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Geohistorical changes and space exploration: a study of the Baikonur Cosmodrome

Alterações geo-históricas e exploração espacial: um estudo sobre o Cosmódromo de Baikonur

ABSTRACT:
This study attempts to identify the geohistorical changes resulting from the establishment of space launch sites based on the experience of the Baikonur Cosmodrome. The concept of geohistory proposed by Braudel (2015, p.630), bibliographic information, memoirs of Soviet scientists and military officers, and official documents were used for the analysis. First, geographical and socio-political aspects related to the establishment of space launch centers were studied, such as proximity to the equator, low population density, and others. It turns out that the Baikonur region suited the interests of the Soviet government at the time, which led to the transformation of a desert region into a dynamic center of interstate disputes during the Cold War. After the end of the Soviet Union, changes in the socioeconomic conditions of the city and the cosmodrome led to a loss of dynamism in the region. Currently, environmental issues and the new techno-economic paradigms of the space sector pose challenges to the continued importance of the Baikonur space center.

Keywords: Baikonur Cosmodrome; Space launch centers; Geohistory

RESUMO:
Nesta pesquisa procura-se identificar alterações geo-históricas decorrentes da implantação de sítios de lançamentos espaciais, por meio da experiência do Cosmódromo de Baikonur. Para a análise, considera-se o conceito de geo-história proposto por Braudel (2015, p.630), informações bibliográficas, memórias dos cientistas e militares soviéticos e documentos oficiais. Inicialmente, foram levantados aspectos geográficos e sociopolíticos relacionados à implantação de centros de lançamentos espaciais, como a proximidade à Linha do Equador, baixa densidade demográfica, entre outros. Observa-se que a região de Baikonur era adequada aos interesses do governo soviético do período, o que levou à transformação de uma região desértica em um polo dinâmico das disputas interestatais durante a Guerra Fria. Após o final da União Soviética, mudanças nas condições socioeconômicas da cidade e do cosmódromo levaram à perda de dinamismo da região e, atualmente, questões ambientais e os novos paradigmas técnico-econômicos do setor espacial apresentam-se como desafios à continuidade do protagonismo do centro espacial de Baikonur.

Palavras-chave: Cosmódromo de Baikonur; Centros de lançamentos espaciais; Geo-história

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INTRODUCTION

Human interest in outer space dates to ancient times, as evidenced by historical records of observations, descriptions, and predictions of the motions of celestial bodies conducted by the Chinese, Chaldeans, Babylonians, Egyptians, and Greeks about 3,000 years BCE (CARLEIAL, 1999; MARTINS et al, 2019). These observations served practical purposes such as the creation of planting and harvest calendars. The development of space science paralleled the development of science itself, physics, and ultimately human´s relationship with non-human nature. According to Carleial (1999, p. 21), by the end of the 17th century, a student of Isaac Newton already had sufficient knowledge of physics to analyze the flight dynamics of a spacecraft.

It was not until the mid-1950s that the ability to launch objects into space from Earth and spaceflight became a reality. The development of intercontinental ballistic missile technology allowed the United States and the Soviet Union access to space to expand their prestige and military capabilities (SHEEHAN, 2007). As a result, the two countries engaged in a space race, especially after the USSR launched the first artificial satellite (Sputnik) from the Baikonur Cosmodrome in Kazakhstan in 1957.

Space launches required the construction of a complex physical and logistical structure to carry them out, as well as the concentration of human capital consisting of engineers, scientists, technicians, and military personnel. These structures, known as spaceports, space centers, or cosmodromes, became dynamic elements of the space race and led to potential geohistorical changes in the areas where they were built, such as Baikonur, Kazakhstan (USSR), and Cape Canaveral, Florida (USA). Space centers tend to be built in geopolitically strategic locations, in regions with characteristics such as proximity to the equator and other favorable environmental factors.

In addition to being linked to strategic and military aspects, space systems have also acquired a strong economic importance in recent decades, due to the use of services associated with this type of activity, such as remote sensing and geolocation. As a result, the number of state and private actors involved in launch activities has grown exponentially since the end of the Cold War (HAYS; LUTES, 2007, p. 207). It is estimated that space objects have been launched into orbit from 27 bases around the world (ROBERTS, 2019). Therefore, a topic of scientific relevance is the study of the impact of space bases on the development of their respective regions.

The article aims to identify geohistorical changes resulting from the establishment of space launch sites based on the experience of the Baikonur Cosmodrome in Kazakhstan. A literature re-

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view and data analysis were conducted using information on the demographic, environmental, political, and economic aspects of the Baikonur region.

For this research, the concept of geohistory proposed by Braudel (2015, p. 612) is used, which considers the importance of interdisciplinarity for understanding long-term relationships and processes: the history that the environment has imposed on humans, but also the history of human adaptation to the environment. According to Braudel (2015, p. 630), geohistory is the study of a double connection: from nature to man and from man to nature; action and reaction mixed and confused, restarted in the reality of each day.

Although the emergence of the space race is a recent phenomenon in human history, it is geohistorically embedded in the processes of human interaction with the environment, in search not only of survival but also of wealth and power. While these processes are influenced by the physical environment, they leave their traces in it, which are the subject of this work.

According to Braudel (2015, p. 634), interactions with the environment have led to a reduction of distances, to a real shrinking of the world, a natural consequence of its unity. A systemic, nonlinear unity, with retreats and advances, where the crossing of the boundaries of the Earth is part of this process of interaction, but not without serious consequences (BRAUDEL, 2015, p. 634).

The paper is divided into four sections. After this introduction, the second section discusses the geographic, political, and economic aspects associated with the establishment of space centers from a geohistorical perspective. The third section deals with the Baikonur Cosmodrome experience, focusing on geopolitical, historical, socioeconomic, and environmental issues. The fourth and final section presents the main considerations and conclusions arising from the study.

THE ESTABLISHMENT OF SPACE LAUNCH CENTERS FROM A GEOHISTORICAL PERSPECTIVE

According to Ribeiro (2015), geography plays a central epistemological role in the development of Braudel's thought, as it is directly linked to the recording of long-term structures inscribed in nature, civilizations, territorial formations, and material landscapes. Likewise, the study of the relationship between society, environment, and territory requires an expanded reading of the historical process.

Geohistory is a tool to study how the environment and the built geographic space have integrated the long-term historical process, and at the same time to observe how historical processes leave their traces in the environment. For Ribeiro

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(2015), one of Braudel's great lessons for the human sciences is that the history of societies is both temporal and spatial, and that space, although changing, presents itself as a structure of history.

For Braudel (2015, p. 613), studying geography or history in isolation leads to a limited understanding of social processes. According to the author, the first step of any social research is to look at the facts under study from two poles: the spatial and the social. To these two poles is added the coordinate "time", this interaction defines the geohistorical analysis. In this study, these poles were used to understand the processes that played a role in the construction of the spaceports.

Since the second half of the 20th century, outer space has become a new stage for political, military, and economic disputes (SHEEHAN, 2007). In this context, this new domain also became part of geography as described by Braudel, in the form of an intertwining of physical-geographical and social space. In studying the development of civilizations around the Mediterranean, Braudel recognized the importance of roads as "lines of force" that could connect different cities and developing civilizations. Contemporary infrastructure, including spaceports, also leads to interactions between geographic and social elements, despite their high complexity (Бродель, 2002, p. 387).

Regarding the spatial (geographic) aspect, Roberts (2019) points out that a satellite must be launched into orbit from a higher altitude and with sufficient horizontal velocity, since payloads launched from lower altitudes are subject to strong atmospheric drag that makes it difficult to achieve adequate velocity. In the author's opinion, an object must be launched from a base on the equator in an easterly direction to take full advantage of the Earth's rotation.

Therefore, some positions on the Earth's surface are more favorable than others for launching payloads into certain orbits. Because all points on Earth's surface inherently have some horizontal velocity, certain space missions can take advantage of this rotation to reduce the total energy required for launch (ROBERTS, 2019). Owing to launches at lower latitudes generally require less energy (and thus less propellant) than launches at higher latitudes, the same launch vehicle can launch more mass from the Kourou Space Center in French Guiana than from the Plesetsk Cosmodrome in Russia. Similarly, a satellite launched from the north of Scotland would require more propellant to reach certain orbits than the same satellite launched from northeastern Brazil (ROBERTS, 2019).

According to Andrade (2018), the Alcântara Launch Center (CLA) in Maranhão (Brazil) stands out among spaceports for its strategic geographic location, 2º18' south of the equator, which provides an advantage for launches into equatorial

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orbit and means greater operational convenience and cost savings, as well as enabling the safe launch of spacecraft over a wide range of azimuths. The advantages of the CLA site for placing satellites in equatorial orbits include fuel savings during rocket launch and greater satellite capacity, which creates competitive advantages (ANDRADE, 2018). Launches from Alcântara can mean fuel savings of up to 30% compared to a launch from Cape Canaveral in Florida (USA), since the use of less fuel means a lower weight of the rocket and therefore a greater capacity to transport the payload (ZAPAROLLI, 2022).

Regarding geographic location, most countries have avoided establishing launch zones in populated areas or in areas encompassing foreign territory or airspace because of the toxicity of rocket propellants and the risk of falling debris. Another important issue is the environmental factors and climatic conditions that complicate launch.

According to Roberts (2019), the risk of natural disasters or adverse weather conditions, such as the possibility of earthquakes, tsunamis, and hurricanes, can make certain locations more or less suitable for launches. As an example, the author cites Japan, which has established its launch bases in earthquake-resistant areas of its territory. The Cape Canaveral area of Florida, on the other hand, is prone to hurricanes, which can cause delays in some launches. CLA, on the other hand, has a low population density and favorable climatic conditions with a well-defined precipitation regime and low temperature variability (ANDRADE, 2018).

Looking at the distribution of orbital and suborbital launch sites on the globe, it is interesting to note that their location and concentration coincide not only with their proximity to the equator, but also with the east-west axis of the Eurasian integration system, which includes China, India, and the Middle East.

From a geohistorical perspective, political and social issues also play a role in the establishment of space launch centers. One of these is accessibility, which refers to a state's ability to have unrestricted access to the launch site, leading it to install bases on its own territory or in locations controlled by the country. Roberts (2019) points out that almost all launch centers have been established in regions that are fully controlled by the operating country, thus ensuring unrestricted access. Another way to gain access would be through international cooperation agreements and technological safeguards, such as the agreement recently signed between Brazil and the United States for the use of the Alcântara Space Center (UNITED STATES OF AMERICA; BRAZIL, 2019).

According to Roberts (2019), another important factor was the use of former colonies and

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overseas territories for the construction of cosmodromes in geographically more favorable locations. As an example, the author cites the Hammaguir Test Center, built by the French military in Algeria in the 1960s, and the Kourou Space Center in French Guiana, considered one of the most active spaceports in the world.

Another problem is the control of the airspace around the centers, since certain launch capabilities may be limited by political relations between the operator country and its neighbors. For example, to avoid opponents in the east, the Israeli space center at Palmachim Air Base launches exclusively in a westerly direction, sacrificing the economic advantage it would have if launches were conducted in an easterly direction.

As a result, some space agencies are entering into cooperative agreements with neighbors and other countries to achieve more efficient launch trajectories. However, the choice of partnerships also depends on issues such as political and strategic proximity between governments and the political stability of regions. In Alcântara, for example, only countries that are members of the Missile Technology Control Regime (MTCR) can operate from the CLA after the signing of the agreement between Brazil and the United States (BRAZIL, 2020).

On the economic aspect, Vitt (2018) reports that space centers stimulate job creation in industries directly related to space transportation and have multiplier effects, e.g., on tourism in cosmodrome regions and other sectors, with the potential to boost regional economic activity. Costa (2021), in his study of the potential for socioeconomic development in Alcântara as a result of the establishment of the spaceport, draws a comparison with the Kourou spaceport. According to the author, Kourou was only a small village with 650 inhabitants, whose economy was based on agriculture, fishing and livestock, located 60 km from the capital of French Guiana. With the establishment of the cosmodrome, the region became a strategic area for French national security, which increased migration flows to the region.

The establishment of Kourou was fundamental to the development of French Guiana, involving the construction of a town on the outskirts of the complex (COSTA, 2021). From the point of view of economic benefits, the author points to the major local transformation generated by the launches of the Ariane satellites in the 1980s. In 2014, the Kourou space base was responsible for 25% of French Guiana's entire GDP (CENTRE NATIONAL D'ETUDES SPATIALES, 2018). On the other hand, most of these benefits have been restricted to a specific section of society, mainly immigrants, to the exclusion of native peoples. The French government chose to hire immigrants as a way of making up for the shortage of skilled local labor.

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Immigrants have come to represent 75% of the center's workforce, which has led to conflicts with ethnic groups in the region (COSTA, 2021).

After considering some of the political and spatial aspects of establishing launch centers, it is important to discuss the impact of these centers on their respective regions. The experience of the Baikonur Cosmodrome, inaugurated in 1955 during the Cold War, can provide some considerations in this regard.

THE BAIKONUR COSMODROME

The Baikonur Cosmodrome is an international spaceport serving mainly the Russian space program, but also other space agencies from various countries. It is located in a desert area in southern Kazakhstan, on the territory that belonged to the former Soviet Union until the 1990s. The site currently covers an area of 6,717 square kilometers.

The spaceport is of unparalleled importance in the history of space exploration. Great achievements were made in Baikonur, including the world's first artificial satellite, Sputnik 1, in 1957 and the first human in space, cosmonaut Yuri Gagarin, in 1961. The powerful Energy rocket, the Buran Space Shuttle and the launch pad for the Proton and Zenit rockets were built in Baikonur. It was also responsible for launching the space modules of two space stations (the Russian Mir and the International Space Station). About 120 Russian cosmonauts and two hundred astronauts from other countries were launched from its platforms. No other space center has performed as many launches as Baikonur (LESKOV, 1993; CARLEIAL, 1999).

The establishment of the Baikonur Cosmodrome in the 1950s is directly related to the dispute between USSR and the United States during the Cold War. Unlike the United States, which at the time was able to project the U.S. Air Force into enemy territory without much difficulty, USSR did not have the means to use its nuclear weapons against its rival. The Soviet strategic bomber, the Tupolev Tu-4, was an old aircraft that could not be refueled in the air and was unable to reach U.S. territory (BRZEZINSKI, 2007).

This made the development of long-range missiles a top priority for the Soviets and led to the test of the first intercontinental ballistic missile, the "R-7." Soon, the same technology proved capable of sending objects into space, such as artificial satellites and later space vehicles. By conquering space, the Soviet Union sought not only to expand its military capabilities but also to propagate its socialist political and economic model and gain international prestige (DOLMAN, 2005, CADBURY, 2007; SHEEHAN, 2007).

In the 1950s, the Soviets were looking for

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a new launch site for the R-7 to replace Kapustin Yar because of the project's unique characteristics. The report of the Interdepartmental Commission to the Central Committee of the Communist Party of the Soviet Union presents some of the factors that led the Soviet military to create the Baikonur spaceport (ИВКИН; СУХИНА, 2010, p. 386-388).

First, a site had to be chosen that would guarantee a range of 6,200 km from the launch point to the drop point of the missile warhead in order to reach the territory of the United States, the main objective of the project. Second, the region was close to a railroad line (Tyuratam junction of the Moscow-Tashkent railroad), an important element for the transportation of equipment and construction materials from Russia. Third, it was necessary to ensure that the objects dropped by the missile during launch fell in an uninhabited area to avoid damage to people and agriculture.

An area of 1,100,000 hectares was expropriated and it was decided that the missiles would take a trajectory that would pass over uninhabited areas. The report concludes that after considering all possible options for the location of the test site for the R-7, Buran, and Burya missiles, the commission concluded that the area near the Syr Darya River, adjacent to the Chkalov-Tashkent railroad line, on the route between Kazalinsk and Jusaly, was the most suitable. As can be seen, proximity to the equator and economic factors do not seem to have been decisive factors in the choice at that time. On February 12, 1955, the Council of Ministers approved the establishment of the new cosmodrome by Secret Decree No. 292-181, entitled "On a New Test Site for the USSR Ministry of Defense" (ИВКИН; СУХИНА, 2010, p. 388-389).

The role of geography in the choice of the test site is mentioned by eyewitnesses in their memoirs. One of Sergei Korolev's closest associates, academician Boris Chertok (ЧЕРТОК, 1999), mentions that several sites were considered for the spaceport, including the Autonomous Republic of Mari, the Autonomous Republic of Dagestan, the region east of the city of Kharabali in the Astrakhan region, and the semi-desert of Kazakhstan near the Tyuratam station in the Kyzylorda region on the banks of the Syr Darya River. According to the reports of General Yuri Mazhurin (НАЧАЛО КОСМИЧЕСКОЙ ЭРЫ, 1994), the region of Western Ukraine was also considered but was not included in the final list for geopolitical reasons related to the proximity of borders with NATO countries and densely populated areas along the missile's trajectory.

Participants in these events point to an important factor in the selection of the site for the cosmodrome. The R-7 intercontinental ballistic missile originally required the maintenance of dispersed radio control points and had to be located in places where these structures could be installed.

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For example, if the launch base was in the Caucasus, one of the points had to be placed in the middle of the Caspian Sea, making the project infeasible. The interference of mountains with the propagation of radio signals was also considered a problem (ЧЕРТОК, 1999). Within a few years, the radio control system was replaced by an autonomous system for launching the R-7, but the decision for the Kazakhstan region had already been made and construction of the spaceport was underway. If the creation of a radio structure had not been mandatory at that time, the cosmodrome could have been built more easily in Stravropol or Astrakhan, two regions with advanced transport infrastructure and closer to Moscow.

Dissatisfaction with the decision to build the test site in Kazakhstan is also described by another participant in these events, engineer and later cosmonaut Konstantin Feoktistov: "The rocket testers and leadership were tired of going to the Kapustin Yar desert; it would be nice if the future test site were located in a fertile place: by the sea or in the North Caucasus. But in this case there was no suitable location for the radio control point. So the North Caucasus and other resorts were out of the question. The central area of Kazakhstan turned out to be a viable option, which, of course, was extremely inconvenient, and everyone, from the people in charge to the workers and testers, complained about the developers of the radio control system" (ФЕОКТИСТОВ, 2005).

The report submitted by the Interdepartmental Commission states that rocket tests would be initiated "on an expeditionary basis" with a minimum of necessary facilities. The need for electricity would be met by electric trains, while accommodation would be in wagons and tents (ИВКИН; СУХИНА, 2010, p. 386-388).

According to the memoirs of General Alexander Maximov, soldiers, engineers, and scientists faced a new testing ground consisting of "steppes, saline soils, dunes, hawthorns, heat and wind, sometimes followed by sandstorms, a multitude of marmots, and no trees" (НАЧАЛО КОСМИЧЕСКОЙ ЭРЫ, 1994). Chertok highlights a number of challenges that the Soviet team faced, including severe temperature fluctuations throughout the year that ranged from 50 to minus 25 degrees Celsius, the incidence of disease, the lack of clean water sources, and the distance of more than 100 km from urban centers (ЧЕРТОК, 1999). It would be difficult to build a relatively large city and scientific and technological center naturally in such a region were it not for the requirements of the project and the constraints imposed by geography.

In 1954, a group of topographers and geologists was sent to the site to carry out the earthworks. From April to June 1955, eight military construction battalions began work, and a large

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amount of equipment was sent to the area. During this time, the construction of wooden houses for the workers also began. The first group of engineers specialized in rockets also arrived (BAIKONUR DM, 2021).

Despite the extreme conditions, much of the work on the Cosmodrome site was completed in less than a year and a half. Soon, the spaceport began to change its surroundings. A city grew up on the new test site. In May 1955, the first residential building (made of wood) was opened in the valley of the Syr Darya River near the Tyuratam station (МЕМОРИАЛЬНЫЙ МУЗЕЙ КОСМОНАВТИКИ, 2015). In the summer of 1956, construction of a brick residential complex began. In early 1957, the number of workers at the test site exceeded 4,000 people. In 1958, the settlement, unofficially called "Zarya", was christened Leninsk. The city project was designed for permanent housing of about 5,000 people. However, due to the intensive expansion of testing activities, by the end of 1959 there were already 8,000 people living in the city, and by the end of 1960 there were more than 10,000 (БОЛЬШАЯ РОССИЙСКАЯ ЭНЦИКЛОПЕДИЯ, 2023).

The name "Baikonur" appeared after 1961, when it became necessary to mention the origin of launches in official pronouncements about space triumphs. The original Baikonur was a mining town located 400 km northeast of the cosmodrome. The use of this name was intended to try to "confuse" enemy intelligence services and avoid revealing the secret of the actual location of intercontinental ballistic missile launches (ЧЕРТОК, 1999). Ultimately, this had little practical effect, as it was soon discovered that the launch trajectory could be easily calculated from observation of the satellite's motion. The name Baikonur remained, although it had lost its original purpose (ФЕОКТИСТОВ, 2005).

In the following years, both Baikonur and its surroundings experienced great growth. By the end of the 1970s, the population of Leninsk reached 70,000 (БОЛЬШАЯ РОССИЙСКАЯ ЭНЦИКЛОПЕДИЯ, 2023). At the height of the Russian space program, during the development of the Energy Buran program, there was a large influx of specialists from all over USSR, who were sent to Baikonur with their families.

Baikonur's heyday coincided with the height of the Soviet Union's space activities, which spanned the period from 1976 to 1986. The cosmodrome was heavily involved in military space activities, particularly in the area of strategic ballistic missiles. At that time, there were about 150 operational Soviet satellites in orbit, of which 80 to 90% were used for military purposes (VILLAIN, 1996, p.130).

At the height of the Cold War, investment in space made up a large part of the Soviet Union's

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military budget, which in turn consumed a large part of the Soviet national budget, accounting for as much as 18% of the GDP of USSR in the 1980s (SEGRILLO, 1997, p. 95). According to Segrillo (1997, p. 95), military spending was significantly excessive compared to the conditions of the Soviet economy as a whole, which later proved to be one of the factors in the collapse of the system. The investments in Baikonur resulted in the city of Leninsk receiving a large number of buildings and reaching a population of 140,000 in the early 1990s (БОЛЬШАЯ РОССИЙСКАЯ ЭНЦИКЛОПЕДИЯ, 2023).

The end of USSR in 1991 brought a new scenario for the maintenance of Baikonur and the sustainability of its surroundings, marked by political and economic obstacles. The development of the cosmodrome transformed an isolated place in the steppes of Kazakhstan into one of the world's leading space capitals. Baikonur was the focal point of the entire Soviet space industry, a modern embodiment of Braudel's "lines of force". After the collapse of the USSR, Baikonur met the same fate as the Mediterranean roads Braudel studied, which fell victim to the collapse of the economic system on which they were based. But unlike the old roads, which soon became arteries of capitalism and regained their importance, the Baikonur Cosmodrome was born of a combination of tremendous enthusiasm and an enormous expenditure of resources, with no concern for the economic return on these activities. Baikonur was part of a gigantic military-industrial complex whose inefficiencies eventually choked the Soviet economy in the late 1980s.

Although Baikonur remained without financial support and lacked market connections, it managed to find its place in the international division of labor, mainly due to its operational capacity and the limited supply of spaceports of the same size in the 1990s. Despite the existence of other smaller cosmodromes in Russia, most Russian commercial launches were only possible from Baikonur, which helped keep the center active.

The 1990s also brought a new geopolitical dynamic that would influence the use of Baikonur. With Kazakhstan's independence, Russia now had its most important space asset on foreign soil. The Kazakhs were not in a position to exploit Baikonur on their own because they had no space companies or educational institutions to train specialists. While there were 8,000 Russians working at the cosmodrome at that time, there were only 38 Kazakhs, half of them in auxiliary services (LESKOV, 1993). The first international agreement regulating the operation of Baikonur was signed between Russia and Kazakhstan in 1992 (RUSSIA; KAZAKHSTAN, 1992). On the basis of this agreement, Russia assumed 94% of the financing of the cosmodrome's facilities. In addition, the former Soviet

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troops stationed at Baikonur became an integral part of the space forces of the Russian Federation.

In the following years, the Kazakh government began to press for the creation of an international consortium between the two countries, in which the Russian side would have no advantage (ГАЗЕТА КОММЕРСАНТЪ, 1994). Moscow firmly rejected this proposal and was able to push through a 20-year lease agreement, which was signed in 1994 (RUSSIA; KAZAKHSTAN, 1994). Although Russia continued to use Baikonur, it no longer had an incentive to develop the cosmodrome and surrounding areas because they belonged to Kazakhstan. At this point, no new buildings were being constructed and the old ones were visibly deteriorating. Russia began to maintain the space facility only under minimal operating conditions (LESKOV, 1993).

In the former city of Leninsk, renamed Baikonur in the 1990s, uncertainty grew about its future. Leninsk / Baikonur was founded as a closed military city, where 82% of the population worked directly or indirectly on the cosmodrome. In the early 1990s, more than half of the population consisted of Russian space specialists, such as military officers and scientists. Because of its strategic importance, the city had a higher standard of living than many Soviet cities and was better equipped than any other city in Kazakhstan (LESKOV, 1993; CHERNYAK, 2016).

Despite its decades of growth, the city of Leninsk/Baikonur had a very precarious productive capacity, unable to sustain itself. After the collapse of the Soviet Union, the city faced economic, social, political, ethnic, socio-demographic and environmental problems. There was a large influx of emigrants from the region. Many military personnel left after control of Baikonur's space activities passed to civilians from the newly formed Russian Space Agency (Roscosmos). It is estimated that a quarter of the population originating from Russia and other former Soviet republics emigrated due to uncertainty about their new legal status and fear of ethnic conflict (LESKOV, 1993; CHERNYAK, 2016).

In 2004, the Baikonur lease agreement was extended until 2050 (RUSSIA; KAZAKHSTAN, 2004). Under this agreement, Russia paid a rent of $115 million per year for the use of the launch center facilities (ROBERTS, 2019, p. 15; AGÊNCIA EFE, 2020). Kazakhstan ratified the agreement only in April 2010, after pressure from the Russian Foreign Ministry (АБИШЕВ, 2010). The Kazakh parliament was unhappy with the amount for the use of Baikonur because half was included in various mutual compensations and not paid in cash. There were also concerns about the legal status of Kazakh citizens in Baikonur (БАСКАКОВА, 2014).

Although agreements have been reached, the central issue remains unresolved. The biggest

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challenge for Kazakhstan remains the future of Baikonur after Russia's departure. The withdrawal of Russian military forces from the region is a clear sign that the country has no long-term plans for the spaceport. In this sense, Kazakhstan will face the difficult task of maintaining and developing Baikonur itself, which of course requires significant scientific, technical and human resources that the country does not currently have.

Since 2012, however, Kazakh authorities have increasingly spoken of the need to sign a new agreement to end the lease to the Russians. According to Talgat Musabayev, president of the National Space Agency of the Republic of Kazakhstan (Kazcosmos), maintaining the lease would slow Kazakhstan's development in the space sector by preventing the government from taking over the operation of the spaceport. Musabayev also sees that the departure of Russian military components would bring about a new scenario that would require a renewed discussion on the civilian use of Baikonur (МУСАБАЕВ, 2014).

In recent years, the environmental impact on the region caused by space activities at the cosmodrome has led to much criticism of the Baikonur administration. There are records of studies showing contamination of soil and vegetation by rocket launches (SHARAPOVA *et al.*, 2020), as well as possible chromosomal changes and mutagenic effects on the region's ecosystems (KOLUMBAYEVA *et al.*, 2014).

The operation of liquid propellant launch vehicles results in environmental degradation, particularly in the areas where the objects impact. There is great potential for explosions and fires in central areas, as well as chemical contamination of soils and water sources. All of these occurrences can be observed in the impact areas of the Baikonur Cosmodrome (SUIMENBAYEV et al, 2019).

According to Kopack (2019), since 2007, a series of violent explosions of Proton-class rocket engines have produced large amounts of toxic debris in central Kazakhstan and increased society's concern about the use of space fuel. However, the activists' position has been suppressed on the grounds of "cosmophobia" There are reports suggesting that Russian and Kazakh authorities have resorted to censorship, intimidation, and detention (KOPACK, 2019).

In the 21st century, the number of launches at Baikonur is much smaller than the hundreds the Soviet Union used to conduct each year. When the United States discontinued the Space Shuttle program in 2011, Baikonur became the only launch center to conduct manned flights to the ISS, putting it back in the spotlight. But the favorable wind was short-lived. In 2020, the U.S. company SpaceX conducted its first private manned launch to the ISS from the Cape Canaveral complex, ending Baikonur's exclusivity. In the near future, Bai-

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konur will also have to compete with emerging space powers such as China and India, which are developing their own advanced launch centers on their territories (ALIBERTI, 2018; HARVEY, 2019).

Russia is already in the process of gradually reducing its dependence on Baikonur, particularly with the cessation of production of the Proton rocket. In 2011, construction began on the new Vostochny Cosmodrome in the Amur Oblast in Russia's Far East. Its first launch took place in 2016. It is expected to replace Baikonur in the long term (ROBERTS, 2019).

The severe environmental impacts associated with the expiration of the treaty with Russia in 2050 create uncertainty about the future of the Baikonur Cosmodrome. Kazakhstan would like to continue exploring Baikonur with other countries. According to Abaideldinov *et al.* (2014), the prospects are favorable because the country has the largest cosmodrome in the world and is working to train new qualified professionals in this field. The Baikonur Cosmodrome currently has five active platforms for nine types of rockets. Substantial public funding and bilateral cooperation agreements are needed to ensure Baikonur's viability in the future (ABAIDELDINOV et al, 2014).

On the other hand, the cosmodrome already shows clear signs of abandonment and disrepair. Debris from five decades of space exploration can be seen. For example, the platform for the rockets used to propel the Buran space shuttle, a project that was discontinued in the 1980s, continues to decay on the site. There is also an abandoned junkyard and the remains of a railroad line (BBC, 2006). In addition, the once thriving neighboring city of Leninsk / Baikonur has a population of only 57,000 in 2023, less than half when space activities were at their peak (BAIKONUR DM, 2023), also illustrating the loss of importance of the cosmodrome.

Global space activities have undergone an intense paradigm shift, with the emergence of new players, such as the private sector and developing countries, new technologies and new products, the so-called new space (PAIKOWSKY, 2017). Baikonur was built under all the standards of the old space: state-controlled space activities, where the main actors were the superpowers and their close allies, motivated by strategic goals in the Cold War scenario. In old space, lengthy and expensive space projects prevailed, with large satellites planned for long periods in orbit, with a relatively conservative R&D structure (PAIKOWSKY, 2017).

Since the end of the Cold War, as public funding for space declined, major space companies, or those indirectly associated with them, sought private activities and investment alternatives (PEETERS, 2018). The decline in public space budgets was exacerbated after the 2008 global economic crisis, which reinforced the paradigm

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shift in the sector with the development of multiple space applications. In addition, the goals have changed. While state actors are primarily concerned with national security, economic growth, development, and international status (power projection), the new non-state actors are more concerned with cost-benefit (PAIKOWSKY, 2017).

For the OECD (2016), this paradigm shift represents a new phase in the history of the space sector, with important implications for governance and the division of responsibilities between governments and the private sector. The Baikonur Cosmodrome, still associated with the context of old space, is therefore facing a new and challenging scenario with economic, political, social and environmental issues.

CONCLUSION

The purpose of this article is to reflect on the geohistorical changes resulting from the establishment of space launch sites, based on the experience of the Baikonur Cosmodrome. Using the concept of geohistory proposed by Braudel (2015, p.630), bibliographic information and primary databases were searched to determine the impact of the launch center on the region where it was established.

The desert region of Kazakhstan (then a member country of USSR) fit very well with the interests of the Soviet government because it had the necessary characteristics for the establishment of a spaceport, such as low population density and access to rail transportation. Two of mankind's first conquests in space, the first satellite and the first manned space flight, emanated from the newly established cosmodrome. Thus began the space race as a material expression of Cold War bipolarity and a potent symbol of technological competition.

The creation of the Baikonur launch center led to a large influx of population to the region, primarily due to the presence of Soviet military personnel, technicians, and scientists. In less than a decade, the desert was transformed into a dynamic city, most of whose inhabitants depended directly or indirectly on the cosmodrome.

Baikonur gradually grew in physical structure and population and became the main space base of the Soviet Union, closely linked to military activities and the Soviet state budget. Thus, the history of the center and its geographical surroundings goes hand in hand with the history of USSR, as the major space projects developed there were linked to the geopolitical goals and the material capabilities of the superpower of the time to implement them.

The end of the Soviet Union and the independence of Kazakhstan brought changes that were reflected in the socio-economic conditions of

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the city and the cosmodrome. Major projects such as the Buran space shuttle were canceled and the space budget was cut, affecting the region and leading to a reversal of population flows and a loss of geopolitical importance of the cosmodrome in the post-Cold War era. Baikonur is still one of the most important space centers in the world, from which most manned interplanetary flights depart, but its surroundings, still associated with the old space, show signs of decay in many ways.

According to Roberts (2019), cosmodromes are becoming an increasingly important factor for the global space industry, given the increase in space activity worldwide and the exponential growth in orbital launches. Still, there are uncertainties about the future of the Baikonur Cosmodrome. Russia is already in the process of moving its activities to the Vostochny Cosmodrome. Also of importance are indications of environmental damage in the region and the techno-economic paradigm shift in the current space sector, which will certainly affect Baikonur.

The implementation of space policy by the state of Kazakhstan, geopolitical changes, diplomatic and environmental issues, and international interests in the continued use of the cosmodrome may affect its ability to revitalize and adapt to the "new space."

In 1996, Villain (1996, p.134) wrote of Baikonur: "For over 30 years, human genius has dwelt, and made of this forgotten corner of the planet a point of departure for the stars, for space." A desolate, uninhabited corner that quickly became a dynamic hub for interstate disputes and has grown old ("old space") in the face of recent changes. The Baikonur experience seems to illustrate well Braudel's (2015, p.624) reflections: "Like watercourses that have phases of youth, maturity, and old age in their erosion cycles, certain landscapes are young, mature, and then old."

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