Development of the defense and industrial complex on the basis of Industry 4.0

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Abstract

The purpose of the article is to study the peculiarities of the development of the defense-industrial complex on the basis of Industry 4.0. This study identifies the main trends of the Fourth Industrial Revolution (Industry 4.0) and the possibility of implementation at the enterprises of the defense industry. The concept of "Industry 4.0" covers modern technologies related to automation, data exchange and production. The tools of Industry 4.0 are digital technologies: big data; quantum technologies; robotics and sensor components; neurotechnology and artificial intelligence; new production technologies; industrial Internet of the Things (IoT); distributed registry systems; wireless communication technologies; virtual and augmented reality technologies. Industry 4.0 leads to the mass introduction of cyberphysical systems in production, to the automation of most production processes, the endowment of devices with artificial intelligence and the introduction of modern technologies. The vast majority of enterprises of the defense-industrial complex of Ukraine are at the level of automation, based on the technologies of Industry 3.0 and even Industry 2.0. It is advisable to continue this integration using the principles of Industry 4.0 and, thus, to make a "digital leap" in the creation of modern weapons. Today, robotic complexes, electronic devices, elements of artificial intelligence, industrial Internet of the Things technologies, and smart factories have been properly developed.

Key words: Industry 4.0, defense-industrial complex, industrial enterprises.

Introduction

The main trend of the industrial development in the middle of the second decade is Industry 4.0. The concept of "Industry 4.0" covers modern technologies related to automation, data exchange and production. That is, it is a set of technologies and concepts for the organization of the value chain, which combines "Cyber-physical systems (CPS)", Internet of things " (IoT) and "Internet of services" (IoS).

Since in 2011, this trend has become appropriate for use by multinational corporations and large industrial enterprises. C. Grifdstaff and a group of businessmen, politicians and scientists initiated the development of the principles of Industry 4.0 as the integration of "cyberphysical systems" in production processes (National Academy of Science and Engineering, 2011). Also, in 2011, representatives of the Industry-Science Research Alliance (Germany) developed the Future Project strategic initiative. This project was supported by the Federal Government and created the Industry 4.0 working group. The global trend of economic and industrial development based on the technologies of Industry 4.0 came in 2014 at the initiative of the President of the World Economic Forum Klaus Schwab (Schwab, 2015).

The development of the principles of Industry 4.0 is quite common now in educational

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institutions. In Ukraine, the technologies of Industry 4.0 are already spreading, but the development of technologies of this industrial revolution is insignificant.

The defense-industrial complex is important for ensuring Ukraine's sovereignty today. The transfer of its capabilities to the principles of Industry 4.0 is urgent. The basis of the transformation on this basis are aircraft and missile technology, radio electronics, power supplies, laser technology, satellites and biological weapons. To this should be added cybersecurity, social networks, virtual reality. It should be noted that the cluster "information and communication technologies" is a significant support for the development of Industry 4.0 in the defense industry. This sector is traditionally a powerful specialist.

Based on the above, it is advisable to develop the basis for the implementation of enterprises of the defense-industrial complex of measures to develop the principles of Industry 4.0.

Problem definition. The purpose of the article is to study the peculiarities of the development of the defense-industrial complex on the basis of Industry 4.0.

In the framework of this study, a problematic issue is highlighted: to determine the main trends of the Fourth Industrial Revolution (Industry 4.0) and the possibility of implementing defense-industrial complex enterprises.

Material and methods

To achieve the goal of this study, a system of general scientific and special methods and approaches was used, in particular: generalization, systematization, empirical research, systematic and logical approach – to develop the theoretical foundations and essence of Industry 4.0; historical, dialectical, methods of system-structural analysis and synthesis - in the study of scientists on the stages of digital transformation for the transition of enterprises to the principles of Industry 4.0.

On the basis of the conducted research the following results are received: features of advanced economic development of the enterprises on the basis of the Industry 4.0 and the basic factors of influence are defined; the essence and trends of Industry 4.0 are studied on a global scale, the main spheres of implementation of the achievements of Industry 4.0 at the enterprises of the defense-industrial complex, as well as the ways of creating additional value are analyzed and singled out.

Results and discussion

The Fourth Industrial Revolution (Industry 4.0)

The fourth industrial revolution (Industry 4.0) is based on the development of knowledge-intensive, high-tech, advanced, innovative technologies. Industry 4.0 is a type of production and operation with a focus on combining technological processes and individual stages of the product life cycle with a network based on Internet of Things technology.

Experts identify four basic technologies, as a result of which revolutionary changes are expected:

- Internet of Things (IoT). In this technology, the Internet is used to exchange information not only between people, but also between different "things", i.e. machines, devices, sensors. A variant of IoT is the Industrial Internet of Things (IIoT), which is the basis for the creation of fully automated production. The role of personnel in this case is to control the operation of machines and respond only to emergencies.

- Digital ecosystems. These are systems consisting of various physical objects, software systems and control controllers that allow you to imagine such a formation as a whole. Physical and computing resources in such an ecosystem are closely linked, monitoring and management of physical processes is carried out using IIoT technologies. Traditional engineering models coexist harmoniously with computer ones in combination with the following:

- Data Driven Decision or simply Big Data. Huge amounts of information accumulated as a result of "digitization" can be effectively processed only by

computers, using cloud computing and artificial intelligence technologies (Artificial Intelligence). The person will receive the processed data, the most convenient for perception, analysis and decision-making;

- a complex of information systems opens for use by customers and partners (digital platforms). These can be digital platforms and systems for managing business processes, for integrating the Internet of Things into physical business processes, for analyzing and forecasting the state of equipment, and so on.

Industry 4.0 leads to the mass introduction of cyberphysical systems in production, to the automation of most production processes, the endowment of devices with artificial intelligence and the introduction of modern technologies.

Scientists have distinguished the following three trends in industrial development (Matyushenko, 2017):

1) digitalization of production processes;
2) use of new materials;
3) smart environments.

The tools of "Industry 4.0" are digital technologies: big data; quantum technologies; robotics and sensor components; neurotechnology and artificial intelligence; new production technologies; industrial Internet of Things (IoT); distributed registry systems; wireless communication technologies; virtual and augmented reality technologies.

For industrial enterprises, this will increase productivity and reduce production costs. The International Business School at the Massachusetts Institute of Technology, together with one of the world's largest management and information technology consulting companies Capgimini, conducted a study that analyzed the performance of 184 large manufacturing companies in various industries. The results of the study showed that the level of readiness of enterprises to implement the principles of Industry 4.0 differs. At the same time, companies that carry out digital transformation are significantly ahead of others in terms of revenue, profitability and capitalization (Fig. 1).

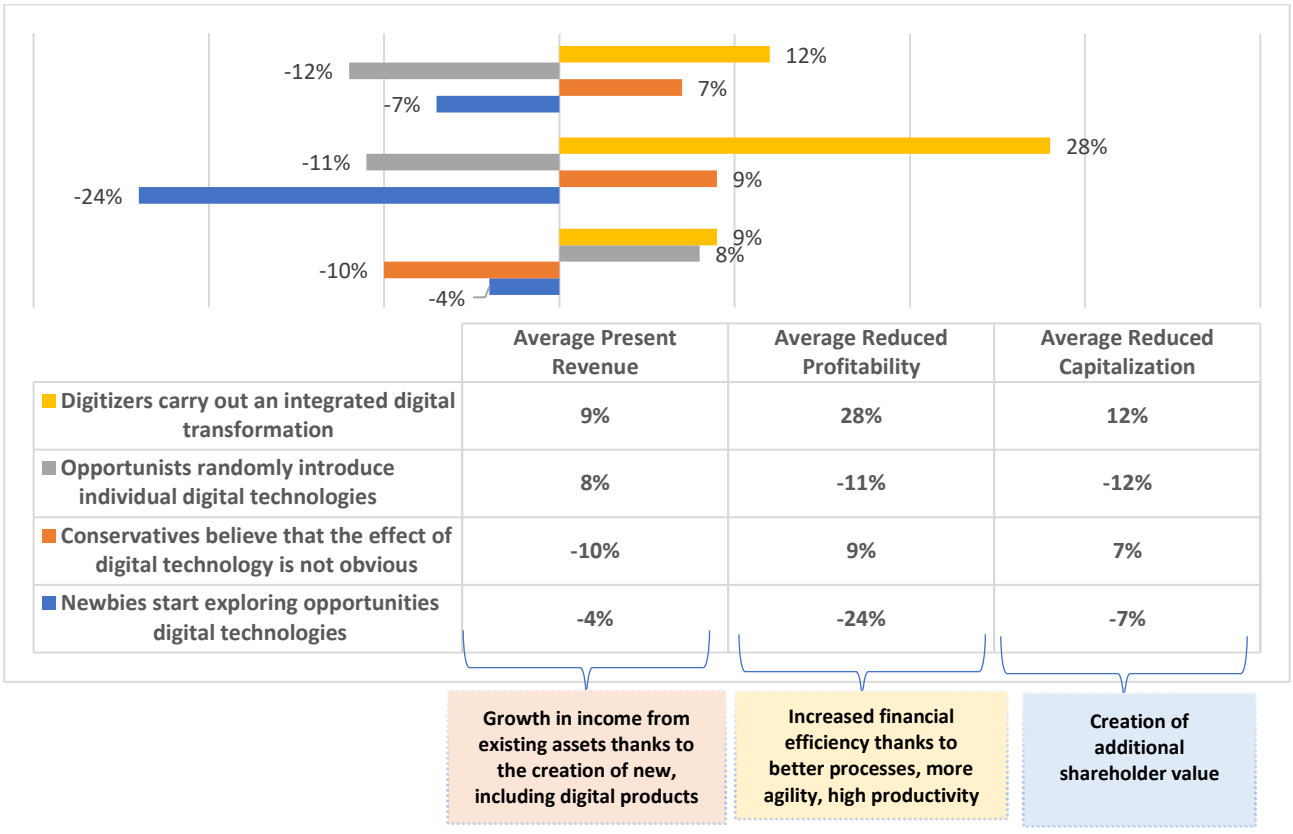

Figure 1 – The main differences between companies in the pace of digital transformation in terms of income, profitability and capitalization.
(MIT management)

Despite the positive aspects of digitalization, there are some difficulties in implementing this process (Fig. 2).

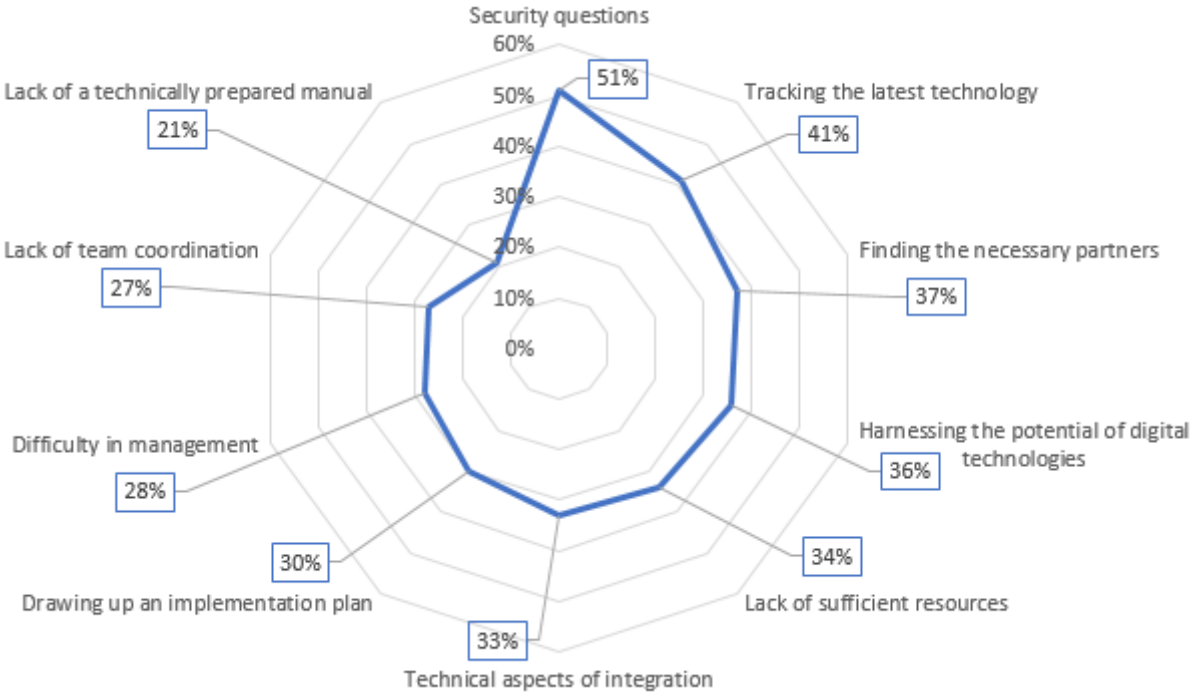

Figure 2 – The main problems of digital transformation of an industrial enterprise (McKinsey, 2017)

To solve these problems, digital platforms are being developed that provide direct interaction between sellers, buyers, suppliers and partners, which minimizes transaction costs and expands the possibilities of interaction. The transition to Industry 4.0 means the ability to adopt and integrate digital and physical technologies to improve performance, become more productive, evolve and innovate. Such processes are accompanied by radical changes for any organization. Experts from the McKinsey Global Institute believe that it will take about 100 years to move to the Industry 4.0 digital platform (McKinsey, 2017).

The third digital revolution, which began in the second half of the last century, is now coming to an end. Its characteristic features are the development of information and communication technologies, automation and robotization of production processes. That is, if Industry 3.0 provided for conventional computerization and automation, then among the important elements of the new type of production – cyberphysical systems, Big Data, artificial intelligence, 3D printing and more. It is also about the evolution of business models of industrial enterprises, as well as the change of production paradigm as a result of the new industrial revolution.

Industry 4.0 has the following features:

- fully automated production, where all processes are controlled in real time and taking into account changing external conditions;
- cyberphysical systems that create virtual copies of objects of the physical world, while controlling physical processes, with decentralized solutions;
- the ability of systems to integrate into one network, interact in real time, self-tune and self-learn;
- active use of Internet technologies that provide communication between staff and machines.

"Industry 4.0" is the integration of the links of the industrial production chain with the use of the latest information and communication technologies: Embedded System; Cloud computing; Big Data, Wireless Communication; Remote and mobile access; 3D printing. At the level of Internet systems, the following are

distinguished: IoT – Internet of Things and IIoT – Industrial Internet of Things, etc. At the instrument level, there are such systems; SiP – system in the package; SoM – system on the module; SoC – system on the crystal. At the level of microprocessor systems, there is a smart device (Smart Device). A digital twin is used during production or operation.

Implementation of Industry 4.0 in the defense-industrial complex

In order to effectively use the elements of Industry 4.0 in the defense industry, it is worth exploring the development of these elements in the civilian spheres, which are already taking advantage of the Fourth Industrial Revolution.

Today, robotic systems, electronic devices, elements of artificial intelligence, industrial Internet of Things, additive manufacturing, smart factories are properly developed. In this regard, the digital economy is developing, where cyber-physical systems form such a concept as “smart city” and the concept of K-countries (“smart countries”).

Remote a cyber-physical system involves the interaction of a human operator with a machine. However, in the concept of Industry 4.0, there is still machine-machine interaction, in which a group of military equipment can autonomously perform a task on the battlefield. In this regard, a new concept of “cobots” (collaborative robot), i.e. a robot that interacts (collaborates with other elements of the system – other robots). According to the international experience of modern military conflicts, one of the promising areas of hostilities is the involvement of various ground remote-controlled (robotic) complexes. In this direction, work is being carried out in Ukraine to study a sample of the remote-controlled Camel platform, which is produced by domestic companies. Design Bureau «Robotics», since 2015, has been developing in the field of creation, testing and preparation for serial production of samples of combat robots and their components.

We pay special attention to the development of the components of the artificial intelligence system and their implementation in the development. We currently have well-developed models of ground-based robotic systems BRP-3 and RSVK-M3. They have passed factory tests and have proven themselves in numerous tests in real combat conditions in eastern Ukraine, among other things, ready for mass production.

The state target defense program for the development of armaments and military equipment for the period up to 2020, approved by the Resolution of the Cabinet of Ministers of Ukraine of March 30, 2016. №284-6, provides for separate development measures, namely:

- development of a remotely controlled base platform (robotic complex) for the installation of combat modules and special reconnaissance and demining equipment;
- development of a remote ground control system armaments and military equipment (for cars and armored vehicles).

Standardization is the foundation of industry development, and for Industry 4.0 it is crucial. The standard in the defense industry is a technology that largely meets the needs of the military. A significant portion of the standard may be classified as “secret”, which increases the combat effectiveness of products that use this standard. The use of standards is controversial. Yes, you should take into account the various documentation from the manufacturers of technical elements of the cyber-physical system. There can be quite a lot of imported equipment and components. The second dispute may be the resolution of a number of issues related to cyber-physical interaction between the human operator and the combat vehicle. In this dispute, it should be remembered that “cyber-physical interaction” acquires a state of “cyber-physiological interaction”.

In the field of Industry 4.0 standardization and unification are carried out by the following organizations: Industrial Internet of Thing; Reference Architecture; NIST (National Institute of Standards and Technology, US) – Current Standards Landscape for Smart Manufacturing Systems; Reference Architectural Model Industry 4.0 (RAMI4.0). It is advisable to focus on ISO 4.0 Industry “ISO focus: The new Industrial revolution”, which describes the application of standards in digitization, for elements of

artificial intelligence, for the operation of robots and more.

Regarding the defense-industrial complex of Ukraine, it is worth noting the expediency of focusing on international standards, but it should be remembered that the standards are not a priority for the technical policies of industrial enterprises. It should be added that the technical policies of industrial enterprises are not common in Ukraine. When using elements of Industry 4.0 in military equipment, it is the technical policy that determines both the success of the manufacturer and the performance of tasks on the battlefield.

Industry 4.0 defines the vision and principles of operation of the "Smart Enterprise". In this case, Industry 4.0 technologies focus on the integration of technological processes, product life cycle and stage of operation through computerized systems and networks (in particular, the Internet).

For the company, the main stages of digital transformation for the transition to Industry 4.0, are presented in Fig. 3.

Figure 3 – Stages of digital transformation for the transition of the enterprise in Industry 4.0

Digital competencies are of paramount importance for the successful implementation of the Industry 4.0 concept. The stages of transition of enterprises to the implementation of the concept of Industry 4.0 are as follows:

1) development of a strategy for the implementation of the concept of "Industry 4.0". To do this, it is important to assess the level of digital development of the company, set clear goals for the next five years, set priorities so that the measures taken bring maximum benefit to the business and are consistent with the overall corporate strategy;

2) development of pilot projects that should have limited coverage but demonstrate the integrity of the Industry 4.0 concept and have corresponding effects. The design will promote interaction with market leaders in the use of digital technologies: cooperation with startups, higher education institutions, industry enterprises – to enhance digital innovation;

3) identification of the necessary competencies, resources and tools for the implementation of the "Industry 4.0" strategy, which can radically improve all business processes. To this end, strategies for attracting specialists and optimizing processes, as well as strategies for implementing new technologies are being developed. The success of the implementation of the concept of "Industry 4.0" will depend on the qualifications and knowledge of specialists;

4) improving skills in data analytics. At the initial stage, it will be advisable to create an inter-functional group of specialists. Later, this function can be fully introduced into the organizational structure of the enterprise;

5) transformation of the company into a digital enterprise to realize the potential of the "Industry 4.0" concept. Create conditions for the development of digital culture: it is necessary that all employees think and act as representatives of the digital generation, showing a willingness to experiment with new technologies and learn new methods of work;

6) active implementation of the ecosystem approach. It is important to establish partnerships, use existing platforms.

The Smart Enterprise uses a modular structure, cyberphysical systems control physical processes, create a kind of virtual copy of the real world, and make decentralized decisions. With the help of the Internet of Things, cyberphysical systems connect and interact with each other and people in real time. With the help of the Internet of Services, internal and third-party services are selected and disposed of by members of the value chain.

In essence, the integration of cyber-physical systems (the basics of Industry 4.0) in technological processes and directly in the operation of products has identified a fundamentally new way to increase the competitiveness of products and functionality of these products. This also applies to the products of the defense industry.

In general, the integration of defense capabilities and the human operator has been a pressing issue for millennia. It was Industry 4.0 that brought this integration to a new level of weapon distancing away from humans on the battlefield without losing the tactical and technical characteristics of the weapon itself. The man-operator, together with the connected network elements of these weapons, provides significant advantages. The main advantage is that the military (human operator) is protected as much as possible, because it is not directly on the battlefield.

Information and communication technologies, in particular elements of the Internet, enable the military to form networks of reconnaissance and combat vehicles. This network can perform combat tasks without the direct presence of the military on the battlefield. When performing combat tasks in this case, it is possible to collect data on the course of the battle and further analyze this data for additional information. This information can be useful for maintenance of equipment, to improve the production process, to improve tactical and technical characteristics.

For manufacturers, elements of Industry 4.0 provide information about the entire product life cycle, which reduces future shortcomings, errors and shortages in the production of new and modernization of existing products.

Regarding the identification of directions of technology development in the era of Industry 4.0, it is necessary to analyze patent activity in countries where Industry 4.0 technologies are properly developed.

For the research we use information from the site of IFI CLAIMS Patent Services (CLAIMS Direct platform), which has been operating since 1955.

Technologies in 2019 by the number of patents formed the following rating:

- first position: electronic processing of digital data (58821 patents);
- second position: transfer of digital information (39301 patents);
- third position: semiconductor devices (28373);
- fourth position: wireless communication networks (24288 patents);
- fifth position: video communication (20062).

Over the last five years (2014–2019), patent applications and issued patents for more than 2,100 of the 4,600 groups have seen an accelerated growth for that of Industry 4.0 in the defense industry (Ten Fast Growing Technologies, 2019): 94% – accessories or device adaptations, information panels; 51% – information and communication technologies adapted for image processing; 42% – computer systems based on specific computational models; 40% – additive production technology; 26% – control systems or regulation of non-electrical quantities; 23% – planes and helicopters.

Regarding the growth rate (Patent Classification Size & Growth, 2019), we have 93.87% for accessories or devices for tools and information panels – 356 patents. Regarding the number of patents, we have the following values: 23847 patents for entering data for data transmission to be processed in a form that can be processed by a computer, and ordering output for data transmission from the processing unit to the output unit, for example, interface location – we have an increase over the five-year period from 2014 to 2019 at only 4.6%. To search for information, database structures for them, file system structures for this period there are 17,398 patents, growth

rate of 4.73%. We have 14,205 patents for network agreements or communication protocols that support network applications, the growth rate is 5.62%. Slightly less, 14025 patents, we have for methods or devices for reading or recognizing printed or written characters or for pattern recognition, such as fingerprints, growth rate – 21.28%. 13614 patents exist for processes or devices adapted for the manufacture or processing of semiconductor or solid-state devices or parts thereof, the growth rate is 3.35%.

Summarizing patent activity, we note that for Industry 4.0 in the field of defense-industrial complex is important to use developments in the fields of information processing, data transmission networks, information and communication technologies, radio electronics, semiconductors.

As for the industrial enterprises of the defense-industrial complex in the conditions of Industry 4.0, it is worth considering the possibility of designing shops on the basis of "smart factories". An example is the Tesla Motors gigafactory. A feature of such shops is their modular structure. The main modules of such shops are the technologies of industrial Internet of Things, machine learning and artificial intelligence. These modules must interact in such a way that the design creates a virtual scheme of the physical environment, which contains both technological processes (shop, factory) and the place of use of the product (battlefield). The interaction of the modules requires, in turn, the use of Big Data. It should be added that each product in Industry 4.0 can be unique and Big Data technologies allow manufacturers to track its life cycle.

Development of Industry 4.0 in Ukraine

The development of Industry 4.0 in Ukraine is subject to the development trends of economic clusters. In Ukraine, there are 9 clusters that are possible for the breakthrough development of the national economy (Foresight, 2018). They can be divided into three groups. The first group contains those clusters that are already quite developed in Ukraine. These include the "Agrarian Sector", the "Defense Industry" (the source states "Military-Industrial Complex") and "Information and Communication Technologies". The following clusters are promising for the strategic development of Ukraine: "New Energy"; "Development of human sciences, biomedical engineering, cell medicine, pharmacy"; "Tourism". The third group is "New substances, materials, nanotechnologies", "High-tech engineering, instrument making" and "Development of transit infrastructure".

Thus, for Ukraine the share of technologies in the industrial complex, including in the defense-industrial complex based on Industry 4.0, is relatively insignificant. However, the best practices of Industry 4.0 in the world's leading countries show that the spread of examples of the implementation of elements of the Fourth Industrial Revolution is actively rising in the media environment. Of course, open information about the technologies of the defense industry will harm the country's defense capabilities and therefore should not promote elements of Industry 4.0 in military equipment. However, the media are gradually attracting the attention of experts to the use of Industry 4.0. This promotes military equipment, which raises the level of awareness of specialists in the availability of such equipment. And this is already commercially feasible, because such equipment and weapons can be sold more expensively.

Production of construction and building materials, design of buildings and structures is properly developed in Ukraine.

The presence of these devices in concrete structures should be anticipated before pouring the concrete mixture. These devices are small in size, do not require autonomous energy sources, but have the ability to "Smart-dust" (smart dust) to notify, if necessary, information about the local load, geometry and integrity of the engineering structure. This information can be useful in both civil and military construction. Knowledge of the strength of fortifications is important. In addition, information retrieval can be periodic, and data can be stored in the Cloud storage. Data analysis will provide an opportunity to gain knowledge about the operation of the facility and its protective capacity. You can also predict the behavior of a

protective structure and take appropriate measures to maintain the proper condition of this structure. This can save both soldiers and military equipment. These strain gauges can be used not only in concrete structures, but also in paving, utilities and machinery.

The intellectual potential of our scientists, educators and industrialists makes it possible to produce elements of robotics and mechanotronics, as well as pneumatics and hydraulics. In particular, for electronic equipment, according to the analytical company "IC Insights", the market growth rate is the following application of elements of Industry 4.0: automotive electronics; telecom radio electronics; Computer Engineering; consumer electronics; electronic systems for industrial and medical purposes. All these applications are directly related to the field of defense-industrial complex.

Thus, in the complex use of Industry 4.0 technologies on the battlefield, monitoring of the war zone (video recording and aerial reconnaissance, as well as with the help of space images) will be useful. Significant amounts of information must be protected in cloud storage and subsequently processed by artificial intelligence technologies. This will greatly simplify the interaction of units on the battlefield and will provide an array of information for further analysis of errors. Training neural networks to find these errors will help prevent misunderstandings between actors on the battlefield. And this will save the lives of soldiers and military equipment. The accumulation of significant amounts of information will contribute to the development of fundamentally new tactical and strategic decisions.

The operation of facilities of the defense-industrial complex and military equipment involves the need for maintenance, prevention and repair. Classically repair works are carried out according to the following approaches: reactive approach, planned and preventive repairs; functioning diagnostics, predictive approach.

The reactive approach is used in the presence of an emergency.

Planned and preventive repairs are carried out according to the approved plan, which is formed on the basis of knowledge from previous experience of operation of such facilities. These repairs prevent future accidents.

The diagnostic method provides an opportunity to determine the condition of the object and make decisions regarding further operation or immediate repair (restoration).

The predictive approach is based on the principles of Industry 4.0. Obtaining and processing a significant amount of data from Big Data, studying them using neural networks and elements of artificial intelligence makes it possible to predict a significant number of possible emergencies and catastrophic situations at facilities. Of course, this approach involves certain costs, but anticipating and eliminating the possibility of an emergency situation at the facility later recoups these costs.

Regarding the technologies of Industry 4.0, which should be developed at the enterprises of the defense-industrial complex and used in products, it is worth noting the development of the principles of this industry in military construction and mechanical engineering, radio electronics and information and communication technologies.

Conclusions

The vast majority of enterprises of the defense-industrial complex of Ukraine are at the level of automation, which is based on the technologies of Industry 3.0 and even Industry 2.0. Of course, business management is aware of the complexity of integrating different automated control systems. Digitization requires significant amounts of funding, and the generation of Industry 4.0 systems requires significant data streams using large data warehouses using Big Data and Cloud technology.

Summarizing the above regarding the use of the principles of Industry 4.0 in the defense industry, we note that this industry is a promising component for solving current and strategic challenges facing the Ministry of Defense of Ukraine to preserve the sovereignty and independence of Ukraine.

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