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PREFACE

O. Ya. Pylypchuk
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In the new issue, our scientific journal offers you nine scientific articles. As always, we try to offer a wide variety of topics and areas and follow current trends in the history of science and technology.

The issue of the journal opens with an article dedicated to the formation and development of natural history museology in Europe in the 15th–19th centuries. The development of scientific knowledge at that time affects the idea of the world order and the place of man in it, and the combination of knowledge with practical experience leads to the birth of true science. It is shown that one of the most important components of the development of natural sciences, in particular biological sciences, was the collection of naturalia (i.e. objects of natural origin), the rapid surge of interest in which contributed to the Great Geographical Discoveries. In chronological order, the further historical development of museum work from private collections in Italy to the formation of a prototype of a genuine museum, which performs the main museum functions such as amassment, storage and demonstration of collections, is considered.

The article by Leonid Griffen and co-authors considers the object and subject of the history of science and technology, its place in the system of sciences. Today, more and more people are turning to the factors that determine the interaction of the society with the environment (productive forces of the society), to study which in the historical aspect and called a special scientific discipline the history of science and technology. The composition and development of the technosphere and noosphere are considered in the article. It is shown that the functioning of the technosphere is based on its interaction with the noosphere, which provides information about the environment and controls the effectiveness of interaction with it. It is formed by combining the mental structures of individuals through sign systems. The production process that ensures the functioning of the society begins with the noosphere, which through individual consciousness controls the actions of each individual, who through the means of production (technosphere) interacts with the natural environment. However, the gradual development of productive forces leads at some point to the fact that the information needed by the individual to perform all necessary actions for the benefit of the society, ceases to fit in his individual consciousness. As a result, there is a new social phenomenon the social division of labor. The cardinal solution to the problem is the prospect of humanity entering infinite space.

The article by Jun-Young Oh and Hyesook Han is devoted to the study of what Understanding mathematical abstraction in the formularization of Galileo's law. Galileo's revolution in science introduced an analytical method to science that typifies the overall modern thinking of extracting, abstracting, and grasping only critical aspects of the target phenomena and focusing on "how", which is a quantitative relationship between variables, instead of "why". For example, to him, the question of 'why does an object fall' is of no significance; instead, only the quantitative relationship between distance from the falling object and time is important. Yet, the most fundamental aspect of his idea is that he introduced a quantified time t. Because, according to atomic theory, vacuum exists between an atom and an object composed of atoms or between objects – ignoring factors that interfere with motion, such as friction – the space for absolute time, which is a mathematical time, can be geometrically defined. In order to justify this mathematical abstraction strategy, thought experiments were conducted rather than laboratory experiments, which at that time were difficult to perform.

The article by Vasyl Andriiashko and co-authors provides a thorough overview of the evolutionary process of the emergence, establishment, and development of the Kyiv school of artistic textiles. It reveals the influence of various factors (ideological, political, economic, and aesthetic) on this process. The historical and factual method allowed us to study socio-economic, as well as historical and cultural factors that contributed to the emergence, establishment, and development of the Kyiv textile school in a chronological sequence. It is established that the very fact of emergence of the Kyiv school of artistic textile, as a community of style, unity of forms, preservation, and continuity of traditions, had unbiased backgrounds since Ukrainian decorative weaving, a part of which is Kyiv weaving, inherited the abundant artistic traditions that were created over the centuries and most vividly manifested through the art of Kyivan Rus.

In the next article, the authors Artemii Bernatskyi and Mykola Sokolovskyi is devoted to the study history of military laser technology development in military applications. For better understanding and systematization of knowledge about development of historical applications in the military field, an analysis of publicly known knowledge about their historical applications in the leading world countries was conducted. The study focuses on development that was carried out by the superpowers of the Cold War and the present era, namely the United States, the Soviet Union and the Peoples Republic of China, and were built in metal. Multiple avenues of various applications of laser technology in military applications were studied, namely: military laser rangefinders; ground and aviation target designators; precision ammunition guidance systems; non-lethal anti-personnel systems; systems, designed to disable optoelectronics of military vehicles; as well as strategic and tactical anti-air and missile defense systems. The issues of ethical use of laser weapons and the risks of their use in armed conflicts, which led to an international consensus in the form of conventions of the United Nations and the International Committee of the Red Cross, were also considered. As a result of the analysis, a systematic approach to the classification of applications of laser technology in military products by three main areas of development was proposed: ancillary applications, non-lethal direct action on the human body and optical devices of military equipment, and anti-aircraft and anti-missile defensive systems.

The author of the following article considered the front line transporter as the embodiment of the USSR military doctrine in the middle of the 20th century. The paper based on a source analysis of the history of creation, design, and production of LuAZ-967, LuAZ-967M, against the background of the processes of implementing projects of small tactical high mobility wheeled vehicles for the armies of European countries, shows that the developing, testing, and commissioning a front line transporter became a deepening of the process of motorization of the Soviet army. The designs of similar vehicles have been analyzed. An attempt to assess the degree of uniqueness of the front line transporter design and its place in the history of technology, as well as its potential as a reminder of science and technology has been made. An analysis of the front line transporter design, its systems, compared with its foreign counterparts, suggests that it is a Soviet refinement of the concept of a small army vehicle, a more specific means directly for the battlefield. At the same time, it was developed taking into account foreign developments and similar designs, imitating individual designs, adapting to the capabilities of the USSR automotive industry.

The next article is devoted to the study, generalization and systematization of scientific knowledge about the history of the establishment, development and operation of the regional railway system in Bukovyna in the second half of XIX – early XX centuries. The authors attempted to analyze the process of creation and operation of railways in Bukovyna during the reign of the Austro-Hungarian Empire based on a wide range of previously unpublished archival documents, periodicals, statistical literature and memoirs. The article studies the development of organizational bases for the construction of railways, the activity of the communication network management, lists a whole range of requirements and tasks set for railway transport in Bukovyna, the progress of their implementation, considers successes and difficulties in this work.

The purpose of the article by authors Sana Simou, Khadija Baba and Abderrahman Nounah is to reveal, recreate as accurately as possible the characteristics of an archaeological site or part of it. The restoration and conservation of monuments and archaeological sites is a delicate operation. It requires fidelity, delicacy, precision and archaeological authenticity. Research during the last two decades has proved that 3D modeling, or the digital documentation and visualization of archaeological objects in 3D, is valuable for archaeological research. The study has opted for the technique of terrestrial and aerial photogrammetry by 3D surveys of architectural elements, to develop an archetype of the deteriorated Islamic Marinid site (a dynasty between the 13th and 15th centuries), and the Roman site (25 BC), located at the Chellah archaeological site in Rabat and Salé cities. The data acquired build an architectural database to archive and retrieve the entire existing architecture of monuments. This study has been completed by photogrammetrists, architects, and restorers.

The issue of the journal ends with an article devoted to the analyzing the prerequisites and conditions for the foundation of an aircraft engine enterprise in Ukraine. Based on the retrospective analysis, the prerequisites and conditions of the foundation of the aircraft engine enterprise in Aleksandrovsk, Ukraine, were considered. There was a severe gap between the Russian Empire and European countries in the development pace of the aviation industry during World War I. This prompted the Russian Empire to raise foreign capital, as well as attract technologies and specialists to develop aircraft engineering and other industries. By 1917, the plant had gained the status of Russia's largest engine-building enterprise in terms of building area and one of the best in equipment. It is evident that the beginning of aircraft engine production in Aleksandrovsk relates to the establishment of a branch of Petrograd Joint Stock Company of Electromechanical Structures and the plant's purchase from the Moznaim brothers.

We hope that everyone will find interesting useful information in the new issue. And, of course, we welcome your new submissions.

HISTORY OF SCIENCE

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Natural history museology: establishment and formation of its theoretical bases

Abstract*. The article presents a brief historical outline of the formation and development of natural history museology in Europe in the 15th–19th centuries. The development of scientific knowledge at that time affects the idea of the world order and the place of man in it, and the combination of knowledge with practical experience leads to the birth of true science. It is shown that one of the most important components of the development of natural sciences, in particular biological sciences, was the collection of naturalia (i.e. objects of natural origin), the rapid surge of interest in which contributed to the Great Geographical Discoveries. In chronological order, the further historical development of museum work from private collections in Italy to the formation of a prototype of a genuine museum, which performs the main museum functions such as amassment, storage and demonstration of collections, is considered. The role of prominent naturalists and philosophers such as F. Bacon, C. Linnaeus, and J.-W. Goethe in the development of museum work is considered and little known facts about their work in this area are presented. The first works of art that show the interiors of "Kunstkameras", which became widespread in Europe in the 17th–18th centuries, are briefly considered. According to the authors, it is on the portrait of the Belarusian educator F. Skorina, which was published in Prague in 1517–1519, that the interior of the first Renaissance "kunstkammer" collections is depicted. Separately, the development of museology in Ukraine since the time of Yuriy Kotermak (Drohobych) (1450–1494) is considered and the differentiation of the concept of "museum" in the monuments of Ukrainian literature of the period of the 16th–18th centuries is studied.*

The authors considered the methodological foundations of natural history museology and analysed the existing classifications of various branches of science. The specificity of natural history museology in the system of museological science is shown, the issue of singling out natural history museology as an independent discipline is discussed. It is proved that the periodization of museology and museum work in certain territories in historical time can be considered correct; the author's development of the periodization of natural history museology in Europe is also given.
Keywords: *history of science; Europe museology; natural history museum; collection of naturalia; development of science museum in Ukraine*

Introduction.

The possibility of consideration of natural history museology as an independent branch of science with its own research objects is still a topic of discussion among researchers of the history of science. Several studies on the history of formation and establishment of science are related to this issue and such research are conducted in many countries of the world.

In her book on natural history museology, Sotnikova (Sotnikova, 2011) partly considered the beginnings of formation of natural history collections in Europe, also paying attention to the largest collections of naturalia in Russia.

Among Ukrainian researchers studying methodological issues and the history of natural history museology, works of authors (Klymyshyn, 2010; Klymyshyn & Shydlovskyi, 2010, 2017; Chernobay, 2016; Shydlovskyi, 2012; Chervonenko, 2016, 2017a) draw particular attention. Issues of formation of natural history museums are also considered in several works of other authors as well, such as (Biliashivskyi, 2012; Biliashivskyi & Rozora, 2004; Nesterovskyi, 2011; Nesterovskyi & Volkonska, 2012; Samoilenko, 2016; Shypulin & Doguzov, 2013; Chervonenko, 2017b).

Many researchers investigated the periodisation of museology (Żygulski, 1982; Waidacher, 1999; van Mensch, 1992; Mauriès, 2002; Grickevich & Guzhalovskij, 2003; Yureneva, 2002, 2003; Sotnikova, 2004, 2011; Kepin, 2005; Tomilov, 2012; Ananiev, 2013; Sapanzha, 2014; Chervonenko & Kepin, 2017). Views of European as well as American, Canadian, and Japanese scientists are generalised in V. G. Ananyev's monograph (Ananiev, 2014).

In the same time, questions related to the determination of "periodisation" in the context of natural history museology have remained beyond attention and no criteria of the term were developed. Issues related to the determination of theoretical bases of natural history museology were not considered either.

Therefore, the aim of the present article is to survey the history of formation of natural history museology in Europe, including Ukraine, as well as to determine the status of natural history museology and its place in the system of science.

The establishment of natural history museology.

After the Middle Ages, in the 16th century the flourishing of culture and spiritual life of the west European society have started. On the background of unevenness and asynchrony of historical development of different regions of Europe, such countries as

Italy, France and Germany became leaders of scientific and cultural life developing cultural tendencies that arose yet in the 13–14th centuries. The development of science in those times largely influenced the view on the structure of the universe and the place of humans in it, while the combination of knowledge with practical experience led to the emergence of true science.

The Age of Discovery had largely effected the rapid surge of interest towards collection of naturalia, i.e. items of natural origin, which allowed introducing the fauna and flora of unknown or barely known continents such as Southeast Asia, North and South America, and Africa to the people of Europe.

The unique geographic location of Italy, where roads from South to North and West to East crossed, as well as the presence of a large number of ports, which served as places of a lively exchange of goods, contributed the best to the detection of rare specimens of unusual items. Eventually these items were included into collections and became commercial items. Italy became one of the first European countries where natural items had been collected along with pieces of art (Laurencich-Minelli, 2017; Sotnikova, 2004; Yureneva, 2002). Practical interest of physicians and apothecaries also prompted the receipt of unusual naturalia and raw materials from overseas, some of which were used as medication allowing to explore their features and influence on the human body. Accordingly, it demanded the improvement of methods of collecting, storing and processing of these materials. Italian physicians and apothecaries in the early 16th century had amassed the best collections of naturalia. The amassment of natural collections became such a popular and prestigious practice that people of the middle class, secular and spiritual authorities, as well as nature explorers had started to collect and amass naturalia in their private collections. Natural collections were also organised at universities, academies and scientific societies. Eventually the number of collections in Italy grew rapidly up to 250 (Olmi, 2019).

The transformation of collections into natural history museums was prompted by the development of natural history as a branch of science. The passion for collecting naturalia in Italy gave an enormous impulse to the renaissance of natural science. The ways nature has developed were studied in universities of Padua, Pisa and Bologna, as well as at judicial institutions, academies, pharmacological societies, private laboratories etc. As a result of using collections, new approaches to exploration of nature and research techniques, Ulisse Aldrovandi (1522–1602) and Athanasius Kircher (1602–1680) had changed the history of natural science (Mauriès, 2002, pp. 8–68).

Renaissance culture most clearly manifested in various forms in Italy. Universities of Bologna and Padua had appointed the very first professors of natural philosophy. The first botanical gardens were created as well, while natural history collections had been used as educational instruments in studying of “materia medica” and philosophical understanding of nature (Sotnikova, 2004, p. 21; Mauriès, 2002, pp. 8–68; Aldrovandi, 1668).

Renaissance collections were generally universal and consisted of, beside naturalia, pieces of art such as paintings, engravings, jewellery, numismatic samples, artistic textiles etc. Items of natural origin were represented by ivory products, amber, minerals, gems, hunting trophies, as well as scientific instruments, globes, astrolabes, compasses, being stored separately but treated as a single collection (Mauriès, 2002, pp. 8-68; Grickevich, 2004, pp. 21–23).

Items to such collections were gathered either randomly or systematically, often not only considering their historical, scientific or artistic value, but also particularity. Such selection of collection items led to an amassment of low-grade materials, which caused a negative attitude towards the collection in general (Yureneva, 2002). Unlike them, collections that had been created considering scientific principles gained final recognition. Renaissance Italian "museolo naturale" became of great importance.

One of the earliest and most notable "museolo naturale" were the collections of Ulisse Aldrovandi (1522–1602) (Fig. 1,2), the first professor of natural philosophy and founder of the first botanical garden of the University of Bologna, Michele Mercati (1541–1593), papal physician and curator of the botanical garden, and Francesco Calzolari (1521–1600), apothecary of Verona, as well as the botanical collection of the physician Andrea Cesalpino (1519–1603). The cabinet of Ferrante Imperato, the apothecary of Naples, which was created in 1580, had its own catalogue "Ritratto del museo de Ferrante Imperato" and was considered as predecessor of a specialised natural history museum (Olmi, 2019).

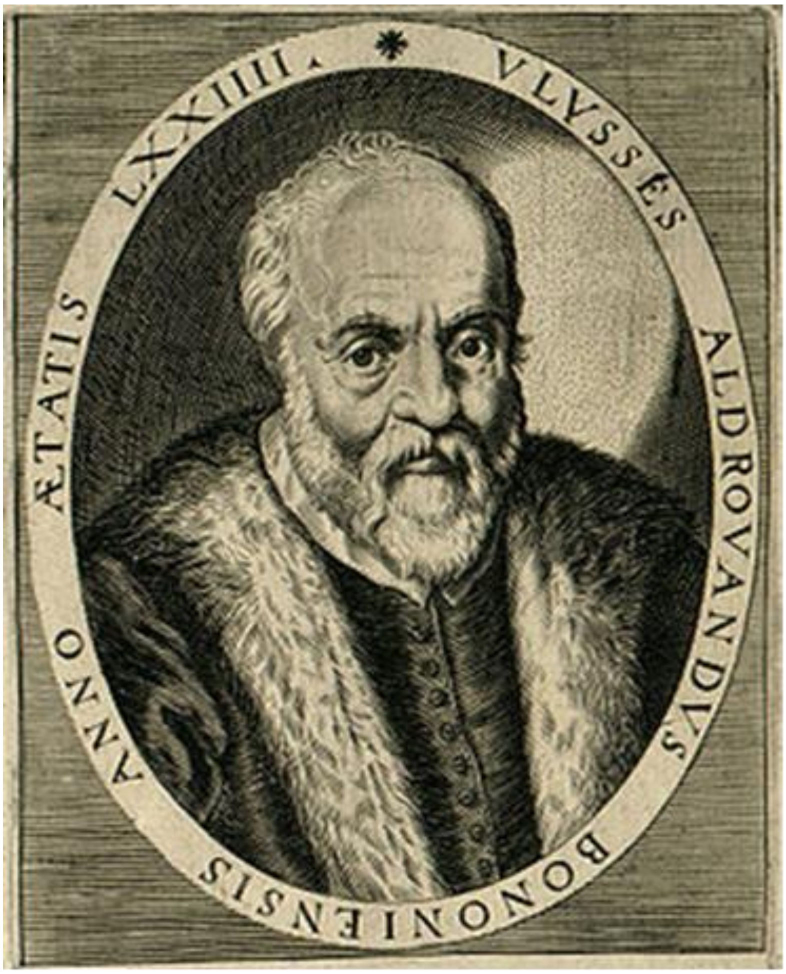

Figure 1. Ulisse Aldrovandi (1522–1602). Photo engraving from the Museum Bologna by O. Chervonenko, 2018.

Figure 2. The current view of Aldrovandi's museum in Bologna, Italy. Photo by O. Chervonenko, 2018.

Collections of naturalia were called "museum" only later. At first, rooms for the storage and demonstration of unusual or valuable items had different names. In Italy, "studiolo naturale" was the most widespread name. Italian naturalists often called their cabinets as museums, which in those times was considered a synonym of the word "collection". Therefore, the word "museum" meant the rooms where collections of specimens of natural origin were stored and studied. In 1669, Paolo Boccone first qualified collections of naturalia as "museum" and noted the "great respect natural history museums had earned in Italy" (Olmi, 2019).

Collecting became a sphere of activity of the upper class – intellectual and social elite, whose authority was risen by the presence of cabinets or botanical gardens in their estates. Collections also became a source of scientific investigations and instrument for education of students. Catalogues of natural history museums of Italy until the late 16th century alongside catalogues of libraries and observatories, as well as descriptions of workrooms, played a leading role in coordination of scientific activities. Therefore, naturalia became study objects losing their utilitarian significance, which is common for museum items.

The Kunstkamera genre.

Since the Renaissance, the first pieces of art showing the interior of "kunstkameras" had appeared. Kunstkameras were widespread in Europe in the 17–18th centuries.

The view according to which anatomical theatres of the 17th century can be considered as museums appeared in some works (Levinson-Lessing,1986, pp. 327–329 ; Ginzburg, 1953).

Pieces of art of the 17–18th centuries showing different images of "kunstkameras" can be divided into two groups. To the first group belong works of art, mainly of graphics, showing natural history and scientific collections, while the second group includes collections of works of painting and crafts. However, on some paintings we can see complex collections including both natural items, anatomical preparations, "curious" items and works of painting and crafts. The images of museum collections of ethnographic and memorial character, which can be considered as independent groups, have reached our time.

The first paintings of "anatomical" plot appeared in the Dutch art in the early 16th century and became widespread in the following centuries. For instance, on the painting of the Dutch painter Rembrandt Harmenszoon van Rijn (1606–1669) "Die anatomie des Doctor Tulp", Signiert und datiert 1632, Den Haag Mauritshuis) we do not see a "museum" interior. According to art critics, the plot of the painting takes place in June–July 1632 in Professor Nicolaes Tulp's own house in Amsterdam, who was the burgomaster of the city in that time (Driessen-van het Reve, 2015). Art critic P. Bonafoux askal suggested that the painting shows a man holding a piece of paper with a list of municipality members invited by the surgeon to an anatomy class (Bonafoux, 2002). Another art critic E. Yu. Fekhner detected a volume of the work of Professor Andreas Vesailius (1514–1564), the Flemish naturalist and founder of the modern medical anatomy (Fehner, 1964). In our opinion, the painting shows the image of one of the seven books of Vesailius' work "Andreal Vesalii Bruxellensis, scholae medicorum Pataui nal professoris De humani corporis fabrica libri septem, Basileae 1543".

We suggest that the portrait, or possibly self-portrait, of the Belorussian enlightener F. Skorina (ca. 1486–1540) printed in his Bible translation "Biblia Ruska" (1517–1519), which was issued in Prague in 22 volumes, is the painting that shows the interior of the first renaissance "kunstkamera" collections. On the engraving ("Kniga Iisusa Sirakha", that is, "Book of the All-Virtuous Wisdom of Yeshua ben Sira") we can see F. Skorina in a room surrounded by natural history collections, scientific instruments and books (Fig. 3).

F. Skorina also was the founder of the botanical garden in Hradčany, Prague in 1535 under King Ferdinand I (Shemyakin et al., 1990).

Figure 3. F. Skorina's kunstkamera. Self-engraving, 1517 (Snyder, 2008, p. 21).

Yureneva (Yureneva, 2003, p. 23) sees natural history museums in a number of engravings of the 15–18th centuries with images of rooms full of cupboards with bottles, flasks with labels written in Latin, and scales inside. However, we suggest that they are images of pharmacies. For instance, the first pharmacy in Kyiv, Ukraine was located in a house built in 1728 in Podilsk District. The pharmacy was founded by Johann Geiter, a German apothecary. From 1750, the pharmacy was run by Georg Friedrich Bunge (1722–1792) (Fig. 4,5) (Beziakin, Kiporenko, & Tyshchenko, 2004). Yureneva refers to exactly that type of interior.

Based on the analysis of catalogues of collections of works of art and direct exploration of the display of local history and art museums of Ukraine, we did not find images of "kunstkamera" collections, particularly of natural history collections. This may suggest that despite the widespread practice of keeping private collection amongst the Ukrainian szlachta (hetmans, Cossack officers), Polish and Lithuanian magnates of the 17–18th centuries, collections in Western Europe had a more "cameral" feature. This was manifested in the creation of art galleries, collections of paintings, pieces of decorative and applied art and small natural history collections as well

(Aleksandrovych, Bazhenova, Rahauskene, Kerkene, & Bumblauskac, 2012). However, we should also consider the possible loss of paintings with images of "kunstkamera" type of interior.

Figure 4. The building of the apothecary-museum in Podil, Kyiv. Courtesy of D. Kepin, 2017.

Figure 5. Part of exhibition. Courtesy of D. Kepin, 2017.

The development of natural history museology.

The first treaties on museology in Europe appeared in the 16–17th centuries – works of S. on Kvichebergau, Munich 1565; F. Bocci, Florence 1591; C. Clement, Lyon 1635; J. Ziebmacher, Leipzig 1658; J. D. Major, Kiel 1674; and J. Reiske, Wolfenbüttel 1685 (Żygulski, 1982 ; Waidacher, 1999, p.368).

In these treaties, a museum is defined as "a collection of antique materials and items which are of particular interest for learned people and heads of schools, and items which are collected, displayed and recorded according to scientific methods". S. Von Kvichebergau was the first in European museology who developed the structure of an "ideal" museum consisting of eight sections, which would present the history of human culture and the natural history of a certain region of a country. The display of such kind of museum would be devoted to the achievements of the scientific thought in the study of natural and historical disciplines. The scientist practically proposed the plan of a thematic museum exhibition. In 1561, the first catalogue appeared in the history of museology – the catalogues of natural and historical collections of Leiden, the Netherlands (Kepin, 2005).

The English philosopher F. Bacon, who founded the experimental science of the Modern era, noted in his work "Pohvala Greiy" (1599) that any scientific establishment should have a library, a botanical garden with menagerie and a pond for fish – "a universal model of nature created privately, a cabinet of natural and artificial items, a chemical laboratory" (Sotnikova, 2004).

In another work, "The New Atlantis" published in 1627, the philosopher practically described the structure of an academy of sciences in the description of "Solomon's House". He proposed to display, in separate rooms, inventions and sculptures of inventors, that is, he first proposed the idea of a museum of science and technology (Bacon, 1977). In this works, Bacon also gave a description of orchards, gardens, apothecaries, parks, "reserves for animals".

In 1621, the Danish physician Ole Worm established the first scientific natural history cabinet (Fig. 6). In 1655, he published the catalogue of his collections in Copenhagen under the title "Museum Wormianum, seu, Historia rerum rariorum: tam naturalium, guam artificiguae Hafniae Danorum in aedibus authoris servantur". In this book, he presented a description of all private collections he was familiar with in European countries. Museum items were classified by the three kingdoms of nature (minerals, plants, and animals) and by artificialia (artificial fabricated items). In his last will and testament, Ole Worm presented his own collection to King Frederick III. Since 1670, the collection has been displayed in the wing of the Marine Arsenal in Copenhagen (Yureneva, 2002; Grickevich, 2004).

The great Czech educator John Amos Comenius in his book "Orbis Sensualium Pictus" (1658) considered the Latin word "muséum" as "…est locus, ubi Studiosus,…secretus ab hominibus, solus sedet, studiis deditus…" (…a place, where a man who studies sciences… sits alone far from people devoting himself to the job…) (Komenskiy, 1957, p. 86).

In the 18th century, theoretic contributions in museology increased in European countries. In 1704–1714, in Frankfurt, three volumes of "Museum Museorum...", an encyclopaedic edition by the German physician and collector M. B. Valentini were published. In 1727, in Leipzig, the handbook "Muzeographia..." was published by C. F. Neickel, in which the first classification of museums in Europe was proposed: 1. "Schatzkammer" — collection of items made from precious metals, items of art and natural history; 2. "Galereie"; 3. "Kunstkammer" — art cabinet consisting of items of arts and crafts, ceramics, glass, as well as tin, ivory, medals, coins, scientific instruments, plaster casts and graphic arts; 4. "Antiguitatenkammer" — cabinet of antiquities mainly of Italian origin; 5. “Studio-Museum” consisting of books, manuscripts, papyri, small plastics; 6. “Rarittatemkammer” (or “Wunderkammer”) — a cabinet of unique collection of rare or artistically made items; 7. “Naturalienkabinett” — cabinet of natural history (Żygulski, 1982, p. 34–38; Waidacher 1999, pp. 137–148).

Figure 6. Ole Worm's cabinet of curiosities, from Museum Wormianum Historia, 1655 (Richards, 2012).

A great contribution into museology was made by C. Linnaeus (1707–1778). Based on his own collection he created a natural history museum in Uppsala in the 1730s. Linnaeus was one of the few scientists who devoted great attention to the development of natural history museology terminology. In particular, in 1732 he published his treatise “Instructio musei rerum naturalium”, in which he defined a museum as an institute which functions include collecting, storing and scientific investigation of material testimonies of humans and natural specimens. Linnaeus was the first who began to prepare museum workers having disciples from several countries, including the Russian Empire, who had defended their theses in natural history museology (Bobrov, 1970, p. 29).

The largest figure in the German culture of the Enlightenment and Classicism J. W. von Goethe devoted great attention to the development of theoretic bases of museums and to methods of preservation of the natural and cultural heritage. In 1777, he developed a project of a museum display of a silver and copper mine in Ilmenau. Goethe proposed methodological recommendations to the conservation of natural history and anthropology collections. From 1803 until his death, he was the head of the library, museum and natural history faculty at the University of Jena. In 1815, he was appointed state minister of the Grand Duchy of Saxe-Weimar-Eisenach becoming "head of supervision of the work of direct institutions of science and art in Weimar and Jena". The philosopher proposed his own classification of museums: art museums (complexes); art galleries; cabinets-museums (Goethe, 1858).

In European museology, Goethe was one of the firsts asking the question "On what auditorium should be exhibitions oriented?" According to him, a museum display should consider the interests of different age groups. Goethe distinguished the methods of creating natural history exhibitions: by braches of knowledge or by a systematic and comparative-typological principle.

Goethe was also concerned about the architecture and artistic decisions on the museum display. Later in his work "Theory of Colours" (1810), he first discovered the relations between colour impressions and the mental state of people (Goethe, 1957).

On the page of his journal "On Art and Antiquity" in 1816 Goethe proposed the term "Museumskunde", that is "museology" (Goethe, 1858).

The establishment of museology in Ukraine.

In Ukraine, the original antique understanding of "museum", prevailing in the era of the Byzantine Empire, as a "sanctuary", "treasury", "temple" was widespread unlike the Renaissance understanding of "museum" in its Italian variant as a place of amassment of systematised and described items for their preservation, investigation and for education (with no cultic function).

The hypothesis that the term "museum" was introduced into the science in Ukraine by Yuriy Drohobych-Kotermak (1450–1494), an outstanding figure of the Renessaince, doctor of arts and medicine, rector of the University of Bologna, was proposed by the Ukrainian museologist Yu. A. Omelchenko (Omelchenko, 1999; Omelchenko & Danilova, 1999), although without referring to any original source. In Omelchenko's opinion, Ukrainian scientists and cultural figures used the term "museum" in the 16–18th centuries in the same understanding as in the Italian Renessaince (Omelchenko, 1999).

Therefore, we consider the differentiation of the term "museum" in monuments of the Ukrainian literature of the 16–18th centuries.

Four scientific works and two letters of Yu. Drohobych-Kotermak have reached our days. They are written in Latin and the word "museum" is absent in them. Based on the analysis of the scientist's works we can assume that he could have his own botanical collection – a herbarium (Drogobych, 2001) (Fig. 7).

In the ancient Slavonic literature, the word "treasury" in the meaning of "museum" (in the understanding of ancient Greeks) is used in the collection of works "Knyzhka…" [Book…] (late 16th century) by I. Vishenskiy (Vishenskiy, 1955).

The term "museum" in monuments of Ukrainian literature was not used before the late 16th century and in the 17–18th centuries the word had several meanings. For example, in the "Latin Lexicon" created by Ye. Slavynetskyi in 1642 and widely known in those times, the word "museum" is defined as "a place for studying" (Nimchuk; Tsiluiko, 1973).

Figure 7. Monument to Yuri Drohobych-Kotermak in Drohobych (Lviv region). Sculptor Theodosius Brugge (1999). Photo by D. Kepin, 2014.

In the "Treatise on the Soul" (1625) written in Old Polish by the rector of Kyiv Brotherhood School (1620–1624) K. Sakovych, the Temple of Apollo in Delphi is considered in a multifunctional meaning as both "sanctuary" and "treasury". There is a similar understanding of "museum" and "the Muses" in the famous philosophical dialogues of H. Skovoroda (1722–1794).

The spread of the Renaissance understanding of "museum" in the territory of Ukraine we associate with F. Skorina's educational activities.

The further development of museology in Ukraine took place in the late 18th – early 19th centuries, which is related to the studying of antique remains in the Northern Black Sea Region, to the organisation of higher educational establishments (universities, scientific communities) and to differentiation of sciences, foremost of archaeology, ethnography, geology, botany, and mineralogy. In the early 19th century, the first historical and archaeological museums were organised in the Black Sea Region. At the University of Kharkiv, a cabinet of rarities and a mineralogical museum was established in 1807, while later, in 1835, also a Museum of Fine Arts. In the late 1800s, a zoological cabinet was created at the Kremenets Gymnasium of then Volyn Governorate, which became a basis for a similar cabinet at St. Volodymyr University of Kyiv (1834). In 1934, the cabinet became a zoological museum in the structure of the university. By the initiative of M. A. Maksymovych, the first rector of

St. Volodymyr University of Kyiv and an outstanding botanist and historian, an archaeological museum was created in 1835, in which natural history collections were also stored. At the University of Lviv, a mineralogical museum was established in 1852, although the first collections originate from 1661. In 1919, by one of the very first decrees of the Ukrainian Academy of Sciences a zoological museum was organised, which since 1966 has been part of the National Museum of Natural History at the National Academy of Sciences of Ukraine, the leading natural history museum of Ukraine, one of the largest natural history museums of Europe.

The place of natural history museology among the branches of science.

Determination of stages in the development of natural history museology is closely related to the history of nature science and it needs a brief overview of classification of sciences in general. Gnoseologists divide science into three large branches such as natural, technical and social sciences (Kedrov & Yudin, 2001). In such sense, natural history museology should be determined as an interdisciplinary science, which is part of museology and focuses on the axiological relation of people to nature. The research objects of natural history museology are monuments of natural origin (both objects of natural landscapes and specimens (naturalia) stored in museums). The subject of natural history museology is to display the history of life on Earth and of development of nature science (see the scheme in Figure 8).

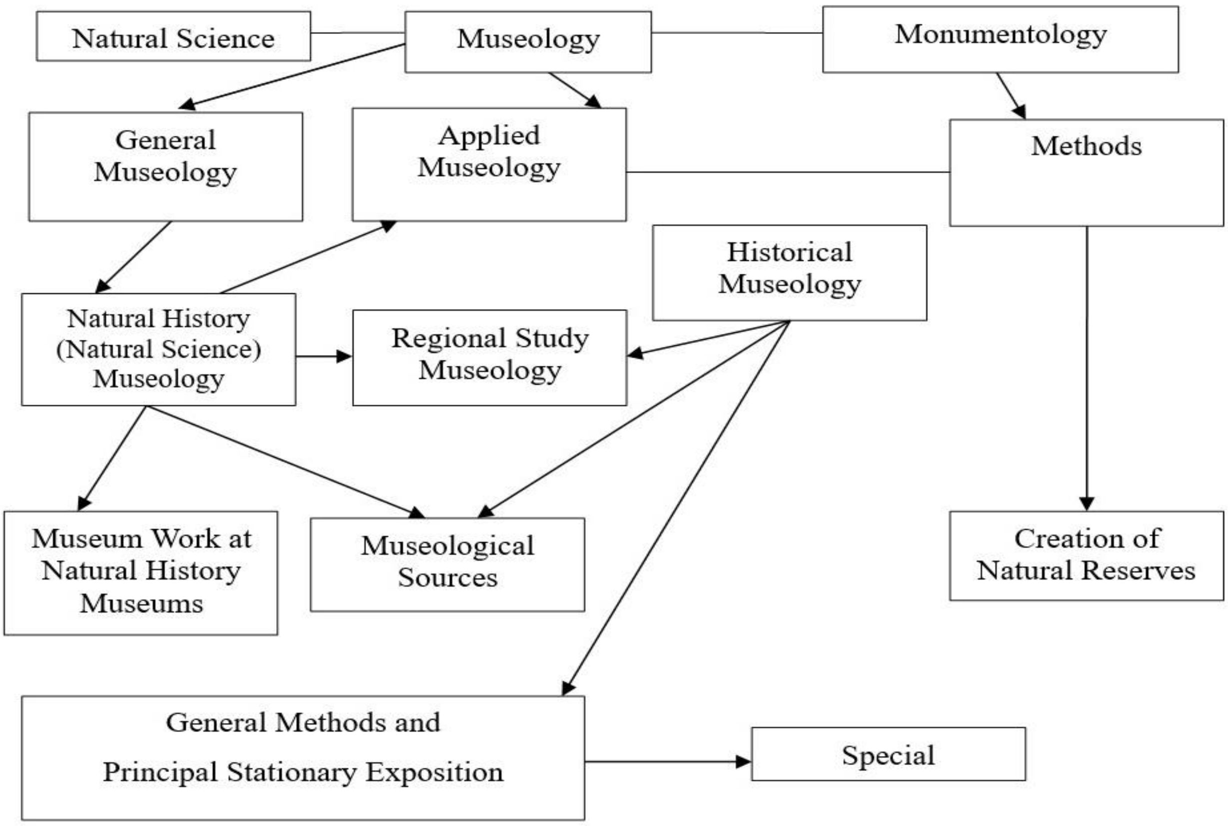

Figure 8. Sheme. Structure of Natural History Museology.

The periodisation of natural history museology, in our opinion, should be based on research of its development and specifics with the consideration of changes in the social and cultural life of the society. Therefore, it is obvious that ***periodisation of museology can be correct only for a particular territory in a particular historical time.***

Conclusions.

Summing it all up, we can conclude that the emergence of natural history museums was promoted by the cultural and scientific development of the society. The first natural history museums were not successors of some pro-museums such as princely or monasterial treasuries, cabinets of naturalia, kunstkameras but appeared as a reaction for social needs reflecting the worldview of that particular society. We argue that in historical studies the terms "pre-museum", "proto-museum" collecting, "pro-museums" are temporal characteristics, while the terms "meso-", "paleo-" and "neo-museum" epochs need further semantic clarifications. Considering the above arguments, we propose the following periodisation of natural history museum development for Europe:

I. Pre-scientific stage:

I-1. Primeval era – development of world perception and formation of natural knowledge of ancient humans

I-2. Greek-Roman era – appearance of the first written data on nature monuments of Europe;

I-3. Middle Ages – appearance of the first natural history collections of museum importance in the 16th century

II. Scientific stage:

II-1. Renaissance and Enlightenment – the emergence of museology as science and formation of museums in the 15–17th centuries;

II-2. 18th century – first half of the 19th century – the emergence of natural history museology and formation of awareness of objects of nature as those that require scientific research and possible preservation for future generations;

II-3. Second half of the 19th century – first half of the 20th century – development of scientific concepts of natural history collections display;

II-4. Second half of the 20th century – establishment of scientific schools of museology and scientific disciplines.

The formation of natural history museology in Ukraine took place in the second half of the 19th century to the 1920–1930s. Methodological bases for exposition, preservation and census of natural items were developed during this very period.

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Природнича музеологія: історія становлення та формування теоретичних засад

Анотація. *У статті представлено короткий історичний нарис формування та розвитку природничої музеології у Європі XV–XIX ст. Розвиток наукових знань у той час дозволяє впливати на уявлення про світобудову та місце людини у ній, а поєднання знань з практичним досвідом призводить до народження справжньої науки. Показано, що однією із найважливіших складових для розвитку природознавства, зокрема біологічних наук, стали* *колекції натуралій – предметів природничого походження, бурхливому сплеску інтересу до яких сприяли Великі географічні відкриття. В хронологічний послідовності розглянуто подальший історичний розвиток музейної справи від приватних колекцій в Італії до формування прообразу справжнього музею, який виконує основні музейні функції:збирання, збереження та демонстрацію. Розглядається роль видатних дослідників природи та філософів Ф. Бекона, К. Ліннея, Й.-В. Гете у розвитку музейної справи та надаються маловідомі факти про їх роботи у цій царині. Коротко оглянуті перші художні твори, на яких зодбажено интерєри "кунсткамер", що набули поширення у Європі у XVII–XVIII ст. На думку авторів, сааме на портреті білоруського просвятителя Ф. Скорини , що вийшов з друку у Празі у 1517–1519 рр., зображено інтерєр перших ренесансних кунсткамерних зібрань. Окремо розглянуто становлення музеології в Україні від часів Юрия Котермака (Дрогобич) (1450–1494) та досліджена диференціація поняття "музей" у памятках української писемності періоду XVI–XVIII ст. Автори розглянули методологічні основи природничої музеології та проаналізували існуючі у наукознавстві класифікації наук. Показана специфіка природничого музеєзнавства у системі музеологічного знання, дискутується питання про виділення природничої музеології як самостійної дисципліни. Доведено, що коректною може вважатись періодизація музеології та музейництва на певних територіях у окреслений історичний час, наприкінці наведена авторська розробка періодизації природничої музеології у Європі.*

***Ключові слова**: історія науки; європейська музеологія; природничій музей; колекції натуралій; розвиток наукових музеїв України*

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Some methodological issues of the history of science and technology

Abstract. *Further development of the history of science and technology requires the solution of a number of methodological problems. The article considers the object and subject of the history of science and technology, its place in the system of sciences. Today, more and more people are turning to the factors that determine the interaction of the society with the environment (productive forces of the society), to study which in the historical aspect and called a special scientific discipline – the history of science and technology. The society as an object of knowledge is a biological organism of the highest level of organization of "cells" – individuals. It exists and develops in the environment due to its own entropy. The society organizes this removal through a specialized subsystem formed on the basis of technical devices – "technosphere". The success of such a process is ensured (through the information field) by another* *subsystem – the "noosphere". These subsystems include both ideal and material objects. The composition and development of the technosphere and noosphere are considered in the article. It is shown that the functioning of the technosphere is based on its interaction with the noosphere, which provides information about the environment and controls the effectiveness of interaction with it. It is formed by combining the mental structures of individuals through sign systems. The production process that ensures the functioning of the society begins with the noosphere, which through individual consciousness controls the actions of each individual, who through the means of production (technosphere) interacts with the natural environment. However, the gradual development of productive forces leads at some point to the fact that the information needed by the individual to perform all necessary actions for the benefit of the society, ceases to fit in his individual consciousness. As a result, there is a new social phenomenon – the social division of labor. On the one hand, there is a division of technological operations between different performers (technological division of labor), and on the other – the selection of individuals who coordinate the efforts of performers and receive impetus to work not directly from public consciousness, but through these persons (social division of labor). As a result, there are special relationships between individuals and their groups (production relations), and thus begins the class period of human existence. And it will continue until the development of productive forces leads to the full transfer of all technological functions to technical systems, which due to the direct interaction of the noosphere and technosphere will put an end to the social division of labor. However, the development of productive forces is also accompanied by the acceleration of entropy in the environment of mankind – the geobiosphere of the planet Earth, which is gradually making it less and less suitable for life. The cardinal solution to the problem is the prospect of humanity entering infinite space.*

Keywords: *history of science and technology; technosphere; noosphere; productive forces; social division of labor; social consciousness*

Formulation of the problem.

The history of science (natural science) and technology has existed for a long time, and recently, due to the processes taking place in the scientific and technical spheres, it has received additional impetus to development. However, it is still impossible to say that this science has fully formulated its methodological basis - although a number of experts have paid considerable attention to these issues. Philosophy, which claims the role of "metascience" (both science and technology) solves its own problems. For example, philosophers of technology believe that technology has a different object and subject from technology and technical science: technology, technical activities and technical knowledge as a cultural phenomenon (object); development of technical consciousness that reflects this object (subject).

It seems indisputable to us that the development of science and technology must be based on a solid methodological foundation, which can be built only by going to some extent beyond the actual science - in the field of social sciences. Attempts to limit the empirical material to this science alone may, in our view, lead to formalistic exercises that are devoid of heuristic value. Therefore, the creation of such a foundation will require joint research by experts in various fields of knowledge.

The defined facts, first of all, concern the scientific status of "history of science and technology". Accordingly, the question arises about the specification of the object and subject of this science, the nature of its links with other scientific disciplines. The question of the internal structure of the "history of science and technology" is important, as it combines two different social phenomena – "science" and "technology". Each of them needs a separate study, as there are certain features of formation and development. At the same time, they together, in a way, determine the nature of the evolution of society. That is why an unbiased analysis of the interaction between these social phenomena allows us to scientifically predict further social development.

History of science and technology as a scientific discipline.

History of science and technology belongs to the field of historical sciences. According to a stable definition, any historical study reproduces a certain process of development. However, the level of theoretical generalization of historical material may be different. The greatest degree of theoretical generalization is achieved, as a rule, in the field of economics. Thus, in historical research, preference should be given to "material communication" - economic relations as the basis of other processes in society. This approach has become decisive in historical science over time, because "as a method, it has given and continues to give very fruitful results ... scientists, even those who do not share the materialist view, have learned in part under the influence of this trend to pay special attention to the economic history which they had despised before" (Tarle, 1903).

However, historians primarily proceed from internal social relations; the relationship of the society with the environment, if taken into account, then at best as a secondary factor. However, today the historical role of those factors that determine the interaction of the society with the environment (technological structure, scientific and technical level, availability of natural resources, etc.) is becoming increasingly clear. To study them in historical development, perhaps, is called a special, very specific science, called *"history of science and technology"*.

The specific purpose of research in the history of science and technology and its study may be different. It seems appropriate to identify at least three goals and, accordingly, three approaches, each of which has its value and significance – depending on the tasks to be solved:

a) *Practical* – to use the positive and negative experiences of science and technology in the processes of their current functioning. This aspect of the history of science and technology plays a particularly important role in specific fields – in relation to both science and technology, as well as their relationship.

b) *Methodological* – to understand the internal laws of science and technology as certain social phenomena that ensure the success of their scientific analysis, and hence the forecast.

c) *Worldview* – mainly for the possibility of understanding the role of science and technology in social development and their interaction with other social phenomena. This allows us to better understand not only the processes of development of science and technology, but also social processes in general.

In particular, systematic and comprehensive ideas about science and technology as social phenomena, their functional structure, development and interaction allows a specialist in a particular field of science and in a particular field of technology to clearly define their place in the society as part of the latter, to correlate their problems and tasks with general tasks and prospects for the development of society as a whole. The study of this discipline, methodological and sociological problems considered in it, first of all has a positive effect on the formation of general historical ideas by specialists in various spheres of public life.

But, like any science, the history of science and technology will develop more successfully, the more clearly it will define its tasks and methods of solving them. And one of the most important is the question of the object and subject of this science.

The object and the subject of history of science and technology.

Despite its specificity and being a completely independent scientific discipline, *history of science and technology* is closely related to other social sciences, especially general history and social sciences (historical materialism, philosophy of history), which are part of the *social sciences*. As for the history of science and technology itself, today, as noted above, it is common to refer to *historical sciences.*

History of science and technology, as well as general history, has as its *object* the society in its development, but they consider it from different angles and aspects, according to which *the subject* of their research is significantly different. It is generally accepted that *the object* of cognition is a set of qualitatively certain phenomena and processes of reality, significantly different in their internal nature, basic features and laws of functioning and development from other objects of this reality. At the same time, *the subject* of knowledge is a certain holistic set of the most important in one respect or another components, aspects, properties and characteristics of the object of knowledge, which is directly studied by this research.

General history has as its object the formation and interaction of various social formations as a certain objectively existing phenomenon, consisting of a series of successive interrelated events. Not only a certain functioning, but also the very existence of these entities directly depends on their production activities, which, in turn, depends on their internal organization in this process. Thus, general history actually considers historical progress as a process of changing *production relations*, which for general history are self-sufficient – taking into account the superstructures they have defined – political, legal, religious, etc.

After all, all existing processes are determined by the driving factors that ensure the interaction of society with the environment. The success and nature of interaction depends largely on the ability of society to influence the environment (directly related to *technology*) and the level of information about the environment necessary for the success of such influence (which is now most fully embodied by *science* – especially natural science).

Since, despite the close relationship, science (science) and technology are different social phenomena, it seems logical at first glance that different sciences should also study their historical evolution. Accordingly, it would seem logical to conclude that the subject of research in the history of science is one – the study of the development of knowledge of laws and phenomena of nature, and in the history of technology – another: the study of the laws of development of productive forces. Therefore, it is sometimes believed that there are two sciences, but very close in research method.

Such a conclusion could be considered logical if the productive forces of society were really reduced to technology. However, it is man who is armed with the technique and the amount of knowledge necessary to create and put it into action, is the most important component of the productive forces. Therefore, what are called productive forces, these factors (information about the environment and the possibility of influencing it) are only in aggregate. Accordingly, even a separate study of the history of technology as a certain force of knowledge is transformed primarily into the history of knowledge that is materialized, in the history of the relevant natural sciences (Kuzin, 1990). Without such interaction, science becomes pointless and technology powerless.

Thus, *history of science and technology,* having the same object of study as *general history* (i.e. the society), its subject is not so much the historical development of society, or even a separate development of science and technology, and he also, as a phenomenon, of course , is of scientific interest), as *a whole,* the evolution of social productive forces that determine this development.

Natural science and its branches, which study certain phenomena of objective reality, social sciences, which are engaged in various types of processes in society, on their own provide only some conditions for the development of productive forces of society. Technology, as a collection of certain material objects, is, figuratively speaking, a useless "pile of iron", and only after the “revival” of a public person, it becomes an effective tool for connecting the society with the environment. And only in total all these factors are subject to study both for understanding the driving forces of history and for prognostic purposes. The latter is achieved by analyzing *the historical path* of technology development – the whole set of technical devices used by people, along with the amount of knowledge necessary for their creation and use as a whole, and in conjunction with other social phenomena.

The society in the environment.

Thus, *the object* of study of the history of science and technology as a historical science is *the society in its evolutionary development*. Given the relationship of the society with the natural environment, we will assume that society is a functionally integrated entity – *an organism of the highest level of biological organization* of “cells” – individuals that function in the environment like any biological organism due to removal into it own *entropy.*

Entropy in the world we know is constantly growing in all existing material formations. But if in inanimate matter it *rises* steadily as a result, then the fundamental feature of living matter (in which entropy is also constantly "generated") is, in the end, its *reduction* due to "removal" into the environment (Kabulov, n. d.).

It should be noted, however, that today among philosophers is quite widely represented the view that the whole universe is recognized as a self-developing system. In such a system there is a vector of growth and *complexity*, ie the development of all nature is *self-organization* or evolution with *increasing* organization of the universe and its parts, including the terrestrial biosphere (Popkova, 2008, pp. 315–317). These statements completely ignore even the indisputable realities, such as that the Sun – the source of life and development on Earth – must go out in full accordance with the second principle of thermodynamics (such realities will once befall other stars and galaxies).

The processes defined are difficult to call development in the general sense of the word. In fact, only systems that are truly self-organizing *(living)* can develop, or, according to V. I. Vernadskij, *"the evolutionary process is inherent only in living matter"* (Vernadskij, 1991, p. 238; Pylypchuk, O. Ya., Strelko, O. H., & Pylypchuk, O. O., 2021).). That is, *"living matter"* carries out its development *solely* through the removal of entropy (with its corresponding growth in the environment). In general, according to one of the creators of quantum mechanics, theoretical physicist E. Schrödinger, a living organism remains alive, only constantly extracting negative entropy from the environment. What is indisputable about metabolism is that the body manages to get rid of all the entropy that it is forced to produce while alive (Schrödinger, 2002, pp. 75–76). And the antientropic (non-entropic) nature of a living system implies that its first and necessary property is *material exchange* with the environment.

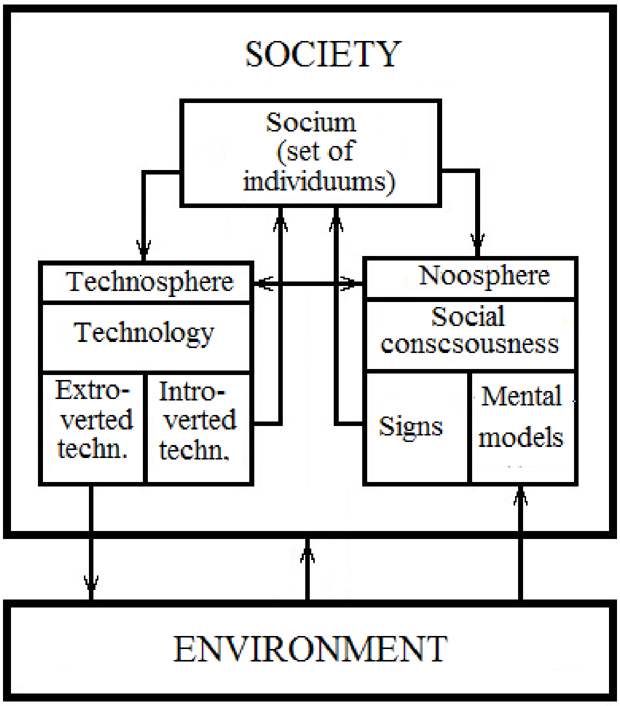

Figure 1. The interaction of the society with the environment.

Obviously, the effectiveness of the system directly depends on the intensity of the process of its interaction with the environment. The desire to increase its efficiency inevitably leads to the complexity of the biological organism, which involves its internal structuring, ie the specialization of its subsystems and the organization of a certain internal relationship between them. In particular, those organs of the biological organism that specialize in interaction with the environment are particularly susceptible to development. However, at a certain stage to intensify this process in the living system there is a need to introduce additional intermediate material elements that are not directly related to the system itself, the complex of which for the society has become *technology*; "Technology occurs when intermediate means are introduced to achieve a goal" (Jaspers, 1986). For society in its interaction with the environment, technology becomes a kind of "shell" that separates and connects them – *the technosphere*, which today attracts special attention of researchers (Herrmann-Pillat). Perhaps it is the development of this term that gives historians of science and technology the opportunity to rethink their concept of technology, better integrate technology history and environmental history, and replace linear temporalities with multilevel models of historical change (Trischler, 2018).

We will try to present the multidimensionality of the existing process on the diagram (Fig. 1). In order to reduce entropy, the society organizes its interaction with the environment through technology. But for the successful material (material and energy) interaction of the society with the environment requires its information support. To this end, the society produces, processes and accumulates information about the environment, about itself as a certain objective reality and about the nature and features of the interaction between these objects. Accumulated information systematized in the mind, create some information "shell" of the society – its *noosphere.*

As for the technosphere, the technical devices that make up its material "substrate", being originally designed to interact with the environment, are no longer limited to the directly specified task. The fact is that this interaction is ultimately carried out by the society in its *entirety*, which is provided by intra-social ties: *material* and *energy* on the one hand, and *information* – on the other. Initially, these connections are made exclusively by "natural" means available to individuals. But in the process of quantitative growth of the society and with the expansion of its range of existence of these funds becomes insufficient. In the field of material interaction, this is the technique of transport and communication (and later some other types of it), which together represent the "intra-social" *introvert* technique – in contrast to the technique of *extrovert,* directly aimed at society's interaction with the environment. In general, they constitute (directly or indirectly) for the society its technosphere.

In the noosphere, the active *material* carrier of social consciousness (ideal) is the brain of each individual, in which due to information received from the environment and its processing, certain *mental structures* are created. In fact, to some extent, similar processes occur in any biological organism with a central nervous system. But it is characteristic of the society that the ideal processes in the mental structures of its components – individuals with the help of external material objects *(sign systems)* merge into a certain holistic phenomenon – *social consciousness*, which is the noosphere in its actual existence.

Let's note that both the technosphere and the noosphere are not frozen. Their formation is evolutionary. In the process of development of the social organism, they undergo a certain evolution, which represents this development in terms of the interaction of society with the environment – their *history*.

Formation and evolution of the technosphere.

Prototechnics became a kind of rudiment of the technosphere (Fig. 2). A typical example of prototechnical devices is the cobweb, which is instinctively created by a spider from a material secreted by its glands (prototechnics I). In nature, there are many other cases of using your own body secretions to create a variety of "technical devices" (bees, caterpillars, etc.). In the future, "external" materials are also used, and eventually only they (for example, beavers for the construction of dams). These "technical devices" are mainly aimed at interacting with the environment of *a certain individual* – including his offspring (in the diagram – "prototechnics II a").

Note that the existing realities are also characterized *by biological superorganisms*, which necessarily create prototechnical devices ("prototechnics II b"). All currently known to us "social" insects that form "collective organisms" (ie bees, ants, termites) in one form or another build or use protective devices (from the environment) and other purposes. Prototechnics differs here primarily in that it is created by *collective* efforts, and different individuals play different roles in this *(polyethism)* (Kipyatkov, 1985, p. 16).

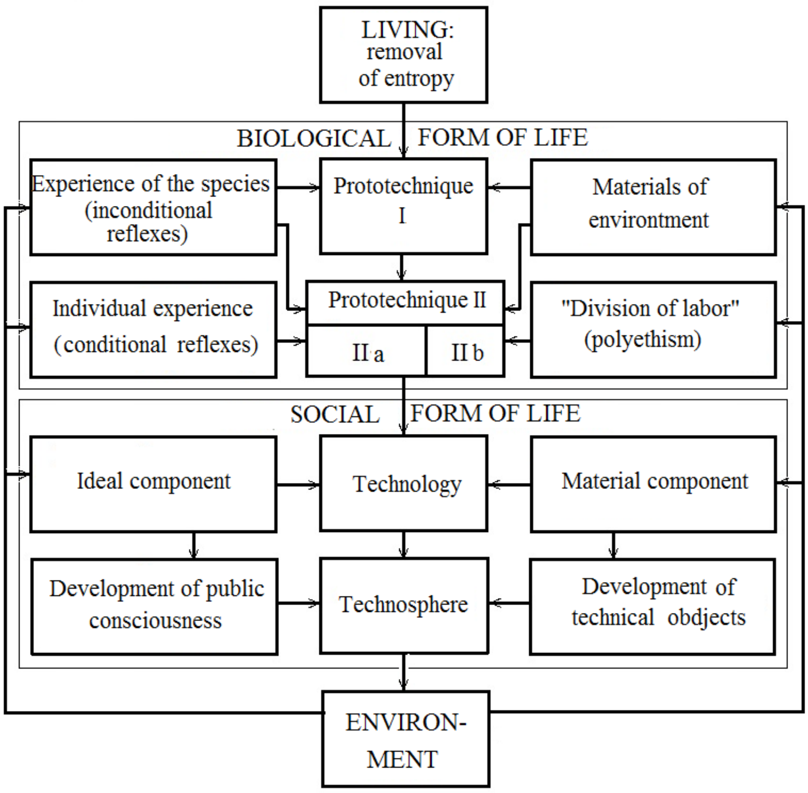

Figure 2. The formation of the noosphere.

However, technology (technosphere) as a social phenomenon, developing on the basis of prototechnics, is qualitatively different from it. Since technology, ensuring the interaction of society with the environment, serves to meet its needs (individual and social), its development in the process of progress of society is in accordance with changing these needs. The eminent German scientist in the theory of mechanisms and machines F. Reuleaux noted in the last century that with the help of technology we force "the internal processes of the material world to act and work for our purposes" (Reuleaux, 1885, p. 1). At the same time, the role of technology in the process of ensuring the functioning of society and the individual (as well as associations that historically arise within the social organism) determines its *structure* as some (relative) whole. Accordingly, it becomes the basis of the primary *classification* of types of technology (Griffen& Ryzheva, 2021).

First of all, it should be noted here that the objects together constitute a set of technical devices that form the basis for direct interaction of the society (through individuals) with the natural and social environment – *consumer goods*. Their man-made nature led to the emergence of tools for the manufacture of these items (more broadly – *means of production*). With the change of social conditions there was a selection of other types of technology, which together and in the relationship form the basis of the technosphere (Fig. 3).

At the stage of primitive society such a division did not occur. In the process of reconstruction of the life of the Paleolithic community it was proved that life was not separated from production activities and did not stand out as an independent phenomenon. A fairly clear separation of the means of production from household appliances occurs only with the transition of the society from the collection to the production economy.

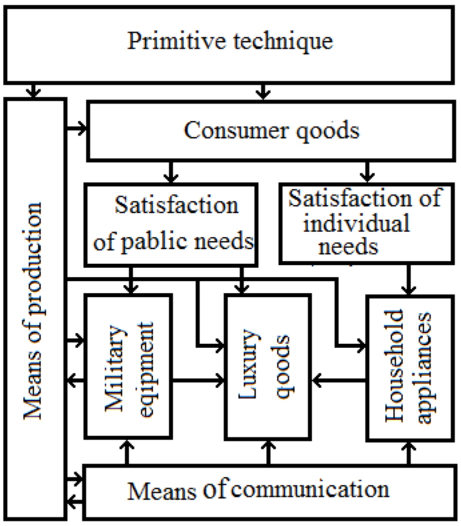

Figure 3. The types of technology and their relationship.

As for the *internal structure* of the means of production, there are different ways of grouping objects, and accordingly different classifications. In the most general form of production equipment, usually divided into three main groups: a) gun equipment; b) machinery; c) automatic equipment. Depending on the tasks solved by scientists, a number of other principles of structuring this type of technology are possible (Garanina, 2020).

In the process of long-term social transformations to the technical devices designed for interaction of society with the environment, which are directly part of the technosphere, are added those designed for interaction between local social formations and individuals already *within* the social organism included in the technosphere. As for the social processes they provide, these types of technology can be divided into *"integrative"* and *"separative"* – respectively, two (unifying and dividing) trends that have occurred and are taking place in the development of society.

An essential condition for ensuring the integrity of any sufficiently complex system is the interaction of its elements (subsystems) in space and time, "as a result of which something disparate and spatially separated acquires a certain integrity and functionality" (Smotrickij, 2010). To do this, the elements of the system (or its subsystem) must have a developed ability to *exchange matter, energy* and *information*, ie the ability *to communicate* properly between them. As a result, another type of technical means (technical class), which has already been mentioned, arises and develops – *means of communication*. It naturally breaks down into two subspecies – technology to ensure communication in the *material* (ie material, and later – in the energy) sphere – *transport,* and technology to ensure communication in the *information* sphere – communication.

Integrative, unifying processes are leading, inherent in social development at all its stages. Separative, ie divisive processes are characteristic only of the historically limited period of internally disparate class society, ie are used by one or another social entity in relations not with the *natural* but with the *social* environment.

Weapons (military equipment) are one of the types of equipment that have played and continue to play an extremely important role in social processes. No less important than in inter-tribal (and later in inter-state) relations, weapons were also in the interaction within certain social formations, namely between the antagonistic social groups that make them up. Another specific type of technology, which also has a separatist character, are *luxury items,* which (regardless of their immediate functional purpose) act as a kind of social "punctuation marks".

Thus, technical objects are created in accordance with the needs of society at one stage or another of its development and constitute, together, such a social phenomenon as technology. As a phenomenon extremely complex and diverse, technology is often considered by researchers in a variety of aspects (Wolff, 2012). However, first of all, we can assume that technology is "a set of human activities created to carry out the processes of production and service of non-productive needs of society" (Larin, 2018, p. 6). However, this set is not yet the technosphere, as some philosophers think (who present the technosphere as a *self*-developing object). In this case, *the subject of its development* is ignored, because it is believed that the technosphere itself is an artificial environment created by the society, i.e. the same *set of technical objects* that people have surrounded themselves with (Popkova, 2018).

According to this statement, we have separate people with their "technical activities", and separately – the "technical sphere", which somehow "self-develops" as *the environment* of this activity. In fact, the technosphere is not an environment for the society, but its *essential component*, which together with the set of technical means formed by *humans* as its *active principle* that separates and connects society with the real environment – the biosphere of the planet Earth. Therefore, the laws of technology development "lie outside its" own "logic". Accordingly, "technology can be presented as a system of self-development, only if it concerns the development of technical and technological production systems, which are human-technical structures" (Glozman, 2008). Successful independent functioning (and even more so "self-development") can be carried out only by a technical system (TS) with "intelligence", which "independently assesses the situation in the aggregate" TS – the world around it "and independently forms goal-oriented behavior". And this is definitely human intelligence. The use of what is called "artificial intelligence" solves only limited specific tasks. According to him, "the term" behavior "means a set of interrelated actions of the effectors of the technical system, carried out to achieve the goals set before the human vehicle" (Karpov, 1990, p. 7). Accordingly, it is necessary to approach technology as an aspect of human activity, and not to study technical actions within the typology of action (Wolff, 2012). Therefore, in our opinion, it is hardly possible to accept the correct conclusion that the technosphere (material basis of the society) is governed not so much by the will of people as by the "internal logic of technology development" (Rozin, 2017).

Formation and evolution of the noosphere.

The functioning in the environment of any biological organism with a central nervous system is directed and controlled by the latter. This applies to both the formation and application of prototechnical devices, carried out by instinct – a set of motor acts and complex behaviors inherent in an animal of a certain species in accordance with the program genetically laid down in its central nervous system. However, such a predetermined rigid program can be effective only under certain natural conditions that persist from generation to generation. In the process of their change, individual experience (learning) acquires a significant role. And the higher the animal on the "family tree" of the animal kingdom, the faster you can expect from it the ability to learn, a greater role of "trial and error" and, accordingly, greater independence from variations in environmental conditions. This ability to learn, learning then proved to be very useful in the formation of human *society*.

In the social organism, the formation of the program of action of each individual is carried out *solely* through the information and skills acquired by him from society in his individual experience. The program of action of a public person together with a set of ideas about the environment and thesociety is what is commonly called *social consciousness*. For its formation and functioning, the interaction between individuals includes *systems of signs* that connect the processes in their brains into a single whole, so that the receipt, storage, processing and use of information is a *social* process, creating a *noosphere* of the society.

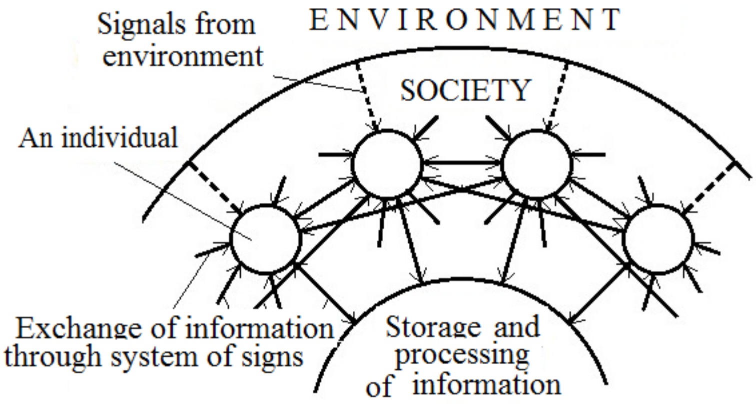

Figure 4. The "neural network" of society.

Thus, in the noosphere, the connection between individual mental structures is provided by external agents – sign systems that include the informational mental process of the individual into *a single social process*, forming a kind of "neural network" of society (Fig. 4). With the introduction of universal "external" codes (regardless of the form of their expression), the human brain, remaining an individual organ, becomes *a social organ*. Mental processing of information from individual (for each individual) becomes public (for a holistic social superorganism). As a result of such a process, what is usually called *"social consciousness"* arises, and on the individual (as its concrete being) – such specifically human phenomena as *thinking* and *consciousness.*

It should be noted that if the actualization of social consciousness is carried out in an *ideal* form with the help of individual human consciousness, then social consciousness itself includes *material* objects. They store information through the "objectification" of the ideal in a variety of objects; when used, it returns to the realm of the ideal through its "objectification" (Ilenkov, 2009). It is sometimes believed that the evolution of human cognition corresponded to the technological expansion of its space-state, increasing its degrees of freedom by tracking invariances and conjunctions in its relations with the world, which should be described as "infosphere" (Wilson, 2017).

Social consciousness, arising on the basis of "socialization" of conditioned reflexes of individuals, determines the development of society. At the same time, it is changing, significantly transforming the nature of the noosphere. However, understanding its essence makes it possible to predict the ways of this development, although some researchers have doubts about this (Lahoz-Beltra, 2018). The same changes that have taken place in the noosphere so far, in particular, in relation to that part of it that is part of the productive forces of society, are presented in the diagram (Fig. 5).

The formation of the noosphere is based on the same animal *instinct* as in the process of biological evolution, which is supplemented by *conditioned reflexes*. Basic social consciousness, which appears simultaneously with the formation of the social organism, can be defined as *ordinary consciousness*, which corresponds to the above–mentioned undifferentiated, syncretic state of technology.

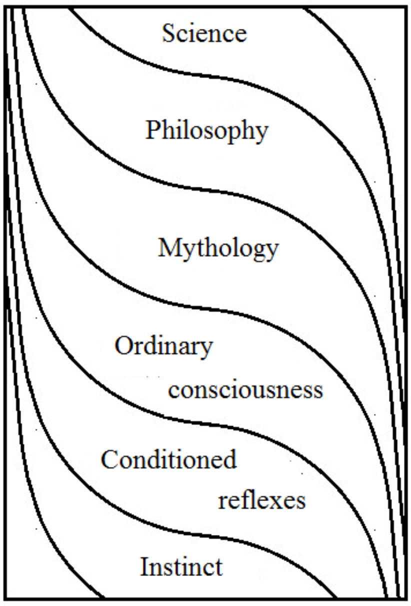

Figure 5. The evolution of public consciousness.

It must be noted that at an early stage of civilizational progress, in the process of human transition from "appropriating" to "producing" economy, from the ordinary consciousness stands out and its part, which is aimed at direct interaction of society with the environment. Since both objects are a certain integrity, such a separation requires the formation in one form or another of *systemic* ideas about the environment and the society. In other areas of life, everyday consciousness remains dominant, but it is constantly evolving, because it is always made of certain adjustments from the emerging systemic ideas.

According to the objective historical realities, the forms of social consciousness on which society's interaction with the environment was based were constantly evolving. At the same time, we recall that when we talk about the "history of science and technology", it should be borne in mind that man began to use and subordinate substances and forces of nature long before the emergence of science. Science is the result of the long-term development of knowledge, which has acquired various forms in the history of mankind. For example, Auguste Comte believed that human thinking is historically characterized by three forms. The first – theological (religious) – explains to man all phenomena by the action of supernatural forces. The second – metaphysical – explanation is found in the action of some "essences" and "causes". Thus, it destroys religious beliefs and prepares the formation of the third form. It is in the third – positive – form that everything is explained scientifically (Kont, 1899).

As for the direct replenishment of knowledge about the world around us, at different stages of development there was a predominance of one of three points:

– obtaining information through the operation of objects directly in the process of life *(practice)*;

– "remote" observation of these and other processes *(contemplation)*;

– purposeful influence on the objects of study to obtain information about them *(experiment)*.

On the basis of the information thus obtained, they were organized into a holistic system, the nature of which was determined by the level of knowledge. Initially, systematization was carried out by "imposing" on the natural environment in its ideal reflection as the organizing beginning of those systemic connections that were known (or rather, familiar) to man in the immediate area of its existence (zoomorphism), and later – in the form of social relations. (anthropomorphism). In its most developed form, such a system is called *mythology* (based on the original element – *the image*). The next step was *philosophy*, which on the basis of seemingly a priori elements – *categories* – perfectly constructed the world. The corresponding scheme in the form of a more or less integral system of elements *(categories)* again "imposed" this construction on reality – as *a picture* that allegedly fully reflected it, although in the most general form. And only at the third, *scientific* stage with the achievement of a fairly high level of knowledge, the world in its full diversity becomes the basis for generalizations in systematically related *concepts*. In all three cases of obtaining and organizing knowledge there is a combination of *practical* approaches (obtaining knowledge directly from the outside world) and *theoretical* (construction based on the acquired knowledge of a system – a generalized ideal model of the world, its elements or aspects) (Griffen, Ryzheva, Nefodov, & Hryashchevskaya, 2021). However, regardless of the methods of cognition, its results, in the end, formed the basis for the functioning of social production.

Development of production and division of labor.

Active interaction of society with the natural environment is carried out in the form of production. Accordingly, production equipment (means of production) is the most important type of technical devices. Therefore, the study of the evolution of the means of production, in particular, changes in their structure, is the most important task in the history of science and technology, which studies the development of the productive forces of the society.

The structure of the means of production in general is represented by the scheme (Fig. 6). It follows logically from the tasks that society solves in the production process. The ultimate goal of the production process is to obtain the necessary objects of society from material taken from nature, through the impact on the latter.

According to the scheme, the production entity must, for this purpose, organize a direct *transformative action* on the subject of labor, *supply of energy* required for these transformations, and *control* over the process that ensures the desired result.

All three functions performed by the production entity in this process have been constantly changing with the improvement of technology and its technical means. The main stages in the development of all three production functions are summarized in Table 1. In particular, to increase productivity, all three functions of the subject of production were gradually transferred *from man to technical devices and systems*.

Virtually all of these changes began at an early stage of human civilization. They took place throughout the process of transformation of production, at all stages of technical revolutions, characterized by the transfer of technology to new production functions, previously performed exclusively by man (Rozin, 2001, p. 121).

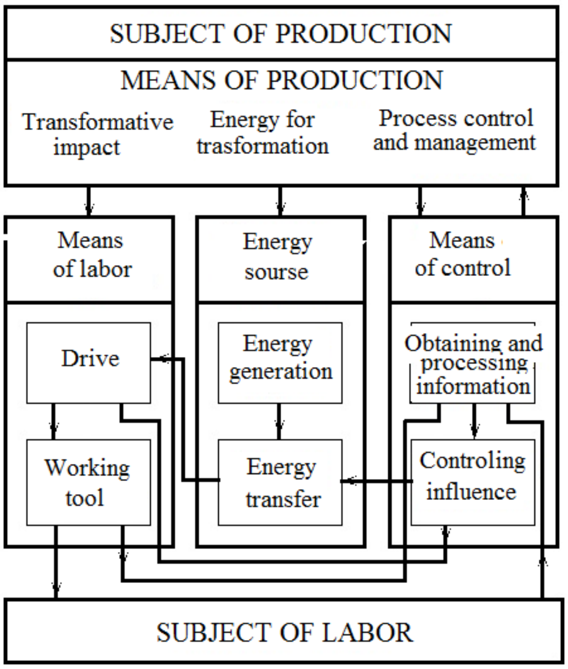

Figure 6. The structure of means of production.

Table 1. The main stages of development are summarized in the table.

Working tool	Energy	Control and Management
Improving the tool and skills of mastering it Specialization of the tool Tool with holder (manual drive) Kinematic connections between energy source and tool (mechanical drive) Technology development - mechanical - thermal - chemical, etc. Electric drive Combined multifunctional tool (including non-contact)	Human muscular strength The power of animals Accumulated solar energy (mechanical) - the wind - water Accumulated solar energy (chemical) - steam engine - engine internal burning Energy of chemical bonds (fuel cells) Nuclear energy - disintegration - synthesis	Organoleptic control Testing Instrumental control Remote and non-destructive testing Automatic control of individual processes Integrated automation, control and management Computer control (automated production control systems) “Deserted” production management (“artificial intelligence”)

With the beginning of *industrialization*, development in all respects accelerates sharply. In particular, the kinematics of the working body is significantly complicated. This process was most clearly characterized by textile production, where the product requires a rather complex manipulation of many identical objects – textile fibers and threads. Advances in this field have given impetus to the spread of complex kinematic devices in other fields. In the future, intellectual efforts were aimed at solving the energy problem. Finally, automation issues have become paramount at the present stage. At the same time, the priority of one of the directions does not exclude the continuation of the development of others.

In-depth study of the issue, in our opinion, also includes a brief historical overview of the realities associated with changing *the subject of labor*. The first were *natural* materials – stone and wood. They were later joined by bones, leather and other materials of animal origin. Then came the turn of *artificial* materials that do not exist in nature (in the so-called "pure" form), but are obtained in some way from natural. In this context, the first was clay (ceramics), then metals. And much later there were *synthetic* materials, especially plastics of various types, obtained by molecular rearrangement of raw materials. New opportunities were brought by the use of *composite* materials, the synergistic properties of which arose due to the integrated use of different raw materials. Finally, in our time, technical progress requires so-called *nanomaterials*, the structure of which is designed in accordance with the required properties of raw materials at the micro level.

Of course, technological progress has become possible only through the constant development of the noosphere – increasing the level of knowledge about the properties of natural objects and the appropriate organization of society. But the need for survival left humanity little time for individual development of already accumulated but poorly systematized knowledge and skills. Initially, as already mentioned, in *the economics of gathering* and primitive forms of hunting (during the Upper Paleolithic), the technical complex had a syncretic, undivided nature, which corresponded to the equally undivided everyday social consciousness. Each member of the community could do any work: "the simplicity and primitivism of primitive technology lead to the fact that related actions can be performed by all members of the community, that is, all light a fire, make bows, arrows, etc." (Ortega y Gasset, 1993). Accordingly, there was no *social division of labor* – except for the "natural" gender and age. The situation changes significantly with the gradual transition to a *"producing economy"*, which requires the development of more information.

The complexity of technology required appropriate training of workers with increasing costs of time, effort and money, which provide for all members of society became impossible. The way out was found through *the division of various technological* operations between individuals, i.e *the social division of labor*. At the same time, due to the strengthening of cooperation in production, there was what was later called the *"separation of mental and physical labor"*. If before each member of the society in the process of production under the influence of public consciousness determined their actions and directly (more precisely, through tools) influenced the object of labor, now there are certain individuals who act indirectly through labor, *through others*, defining and coordinating them actions.

That is, in the society there is a technological ("horizontal") division of labor, supplemented by social ("vertical") (Fig. 7). In other words, on the one hand these processes lead to technological specialization of direct performers, and on the other there is a group of people whose social prerogative was not only the management of general production processes but also the development of the noosphere in general and *technical consciousness* of the society in particular, as productive work is preceded by the activity of consciousness to create an ideal image of this process. Such "activity of consciousness" had a historically definite character, and it was largely determined by general ideas about the world (Gorokhov, 2015, p. 14).

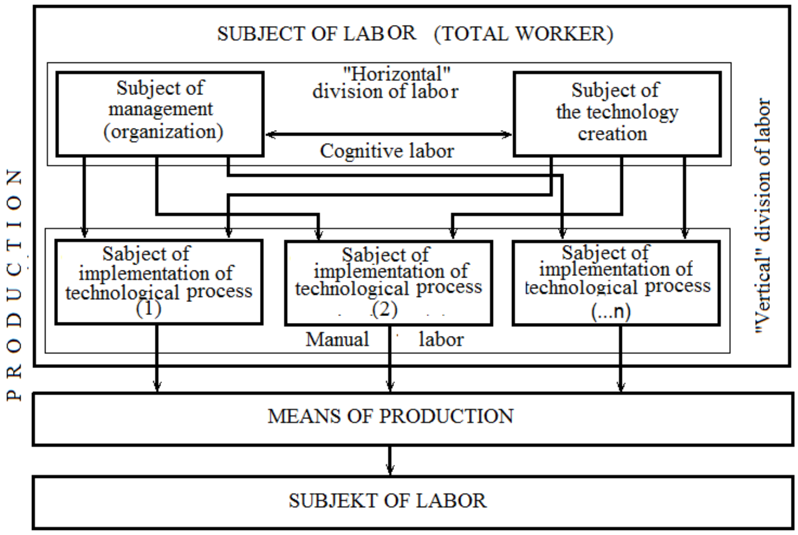

Figure 7. The technological and social division of labor

The role of public consciousness in technological progress.

With regard to the problems of development and functioning of technology, the mythological "model of the world" foresaw an *irrational* – in our view today – a component of almost any technology. In other words, in order to achieve this goal, man also used *magical* actions arising from the aforementioned mythological "theoretical picture" of the world around him.

For a long time, technical consciousness has developed due to the infiltration of general worldviews, regardless of the intentions of both those who dealt with technical problems and those who developed these ideas. Moreover, the division of mental and physical labor caused a negative attitude of the latter to the application of their knowledge in the field of practical activities. They, like Aristotle, were convinced: "Science is considered to be wisdom that is chosen for its own sake and for the purpose of knowledge, and not that which attracts because of its consequences".

Natural philosophy, having replaced mythology, also in its systems created a holistic picture of the world, only if it replaces unknown to its real connections with ideal, fantastic phenomena, which, according to F. Engels, "filled gaps only in the imagination "fiction"". However, in contrast to mythology, these "fictions"were not so much the result of expanding the partial to the general, as an intuitive generalization of previous experience on specific phenomena. Such general ideas created *methodological preconditions* both for further research and for technical consciousness.

In the process of studying reality and "processing" existing information, humanity receives *two* useful results for cognition: *a system of specific knowledge* about the surrounding reality and *methodological methods of cognition*, which together reflect the isomorphism of existing laws in this reality. Later, the former *were formalized* in the form of *a system of sciences*, the latter *systematized* partially in the form of certain laws of *quantitative* change (mathematics), and to some extent in the form of methodology – much less defined *qualitative* “laws” (such as logic, dialectics, synergetics, etc.).

The fundamental imperfection of philosophical systems led to their frequent change and reduction of their role in the cognitive process, and their gradual replacement by *scientific knowledge*. The needs of the development of technology also played an important role in the emergence and development of scientific knowledge, although, as before, it was based mainly on the practical experience and intuition of its creators. The latter was largely based on the intellectual atmosphere of the society, which was formed due to scientific knowledge. It is in this sense that technical knowledge follows the natural sciences and draws from it the necessary information.

However, science (natural science) has never aimed to determine the development of technology with its achievements; she solved her own problems. The creators of technical innovations also used their own developments. Yes, steam engines were invented by people who had no idea about thermodynamics; theoretical electrical engineering began to develop when many electrical devices were already successfully used. However, further *improvement* of technical devices objectively required scientific developments as a guarantee of progress. Nowadays, a number of technical advances are generally based on them (for example, in computer science or nanotechnology).

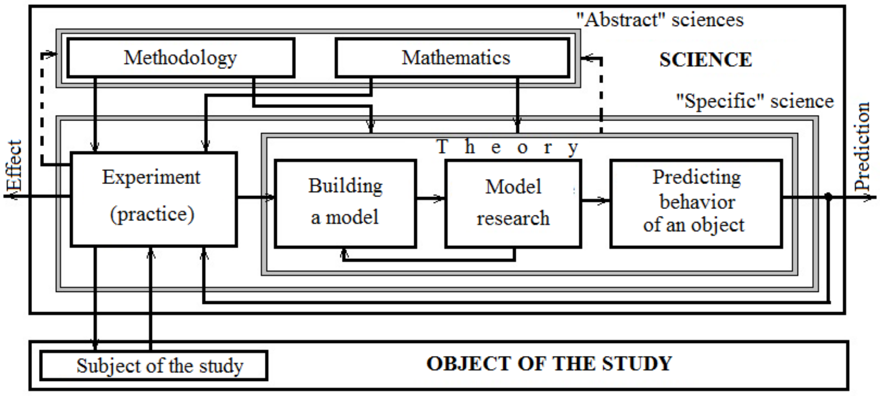

Figure 8. The process of scientific cognition.

In principle, the process of scientific cognition has the form shown in the diagram (Fig. 8). Experimental impact on the object allows you to get some information on which to build a theoretical model of the object. Studies of the model (usually accompanied by its refinements) allow to predict the behavior of the object, which in subsequent studies is again compared with the results, giving rise to new refinements of the model. The generalized results of previous scientific researches in the form of methodological recommendations and mathematical processing play a significant role in the whole iterative process.

However, experimental effects on the object often lead to unexpected results – a new, hitherto unknown *effect*. Provided that if the "effect" is practically useful, it goes into the stage of *technical* development. By creating objects based on such "effects", technology uses them for utilitarian purposes (often without even fully understanding their inner essence). Thus, since science took shape as an independent social phenomenon, engineering and technical practice has focused on the application of scientific discoveries, using not so much its theoretical achievements as various phenomena that took place first in scientific experiments and then on a production scale. The corresponding "effect" in its technical application becomes an object for *technical sciences* and is important for the development of the technosphere.

Thus, at the present stage of progress of human civilization, science has taken on the function of providing society with a system of necessary information, especially for the development of productive forces (Melnik, 2010, p. 13). At the same time, archaic knowledge of the world continues to play a role. In everyday consciousness, elements of mythological ideas are quite common, which is sometimes believed to penetrate even the technical sciences in order to reconcile with their revolutionary dynamics and destructive influence (Zwart, 2022).

And science, despite all the contradictions of its development, continues to assert itself as the main means of obtaining and systematizing knowledge, i.e the formation of the part of social consciousness that is directly "responsible" for society's interaction with the environment – despite all the problems that arise (Carrier & Gartzlaff, 2020). In the future, it is likely to be replaced by another form of cognition, but today there is no good reason to thoroughly discuss this issue, although such attempts are sometimes made (Sismondo, 2017).

The material presented above concerns first of all the modern productive forces of the society, which (to paraphrase K. Marx) can be called their prehistory. In the cognitive plan of studying the development of productive forces (both noosphere and technosphere) analysis of its *patterns* will better understand the future prospects. After all, it will be what can truly be considered the true history of the productive forces of *all mankind*. It will begin just when the true history of civilization, that is, when the "ultimate goal" will be achieved – the transformation of all mankind into a truly *single* social organism. This will create the foundations for solving the main problem that is becoming clearer before us – space travel.

K. Tsiolkovsky's statement: "The earth is the cradle of humanity, but you can not live forever in the cradle", is well known. The removal of entropy from society into the environment is a prerequisite for its existence. Limiting the range of human existence within our planet will inevitably (and soon) will lead to unacceptable levels of environmental entropy. Only boundless space can provide humanity with conditions for further development. However, it should be noted that there is a point of view according to which such an idea of "escape" from our "used" planet is a kind of "quasi-religious form of cosmism". It does not solve anything, but only "encourages the disregard for earthly, environmental and even physical restrictions" (Sideris, 2017). However, other solutions to the problem are palliative in nature, which have a short-term perspective and do not solve the problem of a global nature.

However, the release of humanity into space will be possible only with a qualitatively different level of development of productive forces, ie with the successful solution of two interrelated tasks:

– the formation of the now fragmented humanity is truly a single social organism with the complete exclusion of social differentiation, and hence the full disclosure of the unique personalities of the individuals who make it up, which provides a new quality of *the noosphere*;

– transfer of all production processes to the self-reproducing *technosphere*, i.e complete reliance on the latter direct material interaction of the society with the environment – a kind of “delegation” to it of all technical functions of entropy removal while maintaining only the society's goal-setting, overall control and innovation.

Conclusions.

Thus, the object of study of the history of science and technology (as a historical discipline) is the society, and a specific subject – the evolution of its productive forces. Existing accents allow us to understand the driving forces of social development and create the basis for its scientific forecast. Human society, as a complex “biological system” is a kind of “superorganism”. In the process of its existence and development, it creates two specific subsystems through which it communicates with the environment. Direct material interaction of the society with the existing environment is carried out through a certain shell – *“technosphere”*, formed on the basis of a set of technical devices. Their species meet the requirements of society as a whole and the needs of individual social groups. Information support of this interaction is through another shell – the “noosphere”. It is created by uniting individual consciousness (with the help of sign systems) into a single social consciousness, through which the analysis of the environment and society as a whole is carried out. Together they form the productive forces of society, ensuring its existence and development. Thanks to them, society as a biological system carries out the entropy that is “generated” in the process of activity in the environment. Increasing entropy makes the environment less and less habitable. Solving the problem that arises for society itself requires its significant rationalization. However, according to modern realities, the existing problem can be radically solved only by entering the boundless outer space.

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The authors declare no conflict of interest.

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Деякі методологічні питання історії науки та техніки

Анотація. *Подальший розвиток історії науки і техніки потребує вирішення низки методологічних завдань. У статті розглянуто об'єкт і предмет історії науки і техніки, її місце в системі наук. Сьогодні дедалі частіше звертаються до чинників, що визначають взаємодію суспільства з середовищем (продуктивні сили суспільства), вивчати які в історичному аспекті й покликана особлива наукова дисципліна – історія науки і техніки. Суспільство як об'єкт пізнання становить біологічний організм вищого рівня організації з “клітин”-індивідів. Він існує та розвивається у навколишньому середовищі за рахунок винесення в нього власної ентропії. Суспільство організує це винесення за посередництвом спеціалізованої підсистеми, утвореної на основі технічних пристроїв – “техносфери”. Успішність такого процесу забезпечується (через* *інформаційне поле) ще однією підсистемою – “ноосферою”. Вказані підсистеми включають до свого складу як ідеальні, так і матеріальні об’єкти. В статті розглянуто склад та розвиток техносфери й ноосфери. Показано, що функціонування техносфери опирається на її взаємодію з ноосферою, котра постачає інформацію про середовище та контролює ефективність взаємодії з ним. Вона формується на основі об’єднання ментальних структур індивідів через знакові системи. Виробничий процес, що забезпечує функціонування суспільства, починається з ноосфери, що через індивідуальну свідомість управляє діями кожного індивіда, який через засоби виробництва (техносферу) взаємодіє з природним оточенням. Однак поступовий розвиток продуктивних сил призводить в певний момент до того, що інформація, потрібна індивіду для виконання усіх необхідних дій на користь суспільства, перестає вміщуватись в його індивідуальній свідомості. В результаті виникає нове суспільне явище – суспільний розподіл праці. При цьому з одного боку відбувається розділення технологічних операцій між різними виконавцями (технологічний розподіл праці), а з іншого – виділення окремих осіб, котрі координують зусилля виконавців та отримують імпульс до роботи не безпосередньо від суспільної свідомості, а через вказаних осіб (соціальний розподіл праці). Як наслідок виникають особливі відносини між індивідами та їх групами (виробничі відносини), а отже розпочинається класовий період існування людства. І він продовжиться доти, доки розвиток виробничих сил не приведе до повної передачі усіх технологічних функцій технічним системам, що внаслідок безпосередньої взаємодії ноосфери і техносфери покладе край соціальному розподілу праці. Однак розвиток виробничих сил супроводжується також прискоренням винесення ентропії в середовище існування людства – геобіосферу планети Земля, що поступово робить її все менш придатною для життєдіяльності. Кардинальним рішенням проблеми визнається перспектива виходу людства в безмежний космічний простір*.

Ключові слова: *історія науки і техніки; техносфера; ноосфера; продуктивні сили; суспільній розподіл праці; суспільна свідомість*

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Understanding mathematical abstraction in the formularization of Galileo's law

Abstracts. *Galileo's revolution in science introduced an analytical method to science that typifies the overall modern thinking of extracting, abstracting, and grasping only critical aspects of the target phenomena and focusing on "how", which is a quantitative relationship between variables, instead of "why". For example, to him, the question of 'why does an object fall' is of no significance; instead, only the quantitative relationship between distance from the falling object and time is important. Yet, the most fundamental aspect of his idea is that he introduced a quantified time t. When an object is projected horizontally, the distance travelled at some time in the horizontal direction is summed up as* $d \propto t$*, whereas the distance falling at some time in the vertical direction is summed up as* $d \propto t^2$*. Here, the distance, which is a spatial attribute, is expressed as a function of time, t. That is, time is identified as a homogeneous amount that can be reduced to an algebraic number. It is now possible to calculate the laws of motion of things using functions of time. In this respect, mathematical time was a decisive variable in making mathematisation of physical nature practical. Because, according to atomic theory, vacuum exists between an atom and an object composed of atoms or between objects – ignoring factors that interfere with motion, such as friction – the space for absolute time, which is a mathematical time, can be geometrically defined. In order to justify this mathematical abstraction strategy, thought experiments were conducted rather than laboratory experiments, which at that time were difficult to perform.*

Keywords*: Galileo; quantitative relationship; atomic theory; mathematical abstraction; thought experiment*

Introduction.

There were a number of great practitioners of science in the 17th century, including Galileo, Descartes, Newton and Leibniz. The development of quantum mechanics and relativity in time would be nearly impossible without the crucial role that thought experiments play. In terms of thought experiments, Einstein and Galileo were arguably the most influential thinkers of all time.

In “Dialogue on the Two Chief Systems”, Galileo's motion frame is a ship that flattens the sea like glass. Galileo broke Aristotle's centuries-old concept of universe, but his concept of motion was circular rather than linear. The reason is that Galileo insists on continuity with Greek ideas that emphasize circular motion. Galileo was a 16th-century scientist. At the time, theology viewed the ever-continuing linear movement as a creepy phenomenon that was difficult to accept. Galileo, according to Koyre, would have to shift from finite space to infinite space to include the notion of linear motion. Removing Earth from the center of the universe and allowing it to revolve around the sun is obviously different from allowing it to wander in infinite space (Miller, 1996, pp. 128–129).

It is a concise statement of relativity that “all determined places” are lost due to infinite linear motion (inertial motion) and since every point can be the center in an infinite universe, there is no center. For this reason, it was natural for Galileo in the Renaissance to insist on circular inertia, not straight inertia.

The idealization introduced by Galileo played a role in defining the characteristics of modern science (McMulin, 1985). However, when Galileo tried to present a new theory that would contribute to the development of theory of dynamics, the theory had not yet been proven, and it was later verified by an accurate laboratory experiment. It is never surprising that his efforts were focused on thought experiments, analogies, and exemplary metaphors, not on detailed laboratory experiments. A concept begins as a vague idea, but gradually becomes clear as the theory containing it becomes more concrete and accurate (Chalmers, 1999, p. 106). Science does not simply develop by induction or deduction (Oh, 2021), and the creativity of scientists can be demonstrated through abstraction and scientific thought experiments. In other words, a revolution in thought occurs.

Our study aims to explore the strategy that Galileo used in the thought experiment process in which a concept becomes solidified. Focusing on inertia, which is his most important discovery, the following research questions are presented for this research’s purpose. Taking focus on inertia, where he made his most notable discovery, we devised the following research questions.

First, preliminarily, establish a possible relationship between thought experiment, abstraction, and idealization.

Second, how did Galileo use abstraction and idealization to convince people of his scientific ideas?

Third, how did these strategies contribute to scientific development?

Thought experiment.

Mach wrote in his 1905 essay, "On Thought Experiments", that "Our thoughts are much more manageable than physical facts. Thought experiments are inexpensive". In his time and today, Mach explained clearly to people what thought experiments are: it is the idealization or abstraction of physical conditions that exist.

Galileo's thought experiment, in particular, is intended to prove an already proposed hypothesis, as other scientists do later. However, Einstein's thought experiment is different, as it was not intended for verifying the hypothesis, but for the insight of discovery. These are the two great thought experiments from 1895 and 1907. The thought experiment in 1895 became a special relativity theory 10 years later through thought experiments. In the early stages, all experiments are thought experiments. In 1905, Mach said, "Our thoughts are much more manageable than physical facts. In other words, thought experiments are inexpensive". Mach described a thought experiment correctly, describing it as "an idealization or abstraction of existing physical conditions". Galileo's thought experiment was intended to prove the hypothesis already proposed. Einstein's thought experiment, however, is not a test of hypothesis, but an insight into discovery (Miller, 1996, p. 371).

Based on the above, thought experiments apparently serve several purposes: first, verifying an already established hypothesis; second, constructing a hypothesis; and third, destroying and constructing an existing theory. Brown contends that Plato's thought experiments are a priori, which is both 'constructive' and 'destructive', and that Galileo's thinking experiments are the very ones that can be destructive as well as constructive (Brown, 1991a, p. 41. Brown, 1991b, p. 124. Oh, 2016).

In the author's view, Galileo aspired to prove the law of inertia by justifying and reconstructing the hypothesis that had already been proven. Einstein's thought experiments on free fall, on the other hand, have the function of dismantling and reconstructing existing theories. However, both engaged in mathematical abstraction at first.

Abstraction and idealization.

Abstraction: To give deep thoughts to a certain aspect of the reality they study, scholars will "abstract" the rest. This does not mean that the rest does not exist. The scholars temporarily abandon the rest of them. It is a form of ontological thinking. Mathematics is a study that firmly secures universal laws existing in this world and systematically organizes rules established between them. For example, it is a study that prepares 'the theorem of geometry', which is a rule of algebra or a law on shapes, and allows someone to get the right answer for any purpose at any time. To achieve such universality, "mathematics" abstract. Numbers are highly abstract representations of what exists in reality. According to Butland Russell, the level of abstraction of the "number concept" was heightened by expressing both a pair and two days as number 2. In a sense, it is an epistemological expression, as it emphasizes only the amount that can be expressed mathematically and omits the rest. The higher the universality, the higher the degree of abstraction (Oh, 2016).

The remarkable achievements of science have been made possible by human abstraction ability and mathematics based on it. Being able to abstract is essential to our survival as we evolve. Individuals who possess excellent qualities will have an advantage in natural selection. The strategy of mathematical abstraction in the early stages of theory formation is an important step that demonstrates human mental science, that is, creativity.

In addition, it is on the basis of a specific socio-cultural and ideological phase that mathematics, which is the first science, emerges from history and that practical abstraction takes place. Likewise, Galileo in the modern era accepted Plato's mathematical ideas, rather than Aristotle's biological ideas, as the socio-cultural and ideological basis.

Idealization: Reality is more than simply abstracted - it is also “idealized”. The concept of straight lines is created by idealizing the tight-pulled thread in our heads. By idealizing the surface of a table or the surface of a pond without wind, the concept of a “plane” was created, but in reality, a “straight line” that has no width or thickness cannot exist. The same is true for horizontal planes with no friction at all. Concepts like these are derived from idealizing anything in the world inside the human mind. Nevertheless, it is still meaningful since it is modeled after reality. It is not arbitrarily imagined, but because it relies on what exists in reality, it would be considered to fall under an ontological realm (Oh, 2016). This “thought experiment” can be best described as “an experiment of what cannot be realized in real life based on thoughts only under idealized conditions”; but in reality, it still takes extreme values by using a strategy that gets smaller and smaller in value.

Though Kuhn (1970) stressed the rebuttal significance of Thinking Experiences (TEs) and some of the current episodes do support this, in other cases, TEs may serve a corroborating function. TEs can also play a role in generating theories. Brown (1991a) identified characteristics associated with the relationship between destructive and constructive thought experiments. As part of this study, we intend to examine Galileo's thought experiments in terms of their evaluative role.

Using Galileo's abstraction and idealization strategically.

Scientists believe Galileo was the first to discover a mathematical law through abstract reasoning and devised a thought experiment or practical experimental device under idealized conditions to justify it (Crease, 2003, p. 86).

Therefore, our study first attempted mathematical abstraction to devise a law, and then, in steps 2 and 3, in order to justify such a law, we used thought experiments aimed at idealization conditions.

Stage 1: Mathematical abstracts.

Scientists start with a big picture of the way the world exists, or a big picture of how the data is revealed, while exploring a theory. These big pictures can be derived from metaphysics, mathematics, theology, and other areas. Metaphysics, therefore, can be incorporated into the very structure of scientific methodology by providing criteria that guide from above (Moreland & Craig, 2003, p. 33).

For example, Plato's metaphysical view that "The universe has a perfect mathematical order. Also, God intervened in such a mathematical order", becomes a guide to modern scientists. Actually, it provides an opportunity to escape from the metaphysical question of "why" and move toward a mathematical and abstract world. As Galileo recognized Aristotle's biological theory has a problem with symmetry, he impliedly stretched the meaning of Plato's knowledge to address the problematic situation.

(Galileo) According to Plato, to a Greek astronomer the phrase "relieve the phenomenon" or "find a mathematical model of celestial bodies that conforms to the Greek ideal of order and beauty" means to describe a phenomenon in terms of a circle - a perfect form of Greek geometry. Plato also said, "God is always geometrizing". He is quoting from the Pythagorean school, as he praises the circle. For the Pythagorean school, which explored the "Principle of Unity in Nature", numbers contain the shape of things and are both real and abstract (Gillispie, 1990, pp. 14–15). Mathematics was not only free from the errors of our sensory senses, but we humans were able to use the mathematical language given to us by God.

<Galileo's kinematic explanation: "how?" instead of "why?" >

While Aristotle focused on the question of "why", Galileo saw that the question of "how", which has been subjected to scientific empirical tests, is more important, asserting that it is meaningless if not verified. As such, the historical paradigm of science has shifted from source to method (Dolnick, 2011).

There are all examples of projectile motion. Which Galileo can describe as taking in two dimensions. Galileo first accurately described projectile motion. He showed that it could be understood by analysis, the horizontal and vertical components of the motion separately. This was an innovative analysis, not done in this way by anyone prior to Galileo (Cohen, 1985, p. 117).

Mathematical abstraction in the vertical direction: Free Failing Motion.

All objects consist of homogeneous materials. <**The World of Quantitative Mathematics**> Atomic theory states that all matter is made of atoms, and if the vacuum between atoms is recognized, i.e., if air resistance is ignored, all objects falling vertically in the air must have the same falling rate and acceleration, regardless of time. <**uniformly accelerated motion**>

In addition, as space is geometricized according to mathematical time, quantified time ***t*** (T in figure) is introduced. For instance, the horizontal distance travelled is summarized as **d (area of a triangle, or the rectangular)** $\propto$ **t** and the distance at which an object falling in the vertical direction falls at a particular time as $\mathbf{d \propto t^2}$. <**Mathematical Abstraction**>

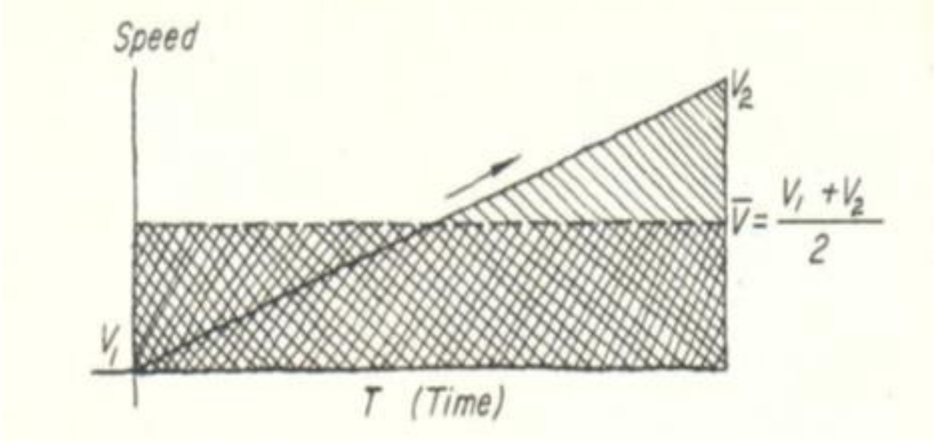

Figure 1. Galileo's Geometry of Space through Time (Cohen, 1985, p. 104).

Mathematics abstraction in horizontal direction: inertial movement.

If vacuum is recognized according to atomic theory, the same speed can be maintained in the celestial sphere as well as on earth, as long as there is no force interfering with motion in the horizontal direction, such as friction. <**circular inertia**>

If, according to simplicity, natural celestial motion is circular (**Plato's hypothesi**s), all matter on earth and celestial sphere are composed of the same material, and all forces that interfere with motion have been removed (**Auxiliary hypothesis or initial condition**), what would happen?

Then, it can be said that objects have a natural property of moving in a constant circular motion, just like in the celestial sphere. In other words, movement precedes stopping in heliocentrism, so according to the atomic theory in which movement is possible in a vacuum, the surrounding environment of an object has become a target that must be removed and ignored.

And, the earth is approximately an inertial system. That is, the nature of an object to move at a constant velocity (circular motion) even on the ground by integrating the celestial sphere and the earth is completely reasonable. Therefore, rotational inertia is a natural motion in the horizontal direction even on the ground.

Although Aristotle limited Plato's ideal world to the celestial sphere in reality, Plato's ideal world was applied even to the earth in the idealized world beyond the observed phenomenon. In this way, the teleological idea of Aristotle's natural tendency was introduced, and hence it cannot be said that it completely deviated from Greek philosophy. Above all, the circular orbit cannot be viewed as radically diverging from Greek teleological ideas, since it illustrates the tendency of celestial bodies to emulate philosophical deities.

Thus, time was abstracted and absolutized on the basis of the entire physical phenomenon. Time has established itself as an independent variable that is vital to the cohesion of the universe and the world.

In the end, Galileo's ideology, which characterized modern science by mathematizing nature and seeking possibility for calculation, transforms space into an algebraic space and sets time as the absolute criteria for all movements over such a space. Mathematics, in this regard, created an objective world in the most original sense from time and space, which are universal forms of the living world. The scale of time

Galileo assumed was a homogeneous and divisible way of measuring time. It was considered that some partial time was no different from others, and that it could be combined and multiplied.

Stage 2: Idealization process (justification of abstraction).

From the **empirical world** of common sense to the **world of idealization** where every power is removed (Fig. 2).

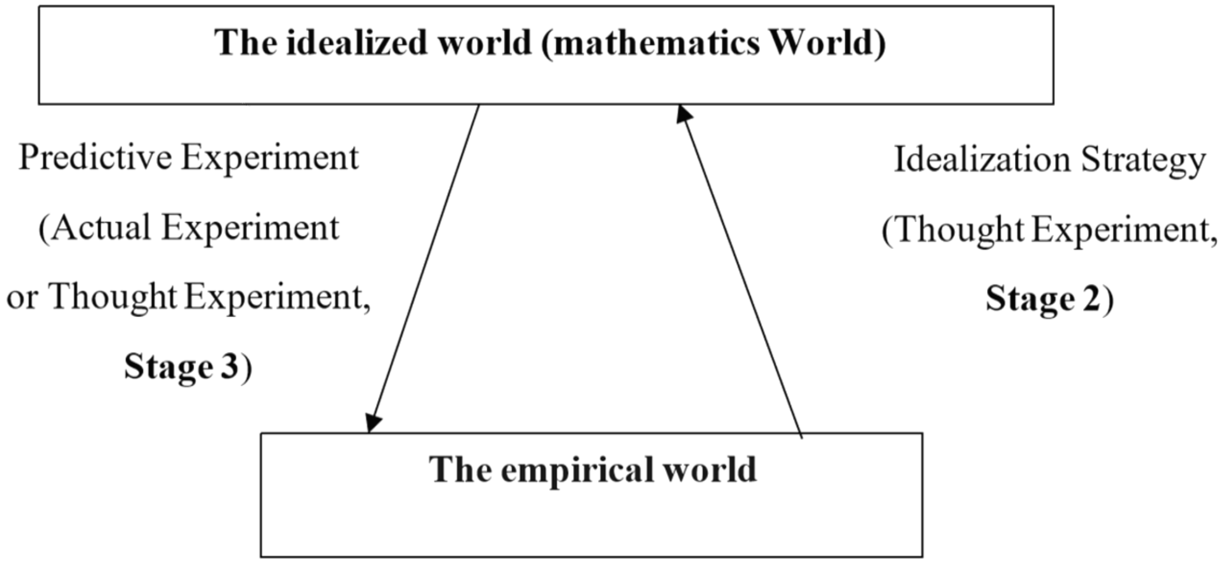

Figure 2. The process of Galileo's scientific inquiry method (Oh, 2016).

<Thought experiment to remove friction from the horizontal plane: Justification of the abstracted hypothesis>

<Justification of New Inertial Hypothesis>

If it is correct that friction force in a plane interferes with the motion of an object (new hypothesis **which is abstracted**), and if the contact surface of the horizontal plane of an object that is freely moving at the same height is smoothed and the friction force interrupting the motion is gradually reduced thereby changing the space over time (**Planned test**), then, can we see what will happen to the motion of that object in the end? (Thought experiment) Perhaps it is reasonable to expect that in this case, the object's motion distance and motion time are getting longer (**$d \propto t$**)? (**a new hypothesis situation**)

And in fact, it is reasonable to imagine that as the object's exercise distance and exercise time become longer and longer, the motion eventually continues. (**Evaluation of a new hypothesis situation)**

So what?

Therefore, it is possible to imagine that all objects have inertia that allows for continuous motion in the idealized horizon where friction forces that interfere with motion in the empirical world are removed. **(The conclusion from the evaluation)**

To support the inertia derived from abstraction, an idealization situation in which friction was removed actually using a hypothesis-deductive method could not be obtained. These thought experiments were used to prove the previously proposed hypothesis (Miller, 1996, p. 371). In addition, Aristotle's teleological and hierarchical laws of physics (assumptions) are destroyed, and a new mathematical law (convergence) in which the celestial sphere and the earth are integrated by reason is constructed. <Platonic Thought Experiment>.

A scenario for an idealized world created by spatial change and scale change over time is being implemented. It is observed that friction force was removed as the spatial change transformed to scale change (Trickett & Trafton, 2007) spatial transformation. Here, the scale change refers to an expansion of space where motion continues as compared to stationary space. In addition, in the evaluation process, scenario results are compared to the problem situation to confirm the comparison result, and the problem situation resolution system mechanism is restated.

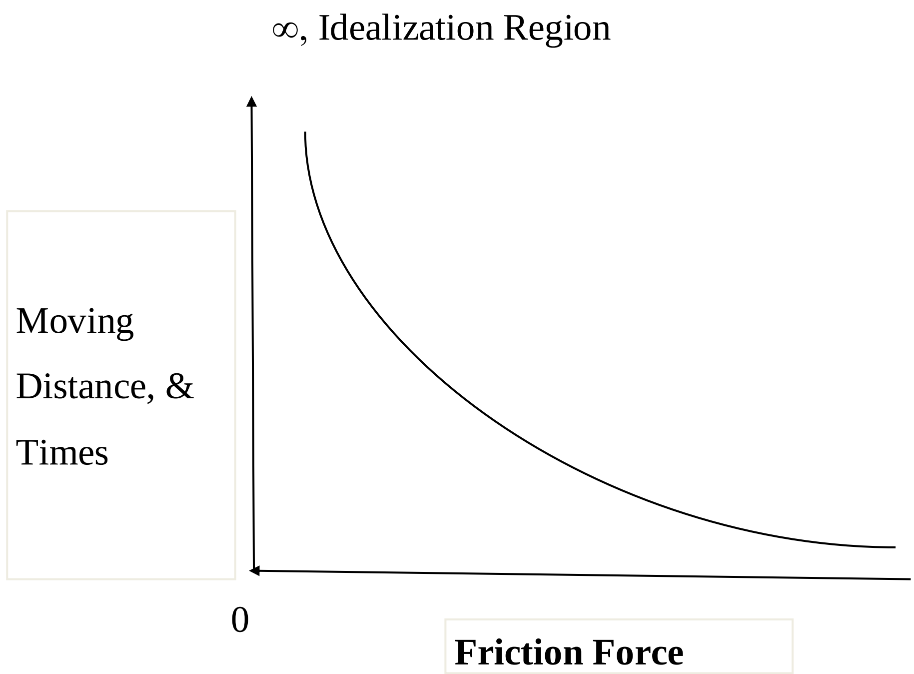

Figure 3. The relationship between the moving distance and friction force during moving of an object.

Figure 3 illustrates how idealization plays a vital role when extrapolating from empirical data obtained through experiments to calculate results for extreme cases. Galileo could infer a phenomenon (objects are in perpetual motion) of an idealized realm, a realm that cannot be obtained through data derived from everyday life or from a narrow range of observation (experiencing how an object in motion will stop farther when friction force is reduced). This is referred to as a limiting case analysis in thought experiments (Nersessian, 1992; Park, Chung, Kwon, & Song, 1998).

However, Galileo did not completely deviate from Aristotle's doctrine, and was circular inertia as a perfect circular motion in the heavens. However, it can be seen that the infinite number of regular polygons is a circle of infinite mathematics.

Stage 3: A predictive experiment of probable real-world phenomena

From **(the idealized world)** to (**the empirical world**)

Norton stated that conclusions reached by the (successful) thought experiment should be proved by actual experiments, not thought experiments themselves (Norton, 1991, p. 131; Norton, 1996, p. 336). In other words, in order to materialize the abstracted theory, an experiment called practice must be accompanied.

Galileo distinguished himself from other philosophers by not only conducting thought experiments, but also by performing real experiments. In fact, the experiments he performed were the beginning of the type of experiment carried out by scientists today. In the meantime, he avoided criticism by claiming that his experiment was unpredictable and that its results could only be approximate.

Experiment in a possible empirical world on a horizontal direction (Fig. 4).

Predictive experiments: If the kinetic component is mathematically broken down and it is observed that only the earth's surface and horizontal components are inertial, independent of the natural tendency to move towards the center of the earth move (mathematically abstracted **hypothesis**), (and) if we drop a heavy object on the mast of a ship that travels at a constant speed when there is no air resistance that interferes with the motion (the **planned experiment** in which space changes over time), (then) the object would fall directly below the mast **(prediction**).

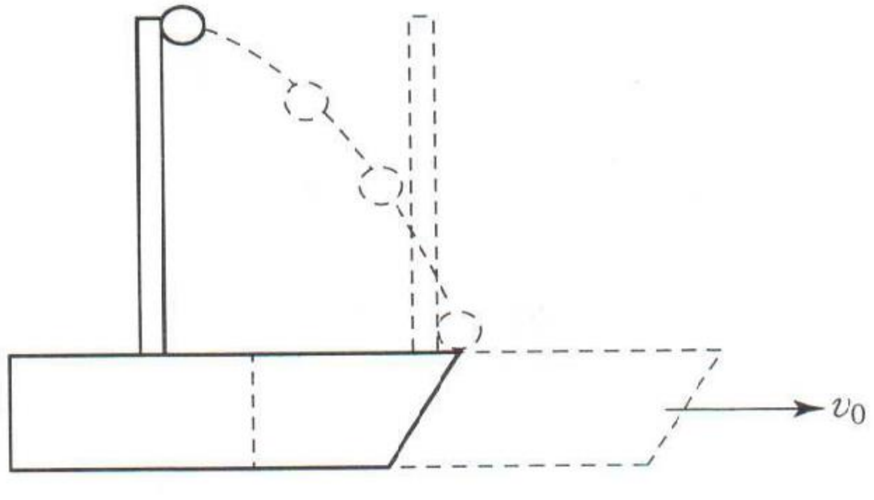

Figure 4. Possible experiments of the law of inertia (Cushing, 1998, p. 106).

Actual experimental results: And, in fact, it falls approximately just below the mast.

(**Therefore**), on a horizontal plane such as the earth's surface, the hypothesis that a moving object continues to move even when a constant force, which is responsible for the movement, is applied is valid.

Actual experiment and thought experiment on vertical free falling motion.

In Galileo's inclined experiment, the fact that the distance rolled down is proportional to the square of time holds regardless of the inclined angles of the surface, so the thought experiment that this proportional relationship holds even in the extreme case, that is, when the inclined angle gradually increases and stands upright is very reasonable. In a letter to his friend Baliani, Galileo describes a method for calculating the acceleration of an object in free fall from an inclined plane experiment (Cohen, 1985, p. 98). In this process, it can be said that the actual experiment and the thought experiment were performed simultaneously (Fig. 5).

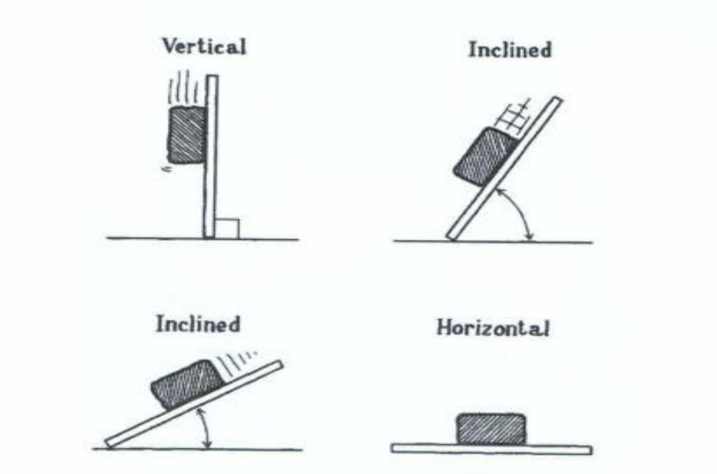

Figure 5. Thought experiment of free fall from an inclined plane (Brown, 2011, p. 3).

It is also the concept of terminal speed from a modern point of view. This thought experiment was already thought of by Galileo (Cohen, 1985, p. 109). If an object falls in dense air, if the object has the same volume and has the same sweeping area, the air resistance increases as the falling speed of the object increases and becomes equal to the weight of the object, the object will have the same speed. Also, if the density of the air is getting smaller and smaller, we have to wait for the terminal velocity to reach a higher falling velocity. After all, without the extreme value of air resistance, the rate of fall of any object will continue to increase, and the increase in velocity will be the same. In other words, taking the limit means that we have progressed to an idealized world and a mathematical world.

Galileo's abstraction strategy.

Aristotle failed to achieve the same level of mechanics as Newton or Galileo through imagination, and it was not because he disregarded facts as the critics claimed in the 17th century. Rather, his desire to stick to the facts too closely is a more pertinent reason. For example, Aristotle did not recognize (abstract) that some aspects of common sense had to be discounted to create a complete theory of motion, and that is why Aristotle’s physics could not be developed into modern science (Gottlieb, 2000, p. 242).

In other words, Aristotle strictly adhered to only common-sense observations. For example, Aristotle, unlike Galileo, did not consider an idealized world like friction-free motion that occurs in a vacuum, as it does according to atomic theory.

Galileo's great achievement was in detecting that in Aristotle's universe, a systematic mathematical discussion of motion theory was impossible. In order to solve this situation, Galileo proposes to separate <first property> from the <second property>. The first property is appropriate as a scientific theory because it can be described mathematically. Examples include speed and acceleration. The second property does not allow for mathematical conversion. Examples of the second properties, which are subjective properties, include special properties such as propensity, scent, and smell. Through this distinction, the first property was used as a material for mathematical theory that can be predicted over time.

Since something "beneficial" for humans is under the control of natural laws, mankind has expanded the scope of accessible objects within the natural world, thanks to the predictive ability of science. Aristotle's physics could not predict the trajectory of an object's motion because it did not contain the appropriate concept of time. However, Galileo abstracted time so that it could also be used in equations dealing with phenomena such as non-periodic falls. He believed that time was mathematically equivalent to space and thus could be used as coordinates. The only way to formulate physics predictably in time and space is in this way (Miller, 1996, pp. 144–145).

If the Earth is at the center of the universe, it consists of heavy soil, water, air, and fire, from bottom to top. Therefore, stones with a lot of soil components must move on their own toward increasing density to reach their target point, the ground.

However, according to the heliocentric theory, such distribution by component becomes meaningless. The cause of Earth's movement is also attributed to universal gravitation. Therefore, in situations where remote forces act, the surrounding environment becomes a collateral situation where there is a vacuum state with no factor hindering motion, so it should be removed or ignored.

Conclusion and suggestion.

Aristotle attempted to teleologically explain why objects on earth fall, while Galileo tried to mathematically describe how they fall. Contrary to Aristotle's argument, Galileo discovered that all objects fall at the same speed regardless of their weight. Methodologically speaking, the way he explained motion did not take into account the 'why' of objects moving. He simply ignored the qualitative nature of objects Aristotle emphasized. Galileo was instead interested in quantities, that is, the mathematical and abstract properties of objects. By excluding the properties of objects such as shapes, colors, and components, Galileo was able to present an abstract mathematical explanation of the behavior of objects (Oh, 2016).

However, with regards to celestial motion, Galileo still maintained a Pythagorean-Platonic position that asserted that nature is written with geometric symbols.

In contrast, Democritus, a descendent of Ionic philosophers, approached differently and established the following principles: every visible thing is made up of small, non-divisible particles called atoms that are moving, especially in an infinite empty space where these particles are in constant motion (Frank, 2011, p. 95).

This was a change in the Ionian concept of theoretical knowledge in the Pythagorean concept. Only the mechanical properties of things were primary. Numbers and geometries were no longer independently inherent in nature. In Newton's mechanics, the formula governing a cosmic mechanical gas is a differential equation, not a numerical rule or a symmetry. Geometry became a theory dealing with empty space, and hermeneutics was merged into geometry by Descartes and separated from realms beyond experience. If Galileo brought abstract time *t* into nature's phenomena, Newton laid the foundation for reducing all motion to time.

Scientists may believe that ideas resulting from abstraction during scientific activities are impressive and revolutionary (Welling, 2007). In the author's view, the geometricization of space and time through mathematical abstraction that is performed by Galileo, as well as the idealization strategy that justifies the laws subsequently obtained should also be introduced into modern science education.

Moreover, high creativity is not the result of a single action, but the result of utilizing several factors in the discovery process that occur over a long period of time in the history of science (Runco, 2014).

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Розуміння математичної абстракції у формулюванні закону Галілея

Анотація. *Революція Галілея в науці ввела в науку аналітичний метод, типовий для загального сучасного мислення, що полягає у добуванні, абстрагуванні та розумінні лише критичних аспектів цільових явищ та зосередженні уваги на тому, "як", що є кількісним зв'язком між змінними, а не на "чому". Наприклад, для нього питання "чому предмет падає" немає значення; натомість важливий лише кількісний зв'язок між відстанню від падаючого об'єкта та часом. Тим не менш, найбільш фундаментальний аспект його ідеї полягає в тому, що він запровадив кількісну оцінку часу t. Коли об'єкт спроектований горизонтально, відстань, пройдена в якийсь момент часу у горизонтальному напрямку, підсумовується як* $d \propto t$*, тоді як відстань, що падає у якийсь момент часу у вертикальному напрямку, сумується як* $d \propto t^2$*. Тут відстань, що є просторовим атрибутом, виражається як функція часу t. Тобто час ідентифікується як однорідна величина, яку можна звести до алгебраїчного числа. Тепер можна визначати закони руху речей, використовуючи функції часу. Щодо цього математичний час був вирішальним фактором у практичній реалізації математизації фізичної природи. Оскільки, згідно з атомною теорією, між атомом і об'єктом, що складається з атомів, або між об'єктами існує вакуум — якщо не брати до уваги фактори, що заважають руху, такі як тертя, — простір для абсолютного часу, який є математичним часом, може бути визначений геометрично . Щоб виправдати цю стратегію математичної абстракції, проводилися уявні, а не лабораторні експерименти, які тоді було важко виконати.*

Ключові слова: *Галілей; кількісні стосунки; атомна теорія; математична абстракція; уявний експеримент*

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Emergence and development of the Kyiv school of artistic textiles in the XX century

Abstract. *The article provides a thorough overview of the evolutionary process of the emergence, establishment, and development of the Kyiv school of artistic textiles. It reveals the influence of various factors (ideological, political, economic, and aesthetic) on this process. The historical and factual method allowed us to study socio-economic, as well as historical and cultural factors that contributed to the emergence, establishment, and development of the Kyiv textile school in a chronological sequence. Both separate Kyiv textile artists' works and the differences of other schools were analyzed by the comparative method. It is established that the very fact of emergence of the Kyiv school of artistic textile, as a community of style, unity of forms, preservation, and continuity of traditions, had unbiased backgrounds since Ukrainian decorative weaving, a part of which is Kyiv weaving, inherited the abundant artistic traditions that were created over the centuries and most vividly manifested through the art of Kyivan Rus. It showed the significance of Kyiv as a major administrative and*

cultural center of Ukraine in the emergence and development of the textile school. The status of the capital city was the reason why prominent artistic forces concentrated there, creating several outstanding textile artworks intended for various purposes during the 1920–1990s. The ideology of the ruling Communist Party of the Soviet Union, which ordered the artworks for its glorification, had a stimulating impact on the emergence of the school. Analysis of the data allowed us to periodize the stages of emergence and development of the Kyiv school of artistic textiles as an educational institution. Typical features of the Kyiv textile school at different stages of its development in 1920–1990s are as follows: a) The presence of a plot theme, the epic breadth of the depicted scene, and the scale in monumental and decorative textiles; b) The stylization of themes, their conventional interpretation, and two-dimensional images that suggest the absence of perspective and the illusory representation of three-dimensional forms in decorative (non-figurative) large tapestries and decorative stage curtains made in various techniques; c) The preservation of established iconographic compositions created by predecessors, but performed in a new (stylistic and coloristic) interpretation in traditional textiles; d) As for the industrial textiles, the presence of two trends in the artistic design of fabrics: The first is associated with the artists' focusing on the entire spectrum of the world (primarily European) textile fashion; The second one involves the transformation of traditional popular graphic themes in fundamentally new compositional developments.
Keywords: *Ukraine; textiles; scientific schools; history; periodization*

Introduction.

Countless works of famous Kyiv artists, who created textile items for various purposes in the XX century, respective publications in art history literature, as well as recognition of the artists' activities, and the importance of their work give grounds to designate this phenomenon as the "Kyiv school of artistic textiles in the XX century". This study is devoted to the issues of emergence and development of the Kyiv school of artistic textiles and scientific analysis of its artistic heritage throughout the XX century.

For the first time, although related to the tapestry, the term "Kyiv school" appeared in the monograph called "Monumental and decorative art in the architecture of Ukraine" (by Veligockaya, Zhizdrinskaya, & Kolomiec, published in 1989 at the Budivelnyk publishing house). In particular, the authors of the publication noted that "lately, the Kyiv school, which in variety, diversity, and individuality of its creative style develops tapestry as a type of monumental art, has powerfully asserted its worth in the Ukrainian tapestry" (Veligockaya, Zhizdrinskaya, & Kolomiec, 1989, p. 78).

Art textile industry refers to one of the oldest crafts in the history of mankind's material culture. Archaeological findings, in particular, fiber spinning tools such as spindles, spindle whorls, as well as fabric prints on the ceramic surface, suggest the existence of textile products on the territory of the modern Kyiv region back in the Neolithic period [VIII–III millennium BC] and the Eneolithic Age [IV–III millennium

BC], the Bronze Age [IV – early I millennium BC], and early Iron Age [early I millennium BC], as well as in all subsequent stages of human history.

The fabric had a significant meaning in the daily life of all social classes. It was widely used for clothing, home decoration, and ceremonial occasions. Back in the princely times, Kyiv and the surrounding settlements were known for the skillful production of decorative fabrics. The success of weaving in Kyivan Rus and the later period was promoted by the fact that one of the major trade ways from the Northern and Western Europe to the East ("from the Varangians to the Greeks") ran through Kyiv. All kinds of goods, including highly artistic fabrics, remained in Kyiv and served as patterns for local craftsmen, in particular, weavers (Andriiashko, 2015).

Most of the surviving textile products belong to the XIX-XX centuries, although there is still evidence of the local carpet production in the XVII century (Peshchanskyi, 1925, p. 5). The lack of ancient fabric samples can be explained by the fragility of organic fibers (Skrzyniecka, 2020; Gleba & Nikolova, 2009), their vulnerability to rotting and burning processes, as well as the belated development of Ukrainian museology. According to the scholars of popular textiles, it was in the XVIII-XIX centuries that the traditions and system of the core types of Ukrainian artistic fabric shaped, while their technological and creative means became fully refined (Selivachov, 2005, p. 67).

The relevance of the article is stipulated by the acute need for humanitarian study of Ukrainian culture, in particular, such a branch as decorative-applied art, one of the varieties of which is artistic textiles. The scientific literature lacks complex studies to fully cover such a multifaceted artistic phenomenon as the Kyiv school of artistic textiles.

Kyiv textile artists who worked throughout the XX century created numerous artworks for different purposes and with different techniques. Among them, most are highly professional creative pieces, which still grace the interiors of public buildings, museums, cafes, and restaurants. Very few of them have been reproduced in catalogs, periodicals, and monographs. The remaining pieces remain unknown to both art admirers and specialists.

As a matter of fact, there is still no research in Ukrainian historical and art literature on the emergence and development of the Kyiv school of artistic textiles as one of the most influential artistic centers in Ukraine.

The study aims at providing a complex coverage of the emergence and development of the Kyiv school of artistic textiles in the XX century.

Source base and research methodology.

The research methodology is based on the comprehensive study of the subject matter. The historical and factual methods used in the studies (Strelko, Pylypchuk, Berdnychenko, Hurinchuk, Gamaliia, & Sorochynska, 2019, Strelko, 2021; Strelko, Berdnychenko, Pylypchuk, Pylypchuk, Sorochynska, & Horban, 2021) allowed us to explore the socio-economic, historical and cultural factors that contributed to the emergence, establishment, and development of the Kyiv textile school in a chronological sequence. The comparative method was applied to analyze the works of separate Kyiv textile artists, as well as to study the differences between other schools.

Results and discussion.

No matter the historical times, Kyiv has always held a remarkable place in the history of Ukraine as a major socio-political and cultural core. As an integrating center, the Kyiv area asserted itself back in the period of pre-Slavic unity formation. This was accomplished due to its favorable location along a large navigable river, on the border of the forest-steppe and Polesie. One can find information about the Kyiv land in chronicles, in particular, "The Kyiv-Pechersk Paterikon", "Tale of Bygone Years", "The Tale of Igor's Campaign", European historical chronicles, and Eastern historical-geographical writings (Shkribliak & Balukh, 2017; Shevtsova, Gorbyk, Mezhenna, Chobitko, Kozak, & Andropova, 2020).

In his work "Archaeological past of the Kyiv area", V. Danylevych described the influence of the city this way: "All other days, the cultural life in the Kyiv area was obviously concentrated around Kyiv. The advantageous geographical position of the city of Kyiv on the border of the steppe and the forest protected it from the steppe danger. In addition, it lies on the Dnipro River, where Desna and Pripyat join it. These are the phenomena that gave Kyiv the greatest power and importance in the whole Kyiv area" (Danylevych, 1925, pp. 129–130).

Kyiv as an administrative and cultural center arose with the ancient Kyivan Rus in the IX century, one of the most powerful states of that period, with a highly developed culture rivaling that of Western medieval Europe. Kyiv, the capital of the state, was a large city by the standards of the time with a population of 50,000 people. The city had well-developed craft industries, which produced a variety of highly artistic pieces. It developed greatly during the heyday of Kyivan Rus and became the most important waterway at that time. In the second half of the VIII century and the first half of the X century, Kyiv was the heart of one of the economic exchange regions of Eastern Europe, which may be regarded as "Khazar-Russian" in contrast to the "Bulgaro-Russian" region that developed in Northern Rus (Tolochko, 2000, p. 430).

Foreign travelers spoke about the place of Kyiv as a trading center of Eastern Europe even before Kyivan Rus emerged because they presented Rus as three states (Kuyavia, Slavia, Artania). Thus, in the early X century, the Arabian geographer Jaihani wrote that the city "Kuyavia trades with other nations and willingly admits foreign merchants, including, of course, eastern merchants" (Hrekov, 1951, p. 104).

The cities of Vyshhorod, Khalep, Trepol, Vytachev, Ivan-horod, Chuchyn, and Pereiaslav became important centers of trade and crafts along the Dnipro's banks. Among the imported goods, there were valuable gold and silk fabrics (brocade, velvet, and wool), while a large volume remained in the cities. They were technically more advanced and could serve as patterns for local weavers.

Mykhailo Lytvyn, a Lithuanian diplomat of the mid-XVI century, in his work "On the Customs of the Tatars, Lithuanians, and Muscovites", assessed the importance of Kyiv as the main center of transit trade with the Eastern countries (Kravchenko & Yakovenko, 1990, pp. 76–77):

"Kyiv is flooded with foreign goods since there is no path that could compete in any way with this ancient and well-known route, which leads from the Black Sea port, that is, from the city of Caffa through the Taurida Gate to the Tavan crossing on the Borysthenes, and from there through the steppes to Kyiv; they carry precious stones, silk, and golden fabrics from Asia, Persia, India, Arabia, and Syria to the north, to Moscow, Pskov, Novhorod, Sweden, and Denmark".

Then Lytvyn continues: "...in the shabby huts of Kyiv ... there appear precious silks, jewels, sable and other furs and spices in such quantities that I have seen silk there sometimes cheaper than cloth in Vilno" (Kravchenko & Yakovenko, 1990, p. 7).

P. Musienko, a researcher of Ukrainian artistic textiles, when describing the place of Kyiv in the XVIII century as a cultural center of weaving craft, noted that the city attracted masters from different places in Ukraine. Weavers from Sumy, Poltava, Sloboda area, Volhynia, and Galicia worked in the Kyiv Pechersk Lavra workshop at different times (Musiienko, 1969, p. 274). M. Selivachov also noted it in the article called "The place of Kyiv in the development of popular art" (Selivachov, 2001): "Many masters from the Kyiv region, nearby Left Bank, and other regions were involved in icon painting, wallpapering, ceramic, and other workshops of the Kyiv Pechersk Lavra and city craft workshops". Such a mutual exchange of experience among artisan weavers favored the nationwide development of textiles in Ukraine and had a positive backward influence on peripheral textile communities.

Kyiv, being a large cultural, educational, ecclesiastical, and economic center of Ukraine, emerges in the composite description of Ivan Kyryllov, chief secretary of the Russian Senate, concluded in 1727 (Melnyk, 1999).

In the XX century, Kyiv still holds the leading position as the administrative and cultural center of Ukraine, thanks to its status as the capital city. In fact, the capital has always been a hub for leading scientists, cultural figures, and artists, who far outnumber other cities in these categories.

Before the Bolshevik revolution of 1917, Ukraine had not a single institution of higher art education, and the higher qualification training of artistic specialists was carried out mainly in the Russian Empire, in St. Petersburg and Moscow. These cities also featured institutions for training arts and crafts specialists: The Saint Petersburg State Art and Industry Academy, named after Baron A. Stieglitz, and the similar college in Moscow, founded by Count G. Stroganov. Art schools in Kyiv, Odesa, and Kharkiv remained under the auspices of the Imperial Academy of Arts, and, accordingly, trained artists following the traditions of the Russian academic school. Apart from these colleges, there were several artistic and artisanal schools (Myrhorod, Kamianets-Podilskyi, Hlynsk) and some private studios in Kyiv, Odesa, and Kharkiv, which complemented the network of provincial art education (Vrona, 1926). Some

Ukrainian artists (M. Burachek, V. Kasian, and B. Kratko) acquired their artistic education abroad. For instance, M. Burachek – in Krakow, V. Kasian – in Prague, and B. Kratko – in Munich.

There were no professional textile artists in Kyiv at that time since no public demand for creative works made in textile techniques existed. In turn, popular art, including artistic textiles, has developed over the centuries due to the domestic demand for artistic woven products.

I. Vrona, a contemporary of that period, pointed out the quantitative and qualitative rise of Ukrainian post-revolutionary art, its sharp deviation from the all-Russian "flow" towards an independent path, and stressed its great diversity, complexity, and inconsistency: "the new art of Ukraine combines the most diverse and numerous trends, directions, and schools; it features opposing tendencies and influences that collide and struggle". The scholar continued that after the revolution, "Ukrainian art if one considers its qualitative and professional level, as well as its importance as a sum of elements in contemporary Ukrainian cultural life, can be considered as born anew and lacking traditions (not reborn)" (Vrona, 1928a).

In the post-revolutionary period (December 1917), the Ukrainian Academy of Arts was founded based on the decision of the Central Council. Its first professors were prominent Ukrainian artists: M. Boichuk, M. Burachek, M. Zhuk, V. Krychevskyi, F. Krychevskyi, A. Manevych, O. Murashko, H. Narbut (Zemlyanaya, 2013; Melnychuk, 2021; Boichenko, Nykyforov, & Hulei, 2020). In 1922, the Academy was restructured into the Institute of Plastic Arts, and the teaching staff of the newly created Institute was replenished with fresh forces (O. Bohomazov, L. Kramarenko, V. Meller, S. Nalepynska-Boichuk). By that time, the Institute had the following workshops: graphic arts, easel painting, theatrical and decorative, monumental painting, weaving and carpets, textile masonry, mosaic, and stained glass. Consequently, there is a reason to believe that it was at this time that the Kyiv school of artistic textiles was founded as well. In 1924, the Institute of Plastic Arts merged with the Institute of Architecture to form the only higher art education institution in Ukraine at that time known as the Kyiv Institute of Art (Vrona, 1926).

As conceived by the leaders of the Academy at the time, the educational institution had to follow a new path, that is, to fit art "to the real challenges of life, bringing it closer to reality and production. Hence, the education of the new Soviet artist must be scientifically founded, proceeding from the functional definition of artistic specialties and the study of the processes and techniques of artistic skill and artistic technique of various kinds, involving the study of technology, the analysis of forms, and elements of art" (Andriiashko, 2006). The teaching staff was tasked with expanding the range of vocational profiles, that is, training artists for the needs of industry such as ceramists, textile workers, timber workers, etc., in addition to the traditional profiles that existed at the Russian Academy of Arts (architecture, painting, and sculpture). Thus, the Academy set out to train specialists of the highest qualification in organizational and creative-synthetic artistic force for all sections of the material or, more precisely, spatial-material arts, "to cover all artistic and material culture, the entire thickness of material life in whatever forms, methods, and materials this culture and life would manifest and express itself" (Vrona, 1926).

In 1925, a textile subdivision was established in the painting department of the Academy of Arts. Its teachers and students, inspired by the popular artistic traditions of the region, continued to look for brand new compositional solutions in their design works of weaving, carpet weaving, and embroidering. The initiator and founder of the subdivision was Serhii Kolos, who studied at the Ukrainian Academy of Arts from 1918 to 1922, where his teachers were M. Boichuk, who had previously held art studios in Italy and Germany (Andriiashko, 2017), and Vasyl Krychevskyi, who had joined the artistic textiles back in 1913 (Lagutenko, 2019; Gryglewski, Chernyshev, Kashchenko, Shilo, Ivashko, Dmytrenko, & Ivashko, 2021). In V. Khanenko's carpet workshops in Olenivka village, several rugs were designed according to his drafts. These included the "Circle" rug and the "empire" rug with a basket of flowers (1913), which were shown at the exhibition of professors during the inauguration of the Ukrainian Academy of Arts on December 5, 1917 (Ruban-Kravchenko, 2004, p. 232).

Being a student of M. Boichuk and V. Krychevskyi, S. Kolos learned many precious instructions from his teachers concerning the formal and stylistic creative foundations of composition structure. As I. Vrona, the rector of the Academy of Arts at that time, noted, "Boichukism" found its independent and more organic path to national art than all other trends in contemporary Ukrainian art. Admittedly, it is a way of manifesting itself in the art of a largely peasant element, but its natural, original, and socio-artistic values are undoubted. The impact of "Boichukism" is manifested quite well in painting, graphics, ceramics, sculpture, and textiles" (Vrona, 1928a).

S. Kolos was appointed chairman of the vocational subject commission of this subdivision and taught the composition discipline and the structure and analysis of fabrics in the department of weaving and carpet weaving at the same time (Vrona, 1928b). Professor F. Lohanko, who taught fibrous materials technology, chemical technology, and dyeing of fibers and fabrics, was among the members of the commission. In 1927, the subject commission was expanded by M. Rokitskyi, the teacher of drawing and painting, M. Khurgyn, the teacher of structure and analysis of fabrics (theory of weaving bindings), and V. Vynohradov, the specialist in the technology of mechanical weaving looms and technology of fiber materials. In 1928, B. Zhuk started working in the subdivision, teaching the history of the textile industry with practical drills (work with the material). The number of students in the subdivision kept growing every year. So, while there were 11 students in the 1925-1926 academic year, the next year there were 29 students, and in 1927–1928, there were now 35 students. By October 1, 1928, 43 people were studying in the textile subdivision. The material base of the training course was improving steadily. Students had the opportunity to work in the weaving and carpet weaving workshop, textile dyeing, and printing laboratory.

In 1928, the Academy formed an Art and Industry Department, which included textile and woodworking subdivisions. It was initiated by I. Vrona, the rector, who wanted to bring art closer to everyday life while training specialists in the industry. The head of the subject commission was B. Kratko, and the secretary was S. Kolos. The commission also included Professor I. Severa and S. Yanushivskyi. Unfortunately, the fights that broke out between the teachers and representatives of different artistic groups led both to the resignation of the Academy management and a change in the strategy of the educational process. In the early 1930s, easel arts became ideologically determinant, and as a result, enrollment in the Art and Industry Department was discontinued. However, artists who graduated from other departments of the Kyiv Academy of Art kept working in the decorative-applied arts. So, at the end of the 1920s, the Academy trained two specialists who had engaged in art textiles and who were among the first who stood at the origins of the Kyiv textile school. In 1927, D. Shavykin graduated from the department of monumental painting, and in 1928, O. Saenko was trained as a "painter in decorating buildings" (Vrona, 1928b). Oleksandr Saenko became involved in creating themed carpets back in the 1920s, developing a series of sketches: Bleach the canvas ("Відбілюють полотно" in Ukrainian), The Cossack and the Girl ("Козак і дівчина" in Ukrainian), Ukrainian antiquity ("Українська старовина" in Ukrainian), Meeting of the Cossack ("Зустріч козака" in Ukrainian) and others. These works "are distinguished by a clear delineation of the image, generalization of forms, internal details, and deliberate decorativeness" (Kara-Vasylieva, & Chehusova, 2005, p. 50).

Since the textile department was subordinate to the painting department, this led to creative inter-influences, as well as mutual enrichment of the fine and plastic resources of future artists. Thus, in our view, owing to this mutual influence, the themed carpets created in the second half of the 1930s tend towards monumental painting. This was encouraged not only by administrative subordination but also by the fact that drawing and painting in the textile department were taught by the same teachers as in the easel and monumental painting departments. It is clear that the teachers of "Boichukism" (M. Boichuk, S. Nalepynska-Boichuk, S. Kolos, M. Rokytskyi) had a great influence on the future textile artists.

The cultural and artistic life of Kyiv throughout the 1920-1980s was replete with multiple art exhibitions, which regularly exhibited the works of popular, traditional, and professional textiles. The state spared no funds in ordering story-themed tapestries, ornamental carpets with portraits of statesmen and Soviet symbols, as these works were ideological, glorifying the Communist Party, "the inspired labor of the Ukrainian village toilers under the collective framework" (Zhuk, 1973, p. 49).

The mid-1930s were favorable years to establish Kyiv textile school as during these years, there was an active construction of recreational centers, palaces of culture, and clubs decorated inside with artistic works, particularly carpets (Suraganov & Suraganova, 2021). The government employed gifted artists such as M. Boichuk, M. Deregus, V. Kasiyan, V. Ovchynnikov, I. Padalka, A. Petrytsky, M. Rokitskyi,

M. Rokytskyi, D. Shavykin, and others to design the cartons of story-themed carpets. Actually, all of them had no previous experience with carpet weaving, so they were unaware of its creative style, which consisted of a conventional interpretation of pictorial themes, their stylization, the lack of linear and aerial perspective, a limited color palette, and two-dimensional images (Zhuk, 1973, pp. 41–43). D. Shavykin (a monumentalist by training) created the most themed carpets, up to ten of them (Novytska, 1948).

The next stage in the establishment of the Kyiv textile school started with the creation of experimental popular art workshops at the Directorate of Arts under the Council of People's Commissars of the Ukrainian SSR. This was announced at the meeting of popular art specialists in the spring of 1934 by D. Zatonskyi, People's Commissar for Education of the Ukrainian SSR. This meeting was attended by architect V. Krychevskyi, artists P. Ivanchenko, M. Rokitskyi, I. Padalka, M. Tsivchynskyi, D. Shavykin, and textile workers S. Kolos, O. Kulyk, T. Flora, and others. By 1935, a workshop of carpets and tapestries had been started at the school (Andriiashko, 2017). Masters from the leading carpet manufacturers of Ukraine (Reshetylivka, Dihtiariv, Skoptsiv, Dobrovelychkivka, and others) were invited to Kyiv to work on them.

A. Moroz claimed that the School of Masters of Popular Art was restructured into experimental workshops in 1937 (Moroz, 1982). In fact, the experimental workshops were restructured into a School of Masters of Popular Art in 1938 (TDAVOVUU, n. d., s. 96). Such master carpet weavers as V. Buriak, N. Vovk, M. Gluschenko, P. Ivanets, M. Kulha, G. Malysh, M. Ponomarenko, M. Schur, and others worked in these workshops periodically or even moved to the city for permanent residence and creative work (Zhuk, 1973, p. 43). Throughout the existence of the school and workshops, the carpets Return from the Field ("Повернення з поля" in Ukrainian) by M. Deregus, Spring Song ("Весняна пісня" in Ukrainian) by H. Pustovit, Lenin and Children ("Ленін і діти" in Ukrainian) by V. Kasian, Voroshilov among Collective Farmers ("Ворошилов серед колгоспників" in Ukrainian) by M. Rokytskyi, and others were created (Andriiashko, 2006).

The strengthening of creative relations between professional easel artists and popular masters was typical for the 1930s. These relations resulted "in the emergence of principally new phenomena on the substrate of popular decorative art with attributes of "easelism", dominated by the individual author's initiative, not so much naive as stylistically cultivated..." (Selivachov, 2001).

In 1940 (1938 according to other sources) (Selivachov, 2005, p. 49), the Kyiv Republican Art and Industry College was created at the School of Masters of Popular Art. Apart from professional artists, masters of popular art also worked among the teachers. For example, the carpet weaving teachers were the artist M. Rokytskyi and the skilled carpet-maker N. Vovk (Butnyk-Siverskyi, 1966, p. 194).

Just after World War II, the Kyiv Republican Art and Industry College, renamed into the Kyiv College of Applied Arts in 1949, resumed its activity (Diachenko, 2019).

Following a long absence, S. Kolos returned to Ukraine and began teaching at the College (he had previously worked as a textile teacher in Uzbekistan and Leningrad) (Krutenko, 1989).

In 1963, the Kyiv Republican Art and Industry College was restructured into the Art and Industry Technical College. The 1960–1990s were marked by the development of artistic textiles intended for decorating the interiors of public buildings, cafes, and restaurants. Such works were ordered through the Art Fund of Ukraine, which had its own creative and production plants. There was a Factory of Monumental and Decorative Art in Kyiv, affiliated with the "Khudozhnyk" Creative and Production Association of Kyiv. The works designed by artists were performed in the factory shop, as well as at Ukrhudozhprom enterprises, mainly at the Reshetylivka Carpet Factory named after Clara Zetkin. Textile works for interiors were also designed and produced by the Experimental Workshop of Decorative Fabrics at the Zonal Scientific and Research Design Institute of Civil Engineering (KyivZNDIIEP).

It's worth noting that the predecessor of the Experimental Workshop of Decorative Fabrics at the KyivZNDIIEP established the workshops on artistic textiles and monumental art at the Research Institute of Architecture of the Academy of Construction and Architecture at the end of the 1940s. Specialists of the workshops were engaged in decorating typical new buildings with monumental and decorative artworks. In 1963, the Academy of Construction and Architecture of the Ukrainian SSR was abolished (Puchkov, 2021). In the late 1980s, the Research Center of Monumental and Decorative Art was created out of the creative workshops of KyivZNDIIEP. It was aimed at designing complex architectural interiors of public buildings. As in previous decades, the center's priorities were monumental and decorative ceramics and artistic textiles.

Summing up, we can assert that the emergence of the Kyiv school of artistic textiles began as an artistic phenomenon in the 1920-1930s and was finally shaped in the 1980s. However, it emerged from the richest traditions of popular art, in particular, weaving, carpet weaving, and woodblock printing on textiles in the Kyiv region of previous times. Serhii Kolos, a highly educated figure and artist of a wide creative range, an outstanding art historian, promoter and collector of popular art, author of articles on Ukrainian decorative-applied arts, in particular, art weaving, familiar with all artistic currents, can be fairly regarded as the founder of this school.

Ukrainian popular art (wall paintings, embroidery, weaving, carpet weaving, woodblock printing on textiles, pysanky, etc.), with its pictorial themes serving as a source of inspiration for the artists, had a great influence on the development of the school (Kostiukova, 2018; Brovarets, 2021; Melnyk, Kyzymchuk, & Zubkova, 2021).

Any artistic branch or style trend is formed over a long period. Here, time acts as a selector tracing and selecting the most essential features, the most distinctive cumulative traits inherent to the artists' works in a given region. The totality of these features, signs, and stylistic differences shape the art school that differs from similar schools in neighboring regions. A preferable (but not mandatory) condition for accelerating its shaping is the presence of fundamental principles or systemic tenets. Lacking these factors, school emergence may be delayed in time because the spontaneous and uncontrolled process makes it unmanageable.

The typical features of the Kyiv school of artistic textiles are: a) The presence of a plot theme, the epic breadth of the depicted scene, and the scale in monumental and decorative textiles (tapestries, panels); b) The stylization of themes, their conventional interpretation, and two-dimensional images that suggest the absence of perspective and the illusory representation of three-dimensional forms in decorative (non-figurative) large tapestries and decorative stage curtains made in various techniques; c) The preservation of established iconographic compositions created by predecessors, but performed in a new (stylistic and coloristic) interpretation in traditional textiles; d) As for the industrial textiles, the presence of two trends in the artistic design of fabrics: The first is associated with the artists' focusing on the entire spectrum of the world (primarily European) textile fashion; The second one involves the transformation of traditional popular graphic themes in fundamentally new compositional developments.

It experienced both rises and crises in the initial period of the establishment of the Kyiv textile school. The development process was not smooth because of the lack of clearly outlined style guidelines, as well as due to ideological pressure on artists from the ruling party, which had usurped all spheres both of material and spiritual life of the Ukrainian people.

The emergence of large-scale themed carpets fell in the mid-1930s when ideological Soviet institutions promoted the development of this type of decorative art. At the beginning of its establishment, the greatest pressure was exerted on the themed carpets, as its pictorial plots were easier for the representatives of the ideological censorship to contemplate and interpret. Traditional popular weaving, as much more indifferent, never faced such a fate, although even this type of textile was imposed with unusual pictorial themes. For example, portrait images of party leaders, generals, political figures, and Soviet heraldry emerged in the ornamental carpets, which, as a rule, did not fit that well into the decorative artwork structure.

As there was no higher educational institution in Kyiv after 1930 (when the textile department of the Kyiv Academy of Art was closed) that would train specialists in artistic textiles, such specialists for Ukrainian enterprises, including the Kyiv region, were trained by the Lviv State Institute of Applied and Decorative Arts (Procop, 2019; Dyachenko, 2021), as well as the Moscow Textile Institute, the Moscow State University of Arts and Industry (formerly Stroganov University), the Leningrad University of Art and Industry named after V. Mukhina, Kaunas State Institute of Applied and Decorative Art, and the LSSR State Art Institute (Šatavičiūtė-Natalevičienė, 2021). Many graduates of the Kyiv State Academy of Art (workshop on the monumental painting) also became involved in creating tapestries, fulfilling orders at the Kyiv Factory of Monumental and Decorative Art of the Art Fund of Ukraine. The Kyiv College of Applied Arts, the predecessor of the present Kyiv State Institute of Decorative Arts and Design named after Mykhailo Boichuk, was also famous for training specialists in textiles. Kyiv State Institute of Decorative Arts and Design named after Mykhailo Boichuk was established in December 1999 based on Kyiv Art and Industry Technical College. By order of the Ministry of Education and Science of Ukraine No. 748 as of July 11, 2018, the Institute was renamed into Mykhailo Boichuk Kyiv State Academy of Decorative Applied Arts and Design.

Kyiv school of artistic textile of 1970–2000s is characterized by the presence of plot, epicity, scale, and monumentality, which distinguishes it from Lviv or Baltic schools, where formally-decorative interpretation of themes and associative figurative thinking prevails. The school had these features since the vast majority of artists who were creating for public institutions, enterprises, and other organizations were devoted to monumental and decorative art. In addition to tapestry, they worked with other materials and techniques, in particular, mosaics (flat, relief, and three-dimensional), ceramics, stained glass, and wall paintings.

The early 1990s were marked by the USSR’s collapse and Ukraine’s independence. Due to the change in the ideological system, the CPSU lost control over all spheres of public life. Art, as a kind of ideology, was not given as much importance as before, so state orders for artistic works became a rarity. Consequently, the number of artistic textile works to decorate interiors has sharply decreased. In fact, the monumental and decorative art workshop within the “Khudozhnyk” Creative and Production Association, which had been fulfilling orders for tapestries, curtains, panels, etc., ceased operating. The textile artists produced pieces mainly for exhibitions, hoping for possible sale to private individuals. The freedom of artistic creativity and the absence of ideological censorship encouraged the artists to creative pursuits in a variety of styles. Designer textiles urged for experimenting, applying new materials, and combining different technical methods (Kostiukova, 2014; Cherniavskyi & Us, 2020; Lukovska, & Kara-Vasylieva, 2022).

Analysis of the above data allows us to make the following periodization and argue that as an educational institution, the Kyiv school of artistic textiles was shaped by the following stages:

1. Art and Industry College (1920-1921); Art and Industry Technical College (1922); Art and Industry Vocational College No. 1 (1922–1930)
2. Kyiv Institute of Plastic Arts (1922–1924);
3. Textile Subdivision of the Painting Department of the Kyiv Academy of Art (1925–1930);
4. Experimental popular art workshops at the Directorate of Arts under the Council of People’s Commissars of the Ukrainian SSR (1935–1938);
5. School of Masters of Popular Art (1938–1940);
6. Kyiv Republican Art and Industry College (1940–1948);
7. Kyiv College of Applied Arts (1949–1963);
8. Kyiv Art and Industry Technical College (1963–1999);
9. Kyiv State Institute of Decorative Arts and Design named after Mykhailo Boichuk (1999–2018)

10. Mykhailo Boichuk Kyiv State Academy of Decorative Applied Arts and Design (2018 – until now).

Conclusion.

More than anywhere else, administrative, cultural, and domestic facilities of various subordination were built and reconstructed in Kyiv. In fact, their interiors had to be decorated. Textile works were widely involved in such works. Since the 1930s, pieces of fine art, in particular, themed carpets, were an instrument of ideological propaganda of the ruling party, hence there was a state order for their production. The need for specialists in textiles led to the establishment of the School of Masters of Popular Art in 1938, which has repeatedly changed its name and subordination, and until today was transformed into a higher educational institution known as Mykhailo Boichuk Kyiv State Academy of Decorative Applied Arts and Design.

During the 1930-1980s, there was a process of improving formal and compositional, figurative and plastic techniques, which endowed Kyiv artistic textiles with distinctive style features (tapestries, weaving, carpet weaving, batik, and factory fabrics).

The traditional weaving of the Kyiv region developed from popular crafts communities, which originated earlier in Bohuslav, Pereiaslav-Khmelnytskyi, and Ivankiv regions. The creative and production base of the Art Fund, KyivZNIIEP, and Ukrhudozhprom allowed for making woven pieces of different sizes and techniques. All these components contributed to the emergence of the Kyiv school of artistic textiles, a distinctive artistic phenomenon in Ukraine.

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The authors declare no conflict of interest.

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Становлення та розвиток Київської школи художнього текстилю у XX столітті

Анотація. *У статті комплексно розглянуто еволюційний процес формування, становлення та розвитку київської школи художнього текстилю. Показано роль різних чинників (ідеологічних, політичних, економічних, естетичних), що впливали на цей процес. Історико-фактологічний метод дозволив у хронологічній послідовності дослідити соціально-економічні, історико-культурні чинники, які сприяли виникненню, формуванню та розвитку київської текстильної школи. Метод порівняння застосовано при аналізі творів як окремих київських художників-текстильників, так і при вивченні відмінностей інших шкіл. Встановлено, що самий факт появи київської школи художнього текстилю, як спільності стилю, єдності формовиражальних засад, збереження й продовження традицій, мав об'єктивні передумови, оскільки українське декоративне ткацтво, складовою частиною якого є ткацтво Київщини, успадкувало багаті художні традиції, які створювались віками і найяскравіше виявили себе в мистецтві Київської Русі. Показано роль Києва як значного адміністративного і культурного центру України у формуванні та розвитку текстильної школи. Саме завдяки статусу столичного міста тут сконцентрувалися потужні мистецькі сили, які протягом 1920–1990-х рр. створили цілий рід видатних текстильних творів різного призначення.*

Стимулюючу роль у формуванні школи зіграла ідеологія правлячої Комуністичної партії Радянського Союзу, яка для свого возвеличення використовувала твори мистецтва, замовляючи їх створення. Аналіз даних, дозволив зробити періодізацію етапів створення та розвитку київської школи художнього текстилю, як навчальної інституції. Характерними ознаками київської текстильної школи на різних етапах її розвитку в 1920–1990-х рр. є: а) у монументально-декоративному текстилі – наявність сюжетного мотиву, епічна широта зображуваного, масштабність, монументальність; б) у декоративних (не фігуративних) гобеленах значних розмірів, декоративних завісах для сцени, виконаних у різних техніках – стилізація мотивів, їх умовне трактування, двовимірність зображення, що передбачає не лише відсутність перспективи, а й ілюзорної передачі об'ємних форм; г) у традиційному текстилі – збереження принципів побудови усталених іконографічних схем композицій, створених попередниками, але виконаних у новій (стильовій та колористичній) інтерпретації; д) у промисловому текстилі – наявність двох напрямків у художньому оформленні тканин: перший пов'язаний з орієнтацією художників на весь спектр напрямків світової (передусім європейської) текстильної моди; другий – з трансформацією традиційних народних зображальних мотивів у якісно нові композиційні розробки.
Ключові слова: *Україна; текстиль; наукові школи; історія; періодизація*

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History of military laser technology development in military applications

Abstract. *The aim of this research is to study the development as well as the known cases of military applications of laser technologies – from the first lasers employed in auxiliary systems to modern complex independent laser systems. For better understanding and systematization of knowledge about development of historical applications in the military field, an analysis of publicly known knowledge about their historical applications in the leading world countries was conducted. The study focuses on development that was carried out by the superpowers of the Cold War and the present era, namely the United States, the Soviet Union and the Peoples Republic of China, and were built in metal. Multiple avenues of various applications of laser technology in military applications were studied, namely: military laser rangefinders; ground and aviation target designators; precision ammunition guidance systems; non-lethal anti-personnel systems; systems, designed to disable optoelectronics of military vehicles; as well as strategic and tactical anti-air and missile defense systems. To summarize and compare the results, an analysis of a number of previous works was considered, which considered the historical development, prospects and problems of the laser weaponry development. The issues of ethical use of laser weapons and the risks of their use in armed conflicts, which led to an international consensus in the form of conventions of the United Nations and the International Committee of the Red Cross, were also considered. As a result of the analysis, a systematic approach to the classification of applications of laser technology in military products by three main areas of development was proposed: ancillary applications, non-lethal direct action on the human body and optical devices of military equipment, and anti-aircraft and anti-missile defensive systems. Due to the constant comprehensive modernization of laser technology systems in use, it was decided not to use the periodic classification* *model, but to indicate important and key events that indicated the main directions of further developmental work. However, it is important to note that the main focus of historical development of laser weapons depended not only on the technological limitations of the time, but also on the military-geopolitical situation in the world.*

Keywords: *laser weaponry; laser rangefinders; target designators; non-lethal laser weapons; anti-ballistic missile laser weaponry; historical review*

Introduction.

The first mentions of focused light usage as a weapon can be traced back to Hippocrates (not to be confused with the Hippocrates the Physician), the Greek commander of the Syracusan forces in 212 BC. According to ancient documents, his troops set fire to the sails of the Roman fleet, focusing sunlight with copper mirrors – a system proposed by Archimedes, the world-famous mathematician and inventor (Olson, 2012). Weapon systems that worked on principles, close to those of lasers, such as “beam guns” have long been one of the staples of science fiction authors, gathering the attention of people around the world. Various concepts of “death rays” appeared in fiction more than a hundred years ago in Wells' 1897 novel “The War of the Worlds”, later appearing in A. F.Ossendovsky's “Brig Horror” (1913), as “death rays” in Dominic's “Rays of Death” novel (1921), as “purple rays” in “Erendorf Island” by V. P. Kataev (1924), in the story of Bulgakov's “Fatal Eggs” (1924) in the form of “red ray of life”, in O. M. Tolstoy's “Hyperboloid of Engineer Garin” (1926–1927) and others. It should be noted that in all these literary works, directed heat or light rays played an extremely negative role in the development of mankind and civilization. This view has advanced along the path of modern research and discovery in the field of science and technology: laser weapons in the world were developed as weapons of mass destruction of the future wars. In the Soviet press, they were dubbed “the devil's rays”. However, in the A. F. Paley “Golfström” (1927), an “orange ray” was shown as a “miracle of Soviet science”, although no practical work in this area was carried out in the USSR.

The first practical steps towards the creation of lasers were made by Albert Einstein in 1916 (Hecht, 2010), with subsequent breakthroughs in the interwar period. The first working laser with a ruby active element was developed in 1957 by Professors Gould and Towns, with the start of their production in the 1960s (Hecht, 2009). They also approved the definition of “LASER” – light amplification by stimulated emission of radiation or “amplification of light by stimulated (forced) radiation”. Just a few years later, in 1964, the first yttrium–aluminum grenade lasers were developed. At the same time, the end of process of development of the first laser designs coincided with the beginning of drastic changes in the vision of the future of armed conflict (Hecht, 2010).

With the development of real laser designs, science fiction has caught on this direction of development, constantly showing laser weapons as the basis of all weapons systems in future intergalactic wars. Thus, in the world-famous Star Wars movies, battles between spaceships take place with the help of “turbolasers”, imperial stormtroopers fight with the Jedi with the help of "laser guns"; the concept of which is also found in the "Warhammer 40,000" world as well as other science fiction universes. Of course, humanity is still far from developing working "laser rifles". However, with the constant progress in the laser development over the past 60 years, laser weapons are slowly becoming a reality.

Research methodology and it's description. Theoretical basis of the study.

In the early years of the "Cold War", the vast majority of studies on the use of lasers as weapons were extremely classified, so much so that it is quite difficult to assess the direction of theoretical work of that era even today; most reliable sources come from in the forms of unofficial stories and memoirs, published by the scientists. However, this trend began to decline in the second half of the 1970s, and short articles on the use of lasers for military purposes, such as the enrichment of military plutonium-238, began to appear in publications such as Nature (Dickson, 1981). Another article in Scientific American (Tsipis, 1981) described the possibility of using gas-discharge lasers to intercept missiles from space. These and other works were directly related to the US Strategic Defense Initiative program (SDI), which aimed to develop both laser weapons as well as other means to destroy the relative military-technological parity between the United States and the Soviet Union. Nevertheless, most of the available theoretical and practical principles on the use of laser radiation as a weapon were written after the SDI program and the Cold War itself, focusing on the development of the concepts about the usage of the laser weapons in their modern form, as well as specific issues, inherent to laser technological applications (Horowitz, 2014).

For example, in April 1997, the US Air Force Secretary, Mr. Widnall, said: *"It isn't very often an innovation comes along that revolutionizes our operational concepts, tactics and strategies. You can probably name them on one hand - the atomic bomb, the satellite, the jet engine, stealth, and the microchip. It's possible the airborne laser is in this league"* (Perram, Marciniak, & Goda, 2004).

Modern theoretical research examines possible principal laser schemes for individual applications (Zejin, Weiqiang, Kai, & Xiaojun, 2021; Yun, Song, & Pei, 2020; Cunha, Giacomelli, Kaufman, Brajer, & Pereira, 2021), while current studies such as Nature (Extance, 2015) and the work of Danson, et al. (2021) analyze problems, inherent to the long-distance usage of lasers.

Nevertheless, by reviewing the practical applications of lasers on military equipment of the past, as well as test data of various prototypes of laser weapons, it is possible to acquire a general picture of the main efforts on the technological development of laser weaponry (Lazov, Teirumnieks, & Ghalot, 2021; Ji, Zong, & Yang, 2020). Such an analysis can provide us an opportunity to find and understand various principles of interaction between scientific progress and its integration into military affairs (Jianli et al., 2022; Zhihe, Jianqiu, & Jinbao, 2021; Kombarov, Sorokin, Tsegelnyk, Plankovskyy, Aksonov, & Fojtů, 2021; Strelko, Pylypchuk, Berdnychenko, Hurinchuk, Korobchenko, & Martyian, 2019; Babyak, Neduzha, & Keršys, 2020; Tao, & Feng, 2020; Romanova et al., 2021; Bernatskyi & Khaskin, 2021).

The purpose of this work is to identify the principles of interaction of scientific progress and its integration into military affairs over time through a multifaceted analysis of the practical military applications of laser technology in the world. This analysis will be divided into several categories, each of which will focus on the chronology of a particular area of usage of the laser technology in military equipment.

Auxiliary uses of laser technology in military applications.

The first practical uses of laser technology in the military were ancillary applications such as laser rangefinders, as well as guidance and targeting systems for guided munitions.

The first laser rangefinders appeared in the Soviet Union between 1963 and 1964, developed by specialists of the Vavilov's Institute of Optics located in Leningrad, USSR (Molebny, McManamon, Steinvall, Kobayashi, & Chen, 2016). However, the first practical application of this technology is attributed to Sweden and Great Britain, which between 1968 and 1970 created several models of laser rangefinders and installed them on armored vehicles. In both cases, the rangefinders were based on a solid-state laser with a ruby active medium, which allowed them to accurately measure the range (Danson, et al., 2021). Of the earliest rangefinders, the British Barr and Stroud LRF (1969) should be singled out as the first documented laser rangefinder, that was installed onto armored vehicles as the part of their production process (Barr, 1999, p. 257).

In the 1970s, laser rangefinders became the norm for large armored vehicles such as tanks, completely replacing stadiometric as well as other forms of optical rangefinders. Each country-manufacturer of military equipment has created its own types of such laser devices, mainly based on solid-state lasers with different active media. In the case of the Soviet Union, these were the 1G42, 1G46 and 1G46M gunner's sights. All three systems use solid-state lasers based on quartz active medium; however, modern Ukrainian developments based on these sights explore the possibility of replacing such obsolete systems with diode lasers.

At the same time, lasers began to be used to "paint" targets of various munitions dropped from aircraft. The first laser-equipped targeting pod for the aircraft, the AN/AVQ-10 (Fig. 1), was adopted in 1969 as a part of the "Pave Knife" laser targeting pod bomb system, later being adapted for targeting of various air-to-ground missiles (van Geffen, 2020). The advent of these technologies has revolutionized the tactics of using aviation in the field, as such laser-guided munitions dramatically reduce the required amount of munitions to destroy the designated target, while also allowing such weapons to achieve consistency, accuracy and cost-effectiveness that was impossible to receive when using conventional weapons. NATO forces have used such munitions during the wars in the Middle East and former Yugoslavia, resulting in a general increase in accuracy, as well as a relative reduction of collateral damage to civilian structures (Flemming, Flower, Huantes, & Kennedy, 2017).

Figure 1. AN/AVQ-10 laser targeting pod “Pave Knife” (Bell, 1984, p. 34.)

Soviet developments in this area led to the development of the “Klen-PS” targeting system in 1975, which is still heavily used on close-support aircraft of the post-Soviet states (Rakhmanov, Paltsev, Kibovskiy, & Devisilov, 2014). It should be noted that in contrast to solid-state lasers used in Western designs, the Soviet guidance systems used a semiconductor heterolaser - a rarely used type of laser technology due to its limitations and specifics. Special lasers for aiming and tracking targets are still used today as parts of modern targeting pods such as Litening III, LANTIRN (Fig. 2) and ATLIS II, which use different kinds of lasers - from solid-state to diode lasers, while the most modern systems (such as Sniper ATP) use multimode lasers with different wavelengths to improve their guidance capabilities (Gaitanakis, Vlastaras, Vassos, Limnaios, & Zikidis, 2019).

Figure 2. LANTIRN targeting pod, equipped with a laser (Lockheed Martin, n. d.).

Over time, the lasers used as means of guidance for guided ammunition became small enough to make their usage on the ground feasible. When the reduction in the size of both laser guidance and receiving systems allowed for their use in ground weapons, laser guidance of ground anti-tank guided missiles (or ATGMs) has become one of the most widespread areas of the laser technology usage in weaponry. The pioneers in this field are considered to be the Soviet guidance systems for "Kobra", "Agona" and "Refleks" gun-launched anti-tank guided missiles (GLATGM's), which were implemented in 1976 T-64B tank, and began to be widely used in all Soviet tanks of the 1980s. This guidance principle has since been widely used in anti-tank weapons and is still used for such anti-tank systems as the Ukrainian "Kombat" (Zaloga, 2011, p. 42). As an example, the Ukrainian-made 1G46M "Promin'" tank sight provides the capability for guidance of "Kombat" gun-launched anti-tank guided missiles (Fig. 3).

With the development of laser technology, laser target designators have become compact enough to be used by individual people. Although the first individual guidance systems were extremely cumbersome, the further development of laser technology has allowed for the development of lasers target designators of sizes, sufficient for comfortable use (Lamb, 2018). The first of such laser units was the AN/PEQ-1 SOFLAM, developed in 1996, using a solid-state Nd:YAG laser (Fig. 4). It saw widespread use by US Army special forces in Iraq, Afghanistan, later seeing service with other countries (Rahmani, 2018; Pushies, 2003, pp. 98–99; Neville, 2016, p. 28). Today, laser "pointers" (the moniker for personal laser aiming devices) have become compact enough to be mounted directly on the assault rifles and machineguns of regular army soldiers (Dyer, Smith, & McClure, 1995, p. 4; Gardony & Horner, 2020; Çelik, 2020) – from the US "AN/PEQ-15" (Jevtić, 2020) to the russian "Perst-4".

Figure 3. General view of the "Kombat" GLATGM with it's laser guidance system installed (Ukroboronservice, 2018).

Figure 4. General view of an AN/PEQ-1C SOFLAM (Shepherd, 2007).

Non-lethal direct application of lasers on the battlefield.

One of the first laser systems designed for direct use in combat operations as an independent combat unit was the Soviet 1K17 "Szhatie" (Fig. 5) complex, developed in 1982–1992 – a laser system designed to counter optoelectronic spotting devices of enemy vehicles. Structurally, the laser complex represented a powerful solid-state laser, with the active medium used being a 30 kg artificial ruby crystal.

Figure 5. 1K17 "Szhatie" complex, Military Technical Museum, Ivanovskoye (Halak, 2013).

The 1K17 complex was designed to suppress electron-optical surveillance systems and fire control systems of armored vehicles in harsh climatic and operational conditions. In 1992, the complex was adopted, but only a few were made, as the price of vehicles equipped with 30-kilogram rubies was simply unaffordable for post-Soviet Russia. Additionally, the laser required a lot of energy to work. To power it, a powerful generator, powered by an autonomous auxiliary power plant was installed, which led to the size of the laser system exceeding the dimensions of the main battle tanks of the period (Rakhmanov, Paltsev, Kibovskiy, & Devisilov, 2014).

In military analytical circles, the People's Republic of China is widely known as being one of the first countries to create and use portable laser systems to blind personnel and disable sensitive electro-optical sensors of vehicles. In 1987 and subsequently, in 1995, Norinco showcased the ZM-87 Portable Laser Disturber at arms shows in the United Arab Emirates and later, the Philippines (Roblin, 2018). The

15 MW neodymium solid-state laser that is able to discharge five laser pulses every second, has been specifically designed to be able to inflict permanent eye damage to human eyes at a range of three to five kilometers, along with an additional ability to inflict temporary blindness to a range of up to 10 km. However, due to changes in the international law, only up to 30 weapons have been produced, with their sporadic public appearances until the early 2000s.

Continuation of the development of such technologies in the PRC is represented by the development of a series of laser "dazzlers" – laser systems designed to disable enemy optics and radars, where temporary blindness is only perceived as a side effect, leading to its use to disperse mass gatherings. Thus, the more modern WJG-2002 emits a green laser, which is more harmful to eyesight than the lasers emitting the red spectre. Emitting the laser emission three times per second, the system is reported to be able to cause temporary dizziness and blindness. Manufactured using nylon injection molding technology, WJG-2002 (Fig. 6) has a range of only fifty meters, its built-in battery being able to sustain twenty minutes of continuous emission (Roblin, 2018).

Figure 6. General view of WJG-2002 laser dazzler. (Nathaniel, 2015).

Personnel Halting and Stimulation Response (PHaSR) is a rifle-sized laser weapon system (Fig. 7), developed in 2003–2006 for use in the US military and law enforcement agencies by ScorpWorks, a research contractor in the Laser Division of the Laboratory's Directed Energy Department. U.S. Air Force Air Force Research in Kirtland, New Mexico (Sirak, 2005). This system used two diode lasers that emit in the non-lethal part of the wavelength spectrum: one in the visible wavelength in the green part of the spectrum and one with the wavelength in the infrared part of the spectrum. The laser light generated by this weapon, temporarily blinds them and reducing their ability to effectively resist (Davison, 2009).

Figure 7. Personnel halting and stimulation response dual-laser weapon (Kumar & Dixit, 2019).

Usage of the laser technology in air-defense and missile defense systems:

One of the most important tasks, that laser weapon development aimed to achieve is to protect against missile attacks, caused by the continuous development and improvement of missile technology. The development of high-power laser emitters has opened up new opportunities for combating certain types of missiles, as effective countermeasures against them became problematic to develop using traditional air defense and anti-missile principles.

The USSR was the first country to achieve significant results in this area of research (Shelyagin et al., 2021). The first work in this direction was carried out at the Terra-3 facility, built-in Kazakhstan in 1966–1968. 19 solid-state ruby lasers, one gas photodissociation and one fiber (3D–01) liquid oxygen laser were created at the site. (Demin, 2010) Many works were carried out on the site, such as:

- a pulse laser with a power of radiation equal to 300 kJ was developed;
- the experimental laser locator LE-1 (Fig. 8) was developed and tested;
- an electro-ionization CO_2 laser with 500 kW power capacity was developed and built;
- “explosive” lasers with a pulse power of up to 1 MJ were developed.

The creation of laser weapons, capable of missile defense while covering strategic importance objects from a possible attack by various weapons, including intercontinental ballistic missiles with nuclear warheads was the main goal of the “Terra-3” program (Zemskov, 2012). The task was not completed successfully, as even the construction of the prototype laser point defense system could not be completed. For this reason, in 1978, further research works at the “Terra-3” facility were suspended

(Demin, 2010). However, research and development, carried out in the "Terra-3" complex significantly advanced soviet science and technology on subjects, related to the program. A significant part of the developments on "Terra-3" subsequently found application in other laser system projects of various purposes.

Figure 8. TG-1 telescope of the LE-1 laser locator, built for the "Terra-3" complex, Sary-Shagan test site (Zarubin & Pol'skikh, 2011).

One such application was a complex of studies, carried out aboard the "1A" flying laboratory (also known as A-60) (Fig. 9), built by the G. M. Beriev Design Bureau in early 1977. Onboard this aircraft, a laser system, designed to study the specifics of laser beams propagation in the upper atmosphere, was installed. According to available information, the research in this direction was carried out in broad cooperation of various design bureaus with enterprises and scientific organizations throughout the USSR, the main of which was Central Marine Design Bureau "Almaz", at the time headed by B. V. Bunkin. The IL-76MD plane, chosen as the base aircraft for the creation of the A-60 flying laboratory, underwent significant changes that altered its appearance. Two generators with a summary power capacity of 2.1 MW were installed onboard the aircraft, but unfortunately, the only additional information available about the laser system is that it utilized a CO_2 laser (Apollonov, 2016).

Figure 9. Beriev A-60 “1A” flying laboratory, 1980s (Cenciotti, 2016).

It is known that during the 1984 tests, a series of test fires against air targets ranging from balloons to old La-17 fighters was carried out (Apollonov, 2016). However, according to some reports, the “1A” flying laboratory has burnt down in 1986, while its descendant, the “1A2” flying laboratory, has been used as a transport aircraft for a long period of time; although it is now known that in 2012-2016 the aircraft was refitted with a new set of lasers, with further work in this direction being carried out under the leadership of prof. Stepanov. The possibility of using airborne laser systems to disable satellites is also being considered.

The next project (Pascallon & Dossé, 2012) of Soviet scientists was the creation of 17F19DM “Skif-DM” (Fig. 10) – a truly gigantic space-based CO_2 laser, created in response to a statement by the US Air Force on the planned deployment of nuclear weapons in space (Sönnichsen & Lambach, 2020). Contrary to popular belief at the time, the statement, despite being a part of a purely hypothetical proposal, was purposefully created to misinform the Soviet leadership for the purposes of facilitating wasteful spending of the Soviet defense budget. According to the designers (Merzhanov, 2016), the incredibly heavy 80-ton module designed by “Salyut” was not able to be launched into space for political reasons, while its design solutions that allow the laser to be stable and efficient in space still impress the minds of engineers with their complexity.

Figure 10. 17F19DM "Skif-DM" (Ignatiev, 2007).

Very little is known about the time-equivalent American analogue of the A-60, the Boeing flying laboratory, based on the Boeing NKC-135A: it was used to study the possible application of airborne use of lasers during the Cold War, utilizing a CO_2 laser with a wavelength of 10.6 μm in a series of undisclosed tests (Rogers, 2001).

Much more is known about its descendant – Boeing YAL–1 flying laboratory (Fig. 11), which was revealed to the public in 2003, although its development is told to have begun in 1996. Initially, the laser installation on board of the aircraft consisted of six chemical oxygen-iodine lasers (Fig. 12) with a wavelength of 1.315 μm and a power of up to 1 MW. From 2007 to 2010, a series of successful missile interception tests were conducted, after which it was announced that the tests of this system had been successfully completed (Ganeev, 2014). However, in 2010, due to the reduction of the departmental budget, the project was stopped. The aircraft was finally dismantled in 2014.

Figure 11. Boeing YAL–1 focusing unit (Rubial & Berges, 2012).

An indirect descendant of these developments is the AN/SEQ-3 LaWS: a solid-state laser (Fig. 13) with a 30–150 kW variable power, emitting in the infrared spectrum, designed to combat unmanned aerial vehicles and small ships such as Somali pirate boats. This system was installed on the US Navy destroyer USS Ponce in 2014 (Strecker, 2018; Hecht, 2018), where it tested positive during the annual test, remaining installed on the ship until its departure from the Navy registers in 2018. The 150 kW weapon was installed onboard USS PORTLAND (LPD 27) in 2019 and has successfully disabled a UAV during an at-sea test in 2020 (Hood, 2021, p. 38).

Perspectives of the usage of laser weapons in such applications are confirmed by the fact that the US Army plans to test laser-only systems in the lower levels of the air defense network with the introduction of DE M-SHORAD systems (Fig. 14), equipped with high-energy (HEL) laser with emission power of up to 50 kW (Feickert, 2018, p. 12), for experimental use in the US Army in the latter half of 2022 (Obering, 2019).

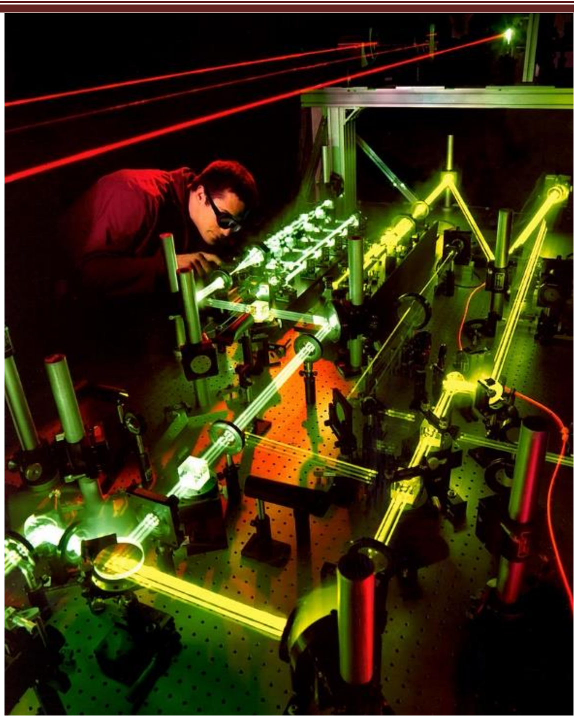

Figure 12. Maintenance of the laser complex mounted abroad the Boeing YAL–1 flying laboratory (Scannell, 2007).

Figure 13. AN/SEQ-3 LaWS aboard USS Ponce (Zabunov & Mardirossian, 2020).

The Ethics of laser weaponry usage.

The use of laser weapons raises many questions not only among scientists, but also in international legal entities, because, according to theoretical estimates, gathered from data about the conflict in Afghanistan (1979–1989), as well as the first Gulf War (1991), widespread use of laser weapons would result in 25 to 50 percent of all human casualties being blinded (Stylianou & Talias, 2014). On the one hand, blindness is considered a "lesser evil" compared to death, however, such permanent trauma changes a person's life forever, severely hampering its capabilities and freedoms.

Figure 14. Raytheon DE M-SHORAD air-defense system on trials (Suits, 2021).

The unconfirmed rumors about the usage of experimental laser weapons by the British Navy during the 1982 Falklands conflict (McCall Jr, 1997; Lazov, Kondratieva, & Dolchinkov, 2019), as well as breakthroughs in laser weapons technology, have led to a number of UN conventions on conventional weapons being held in 1985 and 1995 (Doswald-Beck, 1996). The effectiveness of these resolutions was surprising, as the adoption of these conventions stopped the development and production of several models of laser weapons, the most striking example of which was the Chinese ZM-87, stopping its production entirely, as well as tightening standards for legally acceptable laser weaponry. These moves shifted further developments in this type of weaponry to systems that only temporarily blind enemies, while some other systems were redefined, finding a new application against unmanned aerial vehicles and anti-tank missiles.

Discussion.

In general, all reviews positively consider the prospects for the use of laser weaponry. The Perram, Marciniak, Goda (2004) review stated: *"High energy laser (HEL) weapons are ready for some of today's most challenging military applications. For example, the Airborne Laser (ABL) program is designed to defend against Theater Ballistic Missiles in a tactical war scenario. Similarly, the Tactical High Energy Laser (THEL) program is currently testing a laser to defend against rockets and other tactical weapons. The Space Based Laser (SBL), Advanced Tactical Laser (ATL) and Large Aircraft Infrared Countermeasures (LAIRCM) programs promise even greater* *applications for laser weapons."* The view of this review is supported by the more recent work of Ahmed, Mohsin and Zubar Ali (2021), who believes that: *"Laser weapons have many advantages over traditional weapons. First, the transmission at the speed of light allows laser-based weapons to engage distant targets immediately after detection. Second, the directed laser energy provides less collateral damage and low-profile and covert operations capabilities… Today many types of lasers are available having different power ranges, wavelengths, operating efficacies, spectral bandwidths, and other features. The increase in the maturity of compact optical and laser devices have improved their abilities for military purposes. Consequently, laser technologies have changed the paradigm of modern warfare, by serving in diverse roles, such as indicators & target designators, sensing devices, data relays, active lighting, rangefinders, weather regulators, and directed energy weapons"*. However, judging by the experience of recent research, such as the closure of the YAL–1 program, as well as publicly known recent developments, we can say that these estimates were quite optimistic. This can be attributed to many economic and scientific factors, as well as shifting the focus of work towards the use of laser weapons from strategic to more operational and tactical goals. It is also necessary to mention a large number of problems in the development and production of lasers that need to be addressed, as well as the problems of cooperation between civil and military industries. This is the need for deep cooperation between the civilian and military development process in the Brazilian work by Roso, Moreira and Oliveira, (2014), which stated: *"…according to the evidence of operational applications with laser weapons systems in many conflict situations, a new age in military and civilian cooperation is possible…"*. Hecht (2009) wrote about these same issues: *"Big challenges remain in making high-energy lasers that can fire reliably on the battlefield, with key issues including keeping the optics clean, avoiding optical damage, building durable cooling systems, and making the lasers reliable and affordable. But the task is also vastly easier than SDI's (Ronald Reagan's 1980s program – auth.) goal of building orbiting battle stations capable of blocking a massive Soviet nuclear attack (using lasers – auth.) …"*. However, broadly speaking, there has been significant progress in laser technology, as well as progress in its use as weaponry.

The review shows how laser technology first was used for ancillary purposes (distance measurement and targeting) in the 1960s and 1970s, later the work shifted to a strategic dimension: heavy air defense and anti-missile systems on both sides (USSR and USA) due to military-political opposition to the Cold War period (Terra-3, Skif-DM and SDI), flying laboratories (ALL and A-60) to intercept enemy aircraft and missiles. And only at the end of the Cold War, as well as in the modern era, the focus shifted to improving ergonomics, autonomy and ease of individual use with a comprehensive expansion of laser weapons in search of opportunities for partial replacement of lethal weapons. This makes it possible to point out a few certain key events in the history of laser weapons development, which set the main trends in the development of laser weapons for further development:

1. The first successful installation of a laser rangefinder on a military vehicle (1965) – laser technology is used for auxiliary purposes: range finding, target designation and munition guidance. Solid-state lasers with ruby and glass active media were the main types of lasers used;
2. First successful experiments at the "Terra-3" facility and start of studies that led to the creation of "1A" flying laser laboratory (1973–1975) – laser technology started to be seen as a possible way to form a "missile shield" of the world's superpowers to protect them against the possible nuclear exchange. The overall dimensions of laser complexes used in these applications rose substantially, with a more widespread usage of CO_2 and chemical lasers;
3. The demonstration of ZM–87 at the arms expo in Abu Dhabi (1987) shows that the laser weapons development has shifted to promote its more low–level tactical usage; more and more states have started local developments of laser weaponry for various purposes, including as non-lethal weapons. Various newer laser designs – both diode and fiber – are seeing more widespread adoption.

This method of periodization is considered optimal, because it is difficult to show separate developmental periods of individual areas of technology, because, even as the main developmental focuses shift, the process of continuous modernization and improvement of existing laser systems has never stopped.

Conclusions.

In 55 years, the use of laser technology for military purposes has radically changed the methods of combat operations, becoming an integral part of military affairs. In the process of analysis of the available information on the development of laser weapons, a proposed system to identify turning points in the development of laser technological applications in military equipment, namely – the first installations of lasers in military applications through the installation of auxiliary laser units into military vehicles, studies on the practical possibilities of using lasers as parts of anti-ballistic missile defense systems of superpowers, as well as shift of the focus of development of laser technology towards the small unit tactics and individual use of lasers. It was noted that the changes in the main focus of the laser weapon development are caused not only by the technological progress, but also the changes in the attitude to the possibility of usage of lasers as a possible weapon, as well as the military and geopolitical situation in the world.

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Історія розвитку лазерних технологій у військовому застосуванні

Анотація. *Дана робота посвячена вивченню прогресу та відомих використань лазерних технологій у військовій продукції – від перших спроб в допоміжних застосуваннях до сучасних комплексних систем. Для кращого розуміння та систематизації знань про розвиток застосувань лазерів у військовій галузі було проведено аналіз публічно відомих знань щодо їх історичних застосувань у провідних країнах світу. Дослідження фокусувалось на розробках, що проводились супердержавами ери "Холодної війни" та сучасності, а саме США, СРСР та КНР та були побудовані в металі. Було розглянуто багато напрацювань з різних застосувань лазерних технологій у військовій продукції, а саме: військові лазерні далекоміри; наземні та авіаційні цілевказівники; системи наведення керованих боєприпасів; нелетальні системи придушення ворожої живої сили; системи, призначені для виведення з ладу оптико-електронних приладів військової техніки; а також системи протиповітряної та протиракетної оборони стратегічного та тактичного рівня. Для підведення висновків та порівняння результатів було проведено аналіз ряду попередніх праць, які розглядали історичний розвиток, перспективи та проблеми прогресу лазерного озброєння. При цьому було розглянуто питання етичного використання лазерного озброєння та ризики його використання у збройних протистояннях, що призвели до міжнародного консенсусу у вигляді конвенцій ООН та Міжнародного Комітету Червоного Хреста. У результаті проведеного аналізу було запропоновано систематизований підхід до класифікації застосувань лазерних технологій у військовій продукції за трьома основними напрямками розробки: допоміжні застосування, нелетальна пряма дія на організм людини та оптичні пристрої військової техніки, а також протиповітряні та протиракетні лазерні комплекси. Через постійну всебічну модернізацію систем, де використовуються лазерні технології, вирішено не використовувати періодичну модель класифікації, а зазначити важливі та ключові події, які вказали на напрямок подальшого розвитку. При цьому важливо зазначити, що напрямок розвитку лазерного озброєння залежав не тільки від технологічних обмежень того часу, але й від військово-геополітичної ситуації у світі.*

Ключові слова: *лазерне озброєння; лазерні далекоміри; лазерні цілевказівники; нелетальне лазерне озброєння; протиракетне стратегічне лазерне озброєння; історичний огляд*

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The front line transporter as the embodiment of the USSR military doctrine in the middle of the 20th century

Abstract. *The paper based on a source analysis of the history of creation, design, and production of LuAZ-967, LuAZ-967M, against the background of the processes of implementing projects of small tactical high mobility wheeled vehicles for the armies of European countries, shows that the developing, testing, and commissioning a front line transporter became a deepening of the process of motorization of the Soviet army. The designs of similar vehicles have been analyzed. An attempt to assess the degree of uniqueness of the front line transporter design and its place in the history of technology, as well as its potential as a reminder of science and technology has been made. The experience of using various civilian and military vehicles in the army required the creation of a special small transporter. In each of the countries, developing their designs, embodying new original or time-tested ideas, ones developed vehicles both for the army and for separate armed forced formations. Features of the automotive industry of the countries were reflected in the design of army vehicles. The works and operation Volkswagen Type 82, Volkswagen Schwimmer Type 166, DKW Munga, Volkswagen Type 181 in the armed forced formations in Germany had a significant impact on the spread of the concept of an army small transporter. In France, production of a licensed sample of Willys and the original Citroën Méhari was launched. The Steyr-Daimler-Puch vehicle (Austria) has become one of the most original, successful developments of a small transporter for difficult operating conditions. The development of a front line transporter in the USSR fully corresponded to the challenges of the time and it was carried out through similar stages. The first transporter projects developed by the Scientific Automotive Institute used heavy motorcycle engines mastered in production. It was the lack of the necessary engine for the vehicle that was the main reason for the long proof of the project. Only after the involvement of the designers of the automobile plant in Zaporizhzhia and the installation of units of the mass-produced ZAZ vehicle in the transporter made it possible to prove the design and to master small-scale production. The use of the most powerful engine of a production vehicle, which would correspond to the concept of a* *small army vehicle, had enabled to master mass production for the army and the development of vehicles for the civilian market. An analysis of the front line transporter design, its systems, compared with its foreign counterparts, suggests that it is a Soviet refinement of the concept of a small army vehicle, a more specific means directly for the battlefield. At the same time, it was developed taking into account foreign developments and similar designs, imitating individual designs, adapting to the capabilities of the USSR automotive industry.*

Keywords: *history; museology; vehicle; transporter; design; Lutsk Automobile Plant*

Introduction.

Since the end of the 19th century, a wide variety of vehicle models have been created: high-speed, all-terrain, comfortable, and ascetic ones. But among them, there are not many vehicles that will remain in history, known not for popularity, but for their unique concept and its execution – those who amaze with their simplicity and refined pragmatism. A front line transporter (FLT) – *LuAZ-967* – just such a vehicle. The idea of its creation appeared in the 50s of the 20th century.

Analysis of recent research and publications.

To date, there are practically no scientific works on an objective, thorough study of the history of a front line transporter creation. Unfortunately, only in recent years there has been an increase in interest in objective coverage of the automotive technology history. The number of works is growing, which not only highlights the history of creation, the activities of engineers, but determines the significance of a particular vehicle in the history of the world automotive industry.

When researching the history of the creation of a vehicle, researchers often resort to simplification, arguing that this vehicle was not an independent development, but it was developed under the influence of some foreign vehicle, choosing the subject of copying at their own discretion (Bathory, 2016; Akppwiki, 2018). There are works where the FLT is called a completely Soviet original machine created independently, without taking into account foreign developments, based only on the needs of the Soviet army or, in particular, the airborne troops (Ryabinin, 2020). In most works of modern researchers, the issues of originality or copying of the design of a vehicle and its components are not the subject of research (Kharuk, 2019). More often, researchers pay attention to certain aspects of the FLT design, its original features, and compare it with Soviet cars (Homutinkin & Trigub, 1989; Kochnev, 2017; Kuts, 2018). Today, the research of technology from the standpoint of its museumification and the presentation of the history of the technology development are being updated. The topic is studied both by professional museum workers and monument historians (Griffen, 2014; Karpov, 2014; Honcharova& Pustovalov, 2019) and by collectors and restorers on the pages of periodicals, mainly electronic ones. In such works, questions of research, restoration, storage of equipment as museum artifacts are raised systematically, but at the level of generalizations. The works of collectors, restorers, and researchers of the history of vehicles, on the contrary, are characterized by in-depth detailing, a narrow subject focus.

Research methods.

In the proposed work based on the experience of operating the *LuAZ* vehicle, analysis of the FLT design, its visual study, reports from open sources and a retrospective review of the development of military vehicles in European countries, an attempt to objectively determine the share of original ideas and borrowings has been made. Directions for further scientific research have been outlined in order to clarify the facts and to eliminate inaccuracies and lies. The main stages of the evolution of its design and introduction into serial production have been specified and systematized. Certain important aspects of the restoration and preservation of the FLT have been updated. The history of the development and modernization of a front line transporter, a description of the unique elements and components of the design will help researchers and collectors to restore and to store quite rare vehicles in museums and collections.

It should be noted that in the USSR, considerable attention was paid to the operational familiarization with the latest engineering developments in the field of automotive industry abroad. This was not in doubt and was constantly confirmed in the industry abstract journals, in specialized literature, and popular science publications. The publication was reported primarily to specialists about the latest developments. If it was necessary to study the development in depth, which had prospects for military use, they tried to purchase it directly from the manufacturer. In cases where it was impossible to do this, to purchase through third countries or to steal. A comparative analysis of the design, performance characteristics of the front line transporter and the same type of light vehicles from other countries will eliminate the errors of individual researchers who limited themselves to comparing purely external design features, design elements, finishes, and the vehicle configuration. The comparison of the process of implementation and use of light military vehicles in Europe and the USSR will reveal the features of domestic experience and the degree of compliance with the development of the global automotive industry. Comparison of the stages of the process of developing the concept of a light army vehicle of individual European countries and the Soviet FLT should take place only taking into account the specifics of the development of the automotive industry, engineering activities, taking into account the peculiarities of the historical development of countries.

Results and discussion.

By the beginning of the 30s, a special vehicle for the army (an army vehicle) was not created in the USSR, in accordance with the specific conditions of military operation. Unfortunately, army vehicles were not given due attention even in the second half of the 30s of the 20th century, during the years of the so-called “industrial mobilization”. The country tried to adapt civilian *GAZ* and *ZiS* vehicles for military needs. However, in terms of cross-country ability, carrying capacity, maintainability in the field, simplicity, reliability, they were far from full-fledged military vehicles. That is why, during the Second World War, the Red Army moved in *Studebakers*, *Willys*, *Dodges*, *Fords*, transferred under Lend-Lease, and in captured vehicles.

The operation of such a variety of equipment has enriched the engineers with invaluable experience based on which, after the War, the development of systems for the motorization of the army was intensified. Developing the idea of motorization of different types of troops and armed forced formations, original ideas were embodied, in particular, those that did not pass the test of long-term operation. It was at that time, the end of the 40s – the beginning of the 50s, that the auxiliary-propelled gun *SD-44*, *SD-57* appeared (Skomorokhov, 2018). A motorcycle engine was mounted on the gun carriage with a drive to the wheels of the gun. The engine with a gearbox was supposed to allow the artillery crew to simplify the movement from the tractor to the combat position and its change. The extreme simplification of the design, asceticism, reliability, efficiency, the power of the artillery system – these criteria were difficult to combine in one vehicle.

In general, by the beginning of the 50s, the designs of various army vehicles were well known in the USSR, in particular, simple, ascetic, cheap and technologically sophisticated, powerful, original, floating, military vehicles. Moreover, the Red Army had experience in operating such vehicles (Aleksandrov, 2020). For example, military variants of the *Volkswagen Type 82* (Fig. 1) and *Schwimmer Type 166* (Fig. 2), which were not as massive as the *Willys* or *Dodge ¾*, were used as long as ones could be repaired and spare parts were available.

Figure 1. *Volkswagen Type 82* (Volkswagen Kübelwagen, n. d.).

These small vehicles could go where it was difficult to go and, in some places, it was impossible. *Schwimmer 166* (*German* “float”) was the most massive amphibian of its time (Volkswagen Kübelwagen, n. d.). These vehicles, due to their unique capabilities, were widely used by Wehrmacht intelligence.

Figure 2. *Volkswagen Schwimmer Type 166* (Volkswagen Schwimmwagen, n. d.).

Despite the post-war devastation in Europe, the trend towards increased mobility of armed forced formations has continued. Motorization had to be done with limited finances and resources. For this, there were two ways of implementation: the adaptation of serial civilian vehicles and the development of new original army vehicles. Each country chose its own path. Some countries have tried to go both ways.

In France, after World War II, licensed Willys were manufactured for the army (Varfolomeev, 2021). The same path was followed in Japan, South Korea, and India. Moreover, France also had original developments. The *Citroën Méhari* (1968–1987) (Fig. 3) vehicle is based on the *Citroën Dyane 6* with maximum simplicity and manufacturability (Citroën Origins, n. d.). The vehicle had a troughing plastic body with plastic hinged panels and a soft top (Citroën Origins, n. d.). It was driven by a 26–29hp two-stroke engine. In general, the vehicle was designed for recreation and had only front-wheel drive, but the farmers liked it, it was also used by the police and hunting services. In this regard, since the 70s, its all-wheel drive version has been produced (Voenteh , n. d.).

In the Federal Republic of Germany, invaluable experience in the production and operation of "pelvis" – or "float" –type vehicles (*Volkswagen Type 82*, *Schwimmer Type 166*) has led to the continuation of work on the development and implementation of a new army light vehicle. In 1956, the new all-wheel drive *DKW MUNGA* began to enter the army. Mehrzweck Universal Gelendewagen Allradantrieb is a multi-purpose, universal, off-road, all-wheel drive vehicle (Fig. 4) (Kanunnikov, 2013). Unlike its predecessors, which had a rear-engined layout (*Volkswagen Type 82*, *Schwimmer Type 166*), (Fig. 4) the engine in MUNGA was placed in its front part. The engine is a three-cylinder two-stroke one with a power of

38hp. It has four-speed gearbox with transfer case and center differential. This is a vehicle with a simple, angular body with corrugated stiffeners, a soft top, a folding windshield, and a canvas door on a tubular frame.

Figure 3. *Citroën Méhari* (Citroën Origins, n. d.).

Figure 4. *DKW MUNGA* (Kanunnikov, 2013).

The vehicle *DKW MUNGA* had a mass of 1,085kg and could carry a load of 385kg, overcome a ford of 0.5m without preparation, and reach a maximum speed of 98km/h. The engine power has been constantly increased and the latest models already had 44hp. In small quantities, a modification was made with an extended base, which could already carry up to 690kg of a cargo. A total of 46,750 such vehicles were manufactured, about 31,000 units of which were sent to the army (Kanunnikov, 2013). The vehicle has been sold in the civilian market since 1957. Since 1958, the vehicle has been produced in Brazil for the local market (Kanunnikov, 2013). By the mid-60s, the vehicle no longer met the requirements of the military, primarily in terms of power, carrying capacity, and spaciousness.

In the mid-50s of the 20th century, NATO member countries, according to the adopted military concept, had to optimize the military-industrial complex and to solve the problems of military, defense doctrine to the maximum unify weapons and military equipment or to develop such models that would satisfy the armies of all members of the Alliance. Similar work was carried out in the direction of the development of small arms, aircraft, tanks, light armored vehicles, vehicles.

In the 1960s, France, West Germany, and Italy were building the *Europa Jeep*, a light all-wheel drive amphibian. Work on the project required a lot of time, so in Germany, ones decided to create a temporary replacement for the *DKW MUNGA*. The *Volkswagen Type 181* (Niedermeyer, 2010) continued the concept of the “pelvis” (Kubelwagen) in the layout of the main components (Fig. 5).

Figure 5. *Volkswagen Type 181* (Niedermeyer, 2010).

It was rear-wheel drive and rear-engined. The vehicle was developed with a wide use in the design of components, mechanisms, and parts mastered in mass production of vehicles. The design was based on the components of serial models: the *Beetle’s* engine, the *Karmann Ghia’s* bottom and the body part, the *Transporter’s* rear suspension. Wheel reduction gears have been introduced into the transmission to increase ground clearance. The vehicle retained the concept of a simple body with longitudinal punching to strengthen the panels. The roof is soft, but the door is already a metal one. The vehicle has been produced in Mexico and Indonesia since the early

70s. The *Volkswagen Type 181* was purchased and used by the armies of Austria, Belgium, Denmark, France, Morocco, the Netherlands, Greece, and Turkey (Niedermeyer, 2010).

In 1979, the *Europa Jeep* project was closed and the Bundeswehr began to purchase new military light four-wheel drive vehicles *Volkswagen Type 183 Iltis* (Kutz, 2018).

In Austria, the Steyr-Daimler-Puch Company in the second half of the 50s created an army light vehicle called the *AP 700 Haflinger*, which, after testing, was put into service (Fig. 6) (Fedorov, 2020a). The vehicle embodied the concept of a cheap, reliable, simple army all-terrain vehicle for mountainous terrain.

Figure 6. *AP 700 Haflinger* (Fedorov, 2020a).

An open vehicle had a mass of 500kg and could carry 4 people or a cargo with a total mass of 500kg. The all-wheel drive vehicle was driven by a two-cylinder four-stroke air-cooled engine with a power of 27hp; its layout was rear-engined. The engine was located under the cargo platform. Under the platform, there are two throwback seats in niches. The front seats also throwback. As a whole, the design is more than ascetic in nature. The open vehicle provided for the installation of a canvas top and tubular doors covered with canvas – to improve the conditions of the movement. The windshield swung forward. The minimum comfort and heating of the windshield was provided by an autonomous gasoline heating system (All Oldschool, 2020). Despite the low engine power, the vehicle, due to independent wheel suspension and a 4- and later – 5-speed gearbox, had a high cross-country ability. Its maximum speed on the highway was 75km/h. However, due to the low placement of the engine, the maximum ford without preparation was 0.4m. The latter completely satisfied the military, because the vehicle was primarily intended for mountain infantry units. Its low center of mass increased durability. The vehicle overcame a slope of 65%. A large-caliber machine gun or a 57mm open chamber gun, or a *Bantam* anti-tank missile system, was installed on the vehicle. Some samples were equipped with a winch with a force of 1.5 tons or a power take-off shaft to drive tools: a mechanical saw, a snow plow (Goll, 2003). During 1959–1974, 16,647 vehicles were manufactured. The equipment was used by the armed forces of Austria, Switzerland, Sweden, the Netherlands, Britain, and Australia.

The concept of the *Haflinger* developed in two directions. In the direction of increased power and all-terrain capability, the concept was embodied in the *Pinzgauer* all-wheel drive all-terrain vehicle, which has been mass-produced since 1971, in the direction of simplification, weight reduction – in cargo platforms and vehicles *Military M274 Truck Platform Utility* (USA), *FAUN Kraka-640* (Germany).

So, the creation of a light vehicle in Europe after the Second World War can be divided into stages. The first one is the development of a light military vehicle based on motorcycle components for maximum simplicity and low cost. The second one is the creation of an army vehicle using systems and components of serial civilian vehicles. With the development of military equipment and weapons, the requirements for army light vehicles have changed. However, the developed automotive industry made it possible to quickly develop and to mass-produce a new vehicle, in accordance with the requirements. The highly developed automotive industry allows to quickly adapt the design of a military vehicle to the needs of the civilian market. Conversely, a purely civilian vehicle that interested the military quickly received an army version.

The conflicts in China (1946–1949) and Korea (1950–1953) and the participation of the USSR in them revealed the need for small, simple, cheap high mobility wheeled vehicles that could both drive to advanced positions and take personnel and cargo out of them. For covert movement, the vehicle had to have a low silhouette; for cross-country capabilities on the battlefield, it had to be light, reliable, and, therefore, simple and effective. In order to increase mobility, the ability to swim was considered desirable. The probable theater of military operations for which the Soviet army was preparing included, first of all, Europe with a developed network of small lowland rivers. So, the ability of the vehicle to overcome the river on the move was incorporated into its concept.

A new light army vehicle began to be developed at the Scientific Automotive Institute (Moscow) in the second half of the 50s of the 20th century. After experimental work, the prototype was completed by Chief Designer Boris Futterman in 1957 (Fedorov, 2020a). According to other sources, the prototype was demonstrated to the military in 1958 (Kharuk, 2019, pp. 68–69).

A two-cylinder engine of a heavy motorcycle with a capacity of 22hp was installed on a low flat body in front and all-wheel drive was equipped. The concept of installing a motorcycle engine was known in Europe for creating the same type of vehicles and allowed to accelerate the development of a special vehicle, as well as the development of small-scale production, making it economically feasible. However, low engine power did not provide an opportunity to realize the constructive potential of the vehicle and complicated its operation. In 1959, the development of the model was transferred to the Zaporizhzhia Automobile Plant. The vehicle has received its completed form due to the Zaporizhzhia designers and was first manufactured under the name *ZAZ-967* (Fig. 7) (Fedorov, 2020a) since 1961.

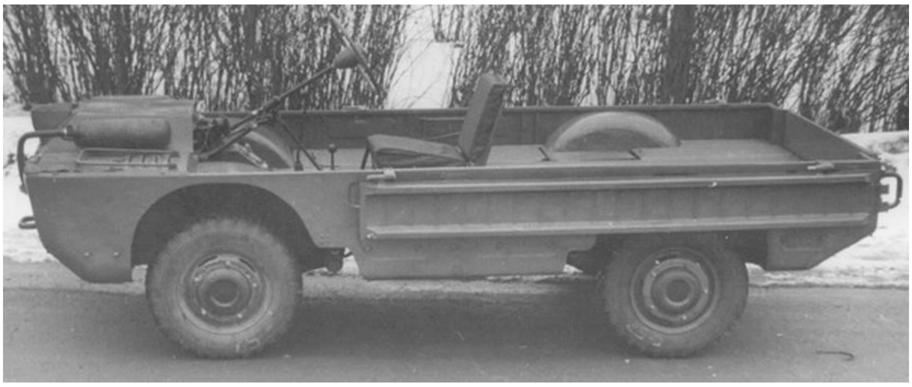

Figure 7. *ZAZ-967* (Fedorov, 2020a).

Without changing the general concept of the vehicle, the main components of the *ZAZ-965* mastered in production were introduced into its design. So, the vehicle received a Melitopol air-cooled engine (MeMZ) that meets the specified criteria of simplicity and reliability. By the way, most military vehicles of this class were equipped exclusively with air-cooled engines by that time (see above). Such an engine has significant advantages in simplicity, reliability, and weight. A *ZAZ* gearbox was installed on the FLT, but its secondary shaft was lengthened to equip the drive to the rear wheels. The vehicle received its final form until December 1967, when its production was transferred to the Lutsk Automobile Plant (Fedorov, 2020b). Since 1968, a small-scale production of the vehicle has begun in Lutsk under the name *LuAZ - 967*.

In 1969, *LuAZ-967* was put into service. In 1972, the vehicle received a more powerful 37hp engine and under the name *LuAZ-967M* it was introduced into mass production in 1975 (Fig. 8 and Fig. 9) (Akppwiki, 2018; Dvorzhak, 2020).

In addition to the engine, the braking system and individual body elements underwent minor changes. A step-down gearbox is attached to the gearbox by a separate unit, thus the cross-country ability of the vehicle at a “belly” speed has been increased. The reduced (“belly”) speed allowed moving only forward. Since, according to the concept, the engine was placed in front of one block with a gearbox, therefore, wheel reducers were introduced into the design. The engine and gearbox from the *ZAZ* vehicle have rear-engined layout. If these nodes were placed in the front-engine layout without modification, the vehicle would have 4 rear speeds and 1 front one. The introduction of wheel reducers is a forced measure in order to change the direction of the wheel rotation, but this is what has strengthened the all-terrain capability. Wheel reducers allowed to increase the ground clearance to 285mm, to improve cross-country ability and a torque transmission. At that time, army *GAZ* and later *UAZ* were made with wheel reducers, but of a different design. The *LuAZ* torsion bar suspension is somewhat more difficult to manufacture, but it is extremely reliable, it is not for nothing that this type of suspension is used on most Soviet tanks, tracked armored vehicles, and armored personnel carriers.

Figure 8. *LuAZ-969M*, front view. (Author's photo).

An interesting solution was the rear-wheel drive in the *LuAZ-967*. The drive shaft rotated in the pipe "to create a rigid connection system – the power unit – the gearbox of the rear axle" (Homutinkin & Trigub, 1989, p. 135). The shaft in the pipe was placed on three bearings. The pipe was fixed rigidly through a threaded connection on four studs on the side of the rear axle and on the side of the gearbox. Grease is poured into the pipe to lubricate the bearings. The shaft transmits torque from the toothed shank through a compensating coupling with internal teeth. The design allows to place the power unit, the gearbox clutch, and the rear axle on only three supports, gives additional rigidity to the body. The design somewhat resembles the invention of Hans Ledwinka – a vertebral frame, which is used in the transmission of vehicles *Tatra* and *Pinzgauer* (Long, 2016, pp. 22–23). However, on the *LuAZ*, the body elements are not attached to the pipe. The pipe connects the gearbox engine and the bridge into one unit and reduces the load on the body. The system is implemented to facilitate maintenance and to repair, to reduce the number of cardan connections, and to improve reliability. The units are easy enough to replace even in the field. It is interesting that the introduction of the rear axle differential lock not only improved the vehicle's cross-country ability, but also increased its reliability. In the event of a breakage of three cardan connections with gearboxes, the FLT could move on 1 surviving rear one with a locked differential.

Figure 9. *LuAZ-969M*, rear view. (Author's photo).

Separately, it is worth noting the design of the body of the neoclassical automobile type. The FLT driver was placed in the middle – a tribute to amphibiousness. Behind him, on the sides of throwback seats, which could be folded to free up space for cargo or install stretchers with the wounded along the sides. Such placement did not worsen the buoyancy of the low-sided body. In order to reduce the silhouette on the car, the windshield was thrown forward – this is often used on army equipment. The steering column could be folded, and the driver could drive the vehicle lying on his stomach – it was for the first time. The dashboard is located in such a way that even lying down, the driver can see the instruments. A searchlight was attached next to the steering column. The body liner for strengthening is corrugated with longitudinal blankings – at that time, very common for such vehicles. The body is waterproof. The output of the drive shafts is made through rubber cuffs. A water pump is installed to pump out water when it enters the body. After leaving the water, it was necessary to unscrew the body plugs and to drain the water. The same would have to be done with the wheel gears – to drain the water until the oil starts to flow out. An entrenching tool (an axe, a shovel) was fixed on the vehicle. Small ladders were attached to the sides of the body for the vehicle to leave the water or to move through funnels, trenches, etc. The ladders could serve as an additional container for 20 liters of fuel. A winch with a cable of 100 meters and a pulling force of 150kgf is mounted ahead. Quite often in the world, military vehicles were equipped with winches, which are designed to increase the cross-country ability of vehicles, to pull them out of the mud, to clear rubble, etc. To do this, the winches developed a significant traction force, for example, individual modifications of the *Haflinger-700-AP*. In *LuAZ*, this device was supposed to help pull up the wounded on a stretcher, that is, it helped to do the work of an ambulance orderly. Consequently, it did not have the necessary effort for self-pulling. Additional equipment included a radio direction finder and radio beacons, through which the orderlies on the battlefield could quickly find the wounded. Radio beacons were distributed to the wounded during the first visit of the FLT for the wounded (Fedorov, 2020b). Thus, the vehicle could perform the widest range of work on the battlefield, fully consistent with the name of the front line transporter. It is interesting that the vehicle versatility was manifested even in the fact that the plates with a red cross on the sides were removable and fixed in special grooves.

Thus, the front line transporter concept evolved from a light motorcycle-powered vehicle to a machine using production vehicle components. With the improvement of the FLT design, its capabilities have improved, the equipment has improved quantitatively and qualitatively, and the range of its applications has expanded. The external elements of the body as blanking, the placement of auxiliary equipment was natural in terms of maximum simplicity, manufacturability, and strength of the structure and the specifics of use.

The FLT production began at the Lutsk Automobile Plant in 1961. Since 1967, the FLT has been completed (Fedorov, 2020b; Kochnev, 2017). On the basis of FLT 1965, a civilian version of the vehicle was developed under the name *ZAZ-969V*. In December 1966, a pilot batch of 50 pieces was made (Homutinkin & Trigub, 1989, p. 3). For about a year, the vehicle was produced under the name *ZAZ-969V*. On December 11, 1967, by order of the USSR Ministry of Automobile Industry, the Lutsk Machine-Building Plant was renamed into the Lutsk Automobile Plant (Homutinkin & Trigub, 1989, p. 4). Accordingly, the vehicles manufactured by the plant were called *LuAZ* instead of *ZAZ* while maintaining the model number.

The civilian vehicle developed on the front line transporter basis inherited the main systems and components from its military “brother”, but with the features inherent in a civilian vehicle (Fig. 10) (Polazhynets, 2019). Autonomous gasoline heating made it possible to warm up the engine for starting in the cold season, which was not the case on other civilian vehicles. There was no winch in the civilian *LuAZ*. The refusal of buoyancy made has led to equip the body with three doors (two on the sides and cargo one – at the rear part of the body). Cheapness in production is embodied in the angular outlines of the body. The body had a canvas top. Behind passenger seats could fold along the sides, turning the vehicle into a small truck.

The vehicle was offered for residents of the countryside and sold in the market in 1985 at a price of 5,100 rubles USSR (Polazhynets, 2019). Such a price is almost 1,000 rubles USSR more expensive than *ZAZ 968M*. By the way, the *ZAZ-969V* is the first domestic (within the former USSR) front-wheel drive vehicle. Index “V” meant “temporary” (Polazhynets, 2019). Due to difficulties with the manufacture of the rear axle, temporarily, during 1966–1968, the *LuAZ-969V* was produced with a drive to the front wheels only (Homutinkin & Trigub, 1989, pp. 3–4). After solving problems with debugging the production of the required number of rear axles, the plant has launched the *LuAZ-969* into mass production.

Figure 10. *ZAZ-969* vehicle, since 1967 – *LuAZ-969* (Polazhynets, 2019).

Thus, due to an attempt to organize mass production of the front line transporter, Ukraine has received another automotive plant in Lutsk.

LuAZ-969V and *LuAZ-969V* corresponded to the world trends of that time in the automotive industry – the production of military and civilian models in parallel. For example, at the Volkswagen plant, along with the production of a passenger vehicle for the military, the *Volkswagen Type 181*, its adapted civilian version was produced. Even outside the *LuAZ-969* body was very similar to the *Volkswagen Type 181*, which was produced since 1968 – similar blankings on sides to enhance the rigidity of the body, the same ascetic, angular shapes, and extreme simplicity.

Since 1979, the civilian, updated *LuAZ-969M* has been put into serial production (Homutinkin & Trigub, 1989, p. 5). Basically, the body has undergone changes, namely, the front part, and the brakes were upgraded. With the development at the *Tavria* mass production at ZAZ, the Lutsk Automobile Plant has started the production of *LuAZ-1302* with a water cooling engine and the corresponding reproduction of the underhood space and the passenger compartment.

The *LuAZ-967 FLT* was produced until 1991 and its civilian version – until 2002 (Kharuk, 2019, pp. 59-60). The FLT was used not only in the troops. After the withdrawal of the Soviet troops from Germany, a significant number of these transporters were sold to the market from warehouses and storage bases. After the collapse of the USSR and the reduction of the army in the former Republics, the FLT also went in the market as excess property. Adventure travellers, hunters liked them very much and over time, they began to replenish private vehicle collections. With the development of the vehicle design, with the growth of military and civilian requirements for them, with the improvement in the vehicle qualities in terms of comfort, power, speed, an acute discrepancy between the *LuAZ-967M* and the new requirements has appeared. The FLT has moved into the category of "curiosities", later – "rarities", "exhibits".

The *LuAZ-967 FLT* has exhibited in many museums of technology, both in Ukraine and abroad. The *LuAZ* army version can be seen more often than a civil one at various exhibitions and festivals of vintage cars, where they cause the interest of visitors.

The *LuAZ* was filmed in a feature movies: *Citizen Nikanorova is Waiting for You* (1978, Mosfilm, directed by Leonid Maryagin), *Men's Company* (1992, Intercom, Tonis, directed by Andrey Rostoksky), *Okhlamon* (1993, Turkmenfilm, directed by Eduard Rejepov), *Nuclear Zone Ranger* (1999, Kinomost Film Company, directed by Vyacheslav Nikiforov), *Birthday of the Bourgeois 2* (2001, NTV-Profit Film Company and "1+1" Studio, directed by Anatoly Mateshko), *Love as an Accident* (2012, Media Trade Union, directed by Alexander Kananovych) – civilian version of *LuAZ*; *Resident's Return* (1982, Gorky Film Studio, directed by Veniamin Dorman), *Oracle Reception* (1992, TO "Eurasia", directed by Georgy Kuznetsov), *The 9th Company* (2005, PC "Slovo", Art Pictures Group, CTC Channel, directed by Fedor Bondarchuk) – the FLT version.

Today, individual examples of the FLT are in military service. In 2014, one refurbished FLT was transferred to the battalion of the Patrol Service of the Ministry of Internal Affairs "Peacemaker" (Channel 5, 2014). In 2018, the 93rd Kholodnyi Yar SMBr operated the FLT with ATMS launchers installed (Censor, 2018), that is, mobility, cross-country ability, reliability, stealth movement of the FLT finds its scope today.

Conclusions.

Thus, the idea of creating a front line transporter is a practical embodiment of the military concept of the Soviet Army in the mid-50s and 60s, according to the probable theater of operations. The FLT development was carried out taking into account the development of the light army vehicle design in Europe, but without its copying. The FLT history includes the main stages of the development of a light army vehicle, characteristic of Western European countries. However, the development of the light army vehicle concept in Europe was embodied in different vehicles of several manufacturers for three decades. In national history, all this is embodied in one FLT. *LuAZ-967* and *LuAZ-967M* have no analogues in terms of performance characteristics. The front line transporter is the original USSR embodiment of a light army vehicle.

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Транспортер переднього краю як втілення військової доктрини СРСР середини XX ст.

Анотація. *В статті на основі джерелознавчого аналізу історії створення, конструкції та виробництва "ЛуАЗ-967", "ЛуАЗ-967М", на фоні процесів реалізації проектів малих армійських автомобілів підвищеної прохідності для армій країн Європи показано, що розробка, випробування та впровадження у виробництво транспортера переднього краю стало поглибленням процесу моторизації радянської армії. Проаналізовано конструкції аналогічних автомобілів. Здійснено спробу оцінити ступінь унікальності конструкції транспортера переднього краю і його місце в історії техніки, та потенціал як пам'ятки науки і техніки. Досвід використання різноманітних цивільних та військових автомобілів у військах викликав потребу у створенні спеціального автомобіля малої вантажопідйомності. В кожній з країн розробляючи свої конструкції втілюючи нові оригінальні чи випробувані часом ідеї розробляли автомобілі для армії так і для окремих армійських підрозділів. Особливості автомобілебудування країн відображались у конструкції армійських авто.*

Значний вплив на поширення концепції армійського автомобіля малої вантажопідйомності мали роботи в Німеччині та експлуатація в армійських підрозділах "Volkswagen Type 82", "Volkswagen Schwimmer type 166", "DKW Munga", "Volkswagen Typ 181". У Франції було налагоджено виробництво ліцензійного зразка "Willys" та оригінального "Citroën Méhari". Автомобіль фірми "Steyr-Daimler-Puch" (Австрія) став однією з найбільш оригінальних, вдалих розробок автомобіля малої вантажопідйомності для важких умов експлуатації. Розробка транспортера переднього краю в СРСР цілком відповідала викликам часу і проходила аналогічні етапи. Перші проекти транспортера розроблені Науковим автомоторним інститутом використовували освоєні у виробництві двигуни важких мотоциклів. Саме відсутність необхідного двигуна для автомобіля стала основною причиною тривалого доводження проекту. Тільки після залучення конструкторів автомобільного заводу в Запоріжжі та встановлення в транспортері вузлів масового автомобіля "ЗАЗ" дозволило довести конструкцію та освоїти малосерійне виробництво. Впровадження більш потужного двигуна серійного автомобіля який відповідав концепції малого армійського авто дозволило освоїти серійне виробництво для армії та розробку авто для цивільного ринку. Аналіз конструкції транспортера переднього краю, його систем порівняно з його іноземними аналогами дозволяє стверджувати, що він є радянським доопрацюванням концепції малого армійського автомобіля, більш специфічним засобом безпосередньо для поля бою. Водночас він розроблявся з оглядом на іноземні розробки та аналогічні конструкції з перейманням окремих конструкції, з адаптацією під можливості радянського автопрому.
Ключові слова: *історія; музеологія; автомобіль; транспортер; конструкція; Луцький автомобільний завод*

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Study of development of regional railway system in Bukovyna

Abstract. *The article is devoted to the study, generalization and systematization of scientific knowledge about the history of the establishment, development and operation of the regional railway system in Bukovyna in the second half of XIX – early XX centuries. The authors attempted to analyze the process of creation and operation of railways in Bukovyna during the reign of the Austro-Hungarian Empire based on a wide range of previously unpublished archival documents, periodicals, statistical literature and memoirs. The article studies the development of organizational bases for the construction of railways, the activity of the communication network management, lists a whole range of requirements and tasks set for railway transport in Bukovyna, the progress of their implementation, considers successes and difficulties in this work. It is determined that private railways, as important transport arteries of Bukovyna, were of national importance and played a significant role in the transport system of Austria-Hungarian Empire. They served the leading economic districts of Bukovyna, acting as an integral part of production in each of them. In other words, they were used for development of local, intersectoral and interregional relations. Regional railways, first of all, played an important role in the social and economic life of Bukovyna region.*

In most cases, they did not carry the strategic cargo, but made it possible to connect the most remote corners of separate areas of the region into a single whole. In practice, local railways were a significant addition to the main central line, providing the latter with a greater intensity of cargo and passenger turnover and thus increasing their profitability. At the same time, the trade volume between the outskirts and the center of the Austro-Hungarian Empire was increased. It contributed to the intensification of economic development of certain districts of Bukovyna region.
Keywords: *Austro-Hungarian Empire; Bukovyna; Chernivtsi; railway transport; regional railway; development history*

Introduction.

The history of various aspects of the life of the Austro-Hungarian Empire was and remains, for many researchers, the object of special attention and the source of constant scientific discussions and disputes (Bulutgil, 2017; Soroka, 2018; Choliy, 2020). Among the complex problems of the historical past of Austro-Hungarian Empire, the matter of development and function of its railroad system is of great interest to historians (Kun, 2019; Fesovets, 2020; Bali, 2014). And it is not an odd thing, as the thorough study of the work of railway transport allows us to identify the fundamental laws of internal development processes of any country, to comprehensively characterize its socio-economic, military, and, in many ways, political state, etc (Hurinchuk, 2019; Strelko & Pylypchuk, 2021a; Strelko & Pylypchuk, 2021b; Strelko, Berdnychenko, & Pylypchuk, 2021). The same can be said about the history of railway transport in the vast expanses of Austro-Hungarian Empire as a whole and its separate regions, Bukovyna, for example. It is explained by the fact that railway communications have always played a crucial role in the implementation of mass transportation of people and cargo, organically combining the interests of people and the economics (Li, Wen & Jiang, 2017; Păun, 2017; Voicilaş, 2017).

For Bukovyna, the period from the second half of the XIX – beginning of the XX century was marked by a significant development of domestic and foreign trade, the growth of the rural and urban population, the strengthening of ties between the city and the village, and the growth of productive power. All the above-mentioned processes indicated a gradual transition from the feudal mode of production to the capitalist one (Dobrzhanskyi, 2017; Lipelt, 2018; Purici, 2017).

In Bukovyna, the communication routes were developed and improved within the frame of the system of progressive capitalism. And this is understandable. After all, it is impossible for the capitalism with its commodity nature of production, the search for profitable sales markets and sources of raw materials to function normally without a good communication network. The state of this network has huge influence on the level of development of transport, which makes up the fourth sphere of material production along with the extractive industry, agriculture and processing industry. In the end, all this is reflected in the overall social, economic and cultural development of the country or any of its separate region. This fully applies to such a wonderful land as Bukovyna.

We are convinced that a comprehensive study of the history of Bukovyna railways will allow us to better understand the state and level of development of the railways of Eastern Europe as a whole, to understand their significance in the economic and cultural development of Bukovyna region. Such a study will make it possible to determine the specifics of the development of railway transport in Bukovyna, its general and distinctive features in comparison with other regions. This will also make it possible to determine the phenomenon of the construction of a railway system in Bukovyna region, which was almost fully developed at the beginning of the twentieth century. The railways remained mostly unchanged with its general features preserved to this day.

Goal of study is to research, generalize and systematize scientific knowledge about the history of the establishment, development and functioning of the regional railway system in Bukovyna in the second half of the XIX – early XX centuries.

Research methods.

Until now, historical science practically ignored the questions of the system of communication routes, in particular railway transport in Bukovyna. The existing scientific researches devoted to the railways of Bukovyna highlight only some aspects of the operation of railways without an organic combination of economic and strategic functions (Soroka, 2018; Kun, 2019; Bali, 2014; Cioanca, 2019). Therefore, under these circumstances, there is an objective need for a thorough study of the railway transport system of Bukovyna during the Austro-Hungarian period. Such an approach gives the opportunity to eliminate a number of unresolved issues that are insufficiently covered by historians and organically associated with the development and functioning of Bukovyna regional railway system in 1866–1918.

Results and discussions.

The study of the history of regional railways in Bukovyna in the late XIX – early XX century is of particular interest for understanding the processes of improvement of transport links in Bukovyna, the economics and the formation of financial capital in Austria-Hungary. The specifics of the construction of regional railways, which required attracting large long-term investments, dictated the need to seek help from banks. Hence the close and strong connection of railway enterprises with banks. That is why, on the example of private railway transport, one can more clearly follow the process of how "banks grow from a modest role of intermediaries to all-powerful monopolists", see the emergence and development of financial capital and methods of its management.

The problem of transport construction and the role of regional railways in the economy of Bukovyna in the 80s of the XIX century in particular as well as its operational subordination were to some extent the subject of research of I. V. Zhaloba (Zhaloba, 1991, p. 17). Having introduced into scientific circulation the materials of various funds from the archives of Chernivtsi, Vienna, Lviv, Zhaloba came to the conclusion that "the initial prerequisite for the development of railways in Austrian Empire, including Bukovyna, was the intensive development of capitalism immediately after the revolutionary events of 1848–1849. Besides this starting point there were other factors that led to the construction of railways in the region. Among them there are the desire of Vienna government to ensure its own military, political, commercial and economic interests of the Austrian bourgeoisie in Eastern Europe, and the need to draw Bukovyna more closely into the state and economic system of Austria-Hungary" (Zhaloba, 1991, p. 15).

It is known that Lviv – Chernivtsi railway was opened on September 1, 1866 (Kaim, Taczanowski, Szwagrzyk, & Ostafin, 2020) and its extension to Suceava was opened on October 28, 1869. The construction of the first Bukovyna railways was carried out by various foreign construction companies after lengthy negotiations on the construction of tracks, railway stations, access roads, etc. "Local and foreign capitalists were interested in the improvement of Bukovyna's transport links, they sought to facilitate the pumping of raw materials from this rich Bukovyna region and the import of industrial goods from the parent state and developed European countries" (Nussbaum, 1950, p. 114). It is clear that transport system construction in Bukovyna accelerated the development of capitalist relations in the regional economy and at the same time became the basis for strengthening of the colonial and imperialist exploitation of the region's working population.

The period of rapid construction of tracks, bridges, railway stations, stations, various technical structures, etc. lasted in Bukovyna for more than three decades – from 1865 to 1898. During this time, the main agricultural areas, timber and rafting points of Bukovyna received access to seaports and the railway system of neighboring states – Romania and the Russian Empire. In addition to the first railway Lviv – Chernivtsi – Iași, whose length was 144 km and which met all the above mentioned needs, this was further facilitated by the construction of a regional railway system, which began its development in the 80s of the XIX century.

If we scratch just the surface of the question of development of the railway system in Bukovyna in the second half of the XIX century, then we'll get the following picture. The first railway Lviv – Chernivtsi – Iași provided an opportunity for Bukovyna's agricultural and local products to reach Romania, Galicia and the central regions of the Austro-Hungarian Empire. Chernivtsi – Novoselytsia railway was built in 1883–1884, its length reached 131 km (Zhaloba, 1990). It connected Bukovyna with the Russian Empire and facilitated the export of Bukovyna forest to the Russian Empire and the import of Russian grain to Bukovyna's mills, as well as carried out transit transportation of Russian bread to Europe through Bukovyna. Hlyboka – Beregomet (on Seret) railway with a length of 53 km with a side line – Karapchev – Chudey (19 km) was constructed in 1886. This railway connected the main line Lviv – Chernivtsi – Iași with the deep timber and livestock areas of Northern Bukovyna. At the same time, the railways were built that connected Chernivtsi with Vashkivtsi, Vyzhnytsia (Nepolokivtsi – Vyzhnytsia line), Luzhany and Zalishchyky (Chernivtsi –

Zalishchyky line). These railways provided Chernivtsi with agricultural products of the agricultural regions of Northern Bukovyna. They were also used to transport timber for further transportation to the Russian Empire.

The critically important stage in the development of transport links between Bukovyna and neighboring states was the connection of the region's railway system with the railways of the Russian Empire and Romania. This connection became possible in 1893 due to the construction of tracks between Novoselytsia and Bălți, Bălți and Odesa. In addition, traffic was opened in the direction of Novoselytsia – Mohyliv-Podilskyi – Zhmerynka – Kyiv. After Chernivtsi railway was connected to one of Novoselytsia, and then with the Russian south-western railway, this railway was removed from under the management of Bukovyna Railways Joint-Stock Company and became a state-owned railway. The following data indicate the cargo turnover of Bukovyna railways: the railways of the Bukovyna region transported 6 million tons of various cargo and 1.35 million passengers in 1895 (Zhaloba, 1990). These railways used 120 railcars.

However, the increase of railway construction did not last long. Following a thirty-year period of relatively revived railway construction in Bukovyna in the last quarter of the XIX century, a period of complete inactivity in this area came. New tracks were no longer built, and many areas of the region, especially mountainous ones, were not covered by the railway system. In general, the direction of railways pursued purely imperialist goals of foreign capital in Bukovyna. As a rule, the tracks were lied out from the center of Bukovyna – Chernivtsi city – to areas that produced agricultural and forest products for export. Due to these circumstances Chernivtsi, which itself also had a favorable geographical position in the south-west of the Austro-Hungarian lands, turned into an important shopping center that carried out export operations not only in Bukovyna, but also in Bessarabia and Moldova.

Nevertheless, the pace of railway construction in Northern Bukovyna lagged far behind the pace of railway construction in other states, for example, in the Russian Empire, Germany, Austria-Hungarian Empire itself, etc. Thus, the railway system of Bukovyna grew from 114 km to 400 km in the period from 1865 to the end of the XIX century, that is it became 3.5 times longer. During the same time, the length of the railways of the Russian Empire increased more than 7 times, Germany – 12 times (in the period from 1845 to 1875), England – 6 times (in the period from 1845 to 1875) (State Archives of Chernivtsi region. Fund 3, Inventory 2, Case 194, Sheets 198; State Archives of Chernivtsi region. Fund 3, Inventory 1, Case 5392, Sheets 1–2).

As a result of the railway construction in Bukovyna, the development of capitalist relations in the regional economy accelerated. At the end of the XIX century, a more rapid development of industrial production began, a number of enterprises processing agricultural raw materials were built, and the forestry and woodworking industry was developing. Most of the products of these industries were exported. At the same time, the improvement of transport links with more developed countries led to increased competition of industrial goods of these countries with products that were produced in

Bukovyna. Under these conditions, home production almost completely disappeared. At the end of the XIX century, a period of decline in crafts began. In general, this was the picture of the social and economic life of Bukovyna in the late XIX – early XX century, outlined by the development of the railway system of the region. Lviv – Chernivtsi – Iași railway, which crossed Bukovyna from Northwest to Southeast, significantly increased trade in the Bukovyna region, but more so did the construction of regional railways. Here is what I. V. Zhaloba says about this: "Local railways have played the important role in the social and economic life of the region. In most cases, they did not carry the strategic cargo, but made it possible to connect the most remote corners of separate districts of the region into a single whole. Such railway tracks were a significant addition to the main railway line, providing the latter with a greater intensity of cargo and passenger turnover and thus increasing its profitability. At the same time, increased trade between the outskirts and the center was achieved, since existing transport obstacles were largely eliminated. Even such goods, which were not even transported previously due to the difficulty of transportation on unpaved roads and significant horse-drawn tariffs, are started to be delivered. This applies to the direction of both from the center to the outskirts, and vice versa. In addition, there was another winning point for the outskirts: they could transport low-value cargo and goods that were not previously exported due to their low profitability. With the emergence of railways, it was more profitable for their boards to transport cargo of even insignificant profitability than to drive empty cars. This has had a positive impact on the economic intensification of regional districts. Of course, the construction of railway tracks did not automatically lead to the development of the local economy – favorable local conditions were needed that could enhance the impact of the new transport means and give a positive result. The cultural and political consequences of the construction of regional railways should also be mentioned. The railways, as a complex type of economic activity, were equipped with modern means of communication – telephone, telegraph. With their help, remote areas gained access to operational information, not to mention the delivery of periodicals and the like" (Zhaloba, 1996).

In the early 70s of the XIX century, one of the most acute and exigent issues in the government circles of Austria-Hungary and military circles, among the commercial and industrial bourgeoisie and landlords, in public publications was the question of immediate measures for the fast development and construction of regional railways in Bukovyna region. The motivation to build these railways arose due to two reasons. On the one hand, it was due to the economic state crisis of 1873, which put an end to the participation of private capital in large-scale railway construction. On the other hand, it was the fact that the main railway lines had already been built and therefore the issue of building of regional railways was on the agenda in government circles. That is why the Ministry of Commerce approved the law on the status of regional railways on May 25, 1880 and the order of the on the status of regional railways was issued on May 29, 1880. According to this law, the decision-making process for the construction of regional railways was simplified, and the measures on facilitation of its operation were determined. This law has been repeatedly supplemented by various legislative acts, as evidenced by the literature data (Strelko & Pylypchuk, 2021a; Strelko & Pylypchuk, 2021b; Strelko, Berdnychenko, & Pylypchuk, 2021). It is clear that these legislative provisions prepared the legal basis, within the frame of which the construction of regional railways in Bukovyna began in the future. In general, the system development plan is based on the priority requirements of the region's economic development. The system of these railways was supposed to connect the agricultural inner districts of Bukovyna with Chernivtsi and with the central railway line thought the shortest route.

The experienced Austrian engineers believed that the network of regional railways should meet the following conditions:

1) to open the shortest ways for agriculture, cattle breeding, forestry, etc. enterprises to sell their products, with access to the central railway line of Bukovyna;

2) to build the shortest connection between the forest districts of Southern Bukovyna and ones of Northern Bukovyna, so the former ones could receive food transported with these railways;

3) to connect some settlement centers of Bukovyna to Chernivtsi and among themselves;

4) to provide the entire railway system with fuel, mainly firewood, and also carry this fuel at affordable prices for use in Eastern Galicia.

The local railways had to meet military and strategic tasks – "the possibility to quickly move and concentrate troops on the borders of the Empire, especially in the south-eastern direction (with Romania and the Russian Empire)" (Russian State Historical Archive, Fund 207, Inventory 3, Case 162, Sheets 138–143; Russian State Historical Archive, Fund 1272, Inventory 1, Case 19, Sheet 3).

The first regional railway in Bukovyna was Chernivtsi – Novoselytsia railway. It was one of the largest regional railways. It connected Chernivtsi with the city located on the border of the land that then belonged to Russian Empire, it crossed the rich and densely populated area of Northern Bukovyna and through Novoselytsia connected with the Russian fertile lands – Bessarabia and Podillia. The construction of Chernivtsi – Novoselytsia railway made it possible to export Bukovyna forest to the southern regions of the Russian Empire, and Bukovyna imported agricultural products from those regions.

The construction of this railway was preceded by almost a decade of struggle between supporters and opponents of the construction of such a long and expensive local line to the border with the Russian Empire. The most far-sighted statesmen and representatives of the Austrian bourgeoisie advocated the construction of this railway, which would facilitate access to the Russian Empire and would benefit the military and political as well as economic interests of Austria-Hungarian Empire. In its turn, Bukovyna Chamber of Commerce and Industry also repeatedly appealed to the Ministry of trade of Austria-Hungarian Empire with a proposal to quickly connect Chernivtsi-Suceava line with Russian railways, as well as with Hungarian railways (via

Maramureș – Sziget). According to the Chamber, this would make it possible to speed up transportation of goods from Bukovyna, Podillia, Bessarabia and north-eastern Romania and reduce its cost. In addition, the opinion of I. V. Zhaloba deserves special attention. I. V. Zaloba claims that "despite the significant progress made by Lviv-Chernivtsi-Suceava railway in the transport industry, its financial situation was initially very shaky, and it had an unstable financial balance. Under these conditions, the Railway Board was actively looking for a way out of the current situation. In his opinion, one of the main reasons for this situation was the lack of free access to the Russian Empire through Novoselytsia and Tomaszów" (Zhaloba, 1996). However, it was only on June 5, 1883 that Bukovyna entrepreneurs and landowners A. von Petrino, N. von Mustatsia, G. Popper, S. Stepanovych and J. von Zottia received permission for the construction of Chernivtsi – Novoselytsia railway. The first meeting of the founders of Local Railway Chernivtsi – Novoselytsia Joint-Stock Company - the first local joint-stock railway company in Bukovyna was held as soon as on July 15, 1883 (State Archives of Chernivtsi region, Fund 300, Inventory 1588, Sheet 1–3).

The state and Lviv – Chernivtsi – Iași Railways Joint-Stock Company participated in the creation of the share capital through purchase of shares.

The construction of Chernivtsi – Novoselytsia railway was carried out by the Austrian company "V. Knauer and E. Gross", which was considered to be very competitive and professional as it also simultaneously built railways in Eastern Galicia. The supervision of the quality of construction was carried out by Lviv – Chernivtsi – Iași Railways.

The construction of Chernivtsi – Novoselytsia railway was completed fairly quickly. Several factors contributed to this: weather, favorable geographical location and enthusiasm of builders. The largest part of work was done only on the one segment - near Boiany village, where it was necessary to carry out large – scale earthworks related to Prut River. There an impressive earth embankment was raised and protective structures were constructed. According to the plan of the builders, this segment of the railway was also supposed to prevent the spread of flooding at Prut river and stop soil erosion. The rails were supplied from Teschen enterprises, oak sleepers and crushed stone for the railway track were supplied by Bukovyna enterprises.

The first test locomotive raced from Chernivtsi to Sadhora along the 7.5 km segment on May 11, 1884 (Eigenverlag der Bank, 1914, p. 35). However, the entire line from Chernivtsi to Novoselytsia was put into operation on July 12, 1884. This 31 km long railway was built in just a month. The stations were opened at Zhuchka, Sadhora, Boiany and Novoselytsia. The railway was designed for a speed of 25 km per hour, two three-axle tender locomotives were constantly operating on this railway (Ziffer, 1908, p. 47).

Lviv – Chernivtsi – Iași Railways Joint-Stock Company took the management over Chernivtsi – Novoselytsia railway after it was put into operation. According to the Treaty dated July 27, 1883 and its annex dated June 5, 1884, this railway was given in the management of the Joint-Stock Company for 20 years. However, the state began to carry out the management of its operation and operation of the central lines in favor of the owners, as early as 1889. And yet the last railway with all its property was bought by the state in 1894. Thus, since January 1 of this year, it has fallen into the category of state-owned railways – the railways that were owned and operated by the state at its own expense (State Archives of Chernivtsi region, Fund 300, Inventory 2, Case 41, Sheet 2; Fund 300, Inventory 2, Case 41, Sheets 4; Fund 300, Inventory 3, Case 111, Sheets 10–18, Sheets 54–55).

The connection of Austrian and Russian railways in Novoselytsia was the important milestone in the development of the local railway Chernivtsi-Novoselytsia and the event that has long been sought by Bukovyna business circles. Back in the late 80s of the XIX century Russian newspapers in Bukovyna made it known that the Russian government intended to build Novoselytsia-Lipcani-Kruty railway (to connect it with the railway line to Odesa) and Novoselytsia – Mohyliv-Podilskyi – Zhmerynka railway (to connect it with the railway line to Kyiv). On May 24, 1889, the Presidium of the regional administration of Bukovyna wrote in this regard to the Ministry of Commerce: "The railway connection with the Russian Empire through Novoselytsia will be of the major significance for Bukovyna, especially in matters of trade" (State Archives of Chernivtsi region, Fund 3, Inventory 1, Case 5392, Sheets 1–2).

The importance of such a connection was also noted by Russian travelers, who visited Bukovyna at that time. In Particular, V. Krestovskij wrote about this: "...this railway will gain commercial and industrial significance only when it connects with the line of the Russian railway, which is currently under construction, as it will connect Chernivtsi with Odesa. As a result, the Austrian Bukovyna will gravitate even more towards Russia and receive the main benefits of transit that is now going exclusively through Romania to Galați. Then most of the cargo will be sent to Odesa after this route will free them of the overhead costs of double loading in Galați and Sulinsky road, as it is often, if necessary, practiced at the present time" (Krestovskij, 1891, p. 93). Both Lviv – Chernivtsi – Iași Railways Joint-Stock Company and Bukovyna Regional Railways Joint – Stock Company (Local Railway Chernivtsi – Novoselytsia Joint – Stock Company was renamed into Bukovyna Regional Railways Joint – Stock Company at the Extraordinary General Meeting on October 5, 1885 in connection with the adoption of a concession for the construction of a number of other railways) were interested in such a connection and expected to significantly improve their financial situation due to an increase in cargo and passenger turnover. This connection was also a major point in the plans of the Russian side. The products from Podilsk, Bessarabia and Kherson enjoyed wide sales in the Austrian provinces of Western Europe, and Russian South-Western Railways enjoyed the profit from their transportation and from the transit of Austrian goods, primarily Galician and Bukovyna forests to the Black Sea coast. The first consultations concerning this matter were held in the early 90s of the XIX century. They ended in holding of international conference in Kyiv in January 1893. At this conference Bukovyna Regional Railways Joint – Stock Company was represented by E. A. Ziffer, who at that time held the position of Vice-President. The connection of railways in Novoselytsia district in June 1893 was the result of the reached agreements (State Archives of Chernivtsi region, Fund 297, Inventory 4, Case 4, Sheets 2–3). However, the construction of Russian railway lines, which were supposed to provide access from Novoselytsia to Odesa and Kyiv, were not completed. They were put into operation in stages, as construction was completed: August 30, 1892 – Zhmerynka – Mohyliv; December 5, 1892 – Slobodka – Rîbnița; November 12, 1893 – Bălți – Ocnița, Mohyliv – Ocnița and Ocnița – Lipcani; December 3, 1893 – Lipkany – Novoselytsia and, at the end, August 21, 1894 – Rîbnița – Bălți (Statistik der in dem im Reichsrathe vertretenen Konigreichen und Landern im Betriebe gestannen Locomotiv-Eisenbahnen, 1902, pp. 70–71). The only 1,225 km long double – track segment in Bukovyna was built here: one with a width of 1,435 m and the second – of 1,532 m. The first was used exclusively for the passage of Austrian trains, and the second one – for the passage of Russian trains in the direction of the Austrian Novoselytsia and back (Statistik der in dem im Reichsrathe vertretenen Konigreichen und Landern im Betriebe gestannen Locomotiv-Eisenbahnen, 1902, pp. 70–71). Chernivtsi – Novoselytsia railway produced the largest profit among the railways of Bukovyna after connection with Russian railway lines (State Archives of Chernivtsi region, Fund 297, Inventory 1, Case 1042, Sheets 1–7).

The construction of Lviv – Chernivtsi – Iași and Chernivtsi-Novoselytsia railways was only the first step in establishing of a railway system in Bukovyna. Naturally, the region's needs for a reliable communication network in the context of improving trade relations were much broader. Lviv – Chernivtsi – Iași railway crossed the Eastern part of Bukovyna that was the most densely populated and flat terrain of the region. However, it, as well as Chernivtsi – Novoselytsia Railway, did not touch the forest storeroom of the region – its main wealth, which gave the main revenues to the regional budget. Of course, this state of affairs caused complaints from Bukovyna business community, primarily entrepreneurs of timber industry. The lack of own capital did not allow to undertake independent significant railway construction projects. At the same time, if the western part of the region could use convenient waterways and the eastern part could use unpaved roads for transporting forest (due to the proximity of Lviv – Chernivtsi – Iași railway), the middle part of the region felt an acute need for a railway to be built there (Bodnarchuk, 2018; Hrytsenko, 1959). This also had corresponding consequences in forestry. The reports of “The forest section of the Agricultural Association of the Dukedom of Bukovyna” showed that in the early 80s of the XIX century only 30–40% of the annually cut forest was sold; only 20–30% of tree trunks went to the production of shingles and sawn timber, and the remaining 70–80% remained to rot. Such valuable forest varieties as, for example, beech were sold as firewood. Such material could be successfully used in other sectors of the economy, in particular, for the production of railway sleepers.

There was also another task that was no less important: to lay railways deep into the region and thus to improve economical use of the region, to strengthen the entrepreneurial spirit there. This would simultaneously facilitate provision of residents of mountainous areas with grain and, in the opposite direction, facilitate the export of livestock and products of the local handicraft industry. In order to resolve this situation, the Austrian government issued a concession for the construction and operation of regional railways on August 29, 1885. It included the following regional railways: Gatna – Câmpulung, Hlyboka – Beregomet with a line of Karapchiv – Chudey and Halikfalfa – Radivtsi with a total projected length of 150 km.

At the extraordinary general meeting of Local Railway Chernivtsi- Novoselytsia Joint – Stock Company that was held on October 5, 1885, it was decided to accept this concession and simultaneously rename the company (as indicated above) (State Archives of Chernivtsi region, Fund 297, Inventory 1, Case 1041, Sheets 2–3). The capital required to build these lines was estimated at 13.3 million guldens. Along with other interested parties, Lviv – Chernivtsi – Iași Railway, the Orthodox Religious Foundation and the regional administration of Bukovyna took part in its creation. The construction was carried out by Karl Meger & K company (State Archives of Chernivtsi region, Fund 297, Inventory 1, Case 1041, Sheets 2–3).

The construction of these railways was performed at a fairly rapid pace. Just almost a year later, on November 30, 1886, 53 km of the Hlyboka – Beregomet railway with Karapchiv – Chudey line (19 km) was put into operation. The following stations were opened on the line from Hlyboka to Beregomet: Hlyboka, Karapchiv, Storozhynets, Sloboda-Komarivtsi, Zhadova, Lukavets and Beregomet, as well as stops in Ropcha and Pantsi (now Kalinivka village of Storozhynetskyi district). Two stations were built in Petrivtsi and Chudey and a stop in Kuptsi on the Karapchiv – Chudey branch (Ziffer, 1891, p. 96).

After the construction of Hlyboka – Beregomet railway line began, a concession was granted for the construction and operation of 9 km of wood-transport line from Beregomet railway station to the steam sawmill in Mezhybrody. Its construction was carried out simultaneously with Hlyboka – Beregomet railway line and was completed on December 21, 1886 (Studnytskyi, 2017, pp. 72–82).

At the end of the 80s of the XIX century, the local railways of Southern Bukovyna were also put into operation: 67-kilometer long Gatna – Câmpulung line — on May 1, 1888; 8-kilometer long Halikfalfa – Radivtsi line – on November 17, 1889; as well as 20-kilometer wood-transport Vama-Rus-Moldavytsa line – on August 15, 1889 (Worobkewicz, 1893, p. 116).

Under the relevant agreements Lviv – Chernivtsi – Iași Railway Company carried out the operation of Hlyboka – Beregomet – Mezhybrody and Gatna – Câmpulung railway lines. After the company was subordinated to the state administration in June 1889, all the above-mentioned railways, as well as those, whose construction was completed after the specified period, were transferred to state management. From that time until the beginning of XX century, they were in the category of private railways, the operation of which was carried out by the state at the expense of the owners (State Archives of Chernivtsi region, Fund 300, Inventory 1, Case 279, Sheets 1–2).

Thus, at the beginning of 1890, the total length of the railways of Bukovyna Regional Railways Joint – Stock Company was 208 km. The amount of 14.7 million guldens was invested in them (Denkschrift anlasslich des 25-jahrigen Bestandes der Aktiengesellschaft "Bukowinaer Lokalbahnen", 1908, p. 8).

Conclusions.

The period of rapid construction of tracks, bridges, railway stations, stations, and various technical structures, etc. lasted in Bukovyna for more than three decades – from 1865 to 1898. During this time, the main agricultural areas, timber and rafting points of Bukovyna received access to the seaports and railway systems of neighboring states – Romania and the Russian Empire. But this goal was achieved not only due the construction of the first railway Lviv – Chernivtsi – Iași that was 144 km long and met all of the above mentioned requirements, but also due to the construction of a regional railway system of the region, which began to develop in the 80s of the XIX century.

It is determined that private railways, as important transport arteries of Bukovyna, were of national importance and played a significant role in the transport system of Austria-Hungarian Empire. They served the leading economic districts of Bukovyna, acting as an integral part of production in each of them. In other words, they were used for development of local, intersectoral and interregional relations.

Regional railways, first of all, played an important role in the social and economic life of Bukovyna region. In most cases, they did not carry the strategic cargo, but made it possible to connect the most remote corners of separate areas of the region into a single whole. In practice, local railways were a significant addition to the main central line, providing the latter with a greater intensity of cargo and passenger turnover and thus increasing their profitability. At the same time, the trade volume between the outskirts and the center of the Austro-Hungarian Empire was increased. It contributed to the intensification of economic development of certain districts of Bukovyna region.

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Дослідження історії формування мережі регіональних залізниць на Буковині

Анотація. *Стаття присвячена вивченню, узагальненню та систематизації наукових знань про історію становлення, формування та функціонування мережі регіональних залізниць на Буковині у другій половині XIX – на початку XX століть. На основі широкого кола раніше не опублікованих архівних документів, періодичних видань, статистичної літератури та мемуарів, автори здійснили спробу проаналізувати процес створення та функціонування залізниць на Буковині періоду правління Австро-Угорської імперії. У статті досліджено становлення організаційних основ спорудження залізниць, діяльність механізму управління комунікаційною мережею, перелічено цілий комплекс поставлених перед залізничним транспортом Буковини вимог і завдань, хід їх виконання, розглянуто успіхи і труднощі у цій роботі. Встановлено, що приватні залізниці, як важливі транспортні артерії Буковини, мали загальнодержавне значення і відігравали значну роль в транспортній системі Австро-Угорщини. Вони обслуговували провідні економічні райони Буковини, виступаючи в кожному з них складовою частиною виробництва. Іншими словами, з їх допомогою здійснювалися місцеві, міжгалузеві і регіональні зв'язки. Регіональні залізниці, в першу чергу, відігравали важливу роль в соціально-економічному житті буковинського краю. В більшості випадків вони не несли на собі вантажу стратегічного призначення, але давали можливість з'єднати в єдине ціле найвіддаленіші куточки окремих областей. Практично місцеві (локальні) залізниці були значним доповненням до основної трансмагістральної лінії, забезпечуючи останній більшу інтенсивність вантажо- і пасажиро обороту і підвищуючи таким чином їхню рентабельність. При цьому досягалося посилення товарообміну між окраїною і центром Австро-Угорської імперії. Разом з цим відбувалася інтенсифікація економічного розвитку окремих районів буковинського краю.*

Ключові слова: *Австро-Угорщина; Буковина; Чернівці; залізничний транспорт; регіональні залізниці; історія створення*

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The integration of 3D technology for the conservation and restoration of ruined archaeological artifacts

Abstract. *The restoration and conservation of monuments and archaeological sites is a delicate operation. It requires fidelity, delicacy, precision and archaeological authenticity. The aim is to reveal, recreate as accurately as possible the characteristics of an archaeological site or part of it. Research during the last two decades has proved that 3D modeling, or the digital documentation and visualization of archaeological objects in 3D, is valuable for archaeological research. As well, as for conservation and presentation to a wide audience, as it allows the creation of realistic and accurate digital copies of archaeological objects. In the past, 3D modeling technologies were prohibitively expensive and too technologically specialized to be integrated into most historical heritage projects. However, advancements in computing and digital photography over the past decade have resulted in several low-cost, user-friendly options for 3D modeling, using photogrammetry. The latter has been used successfully for documentation of historic cultural. In recent years, this technology has become increasingly more popular for archiving, which provide the 3D model and digital ortho-image using high accuracy dense 3D points. The study has opted for the technique of terrestrial and aerial photogrammetry by 3D surveys of architectural* *elements, to develop an archetype of the deteriorated Islamic Marinid site (a dynasty between the 13th and 15th centuries), and the Roman site (25 BC), located at the Chellah archaeological site in Rabat and Salé cities. However, the recognition of the importance of these Islamic sites, in terms of the evolution of Moroccan Islamic art, requires the combination of large-scale scanning capability of unmanned terrestrial, aerial photogrammetry and the photorealistic rendering of 3D, as well as exhaustive research on the history of this cultural site. The data acquired build an architectural database to archive and retrieve the entire existing architecture of monuments. This study has been completed by photogrammetrists, architects, and restorers.*

Keywords: *cultural heritage; photogrammetry; survey; architectural archiving; 3D reconstruction ; museology*

Introduction and research aims.

Unfortunately, Moroccan cultural heritage, despite its high potentials, such as many monuments, archaeological sites and valuable scientific data, has hardly benefited from the use of digital and new technologies. Therefore, the implementation of Photogrammetry for documentation, analysis and dissemination of archaeological findings to archaeologists is essential to make cultural heritage in Morocco accessible to the human community more easily and scientifically through these techniques. It enables us to produce accurate information on objects. Providing a 3D model of these monuments and sites can be a good way to document and record these works as they provide geometric measurements and extract quantitative information with good accuracy, which can be used to prepare restoration plans.

These methods are able to provide digital documentation and 3D modelling of historic monuments (Martin, Meynard, Pierrot-Deseilligny, Souchon, & Thom, 2017). Also, to generate 3D and 2D models, and, tips for virtual recovery of cultural heritage. Nowadays the world loses its heritage identity faster than they can be documented (Thomas, 2017). There is a particular need for technical guidance on recommended workflows, from data capture through to archiving based, if possible, on free software. This will greatly reduce the cost in terms of research and expense in the commercial sector and will ultimately lead to an enhanced record and understanding of our archaeological heritage (McCarthy, 2014).

In the last years, Photogrammetry was used for aerial and terrestrial applications largely motivated for the conservation of cultural heritage monuments (Hill, 2019). Terrestrial laser scanning technology allows fast and efficient collection of 3D coordinates of cultural heritage object automatically (Yastikli, 2007). The terrestrial Photogrammetry by camera photo is generally the most used technologies to virtually reconstruct the entity geometry of the monuments (Thomas, 2017). Using low-cost equipment like digital camera proved to be adequate to promote cultural heritage over the web such as virtual reality (Koutsoudis, Arnaoutoglou, & Chamzas, 2007).

Historical documentation using UAV-based images a significant time-saving compared with traditional measurement techniques (Colomina & Molina, 2014). The cost of UAV systems is major factors that determine the budgets of cultural heritage documentation projects (Bakirman et al., 2020). Loaiza Carvajal and al. (Loaiza Carvajal, Morita, & Bilmes, 2020) recommended that close range objects reconstructed by digital Photogrammetry allow an exact reconstruction, with micrometric resolution and a high-quality texture, used in the case of institutions that require the digitization of objects of heritage value. Also, Himasari Hanan and al. recommended that close range Photogrammetry techniques provide flexibility in data acquisition as the non-metric camera can be operated by almost anyone and more affordable (Hanan, Suwardhi, Nurhasanah, & Bukit, 2015). Compared to other 3D modelling techniques, they deliver a variety of data, from 2D images of photographs, dense point clouds, the geometry of the object and solid 3D model.

The choice of the appropriate method for 3D modelling is very important in the documentation, because the product model must also have the desired detail, in addition to being accurate(Alby & Grussenmeyer, 2012). This paper presents, an approach combining digital camera, UAV and image data, to model and reconstruct architectural features; in order to provide sufficient and comprehensive data regarding the documentation and evaluation of Abu AlHassan's Madrasa, and the Roman remains located at the archaeological site of Chellah. Also, the Madrasa Al-Marinia in sale city (13th century). This will allow us, through the documentation and archiving of these historical data, to determine the physical damage in order to provide the necessary intervention and conservation methods.

Study sites.

Our chosen study sites (Figure 1) located in Salé city (Morocco) and, on the Chellah archaeological site in Rabat city (capital of Morocco); this site offers conditions conducive to human occupation from the earliest antiquity (7th-6th c. BC) (Terrisse, 2011). In 2012 it was added to the United Nations Educational, Scientific, and Cultural Organization (UNESCO) world heritage list (https://whc.unesco.org/fr/list/1401) (Salih & Amrani, 2012). The first site is the Marinid Madrasa of Abu Al-Hassan which is a Quranic school serving as a college and a student residence (Boukous, 2011; Shatzmiller, 2011). The second site is Madrasa Al-Marinia; it was built in the first half of the 14th century under the reign of the Marinid Sultan Abu al-Hassan ben Uthman, in the city of Sale near of the city of Rabat (Pennell, 2003). These Madrasas served a cultural, educational and political role (Belhaj, Bahi, & Akhssas, 2017), they were erected to deserve the favors of Allah, to do religious and God-pleasing work, to restore religious teaching and science, and to strengthen the political power of the rulers (Belhaj et al., 2017; Daniotti, Gianinetto, & Della Torre, 2020). The Marinid dynasty that ruled Morocco and the whole of the Maghreb for nearly two centuries, from the second half of the 13th century to the first half of the 15th century (Nagy, 2020; Shatzmiller, 2011).

The third site is the Romain settlements (in 25 B.C.). According to the excavations and the archaeological studies we can establish the portrait of Sala during the period of reign of Juba II. The city was laid out in terraces like some other great centers of the Hellenic East. On these narrow terraces were discovered many pre-Roman buildings, some of which were later integrated into the buildings of the Roman period and thus survived the stratification of the successive periods. It is to this Hellenic period that belong three temples and public buildings with isodomic wall structure or Moretan style with alternating blocks, warehouses built with mud bricks and paving of the streets in local sandstone (Boube, 1999).

Figure 1. Study area, a) Madrasa of Abu-Al-Hassan, b) The Roman site, c) AlMadrasa Al-Marinia. (Source: Google earth pro).

Material features and methodology.

Photogrammetry as any measurement technique that allows the generation of 2D or 3D digital models of the object as an end product (Daniotti et al., 2020; Obradović et al., 2020). Of course, this is the case when using photographic images, but it is still the case when any other type of 2D acquisition is used, for example, radar, or a scanning device: the photogrammetry process is basically independent of the type of image (Alberti, Ferretti, Leoni, Margottini, & Spizzichino, 2017; El-Din Fawzy, 2019). In this case, we used a digital camera that allows measurement of a large number of points placed on the object monitored without the need for them to be accessible but only visible (Cucci, Picollo, & Vervat, 2012). And a series of overlapped images were collected using UAS based digital and multispectral cameras Table 1.

a. Digital Camera.

Many architectural features (the columns, door arches, Fountain, and Mihrab) were photographed using a digital camera: Canon EOS 700D.

Table 1. Camera specifications

	Camera specifications
Brand of camera	Canon
Camera model	Canon EOS 700D
Type	22.3 x 14.9mm CMOS
ISO sensitivity	ISO-160
Focal length	F/4
Total pixels	Approx. 18.5 megapixels
Sensor cleaning	EOS integrated cleaning system

Table 2. Technical specifications of devices used

	Camera specifications
Brand of camera	Canon
Camera model	Canon EOS 700D
Type	22.3 x 14.9mm CMOS
ISO sensitivity	ISO-160
Focal length	F/4
Total pixels	Approx. 18.5 megapixels
Sensor cleaning	EOS integrated cleaning system

b. UAV-drone.

In recent years, UAVs or drones have been used in various archaeological areas, including site identification, mapping, and site modelling (Liang, Li, , Lai, Zhu, Jiang, & Zhang, 2018; Rocheleau, 2005). Given the limitations of drone availability for photography, cloud cover and satellite orbital characteristics that do not allow us to capture a specific location at a given time, UAVs have advantages such as cost reduction, low-level shooting capacity, high resolution images and high time flexibility (Rocheleau, 2005; Singhal, Bansod, & Mathew, 2018). For images acquisition, a 1-inch camera sensor camera is mounted on the DJI Phantom 4 Pro. This camera offers a multi-format sensor, which leads to a 20megapixel resolution. The Phantom 4 Pro also features DJI's Flight Autonomy system, providing you with five directions of obstacle sensing. The camera specifications are listed in Table 2.

Figure 2. Example of 75% recovery on two consecutive images (source: Authors).

The different architectural structures have established that the measurement must be carried out at different angles (Obradović et al., 2020). In order to have sufficient quality and accuracy, we will strive to achieve a minimum image to the image recovery rate of 75% (Figure 2) (Lee, 2018, Bedford, 2017). For the image in the Figure 3 representing a length of 1m, the digitized surface of 25% of this length, or 0.25m, is shifted parallel to the digitized surface to produce the following image (Ginzler & Hobi, 2015).

Figure 3. A series of corresponding images to digitize a surface (source: Authors).

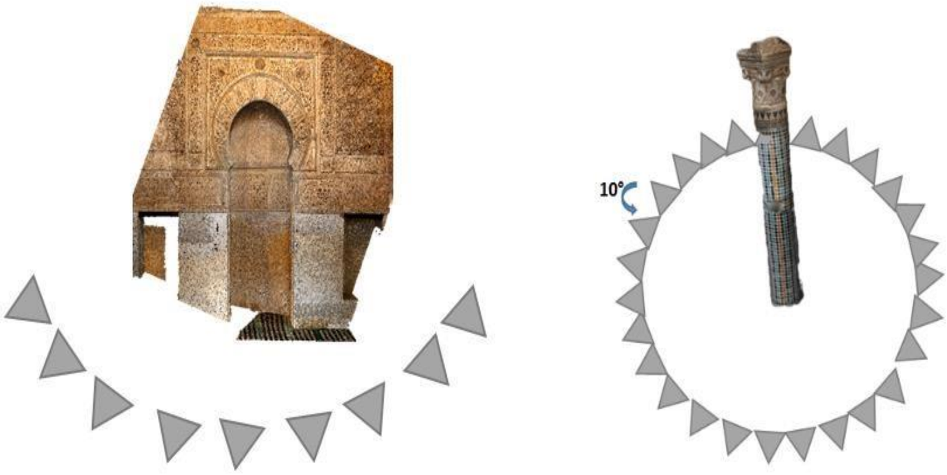


Figure 4. Positions of the device for angle scanning (source: Authors).

In the Figure 4, the grey triangle represents the location of the camera at the time of acquisition. Particular care must be taken to ensure that the edges of the object are present in several images so that only the central elements are covered (Bedford, 2017). To do this, the images were made beyond the desired object to have a recovery in the corners and edges of the object. For that, a point of the object must be visible at least on two images in order to be reconstructed (Pollefeys, 2000).

In the image (Figure 4), the surface to be digitized has an angle, so a movement around the angle has been initiated to connect the two surfaces, as shown in the diagram. This movement must always respect a minimum overlapping of 75%, and generally includes at least six photographs on an angle (New Jersey Department of Transportation, 2009; Bedford, 2017). For the columns, we need a 360° scanning around the object, to obtain the desired recovery (Rosin et al., 2018), since the object is highly textured; we have made 36 steps of 10° each.

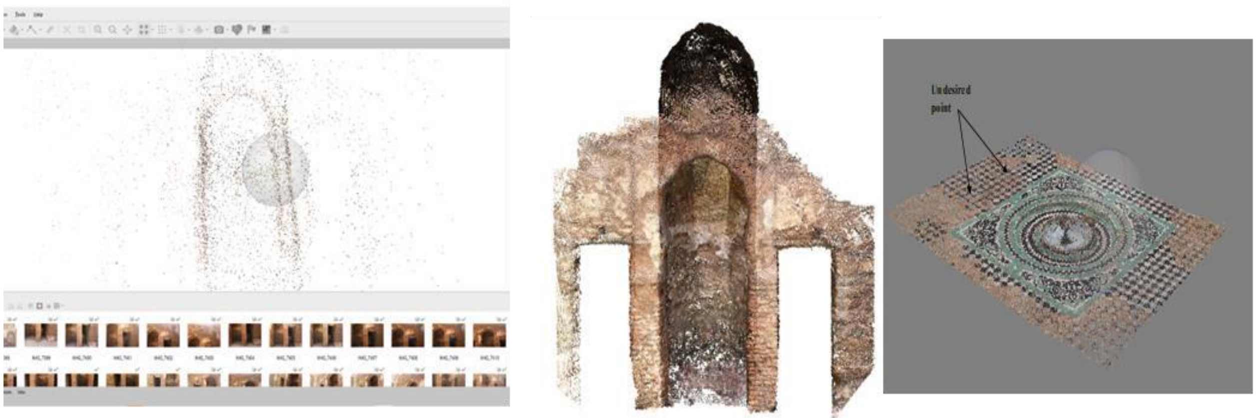


Figure 5. Pretreatment of a point cloud: undesirable points in the scene (source: Authors).

A total of 385 were taken using a DJI Phantom 4 Pro (DJI). Its price range is around 0.2% that of professional UAVs. The altitude was 5–30 m. The side lap and along-track overlapping were 85%.

Agisoft Metashape software was used for photogrammetric processing of digital images and 3D spatial data generation. This software based on structure from motion (SfM) method (Shervais, Dietrich, & Lauer, 2019), which is a photogrammetric method for creating three-dimensional models of a feature or topography from overlapping two-dimensional photographs taken from many locations and orientations to reconstruct the photographed scene (Bedford, 2017; Shervais, Dietrich, & Lauer, 2019). And has been implemented in many applications such as archeology (Chiabrando, Donadio, & Rinaudo, 2015), DEM creation (*Agisoft Metashape*, 2019), geodesy (Cook & DeSanto, 2019), geomorphology (Micheletti, Chandler, & Lane, 2015), and structural geology (Saputra, Rahardianto, & Gomez, 2017). It uses Scale Invariant feature transform (SIFT) algorithm (Napolitano & Glisic, 2018), which included four steps; scale–space extrema detection, key point localisation, orientation assignment, and key point descriptor (Bakirman et al., 2020; Peña-Villasenín, Gil-Docampo, & Ortiz-Sanz, 2019). In the first stage, it uses the difference of Gaussian function *(1)* to identify potential points of interest; naturally according to the algorithm these points are invariant to scale and orientation (Bakirman et al., 2020; Lee, 2018):

$$L(x, y, \sigma) = G(x, y, \sigma) * I(x, y) \tag{1}$$

Where * is the convolution operator, G(x, y, σ) is a variable-scale Gaussian and I(x, y) is the input image.

To determine the key-point localisation in the scale-space, difference of Gaussians is one such technique, locating scale-space extrema, D(*x*, *y*, σ) by computing the difference between two images, one with scale *k* times the other. D(*x*, *y*, σ) is then given by (Bakirman et al., 2020) *(2)*.

$$D(x, y, \sigma) = L(x, y, k\sigma) - L(x, y, \sigma) \tag{2}$$

The key-point descriptor *(3)*, described below, can then be represented relative to this orientation, achieving invariance to rotation. The approach taken to find an orientation is (Bakirman et al., 2020):

$$\begin{gathered} M(x, y) = \sqrt{\left(L(x+1,y) - L(x-1,y)\right)^2 + \left(L(x,y+1) - L(x,y-1)\right)^2} \\ \varphi(x,y) = \tan^{-1}\left(\frac{L(x,y+1)-L(x,y-1)}{L(x+1,y)-L(x-1,y)}\right) \end{gathered} \tag{3}$$

Where L (x, y) is an image sample, m (x, y) is the gradient magnitude, and (x, y) is orientation. Finally, unique descriptors for each key point are computed to conclude the SIFT process.

Photogrametric results and disscussion.

The Photogrammetry process used in this study is less expensive compared to other techniques such as laser scanning. Digital Photogrammetry applied to historical heritage has great potential as a mechanism and a tool for documentation, dissemination and enhancement, and even restoration and monitoring (Calin, 2015; Wei et al., 2019).

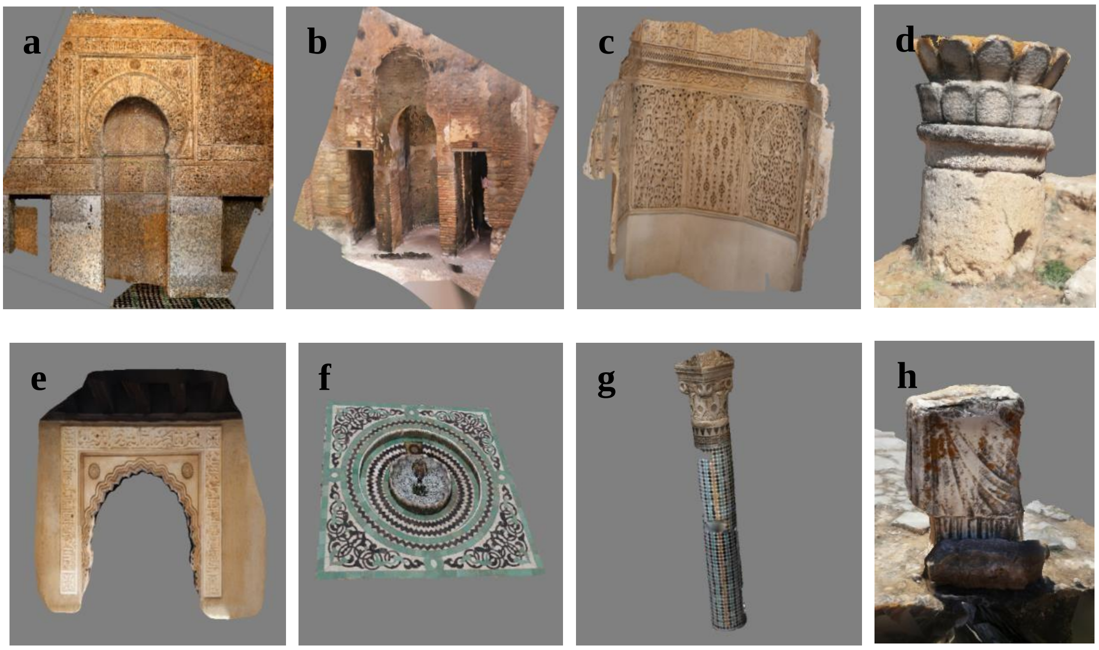
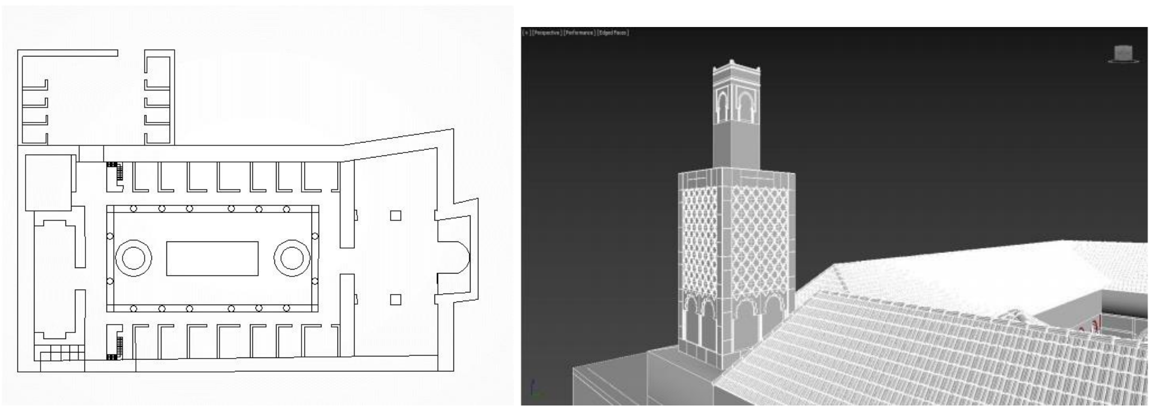


Figure 6. 3D modelling of architectural features, a-c) Mihrab Al-Marinia, b) Mihrab remain of Madrasa of Abu Al-Hassan, d) The Romain Fountain e) door of Madrasa Al-Marinia, e) The Marinid Fountain, g) The Marinid column, h) The Romain statue, (source: Authors).

In order to obtain consistent data (Figure 6), the pretreatment phase (Figure 5) is necessary to reduce undesired scenes and noise in the point cloud, and to keep that the points of interest for the model. The digital models resulting from the point cloud modelling are simple models, made from data from the field. These products can be used for video and animation creation. And also, can create measurement supports (Loaiza Carvajal et al., 2020) (Figure 7), as well as generate 2D plans, and cross-sections (Figure 9), and create profiles (Yilmaz, Yakar, Gulec, & Dulgerler, 2007; Galantucci & Fatiguso, 2019).

Figure 7. Point cloud as a support for measuring (source: Authors).

Figure 8. Aerial view of the current state of the study area (DJI Phantom pro4) (source: Authors)



a b

Figure 9. The Medersa Marinid, (a) 2D plan, and (b) 3D model (non-textured view) , (source: Authors).

The acquired images by drone are used to generate and integrate 3D models, generate orthophotographs, with precision, and perform visual inspections of the site in its current state (Figure 8).

These models can serve as a reference for future studies and even for public diffusion based on better production proposals that produce more accurate documentation, dissemination and interpretation (Grussenmeyer, 2003; Martin, Meynard, Pierrot-Deseilligny, Souchon, & Thom, 2017). Despite the advantages of the method and sub-processes, it also faces practical complications that are generally related to climatic conditions (wind, rain, other), as well as the availability of disparate technological means, such as the current situation itself, or the environmental sphere, lighting conditions, solar radiation and others (Aparicio, Espinoza-Figueroa, Aguirre, Mejía, & Matovelle, 2018).

The 2D data and models generated from terrestrial photogrammetry are exported to the 3Ds Max platform which allows, through the use of advanced modelling techniques, the construction of a three-dimensional digital model that can be visualized, manipulated and modified at any time, being able to develop different versions of the same model (Figure 10).

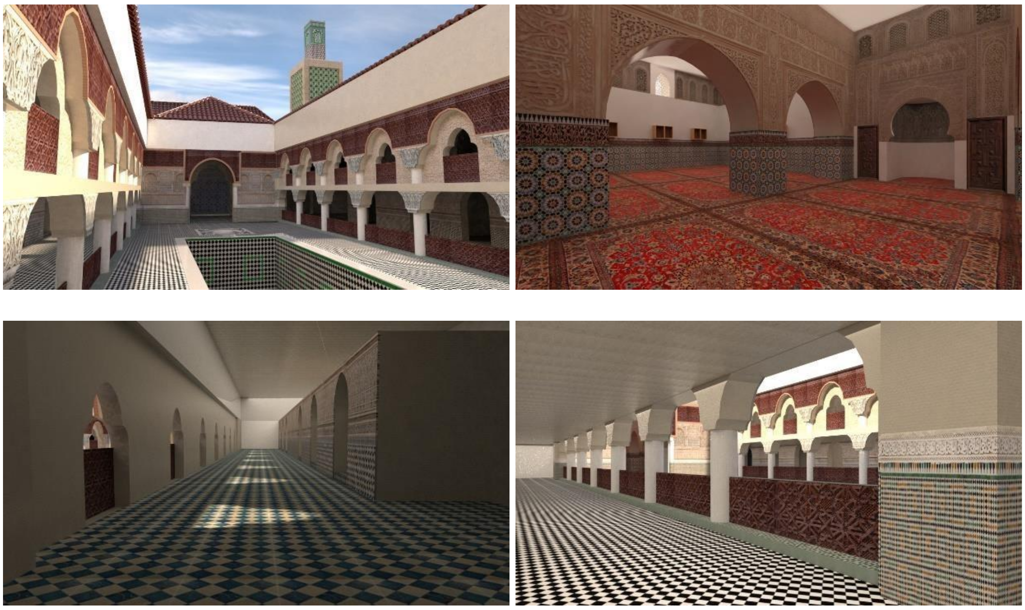


Figure 10. Multiple view of 3D photorealistic model of Marinid architectural features, (source: Authors).

A question was posed during the modelling of the Medersa that was not very clear in the books on the history of the site: how many floors did this site have? Some hypotheses take into consideration, due to the traces of the stairs that are still visible. The first hypothesis is that the site is constituted by the ground floor and two floors, it is based on similar Medersa built in the same period and by the same Marinid dynasty, and especially that of Abu Al-Hassan located in the Sale city, and El Attarine in Fez. The second hypothesis, it has been proposed that the site consists of the ground floor and a single floor, based on a comparison between the supporting structures; the square and circular columns of the Medersa Marinid in Chellah and other similar sites. The square columns of the study site are (50×50) cm, and the circular columns (25×25) cm in size, while those of Medersa Abu Al-Hassan and El Attarine are twice as large. Indeed, the first hypothesis was eliminated and the second was used as a model (Simou, Baba, Nounah, & Aarab, 2020).

Conclusions.

Betting on technologies applied in everyday life shows the improvement of heritage conservation processes, also shown by this study, through the effective restoration, for example, of the damaged Mihrab of Madrasa Marinid, whose immediate value has slowed the loss of individual value of the object and of course of the architectural complex. In general, the demand for 3D technologies to digitize heritage is increasing rapidly and efficiently (Alshawabkeh, El-Khalili, Almasri, Bala'awi, & Al-Massarweh 2020; Xie & Matusiak, 2016). This is a promising option for the future, and current efforts are focused on cost-effectiveness, speed, efficiency and accessibility to capture and compute large-scale 3D virtual models from archaeological discoveries (Erenoglu, R. C., Akcay, & Erenoglu, O., 2017). Although photogrammetry helps to digitally record historical remains with a high level of detail (Yang et al., 2020), this will facilitate the rehabilitation and effective analysis of cultural sites by cultural centers. This study provides a three-dimensional documentation of the Medersa Marinid site located at the Chellah Archaeological Site, combining different methods after their examination, starting with aerial photogrammetry by drone which allowed us to carry out a survey of the site in order to have an overview of the current state of the site, and terrestrial photogrammetry with a digital camera, which is one of the most economical and rapid ways to digitize archaeological objects, this methods has allowed us to generate three-dimensional models of some architectural models that are still durable in the site, with high quality and with the ability to display all parts of these objects as a 3D file and orthophotographs, which have been a valuable addition to this documentation. Then, to use the data retained by photogrammetry methods to modelling software, to reconstruct and record the studies of the Medersa Marinid Monument through graphic documentation. The selected 3D virtual models are reactive and allow to quickly analyzing the construction elements and associated data. These technologies open up new opportunities for the management and conservation of this cultural heritage, and even for the tourism and educational processes that attempt to bring this heritage closer to the new generations.

Unfortunately, Moroccan archaeology, despite its high potential, such as many archaeological sites and valuable scientific data, has hardly benefited from the use of digitization and new technologies. Therefore, the introduction of digital methods of documentation, analysis and dissemination of archaeological findings to archaeologists is essential to make archaeology in Morocco accessible to the human community more easily and scientifically through these techniques.

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Conflicts of interest.

The authors declare no conflict of interest.

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Інтеграція 3D-технологій для консервації та реставрації зруйнованих археологічних артефактів

Анотація. *Реставрація та консервація пам'ятників та археологічних об'єктів – справа тонка. Вона вимагає делікатності, точності та археологічної достовірності. Ціль полягає в тому, щоб максимально точно виявити, відтворити характеристики археологічного пам'ятника або його частини. Дослідження останніх двох десятиліть довели, що 3D-моделювання, або цифрова документація та візуалізація археологічних об'єктів у 3D цінні для археологічних досліджень, а також для консервації та представлення широкій аудиторії, оскільки дозволяє створювати реалістичні та точні цифрові копії археологічних об'єктів. У минулому технології 3D-моделювання були надмірно дорогими та надто технологічно спеціалізованими, щоб їх можна було інтегрувати у більшість проектів історичної спадщини. Однак досягнення в розвитку обчислювальної техніки та цифрової фотографії за останнє десятиліття призвели до появи кількох недорогих та зручних варіантів 3D-моделювання з використанням фотограмметрії. Останній був успішно використаний для документування історико-культурної спадщини. В останні роки ця технологія стає все більш популярною для архівації. Вона забезпечує* *отримання 3D-моделі та цифрового ортозображення з використанням високоточних щільних 3D-крапок. У дослідженні був обраний метод наземної та аерофотограмметрії за допомогою тривимірних зйомок архітектурних елементів, щоб розробити архетип занепаду поселення ісламських маринідів (династія між 13 і 15 століттями) і римського поселення (25 р. до н. е.), розташованого на археологічних розкопках Челлах у містах Рабат та Сале. Проте визнання важливості цих ісламських пам'яток з погляду еволюції марокканського ісламського мистецтва потребує поєднання великомасштабного сканування безпілотними наземними засобами, аерофотограмметрії та фотореалістичного 3D-рендерингу, а також вичерпних досліджень з історії цього культурного об'єкту. Отримані дані створюють архітектурну базу даних для архівування та відновлення існуючої архітектури пам'ятників. Це дослідження виконано фотограметристами, архітекторами та реставраторами.*

Ключові слова: *культурна спадщина; фотограмметрія; обстеження; архітектурне архівування; 3D реконструкція; музеологія*

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Analysis of prerequisites and conditions for the foundation of an aircraft engine enterprise in Ukraine

Abstract. *World War I proved air forces to be a critical driver for warfare outcomes. Mastery of the latest technology appeared to be crucial to the battle's success. The combat capabilities of airplanes improved manifold due to the increased power of aircraft engines, thus initiating a new era in aeronautics. By July 1917, the*

aviation of the Russian Empire included 91 air squadrons and 5 units of heavy multi-engine aircraft known as Ilya Muromets. Several enterprises, including the town of Aleksandrovsk, were manufacturing engines for these planes. The origin of engine production in Aleksandrovsk was associated with the establishment of a branch of Petrograd Joint Stock Company of Electromechanical Structures called Deka. The article aims at analyzing the prerequisites and conditions for the foundation of an aircraft engine enterprise in Ukraine. While drafting the article, the authors relied on chronological, historiographical, and other historical methods of research, which have been widely used both in considering the contribution and influence of certain individuals and reviewing the stages of creation and development of separate enterprises, as well as specific industries. Based on the retrospective analysis, the prerequisites and conditions of the foundation of the aircraft engine enterprise in Aleksandrovsk, Ukraine, were considered. There was a severe gap between the Russian Empire and European countries in the development pace of the aviation industry during World War I. This prompted the Russian Empire to raise foreign capital, as well as attract technologies and specialists to develop aircraft engineering and other industries. By 1917, the plant had gained the status of Russia's largest engine-building enterprise in terms of building area and one of the best in equipment. It is evident that the beginning of aircraft engine production in Aleksandrovsk relates to the establishment of a branch of Petrograd Joint Stock Company of Electromechanical Structures and the plant's purchase from the Moznaim brothers.
Keywords: *Russian Empire; history of technology; aircraft engineering; Ilya Muromets aircraft; first aircraft engine; bomber*

Introduction.

Aircraft engine production in the city of Zaporizhzhia (Ukraine) has already been existing for over 100 years. This legendary history started with making an engine for the famous aircraft, the world's first mass-produced multi-engine bomber named after Ilya Muromets (see Fig. 1), the Russian hero of epic poetry. This aircraft, which gained wide fame during World War I, became a symbol of the emergence of the aviation and aircraft industry in the Russian Empire (Kemaloğlu, 2014; Vasilev, K. K. & Vasilev, Yu. K., 2017; Bogdanov, 2021; Vasigh & Azadian 2022). Zaporizhzhia engine-building plant runs along with this industry from its starting point. Its activity influenced not only the industry of the Russian Empire but also the world aviation industry.

The article aims at analyzing the prerequisites and conditions for the foundation of an aircraft engine enterprise in Ukraine.

Research methodology.

While drafting the article, the authors relied on chronological, historiographical, and other historical methods of research (Li, Kuhn, Bar-Yosef, Chen, Peng, & Gao, 2019; Li, Kuhn, Bar-Yosef, Chen, Peng, & Gao, 2019; Michel & Smadja, 2021;

Sulistyo, Khakim, Jauhari, & Anggraeni, 2021; Lenc, Martínek, Král, Nicolao, & Christlein, 2021), which have been widely used both in considering the contribution and influence of certain individuals (Baig, Al-Ma'adeed, Bouridane, & Cheriet, 2018; Pylypchuk & Strelko, 2020; Strelko & Pylypchuk, 2021) and reviewing the stages of creation and development of separate enterprises, as well as specific industries (Lee, Lee, Kim, & Shin, 2018; Sizov, 2019; Lamberg, Lubinaitė, Ojala, & Tikkanen, 2021; Manioudis & Milonakis, 2021; Wang, Chang, Xu, Wang, & Kadirkamanathan, 2021).

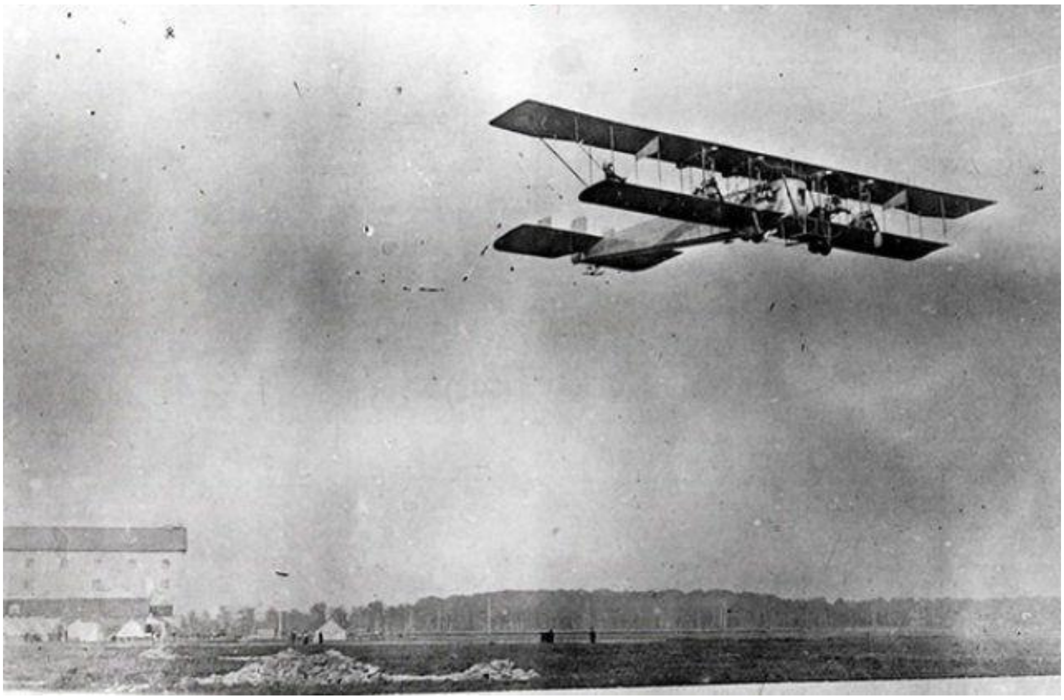

Figure 1. The largest pre-WW1 plane – S-22 Ilya Muromets (Lazko, 2020).

Results and discussion.

The Russian Empire's failure to develop aircraft engine production was a weak spot for the emerging aviation industry, so the Main Military-Technical Administration and the Air Fleet Directorate had to perforce rely on foreign manufacturers of aircraft engines. Shortly before World War I, the Military Ministry acquired licenses to build Gnome rotary engines in the Russian Empire from components manufactured in France. The engines were assembled at the plant of the Society of Gnome & Rhône Engines, founded in Moscow in 1912 (Popov, 2019). It's worth noting that French people prevailed among the employees of these Moscow assembly workshops.

The Russo-Baltic Wagon Factory in Riga, which in addition to railway cars also constructed vehicles, started mastering aviation production several years before the outbreak of the First World War.

In 1911, the board of the Russo-Baltic Wagon Factory invited Igor Ivanovich Sikorsky, a young designer, who became the head of the aviation department of the St. Petersburg plant. Such aviation designers as K. K. Ergant, M. F. Klimikseev, A. A. Serebrennikov, A. S. Kudashev, G. P. Adler worked in the department of

I. I. Sikorsky. The same year, the Russo-Baltic Wagon Factory designed and built the four-engine aircraft known as Russian Vityaz, which was tested on May 13, 1913 (Zhurilo, Gutnyk, & Zhurilo, 2022). The next multi-motor aircraft, built at the Russo-Baltic Wagon Factory, was the Ilya Muromets aircraft. The upper wingspan made up 34.5 m, with a bearing surface area of 182 m^2 and a distance between upper and lower wings of 2.5 m (Beggs & Sikorsky, 2014). Ilya Muromets featured a pilot's cabin, a living room, a bedroom, and a toilet. Basically, it was a complete airborne house. The plane had electric lighting. It weighed 3,500 kilograms unloaded. When designing Ilya Muromets, a solid fuselage was used for the first time, enclosing the cabin in a single streamlined body. The main materials were pine, plywood, and canvas fastened with metal parts. The designers of Ilya Muromets supposed not only military but also purely civil use of the machine, so G. V. Alekhnovich, test pilot, proposed sending the Ilya Muromets aircraft with an expedition to the North Pole.

Ilya Muromets's first flight failed. After climbing to less than eighty meters, the aircraft suddenly lost speed, collapsed on the left wing, and fell to the ground. Fortunately, the pilot sustained only minor injuries. The accident was caused by the installation of an additional wing, which disrupted the proper alignment of the aircraft. The aircraft was repaired within five days, the wing was removed, and Ilya Muromets successfully passed flight tests. In February 1914, the aircraft set a record, lasting five hours in the air with sixteen passengers on board (Fortier, 1996, p. 4).

This masterpiece of the aviation industry of the Russian Empire was demonstrated at Tsarskoye Selo to Emperor Nicholas II (Jones, 2013). On December 10 (23), 1914, the Emperor approved the decision of the Military Council to create a squadron of Ilya Muromets bombers, headed by M. V. Shidlovsky. Today, he is considered to be the founder of the strategic aviation of the Russian Empire.

World War I proved air forces to be a critical driver for warfare outcomes (Schwonek, 2014; Karataev, Adinyaev, Artemova, & Volkov, 2019; Degtyarev, Gerasymov, Gut, & Polyakova, 2021; Rance & Snape, 2021). Mastery of the latest technology appeared to be crucial to the battle's success. The combat capabilities of airplanes improved manifold due to the increased power of aircraft engines, thus initiating a new era in aeronautics of the Russian Empire.

Before World War I, the Russian Empire was already training aircrew at several specialized aviation schools. However, there were not enough graduates to meet the staff shortage in the booming aviation industry. Some Russian pilots were trained abroad, particularly in England and France, where they mastered a course that included flights with an instructor, independent flights, motor training, aerobatics, and bombing. By July 1917, the aviation of the Russian Empire included 91 air squadrons and 5 units of heavy multi-engine Ilya Muromets aircraft (Shunkov, 2022, p. 57). Naval aviation consisted of 32 air detachments. By June 1, 1917, there were 645 pilots in the front detachments of the Russian Empire, 53 pilots in the rear detachments, 26 pilots in the divisions, and 15 members in the air-front departments and air groups. About half of all aircrew died in the air battles of World War I.

There was a severe gap between the Russian Empire and European countries in the development pace of the aviation industry during World War I. Over the war period, the Russian Empire built 5012 aircraft, while England produced 55,000 pieces, France – 51,100, and Germany – 46,000 (Sinikov, 2014). The Russian Empire built 1,511 engines, England – 41,000, France – 93,000, and Germany – 40,200.

Ilya Muromets was equipped with seven machine guns to assist in combat operations (Chaney & Greenwood, 2019). This aircraft proved to be a perfect frontline machine, performing over 400 combat sorties and dropping almost 65 tons of bombs (Sikorsky, 2007, p. 10). For the first time in the world practice, the bombs weighing 25 poods were designed specifically for the Ilya Muromets aircraft. The Russian plane was the sole one in the world, capable of carrying such bombs. Named after the Russian epic hero, the aircraft inflicted heavy damage on the enemy. For example, on June 14, 1915, Bashko, a pilot of the Ilya Muromets bomber, dropped some bombs at Prazharovsk station, destroying an enemy train full of shells (Jones, 2019). Three German Brandenburgs attacked the Russian aircraft. Despite being wounded and having its fuel tanks breached, Bashko managed to fly over the frontline on this aircraft.

In the summer of 1915, the Russo-Baltic Wagon Factory launched mass production of the RBZ-6 engine with 150 HP capacity based on the German single-row six-cylinder engine called Argus, and by 1915, this engine began to be installed on the Ilya Muromets aircraft (Shavrov, 1974, p. 49). For a while, this used to be the main engine for this type of plane. After the aircraft was adopted by the army of the Russian Empire, more powerful 220 HP Renault engines, which were produced in Petrograd at the Russian Renault plant (later this enterprise was renamed Red October, Klimov Plant, now it is known as JSC UEC-Klimov), were installed to improve its flight and technical performance (Sikorsky, 2007, p. 10). Petrograd plant capacity was up to ten engines per month and, except for Ilya Muromets, 220 HP engines produced by Russian Renault were supplied to several types of experimental aircraft of the Russian Empire (Kulikov, 2001).

German and Austrian planes and, among others, two-seat Albatros reconnaissance aircraft with Mercedes engines of 100 HP were taken as “trophies” by Russian troops during World War I. Then, copies of these engines were manufactured in the Russian Empire. In the second half of 1916, the production of Mercedes engines was established in the Russian Empire (Kulikov, 2001).

In September 9, 1915, the Technical Department of the Main Military-Technical Administration signed a contract No. 23500 with the Duflon, Konstantinovich & Co. in St. Petersburg to manufacture one 25 Mercedes engines rated at 100–105 HP, and one hundred Benz-type rated at 150 HP (Boguslaev, 2011, p. 51). Engineer B. N. Vorobyev headed the group to develop detailed drawings of the M-100 Mercedes engine. Vladimir Yakovlevich Klimov, the future Chief Designer, whose name is borne by the famous St. Petersburg aircraft engine enterprise, did an internship at the Deka plant in Aleksandrovsk during his studies at the Imperial Higher Technical College at the recommendation of N. R. Brilling, one of the pillars of the Russian aircraft engine building, where took part in developing the M-100 engine.

The aircraft engine enterprise in Aleksandrovsk was founded at the junction of the eras of two plants (the agricultural machinery plant of the Moznaim brothers and the St. Petersburg electromechanical enterprise Deka), which, although having completely different specifics, were located side by side in Taras Shevchenko Square, which prompted their merger (SAZR, Fund 24,Inventory 1, Case 956, Sheet 16).

The emergence of engine production in Aleksandrovsk was associated with the establishment of a branch of Petrograd Joint Stock Company of Electromechanical Structures called Deka. By the outbreak of World War I, the St. Petersburg enterprise founded by L.-E. Duflon was pretty famous among the business circles of the Russian Empire (Nemkov, 2009; Sashnikova, 2016, p. 38; Pestrikov, Yermolov, & Slyozkin, 2021; Erdogan, 2021, p. 398).

A Swiss citizen of French ancestry, Louis-Edouard Duflon graduated from the Faculty of Physics and Mathematics of the Zurich Polytechnic Institute and then worked at the Breguet Electromechanical Plant in Paris (Boguslaev, 2011, p. 49–50). In the early 1890s, the ambitious Frenchman arrived in St. Petersburg, where he got a job as an electrical engineer at the electrical plant of Prince Tenishev & Co. However, being rather daring, Louis-Edouard Duflon came to the Russian Empire with other goals than to remain a hired worker. First, he managed to become a representative of two Parisian companies, Sotter, Harlez & Co., a manufacturer of electric machines, and E. Gabriel & H. Angenolt, a manufacturer of incandescent lamps. Duflon's career in the Russian Empire was made possible by the approximation between the Russian Empire and the French Republic. The share of the French capital in the economy of the Russian Empire increased sharply, and during 1869–1887, 17 foreign enterprises emerged in the Russian Empire, 9 of which were French.

In 1892, Duflon founded an electrical workshop in St. Petersburg, employing 15 people (Alekseev, 2012). The workshop was engaged in the installation of electrical equipment. Later, Duflon found a companion, Apollon Vasilievich Konstantinovich, an owner of a small technical bureau in Moscow on Maroseyka Street. Konstantinovich, as much as Duflon, represented the French firm Sotter, Harlez & Co. As a result of their partnership, Duflon & Konstantinovich (Deka) emerged. It was a Moscow-Petersburg enterprise, but very soon A. V. Konstantinovich, who was doing much better than the St. Petersburg branch, began to play first fiddle in their duet. Basically, Konstantinovich was the main reason why the Deka enterprise acquired such respectable clients as the Aleksandrovsk Mechanical Plant in the capital, the Goujon plant in Moscow, and the Nikolayevska Railway Company. Still, even those clients were not enough to boost the enterprise of Duflon and Konstantinovich. The companions were supported by Sotter, Harlez & Co. At their recommendations, Duflon and Konstantinovich received government orders from the Military and Naval ministries of the Russian Empire for the supply and installation of electromechanical equipment for the ships of the Russian fleet.

On December 20, 1895, Duflon and Konstantinovich bought a land plot on Lopukhinskaya Street in St. Petersburg (now Academician Pavlov Street), where they began building the plant. The plant's buildings (a forge, a mechanical workshop, a room for a steam engine) were built quite promptly, and on December 14, 1896, the enterprise commenced operations. In 1897, Deka got an order to supply and install electrical equipment for the naval artillery. Deka specialists and workers installed electrical equipment on the ships of the Baltic and Black Sea Fleets, and the Port Arthur Squadron. In particular, they worked on the coastal defense battleship General-Admiral Apraksin, the squadron battleships Peresvet, Oslyabya, Petropavlovsk, Prince Suvorov, etc. These ships were involved in the tragic Battle of Tsushima. Besides orders from the defense ministries, Deka fulfilled contracts for lighting in the imperial theaters. As the workload increased, the number of plant staff reached three hundred employees.

It is worth mentioning that in this pre-war period, Deka already contributed to aeronautics in the Russian Empire. In 1910, an aeronautics department was opened at the plant.

In 1912, the airship called Kobchik (2,150 cubic meters shell volume, 45 m length, 8 m diameter, and 50 km/h maximum speed), designed by S. N. Nemchenko and A. E. Garuta, was developed and successfully tested at Deka (Lashkov & Golotyuk, 2015).

At the beginning of World War I, when the Russian Empire was rushing to catch up with the Western countries in aircraft production, the Deka enterprise started working hard on aircraft engine construction. Although Deka had a large and well-equipped production base with enterprises in Petrograd, Moscow, Kharkiv, and Yekaterinburg, all its departments were already loaded with military production. Extra production facilities were needed to fulfill the new contract. It was originally planned to open a branch in the city of Sevastopol to build, and the negotiations had already begun to buy land and factory buildings (Boguslayev, 2011, p. 52). However, there was an objection from the Engineering Department. Then the Deka board turned to the factory of Hatskel and Rafael Moznaim in Aleksandrovsk (now the city of Zaporizhzhia in Ukraine). Yet there were difficulties as well. To overcome them, they had to contact the August Chief Petty Officer of the Air Fleet, the Grand Duke Alexander Mikhailovich Romanov. After Grand Duke Alexander Romanov stepped in, the acquisition of the Aleksandrovsk plant proceeded apace.

On November 23, 1915, the Duflon, Konstantinovich & Co. applied to the City Council of Aleksandrovsk with the request to allocate a land plot on Shevchenko Square next to the agricultural machinery plant of the Moznaim brothers (Kozlova, 2010, p. 33).

It was about creating a branch of the capital's enterprise in the city of Aleksandrovsk. Negotiations with the City Council were conducted by the managing director of the joint-stock company, Pyotr Pavlovich Azbelev (Boguslaev, 2011, p. 49), retired Navy Major General, who informed that the enterprise intended to establish the production of internal combustion engines and, in particular, aircraft engines in

Aleksandrovsk, promptly employing about a thousand employees from the local people. In addition, when the war would be over, the enterprise intended to focus on electromechanical production, namely, the production of electric engines, dynamos, and electric drives for mine and mill devices. This issue was considered at the meeting of the City Council on November 25, 1915. The City Council ruled to sell the land plot on Shevchenko Square next to the plant of the Moznaim brothers with a total area of 5.469 hectares, setting a price of 4 rubles per square fathom. Ten the Council allowed the enterprise to run a railroad track to the plant. The rent for using the land under the railroad track was set at 30 kopecks per square fathom.

On December 24, 1915, P. P. Azbelev, the managing director, informed the Aleksandrovsk City Council that the Joint Stock Company of Electromechanical Structures had purchased the plant of the Moznaim brothers along with the manor. Therefore, Deka displaced its unfortunate neighbor and finally acquired their fading production (Boguslaev, 2011, p. 52). Its owners failed to secure military orders and the demand for civilian products was steadily decreasing. Things were getting worse for the Moznaim brothers, so the Deka board managed to agree with them, and soon the plant changed its owner (SAZR, Fund 24, Inventory 1, Case 2014, Sheet 20). Having decided to avoid litigation, the administrator on the Moznaim brother's case sold the land plot on Shevchenko Square of 3,648 square fathoms to the Joint-Stock Company of Electromechanical Structures on February 16, 1916, "with all the buildings, facilities, and agricultural equipment not yielding any income, as well as machinery and tools, which were not operating..." for 300 thousand rubles (SAZR, Fund 24,Inventory 1, Case 956, Sheet 16).

In December 1915, the bill of sale was signed, and in April 1916, new production buildings were built and equipped with modern machinery purchased in America and delivered via Arkhangelsk and Vladivostok at a total cost of 500 thousand rubles (Boguslaev, 2011, p. 52). Then other workshops were built, as well as facilities specializing in the future business activity of the enterprise. The main new building was the 419 m^2 test station, a large spacious building with a stand, the necessary utilities, electric lighting, and ventilation. After the plant expansion, it became the largest engine-building enterprise in Russia in terms of building area and one of the best in equipment. The factory had the following technical equipment: a single-cylinder steam engine of 22 HP, a Cornish steam boiler with a heating surface of 40 m^2, a Sulzer steam engine of 350 HP, and two steam boilers with a heating surface of 90 m^2 each. Moreover, there were 86 units of metal and woodworking machines in the Deka plant (Fig. 2). The annual income of the enterprise totaled 150 thousand rubles.

Construction and installation works were usually carried out in-house by specialized hired labor crews. As of May 1, 1916, there were 263 workers at the Deka plant, and more than half (146 men and 30 women) of them were employed in construction (Ivanov, 2010). Prisoners of war (Croats, Slovaks, Czechs, Poles, Romanians, and Germans) were involved in the construction work. As of October 1917, there were 70 of them. The construction of the two-story brick building of the steel foundry (total area of 1,344 m^2) with metal truss roofing and lantern glazing along the whole length of the building, as well as premises for casting molds and blowers was started at the Deka plant. In 1915–1916, 4,520 m^2 of premises were built at the plant in addition to the production areas of the former Mozaim brothers plant.

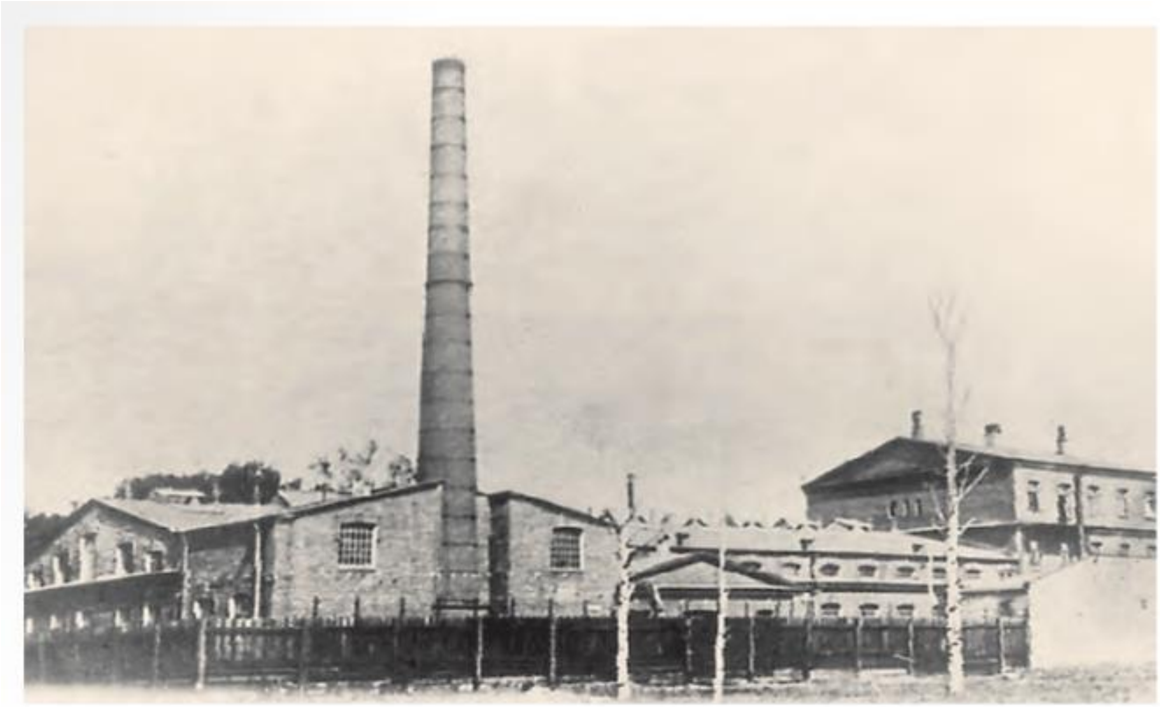

Figure 2. The Deka plant in 1916 ((Boguslaev, 2011, p. 52).

The first five single-row six-cylinder Deka M-100 engines with spare parts and one extra set had to be delivered by the end of August 1916 (see Fig. 3). It turned out to be extremely challenging. The German design "did not fit" neither with the technology and the system of limits and fits adopted in the Russian Empire nor with the capabilities of Russian and American machines. They had to figure out the materials used by the German designers and select a local replacement, bearing in mind the need for strength, heat and wear resistance, as well as friction properties. The work on the "adaptation" of the Mercedes engine to our production was led by engineer Vorobyev, and the development of the more powerful Benz was handled by engineer Kireev (Boguslaev, 2011, p. 57).

In August 1916, the first vertical single-row six-cylinder 100 HP water-cooled Mercedes engine named Deka M-100 was produced at the Deka plant in Aleksandrovsk and submitted for testing (Fig. 4). Major General Pnevsky reported to St. Petersburg: "...the first 100 HP engine, made entirely of Russian materials, was put into operation and yielded quite satisfactory results" (Boguslayev, 2011, p. 53). The plant proceeded to execute the contract in full. Soon the managing director of the company, P. P. Azbelev signed contract No. 23500 of September 9, 1915, with the Technical Department of the Main Military-Technical Administration to supply aircraft engines.

According to the contract, the Deka plant was committed to supplying the army with 25 aircraft engines of the Mercedes 100–105 HP type and another 100 aircraft engines of Benz 150 HP type. The contract amounted to 2 million 473 thousand rubles (Boguslaev, 2011, p. 51).

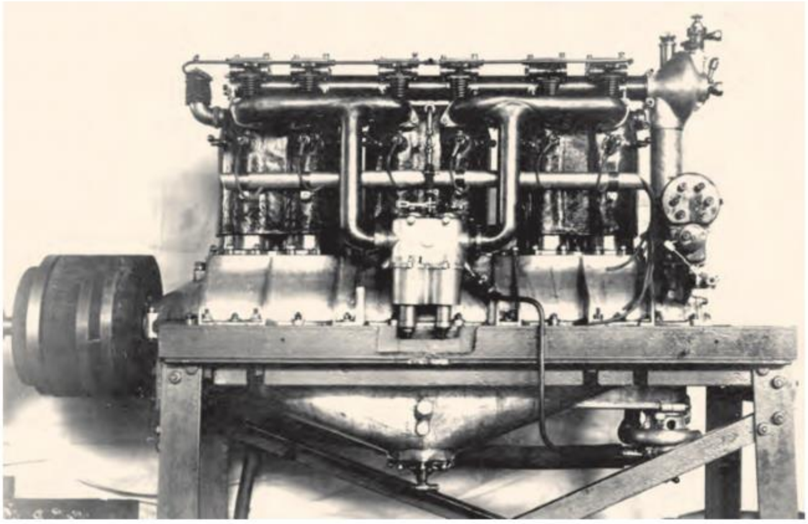

Figure 3. The Deka M-100 engine (Boguslaev, 2011, p. 51).

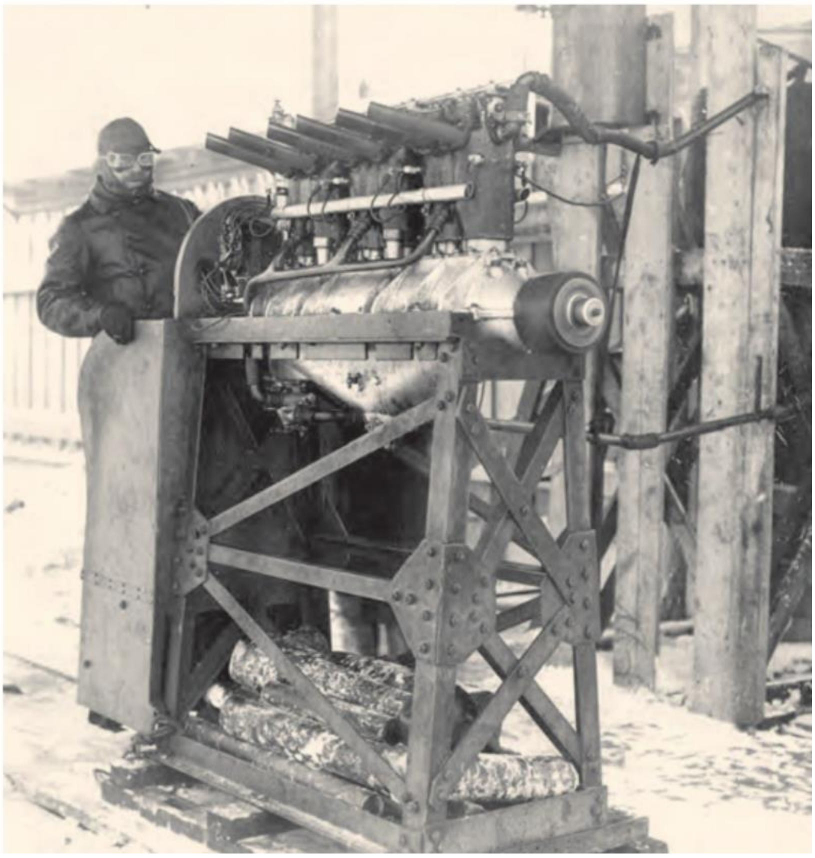

Figure 4. 6-hour testing of the DEKA M-100 engine. Controls the operation of the engine B. N. Vorobyov. Aleksandrovsk, 1916 (Boguslaev, 2011, p. 51).

Having developed the detailed drawings of 100 and 129 HP engines, B. N. Vorobyev proceeded to the development of the technical project of a 160 HP aircraft engine, which was completed in August 1916. In October, the project was approved by the Technical Committee of the Military Air Fleet Department and recommended for implementation. The Technical Committee advised B.N. Vorobyev to increase the engine capacity and modify its design so that parts of the 175 HP Mercedes aircraft engine could be used. Upon refinement of the project, the design of the new M-168 engine rated at 168 HP was obtained. Then the Military Air Fleet Department and the Joint Stock Company of Electromechanical Structures signed Amendments No. 35835 and No. 35836 dated April 5, 1917, which, instead of producing and supplying 180 units of M-129 engines, provided for producing and supplying 180 units of M-168 engines (Boguslaev, 2011, p. 55). They started manufacturing parts for this engine. In 1917, the Deka plant in Aleksandrovsk, in addition to the Mercedes engines rated at 129 HP, mastered the production of the same type of engine rated at 170 HP.

Apart from the production of aircraft engines, the Deka plant also took other orders from the Military Department. For example, on November 25, 1916, the plant received order No. 39814/17202 for the manufacture of 400,000 projectiles intended for throwing from airplanes, for 19 kopecks apiece, amounting to 76,000 rubles (Boguslaev, 2011, p. 56).

By the end of World War I, the administrative building with an area of 721,2 m^2, a brick two-story mechanical workshop with an area of 1947 m^2 with the adjacent storehouses, and household premises for tool equipment were constructed at the plant. The plant commissioned an outbuilding to the steel foundry to accommodate non-ferrous castings, a plant garage, and an expanded boiler house with a machine hall.

There were several aircraft-engine plants in the Russian Empire during World War I: Gnome and Rhône plant and Salmson plant in Moscow, the aviation department of the Russo-Baltic Wagon Factory in Petersburg, the Motor plant in Riga, the Russian Renault plant in Rybinsk, the Deka plant in Aleksandrovsk. The year 1917 began with the February Revolution. However, by the outbreak of the Civil War in the Russian Empire (1917–1921), all these enterprises collapsed, engine production was terminated, and it seemed that the Russian Empire would cease to be an aviation power once and forever.

It was these force majeure circumstances that prevented the intensification of aircraft engine building in the Russian Empire. During 1917, the board and staff of the Deka plant in Aleksandrovsk did their best to continue producing engines and to preserve the enterprise from embezzlement, but the enterprise could no longer exist in its former state and was dissolved on December 24, 1917 (Ivanov, 2010). However, the Deka plant was nationalized by the Decree of the Council of People's Commissars of January 20, 1918, just less than a month later. Under such circumstances, it could not operate and went out of business for a long time. Thus the Vorobyev and Kireev engines never had a significant impact on the development of aviation in the Russian

Empire, but they were the starting point of aircraft engine production in the Zaporizhzhia region.

Conclusions.

Based on the retrospective analysis, the prerequisites and conditions of the foundation of the aircraft engine enterprise in Aleksandrovsk (Zaporizhzhia), Ukraine, were considered. There was a severe gap between the Russian Empire and European countries in the development pace of the aviation industry during World War I. This prompted the Russian Empire to raise foreign capital, as well as attract technologies and specialists to develop aircraft engineering and other industries. It is evident that the beginning of aircraft engine production in Aleksandrovsk relates to the establishment of a branch of Petrograd Joint Stock Company of Electromechanical Structures and the plant's purchase from the Moznaim brothers.

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Аналіз передумов та умов створення в Україні авіамоторного підприємства

Анотація. *Перша світова війна показала, що авіація стала серйозним чинником успіху у бойових діях. Для успішного ведення війни тепер особливо*

необхідним стало володіння новітньою технікою. Бойові можливості літаків багаторазово покращали через підвищення потужності авіаційних моторів, завдяки чому починалася нова ера в повітроплаванні. У липні 1917 року в авіації Російської імперії налічувався 91 авіазагін та 5 загонів важких багатомоторних літаків "Ілля Муромець". Двигуни для цих літаків виробляли кілька підприємств, у тому числі в місті Олександрівськ. Початок моторного виробництва в Олександрівську пов'язаний із створенням тут філії Петроградського акціонерного товариства електромеханічних споруд "ДЕКА". Метою статті є аналіз передумов та умов створення в Україні авіамоторного підприємства. При підготовці матеріалів статті, автори використовували хронологічний, історіографічний, та інші історичні методи досліджень, які знайшли широке застосування, як при розгляді внеску та впливу як окремих особистостей, так і огляду етапів створення та розвитку як окремих підприємств, так і окремих галузей промисловості. На основі ретроспективного аналізу розглянуто передумови та умови створення в Україні авіамоторного підприємства в Олександрівську. У роки Першої світової війни мало місце серйозне відставання Російської імперії від європейських країн у темпах розвитку авіагалузі. Це стимулювало Російську імперію до залучення іноземного капіталу, технологій та фахівців для розвитку авіабудування та інших галузей промисловості. Завдяки цьому до 1917 завод стає найбільшим моторобудівним підприємством Росії за площею капітальних будівель і одним з кращих по оснащенню. Показано, що початок авіамоторного виробництва в Олександрівську пов'язаний із створенням тут філії Петроградського акціонерного товариства електромеханічних споруд та покупкою заводу у братів Мознаім.
Ключові слова: *Російська імперія; історія техніки; авіабудування; літак "Ілля Муромець"; перший авіадвигун; бомбардувальник*

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