russia’s Roscosmos.” https: //interfax.com/newsroom/top-stories/86429/.

———. 2023. “Запуск импортозамещенного спутника “Глонасс-К2” планируется в 2025 году [Import substituted Glonass-K2 satellite to be launched in 2025].” https://www.interfax.ru/russia/935864.

Interfax. 2023a. ““Роскосмосу” нужно пять лет для полного импортозамещения приборов для спутников [“Roscosmos” needs five years for full import substitution of components for satellites].” https://www.interfax.ru/russia/886464.

———. 2023b. “Борисов предложил Алжиру и Египту поучаствовать в создании российской орбитальной станции [Borisov offered Algeria and Egypt to participate in the creation of a Russian orbital station].” https://www.interfax.ru/russia/909672.

———. 2023c. “Запуск импортозамещенного спутника “Глонасс-К2” планируется в 2025 году [Import-substituted Glonass-K2 satellite to be launched in 2025].” https://www.interfax.ru/ business/946809.

———. 2023d. “Разработка нового метеоспутника “Арктика-МП” начнется в 2026 году [Development of the new Arktika-MP weather satellite will begin in 2026].” https://www.interfax.ru/ russia/886644.

ISS Reshetnev. 2009. “Сибирские «Лучи» [Siberian “Luchi” (Rays)].” https://webcitation.org/ 67zaQxp0n?url=http://www.npopm.ru/images/File/magazin/2009/m8-screen.pdf.

Izvestiya. 2023a. “Кадровый холод: потеря «Луны-25» может привести к перестановкам в «Роскосмосе» [Personnel cold: the loss of Luna-25 may lead to reshuffles at Roscosmos].” https://web.archive. org/web/20230822094106/https://iz.ru/1562258/andrei-korshunov/kadrovyi-kholod-poterialuny-25-mozhet-privesti-k-perestanovkam-v-roskosmose.

———. 2023b. “Российский спутник-ретранслятор «Луч-5Х» выведен на орбиту [The Russian Luch-5X relay satellite is put into orbit].” https://iz.ru/1482328/2023-03-13/rossiiskii-sputnikretransliator-luch-5kh-vyveden-na-orbitu.

Katz, Luba, R. Lindbergh, O. Shykov, A. Balakrishnan. 2023. *Russia Space Talent*. IDA D-33069. March 2023. https://www.ida.org/research-and-publications/publications/all/r/ru/russia-space-talent

Khrunichev State Research and Production Space Center. n.d. “Семейство Рокет-Носителей «Ангара» [The Angara Launch Vehicle Family].” Accessed March 13, 2024. https://web.archive.org/web/ 20210804082903/http://www.khrunichev.ru/main.php?id=44.

Korolev, I. 2021. “Россия отказалась от грандиозного проекта глобальной спутниковой связи [Russia has abandoned a grandiose global satellite communications project].” https://www.cnews.ru/ news/top/2021-08-16_rossiya_otkazalas_ot_grandioznogo.

Korolev, P. 2023. ““Роскосмос” и “Решетнев” займутся разработкой группировки “Скиф” [Roscosmos and Reshetnev will develop the Skif constellation].” ComNews. https://www.comnews.ru/ content/229694/2023-10-25/2023-w43/1007/roskosmos-i-reshetnev-zaymutsya-razrabotkoygruppirovki-skif.

———. 2023. “Новый “Гонец” отправится на орбиту в 2027 году [The new “Gonets” will go into orbit in 2027].” https://www.comnews.ru/content/230322/2023-11-22/2023-w47/1008/novyygonec-otpravitsya-orbitu-2027-godu.

Kotov, M. 2022. “Решительный отказ: почему Россия прекращает выпуск своих самых мощных ракет «Протон» [Resolute refusal: why Russia is stopping production of its most powerful Proton rockets].” https://www.forbes.ru/tehnologii/363553-reshitelnyy-otkaz-pochemu-rossiya-prekrash chaet-vypusk-svoih-samyh-moshchnyh-raket.

Krebs, G. n.d.a. “Arktika-M 1, 2, 3, 4, 5.” Gunter’s Space Page. Accessed Feb 19, 2024. https://space.skyrocket.de/doc_sdat/arktika-m.htm.

———. n.d.b. "Kanopus-V 1, 2." Accessed Feb 19, 2024. https://space.skyrocket.de/doc_sdat/kanopus-v.htm.

———. n.d.c. "Uragan-K (GLONASS-K, 14F143)." Accessed Feb 19, 2024. https://space.skyrocket.de/ doc_sdat/uragan-k1.htm.

Krestyahskiye Vedomosti. 2023. "Шесть спутников "Смотр-Р" будут запущены в 2026–2028 годах — "Космическая связь" [Six Smotr-R satellites to be launched in 2026–2028 - Russian Satellite Communications Company]." https://kvedomosti.ru/?p=1147737.

Kuzovnikov, A. n.d. "Современные технологии персональной спутниковой связи, предлагаемые многофункциональной системой «Гонец-Д1М» с орбитальными группировками космических аппаратов «Гонец-М» и «Гонец-М1» [Modern technologies of personal satellite communication offered by the multifunctional system "Gonets-D1M" with orbital constellations of Gonets-M and Gonets-M1 spacecraft]." ISS Reshetnev. Accessed March 13, 2024. https://www.itu.int/en/ITUD/Regional-Presence/CIS/Documents/Events/2014/09_Yerevan/Sesson_2_Kuzovnikov.pdf.

Lantratov K., Kamentsev V. 1999. "Космический «Экспресс» с литерой А [Space "Express," letter A]." https://web.archive.org/web/20120306221519/http://www.novosti-kosmonavtiki.ru/content/numbers/203/09.shtml.

Lenta. 2023a. "Объяснены большие сроки импортозамещения спутников «Глонасс-К2» [Long delays in import substitution of Glonass-K2 satellites explained]." https://lenta.ru/news/2023/12/ 12/ob-yasneny-bolshie-sroki-importozamescheniya-sputnikov-glonass-k2/.

———. 2023b. "Разработчик «Циркона» объяснил досрочный запуск спутника «Кондор-ФКА» [The "Zircon" developer explained the early launch of the Kondor-FKA satellite]." https://lenta. ru/news/2023/06/08/kondor/.

Luzin, P. 2021a. "Roscosmos Suffers from Russia's Confrontation with the US." *Eurasia Daily Monitor* 18 (99). https://jamestown.org/program/roscosmos-suffers-from-russias-confrontation-withthe-us/.

———. 2021b. "Russian Space Spending for 2023." *Eurasia Daily Monitor* 20 (25). https://jamestown. org/program/russian-space-spending-for-2023/.

———. 2021c. "The Commercial Space Sector and Russia's Space Strategy." *Eurasia Daily Monitor* 18 (159). https://jamestown.org/program/the-commercial-space-sector-and-russias-spacestrategy/.

———. 2023. "Moscow in Urgent Search of New Space Partners." *Eurasia Daily Monitor* 20 (109). https://jamestown.org/program/moscow-in-urgent-search-of-new-space-partners/.

Maidenberg, Micah and Mauro Orru. 2022. Russia Hals Rocket-Engine Deliveries to the U.S. March 3, 2022. https://www.wsj.com/livecoverage/russia-ukraine-latest-news-2022-03-03/card/russia-halts-rocket-engine-deliveries-to-u-s--cXv7UBKAVZVCkeoZ6Iiy

Malkov, S P., and C Doldirina. 2010. "Regulation of Space Activities in the Russian Federation." *National Regulation of Space Activities,* 315–333. https://aerohelp.com/sites/default/files/ sergey_p._malkov_catherine_doldirina_space_activities.pdf.

Mapgroup. 2016. "Арктика-Р 1, 2/ СМОТР 1, 2 [Arktika-R 1, 2/ SMOTR 1, 2]." https://mapgroup. com.ua/kosmicheskie-apparaty/27-rossiya/1598-arktika-r-1-2-smotr-1-2.

Mathieu, C. 2010. "Assessing Russia's space cooperation with China and India—Opportunities and challenges for Europe." *Acta Astronautica* 66 (3-4): 355–361. https://www.sciencedirect.com/science/article/pii/S0094576509003877?casa_token=LWJ_-XyOaCYAAAAA:XHgBHybn938jroTTnHPY_mtvIJC1B6ECC7LUoGQ9D8tlr-Too4MtsQDdhHiEGW3Onvvc9K-XsNHk.

McDowell, J. C., 2024. General Catalog of Artificial Space Objects, Release 1.5.4, https://planet4589.org/space/gcat

McGuire, G. 2024. "Conspiracies and Cosmonauts: The Baikonur Cosmodrome and Popular Narratives of Ecological Disaster in Contemporary Kazakhstan." In *Post-Colonial Approaches in Kazakhstan and Beyond: Politics, Culture and Literature,* 163–187. Springer. https://link.springer.com/ chapter/10.1007/978-981-99-8262-2_7.

National Aeronautics and Space Administration. 2019. *NASA'S Management of Crew Transportation to the International Space Station*. Report No. IG-20-005. https://oig.nasa.gov/wp-content/uploads/2024/02/IG-20-005.pdf

———. n.d. "The International Space Station Transition Plan." Accessed March 13, 2024. https://www.nasa.gov/faqs-the-international-space-stationtransition-plan/.

———. n.d.a. "Visiting Vehicles." Accessed Jan 5, 2024. https://www.O.gov/international-space-station/space-station-visiting-vehicles/#:~:text=Four%20spaceships%20are%20docked%20at,85%20and%2086%20resupply%20ships.

———. n.d.b. "ISS Expeditions." Accessed Jan 5, 2024. https://www.nasa.gov/international-space-station/expedition-missions/

National Association of Oil and Gas Services. 2019. "«Газпром» и Thales Alenia Space намерены объединить усилия по производству космических аппаратов [Gazprom and Thales Alenia Space intend to join forces on spacecraft production]." https://nangs.org/news/technologies/gazpromithales-alenia-space-namereny-obaedinity-usiliya-poproizvodstvu-kosmicheskih-apparatov.

News of Belarus. 2011. "Белорусский спутник дистанционного зондирования Земли будет запущен в марте-апреле [Belarusian Earth remote sensing satellite to be launched in March-April]." https: //web.archive.org/web/20110127042241/http://www.belta.by/ru/all_news/society/Belorusskijsputnik-distantsionnogo-zondirovanija-Zemli-budet-zapuschen-v-marte-aprele_i_540268.html.

Noviy, V, D. Skorobagatko, and A. Dzhordzhevich. 2018. “ВЭБ возвращается из космоса [VEB returns from space].” https://www.kommersant.ru/doc/3752454.

NPO Lavochkin. 2015. “Электро-Л [Elektro-L].” https://web.archive.org/web/20150901155459/http: //www.laspace.ru/rus/electro.php.

NPO Mash. 2024. “Space Borne Complexes, Systems and Vehicles.” http://npomash.ru/activities/en/ integrkosm.htm.

NTs OMZ. 2023. “Первый радиолокационный спутник «Кондор-ФКА» выведен на орбиту [First Kondor-FKA radar satellite launched into orbit].” https://ntsomz.ru/kondor_fka_zapusk_ vostochnyi/.

Paradiso, R. 2023. “Arktika-M: The Eye on The Arctic.” Space Voyaging. https://www.spacevoyaging.com/arktika-m-the-eye-on-the-arctic.

Permyakov, R. 2023. “«Новый космос»: глобальный ландшафт и модели коммерциализации [“New Space”: global landscape and commercialization models].” Space Economics 4 (6): 12–25. http: //vestnik-glonass.ru/news/corp/i-khochetsya-i-koletsya-ekspert-o-sotrudnichestve-roskosmosas-chastnikami/.

Podvig, P. 2002. “History and the current status of the Russian early-warning system.” *Science and global security* 10 (1): 21–60. https://www.tandfonline.com/doi/abs/10.1080/08929880212328?casa_token=_XxB5nGqjzgAAAAA:cKhJnkidIxnkXhzJfUirnxE_vhBpl0hRmelFkwhNytKRdFoBpxEEjbGQj5bLeVc3CZyxrWkSMADuWf8.

PortNews. 2023. “Россия в 2025 году выведет на орбиту первый спутник системы «Экспресс-РВ», который охватит Арктику и СМП [Russia will launch the first Express-RV satellite in 2025, which will cover the Arctic and the NSR].” https://portnews.ru/news/345897/.

Puzanov, A.V., Dmitriev O.Yu., Alekseev I.A., Bezmaternykh D.M., Balykin S.N., Troshkin D.N., Gorbachev I.V., and Kuzniak Ya. 2016. “Приоритетные Задачи Обеспечения Безопасности и Экологического Сопровождения Пусков РН Типа «Союз», Направления их Реализации» [Priority Tasks of Safety and Environmental Support of Soyuz LV Launches, Directions of Their Realization].” *Proceedings of the All-Russian Scientific and Practical Conference,* https://www.researchgate.net/publication/315572038.

RBK. 2010. “Спутники ГЛОНАСС выведены на орбиту [GLONASS satellites put into orbit].” https: //web.archive.org/web/20150703124643/http://top.rbc.ru/society/02/09/2010/459145.shtml.

———. 2016. “Научный институт «Роскосмоса» сообщил о потере связи с метеоспутником [Roscosmos research institute reports loss of communication with weather satellite].” https://www.rbc. ru/rbcfreenews/583848379a7947ae5b65b575.

———. 2017. “Правительству предложат создать глобальную спутниковую сеть за 299 млрд [The government will be asked to create a global satellite network for 299

billion].” https://www.rbc.
ru/technology_and_media/22/11/2017/5a159bdb9a79476a55456d2b.

———. 2018. “«Дочка» «Роскосмоса» представила спутниковую систему «Эфир» за 299 млрд [A subsidiary of Roscosmos unveiled the Efir satellite system for 299 billion].” https://www.rbc.ru/
technology_and_media/22/05/2018/5b03edff9a7947620e3bbbde?from=main.

———. 2019a. “Проект «русского OneWeb» подорожал до 534 млрд [The “Russian OneWeb” project has risen in price to 534 billion].” https://www.rbc.ru/technology_and_media/15/04/2019/
5cb07f389a794763325bad14?from=from_main.

———. 2019b. “Россия отказывается от серийного производства спутников ГЛОНАСС [Russia refuses serial production of GLONASS satellites].” https://www.rbc.ru/society/25/06/2019/ 5d10ef6d9a79476950dcf15e.

———. 2020. “Борисов — РБК: «Я не дипломат, я должен готовиться к худшему» [Borisov to RBK: “I am not a diplomat, I must prepare for the worst”].” https://www.rbc.ru/interview/ society/21/12/2020/5fdc8e669a7947043ec1fe49.

———. 2022a. “Борисов заявил об отставании России в производстве спутников [Borisov said Russia is lagging behind in satellite production].” https://www.rbc.ru/economics/29/07/2022/ 62e432919a79476908cf047d.

———. 2022b. “Борисов заявил, что дату ухода России с МКС еще не выбрали [Borisov said that the date of Russia’s departure from the ISS has not yet been chosen].” https://www.rbc.ru/
technology_and_media/29/07/2022/62e3d6029a794741c0c24d31.

———. 2023a. “Борисов заявил о неконкурентоспособности российской индустрии спутников [Borisov declared the Russian satellite industry non-competitive].” https://www.rbc.ru/politics/27/10/ 2023/653bab0b9a7947b643fb1909.

———. 2023b. “Глава «Роскосмоса» назвал причину крушения «Луны-25» [The head of Roscosmos named the cause of the Luna-25 crash].” https://www.rbc.ru/technology_and_media/21/08/
2023/64e376529a79472d44187d71.

Reuters.com. 2021. “Russia expands 'foreign agent' crackdown to cover military sector.” https://www.reuters.com/world/europe/russia-expands-foreign-agent-crackdown-cover-military-sector-2021-10-01/

RIA Novosti. 2013a. “Первый российский лунный аппарат отправится в космос не ранее 2016 г [The first Russian lunar lander will go into space no earlier than 2016].” https://web.archive.org/web/20131016180713/http://ria.ru/space/20131015/970091491.html.

———. 2013b. “Проблемы с финансированием российской лунной миссии “Луна-Глоб” решены [Problems with the financing of the Russian lunar mission Luna-Glob have been solved].” https: //ria.ru/20130116/918349805.html.

———. 2015a. “Разработчик: проблемы на спутнике “Кондор-Э” будут решены до конца мая [Developer: problems on the Kondor-E satellite will be solved by the end of May].” https://ria.ru/20150514/1064512832.html.

———. 2015b. “РКЦ “Прогресс”: летный образец ракеты “Союз-5” ожидаем к 2022 году.” https: //ria.ru/20150818/1190701345.html.

———. 2017a. ““Роскосмос” принял конструкторский макет станции “Луна-25” [Roscosmos accepted the design model of the station Luna-25].” https://web.archive.org/web/20170819020921/ https://ria.ru/science/20170818/1500604238.html.

———. 2017b. “В России разрабатывают многоразовую ракету [Russia is developing a reusable rocket].” https://ria.ru/science/20170120/1486121007.html.

———. 2018a. “Проект “Роскосмоса” по всемирному доступу в интернет назовут “Эфир” [Roscosmos’ project for worldwide Internet access will be called “Efir”].” https://ria.ru/20180522/ 1521061202.html.

———. 2018b. “Совет РАН отложил решение по переносу пуска лунной миссии [RAS Council postpones decision on postponing the launch of the lunar mission].” https://web.archive.org/web/20180511150226/https://ria.ru/space/20180511/1520374173.html.

———. 2019a. “В ближайшие 15 лет запустят 46 спутников системы ГЛОНАСС [46 GLONASS satellites will be launched in the next 15 years].” https://ria.ru/20190509/1553373759.html.

———. 2019b. “Названы возможные сроки запуска сверхтяжелой ракеты “Дон” [Possible dates for the launch of the Don super-heavy rocket have been announced].” https://ria.ru/20190214/ 1550826415.html.

———. 2019c. “Россия модернизирует систему спутников-ретрансляторов “Луч” в два этапа [Russia will modernize the Luch relay satellite system in two stages].” https://web.archive.org/web/20191101091106/https://ria.ru/20191101/1560470756.html.

———. 2020. “Для вывода спутников системы “Сфера” потребуется 148 запусков ракет [148 rocket launches will be required to launch the Sfera satellites].” https://ria.ru/20200120/1563613506. html.

———. 2021a. “В РКЦ “Прогресс” объяснили задержку с разработкой ракеты “Амур-СПГ” [RSC Progress explained the delay in the development of the Amur-LNG rocket].” https://web.archive.org/web/20210210102043/https://ria.ru/20210210/raketa-1596785934.html.

———. 2021b. “Договор об аренде Россией Байконура до 2050 года вступил в силу [Agreement on Russia’s lease of Baikonur until 2050 has gone into effect].” https://ria.ru/20210804/baykonur1744391874.html.

———. 2021c. “Срок изготовления двигателя российской многоразовой ракеты перенесли [Russian reusable rocket engine production deadline postponed].” https://ria.ru/20210530/raketa-1734775 665.html.

RIA Novosti. 2022a. “Космическая элементная база на 80% состоит из иностранных составляющих [Space components base consists of 80% foreign components].” https://ria.ru/20110301/34073013 2.html.

———. 2022b. “На космический проект “Сфера” направили 14 миллиардов рублей из госбюджета [14 billion rubles from the state budget were allocated for the Sfera space project].” https://ria. ru/20221022/finansirovanie-1825979133.html.

———. 2022c. “На ПМЭФ рассказали, когда спутник “Экспресс-АМУ4” запустят на орбиту [SPIEF told when the Express-AMU4 satellite will be launched into orbit].” https://ria.ru/20220616/ sputnik-1795625152.html.

———. 2022d. “Стартовый комплекс “Союзов” на космодроме Куру законсервируют навсегда [Soyuz launch complex at the Kuru Cosmodrome will be permanently mothballed].” https://web. archive.org/web/20220319105238/https://ria.ru/20220319/kosmodrom-1778999124.html.

———. 2023a. “Борисов рассказал о производстве спутников для российской группировки [Borisov spoke about the production of satellites for the Russian constellation].” https://ria.ru/20231226/ sputniki-1918314533.html?in=l.

———. 2023b. “В “Энергии” рассказали, когда запустят коммерческий модуль РОС [RKK Energia discussed when the commercial ROS module will be launched].” https://ria.ru/20231117/stantsi ya-1909985027.html.

———. 2023c. “НПО машиностроения: даем возможность онлайн наблюдать за поверхностью Земли [NPO Mashinostroeniya: we give an opportunity to observe the Earth’s surface online].” https://ria.ru/20230526/npo_mashinostroeniya-1874085498.html.

———. 2023d. “Путин одобрил идеи “Роскосмоса” по созданию российской орбитальной станции [Putin approved Roscosmos’ plan on creating a Russian orbital station].” https://ria.ru/20230412/ kosmos-1864919581.html.

———. 2023e. “Ступень ракеты “Амур-СПГ” можно будет использовать более 50 раз [The AmurLNG rocket stage can be used more than 50 times].” https://ria.ru/20230426/raketa-1867945714. html.

———. 2023f. “Юрий Борисов: Россия должна производить к 2025 году 250 спутников ежегодно [Yuri Borisov: Russia should produce 250 satellites annually by 2025].” https://ria.ru/20230210/ borisov-1850850429.html.

———. 2023g. ““Роскосмос” потерял 180 миллиардов рублей из-за недружественных стран [Roscosmos lost 180 billion rubles because of unfriendly countries].”

———. 2023h. “В РКК “Энергия” рассказали, как можно будет сменить “ядро” РОС [RSC Energia discussed the possibility of changing the ROS core module].” https://ria.ru/20231226/stantsiya1918072159.html?in=l.

Roscosmos. 2015. “Роскосмос: МКСР «Луч» Принята в Опытную Эксплуатацию [Roscosmos: The Luch MSRS Was Put Into Operation].” https://web.archive.org/web/20200303224452/https: //www.roscosmos.ru/21886/.

———. n.d. “Спутниковая система персональной связи «Гонец» [“Gonets” satellite system for personal communication].” Accessed March 13, 2024. https://www.roscosmos.ru/23941/.

Rossiyskaya Gazeta. 2023. “Борисов: Перед Роскосмосом стоит грандиозная задача перейти к серийному выпуску спутников [Borisov: Roscosmos is facing a grandiose task to move to serial production of satellites].” https://rg.ru/2023/10/27/borisov-pered-roskosmosom-stoitgrandioznaia-zadacha-perejti-k-serijnomu-vypusku-sputnikov.html.

Rostec. 2023a. “Радиолокационный спутник «Кондор-ФКА» приступил к работе [The KondorFKA radar satellite began operations].” https://rostec.ru/news/radiolokatsionnyy-sputnikkondor-fka-pristupil-k-rabote/?sphrase_id=5009301.

———. 2023b. “Ростех в разы увеличил ресурс спутника «Кондор-ФКА» [Rostec multiplies the resource of the Kondor-FKA satellite].” https://rostec.ru/news/rostekh-v-razy-uvelichil-resurssputnika-kondor-fka/?sphrase_id=5009301.

Roulette, J. 2022. “Russia mulls early return of space station crew after Soyuz capsule leak.” https: //www.reuters.com/lifestyle/science/russia-mulls-early-return-space-station-crew-after-soyuzcapsule-leak-2022-12-23.

Russian News Agency TASS. 2015. “Российская ракета-носитель союз-2.1б. Досье [Russian Launch Vehicle Soyuz-2.1b. Dossier].” https://tass.ru/info/2065906.

———. 2017. “Роскосмос планирует выйти на рынки Юго-Восточной Азии и Латинской Америки [Roscosmos plans to enter the markets of Southeast Asia and Latin America].” https://tass.ru/ kosmos/4806854.

———. 2019. “Комплекс “Байтерек” планируют эксплуатировать на Байконуре до 2062 года [Russia may deploy more than 2,000 new satellites in orbit by 2036].” https://web.archive.org/web/20191113132251/https://tass.ru/kosmos/7107747.

———. 2020a. “В Роскосмосе заявили, что многоразовая метановая ракета заменит действующие ‘Союзы-2.’” https://web.archive.org/web/20201008053250/https://tass.ru/kosmos/9629833.

———. 2020b. “РКЦ ‘Прогресс’ может в этом году начать работу над созданием ракеты-носителя ‘Союз-6’ [RSC “Progress” may this year begin work on the development of the ‘Soyuz-6 carrier rocket’].” https://web.archive.org/web/20200131022347/https://tass.ru/kosmos/7534687.

———. 2020c. “Роскосмос планирует запустить спутники “Канопус-В”-О в 2024 и 2025 годах [Roscosmos plans to launch Kanopus-V-O satellites in 2024 and 2025].” https://tass.ru/kosmos/ 8357045.

———. 2020d. “Со стартового комплекса для “Ангары” на Восточном будет осуществлятьця до 10 пусков в год [Up to 10 launches per year will be carried out from the Angara launch complex at Vostochny].” https://web.archive.org/web/20211229023500/https://tass.ru/kosmos/10299785.

———. 2021. “Рогозин сообщил, что создание системы “Сфера” обойдется в 0,8 трлн рублей.” https://tass.ru/kosmos/11577571.

———. 2022a. “Thales Alenia Space приостановила работу над проектом в России [Thales Alenia Space has suspended work on a project in Russia].” https://tass.ru/ekonomika/15410393.

———. 2022b. “Изготовитель “Глонассов” и ГП КС займутся изготовлением спутника “ЭкспрессАМУ4” [Glonass manufacturer and RSCC to manufacture Express-AMU4 satellite].” https://tass. ru/ekonomika/15256091.

———. 2022c. “Роскосмос запустит девять спутников к 2026 году для развития Арктики [Roscosmos to launch nine satellites by 2026 for Arctic development].” https://tass.ru/kosmos/16118411.

———. 2022d. “Роскосмос планирует начать запуск спутников “Беркут” с 2025 года [Roscosmos plans to launch Berkut satellites from 2025].” https://tass.ru/kosmos/14475561.

———. 2023a. “Russia to deploy Grifon CubeSat orbital monitoring system in 2024-2026 — Roscosmos.” https://tass.com/science/1704099.

———. 2023b. “Russia’s second meteorological satellite Arktika-M launched from Baikonur put into orbit.” https://tass.com/science/1722329.

———. 2023c. “АО “Решетнев” планирует выпускать спутники “Гонец-М1” и “Скиф” с тактом в семь дней [Reshetnev JSC plans to produce Gonets-M1 and Skif satellites with a cycle time of seven days].” https://tass.ru/kosmos/17912813.

———. 2023d. “Белоусов заявил, что космос будет по-настоящему открыт для российского частного бизнеса [Belousov said that space will be truly open to Russian private business].” https://tass. ru/kosmos/16812427.

———. 2023e. “Борисов заявил, что МКС подходит к финишу эксплуатации [Borisov said that the ISS is approaching the finish line of operation].” https://tass.ru/kosmos/19134763.

———. 2023f. “Борисов: работа МКС будет продлеваться “настолько, насколько это будет возможно” [Borisov: ISS operation will be extended “as far as possible”].” https: //tass.ru/kosmos/19285703.

———. 2023g. “В Подмосковье завершается строительство административного корпуса производства спутников [Construction of an administrative building for satellite production is being completed in the Moscow region].” https://tass.ru/ekonomika/18044721.

———. 2023h. “Запуск первого спутника “Электро-М” ожидается после 2030 года [The launch of the first Electro-M satellite is expected after 2030].” https://web.archive.org/web/20230323054317/https://tass.ru/kosmos/17341655.

———. 2023i. “Первый пуск метановой ракеты “Амур” планируется в 2028-2030 годах [The first launch of the Amur methane rocket is planned for 2028-2030].” https://tass.ru/kosmos/18387525.

———. 2023j. “Первый спутник “Кондор-ФКА” в ближайшие дни отправят на космодром [The first Kondor-FKA satellite will be sent to the launch site in the coming days].” https://tass.ru/ kosmos/17338087.

———. 2023k. “Предсерийная партия спутников “Марафон” будет запущена в 2025 году [A preproduction batch of Marafon satellites will be launched in 2025].” https://tass.ru/kosmos/ 17392115.

———. 2023l. “Проект спутниковой группировки “Грифон” войдет в программу “Сфера” [The Grifon satellite constellation project will be included in the Sfera program].” https://tass.ru/ kosmos/19087507.

———. 2023m. “Работы по миссиям “Луна-26” и “Луна-27” будут форсироваться [Work on the Luna-26 and Luna-27 missions will be accelerated].” https://tass.ru/kosmos/18553353.

———. 2023n. “Роскосмос надеется найти партнеров в африканских странах [Roscosmos hopes to find partners in African countries].” https://tass.ru/kosmos/17102057.

———. 2023o. “Роскосмос предложил странам Африки участие в работе Российской орбитальной станции [Roscosmos offered African countries to participate in the work of the Russian orbital station].” https://tass.ru/kosmos/18163773.

———. 2023p. “Роскосмос продолжит работы по разработке многоразовой метановой ракеты “Амур-СПГ” [Roscosmos will continue work on the development of the Amur-LNG reusable methane rocket].” https://tass.ru/kosmos/17240203.

———. 2023q. “Россия к 2036 году может развернуть на орбитах более 2 тыщ. новых спутников [The Baiterek complex is planned to be operated at Baikonur until 2062].” https://tass.ru/ kosmos/19127643.

———. 2023r. “Федеральный проект сверхтяжелой ракеты-носителя в ближайшее время направят на согласование [The federal project for a super-heavy launch vehicle will soon be sent for approval].” https://tass.ru/kosmos/18479279.

———. 2023s. “Эксперт назвал спутник “Кондор-ФКА” прорывом для российской космонавтики [Expert calls Kondor-FKA satellite a breakthrough for Russian cosmonautics].” https://tass.ru/ kosmos/17858945.

———. 2023t. “В “Энергомаше” рассмотрели итоги проработки маршевого двигателя ракеты “Корона” [Energomash reviewed the results of the development of the Corona rocket's thrust engine]”. https://tass.ru/kosmos/18947311

———. 2023u. “В Роскосмосе рассказали о возможностях ракеты “Корона” [Roscosmos revealed the capabilities of the Korona rocket].” https://tass.ru/kosmos/17402671.

———. 2023v. “Борисов заявил, что создание РОС до 2032 года оценили примерно в 609 млрд рублей [Borisov said that the creation of the ROS until 2032 was estimated at about 609 billion rubles].” https://tass.ru/kosmos/19134983.

———. 2024. “Борисов: эскизный проект Российской орбитальной станции соответствует требованиям [Borisov: preliminary design of the Russian orbital station meets the requirements].” https://tass.ru/kosmos/19901707.

Russian Space Research Institute. 2023. “Luna-25.” https://iki.cosmos.ru/research/missions/luna-25.

Safronov, Ivan. 2018. “«Сфера» получила «Эфир» и бюджет [“Sfera” got “Efir” and a budget].” https://www.kommersant.ru/doc/3689790.

Sauer, P. 2022. “Russia says it will quit International Space Station after 2024.” https://www.theguardian.com/science/2022/jul/26/russia-opt-out-international-space-station-2024-build-own-outpost.

Semanik, Mitch and Patrick Crotty. 2023. “U.S. Private Space Launch Industry is Out of this World.” Nov 2023. Office of Industry and Competitiveness Analysis: U.S. International Trade Commission. https://www.usitc.gov/publications/332/executive_briefings/ebot_us_private_space_launch_industry_is_out_of_this_world.pdf

Semenov, Yu, ed. 2001. *Ракетно-космическая корпорация “Энергия” имени СП Королева. На рубеже двух веков: 1996-2001 [SP Korolev Rocket and Space Corporation Energia. At the Turn of Two Centuries: 1996-2001].* RKK Energia.

Smith, M. 2022. “Borisov Clarifies Russia’s Space Station Plans.” https://spacepolicyonline.com/ news/borisov-clarifies-russias-space-station-plans/.

Sprenger, Carsen. 2008. “State-Owned Enterprises in Russia.” October 27, 2008. https://www.oecd.org/corporate/ca/corporategovernanceprinciples/42576825.pdf

Stavrogina, Anna. 2023. “Госкорпорация «Роскосмос» уходит в «Сферу» [Roscosmos State Corporation is going to the sphere (Sfera)].” https://mashnews.ru/goskorporacziya-roskosmos-uxoditv-sferu.html

Stephen, C. 2022. “Soyuz rocket launches with demo satellite for Russian internet constellation.” https: //spaceflightnow.com/2022/10/22/soyuz-gonets-skif-d.

Swanson, A. and N. Chokshi. 2023. “U.S.-Made Technology Is Flowing to Russian Airlines, Despite Sanctions.” May 15, 2023. https://www.nytimes.com/2023/05/15/business/economy/russia-airlines-sanctions-ukraine.html?login=email&auth=login-email

The Government of Russia. 2017. Об утверждении федеральной целевой программы «Развитие космодромов на период 2017–2025 годов в обеспечение космической деятельности Российской Федерации» [On Approval of the Federal Target Program “Development of Cosmodromes for the Period 2017-2025 to Ensure Space Activities of the Russian Federation”]. http://government.ru/docs/29338/

———. 2021. “«Роскосмос» поэтапно переходит с множества ФЦП на единую госпрограмму [“Roscosmos” gradually shifts from multiple FTPs to a single state program].” http://government.ru/info/41915/.

———. 2023a. “Андрей Белоусов: Подписано соглашение по «дорожной карте» «Перспективные космические системы и сервисы» [Andrei Belousov: An agreement was signed on the road map “Perspective space systems and services”].” http://government.ru/news/47552/.

———. 2023b. “ПАСПОРТ “дорожной карты” развития высокотехнологичного направления “Перспективные космические системы и сервисы” на период до 2030 года [Roadmap for the development of the high-tech area of “Advanced space systems and services” for the period until 2030].” https://nti.fund/7_%D0%A4%D0%B8%D0%BD%D0%B0%D0%BB%D1%8C%D0%BD%D0%B0%D1%8F_%D0%94%D0%9A_%D0%A7%D0%B0%D1%81%D1%82%D0%BD%D1%8B%D0%B5_%D0%BA%D0%BE%D0%BC%D0%BF%D0%B0%D0%BD%D0%B8_27122022.pdf.

United Nations Committee on the Peaceful Uses of Outer Space. 2023. “International Lunar Research Station (ILRS).” https://www.unoosa.org/documents/pdf/copuos/2023/TPs/ILRS_presentation20230529_.pdf

Ustinova, A. 2018. “ГПКС выбрало создателей новых “Экспрессов” [RSCC has selected the creators of new Expresses (satellites)].” ComNews. https://web.archive.org/web/20231106055435/https://www.comnews.ru/content/114463/2018-08-15/gpks-vybralo-sozdateley-novyh-ekspressov.

Vedneeva, N. 2021. “Создатель ракетных двигателей раскритиковал причину приостановки создания супертяжа [Rocket engine maker criticized the reason for the suspension of supercarrier development].” Moskovskij Komsomolets. https://web.archive.org/web/20210930075646/https://www.mk.ru/science/2021/09/15/sozdatel-raketnykh-dvigateley-raskritikoval-prichinupriostanovki-sozdaniya-supertyazha.html.

———. 2023. “Академик Тестоедов рассказал о перспективах развития отечественной навигационной системы [Academician Testostoyedov spoke about the prospects for the development of the domestic navigation system].” Moskovskij Komsomolets. https://www.mk.ru/science/2023/12/ 13/akademik-testoedov-rasskazal-o-perspektivakh-razvitiya-otechestvennoy-navigacionnoysistemy.html.

Vedomosti. 2023a. “«Роскосмос» хочет продавать спутниковые снимки Земли органам власти [“Roscosmos wants to sell satellite images of the Earth to authorities].” https://www.vedomosti. ru/technology/articles/2023/10/10/999695-roskosmos-hochet-prodavat-sputnikovie-snimki.

———. 2023b. “Юрий Борисов: «Мы будем работать над созданием более серьезной группировки» [Yuri Borisov: “We will work on creating a more comprehensive (satellite) constellation”].” https://www.vedomosti.ru/technology/characters/2022/12/21/956268-budem-rabotat-nad-sozdaniemsereznoi-gruppirovki.

Via Satellite. 2002. “Russia’s Soyuz to Launch from French Guiana - Via Satellite.” July. https: //www.satellitetoday.com/uncategorized/2002/07/17/russias-soyuz-to-launch-from-frenchguiana.

Vidal, F, and R Privalov. 2023. “Russia in Outer Space: A Shrinking Space Power in the Era of Global Change.” *Space Policy,* 101579. https://doi.org/https://doi.org/10.1016/j.spacepol.2023.101579. https://www.sciencedirect.com/science/article/pii/S0265964623000462.

VNIIEM. 2016. “Космический Комплекс «Канопус-В» [Kanopus-V Space Complex].” https://web.archive.org/web/20160628084213/http://vniiem.ru/ru/index.php?option=com_content&view= article&id=630:-l-r&catid=85:--l-r&Itemid=62.

Vorontsov, D. 2013. “«Союз» с метаном [“Soyuz” with methane].” https://www.cosmos.kz/pdf/KIT_web%208.pdf.

Wall, Michael. “Russia threatens to leave International Space Station program (again).” April 03, 2022. https://www.space.com/russia-threatens-leave-international-space-station-program-rogozin

Yanigin, V. U. 2019. “Современные проблемы и перспективы ракетно-космической промышленности России [Current problems and prospects of the Russian rocket and space industry].” https:// nbpublish.com/library_read_article.php?id=12363.

Zak, A. 2018. “Russia Is Now Working on a Super Heavy Rocket of Its Own.” Accessed February 19, 2024. https://www.popularmechanics.com/space/rockets/a16761777/russia-super-heavy-rocket/.

———. n.d. a. “Angara is born in the wreckage of USSR.” RussiaSpaceWeb.com. Accessed February 19, 2024. https://www.russianspaceweb.com/angara_origin.html.

———. n.d. b. “Angara project in 2023.” Accessed Feb 19, 2024. https://www.russianspaceweb.com/ protected/angara-2023.html.

———. n.d. c. “Angara-1.2 flies its first mission.” RussiaSpaceWeb.com. Accessed February 19, 2024. https://www.russianspaceweb.com/angara1-flight1.html.

———. n.d. d. “Angara-1.2 flies its second mission.” Accessed Feb 19, 2024. https://www.russianspaceweb.com/protected/angara1-2-flight2.html.

———. n.d. e. “Angara-5 to replace Proton.” RussiaSpaceWeb.com. Accessed March 13, 2024. https: //www.russianspaceweb.com/angara5.html.

———. n.d. f. “Building Angara.” RussiaSpaceWeb.com. Accessed March 13, 2024. https://www.russianspaceweb.com/angara_development.html.

———. n.d. g. “Ekspress communications satellite series.” RussiaSpaceWeb.com. Accessed Feb 19, 2024.https://www.russianspaceweb.com/express.html.

———. n.d. h. “Elektro-L weather satellite series.” RussiaSpaceWeb.com. Accessed Feb 19, 2024. https: //www.russianspaceweb.com/elektro.html.

———. n.d. i. "GLONASS-K2 satellite series." RussiaSpaceWeb.com. Accessed Feb 19, 2024. https: //www.russianspaceweb.com/glonass-k2.html.

———. n.d. j. "Gonets communications satellites." Accessed March 13, 2024. https://www.russianspaceweb.com/gonets.html.

———. n.d. k. "Kanopus satellite series." RussiaSpaceWeb.com. Accessed Feb 19, 2024. https://www.russianspaceweb.com/kanopus.html.

———. n.d. l. "KazSat satellite family." Accessed March 13, 2024. https://www.russianspaceweb.com/ kazsat.html.

———. n.d. m. "NEM prepares for space station role." Accessed March 13, 2024. https://www.russiansp aceweb.com/protected/nem-2023.html.

———. n.d. n. "Proton fails to deliver Yamal-402 communications satellite into correct orbit." RussiaSpaceWeb.com. Accessed Feb 19, 2024. https://www.russianspaceweb.com/proton_yamal402. html.

———. n.d. o. "Roskosmos launches radar-observation satellite." RussiaSpaceWeb.com. Accessed Feb 19, 2024. https://www.russianspaceweb.com/kondor-fka.html.

———. n.d. p. "Russia builds Arctic satellite network." RussiaSpaceWeb.com. Accessed Feb 19, 2024. https://www.russianspaceweb.com/arktika.html.

———. n.d. q. "Russia launches newly redesigned navigation satellite." RussiaSpaceWeb.com. Accessed Feb 19, 2024. https://www.russianspaceweb.com/glonass-k2-13l.html.

———. n.d. r. "Russia plans Starlink equivalent." Accessed Feb 19, 2024. https://www.russianspaceweb. com/protected/sfera-program.html.

———. n.d. s. "Russia's another piloted rocket detailed." RussiaSpaceWeb.com. Accessed February 19, 2024. https://www.russianspaceweb.com/soyuz5-lv-ptk.html.

———. n.d. t. "Russian communications satellites." RussiaSpaceWeb.com. Accessed Feb 19, 2024. https: //www.russianspaceweb.com/spacecraft_comsats.html.

———. n.d. u. "Russian space industry in the first decade of the 21st century." RussiaSpaceWeb.com. Accessed Feb 19, 2024. https://www.russianspaceweb.com/centers_industry_2000s.html.

———. n.d. v. "Stalled crew vehicle threatens future of Russian space flight." Accessed March 13, 2024. https://www.russianspaceweb.com/protected/ptk-2023.html.

———. n.d. w. "The commercial module for the Russian Orbital Space Station, ROS." Accessed March 13, 2024. https://www.russianspaceweb.com/protected/ros-commercial.html.

———. n.d. x. "The Russian space agency, Roskosmos." RussiaSpaceWeb.com. Accessed Feb 19, 2024. https://www.russianspaceweb.com/roskosmos.html.

———. n.d. y. "The Russian space industry at the turn of the 21 century." RussiaSpaceWeb.com. Accessed Feb 19, 2024. https://www.russianspaceweb.com/centers_industry_2000s.html.

———. n.d. z. “The Soyuz-5 rocket might need a new launch pad.” RussiaSpaceWeb.com. Accessed Feb 19, 2024. https://www.russianspaceweb.com/protected/soyuz5-2023.html.

———. n.d. aa. “The Yamal satellites series.” RussiaSpaceWeb.com. Accessed Feb 19, 2024. https://www.russianspaceweb.com/yamal.html.

———. n.d. bb. “Vostochny hosts its first launch!” RussiaSpaceWeb.com. Accessed February 19, 2024.https://www.russianspaceweb.com/vostochny.html.

———. n.d. cc. “Luch satellite.” Accessed Feb 19, 2024. RussiaSpaceWeb.com. https://www.russianspaceweb.com/luch.html.

———. n.d. dd. “In solitary confinement: Russian space program in the 2020s.” Accessed Feb 19, 2024. RussiaSpaceWeb.com. https://www.russianspaceweb.com/protected/russia-2020s.html.

———. n.d. ee. “Russian space program: A decade review (2000-2010).” Accessed Feb 19, 2024. RussiaSpaceWeb.com. https://www.russianspaceweb.com/russia_2000_2010.html

zakupki.gov. n.d. “Procurement Number 0995000000220000033.” Accessed Feb 19, 2024. https://web.archive.org/web/20220120172254/https://zakupki.gov.ru/epz/order/notice/ok504/view/ common-info.html?regNumber=0995000000220000033.

Abbreviations

BRICS	Brazil, Russia, India, China, South Africa, Iran, Egypt, Ethiopia, and the United Arab Emirates
EO	Earth-observing
ESA	European Space Agency
EVA	extravehicular activity
FAA	Federal Aviation Administration
FTPs	Federal Targeted Programs
GCAT	General Catalog of Artificial Space Objects
GLONASS	Russia's global navigation satellite system
GPS	Global Positioning System
GSS	Gazprom Space Systems
HDTV	high-definition television
ICAO	International Civil Aviation Organization
IDA	Institute for Defense Analyses
IGA	International Governmental Agreement
ILRS	International Lunar Research Station
ISS	International Space Station
ITU	International Telecommunications Union
LEO	low-Earth orbit
Lox	liquid oxygen
MSRS	Multifunctional Space Relay System
NASA	National Aeronautics and Space Administration
OSTP	Office of Science and Technology Policy
PNT	position, navigation, and timing
PwC	PricewaterhouseCoopers
R&D	research and development
ROS	Russian Orbital Station
ROSHYDROMET	Russian Service for Hydrometeorology and Environmental Monitoring
RSCC	Russian Satellite Communications Company
SLC	Soyuz Launch Complex
SOEs	State-owned Enterprises
SSTL	Surrey Satellite Technology Limited
STPI	Science and Technology Policy Institute
UAV/UAS	unmanned aerial vehicle/unmanned aircraft system
ULA	United Launch Alliance
VNIIEM	All-Russian Scientific Research Institute of Electromechanics

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*: XX-10-2024

2. REPORT TYPE: FINAL

3. DATES COVERED *(From - To)*:

4. TITLE AND SUBTITLE: Trends in Russian Space Development

5a. CONTRACT NUMBER: NSFOIA-0408601

5b. GRANT NUMBER:

5c. PROGRAM ELEMENT NUMBER:

5d. PROJECT NUMBER: ET-20-5115

5e. TASK NUMBER:

5f. WORK UNIT NUMBER:

6. AUTHOR(S)

Panko, Pavel
Katz, Luba
Cohen, Dylan H.
Balakrishnan, Asha

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

IDA Science and Technology Policy Institute
1701 Pennsylvania Ave., NW, Suite 500
Washington, DC 20006-5805

8. PERFORMING ORGANIZATION REPORT NUMBER: IDA Product 3001835

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES):

10. SPONSOR/MONITOR'S ACRONYM(S):

11. SPONSOR/MONITOR'S REPORT NUMBER(S):

12. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution is unlimited (8 October 2024).

13. SUPPLEMENTARY NOTES

14. ABSTRACT

The former Soviet Union has a long and distinguished history in space exploration. As the first country to launch a satellite into orbit and send the first human into space, the space program is one of the country's proudest accomplishments. In recent times, Russia remains a major space power despite recent economic hardships and technological challenges, and has publicly committed to maintaining its role as a global space leader. But Russia has fallen behind other leading spacefaring nations that have adopted new concepts, such as reusable launch vehicles and proliferated small satellite constellations. Over the next decade, efforts to modernize Russia's space capabilities may help Russia maintain its stature as a global power, but it is not assured. Through the review of literature, news articles, launch data, procurement data and other sources, the Science and Technology Policy Institute (STPI) assessed Russia's current space capabilities, future challenges, and the presence and viability of the future Russian space enterprise.

15. SUBJECT TERMS

space; Russia space; commercial space; international space station; global space partnerships

16. SECURITY CLASSIFICATION OF: a. REPORT	b. ABSTRACT	c. THIS PAGE	17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
Unclassified	Unclassified	Unclassified	Same as Report	121	Kulinowski, Kristen
					19b. TELEPHONE NUMBER *(Include area code)*: 202-419-5491

Reset