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Industrial Metaverse

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SOURCES OF NEW INDUSTRIES. ISSUE 5. ARTIFICIAL INTELLIGENCE IN INDUSTRY

Expert report

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This report was prepared jointly by the Center for Strategic Research «North-West» and the Innovations and Youth Initiatives Support Fund of St. Petersburg with the support of the government of St. Petersburg.

The purpose of this report was to define the potential role of the global industrial metaverse formation trend for the industrial companies, government bodies and other organizations of the Russian Federation.

In the report industrial metaverse is defined, market structure and possible evolution pathways are examined. The report contains critical analysis of the global experience, various opinions and approaches to the emergence of the industrial metaverse market.

One of the key points of the report is that to ensure technological sovereignty and to secure its positions in the world, Russian industry needs to form its own experimental grounds for industrial metaverse readiness.

This report may be used by the industrial leaders of digital transformation as well as other participants of this process including service companies, government bodies, science and education sector.

The series "Sources of new industries"

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Content

Glossary

API	application programming interfaces
AR	augmented reality
BIM	building information model
CAD	computer-aided design
ECMWF	European Centre for Medium-Range Weather Forecasts
ERP	enterprise resource planning
ESA	European space agency
EUMETSAT	European operational satellite agency for monitoring weather, climate and the environment from space
IT	information technology
IoT	Internet of Things
MEMS	micro-electromechanical systems
MES	manufacturing execution system
OT	operational technology
PLM	product lifecycle management
RFID	radio frequency identification
VR	virtual reality
XR	extended reality
GDP	gross domestic product
AI	artificial intelligence
MFC	Multifunctional centers
R&D	research and development
OECD	Organisation for Economic Co-operation and Development
CNC	computer numerical control

List of drawings and cases

Introduction

Is the industrial metaverse a new “bubble” or a dramatic transition in the manufacturing sector of the economy?

The theme of the metaverse quickly gained popularity in 2021 at the instigation of the leadership of large US technology companies. According to this concept, social networks and consumer platforms will

move to the creation of an “embodied internet” 1 - a media platform open to third parties and content creators, accessible through virtual reality technologies.

This step was an attempt to mobilize investment market resource, additional monetization of previously made investments in virtual and augmented reality technologies, blockchain and NFT as the support of the new entertainment industry. In 2023, in the context of massive layoffs of entire divisions of technology companies, including those specially created for the development of the metaverse 2

, became

it is obvious that this attempt did not achieve its goal.

It is impossible to judge unequivocally what became the main the cause of failure. We list only the most important ones.

1. Crisis phenomena of 2022–2023 in the financial and technology markets, manifested in the form of a decrease in global funding for startups and new projects in the field of the metaverse and related technologies.

2. Large-scale criticism from the wider audit ria, which met the visionary ambiguously offers and frankly crude products presented by the company after the announcement of the new vector ra to the metaverse.

3. A new popular trend is artificial intelligence and generative models, for example ChatGPT and Midjourney, which have displaced the metaverse from the front pages of the media and shown the fastest growth of the user base in the history of the Internet.

services.

We can say with confidence that the metaverse in its consumer form has not yet taken place, and projects for its development have been frozen even by those companies that were at its origins 3.

However, the prospects for a large-scale disruption of the existing paradigm with the help of the metaverse and the need to recoup the investments already made in this

The polarized direction of the funds is pushing technology companies and digital transformation leaders to reconsider the concept of the metaverse and the sources of its growth. Already in 2022, technology Wall Street and consulting agencies are beginning to receive reports of the imminent super-fast growth of the “industrial metaverse”, which will transform the organization of production, approaches

to plant and product design, logistics, training and other aspects of industrial production and the real sector of the economy as a whole.

The authors of the report consider meta- taken precisely from the industrial point of view, which determined the selection of cases and experts who participated in the preparation of the publication.

The management of industrial companies is an audience that is significantly different from users of social networks and entertainment services who rushed to buy plots in the virtual gaming world of Decentraland in 2021. Making long-term investment decisions in industry requires more than media popularity. We need specific business results, increased competitiveness, and solutions to critical problems.

and creating new stock for productivity growth. The followers of the industrial metaverse promise all this.

Is the industrial metaverse, at first glance a collection of well-known digital technologies, a new dramatic

a transition in the manufacturing sector of the economy—or simply a bubble that reflects the short-term economic interests of a small set of global players?

According to some experts, there can only be one metaverse. Perhaps this is an indication of the nature of the trend - the desire to enter into the integration of already presented digital platforms and add-on

above them.

1 Mark in the metaverse: Facebook's CEO on why the social network is becoming 'a metaverse company' // The Verge. URL: theverge. com/22588022/mark-zuckerberg-facebook-ceo-metaverse-interview (accessed 04/20/2023).

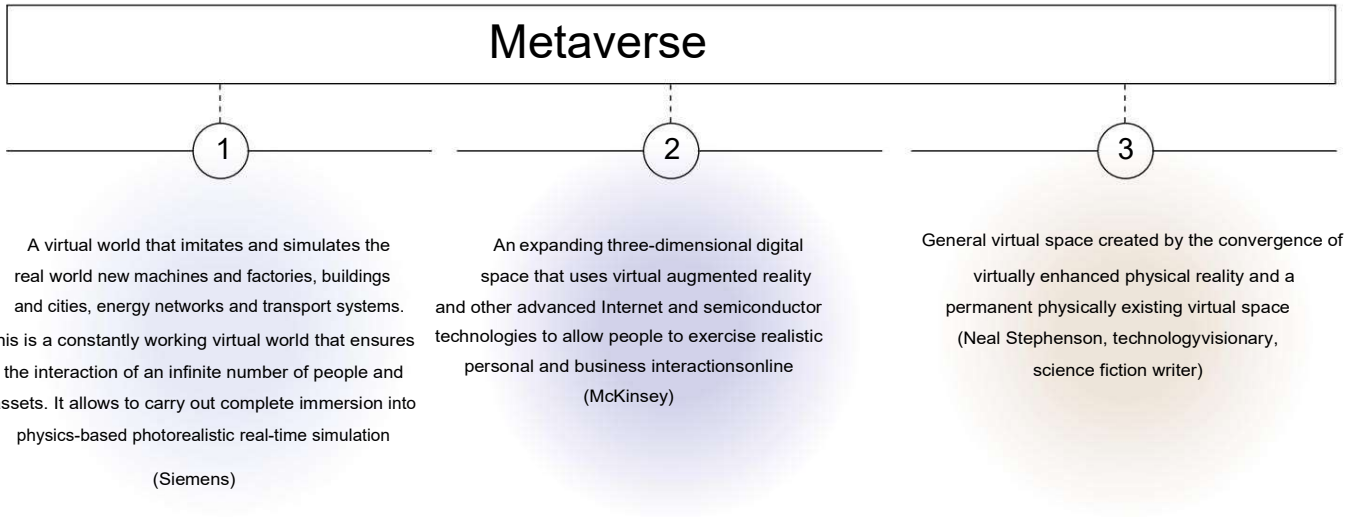
2 Microsoft reportedly makes job cuts across metaverse, Surface and Xbox units // SiliconANGLE. URL: siliconangle. com/2023/02/10/microsoft-reportedly-makes-job-cuts-across-metaverse-surface-xbox-units/ (accessed 04/20/2023).

3 Mark Zuckerberg Quietly Buries the Metaverse // TheStreet. URL: thestreet. com/technology/mark-zuckerberg-quietly-buries-the-metaverse (accessed: 04/20/2023).

1

What is the metaverse?

There is currently no generally accepted definition of the metaverse that is applied at the standards level (or even at the industry level). Various
Industry players and technology visionaries are defining the metaverse.



Within the framework of this report, the metaverse is defined by the authors as an organizational and technological system that connects and ensures the interoperability of individual digital and hardware platforms. It is scalable and expandable and can be used for a variety of tasks, including business, entertainment, collaboration and other user scenarios. Each of them will use its own set of digital technologies, including virtual and augmented reality, artificial intelligence, blockchain, cloud and edge computing technologies, tools for creating and promoting digital content.

In turn, the industrial metaverse is an organizational and technological system that connects individual cyber-physical platforms of industry and digital objects freely moving between them, ensuring total digitalization of the industrial sector (technological processes and the interaction of various digital objects with each other, incl. hours outside the set of planned interactions), reduction of transaction costs at all stages of the production and logistics chain and in service functions due toefficient logistics of resources in human-machine systems.

2

The metaverse is formed by combining end-to-end technologies into a single structure

The metaverse can be considered as a new stage in the development of the Internet, including the industrial Internet of things. It opens up many opportunities due to the increase in the volume of data collected and processed, new access devices and increased interaction. As with the Internet, the metaverse is an example of technological convergence, which involves the integration of technologies into a common package to perform actions based on the use of shared resources and interfaces.

Structurally, the technological package of the metaverse is divided into seven categories: ries, which can be divided into 21 components (Fig. 1).

1. Infrastructure and equipment

- data networks, including mobile networks (5G/6G, Wi-Fi)
- energy efficient (7-4 nm and less) computing Manufacturing equipment as part of individual connected devices or processing centers data
- data collection devices - RFID tags, MEMS sensors, including hyproscopes, accelerometers, flow, gas, magnetic field sensors, etc.
- stationary and mobile robotic systems for performing production and service tasks

2. Control interfaces

- mobile devices, smartphones, computers, tablets are now the most common access points to the metaverse
- wearable devices, VR/AR/XR glasses - the most immersive interfaces for accessing the metaverse
- wearable and stationary sensors and input/output devices provide recognition gestures, tactile communication
- invasive and non-invasive neural interfaces provide direct control of the metaverse and feedback to the human nervous system

3. Enabling technologies

- artificial intelligence is used for creating automatic control systems, data processing, virtual assistants and simulations in the metaverse
- blockchain is responsible for transaction security, authentication and identity management in the metaverse
- technologies and architectures of cloud and edge-calculations manage load distribution on computing and storage equipment for maximum efficiency and for reducing signal delays

4. Platforms

- modeling platforms and 3D engines are needed to create objects and spaces in the metaverse
- geomapping systems are used to create virtual copies of physical spaces and link virtual objects to physical ones
- application programming interfaces (APIs) allow various components of the metaverse to interact, and developers to create create new applications and services

5. Content and application creation tools

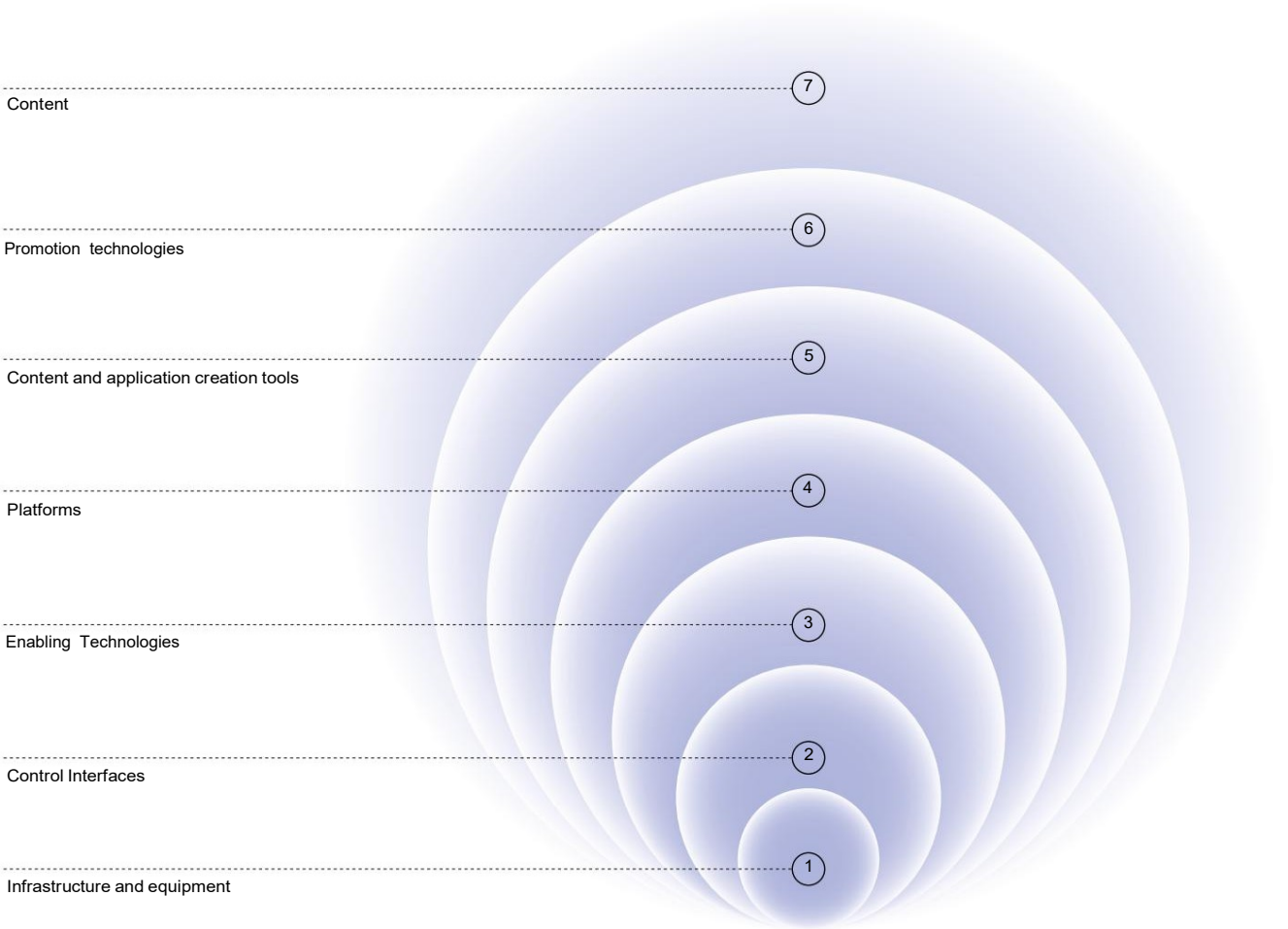
- software solutions PLM, BIM, ERP, CAD, MES for creating integrated digital twin systems and applications for working with products, processes, documentation, etc.
- geomapping systems for virtual copying of physical spaces and linking virtual objects to physical ones
- application programming interfaces (APIs) provide interaction between various components of the metaverse and allow the development new applications and services

6. Promotion technologies

- information and knowledge retrieval systems, intelligent virtual assistants and chatbots
- recommendation systems, advertising technologies gies, marketplaces

7. Content

- virtual spaces and their content, including digital twins and digital twin systems kov, simulation scenarios
- media content, including video, audio and games

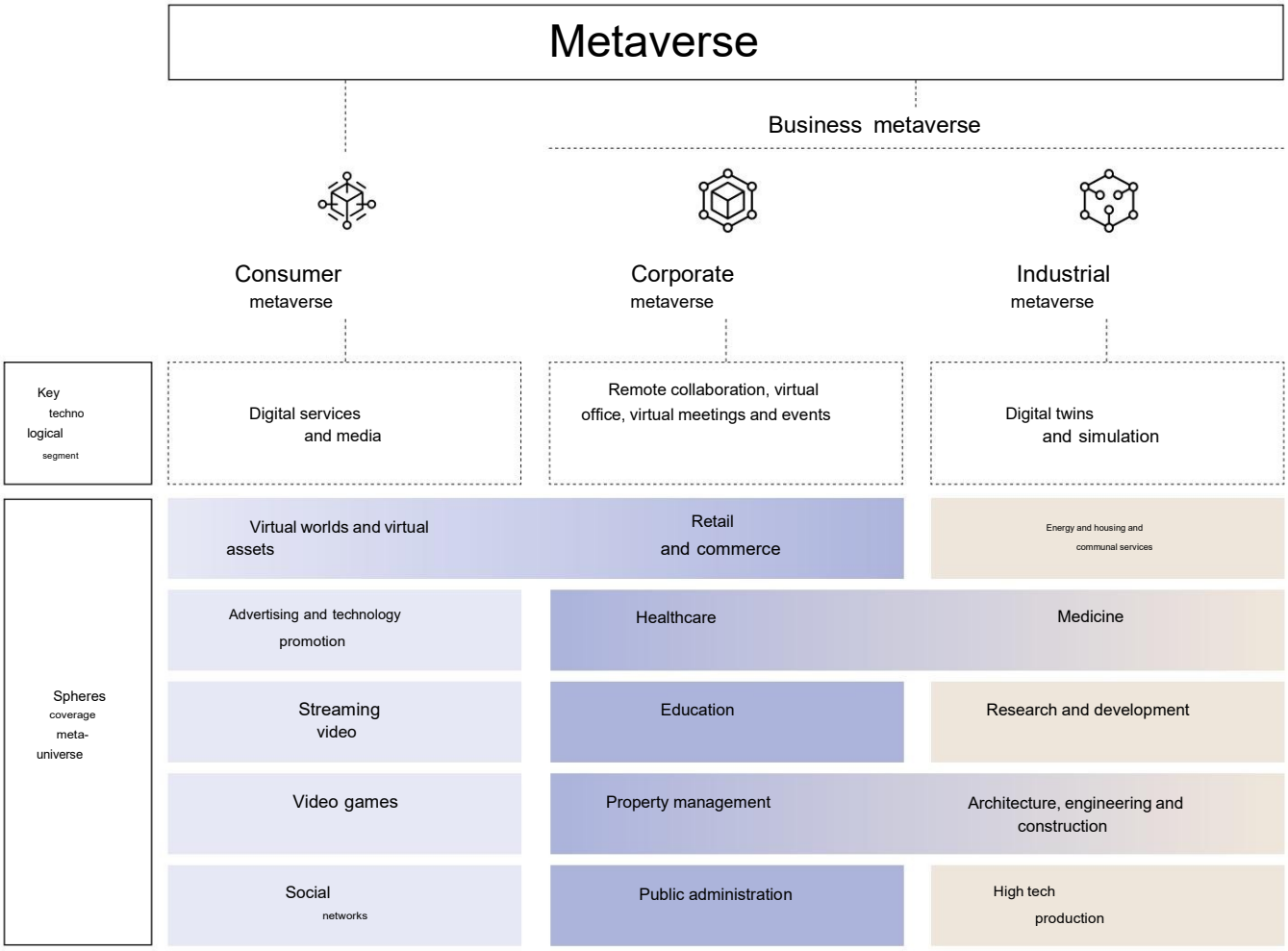


Pic. 1.
Components of the metaverse as technology package

Source: SSR North-West based on materials from Credit Suisse and McKinsey

Each type of metaverse has its own goals and objectives for the use of technology, a set of market players, scale and operating principles. We can distinguish the consumer metaverse, corporate and industrial (Fig. 2) 4. It is the industrial metaverse that is the focus of this report.

4 A Look At The Technical Realities Of A Virtual Metaverse // ABI Research. URL: 6705264.fs1. hubspotusercontent-na1. net/hubfs/6705264/ Marketing/Whitepapers/A%20 Look%20at%20the%20 Technical%20Realities%20 of%20a%20Virtual%20 Metaverse/ABI_Research_ Technical_Realities_ of_a_Virtual_Metaverse. pdf?hsCtaTracking=0ff62bf8- f2a7-44a3-8ba1-80eca9ec5 6b9%7Cf31b2ff3-8b38-4ae0- 9759-8237d5861db7 (date of access: 04/20/2023).



Pic. 2. Segments of the metaverse
Source: ABI Research

The industrial metaverse combines digital twin technologies, simulation and industrial solutions in virtual reality. Digital twins are the basic “building block” of this metaverse, one of its key elements. With their help, you can model the state of virtual copies of physical products, processes or assets throughout their entire life cycle. Immersing digital twins in a virtual environment allows them to be combined into systems and used in various scenarios. However, for now, digital copies of enterprises, transport complex facilities and cities remain experimental and may not be effective enough in real life.

conditions.

Case 1

Hyundai and Unity are building a metafactory

Source: Hyundai5

5 Hyundai Motor and Unity to Build MetaFactory Accel-erating Intelligent Manufactur-turing Innovation // Hyundai. URL: hyundaimotorgroup.com/news/CONT0000000000005240 (date of access: 04/20/2023).

The Korean automaker and the American 3D engine developer have announced a partnership to create a metafactory. A digital twin of real production was launched on a scalable platform of the industrial metaverse, which is aimed at several stakeholder groups.

Managers will be able to optimize tion, simulate scenarios and solve management problems without physical presence. Product consumers can order customized cars directly from the factory, choosing from a set of modules and testing the configurations in a virtual reality.

Metafactory has become a key component project to create a global hub for innovation in transport (HMGICS), which Hyundai is deploying in Singapore.

Digital twins integrated into systems will make it possible to interact between different stakeholders, sharing digital and physical assets that can be accessed from common digital platforms. This new market organization has the potential to be the qualitative transition that the industrial metaverse will create, and this is what distinguishes it from the current set of digital technologies.

However, these same qualities turn into one of the main barriers to the development of industrial metaverses. If the integration of digital twins of one enterprise into a single interoperable system becomes a logical continuation of the digital transformation process, then the creation of joint platforms is not such an obvious step for the market, since it significantly changes the rules of the game. But if joint platforms show qualitatively higher operational results, this will provide significant competitive advantages to their manufacturers.

Case 2

Schlumberger and Rockwell Automation have created a joint venture Sensia to develop digital oilfield technologies

Source: Sensia 6

6 Sensia. URL: sensiaglobal.com/Discover-Sensia (date of access: 04/20/2023).

Sensia is an integrator of digital technologies in the field of oil production with a comprehensive set of technological services based on a combination of virtual and augmented reality, artificial intelligence, and digital twin technologies.

This ensures the interoperability of all digital technologies and services to achieve the maximum effect of optimization, automation and industrial safety.

To better understand the characteristics of the industrial metaverse, it is necessary to
We need to compare and separate it from consumer and corporate.

The consumer metaverse is represented by the market for digital services and multimedia materials. In the modern entertainment industry, it is already difficult to determine whether a user is playing a computer game, communicating or consuming video content. This happens precisely because the “seams” between types of activity are smoothed out: often these actions can be carried out without leaving one application, which allows us to talk about a metaverse. The consumer metaverse includes virtual spaces and assets, such as plots of land in virtual worlds, game items and other objects of purchase and sale, which have recently caused a stir among users. A critical component of the consumer metaverse is advertising and advertising technologies, which are increasingly penetrating content.

The corporate metaverse is a set of technologies that is used in business for immersive collaboration tasks (creating hybrid workplaces for collaboration in virtual reality: organizing meetings, training, employee communication, designing and using tools for creating digital models of objects and processes) . In the industrial metaverse, the emphasis is not on collaboration or linking production with consumption, but on increasing the operational efficiency of industry by maximizing the use of collected data, ensuring the integration of digital

technologies. For example, the industrial metaverse in terms of information modeling technologies (IM) involves the development of data management entering the information model or created by it through the formation of common standards, protocols and file formats. This allows you to integrate TIM with CAD, PLM and ERP systems, which eliminates transaction costs between the stages of design, capital construction, organization of production lines, life cycle management of an industrial facility, as well as financial and personnel

and other resources of an individual enterprise or holding as a whole.

The potential of convergence should not be underestimated. It is precisely at the intersections of technologies, ensuring their interconnection with each other, that it becomes possible to exclude a person from the hierarchy of information and knowledge transfer, the process of content creation and the production and logistics chain. It is convergence, and not any separate technology within the previously mentioned technological

package, gives rise to such a phenomenon as the industrial metaverse.

3

Why do industrial companies need metaverses?

3.1 The key function of industrial metaverses is to reduce costs and increase the operational efficiency of companies

The metaverse is being formed by achieving interoperability of a set of digital technologies that reduce the operating costs of industrial companies. Interoperability in the metaverse is understood as the ability to interact, exchange data and use it to enable transactions, move objects and information between systems, platforms, environments and technologies 7 . Interoperability involves not just adding up the operational effects from the implementation of each of the technologies that make up the metaverse, but also the emergence of an additional effect by eliminating the “seams” between these technologies. This means an additional reduction in transaction costs, which can become the basis for rapid growth in productivity.

labor pressure, which has slowed down in recent years in developed economies.

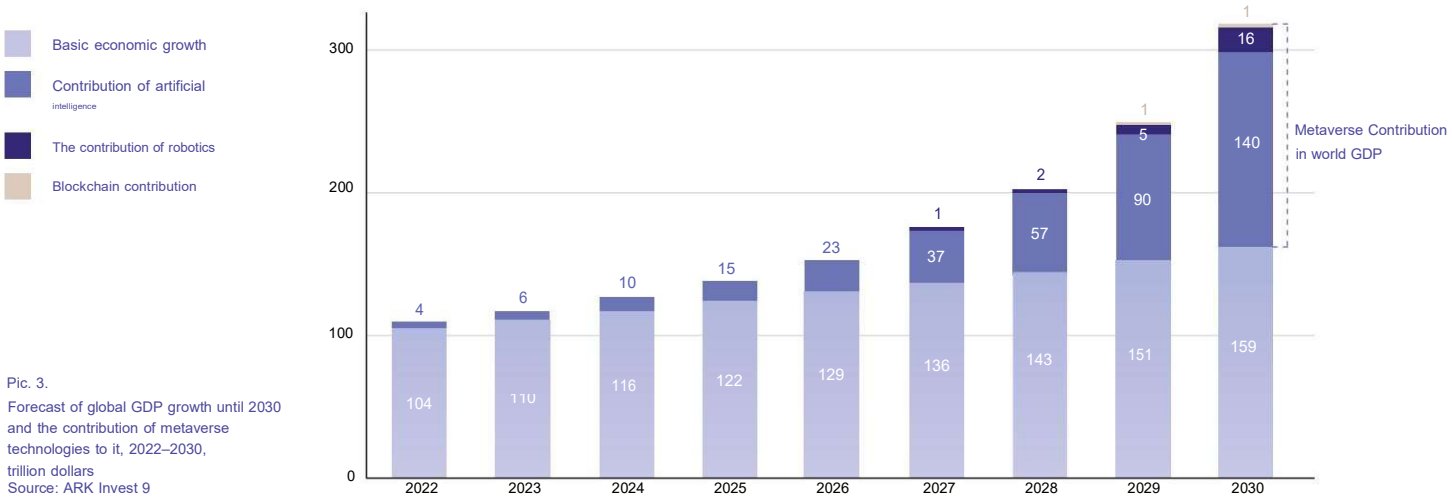
For example, in 2023, ARK Invest presented a provocative forecast that the technological components of the industrial metaverse will triple global GDP by 2030. Artificial intelligence will increase the productivity of intellectual labor fourfold, and the total direct and indirect contribution of AI to GDP will be equal to $140 trillion 8. Robotics is also significant as a critical component of the metaverse: its contribution will be $16 trillion; blockchain technology - 1 trillion. But the listed technologies will not provide such a huge contribution on their own. It is only possible thanks to technological convergence, which will lead to the formation of an industrial metaverse. There is a possibility that these estimates are overestimated by analysts and do not take into account the inertia of markets, but they reflect the general trend and balance of the potential contribution of technologies to the industrial metaverse

into the economy.

7 Interoperability in the Metaverse // World Economic Forum. URL: www3.weforum.org/docs/WEF_Interoperability_in_the_Metaverse.pdf (accessed: 04/20/2023).

8 BIG IDEAS 2023 // ARK Invest. URL: research.ark-invest.com/hubfs/1_Download_Files_ARK-Invest/Big_Ideas/ARK%20Invest_013123_Presentation_Big%20Ideas%202023_Final.pdf (access date: 04/20/2023).

9 BIG IDEAS 2023 // ARK Invest. URL: research.ark-invest.com/hubfs/1_Download_Files_ARK-Invest/Big_Ideas/ARK%20Invest_013123_Presentation_Big%20Ideas%202023_Final.pdf (access date: 04/20/2023).



Pic. 3.
Forecast of global GDP growth until 2030 and the contribution of metaverse technologies to it, 2022–2030, trillion dollars
Source: ARK Invest 9

Case

3

BMW Factory Simulation (Regensburg, Germany, 2021)

Source: BMW Group 10

10 BMW Group and NVIDIA take virtual factory planning to the next level // BMW Group. URL: press.bmwgroup.com/global/article/detail/T0329569EN/bmw-group-and-nvidia-take-virtual-factory-planning-to-the-next-level?language=en (accessed 20.04.2023).

Initial task: build a plant for the production of transmissions for electric vehicles. Using metaverse technologies, it was necessary to evaluate the design of the production chain, find possible problem points, and optimize processes.

The solution was to model the entire production complex (including equipment, premises, personnel, etc.) and launch it in virtual form with the simulation of all production processes. During the six months the plant operated virtually, the company changed about 30% of the original design

production complex.

In the future, the use of such simulations (essentially "islands of the metaverse") will become part of the company's regular work, as well as BMW's plans to introduce AI into production. Machine learning algorithms can simulate robots performing joint actions and help build efficient workflows.

The company plans to use simulations to train robots in more complex, complex production operations. This project became the first case of an industrial metaverse in discrete production, executed in an integrated form for an automobile company on the Omniverse platform.

Opinion

Eldar Ramilievich Shavaliev,

Director of the Center for Digital Transformation of KAMAZ PJSC

On defining the industrial metaverse

As the practice of our company shows, we do not need to define the industrial metaverse in any way. Our approach to digital transformation assumes, first of all,

to solve specific production problems and achieve operational indicators. We do not operate in the industrial metaverse and most likely we will not.

About digital twins

We have a separate area of activity, associated with computational models around the product, and here we can note growth. At this stage, the main task is formulated as part of the course on import substitution and transition to calculation models using domestic natural products.

The second area of this topic is digital high production doubles. We have programs of simulation modeling, starting from the enterprise level to modeling on the scale of individual operations.

The third area of application of digital twins is the product and obtaining a model of products in operation. If in the first case we were talking about development, then here we are already engaged We consider the product from the point of view of its life cycle during operation. There is a connected car that sends data, behavior models have been developed depending

on the nature of operation, quality of driving, cargo parameters.

Digital twins always decide difficult task. If we talk about production planning, a separate area of the company's work is related precisely to

check the possibility of fulfilling production tasks and answer the question when a particular production task can be completed. Digital twin for KAMAZ -

it is a decision making system and improvement

quality of the decision or (if ready-made algorithms are available) transfer of decision-making rights car.

About artificial intelligence

Regarding the introduction of AI technologies into activities, company, they are used primarily in creating a product. This includes

technological products such as autonomous driving, ADAS systems. It is worth mentioning digital platforms that optimize movement

tion as at the management level of an individual vehicle, and at the level of systems for interaction of vehicles with the infrastructure and with each other.

The second group is related to production tasks: this is a recommendation system in the decision-making process, planning, forecasting. A separate block is machine vision in quality control and everything related to the objective control system.

The limitations to the further development of the use of AI are related not so much to technology, but to the readiness of the production area. Here everything depends on the degree of organization of the process, automation and digitalization of data. Our main goal remains to increase production efficiency, including through robotization of processes.

About robotization

Robotization is a direct tool. KAMAZ has developed a program with testing daily analysis of areas to determine where and how we can use robotic systems. The main barrier at this stage is

this is the absence of domestic complexes.

In addition, there are economic restrictions associated with the low market volume, production and, as a consequence, the inability to achieve economies of scale.

About blockchain

Now we do not see the need to implement blockchain. Perhaps in the future marking of parts will begin. Cryptocurrencies

we consider as a possible means of tezha in import-export operations.

About the data market

KAMAZ has a data management policy that ensures data quality

and integrity, however, is not directly related to the market. With its help, certain rules are followed in tasks where data is used (in preparing marts and data aggregations). To move to the market level, you need to understand the specific business value of the data.

About computing resources and overcoming their deficits

With the problem of shortage of computing power during digital transformation of KAMAZ does not collide. The company came to the realization that it could not do without locally scalable computing. We are actively working with cloud technologies. These services are deployed with the participation of partners; the company, for its part, is responsible for the contours related to safety

danger.

Edge technologies are not so relevant for us. alny, since at the present stage of computing It is cheaper to carry out the measurements centrally. As users of the product, we do not see any problems with capacity availability.

About data networks

Problems with data transmission networks do not arise now. Current Wi-Fi technologies are sufficient To achieve our production goals, the business need for 5G technologies has not yet formed. KAMAZ is a local

ny plant, for which the entire network infrastructure is built on optical data transmission. However, if it is subsequently adopted

decision to deploy high-speed networks on highways, then our car will certainly use them.

About virtual reality technologies

In our case, virtual technologies find classical areas of application. So, the company uses them in personnel training. We conducted a study of the problems of VR in service maintenance, but found out that there is no demand. We are considering the possibility of organizing mobile teams with remote support for use at remote sites, namely -

at the quarries.

We tested in production several hypotheses, but so far they have not been confirmed. For example, wearable VR devices have not received development. At the same time, transferring data to tablets and phones is becoming more common country wide.

About the industrial metaverse as a driver of organizational transformation

As a practitioner, I believe that the concept of an industrial metaverse largely embraces existing technologies. At the same time, there are indeed opportunities to expand blockchain into practical areas. There is a con-

The specific applications being worked on and the advancement of new concepts can motivate change. In other words, these

designs can be useful if the company needs an organizational shake-up.

When a company has a clear business development strategy, digital technologies will primarily be a tool for increasing operational efficiency. We can also talk about the obvious circumstances of digital transformation, when technology becomes a key factor in business restructuring.

3.2
The industrial metaverse will help solve a number of problems in providing industry with personnel

One of the key goals and the most important use case for the industrial metaverse is already staff training. The industrial metaverse makes it possible to implement a human-centric approach to solving this problem using augmented reality technologies, including VR, AR, XR, etc. Industrial metaverses can launch a large-scale transformation of engineering and IT education and, in general, a reorganization of labor, approaches to personnel political policy on the scale of entire industries and states.

Similar transitions have already taken place in history. The latter occurred in the late 2000s - early 2010s and was associated with the massive use of computer modeling and digital technologies 11.

The new transition in personnel training will be based on the features industrial metaverse, among which the main ones are worth noting:

- training assistants based on artificial intelligence (provide comprehensive consultations, perform a comprehensive assessment of competencies and make recommendations for improving the effectiveness of training);
- systems of virtual contextual annotations for each object, including step-by-step guides, tips and reminders;
- virtual exercises, including game scenarios in which standard and non-standard problems, emergency situations, etc.

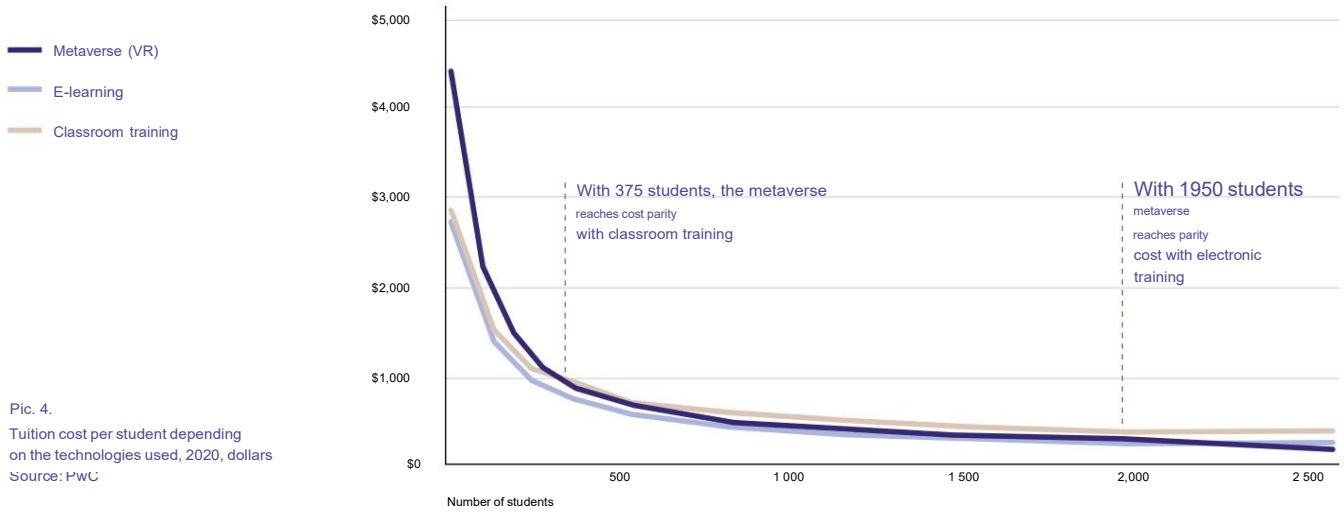
The Metaverse will significantly reduce the amount of time and resources spent on training specialists for specific tasks. According to a PwC study 12, VR training helps learners focus better on the material, creates an emotional connection and increases confidence when using skills. All this makes it possible to increase the effectiveness of training by four times. In practice, this means that material that would take two hours of class time to master in a traditional classroom can be mastered in 30 minutes in the metaverse. The increased speed of training allows it to be effectively integrated into the work schedule of employees, which leads to a significant increase in return on investment (ROI) in corporate education.

When scaled, learning in the metaverse becomes cheaper than other formats (Figure 4). Learning in the metaverse requires 48% more initial investment in course development and equipment (including virtual reality glasses). But as soon as the number of students in one course reaches 375, the cost reaches parity with traditional education, and if there are already 1950 students, parity with e-learning is achieved. With 3,000 students, VR training becomes 52% cheaper than traditional training.

But the key advantage of learning in the metaverse is not so much its low cost, but the ability to focus on competencies that are difficult to develop in traditional learning conditions. This includes working with equipment and skills to behave in difficult and dangerous situations (in case of fires, industrial accidents, etc.).

— Modern engineering education: textbook. allowance / A. I. Borovkov [etc.] // TsSR "North-West". URL: csr-nw.ru/publications/detail.php?ID=582 (access date: 04/20/2023).

12 The Effectiveness of Virtual Reality Soft Skills Training in the Enterprise // PwC. URL: pwc.com/us/en/services/consulting/technology/emerging-technology/assets/pwc-understanding-the-effectiveness-of-soft-skills-training-in-the-enterprise-a-study.pdf (accessed 04/20/2023).



Pic. 4.
Tuition cost per student depending on the technologies used, 2020, dollars
Source: PwC

The penetration of the metaverse and VR into training, the reduction in cost and increased payback of personnel projects is forcing the business and educational sector to begin rethinking the role of education, training and retraining of personnel in conditions when the metaverse will be formed and widely available. For industrial companies, there is a need for closer cooperation with the educational sector, including providing their industrial metaverse or parts thereof for training personnel and implementing educational programs. Metaverse vendors and integrators can implement similar models so that new generations of engineers and industrial workers are trained for specific software and equipment, which increases the possibility of introducing the products they develop. The implications of this for the education sector are detailed in Section 7.

In addition to educational functions, the industrial metaverse allows for new approaches to personnel logistics. In particular, eliminate the need for qualified specialists to travel to industrial facilities for inspections, work with equipment and other tasks. This is especially true for the energy, oil and gas and other geographically distributed industries. This is discussed in more detail in section 5.1.

3.3
Under certain conditions, the industrial metaverse will play a role in achieving the green agenda of companies

The industrial metaverse extends the scope of digitalization to the simultaneous management of various types of simulations. Ability to predict
production processes and results at the product design stage and estimating the amount of necessary resources allows you to avoid unnecessary operations (such as the production of different variants of components at the product development stage). Example: The Boeing 777 was the world's first commercial aircraft designed entirely digitally. Engineers created a virtual twin of the aircraft using precise simulations so that thousands of parts could be tested, replaced, modified and tested again—without the cost or waste of physically producing those parts, reducing the carbon footprint.

Interaction between digital twins helps further reduce CO2 emissions as the twins begin to operate as a network of heterogeneous synchronized simulations. This further increases the realism of the simulation. Thus, only by combining digital twins of factories and smart cities into a single metaverse will it be possible to accurately assess the carbon footprint of a city 13.

However, it is also necessary to take into account that the industrial metaverse uses colossal computing power, which consumes a significant amount of energy. This means that it also creates its own carbon and environmental footprint. For example, training one AI model creates about 284 tons of CO2 , and hundreds and thousands of AI agents can operate within the industrial metaverse 14. Therefore, the priority becomes the development of energy-efficient technologies for creating digital twins, training artificial intelligence and conducting other operations in the industrial metaverse .

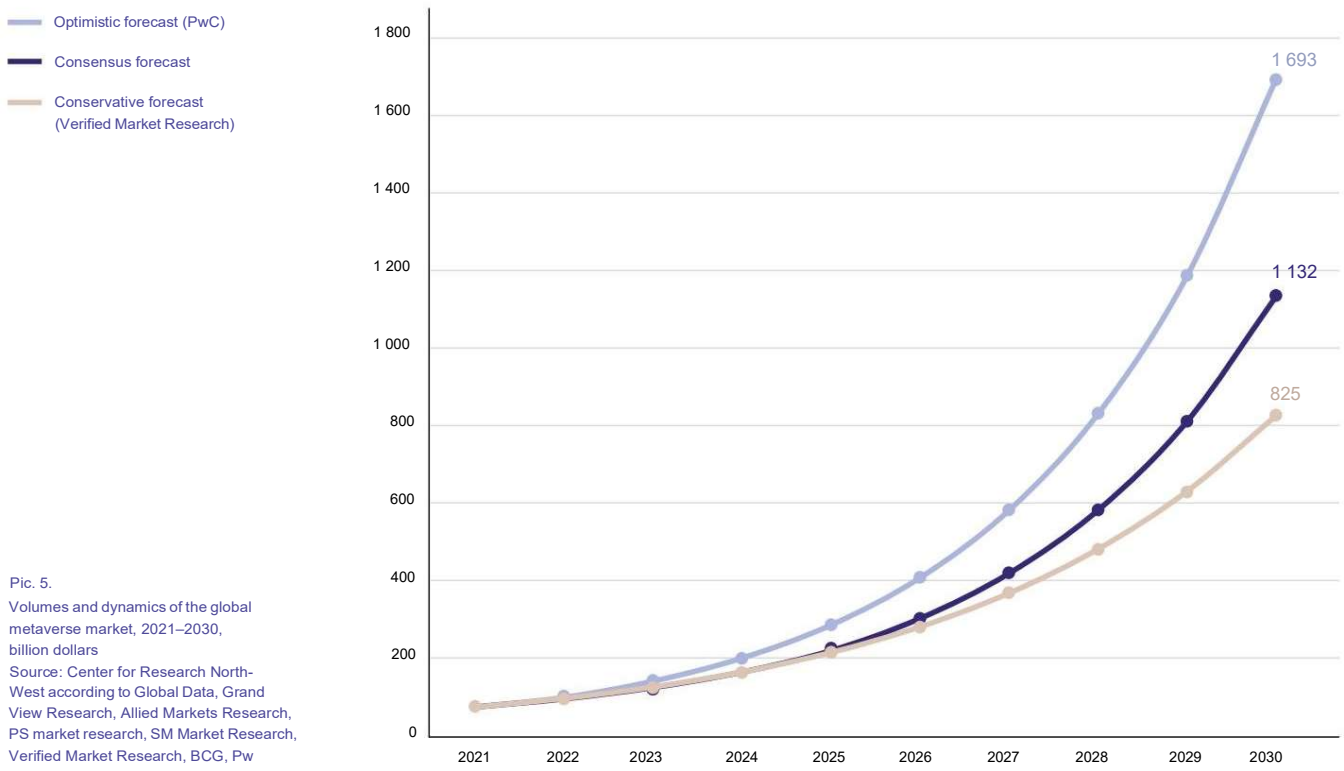
13 On the way to the industrial metaverse // Capgemini.
URL: capgemini.com/insights/research-library/on-the-way-to-the-industrial-metaverse/ (access date: 04/20/2023).

14 Liu Jianya and Guo Liang: “The carbon footprint of the metaverse can be reduced” // The UNESCO Courier.
URL: courier.unesco.org/en/articles/liu-jianya-and-guo-liang-carbon-footprint-metaverse-can-be-reduced
(access date: 04/20/2023).

4

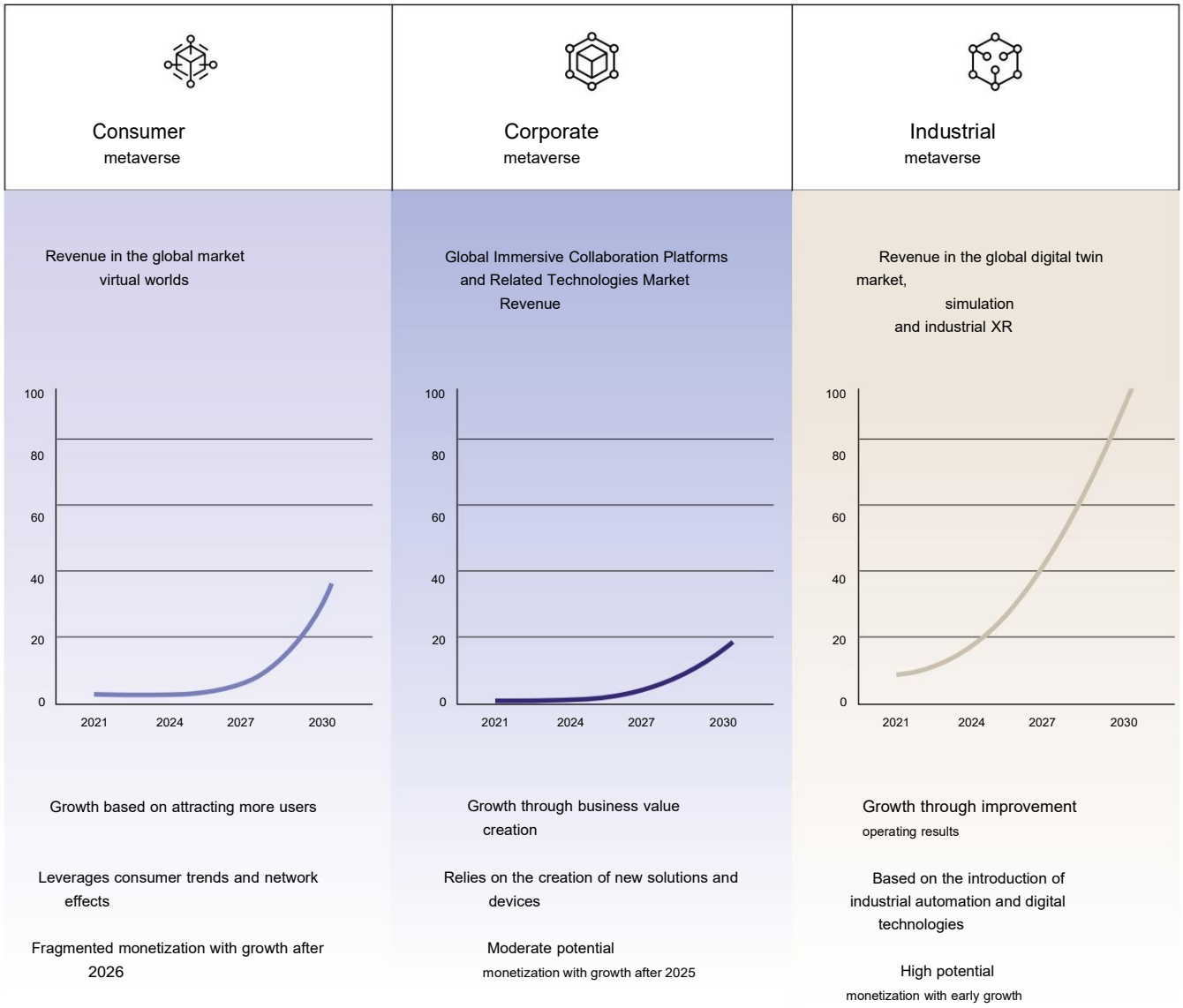
The industrial metaverse is a possible space for new markets

In 2022, the metaverse market size was about $95 billion, including tea, all the technological components of the metaverses - hardware, software, content, etc. (see section 2). Analysts predict the growth of this market at an annual rate of about 40% until 2030 and reaching a volume of from 800 billion to 1.6 trillion dollars by the end of this period (Fig. 5).



Pic. 5.
Volumes and dynamics of the global metaverse market, 2021–2030, billion dollars
Source: Center for Research North-West according to Global Data, Grand View Research, Allied Markets Research, PS market research, SM Market Research, Verified Market Research, BCG, Pw

Analysts predict that the industrial metaverse will grow most rapidly in the next two to three years. Global company revenue from the industrial metaverse, represented by digital twins, simulation, industrial AR and VR, should reach $23 billion by 2025, and $100 billion by 2030 (Fig. 6).



Pic. 6.
Global metaverse markets by functional type, 2021–2030, billion dollars.

Source: MIT Technology Review

At the end of 2022 - beginning of 2023, in terms of the formation of the industrial metaverse, the main contours of development and promising directions were outlined. The Metaverse has become one of the central themes of the World Economic Forum. At the Defining and Building the Metaverse platform, working groups have been formed to develop policies in the field of managing the metaverse and creating economic and social value 15. Corresponding initiatives are being launched in the OECD 16. All this allows us to say that in In the coming years, methods for developing the metaverse in industry and the social sphere will appear on a global scale, and the first directions of public policy will be launched.

For Russian industrial companies and industry software vendors, now is the time when investments in projects to create an industrial metaverse can ensure entry into this market as owners of key technology products. With a later start, the best thing that makes sense to count on is the position of integrators of foreign solutions. Moreover, a significant amount of domestic engineering software, digital platforms and services may turn out to be obsolete if their integration is not ensured

into industrial metaverses.

15 Defining and Building the Metaverse // World Economic Forum. URL: initiatives.

weforum.org/defining-and-building-the-metaverse/
connect (access date: 04/20/2023).

16 Global Scenarios 2035:
Exploring implications for the future of global collaboration and the OECD // OECD iLibrary.

URL: oecd-ilibrary.org/sites/df7ebc33-en/1/3/1/index.html?itemId=/content/publication/df7ebc33-en&_csp_=cc4ae06ed263c4334853de24a3b5c7a9&itemIGO=oecd&itemContentType=book#boxsection-d1e893 (date of access: 04/20/2023).

4.1

Market factors for industrial development metaverses

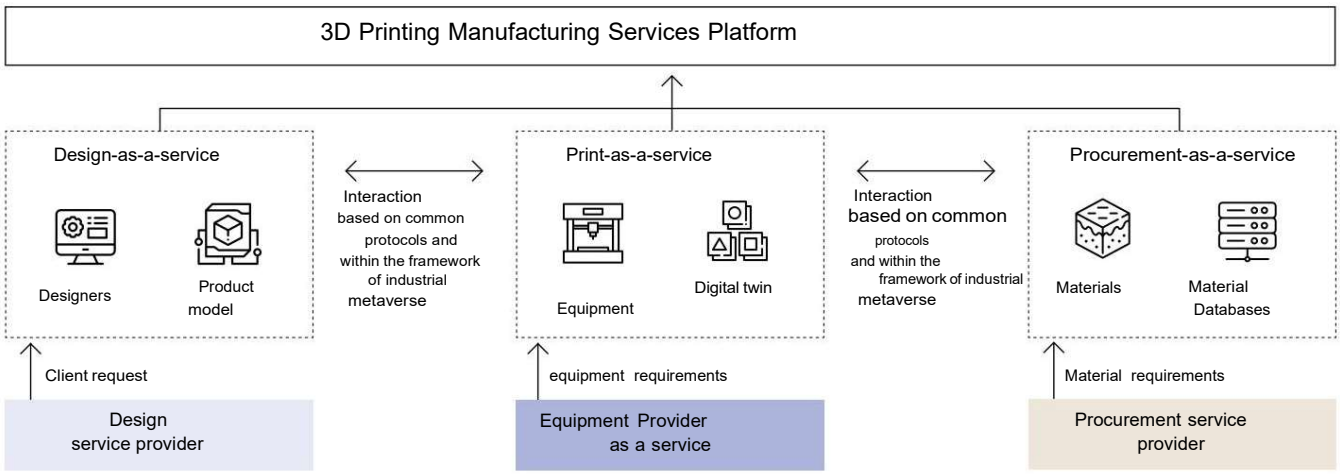
Industry can develop new business models and services in the metaverse faster than the consumer or enterprise sectors

The industrial metaverse is not only a technological package, but also a new organizational model of the digital technology market, integrating with the market of industrial equipment and services. Such convergence could enable the capitalization of digital assets and copies of capital assets. Market positions focused on new business models are emerging, and new players are emerging. For example, in China, projects for manufacturing service platforms based on digital twins are being developed (Digital twin-driven manufacturing service collaboration platform) 17.

17 Feng Xiang. Digital Twin Driven Service. Chapter 2: Digital twin-driven service collaboration. - Academic Press, 2022. - P. 33–58.

The main goal of creating such platforms is the dynamic integration of service functions and production capacities of an enterprise or group of enterprises. This leads to the emergence of multi-stakeholder production systems, in which each participant benefits from access to a single infrastructure that performs optimization, modeling, predictive analytics, and allocation of production capacity and service capabilities. This increases the efficiency of resource use and their flexibility in the production of customized products, and reduces costs.

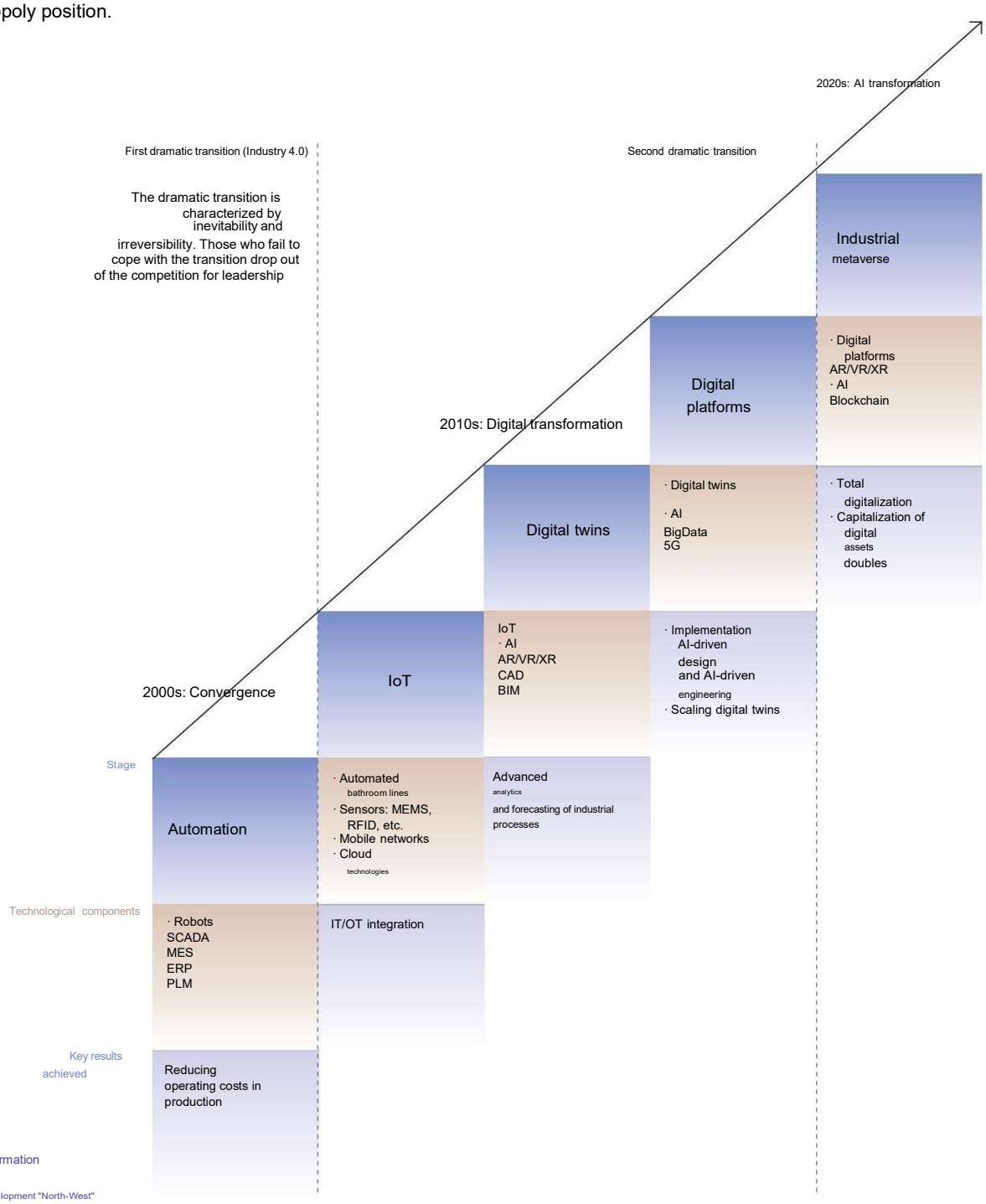
Interaction between stakeholders within such platforms is based on technologies and principles of the industrial metaverse: interoperability, uniform standards for data transfer, use of blockchain in financial
calculations, distribution of loads and tasks based on intelligent analysis of available resources (Fig. 7).



Pic. 7.
Example architecture of a collaborative 3D printing platform
Source: Feng Xiang. Digital Twin Driven Service. Chapter 2: Digital twin-driven service collaboration. — Academic Press, 2022

Existing digital manufacturing systems focus on industrial automation, production process modeling, integration of production and business functions (IT/OT integration). The industrial metaverse is the next level of convergence, involving cross-domain and cross-industry cooperation. This significantly saves time and resources spent on exchanging information between different enterprises within the structure of one corporation (or between corporations). The industrial metaverse, as a field of experimentation, should become an area of advanced research and development.

The industrial metaverse is a potentially new stage of digital transformation in industry, comparable in importance to Industry 4.0. The business models described above could help the industrial metaverse enable companies to generate sustainable cash flow from digital twins, data and models. Achieving a high level of interoperability will make it possible to implement total digitalization of industry, i.e., rapid automated scaling of standard solutions to all similar processes of the company. Such a transition could be dramatic for industry - inevitable, irreversible and critical for maintaining market positions (Fig. 8). However, this assumption remains theoretical, since no global player has yet made such a transition. Even established alliances, often representing a collaboration between an industry leader and a technology company (BMW-Nvidia, Hyundai-Unity), have not achieved a large-scale breakthrough in their experiments that would allow them to achieve a monopoly position.



Pic. 8.
Stages of digital transformation industry
Source: Center for Social Development "North-West"

A framework for standardization emerges in the industrial metaverse

Unlike the development of specific industrial use cases for the metaverse, the process of standardizing the industrial metaverse seems to be truly comprehensive. The process is led by global companies that gather a significant number of participants to launch universal standards. Several dozen companies take part in the largest forum for standardization of the metaverse, including Nvidia, Autodesk, Huawei, Intel, AMD, etc. 18. These formats include not only Western companies, but also Chinese ones, including competing ones together. Within this framework, the market leaders of the industrial metaverse successfully promote their developments as an industry standard. For example, Nvidia, on its Omniverse platform, is creating the Universal Scene Description (USD) standard - an open framework and file format that lays the foundation for the description, collaborative development, and simulation of 3D environments. The company is making significant efforts to introduce the usd format in architecture, design, robotics, manufacturing sectors and industry in general 19.

18 The Metaverse Standards Forum. URL: metaverse-standards.org (accessed: 04/20/2023).

19 What is Universal Scene Description? // NVIDIA. URL: developer.nvidia.com/usd (accessed 04/20/2023).

4.2

Limitations for industrial development metaverses

The industrial metaverse has significant limitations that do not allow us to implement it directly today into real production processes on the scale of entire holdings and industries 20. All restrictions can be conditionally divided focus on technological, resource and regulatory issues.

20 Deployment in the Industrial Metaverse // World Economic Forum. URL: youtube.com/watch?v=w58jWDuUafA (date of access: 04/20/2023).

Technological limitations

Technological development of industrial metaverses occurs according to the principle of combinatorial innovation. New technologies are created through the convergence of existing trends that have different degrees of technological maturity. Therefore, overcoming the limitations of industrial metaverses depends on the development of the following digital technologies.

1. Technology artificial intelligence

Industrial AI systems underlie the basic functions of the industrial meta-universe: forecasting, optimization, simulation, etc. The most important requirements for such systems: explainability, ability to perform multiple tasks,

including computer vision, natural language recognition and contextualization - linking collected data with events in physical space to create and update knowledge bases. Currently, the scaling of artificial intelligence technologies is limited by issues of trust, control over decisions, and high requirements for computing power. Another important direction related to AI is the creation of virtual assistants and language models that help a person manage and navigate the colossal flow of information and data generated by the industrial meta-universe.

2. Technologies modeling and simulations

For industries that work with physical objects and create complex high-tech products, it is important to consider the properties of materials and the behavior of the object in the physical world. Many natural processes have not yet been digitized due to the lack of knowledge about them or the computing power to model them.

3. Network technologies

For the industrial metaverse to function, it is necessary to ensure the ability not only to transfer enormous amounts of data between a wide and geographically distributed network of devices, but also to do this with minimal delays. For the consumer metaverse, latency needs to be 10-20ms, and for the industrial metaverse, latency needs to be even lower. Currently, the main communication technology being considered for the industrial metaverse is 5G: it provides 1ms latency. But mobile networks do not have sufficient bandwidth 21. Therefore, it will be necessary to significantly increase the volume of computing on network devices (edge computing) and create new architectures that combine edge, cloud networks, and distribution of loads and data between devices. In addition, the very principles of global information exchange that underlie the modern Internet are not capable of providing the bandwidth and speed of information transfer that is required for industrial metaverses.

21 Meta's engineering director outlines the metaverse latency problem // Light Reading. URL: lightreading.com/digital-infrastructure/metas-engineering-director-outlines-metaverse-latency-problem/d/d-id/777839 (access date: 04/20/2023).

4. Hardware wearables solutions for extended reality

The main task is to develop solutions that will be comparable in convenience to smartphones, and in the future will replace them in the consumer electronics market. Today, virtual reality glasses are offered as such devices, which should become compact and comfortable for everyday wear. It is these devices, not proprietary solutions, that will provide the basic access point to industrial metaverses.

5. Neural interfaces

This technology allows you to control devices and systems using signals from the human nervous system (i.e., the power of thought). Neural interfaces may seem like an alternative to wearable augmented reality solutions, but they are a much less mature technology. Existing neural interfaces have not yet reached the mass market and are invasive (requiring a physical connection to the human nervous system). This greatly limits the potential for introducing neural interfaces as devices for working with the industrial metaverse.

6. Cybersecurity

The industrial metaverse will store, create and process a wealth of sensitive data from companies and individuals. In addition, industrial processes that could potentially become sources of man-made disasters will be controlled through the metaverse. Therefore, for the functioning of industrial metaverses, security technologies are needed that cannot be hacked. Currently, quantum encryption is considered such a technology, but it remains unavailable to the market.

Overall, the development of underlying technologies has a significant impact on the capabilities and efficiency of industrial metaverses. The combination of these technologies allows you to create flexible, autonomous and smart systems that can solve complex problems in real time and provide effective management
production processes and resources.

Resource limitations

The demand for resources grows in proportion to the scale of industrial meta-universes and the degree of their implementation in the operational activities of enterprises. Resource limitations include the following.

1. Lack of personnel and competencies	The industrial metaverse will require a new approach to jobs and competencies of company employees. Specialists accustomed to working with 2D materials (X-rays, drawings, maps) will not be able to quickly switch to working in a three-dimensional environment.
2. Lack of computing power and data processing equipment	At the current level of technological development, one of the key limitations is computing power. This determines the leadership of large companies that own computing resources in technologies such as artificial intelligence. The emergence of an industrial metaverse will further increase the demand for computing. This part will require not only technological improvement of computing equipment, but also a significant increase in the volume of investments in equipment available on the market - the creation of data centers, supercomputer centers, etc.
3. Shortage of quality data	While data collection technologies are available, not all of them are useful and of high quality, allowing for effective forecasting and decision-making. Experts at Epoch predict that by 2026, we may run out of data to train 22 language models.

22 We could run out of data to train AI language programs // MIT Technology Review. URL: technologyreview.com/2022/11/24/1063684/we-could-run-out-of-data-to-train-ai-language-programs/ (date of access: 04/20/2023).

Regulatory restrictions

1. Restrictions on the use of digital models in state examination, certification, etc.

2. Restrictions on the use of certain categories data - personal data of citizens and other confidential data.

Dmitry Stanislavovich Ivanov,

Director for Innovative Development of PJSC "UEC-Saturn"

On defining the industrial metaverse

It is incorrect to call what is happening now in terms of the integration of digital technologies a metaverse. The term “digital platform” is closer to me. An industrial object is finite; a set of such objects in a virtual environment is a virtual factory. When we talk about a digital platform, we imagine an endless number of industrial facilities and their digital twins. In this case, there may be several platforms, although not many. There can only be one metaverse.

About digital twins

The digital twin gains significance when an economic model based on it is formed and new types of business models emerge. At the present stage, the product manufacturer directly benefits from the use of digital twins. On the other side,

they are in the area of operation of the buyer, that is, the customer of the service. Here a certain architecture begins to build. Data is generated by entities owned by different companies. When the systems that make up this architecture are characterized by trust and security

In fact, we can talk about a set of technological solutions such as a digital platform, but not a metaverse. In the UEC there are solutions related to product design, and sets of digital twins

appear. However, at this stage they have not yet been integrated into production. All these

individual software components to be integrate into a single ecosystem.

Existence of a digital twin

the whole production seems doubtful until a way to monetize it is invented. Meanwhile, it is difficult to imagine the formation of a modern service model without a digital twin. A digital twin allows you to enter into a business model of selling one unit of product performance. But in this case, selling the product itself becomes impossible.

About artificial intelligence

Artificial intelligence is a set of algorithmic systems capable of self-development. If development does not occur, then it is simply a certain algorithm that has certain useful

new characteristics, has an advanced search function, can automate the assembly process, and so on. However, until it is proven that this set of codes is capable of creating a new independent intelligent

intellectual unit, it cannot be said that it is artificial intelligence. The word “artificial” emphasizes that this is only a similarity

intelligence.

At the current technological stage

for the development of both digital platforms and the industrial metaverse, there is definitely not enough

the level of artificial intelligence systems is melting. In AI, we are at the initial stage of development. The cost of the elements should change. We probably need to study the topic of integration of humans and certain artificial components. The meta-universe must have the characteristic of no alternative, suggesting that individual models cannot exist outside of this meta-universe and technological platform. In AI, the key development factor, in my opinion, will be autonomy. The more autonomous the system, the more resistant it is to risks in terms of the main parameters of its functioning.

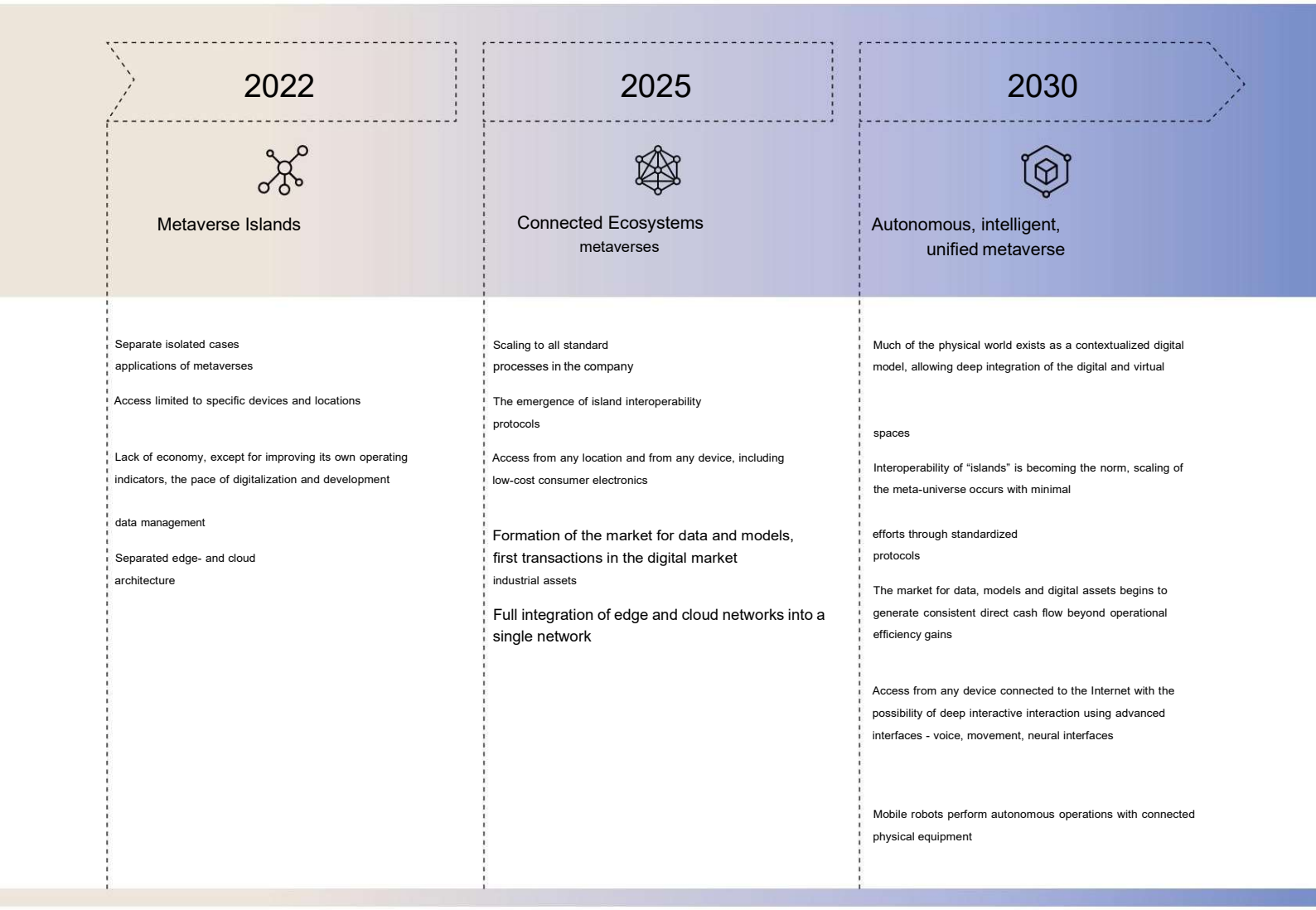
About blockchain

Blockchain as a technology that ensures the uniqueness of any objects will be in demand and will develop, just as attempts to introduce digital currencies will continue. All this represents steps towards certain solutions for the verification and immutability of personal data. However, the need for this is difficult to assess. The real flourishing will begin when the use of blockchain becomes economically feasible.

4.3

Prospects for the evolution of industrial metaverses: from “islands” to a unified intellectual metaverse

Assuming certain rates of convergence and development of basic technologies and overcoming the limitations of the metaverse, we can imagine a possible path for the evolution of the industrial metaverse (Fig. 9):



Pic. 9.
Evolution of industrial metaverses
Source: Cognite [23]

[23] The Industrial Metaverse: More than a Glorified Digital Twin? //Cognite. URL: cognite.com/en/blog/the-industrial-metaverse-more-than-a-glorified-digital-twin (accessed 04/20/2023).

“Islands” of metaverses are the current stage at which pilot, isolated projects with low compatibility appear in industrial companies, which cannot be scaled even within the companies’ own industrial functions. Access to these metaverses is limited and can only be done from specific devices. There is no monetization system, apart from reducing its own operating costs. Basically, the execution part is deployed in the cloud; edge networks are rarely used.

Connected Metaverse Ecosystems: With the rapid pace of technological innovation, this stage could be reached as early as 2025 and could trigger explosive market growth. At this stage, the scaling of “islands” will begin, they will become the market norm. Protocols will appear that ensure compatibility and interoperability of individual “islands” and the connection of metaverses of different companies. The formation of a market for data and models, mechanisms for trading and exchange of digital assets is starting. A system of information exchange between edge and clouds will emerge and will more closely connect the digital world with the physical.

An autonomous and intelligent unified metaverse will be achieved by 2030 or later 24. At this stage, the term “industrial metaverse” will more often be used in the singular, as is now “internet” (rather than “internets”). Virtually the entire industrially relevant physical world will be digitalized, mapped, and contextualized. The meta-universes of individual companies will be able to easily integrate, and the use of collaborative platforms will become the market norm. The industrial meta-universe can be accessed from any device connected to the Internet, and interaction with it will be based on natural interfaces (voice, movements, possibly neural interfaces). Data and models will become a liquid product capable of ensuring a sustainable financial flow.

An autonomous and intelligent unified metaverse is an ideal, utopian market state that will likely only be achieved by
individual experimental sites, in individual industries and states. However, this is precisely the target image for technological optimists.

Apparently, for our country in the next decade, the creation of “islands” of metaverses will become a key task in launching the market for industrial metaverses. Rapid scaling (and even more so the transition to a unified industrial metaverse) will most likely be hampered by market inertia, international restrictions and the generally low maturity of the technologies required for this. Possible scenarios for the development of the industrial metaverse in Russia in the context of the global challenges facing the country are presented in more detail in Section 6.

24 Among the experts there are different opinions regarding pace of development of technological package and terms of transfer progress between stages of development industrial metaverse. Due to the inertia of changing the legislative framework, development models and institutions

industry the emergence of a single the new industrial metaverse - in the full sense of the word - may be delayed until the 2050s.

Anatoly Vyacheslavovich Kulakov,

Deputy General Director for Information Technology

simulation modeling, head of the information modeling support department of Gipro-Nickel Institute LLC (Norilsk Nickel)

On defining the industrial metaverse

In my understanding, the definition of the industrial metaverse is close to the theme of Industry 4.0. In both cases we are talking about self-regulating systems. An analogy can be drawn with climate control in a car: it takes information from sensors and, using simple algorithms, controls the operation of the air conditioner, heater and fans to maintain the set temperature in the cabin. A digital twin operates on the same principle, only on a different scale. This system includes the Internet of things, a database of interconnected knowledge and decision-making algorithms, including those based on machine learning. Industry strives for self-correlation, self-optimization and self-tuning of production based on the planned forecasts.

The combination of these processes can be call it a metaverse, where, on the one hand, a digital twin operates, and on the other, objects of reality are controlled. When we talk about the meta-universe, we are talking about interaction within one system.

About the experience of implementing an industrial metaverse

Gipronickel is at a stage where high-quality data and related information is being created. Now we are making attempts to reach the level of visibility, passing information through databases and creating interfaces convenient for human perception - a digital master plan, dashboards. This is an important intermediate stage before entering a self-regulating system (with the participation of software agents), in which the value of visualization will not be the same high.

Gipronickel is trying to grow its platform as a tool for collecting and transmitting data. But I wouldn't characterize it as one thing. Rather, the platform represents a set of microservices for working with data. Difficulties arise when trying to organize this information, ensure interoperability data density.

On the interests of industry in the transition to the metaverse

Companies are interested in creating a self-regulating system because it contains hidden potential for increased productivity, reliability and safety. With everything There are no examples of implemented projects or ready-made paths. But there are advances, for example, Norilsk Nickel has “lakes” of data that change in solving logistics problems.

Digital twins, which are created for the operation and maintenance of assets, as a direction of development have a lower priority than twins of production processes. This is primarily an investment opportunity:

This direction is being tested, but has not yet entered into operational activities. The difficulty is the fact that there is no ready-made system that could be considered as an example. Among all the technologies in the industrial metaverse, computer vision is currently being implemented most effectively. For example, it allowed us to achieve good operational results when monitoring the quality of incoming ore for setting up processing equipment. But many projects come down to demonstration vendors on the effectiveness of their software products. This often takes the form of a pilot project, the results of which, once published, are very are rarely implemented into operational activities, since this requires a new approach to methodology, equipment, and instructions. The development of the industrial metaverse in Russian companies is limited by the need for significant investments. Pilot projects are important for testing the methodology, however do not always achieve operational results.

Suppose we are introducing a new business process in one workshop out of five operating. Due to the fact that the others continue to work in accordance with the old instructions, the new one is still forced to interact with them through the old interfaces. All documentation has to be duplicated, and then it loses in terms of efficiency. A complete transition of all five workshops creates great risks; confirmed testing and experimentation are needed. But at none of the production facilities does the management take the initiative to become a platform for such an experiment; the position here is rather careful.

The situation will change if we create construction of completely new factories complete with new systems and business processes. And even in this case, it will be difficult to integrate the technologies of the industrial metaverse into the contours of the project, since not everyone finds such a transition economically feasible.

5

Architecture and market players of industrial metaverses

Participants in the industrial metaverse market can be divided into two categories. The first includes companies providing services, hardware, software and infrastructure - they make money directly from the implementation of industrial metaverses. The second category includes industrial

established enterprises that receive operational results in the form of increased production efficiency, overcoming personnel shortages, and reducing their carbon footprint (described in detail in section 3). Among them we can distinguish “early followers” - enterprises that are actively involved in joint ventures.

pilot projects with technology companies to launch industrial metaverses.

The most studied area of application of the metaverse is education (Fig. 10). As mentioned earlier, training in various industries remains one of the most effective uses of the metaverse today. Another important cross-cutting area that is actively studying metaverses is energy. Metaverses are used in the production of generating equipment and control of electrical grid infrastructure. The energy

industry has given rise to the prototypes of the industrial metaverse—smart grids, in which energy distribution can be controlled through completely virtual digital models of devices.

Case 4

Chinese State Shipping construction corporation uses industrial metaverse in the production of wind power plants and network management

Source: CSSC 25

China Shipbuilding Corporation (CSSC) is one of the world's largest manufacturers of wind power plants. This is a branched holding: more than 22 companies are involved in the production of one turbine for a windmill, including those related to the military industry, which have valuable competencies

in hydraulics and microelectronics.

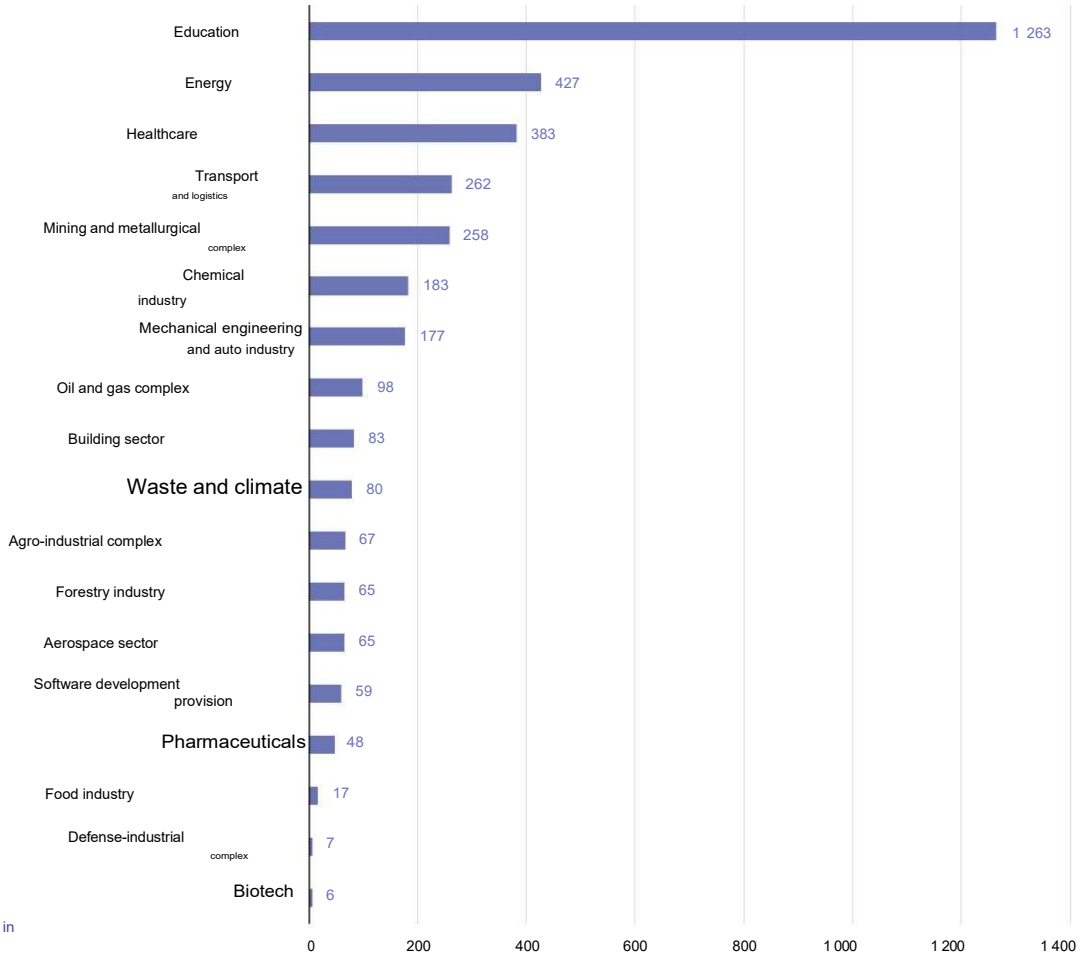
To improve the efficiency of asset use, the company uses digital platforms for collaborative research and development, design, production, service and management.

They include participants throughout the chain production - from the supply of components to product life cycle management, generation and energy distribution.

25 Introduction to the CSSC Whole Industrial Chain // CSSC. URL: cssc-hz.com/?en/Technologies/Collaboration/ (date of access: 04/20/2023).

Metaverses are also actively penetrating into the healthcare sector: one of the landmark projects here is Siemens Healthineers - a digital platform of solutions and services in the field of medical care, diagnostics, remote surgical operations and hospital management 26.

26 The industrial metaverse is changing the world in these 4 key ways // Technically. URL: technical.ly/software-development/industrial-metaverse-world-economic-forum-panel/ (date of access: 04/20/2023).



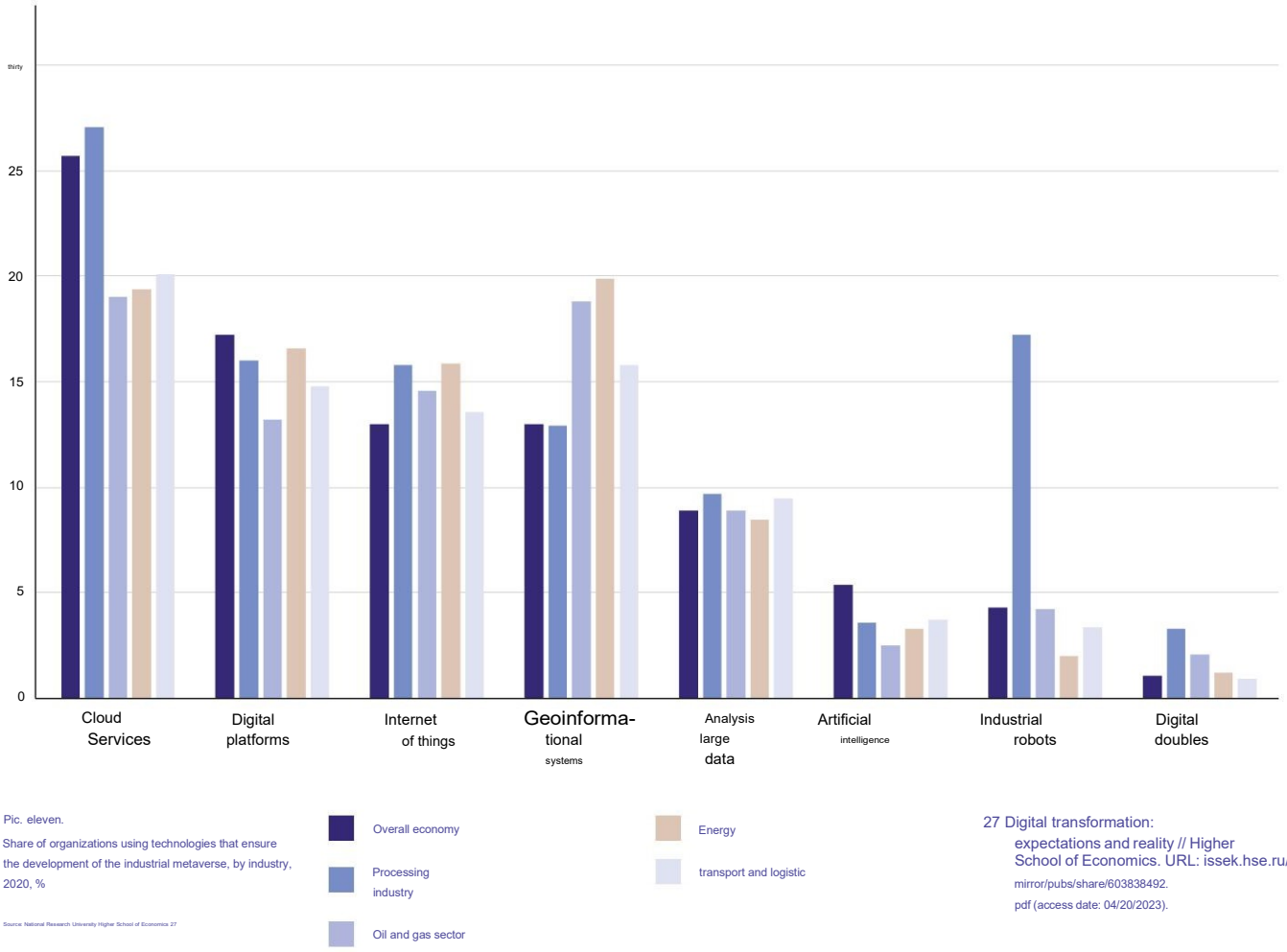
Pic. 10.
Rating of industry readiness for the metaverse by number of publications in Scopus, 2012–2022, pcs.
Source: SSR North-West according to Scopus

The first “islands” of metaverses are beginning to appear in Russia. As throughout the world, they primarily arise in large manufacturing companies that have sufficient scale of production and resources to purchase equipment, engineer industrial systems and conduct R&D. Among the “early followers” of the industrial metaverse in Russia are Gazprom Neft, structures of Rostec, Rosatom, Norilsk Nickel, Russian Railways,

although their solutions cannot yet be called metaverses.

The evolution of the Russian market is taking place within the global vector. For example, Gazprom Neft’s approach to the metaverse involves a gradual complication and formation of an industrial metaverse - from the creation of digital twins of individual equipment to a common ecosystem of all sites, which corresponds to the transition from “islands” of the metaverse to “connected ecosystems.”

However, the overall level of implementation of technologies that ensure the development of the industrial metaverse in Russia remains low. Only 3.3% of manufacturing organizations and 1.1% of enterprises overall use digital twin technologies, a key component of the industrial metaverse. The rate of implementation of artificial intelligence also remains low - about 5% on average for the economy (Fig. 11).



Pic. eleven.

Share of organizations using technologies that ensure the development of the industrial metaverse, by industry, 2020, %

Source: National Research University Higher School of Economics 27

27 Digital transformation: expectations and reality // Higher School of Economics. URL: issek.hse.ru/mirror/pubs/share/603838492.pdf (access date: 04/20/2023).

The key advantage of implementing metaverse technologies should be not only the transfer of some activities, such as personnel training, to a virtual environment, but also the transition to a new level of productivity that new business models based on the industrial metaverse can provide.

Following this, a market for data and models will begin to form, and the scale of the market for IoT devices, microelectronics, and software will grow. This will lead to an expansion of the segment of service companies, which will be open to the expansion of holding structures: internal industrial software development centers, equipment manufacturers for the cross-industry industrial metaverse. As a result, the “early adopters” of the industrial metaverse in Russia will be able to gain control over the assets and technologies that ensure operational efficiency and competitiveness of everything

industrial market.

5.1

Industrial metaverses in the oil and gas sector

An important industry for the deployment of industrial metaverses is the mining sector. It places high demands on the payback of deposits, the efficiency of logistics and the forecasting of natural environments to which there is not always physical access: mineral deposits, mines, relief, seabed and water surface. Hence the peculiarity of this sector -

the need to create digital twins of natural objects.

These digital twins require much more computing power than digital twins of industrial equipment. In addition, it is necessary to take into account many natural laws and undetermining factors.

divisions, for example, to predict the movement of Arctic ice.

The industrial metaverse requires not just the creation of digital twins of natural objects, but also their interconnection with production processes and company operations. Therefore, each project to create a metaverse “island” in the oil and gas sector relies on unique solutions depending on the natural conditions, geology and geographical location of the field, which complicates the scaling of the industrial metaverse.

Case 5

Tsifra Group is developing the concept of “Digital Asset” - the next step in the evolution of digital twins of fields

Source: VC 28

28 Digital twins of oil and gas deposits and assets: what are they can give to the industry and what is needed to create them // VC. URL: vc. ru/zyfra/451619-cifrovye-dvoyniki-neftegazovogo-mestorozhdeniya-i-aktiva-chto-oni-mogut-dat-otrasli-i-chto-nuzhno-chtoby-ih-sozdat (date of access: 04/20/2023).

If the basic digital twin of a field reflects the “reservoir, well, collection network” system, then the digital asset adds accounting for energy, personnel and economics.

In the case of a digital twin, the user operates with technological indicators (oil flow rate, number of wells, volume of flushing solution). In a digital asset, these indicators are recalculated to the economy (cash flows, net present value, profitability index, etc.).

The industrial metaverse also enables a new approach to talent in the oil and gas sector. Previously, each field had to ensure the presence of qualified specialists monitoring the operation of industrial equipment. Now virtual and extended reality technologies allow one expert to be responsible for several fields at once, carrying out remote monitoring and consulting workers on site 29.

29 Augmented reality (AR) & virtual reality (VR) // Shell Global. URL: shell. com/energy-and-innovation/ digitalisation/digital-technologies/ar-vr.html (access date: 04/20/2023).

In high-tech areas of the oil and gas sector, sensitive to the speed of research and development (chemistry and oil and gas refining), one of
The key advantages of industrial metaverses are the integration of innovative functions of several participants, the assembly of industry datasets, a fleet of digital twins and artificial intelligence models that allow

They are accelerating the pace of creating and bringing new materials to market.

Case 6

KNRTU is creating an industrial metaverse together with Sibur, Gazprom and other industrial partners

«ПРОМХИМТЕХ»

Source:: KNRTU 30

30 KNRTU held a round table on advanced engineering schools // KNRTU. URL: kstu.ru/event.jsp?id=135434 (access date: 04/20/2023).

The industrial metaverse is one of the projects of the advanced engineering school Promkhimtekh. It is a digital twin platform

kovs with the possibility of simulation, the participants of which can be industrial enterprises and scientific
ny organizations.

Users will enter data themselves
resource, and KNITU-KKhTI as an operator will check their accuracy and manage the collected data. In the future, this will accelerate the pace of research and development aimed at solving the production

scientific tasks, design of new materials.

Mikhail Dmitrievich Korolkov,

Head of
strategic development of information
technologies of Gazprom Neft PJSC

On defining the industrial metaverse

When defining the industrial meta-universe, it is important to keep in mind that we are not talking about individual users, since people are not the main consumers here. Its essence lies in the idea of digital twins brought to the final stage. The industrial metaverse is an environment for the work and interaction of software agents and people. We can talk about the existence of a multi-agent system: each agent works within its own model.

The new trend is becoming a unified office A social, accessible system is the basis for modeling and interaction. Such a system can be expected to acquire emergent properties as simple agents solve complex problems in interaction. The key question is whether they should operate within a single model or on separate areas.

When there is a general model of everything, agents understand the algorithm of actions more clearly. However, creating a single universal model requires serious resources. Most likely, the movement Movement in this direction will continue, but its speed is difficult to predict. Single for now No one has yet been able to build a model of the company. You can refer to examples of the implementation of innovations of the previous generation: although 15 years ago the topic of business process modeling was popular, in reality only a few companies implemented it. These include, for example, BMW.

About digital twins

Gazprom Neft is developing a number of local digital twins: filling and updating of data, algorithms become more accurate. However, a global strategy for action in this direction has not yet been formulated. It is precisely for this purpose that we are launching the process of forming a concept for the company's development in the field of the metaverse.

Among specific models, we can mention the key one for us - the reservoir model. United There is no model yet, it is represented by many individual components. A unified model of the underground part of the field should be presented by the "Self-learning reservoir model" project. The program is aimed at integrating existing components to create a single digital twin of a significant part of underground components of the deposit - with the prospect of its full coverage. We see here reaching a qualitatively new level of technology application.

About artificial intelligence

If we talk about the global model of the industrial metaverse, then, probably, the only possible approach is to build this model using artificial intelligence technologies, since there are not enough human resources to realize such a goal.

About robotization

Gazprom Neft has a digital transformation strategy, which involves digital data collection, analysis and decision-making. Decisions are made either by people or robots. In the future, robots will become the executors of decisions made digitally. Robotic systems need to be embedded in the metaverse - that's where the orders will come from. The robot must complete the given task and provide feedback.

About blockchain

Discussing the issue of introducing blockchain into action activity of the company, it can be stated that At this stage, we did not find any possible scenarios for its industrial application, although there was a period of active study of this topic.

Blockchain is relevant where there is a lot of independent these players, complete trust between them has not been formed, because the blockchain is a tool for creating this very trust. However, in the event of a transition to a metaverse common to all market participants, blockchain may acquire relevance.

Regarding the need to implement blockchain into the industrial metaverse. In the modern sense, it is controlled by a company company is the creator, and only those whom the company trusts are allowed into it. In this case, there is no need for a blockchain. It will probably open in the future new opportunities, but at the present stage the issue of its implementation is not a priority.

About the data market

Gazprom Neft has a data strategy nykh, which determines the principles and approaches to working with them. The Metaverse will create new opportunities for deepening activities in this direction. If we talk about exchange and trade data and models as market products,

The company has no experience in this, nor does it understand knowledge of what and how to trade in this case.

But if we assume that by loading all the data and building one big model, we get a result similar to ChatGPT (a supergeologist or superengineer will appear), then there is a basis for the exchange of qualitative

data with other market participants.

About computing resources and overcoming their deficits

In the future, Gazprom Neft will have to solve the problem of a shortage of computing power during digital transformation, since significant resources are required to create large models. In Russia, only technology companies such as Sber, Yandex, VK have them. Industrial companies do not have such resources, and a specific business case is needed to justify the need for them. The industry does not have the competence to create super-computer data centers. Until now, this issue has not been of great importance, but in the near future it will become relevant.

When it comes to working with external computing providers, everything depends on the company's policy. For example, Gazprom Neft does not work with external services.

Promising in this regard are edge computing technologies that raise the question of how integration will occur at the level of data, models, and tasks. Scope of study there is little research, scientific research is needed, which These will allow breakthroughs to be made.

About data networks

The problem of data networks does not occur at all levels. The Metaverse is the basis for collaboration between software agents. These include agents - logic planners

sticks and centralized services that have no communication problems. Difficulties arise at the level of robotization. Gazprom Neft is implementing an initiative to create a deserted construction site. Here the issues of data transmission networks are of great importance. At the moment, the problem is not associated with the idea of a metaverse, but over time these issues may be considered.

train together.

About virtual reality technologies

VR as a technology seems to be just one of a number of means of accessing the metaverse and does not appear to be its main tool. For most users, a 2D screen will be sufficient. With regard to the development of areas of VR application, Gazprom Neft has a medium-term action plan

and a set of local cases. Developing long-term plans can be

stimulated with the adoption of the concept of the metaverse.

About other problems associated with creating an industrial metaverse

In the context of the structural image of the industrial metaverse, in addition to the blocks mentioned above, it is worth mentioning the platform part. There must be a platform that will allow the creation

create, launch, store, manage the life cycle of the generated models, and software agents will interact on it.

Besides the technical aspects, there are many business issues. First of all, who and what will be the source of these technological solutions, because there are none in the country now. Existence There are many gaps: there are no domestic platforms, no headsets, no AI, and it is unclear who will fill them and under what conditions.

The world's leading platformers include NVIDIA and OpenAI. The platform issue is one of the most difficult. There are either no domestic solutions in this area, or they are not scalable. This is where economics rise

and political questions - who will be the initiator, investor and organizer of the creation of such a platform?

Even if we are talking about creating the Gazprom Neft meta-universe, thousands of players will enter it (taking into account the number of our contractors). The question is how this will be organized from a business point of view. One approach is to regulate this at the contract level. However, everything can be more complicated, for example, if the contractor has technology behind which

he wants to leave authorship, but which he also must be incorporated into our metaverse. It is not yet entirely clear how to implement this.

The industrial metaverse must have a universal, cross-industry character. There is no point in offering many solutions. A group of four to five large companies should be formed - a “critical mass” interested in the development of a single industrial meta-universe.

5.2 Industrial metaverses in the space industry

In the space industry, industrial metaverses are associated with several areas: the creation of a digital twin of the Earth and other planets, the construction of spacecraft on Earth and in space.

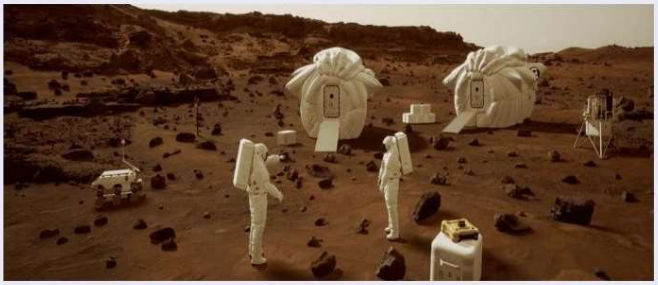
Creating a digital twin of the Earth and other planets

The space industry has been and remains a technological pioneer and the main customer for developments for large problems for which the metaverse is most suitable. As a result, the industry is seeing a flurry of metaverse projects for extraterrestrial scientific research, especially in areas such as deep-space exploration.

space, galaxies and planets.

Case 7

NASA and Epic Games are creating a digital twin of Mars



Source: The Metaverse Insider 31

The MarsXR project already includes virtual space - a copy of 400 km2 of terrain, simulation of Martian weather, rovers and spacesuits. Together with Epic Games, the owner of the engine Unreal Engine 5, NASA has launched a competition to develop new objects that will simulate the processes of deploying a Mars colony, field scientific research, equipment maintenance and surface exploration.

31 NASA Teams Up with Epic Games to Enter the Metaverse with a Bold Challenge // The Metaverse Insider. URL: https://metaverseinsider.tech/2022/06/10/nasa-teams-up-with-ep-ic-games-to-enter-the-metaverse-with-a-bold-challenge/ (accessed 04/20/2023).

The industrial metaverse is capable of creating a digital twin of the Earth from individual geographical, industrial objects and cities. This will allow predict natural phenomena, create models and scenarios - especially climate processes and areas of industry and economics, for example in the construction industry 32. As part of one of the main international programs on digital dis- researchers from the European stationary sounding Destination Earth 33, 34

32 Scientists start work on simulation of entire Earth // The Byte. URL: futurism.com/the-byte/scientists-start-simulation-entire-earth (accessed: 04/20/2023).

The Center for Medium-Range Weather Forecasts (ECMWF), the European Space Agency (ESA) and the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT) plan to create and launch a complete digital twin of the Earth between 2024 and 2030 to improve weather forecasting models by converging existing 35. 36.

Private business has joined the race to create a digital twin of the Earth. For example, Lockheed Martin, in collaboration with NVIDIA, is working to create a digital twin of the Earth's climate processes for the National Oceanic and Atmospheric Administration on the OpenRosetta3D platform 37. As the constellation of satellites is deployed and the volume of data received from various aircraft using technology

increases, artificial intelligence and machine learning, the speed of modeling processes occurring on Earth can increase exponentially. This will make it possible to filter out important information and more accurately describe physical processes 38. Thus, the use of a quantum computer will help generate models necessary for the analysis, prediction and prevention of natural disasters, and management of natural resources 39.

Construction of spacecraft on Earth and in space

For the first time, a digital twin for the space industry in the form of a prototype simulator was introduced under the Apollo 40 program in the 1960s - 1970s. Nowadays, when designing and creating spacecraft, companies are developing and using digital twins, virtual reality elements and other solutions to improve production efficiency and simulate various states during the operation of spacecraft. In particular, to reduce financial and time costs for production, subsequent maintenance and increase the volume of product output using 3D printing

and products by improving technical characteristics, such as increasing the life cycle, radiation resistance, miniaturization, etc. 41.

For greater production efficiency in the space industry, the Space Factory 4.0 concept is being considered (as part of the development of commercial production of NewSpace spacecraft). It involves the introduction of robotic assembly of modular satellites on Earth (and then in orbit) based on the use of digital twins, human-machine interface and other production technologies 42. At the first stage of Space Factory 4.0, international space industry companies are gradually introducing various services for increasing the production of satellites within the framework of conveyor production at “superfactories” 43.

33 Destination Earth - new digital twin of the Earth will help tackle climate change and protect nature // European Commission. URL: ec.europa.eu/commission/presscorner/detail/en/IP_22_1977 (date of access: 04/20/2023).

34 Destination Earth // European Commission. URL: /digital-strategy.ec.europa.eu/en/policies/destina-tion-earth (accessed 20.04.2023).

35 Scientists begin building highly accurate digital twin of our planet // ETH Zurich. URL:ethz.ch/en/news-and-events/eth-news/news/2021/02/a-highly-accurate-digital-twin-of-our-planet.html (accessed 20.04.2023).

36 A digital twin of Earth for the green transition // Nature. URL: nature.com/articles/s41558-021-00986-y (date of access: 04/20/2023).

37 Lockheed Martin to Build Digital Twin for NOAA With NVIDIA // Via Satellite. URL: satellitetoday.com/technology/2022/11/17/lockheed-martin-to-build-digital-twin-for-noaa-with-nvidia/ (date of access: 04/20/2023).

38 Scientists begin building highly accurate digital twin of our planet // Phys.org. URL: phys.org/news/2021-02-scien-tists-highly-accurate-dig-ital-twin.html (accessed 04/20/2023).

39 Artificial Intelligence, machine learning, and block-chain in quantum satellite, drone and network / edited by Thiruselvan Subramanian, Archana Dhyani, Adarsh Kumar and Sukhpal Singh Gill. – CRC Press, 2023. – 244 p.

40 NASA's Learn-to-Fly Project Overview // NTRS – NASA Technical Reports Server. URL: ntrs.nasa.gov/api/citations/20190027218/down-loads/20190027218.pdf (access date: 04/20/2023).

41 Industry 4.0 and the Future of UK Space Manufacturing: Final Report // London Economics. URL: london-conomics.co.uk/wp-content/uploads/2019/07/LE-Industry--4.0-and-the-Future-of-UK-Space-Manufacturing-Final-Report.pdf (accessed 04/20/2023).

42 Space Factory 4.0 – New processes for the robotic assembly of modular satellites on an in-orbit platform based on “Industrie 4.0” approach // German Aerospace Center (DLR). URL: elib.dlr.de/123546/ (date of access: 04/20/2023).

43 China's Satellite Super Factories and US National Security // MCPA. URL: public.milcyber.org/activities/magazine/articles/2021/baughman-chinas-satellite-super-factories (accessed 04/20/2023).

Cooperation between Boeing and Millennium Space Systems for the purpose of producing satellites

Source: Metal AM 44

44 Boeing and Millennium Space Systems launch high-throughput small sat-ellite production facility // Metal AM. URL: https://www.metal-am.com/boeing-and-millennium-space-sys-tems-launch-high-throughput-small-sat-ellite-production-facility/ (accessed 04/20/2023).

Companies plan to use digital modeling, 3D printing in the manufacture of cases (transition from polymer to metal printing) and other components to reduce production time. The new plant plans to produce 300 small spacecraft per year for the purposes of the US Government to form a constellation of satellites to provide communication services.

Among the markets of the space economy of the future, promising areas stand out, the development of which is directly related to the industrial metaverse.

- Providing telecommunications
- Safety of processes on Earth and in space
- Cybersecurity
- Space tourism and modeling various processes on the space station and spacecraft tach in virtual space
- Long range research space
- Monitoring climate and other phenomena on the earth's surface
- Production and service space devices and other equipment on Earth and in space with the prospect of creating digital orbital factories

Companies that are already using individual achievements of the industrial metaverse in the production of spacecraft and other objects will in the future be able to become leaders in the space services market both on Earth.

le, and in outer space.

5.3
Metaverses in provision
public services and public administration

For the state, the opportunities of industrial metaverses (increasing operational efficiency, reducing costs, increasing transparency and safety of production activities and services) are no less important than for industrial companies.

Industrial metaverses will allow for accurate online monitoring and forecasting of the consumption of resources and services operated by government agencies. This applies to electricity, water, transport infrastructure, and social facilities. Integration of data and digital twins of government facilities and industrial enterprises will become one of the key directions for the formation of a unified industrial metaverse, in which the state will be a key participant.

Case 9

Dubai Electricity and Water Authority (DEWA) has launched its DEWAverse metaverse

Source: Government of Dubai 45

45 DEWA launches DEWAVerse platform-form on Metaverse // Govern-ment of Dubai. URL: dewa.gov.ae/en/about-us/media-publica-tions/latest-news/2022/10/dewa-launches-dewaverse-platform-on-metaverse (accessed 04/20/2023).

DEWAverse is equipped with a set of tools for remote collaboration with the digital twin of the electricity and water supply system.

In addition, there are metadrones that collect information, maintain and generate reports on the operation of solar panels, and tools for automatically creating digital twins of electrical equipment.

It is the state that will be the key stakeholder of digital twins of cities and will have the opportunity to use them to implement its functions and tasks. Let's list some of them.

1. General control and optimization of use city resources: electricity, water, heat, utilities technology

2. Monitoring the environmental situation: emissions greenhouse gases, harmful substances, pollution

3. Public services in the metaverse (digital twins administrative buildings, virtual MFCs, predictive knowledge of government services based on intelligent lectual analysis aggregated data from different sources) will allow significantly increase the speed of service to citizens

4. Virtual tourism and events (visiting digital twins museums, virtual presence at the we are in the city of sports and cultural events) will help increase reach and monetization tourist and cultural sites

On a global scale, solid government investments in the creation of the metaverse are already visible. These are mainly urban projects aimed at developing services based on a digital twin. In fact, we can witness the formation of virtual geography - a system of geographical spaces in a virtual environment. The main value of this space will be access to a more complete understanding and modeling of a new aesthetics of urban space, as well as to the formation of new values of a society deeply integrated into the digital environment. Virtual geography is an additional way to improve the city's image and gain access to new types of income; a way to test new approaches in the design of promising products, modeling new types of industrial production and technological services.

Dubai has adopted its metaverse strategy. Among the priorities are the development of virtual tourism, education, government services and the creation of a virtual real estate market in the digital twin of the city. According to the Minister of Artificial Intelligence, Digital Economy and Remote Work of Dubai, the strategy will create conditions in which "the entire metaverse will revolve around Dubai." 46. The South Korean government is making significant investments in the metaverse: their efforts are aimed at developing the media sphere and virtual events and creative economy in the metaverse.

46 Dubai Metaverse Assembly Outcomes Report // Dubai Future Foundation. URL: https://www.dubaifuture.ae/wp-content/uploads/2022/12/TheMetaverseAssembly-OutcomesReport-WP-English.pdf (access date: 04/20/2023).

Case 10

Seoul authorities presented the first digital twin of the city – Metaverse Seoul

Source: RB 47

47 Metaverse Seoul - Government South Korea launched the long-awaited metaverse with government services and brand offices // RB. URL: rb.ru/longread/metaverse-seoul/ (date of access: 04/20/2023).

Residents of South Korea can now move through a virtual copy of part of the city by creating their own digital avatar.

One of the points of attraction has become virtual city administration, where citizens provide us with consultations. Virtual representative offices of Samsung and other large companies have opened in Metaverse Seoul. Educational organizations are reporting the transfer of part of their educational programs to the metaverse, and businesses are providing virtual commercial services and sells digital goods in the global space.

The total investment in the project is forked 180 million dollars. The first stage of "construction" of the metaverse is completed in 2023, the second and third stages are planned. In the future, some services will become available only in the metaverse.

5.4
Metaverses in higher education, science and training for industry

As was shown in section 3.2., the development of industrial metaverses creates the prerequisites for the launch of a new generation of educational programs for training
team of engineers.

To remain competitive, the academic sector needs to develop two types of strategies. The first includes adaptation strategies that involve revising the content and methodology of educational models to adapt to the developing technologies of the metaverse. The second type is transformational models, which focus on creating educational ecosystems that include universities, industrial partners and technology companies, where each participant makes an active contribution to the process of mass training in the metaverse. Universities in such ecosystems not only train personnel to work in new conditions, but also actively participate in the process of forming and managing the development of the industrial metaverse 48.

48 Dubai Metaverse Assembly Outcomes Report // Dubai Future Foundation. URL: https://www.dubaifuture.ae/

wp-content/uploads/2022/12/ TheMetaverseAssembly-OutcomesReport-WP-English. pdf (access date: 04/20/2023).

Strategies for adaptation of the academic sector in the context of the development of the industrial metaverse

The introduction of metaverse technologies into educational activities is associated with the use of the metaverse as a new platform for learning. This process includes the development of educational content, as well as methods, technologies and new teaching formats. Key applications include procedural skills development (for example, in surgery or operating complex manufacturing equipment), AR-based training, emergency response training (industrial emergency simulation), laboratory simulations (safety training).

Case

eleven

University of Tokyo and Mitsubishi launch "Meta-Universe Engineering School"

東京大学大学院
工学系研究科
SCHOOL OF ENGINEERING
THE UNIVERSITY OF TOKYO

Source:
University of Tokyo49

49 Announcing the Launch of “Metaverse School of Engineering” Promoting D&I and Developing DX Human Resources // University of Tokyo. URL: https:// www.tu-tokyo.ac.jp/en/press/pr2022-07-21-001 (date of access: 04/20/2023).

Objectives of the engineering school: promoting engineering specialties through virtual visits
production sites and practical work shops; implementation of educational engineering
programs; implementation of retraining programs in digital skills (including digital design skills), use of artificial intelligence for employees of engineering companies.

According to the expectations of the university management, the school will be able to train 100,000 people, which will help solve the problem of mass demand for specialists in digital transformation in industry.

ny companies.

University of Houston Company Nvidia and oil services company TechnipFMC teamed up to create software for the industrial metaverse

Source: University of Houston 50

50 Accelerating the Evolution of the Industrial Metaverse // University of Houston. URL: uh.edu/news-events/stories/2022-news-articles/august-2022/08312022-metaverse-houston-tech-nip-nvidia-ai.php (access date: 04/20/2023).

The University of Houston (as part of the AI Innovation Consortium) has teamed up with software company Nvidia and oil and gas engineering and services company TechnipFMC to create industrial metaverse applications.

In 2020, an industrial AI incubator and a digital oilfield laboratory appeared on the university campus. In 2021, the consortium held a conference

tion on artificial intelligence. The AI Consortium also includes the University of Pennsylvania, the University of Louisiana, and the University of Louisville (Kentucky).

The group works on the world's largest portfolio of industrial applications for the oilfield services industry and other manufacturing sectors.

The consortium participants strive to so that an operations technology specialist or any other person responsible for production can use an augmented reality platform, a wearable computer, or simply a smartphone to seamlessly connect their real-life work environment with the industrial metaverse.

5.5
Market of companies providing services and technologies of the industrial metaverse

The market for industrial metaverses is much less monopolized than the market for consumer or enterprise metaverses, which is represented by "big tech companies." BigTech enters certain market segments -
ka industrial metaverses, but does not yet claim to be the architect of the entire market, as is the case with the consumer or corporate segments.

The market for industrial metaverses has not yet been consolidated, since the solutions industry needs are highly customized and
vary depending on the region, industry, and the level of readiness of individual production facilities for digital transformation. However, the formation of industrial metaverses as federated cross-industry cyber-physical production systems prepares fertile ground for monopolization and control over supply chains. Like Big Tech on the modern Internet, the main beneficiaries of the industrial metaverse will be the owners of the infrastructure and platforms that tie the metaverse together, providing rapid digital twin development capabilities and analytical services.

An example is the Chinese industrial meta-universe market. The largest number of companies is concentrated in the field of basic technologies: this includes both giants (such as Siemens and Nvidia) and small companies. On more complex layers of the metaverse, the number of companies is significantly smaller, and they are represented mainly by regional players. Industry integrators are taking the position of collectors of metaverses: providers of digital systems in the energy sector, port logistics, fashion design or the manufacturing sector 51.

51 An Overview of China's Industrial Metaverse in 2022 and Beyond // EqualOcean. URL: equalocean.com/research/2022080915130 (access date: 04/20/2023).

Case 13

Fujitsu: metafactory as a platform

Source: : Fujitsu 52

52 Digital twins and the metaverse are converging: welcome to the metafactory // Fujitsu. URL: corporate-blog.global.fujitsu.com/fgb/2022-07-14/01/ (accessed 04/20/2023).

The Japanese electronics manufacturer and software developer sees the metafactory as a virtual environment containing digital twins. Fujitsu does not create production systems themselves: the company's ambition is to become the owner of a platform and marketplace for industrial applications, which will allow external enterprises to develop point solutions.

Fujitsu plans to keep this platform
through the development of standards, as well as general control over cybersecurity technologies, identification, AI trust and network infrastructure.

It is highly likely that the global metaverse market will ultimately monopolized by companies that were the first to create scalable cross-industrial solutions. When the market matures, the already small number of global companies that determine the direction of the world economy will become even smaller.

Assessing the future potential of the industrial metaverse market, It is worth highlighting a number of key positions on it.

1.
Suppliers of software and hardware The military components of the metaverse are mainly represented by deeply specialized technology companies, owning a specific product as part of the industrial metaverse (vendors of industry software, operators of financial settlements using blockchain, manufacturing

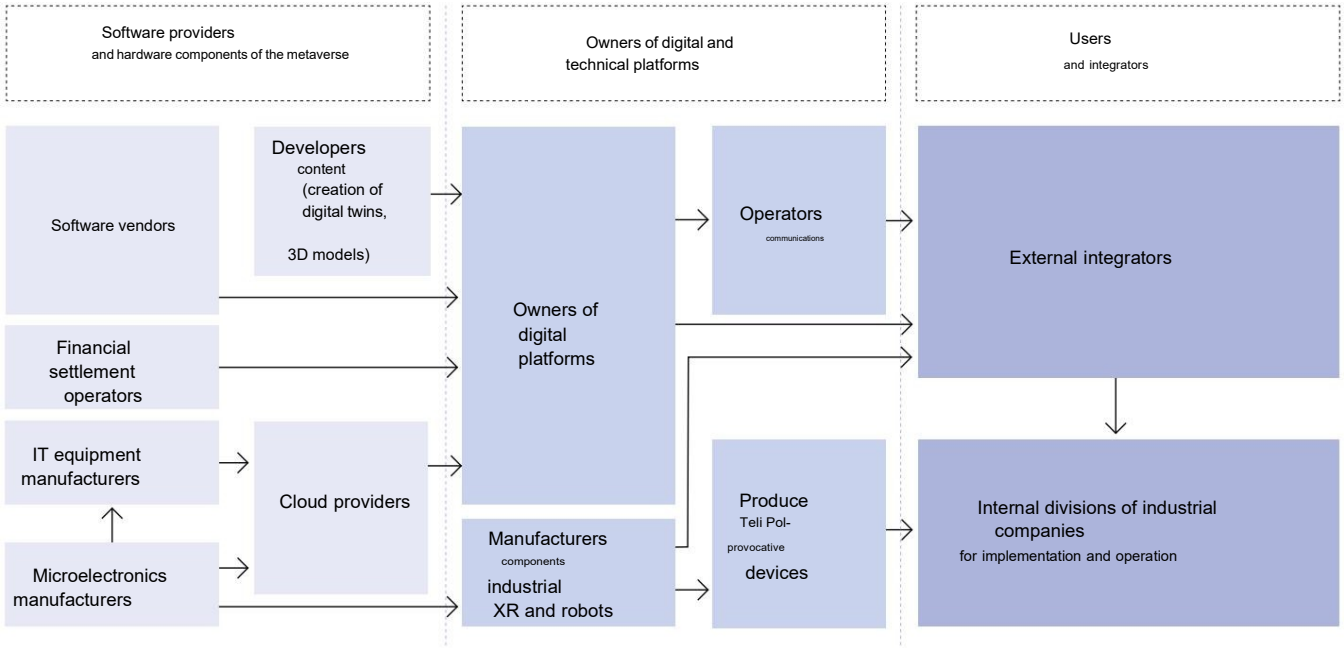
manufacturers of microelectronic components and IT equipment). In this category in Russia there is a shortage of microelectronics and physical equipment, while the market for software vendors and the content is quite rich.

2.
Owners of digital and technical platforms retain specific technical competencies within large markets. This category includes mobile network operators, holders of TIM, CAD platforms, etc. In Russia there is a fairly wide selection of platforms and service providers. Scarce

are the positions of manufacturers of industrial virtual and augmented reality components and robots, including under- other user devices.

3.
To users and integrators industrial companies and their departments of digital transformation and digital infrastructure, which are present in any large holding company today. Moreover, on the market There is a position of an external integrator who can serve both large and medium-sized businesses. And there are many such companies in the country.

The shortage of players investing in industrial metaverses in Russia may cause the country to miss out on good development opportunities. At the same time, the formation of an industrial metaverse will increase the significance of unclosed market positions and potential revenue volumes, which should lead to the filling of empty niches with new players. Thus, the industrial metaverse in Russia (especially areas related to equipment production) is promising for investment.



Pic. 12. Key positions in the industrial metaverse market

Source: Center for Social Development "North-West" based on materials from Credit Suisse 53

53 Metaverse: A guide to the Next-Gen internet // Credit Suisse. URL: credit-suisse.com/media/assets/corporate/docs/about-us/media/media-release/2022/03/metaverse-14032022.pdf (access date: 04/20/2023).

Alexey Vladimirovich Korablev,

President of the R-Pro concern

On defining the industrial metaverse

The industrial metaverse is more about marketing prospects, both in the West and in Russia. The issue of digital twins 15-20 years ago was also mostly a marketing issue. All this time, the R-Pro concern has been working on the topic of digital twins and has implemented more than 200 projects in this area. A state standard in the field of digital twins has already appeared, and when designing new factories, tasks are immediately set to create a digital twin, program equipment

ore in it.

About digital twins

The digital twins of production that we are now creating are a prototype of the future industrial metaverse. Development prospects here are related to the development of doubles for various scenarios: for R&D, product, technological, organizational innovation and everything related to personnel training. It is important to ensure the transfer of one technology between scenes.

conventional options: dive
factories in virtual reality, virtual
meetings.

About artificial intelligence

There is active integration of digital twins and neural networks. Together with Big Data and digital twins, new digital entities are emerging that allow the use of AI at the level of production system management. Then the result can be transferred to the physical level - ultimately, control over the decision-making will be exercised by a person. It is the collaboration of artificial intelligence and humans that is the essence of Industry 5.0.

On the national objectives of implementing the industrial metaverse

For Russia, an important factor was import substitution and departure from foreign systems. In the West there are large umbrella software environments such as Siemens and Dassault. The latter are 30 percent dependent on government funding. For the development of such software in our country, government programs are also needed. However, this does not imply centralization of the market. "R-Pro", for example, works equally effectively with both small and large

ny companies, including state-owned ones.

6

Industrial metaverse: technological sovereignty and state interests

6.1 Industrial metaverses can become an important geopolitical factor and influence the position of states in international alliances

The industrial metaverse is by nature a federated, cross-sectoral platform that seeks to cover all aspects of the manufacturing system. Its development cannot be limited to national supply chains, otherwise there will be a colossal gap between the effectiveness of international economic cooperation and domestic economic cooperation. Therefore, in the area of the industrial metaverse, if the market grows at a rapid pace, it will be extremely important to ensure technological sovereignty.

The global market for industrial metaverses will develop in at least two techno-economic blocs opposing each other. They began to take shape with the beginning of the trade wars between the USA and China, the reason for which was
Mutual political and economic contradictions between the two powers began to grow. The process of divergence between the two economic systems continues today at the level of basic industrial solutions (production of microelectronics, communications equipment, software). Next, it will move to the technological level (differences in the applied hardware and software architectures, industrial standards). In the long term, the principles of the economic structure in the world's two largest economies may become radically different from each other, which will lead to differences in business models

and the corporate composition of market participants.

To ensure the technological sovereignty of the Russian Federation, maintain the competitiveness and productivity of the economy, it is necessary to ensure that Russia has its own software, hardware solutions and a set of industry players or a “controlling stake” in the supranational industrial metaverse. Integration into foreign ecosystems will require imports

third party standards; Lack of participation in the creation of metaverses will limit the ability to produce competitive products. Therefore, in the future, Russia will be involved in one of the emerging techno-economic blocs - or create its own. Success in forming a bloc will depend on the presence of national companies in each layer of the industrial metaverse.

6.2
Unlocking the potential of industrial metaverses is impossible without a regulatory framework

As already mentioned in section 4.1., standardization of the industrial metals market universes is an actively developing area supported by key global players and international standards organizations. But at the national level there are still many tasks in the normative and regulatory part.

To scale industrial metaverses, governments must define rules for handling data, conducting transactions, and respecting intellectual property rights. The industrial metaverse is the area of interaction between legal entities and individuals. As in physical space, conflicts of interest, abuse and violations are possible here. In this regard, the state must provide a legislative framework, regulation

establishing the metaverse, create tools for monitoring and executing the installation lennogo norms.

Financial relations in the metaverse are a subject of particular interest to the state. It is the industrial metaverse that will formulate the requirements for the introduction of blockchain-related policies - projects to issue digital national currencies and control over the circulation of cryptocurrency. In turn, betting on blockchain and the industrial metaverse will create

new mechanisms of trade between enterprises on the domestic market and with external them partners.

Government control and management of the industrial metaverse can take many forms. Among other things, "regulatory sandboxes", creating specialized associations and non-profit organizations.

Case 14

China State Mobile Communications Association has formed a Metaverse Committee

Source: Reuters 54

The committee included 17 companies participating in the metaverse market, including Tencent. Experts call the key task of the committee to establish control over the metaverse at the stage of market development. In particular, within the framework of the Committee such

initiatives such as the replacement of cryptocurrency payments with the digital yuan, strict rules for registration and identification of users.

One of the central projects of the Committee was also the creation of Chinese VR devices and virtual content with national specifics.

54 Analysis: A metaverse with Chinese characteristics is a clean and compliant metaverse // Reu-ters. URL: reuters.com/markets/funds/metaverse-with-chinese-char-acteristics-is-clean-com-pliant-metaverse-2022-01-25/ (access date: 04/20/2023).

6.3
The state as one of the actors shaping the metaverse market

The expansion of the industrial metaverse market to scale will be especially rapid where the government provides infrastructure for industrial metaverse tasks, including the allocation of computing power, the creation of platforms for working with VR, software development platforms and applications.

The presence of the state infrastructure of the industrial metaverse contributes to the development of this direction in state companies and small and medium-sized businesses. It will provide a connection between industrial metaverses and government management of industry, as well as other areas of the economy.

In addition, large companies with state participation, for example in China, are among the key beneficiaries of the industrial metaverse.

Case 15

South Korean government to invest $187 million in state-owned metaverse

Expanded Virtual World

Source: Cointelegraph 55

55 South Korea to invest $187M in national metaverse project // Coin-telegraph. URL: https://cointelegraph.com/news/south-korea-to-invest-187m-in-national-metaverse (accessed 04/20/2023).

The goal of the government project is to create an infrastructure for the development of technology and media companies developing content in the metaverse. The number of companies that took part in the project amounted to several hundred, which makes the Korean project the most aggressive government initiative to launch the metaverse market.

The state can also be involved in initiatives to develop personnel for work in industrial metaverses. This particularly applies to specialist training programs and funding of basic research. Metaverses can become a way to improve the quality of public services, including those provided digitally, and an approach to shaping public policy regarding investment markets of the future in the consumer and industrial segments. Perhaps this is why many cities in Asia and the Middle East are already investing in creating copies of themselves in metaverses (this was discussed in Chapter 5.3).

Dubai Future Foundation launches metaverse acceleration platform

Source: DIFC Innovation Hub56

The purpose of the platform is to train teams and build human resources for the metaverse. In addition to master classes, participants have the opportunity to develop their own project and attract funding.

56 Metaverse Accelerator Program // DIFC Innovation Hub. URL: innovation-hub.difc.ae/programmes/Metaverse-Accelerator-Programme (date of access: 04/20/2023).

6.4
To avoid losing the productivity race, Russia needs an experiment in the industrial metaverse

International experience and cases presented on the pages of this report show that the formation of the market for industrial metaverses in the world is a set of experiments. Nevertheless, even these several dozen or hundreds of experiments were able to form a certain software and hardware market, standards and approaches to creating industrial metaverses. Most likely, the next investment cycle in the global industry of developed and some developing countries will involve initially digital (digital native) production projects.

Therefore, in order to maintain technological sovereignty and keep up with competitors on the world stage, Russian industry needs to create its own experimental sites. Moreover, large industrial companies should become the key investors. Experiments in the industrial metaverse will require not individual lines or fields, but a little more - several individual enterprises participating in the overall production and logistics chain.

The key challenge for Russia in terms of implementing such an experiment is
In the current conditions, this will become not only the complexity of organizing the industrial metaverse, but also its equipping with domestic hardware and software. The experiment will help reveal the technological, production and personnel shortages of Russian industry and the technology sector - and this only exacerbates its need.

Case 17

Siemens created Digital Native Factory in Nanjing (China)

Source: Siemens 57

57 The Digital Native Factory // Siemens. URL: https: siemens.com/global/en/com-pany/topic-areas/digital-enterprise/dex/digital-native-factory.html (accessed 04/20/2023).

Siemens assets in Nanjing included two production private sites producing drives, motors and CNC controllers, and separate logistics facilities.

Through completely digital design (based on the integration of production, logistics data and automation) and optimization models, the company opened a unified production

but a logistics platform.

Digital Native Factory allowed Siemens to increase reduce production volumes per area by 200%, labor productivity by 20%, and speed of delivery of components by 50%.

Conclusion

The industrial metaverse is a theoretical model of future market organization. It requires a careful, experimental approach. But you can't ignore it

As the analysis of global markets, cases and international experience given in the previous section shows,
In the following sections of the report, the industrial metaverse is currently a theoretical model of the industrial market of the future, which may be partly true, partly wrong.

Despite this, they are investing in industrial
metaverse has long been not only technologically
Chinese companies interested in creating a market
for their products and services, but also traditional industrial giants -
Siemens, BMW, Hyundai, Schlumberger
and many others.

Most likely in the next five to ten
We should not expect widespread adoption of the industrial metaverse for years, although unexpected breakthroughs are possible. Just look at how quickly artificial intelligence systems are developing.

lecture and what unobvious shifts they cause in many industries. But such trends as the development of interoperability, the formation of industry-wide and cross-industrial platforms, the capitalization of digital assets, data and models,

relevant today and recognized as promising,
although not an existentially important area of investment for industry.

At a minimum, the industrial metaverse can become an area of experimentation for Russian companies that will ensure readiness for a dramatic transition - if one is necessary.

In a scenario in which this transition begins to occur rapidly (as many Western analysts point out), the metaverse will allow early

their followers to carry out expansion into markets and gain a foothold in a monopolist position. And it carries
a potential threat to everyone who did not have time to take part in a possible race. Therefore, leaders of industrial companies should carefully monitor trends and changes in the industrial metaverse.

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