Space Science and Education: Legal Analysis of the Experience of China and Ukraine

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The article analyzes the legal experience of space science and education in China and Ukraine. It is proved that the legal and organizational regulation of the space industry of China and Ukraine reflects different trends. China has progressed in space science and education, while Ukraine has stagnated. China has taken the best of Soviet and Western expertise. Ukraine was left with the worst achievements of the Soviet-era public administration and did not introduce the competitive mechanisms of Western society. It is concluded that individual scientists and designers in Ukraine have preserved their outstanding potential in space research. Ukrainian space education has a long and illustrious history.

Keywords: scientist, China, competition, designer, space industry, science, education, legal analysis, public administration, Ukraine

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Introduction

Science and education play an important role in the development of any high-tech field, including the space industry. In recent years, space science and education have begun to progress dynamically. This is primarily due to the active involvement of private space companies and private financial capital in the use of outer space.

China is one of the leading space powers, which, along with the United States, is today at the forefront of the study and usage of space. In turn, Ukraine has a glorious tradition of developing and manufacturing rocket launchers and other space products. Originally, national space actors transferred technology to China. However, in the contemporary world, China has been able to make significant progress in space exploration. This was accomplished by combining Soviet and Western experience in technical, economic and financial support of space science, as well as technology and education development. The Ukrainian space sector has been in decline in recent years, primarily due to legal and organizational miscalculations of the highest state authorities. In today's circumstances, Ukraine's national cosmic industry in general, as well as cosmic science and education, must draw on Chinese expertise.

Why have Chinese space science and education flourished? The legal and organizational causes are highlighted in the following article. What, on the other hand, is the reason for the decline of space science in Ukraine? Simultaneously, the phenomenon of how Ukrainian space education has managed to remain at a good level and continue to develop was described without paying attention to the modest success of national space companies in the field of use and research of outer space.

The article focused on comparing the advantages of the public administration system of China's space industry to insignificant public administration in Ukraine. It is concluded that only the transition to market-based competitive principles, which are based on private ownership and public-private partnership, can improve the state of affairs in the Ukrainian space industry and space science as a whole.

Historical and legal retrospective of space science in Ukraine

Ukrainian scientific schools occupied a leading position in the space industry of the Soviet Union. First and foremost, due consideration was given to the development and production of carrier rockets. Most of the strategic military missiles of the Soviet Empire were designed by the Southern Design Bureau and manufactured at the Southern Machine-Building Plant, located in Dnipro (Ukraine). However, it is worth mentioning that more than two thousand subcontractors from different regions of the Soviet Union were engaged in the supply of components for Pivdenmash (Voight, 2018).

In general, it should be noted that when Ukrainian lands became part of the Soviet empire, the direct involvement of national experts in civil space projects was limited **(**Kukushkin & Levenko, 2018; Kavats et al., 2018; Soroka, 2020). It is natural that in the early years of Ukraine's independence, national space research was based on the traditions and remnants of the potential of the Soviet military-industrial complex (Baklanov, 2013).

From the point of view of public administration, it is necessary to note that the National Space Agency of Ukraine was established on February 29, 1992, based on the need to preserve and further develop the scientific, technical, and production potential of Ukraine's space industry in order to solve socio-economic problems (About creation, 1992). It should be emphasized that at the time, neither the officials of the State Space Agency nor the management of scientific institutions and enterprises had any experience in international civilian space activities. Unfortunately, state space structures in Ukraine have used scientific developments in rocket and space experience from the previous era for more than 30 years. During this time, they created 7 questionable satellites. Zenit military missiles were converted into civilian ones under the commercial name "Zenit-3SL." Certain foreign commercial entities with corrupt ties to high-ranking government officials have long used Soviet-made military ballistic missiles in Ukraine during the Soviet era to convert launches of carrier rockets known as "Dnipro" and "Tsyklon-3." Despite the fact that there was and still is a lot of scientific and design potential, no new launch vehicles or civilian missile systems were developed (Bilenchuk et al., 2022).

For a long time, the space industry has been reforming on the basis of equality of all forms of ownership and the establishment of competition. There are currently state-owned space companies that receive insufficient government funding and state order (Baklanov, 2013).

To avoid bankruptcy, the Cabinet of Ministers intervenes and, through the Parliament of Ukraine, provides subventions to some state-owned enterprises in the space industry to cover their critical accounts payable. For example, the Verkhovna Rada amended the law "On the State Budget of Ukraine for 2020," which provided for the introduction of a new budget program by replenishing the authorized capital of the state enterprise "Production Association Southern Machine-Building Plant named after Alexander Makarov" to repay wage arrears, the only social contribution, certain taxes and budget expenditures with the amount of UAH 2,318.228 million (The Verkhovna, 2020).

Only on January 29, 2020, the Law of Ukraine came into force, allowing private entities to operate in space. After all, according to the document, the subjects of space activities can be enterprises, institutions and organizations of any form of ownership, including international and foreign, which carry out space activities (On amendments, 2019).

Ukraine established space programs after regaining independence. However, allocated public funds and loans secured by state guarantees were not effectively used (Levenko &

Drozdenko, 2021). This is confirmed by the fact that there were space programs, but there was no practical achievement **(**Kuznetsov, 2021).

The participation of individual space firms in foreign commercial companies required state funding without profit for the state. This is how financial debts came into being (The companies, 2021).

As a result, the once powerful design and missile building potential of Ukraine to create new ballistic missiles had been destroyed. Unfortunately, space science gradually declined (Holovinska, 2011). At the same time, some top managers of state space enterprises and research institutions have amassed multimillion-dollar fortunes. For example, the Soyuz Research Institute was completely liquidated (About, 2013).

Despite these unfavorable aspects, it should be emphasized that the high scientific and design potential of Ukrainian scientists is preserved. Alas, the space industry's public administration system is currently one of the worst in the world and is nearly Soviet in nature. The state entities of the space sector are left with essentially no state funding, which is a negative attribute. State-owned space companies and scientific institutions have long operated under artificial administrative monopolies, but have been unable to profit from them. After all, they are deprived of international business self-sufficiency. Moreover, the state not only does not help them develop, but on the contrary, restrains by specialized administrative measures.

Thus, the situation in Ukraine is somewhat paradoxical. Ukrainian scientists and designers have one of the world's best experiences in the development and construction of carrier rockets. However, due to the insignificant system of public administration, they do not have the opportunity to attract financial investment in the space industry. As a result, virtually no new civilian rocket and space complex has been developed in Ukraine since independence.

Legal and organizational experience of science and education in China

China is one of the mightiest space powers, boldly and ambitiously competing with the United States, leaving far behind the once space power – Russia. One of the latest successes of Chinese scientists is the launch into orbit of 5 satellites of the Jilin-1 Gaofen 03D (04-07)/04A series. The launch was conducted on April 30, 2022, by the Long March 11 Haisheyao-3 carrier rocket in the waters of the East China Sea. This is the Chinese version of the sea launch from the floating platform De Bo 3. The satellites will be mainly used for remote sensing of the Earth when planning the construction and reconstruction of cities and monitoring of natural disasters (Jing, 2022).

The Long March series launch vehicle in the solid propellant version was launched for the 418th time; the Jilin-1 orbital group currently contains 46 satellites, allowing to observe everywhere in the world at any time. Due to the application of trends in the development of rocket and space technology in the People's Republic of China, this event is no less significant than the launch of lunar rovers (Levenko, 2019).

Chinese space science and education trends have their own history. The popular perception of ancient Chinese legends and the culture of fireworks has nothing to do with modern space science and education. After all, it was only a millennium ago that the first missile technology was seriously used for military purposes in China. The army of the Republic of China used mortars successfully in the 1920s, much earlier than many other armies around the world. For instance, mortars played a major role in the hostilities of the war between Soviet Russia

and the Chinese army in 1929 for the China-Eastern Railway, which was built in the lands of China by the Russian Empire. Its center was located on Chinese territory in the city of Harbin (Levenko, 2019).

After all, in its technical essence, the mortar is a small prototype of a ballistic missile on solid fuel, which is ejected from the barrel of the mortar during a dynamic fire launch. Decades later, this method of launching military missiles gained much popularity under the same name – "mortar."

In terms of the practical development of modern space science and education in China, famous scientist Chenzhi Li accurately described the first stage (before 1991). He claims that the decision of communist China (1954) to develop nuclear weapons and launch vehicles (1956) was the impetus for the development of space science and education. Thus, rocket cosmic science and education in China emerged solely due to defense missions, and this trend has changed little by 2022. There was a tendency to study, borrow and use foreign experience in order to create their own high-tech developments, rather than to shy away from international experience and to be somewhat cynical in terms of intellectual property rights. Hundreds of scientists and also researchers of Chinese origin with the practical experience from the United States and other Western countries were invited to China. In 1957, the United States was already conducting flight tests of the first model of the Polaris-A1 submarine. Its design took into account both the influence of German specialists who moved to the United States after World War II and the advanced technologies of Americans (Li, 2013).

The desire of the Soviet Union to seize China's sphere of influence in the confrontation with the United States led to the transfer of documentation and technology for the production of a serial R-5 carrier rocket, which was capable of delivering nuclear warheads. The manufacturer of the R-5 was the so-called mailbox 186, located in Dnipro, Ukraine. In order to reduce costs and time to create their own ballistic missile, the R-5 was replicated in China with the increased size of different parts, particularly the liquid rocket engine. The decades of the trial were crowned with the successful adoption of the ultimate program for rocket and space technology development in 1991 (Li, 2013).

The trend of creative borrowing of foreign technologies continues to this day. The Fifth Academy under the Ministry of Defense of the People's Republic of China was established and later modernized several times to develop missiles and production technologies. The Chinese Academy differs from Ukrainian ideas and Western paradigms in general. After all, similar in name, Western categories often acquire the characteristics of anonymity. There are dozens and hundreds of research institutes, organizations, enterprises, and companies in China, the largest of which employ up to 200,000 people. It conducts rocket and cosmic technology research, design and construction, testing, and manufacturing. The Academies collaborate with the National Space Administration of the People's Republic of China, which has the right to openly present space exploration in China and cannot function without the Academies. A huge number of universities have been established in the PRC, some of which have a clearly defined rocket and space orientation in the training of specialists in the implementation of applied research. The academy not only ensures the development of Chinese science, technology and higher education, but also supervises the development and manufacture of rocket engines. In the city of Xi'an, Shaanxi Province, the Northwestern Polytechnic University has been established with 13 institutes, where 1,300 professors and associate professors educate students and conduct research in 52 different specialties (Northwestern, 2022).

Some research institutes and plants have been relocated from Xi'an to Hohhot city of Inner Mongolia Autonomous Region, where the Inner Mongolia University of Technology, with 52 research institutes and dozens of disciplines, provides training, particularly in fuel chemistry. There are 2068 teachers in total, including 705 professors and associate professors (Mongolia, 2022).

Equally interesting are the Northern University of China, Taiyuan City, Shanxi Province (missile weapons and artillery are being developed here), as well as many other higher education institutions of the Ministry of Education. The Harbin Institute of Technology is the main training center for rocket and space technology, operating under the auspices of the Ministry of Industry and Information Technology of the People's Republic of China. There are 23 research schools with many institutes and scientific centers, where 25,000 students get an education (Harbin, 2022).

The educational process of Harbin Institute of Technology is carried out on the basis of: "one school, three districts." The Harbin Institute of Technology has two departments located in Weihai, Shandong Province, on the Shandong Peninsula, which specializes in naval missile research and in Shenzhen City, Guangdong Province in southern China.

Among the many Harbin Institutes of Technology, the Space Environment Simulation Research Infrastructure is particularly well known (Institute, 2022). It specializes in modeling the space environment and conducting research of its impact on space technology and materials. By 2022, it will be a full-fledged, relatively independent center of space science and education. It focuses on the study of fundamental scientific issues in the field of space materials, devices, magnetosphere physics, space environment, etc. The institute owns the most modern systems of analysis and measurement. SESRI's research capabilities cover fundamental categories of scientific problems: the evolution of the structure and characteristics of materials in the integrated space environment; mechanisms of life in the space environment; propagation and evolution of space plasma and the physical mechanism of its interaction with spacecraft. SESRI has various particle accelerators. Accelerator of protons and heavy ions at 300 MeV, which are the main source of radiation, supplies protons at 100-300 MeV and heavy ions at an energy of 7-85 MeV / u to study the interaction of radiation from high-energy space particles with a special device and life support module. To meet the above requirements, the installations use a combination of the electron-cyclotron resonance ion source, linear accelerator injector and synchrotron. The linear accelerator injector delivers heavy ion beams with energy of 1 structure of the linear accelerator RFQ (radio frequency quadrupole) and IH-DTL (accelerator with a drift tube type Interdigital H-mode). The synchrotron accelerates heavy ions to 85 MeV / nucleon and the proton beam to 300 MeV, as well as the third whole resonance and method RF-KO (RF-Knock-Out) (Jiang et al., 2019).

Such specialization of universities in conducting basic research with applied tasks is traditional for China. At the same time, trends in the transfer of military technology to the civilian sector play a key role. The conversion of the defense and missile industry in China began in 1991. A special program for the commercialization of military technology is still in place. However, the administration is under the control of China's military action at all levels of public administration, up to local initiatives. It is critical to include the development of rocket and cosmic technologies in China's five-year plans for socio-economic development. Simultaneously, strict control over the implementation of plans and high responsibility for their non-implementation are applied. These plans concern both China-wide goals and development at the provincial level, including in the field of education. The following activities resulted in the establishment of China's fifth

spaceport – the sea launch. The East China Dongfang Spacecraft Launch Port was founded in Yantai, Shandong Haiyan area. Coastal cities on the Shandong Peninsula are rapidly developing. Yantai is well-known for its research institutes dedicated to the design and production of communications satellites and satellite equipment. Yantai produced 96 percent of all computers on the Chinese space station, 90 percent of the electronics in Chinese space suits Feitian, as well as wireless space communication (Zhang, 2022).

Weihai, which is nearby, has a branch of the Harbin Institute of Technology. Next on the coast is the industrial giant Qingdao, with one of the largest Earth remote sensing centers in China. Such a conglomerate of science, technology, and education in Qingdao and Yantai with a dozen different universities is converting rocket space technology into the private sector through public-private partnerships, leading to the creation of a special industrial zone with China's first maritime spaceport. The full cycle of design, manufacture, launch of satellites and use of space information for remote sensing of the Earth is provided there. Another up-to-date Earth Remote Sensing Center has been set up in Yantai. This is the most powerful achievement of China's space rocket technology in the last 30 years. The first launch of the carrier rocket in the Yellow Sea was performed following a one-stop principle, i.e., integration of the final assembly of the carrier rocket at the plant in Haiyan, the conduct of general tests, a departure from port and launch in the waters of the Yellow Sea (Deng, 2022).

It is planned to produce and launch ten carrier rockets per year at the Haiyan Commercial Solid Fuel Industrial Base. It also intends to establish a research and production base for commercial Galaxy Power solid rockets developed in Beijing by Space Technology Co., Ltd. The total value of the products will exceed 10 billion yuan. The development of Chinese science, technology and education is directly related to the modern space achievements of China (Deng, 2022).

Thus, by borrowing technology from the United States and the Soviet Union, China has been able to become the most developed country in the world in terms of space science and education. This success is based on the public funding of the military, which gradually began to transfer its development to a private business relying on strict public-private partnership control.

Space education in Ukraine: legal and organizational aspects

Space education in Ukraine developed primarily at the Physical and Technical Faculty of Dnipro National University, which was established in 1951. Until 1991, it was the only and secret faculty of higher education that trained personnel for ballistic missile design, construction, testing and mass production.

The training was conducted on the full-time and evening forms. Evening education was provided mainly by leading specialists and scientists from mailbox 86 and mailbox 2289, who already had practical experience, as well as students working in the space industry. The level of professional knowledge was extraordinarily high. The traditional places of employment for the graduates of the faculty were the basic enterprises – State Design Bureau "Southern," "Southern Machine-Building Plant," Institute of Technical Mechanics of the National Academy of Sciences of Ukraine and the State Space Agency of Ukraine, as well as Educational and Research Institute of Mechanical Engineering (Faculty, 2022).

In today's world, the latter has ceased to exist, and other named subjects of practical space activities do not hire graduates of space specialties. The subjects of practical space activities

do not have international legal and administrative-organizational independence because of the unreformed system of public administration. On the other hand, the subjects of practical space activities are not provided with state funding.

During the period of Ukraine's independence, space specialties were approved at the Kyiv Polytechnic Institute, Kharkiv Aviation Institute and the National Aviation University. The only Technical Missile College in Dnipro and Higher Professional College train highly qualified workers in missile specialties.

For example, at the National Technical University of Ukraine, "Igor Sikorsky Kyiv Polytechnic Institute," the Institute of Aerospace Technology with all levels of higher education is successfully operating. In particular, doctors of philosophy are trained in the specialty "Aviation and rocket and space technology." Thereby, trained specialists are able to set and solve complex research problems, in particular, to improve existing and develop new methods of designing rocket, space and aviation equipment and to carry out their scientific testing. At the same time, graduate students have the opportunity to do internships in European universities thanks to the international mobility programs Erasmus and Erasmus Plus. Partner universities: Warsaw University of Technology (Poland), Central School of Nantes (France), University of the Basque Country (Spain), University of Trento (Italy), Czech Technical University (Czech Republic), Budapest University of Technology and Economics (Hungary), Dublin Institute of Technology (Ireland), University of Southampton (UK), Stuttgart Technology University (Germany), Berlin University of Technology (Germany), Northwestern Polytechnic University (China), Dalian Maritime University (China), etc. (Aeronautic, 2020).

Thus, space education traditionally functions and progresses in Ukraine. Most talented graduates of national space universities find employment in developed Western countries.

Legal and organizational factors of the development of modern space science and education in Ukraine

There are a number of negative facts and challenges in the field of space science in Ukraine. From the point of view of public administration, the state space agency is not independent. It functions within the political and public administration of the Ministry of Strategic Industries of Ukraine. The space rocket industry, which produces strategic missile carriers, does not receive adequate funding.

As a result of the full-scale invasion of Ukraine by the Russian Federation, their terrorist forces are destroying military and civilian targets in Ukraine with ballistic and cruise missiles. Unfortunately, the military-political leadership does not have the means to repel the aggressor (Russian, 2022).

After all, Ukraine has not had any practical success in space science or in the production of rocket technologies in the last 30 years. The situation in the world is the opposite, based on public-private partnership with the use of defense tasks as a basic element.

Nowadays, Ukraine has a legislative opportunity to engage private entities in space activities. The State Space Agency, which is supposed to create a mechanism for legal regulation, has not undertaken any action. The agency did not even adjust its documentation to the peculiarities of the legal regulation of private space science and technology. As a result, private initiatives are not supported by the state. In fact, there are private space science initiatives in Ukraine, but they are exported to the United States, Great Britain, France, South Korea and other democracies.

At the same time, state structures, at the level of enterprises, scientific and educational institutions, still do not differ from the structures of the military-industrial complex of Ukraine of the past era – and therefore, cannot be maintained without reform by a modern democratic state with a market economy.

After the abolition of the state monopoly on space activities, numerous private micro design bureaus and companies were formed in Ukraine (Research, 2022). One of them is Science & Space LLC, which already has modern projects of the rocket and space complex and reusable rocket engine on non-toxic and non-cryogenic fuel components (rocket complex and engine patented in Ukraine), as well as several revolutionary technical proposals for launch vehicles, which were reviewed by officials in Ukraine (Mission, 2022).

Therefore, a powerful scientific space potential in the heart of Ukraine is not in high demand today. Scientists and practitioners of the national space industry are implementing their plans in developed Western democracies: Britain, the USA, France, South Korea and others. The space activities are primarily conducted by private research institutions and businesses, which are more mobile and proactive. They are not so burdened by the negative public administration of regulatory bodies.

Conclusions

The legal and organizational regulation of the Chinese and Ukrainian space industries reflects different trends. Ukraine has previously enjoyed great success. However, under the current circumstances, no progress has been made. China, on the other hand, began to actively develop space science and education only in the 1990s. Space science and education flourished in China and withered in Ukraine. Indeed, in terms of public funding and competitive research, China has taken the best from the Soviet empire and Western countries. On the contrary, Ukraine has stuck in the public administration systems of the past era, has not introduced competitive development mechanisms and left the national space industry without funding.

Space science in Ukraine has preserved its high-tech potential at the level of individual scientists and designers. Ukrainian space education is traditionally strong and evolving. However, talented graduates of higher educational institutions of Ukraine usually work in specialized companies in Western democracies. In 2020, space science and education in Ukraine began to develop at the expense of private initiatives. Ukraine's private cosmic industry is focused on Western and Chinese investments and space markets.

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