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EVALUATION OF DUAL USE MATERIALS SCIENCE TECHNOLOGIES ISSUE IN UKRAINE – «TRICK OR TREAT»

The object of this research is materials science dual-use technologies and their transfer. It is important to study the problems of transfer of dual-use technologies and related prerequisites, as well as their vital role in Ukraine, trying to understand how to fix all those in the right legal and political way, otherwise, literally, it looks like a chasing a ghost. To successfully solve this problem, one need to understand that in this case there no turnkey solutions ever exist. The complex nature of dual-use technologies and their potential for development of the economies of any countries make fundamental for both R&D and political debates. It should be noted that there has never been a clearly defined line between defense and civilian research, and that line is still rather dimmed and blurred. Dual technologies become being applied in more and more industrial sectors, from nuclear science and materials science to electronics, etc., and those are attracting increased interest from developers, policymakers and legislators. The erosion of civil and defense industrial bases and principles, as well as an avalanche growing number of problems associated with undefined dual-use functions and misuse make it difficult to distinguish between civilian and military products and platforms and complicate issues of export control and technology transfer. The concept of creating a so-called «scientific and technological depository of advanced material science technologies» by high-tech states and its' profound significance for state's security is also being debated. The establishment of a scientific and technical deposit is considered as a common task of national economy and security of states. A required and vitally important condition for a successful development of scientific and technological progress is the timely creation of a scientific and technical reserve of modern technologies, which provides a solid basis for new developments, state economy and military-industrial complex. The work also assesses the symbiosis of a public-private model to manage dual-use technologies in the interests of state's security. In the course of the study, an integrated approach was employed: an analysis of world experience, as well as a retrospective and historical-evolutionary and logical approach were used to arrive the above said tasks.

Keywords: *advanced materials science technologies, dual use technologies, scientific and technological deposit, critical technologies, export control.*

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1. Introduction

During the last decade governments, civilian and defense related companies have been expressing and still are substantial interest in the issue of dual use technology: technology that has, briefly speaking, both military and civilian applications. Though the concept of dual use technology is not that new, for some technology fields its meaning has shifted from a problematic to a desirable feature. The concept entered the extensive discourse on weapons and technology exports [1] that started in the years after the World War II. In the era of globalization, a line between dual-use technologies [2] and *«just»* technologies is so fast blurred. The modern world is based on dual technologies that can be used both in military and civilian sector. The priority of dual technologies in development of civilization is understandable for all countries, but they are of particular importance for the Ukraine [3]. Historically, the best domestic technological advances were concentrated in the defense sector only. In the West, the technologies often come in military from civilian industry; for the Ukraine, until recently, this option was completely uncharacteristic. Overcoming of many difficulties that Ukrainian industry faces is associated with accelerated development of dual-use technologies [4] and their implementation into industries. This direction now becomes of a priority in the state scientific and technical policy of Ukraine with regard to the processes of integration into the world economy and inevitable competition with the western companies. In fact, on the basis of dual technologies, the most important areas of the Ukrainian's economy are being reequipped – transport, communications, power sector, engineering, medicine, agriculture, etc.

In consequence, the following questions may then be raised therein: what are dual-use materials science technologies and how can they be distinguished from other technologies? Are those should be considered as a total privilege of the government as it was in the USSR or they could be found under the umbrella of a public-private model? Or are there other more conceptual and less technical reasons? All of this also rises a lot of debates around the concept of so-called *«scientific and technological depository* *of advanced material science technologies»* introduced by high-tech states and its' profound significance for state's security. Undoubtedly that a certain impact and influence on international security is caused by transfer of sensitive materials science technologies, a dilemma of filing up those in a stock for tomorrow's application and this proves a rationale of the present effort. Thus, its *object* is materials science dual-use technologies and their transfer [5] and *aim* is to assess an evolution of premises of those technologies appeared in Ukraine after the Independence and those developed until nowadays. And also to debate a concept of *«scientific and technological depository of advanced material science technologies»* and its profound significance for state's security.

2. Methods of research

Mechanisms for actual *viz.* commercial transfer of materials science production technologies of dual-use virtually do not exist and there are strong political, economic, security and legal reasons for this. Nevertheless, despite the above said, the transfer of intangible technologies and conditions associated with it have continued to ignite a huge interest in the last decade. The process of technology transfer as a whole is neither simple nor systematic and far from being that perfect, especially when it comes to dual-use technologies and at present reduced to a short relationship between supplier/recipient only. Thus, this endeavor makes an attempt to analyze and scrutinize historical, political, and mental barriers between technology supplier/recipient and future prospects and real steps forward. It also undertakes an attempt to raise debates around a concept of *«scientific and technological depository of advanced material science technologies»* and its' significance for state's security. The study employs qualitative methodology and is under the umbrella of a descriptive research design to agree on historical and other implications for a transfer of intangible technologies and state's security. As above mentioned, the issue of dual use technology received substantial interest in the past decade, both from policymakers and analysts. Political, and legal analysis are conducted in relation to these technologies, actions and questions popped up nowadays associated with 'em. This descriptive research portrays a rather accurate profile of current situation happened around the dual use technologies in Ukraine. This design offers a profile of described relevant aspects of the problems of interest therein from author's individual perspective.

3. Research results and discussion

The development of materials science technologies of tomorrow is a key factor which determines any country's economic position and status all over the world. In the United States, Great Britain, Japan, Germany, Singapore, it is believed that the advanced materials science technologies being developed should be considered from a perspective of their wider use in both civilian and military applications and a creation of scientific and technological deposit of materials science technologies (STDMST) is being considered as a common task of national economies and securities. An indispensable condition for a successful development of S&T progress is timely creation of STDMST, which is a solid basis for new developments and industries. This process is considered to be a matter of special concern for any state, is regulated by state and, therefore, is a subject to state's planning. In the modern era, which can arbitrarily be called as the *«era of emerging technologies»*, the concept of such *«a deposit»* bears much deeper meaning than that one previously accepted, since the objects of accumulation are not only raw materials and/or products, but accumulated scientific knowledge and advanced materials science technologies. Therefore, the concept of *«deposit»* is more correctly to be interpreted as *«accumulation»* [6]. That is why the leading foreign countries devote so much attention and efforts to such an «accumulation» and even allocate entire government programs to it (for example, the Program on National Critical Technologies (USA)). The program was the most important tool to implement the US New Approach to Ensure Military and Technical Superiority (mainly elaborating the future (*«the deposit»*) of advanced technologies, rather than new weapon systems) and at the same time, advanced military and technical development. In fact, this program took one of the first places in the general hierarchy of those means ensuring the US military and technical superiority. The National Critical Technologies Panel was established by the Fiscal Year 1990 Defense Authorization Act (P. L. 101–189) [7] through the amendment of the National and Technological Policy, Organization and Priority Act of 1976. The Panel was charged with identifying 30 national critical technologies, the most important for national security and economic development in the long run. This program was a complex of interrelated activities aimed at accelerated development of technologies that provide opportunities for both consistent, evolutionary improvement of the main advanced weapon systems and the formation of a basis for technological breakthroughs in order to ensure the US military and technical superiority. The exact number of technologies in the program was updated annually, and changes taken in technologies mission were insignificant. The reasons were that from the very beginning, the basis for implementation of the program implied the requirements for functional interconnectedness of technologies and a continuity of their development.

At the same time, STDMST establishment, experimental development, serial production – all these stages have much in common – its consistency, focus and a strict adherence to the principle of *«narrowing»* of the work as it approaches to a pilot sample or prototype, and further to a real model adopted for service. In Ukraine, as in other countries of the former Soviet Union, materials science technologies have traditionally been evaluated primarily by their importance to tackle military tasks. The announced state conversion program in the early 90s was supposed to correct the pernicious bias of the economy into the military sphere. It was assumed that advanced military technologies would have proven to be equally effective in civil life, nevertheless the expected effect was not achieved due to a number of significant reasons. After the collapse of the Soviet Union, there was observed an avalanche growth of a foreign economic activity which happened due a failure of the totalitarian system and government's full eye control as a whole. A lot of *«businessmen»* and scientists tried to get some *«private»* benefit out of the chaotic situation. At that time, *«frontiers»* were erased overnight and people being mostly isolated within the USSR for a long time became to realize the way of living outside. Not having this kind of standards and living not

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beyond but much close to a line of poverty for many of them, commercial interests became more important and visibly understandable than the economic and political security of Ukraine, thou. In combination with disappearance of many administrative mechanisms, this brought to an increase in physical volume of sales of dual-use goods and technologies abroad, which posed a threat to national security, as well as reduced a competitiveness of Ukrainian economy. Another reason was that in Ukraine, the system of export control of strategic goods and technologies was developed simultaneously under the influence of Western and Soviet models. The Soviet model was designed to terminate any transactions that did not meet national interests even before they were concluded, based on a rather complicated and informal internal and interdepartmental procedures of coordination with the final stage of discussion and approval of each important contract at the highest level (Politburo of the Central Committee of the CPSU). After 1991, the situation changed. The growing decentralization of control led to the fact that not every deal went through the tried and tested channels of the Soviet era. The incipient mechanism of the Western type was far from being that perfect and covered only the most visible and least important sphere of control from the point of view of criticality – the export of goods outside the customs territory during transactions between independent counterparties. As a result, multiple so-called *«open windows»* arose, taken by those whose goal was to enrich themselves as soon as possible and as a result the military-industrial complex (MIC) suffered more and more underfunding. In general, during the *«Perestroika period»*, due to the above reasons, a catastrophic underfunding of science, and due to a landslide and chaotic transition of state property to a private ownership in Ukraine, the high-tech sector was the most affected at that times. Thus, according to the open sources, approximately 90 USD is budgeted per scientist in Ukraine, while in other countries this amount is ten times higher: Estonia – 1303 USD, the USA – 1471 USD, Israel – 1990 USD. The innovation being the main engine of state's world rank and economy is *de jure* supported by the state: The Law of Ukraine «On Science and Technology Policy» [8], Clause 48, provides for the financing of science in the amount of at least 1.7 % of Ukraine's GDP per year. Nevertheless, such a «grace» for science was only in the first years of independence, and as of today the amount of financing is in 6 times lower than the norm: in 1991 it arrived to 2.4 % of GDP (as in the most innovative countries), in 1992 it decreased to 1.5 % GDP, in 2007 – 0.9 % GDP, in 2017 – 0.16 % GDP and in 2018–2019 [9] it was only 0.17 % GDP. Most surprisingly, that some authors cite figures indicating a significant increase in funding for science in Ukraine, but at the same time completely forget about drastic hryvnia devaluation during its existence, for example, from 1996 to 2014 it fell more than approximately 20 times [10]. Despite the declared elevation of financial support, according to the budget 2019, the National Academy of Science of Ukraine remained underfunded by almost 70 million USD [11].

«All six Ukrainian academies of sciences have less finance than one Prosecutor General. Compared to 2009, the Ministry of Internal Affairs has an increase in funding of 775 %, Security Service of Ukraine – 367 %, Prosecutor's General Office – 640 %, Academy of Sciences – 107 %», – said Anatoly Shirokov, chairman of the National Academy of Science of Ukraine (NASU) workers union [11].

Visibly, to develop all the technologies of paramount importance for the economic development of country is beyond the power of any state, no matter how economically powerful it is. Therefore, special state support and care should be rendered, first of all, to development and supervision of dual-use technologies, which are, as a rule, the most advanced, knowledge-intensive, and expensive.

Thus, what a «dual use» means? The term dual is used in its generic sense to denote the mathematical number «2». When used in relation to an operative verb such as use, «dual» means more than one, nature, or characteristic of a given object or method, or any other word it qualifies. More specifically, in the context of materials science technologies, dual use can be defined as being a usage which has both civil and military application, whether proven or potential. In a more general sense, dual use also embraces weapon technologies and their systems and sub-systems, in any of their different basing modes: ground or mobile, ship- and air-mounted, etc. However, while there are a great variety of weapon specific systems that could be associated with, it is the non-weapon technology that could be employed for military purposes which is the most difficult to define.

Dual-use issues in science and technology are increasingly discussed nowadays in literature [12] and in policy-making circles, as well as in media and in public discourse. However, there presently exists no widely accepted definition of dual-use. While previously the term was used in relation to specific technology applications, latterly research too has entered the debate on dual use. A clear definition is necessary to ensure adequate consideration of the ethical issues involved. This definition should be neither narrow, hence liable to rule out issues of genuine importance, nor wide, making oversight of dual-use science ungovernable. For example, if the definition of dual-use is limited to particular experiments in the life sciences [13] involving dangerous biological or chemical agents, then scientists or policymakers may fail to take into account other types of potentially dangerous R&D. Meaning the research that could be used to play havoc with computer networks, jeopardize buildings or contaminate the food supply. If the definition of dual use is too wide in a scope, it may be applied to areas of science that are very unlikely to be used for malevolent purposes, place futile administrative burdens on scientists, and eventually boost innovation that might prove beneficial to society.

Early definitions of dual-use imply that a technology has both military and civil applications. This interpretation of dual use gained currency in a debate on weapons and technology exports which began soon after World War II, serving to underpin national export control legislation and international treaties for the US and its allies [14]. It is also applied in non-proliferation treaties and arrangements [15] referred to conventional arms and other technologies used in military to promote national security (e. g. ballistic and missile technologies, cryptography, etc.). Under the export control regime, access to dual use materials and technology is limited within a competition with foreign military challenges, while in parallel, state own military and civilian environments can derive the benefits from such technologies [16]. Since the end of the Cold War, the military/civil purpose concept of dual use has been used increasingly to promote states economic interests. Thus, the dual use aspect of a technology is considered as something that should be encouraged, since it helps to advance modern weapon systems while at the same time pursuing a state's economic competitiveness through integration of military and civil contexts and a more efficient allocation of R&D funding between them. Governance of this approach to materials science dual-use technologies is almost exclusively dependent on national (i. e. export control) and international (i. e. sanctions) legislation. Recent accounts of dual-use in science focus on a misuse, rather than pure civil and/or military application. The main idea is that dual-use dilemmas pop up when materials science technology has a primary intended application or use which is peaceful, and a second one which is supposed to be military or prohibited and is not initially intended by those who developed the technology in the first place. As it was above said this conception of dual-use was first introduced immediately after World War II, in debates on application of nuclear physics to weapons of mass destruction (WMD) development. More recently, it was widely employed in discussion of increasing risk of malevolent use of biotechnology by terrorists and criminals, following the anthrax attack in the autumn of 2001 and publication of several research works on highly virulent pathogens. Besides concerns for human health, an increasing concern for human rights related misuses of technology prompted a diffusion to elaborate more the definition of dual use, which has the potential to address issues as diverse as individual or social wellbeing, privacy, and environmental, information, or infrastructure security. Governance of this approach to dual use does not depend solely on national and international legislation, but also on self-regulation in engineering profession (e. g. research ethics, codes of conduct, Internal Compliance Program (ICP) and institutional oversight) and on a stronger role for civil society in determining what should count as benevolent. The categories benevolent/malevolent encompass civilian/military purposes, insofar as some military non-offensive purposes might be good (e. g. the aerosolization of a pathogen undertaken for protective purposes). In order to understand the nature and dangers of aerosolization with a view to preparing safeguards against an enemy known to be planning to use the aerosolized pathogen as a weapon. Moreover, the distinction between benevolent/malevolent purposes seems more suited to addressing dual use concerns in engineering, since it focuses on the potential for engineering science to be misused, regardless of the context (i. e. civilian or military) in which it is developed.

Thus, the dual-use technologies include [17] technologies used in a development of weapons and military equipment that can be used to create civilian products, as well as the technologies related to civilian products, potentially suitable to be employed in the defense sector. Dual use technologies possess significant advantages over solely military and civilian technologies, which consist in the fact that they can stimulate their development and shorten an implementation period, as well as a transformation of military and civilian technologies due to the fast turnover of funds invested in dual technologies:

– reduce a technological gap between military and civilian sectors of economy, which allows, if necessary, to use a potential of entire industry of state in the interests of defense and industrial complex;
– provide an opportunity to optimize and minimize costs of state budget and extra budgetary funds for the maintenance of scientific, technical and industrial potentials, as well as production costs, accounting for changing conditions;
– reduce military expenses on a development of a scientific and technological reserve of a dual use and make possible to concentrate the efforts on development of purely defense technologies in order to create military needs of tomorrow. Dual use technologies as a product are rather specific, on the one hand, they are based on scientific and technological achievements or intellectual property (IP) embedded in those, on the other hand, the technologies should possess standard consumer properties, i. e. scientific and technological progress should be brought to a level of goods to become a technology. As a rule, the second component is financially more voluminous, although the first one determines technology's IP. The transfer of intellectual or innovative part of technology allows to determine the essence, and stage of introduction into production required to bring it to the goods level. Such specific technology when it is promoted to the market requires the effective management, including governmental as well.

The need for state support and management of transfer of dual-use technologies is especially important for Ukraine at present. The scientific, technical and technological bases created in previous years, moreover, as a rule, in public sector of the economy, having fallen into the conditions of an emerging technology market, are used extremely inefficiently. Many R&D organizations and institutes, especially academic ones, having the highest scientific and technical potential and creating world-class intellectual property, are not able to independently bring those inventions to the level of full-fledged technology and therefore often offer *«semi-finished products»* to the market. As a result, the cost of such a product is low, below the objective and competitive market. In addition, the fragmented actions of domestic scientific institutions to conclude contracts with customers, their inadequate legal training allow customers to impose their unfavorable conditions for authors, primarily in terms of protecting IP rights and a financial side of contracts. That is why a commercialization of dual-use technologies is possible only with the successful and close interaction of R&D organizations, MIC enterprises and a private sector in the following matters:

– selection and evaluation of technologies with commercial potential;
– patent search;
– assessment and protection of intellectual property (IP) and know-how;
– preparation of license agreements, contracts for a provision of consulting services, agreements on scientific, technical and industrial cooperation;
– legal assistance in case of violation of IP rights and unfair competition;
– management of newly created small enterprises to commercialize R&D results;
– search and attraction of investors for start-up and subsequent financing of commercialization of R&D results created at the expense of state budget.

A solution of these problems will significantly elevate an efficiency of innovation process in state's economy as a whole and in the military-industrial complex in particular. The functions to ensure the solution of these problems must

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be assigned to a specialized organization that will be able to integrate enterprises and their developments for bigger projects. In this case, methods and mechanisms of a cluster approach using preferences of special economic zones of technology-innovative and industrial-production types (so-called technology parks), which was not without success implemented in the military-industrial complex under the planned Soviet economy, may turn out to be a rather effective.

As the world experience shows, one of the most effective forms of implementation of such a policy is to create the public-private partnerships, in the capital of which, the local authorities, commercial partners and institutional private investors can participate, who conclude strategic cooperation agreements. A good example is the US Department of Defense (DoD) Science and Technology Dual Use Program. Dual-Use Science and Technology Program and afterwards the Technology Reinvestment Project (TRP) [18] connect the research communities of military and civil sectors, allowing the formation of partnerships between the US armed forces, private industry, and universities. Special departments transfer new R&D developments created as part of the implementation of the DoD programs to the industry. Also, teams uniting representatives of the military department, industrial companies, venture capital investors and technology brokers can be created. The strategy of dual use technologies and innovations as a new way of organization of business, including the military-industrial sphere, played a significant role in development and expansion of possibilities of public-private partnership in the US economy, which, however, would not have been possible without improvement of a legislative framework of innovation activity. An abrupt intensification of activities in the field of transfer of dual use technologies and a development of new ways of organization of military business in the United States occurred in the 90s of the last century. Today, the technology transfer occupies a significant place in the military-technical policy of the US Defense Ministry, and not only in the form of direct transfer of military technologies, but also in the form of dissemination of S&T knowledge, organizational and managerial methods, production experience, etc.

4. Conclusions

The analysis shows that being created public-private structures definitely contribute to MIC innovative development, which should take place in accordance with a development of the process of MIC modernization and re-arrangement, aimed at increasing its effectiveness.

Thus, an emphasis on development of dual-use materials science technologies enables not only to elevate a technological level of state's defense industry by mean of its technological re-equipment on a domestic base, but also with the minimum use of budgetary funds, to create STDMST for a generation of weapon systems of tomorrow, and ultimately re-equip the Ukrainian Army and strengthen and solidify a position of defense industry at the world arms market.

The symbiosis of public-private structures will significantly increase a transparency of transfer of dual use materials science technologies and will cut off illicit information exchange and illegal financial and materials flows. It also ensures the most effective and complete efforts, IP, and resources of R&D teams of the National Academy of Sciences of Ukraine.

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