UDC 658.51
https://doi.org/10.32362/2500-316X-2023-11-4-105-115

RESEARCH ARTICLE

Organization of an engineering center for industrial import substitution

Dmitry Kh. Mikhailidi [1],
Alexander V. Ragutkin [2],
Dmitry O. Skobelev [1, 2],
Alexey B. Sukhaterin [2, @]

[1] *Environmental Industrial Policy Center, Moscow, 115054 Russia*
[2] *MIREA – Russian Technological University, Moscow, 119454 Russia*
[@] *Corresponding author, e-mail: suhaterin@mirea.ru*

Abstract
Objectives. Following the imposition of sanctions against the Russian Federation, which included a ban on the supply of foreign electronic equipment—including automation systems—to Russian enterprises, the continuing development of science and technology in Russia became a question of ensuring technological sovereignty according to the principle of import substitution. According to plans developed by the Ministry of Industry and Trade of the Russian Federation, the policy of import substitution, including automation systems, will ensure the replacement of imported equipment with domestic counterparts.
Methods. Approaches underlying the joint project of MIREA – Russian Technological University and Environmental Industrial Policy Center to solve the problems of import substitution are described. Various substitution strategies available in the world experience, as well as objective and subjective obstacles to their implementation in Russia, including the insufficiency of domestic regulatory legal acts and previously formed attachments to imported technologies and regulatory frameworks, are considered. Distinctive features of contemporary external relations are adduced to the necessity and urgency of developing technological sovereignty. The main functional requirements for a software and hardware platform for developing modern automated control systems (ACS) for mechanical engineering applications, as well as the required capabilities of an engineering center for solving applied problems of overcoming import dependence, are described. The components of the production of capital goods (engineering) and its role in the product life cycle are shown.
Results. The selection of a pilot engineering object comprising a sectional glass-forming machine, along with a software-hardware complex including elements of industrial electronics and ACS, is justified. The main functional elements of the ACS and their interrelations are shown.
Conclusions. The results confirm the necessity of achieving complete import substitution for the creation of digital products. Prospects for cooperation with interested organizations are shown.

Keywords: product life cycle, technological sovereignty, import substitution, mechanical engineering, software and hardware platform, glass-forming machine, automated control system, reverse engineering

• **Submitted:** 24.04.2023 • **Revised:** 08.06.2023 • **Accepted:** 21.06.2023

For citation: Mikhailidi D.Kh., Ragutkin A.V., Skobelev D.O., Sukhaterin A.B. Organization of an engineering center for industrial import substitution. *Russ. Technol. J*. 2023;11(4):105–115. https://doi.org/10.32362/2500-316X-2023-11-4-105-115

Financial disclosure: The authors have no a financial or property interest in any material or method mentioned.

The authors declare no conflicts of interest.

НАУЧНАЯ СТАТЬЯ

Организация инжинирингового центра для импортозамещения в промышленности

Д.Х. Михайлиди [1],
А.В. Рагуткин [2],
Д.О. Скобелев [1, 2],
А.Б. Сухатерин [2, @]

[1] *Научно-исследовательский институт «Центр экологической и промышленной политики», Москва, 115054 Россия*
[2] *МИРЭА – Российский технологический университет, Москва, 119454 Россия*
[@] *Автор для переписки, e-mail: suhaterin@mirea.ru*

Резюме
Цели. После введения санкций против Российской Федерации и запрета поставки иностранной электронной техники, в т.ч. систем автоматизации, российским предприятиям, важнейшей задачей развития науки и техники в России является обеспечение технологического суверенитета. Один из «кирпичиков» в фундаменте решения данной задачи – это импортозамещение. Согласно планам, разработанным Министерством промышленности и торговли Российской Федерации, курс на импортозамещение поможет произвести замену импортного оборудования отечественными аналогами.
Методы. Описываются подходы, положенные в основу совместного проекта РТУ МИРЭА и НИИ «ЦЭПП» по решению задач импортозамещения. Рассмотрены имеющиеся в мировом опыте стратегии замещения, а также объективные и субъективные препятствия для его проведения в России, среди которых недостаточная функциональность нормативно-правовых актов и сформированная привязанность к импортным технологиям и правилам. Показана особенность современных внешних взаимоотношений России как причина необходимости и срочности формирования технологического суверенитета. Описаны основные функциональные требования к программно-аппаратной платформе для построения современных автоматизированных систем управления (АСУ) для машиностроения, а также возможности инжинирингового центра для решения прикладных задач по преодолению импортозависимости. Показаны составные части производства средств производства (машиностроения) и его роль в жизненном цикле продукции.
Результаты. Обоснован выбор пилотного объекта инжиниринга – секционной стеклоформующей машины, предмета разработки – программно-аппаратного комплекса, включающего элементы промышленной электроники и АСУ, показаны основные функциональные элементы АСУ и возникающие между ними связи.
Выводы. Подтверждается, что в создании цифровых продуктов необходимо добиться полного импортозамещения. Представлены перспективы сотрудничества с заинтересованными организациями.

Ключевые слова: жизненный цикл продукции, технологический суверенитет, импортозамещение, машиностроение, программно-аппаратная платформа, стеклоформующая машина, автоматизированная система управления, реверс-инжиниринг

• **Поступила:** 24.04.2023 • **Доработана:** 08.06.2023 • **Принята к опубликованию:** 21.06.2023

Для цитирования: Михайлиди Д.Х., Рагуткин А.В., Скобелев Д.О., Сухатерин А.Б. Организация инжинирингового центра для импортозамещения в промышленности. *Russ. Technol. J.* 2023;11(4):105–115. https://doi.org/10.32362/2500-316X-2023-11-4-105-115

Прозрачность финансовой деятельности: Авторы не имеют финансовой заинтересованности в представленных материалах или методах.

Авторы заявляют об отсутствии конфликта интересов.

INTRODUCTION

From the point of view of classical economics, the expenditure of resources on import substitution cannot be considered highly efficient. This is explained by the fact that the customer of the process will be forced to spend money to re-learn the existing mode of production.

The reasons prompting the Russian Federation to import substitution policy in 2023 were not so much fundamental, stemming from the opportunity to increase domestic economic potential, as situational, caused by sanctions, which created an existential threat to the state and its economy [1]. The prevailing environment of hostile or suspended relations with yesterday's economic partners dictates the need and urgency to localize the full range of products. At the same time, critical types of production activities need to be oriented exclusively to the domestic market, recreating production chains within the country [2].

In 2022, a comprehensive block of urgent measures was introduced in response to the sanctions policy, which, although contradicting the concept of import substitution, made it possible to avoid the risks of a catastrophic fall in production and consumption. Thus, while allowing parallel imports without the permission of rights holders and zeroing import duties merely changed the form of import dependency, they appear to have represented a necessary temporary solution, not only in terms of creating a window for the creation and consumption of domestic products, but also in terms of allowing the characteristics of domestically manufactured goods to be improved as compared with their imported equivalents. This provides a basis on which the imperative to create technological sovereignty can be formulated.

CAPITAL GOODS PRODUCTION AS THE BASIS OF THE TECHNOLOGICAL SOVEREIGNTY OF THE COUNTRY

Under contemporary conditions, a particular country generally specializes in the production of those products where it has an advantage in terms of its possession of factors of production [3]. Comparative cost theory [4, 5] considers that a country cannot have a competitive advantage across the entire spectrum of locally produced goods, which are also available on global markets. Under sanctions, however, the need for domestic production increases regardless of the presence or absence of competitive advantages.

An analysis of the industrial life cycle diagram depicted in Fig. 1 shows that the sector of manufacture of technical means of production or mechanical engineering, which has an impact on the whole chain of transformations (redistribution) of the substance—from the extraction of raw materials to the disposal of the product. Obviously, synchronization of multivector substitution is required—manufacture of the means of production and consumption items. Ultimately, the need for consumption should ensure the effectiveness of import substitution of the technical means of production.

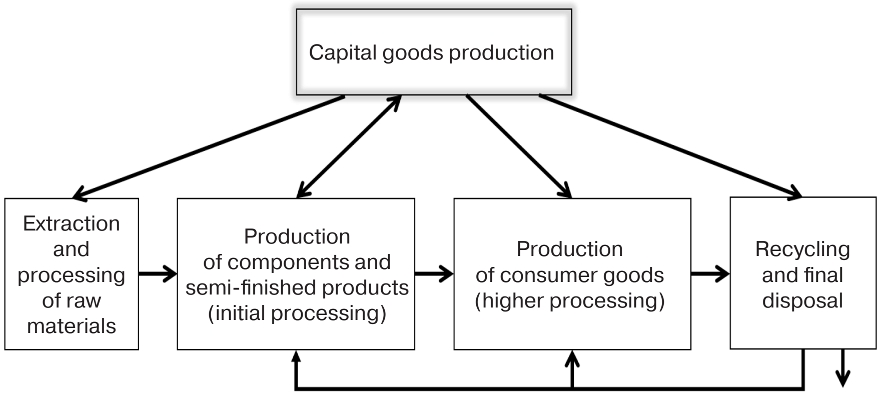

Fig. 1. Diagram of the industrial product lifecycle

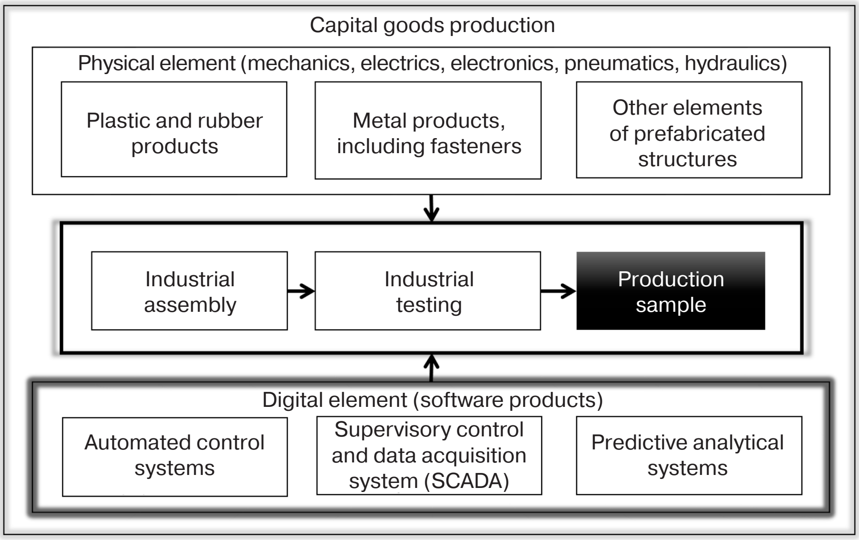

Fig. 2. Interaction of industrial elements in the production of capital goods

The mentioned sector consists of two industrial elements (Fig. 2): physical (machines, machining workstations) and digital (data collection, process control). The digital element is implemented in the physical by means of software and hardware platforms (SHP) to ensure the proper functionality of automatic control systems, relying on actuators (valves, servo drives, etc.). The supervisory control and data acquisition (SCADA) system is used to control complex production equipment, which centralizes the functions of actuators, as well as providing production statistics for automated control systems (ACS) of the technological process and for predictive analytical systems.

As well as constituting a national security goal, the development of mechanical engineering represents a fundamental condition for further growth and development of the country. Even taking into account the reduction already occurring over the past 8 years, the continuing dependence on imports for 50–90% of equipment components represents the main constraint on the development of domestic production and ensuing economic growth.[1,2,3,4,5] This determines import substitution priorities, without which the associated processes are likely to occur haphazardly and lacking proper efficiency [1].

An import substitution phase was experienced by the majority of newly industrialized countries during the period between the 1950s and 1970s [6]. This was concomitant with the economic assumption that the economic situation of commodity-exporting countries (developing countries) will tend to deteriorate if they do not resort to an import-substitution policy during the process of industrialization (Prebisch–Singer hypothesis [7]). While South American countries mainly concentrated their efforts on saturating domestic markets, Southeast Asia tended to be more export-focused. While the export strategy turned out to be more effective [8], this could only be achieved if the national currency is constantly weakened, which tends to lead to a decrease in the added value of the product, high domestic inflation, or restrictions on the growth of living standards [9].

In Russia, import substitution (where it was implemented) was based on an export strategy [10]. In November 2015, the State Council of the Russian Federation adopted basic decisions on this issue. As part of the recommended actions, it was proposed to:

- support the process of import substitution with financial resources, mainly through changes in taxation, as well as with funds from the Industrial Development Fund and the Federal Corporation for the Development of Small and Medium Business, including project financing and the provision of state guarantees;

[1] Order of the Ministry of Industry and Trade of the Russian Federation No. 2486 dated 07.07.2021. https://rulaws.ru/acts/Prikaz-Minpromtorga-Rossii-ot-07.07.2021-N-2486/. Accessed April 04, 2023 (in Russ.).

[2] Order of the Ministry of Industry and Trade of the Russian Federation No. 2913 dated 02.08.2021. https://rulaws.ru/acts/Prikaz-Minpromtorga-Rossii-ot-02.08.2021-N-2913/. Accessed April 04, 2023 (in Russ.).

[3] Order of the Ministry of Industry and Trade of the Russian Federation No. 3273 dated 20.08.2021. https://rulaws.ru/acts/Prikaz-Minpromtorga-Rossii-ot-20.08.2021-N-3273/. Accessed April 04, 2023 (in Russ.).

[4] Order of the Ministry of Industry and Trade of the Russian Federation No. 2882 dated 30.07.2021. https://rulaws.ru/acts/Prikaz-Minpromtorga-Rossii-ot-30.07.2021-N-2882/. Accessed April 04, 2023 (in Russ.).

[5] Order of the Ministry of Industry and Trade of the Russian Federation No. 2881 dated 30.07.2021. https://legalacts.ru/doc/prikaz-minpromtorga-rossii-ot-30072021-n-2881-ob-utverzhdenii/. Accessed April 04, 2023 (in Russ.).

- completely focus the system of public procurement on the purchase of domestic equipment, applying special incentives to stimulate Russian production facilities;
- create a system of centralized management of import substitution and related control, which would allow blocking the purchase of foreign products if Russian analogs are available.[6]

In pursuance of these tasks, several laws and regulations (L&R) were enacted, in particular, RF Government Decree No. 208[7] and RF Government Decree No. 209[8] dated February 18, 2022. While acknowledging their obvious advantages, we would like here to draw attention to some of their disadvantages. For example, the criterion of effectiveness stipulated in RF GD No. 209 is the number of created sets of design documentation, which cannot be said to reflect economic effectiveness. While RF GD No. 208 seems to offer a better mechanism, it lacks mechanisms for the vertical integration and aggregation of development objects according to various attributes; moreover, each component is developed by separate teams, which greatly increases the unit costs of product development as a whole [11].

Local development of software and electronics is supported in Russia. Import substitution programs are additionally implemented within the framework of the national project Small and Medium Entrepreneurship, where the division of efforts occurs in two directions: deployment of serial production, as well as the production of unique equipment and the creation of new technologies facilitating the introduction of know-how and science-intensive capital goods [12].

The purpose of the enacted L&R is to support the deployment of domestic production to create products that replace imported analogs and surpass the latter in their consumer characteristics, as well as leading to the development of new technologies (Fig. 3) [13]. For the Russian economy, this concerns not only products, but also technologies and institutions (rules), whose import has largely determined the continuing dependence on global engineering development centers. This development strategy was imposed not only on industry, but also in education and science, whose development is tied to external assessments and standards: the result was the "implicit sanctions model" [1] implemented long before the beginning of the present confrontational era.

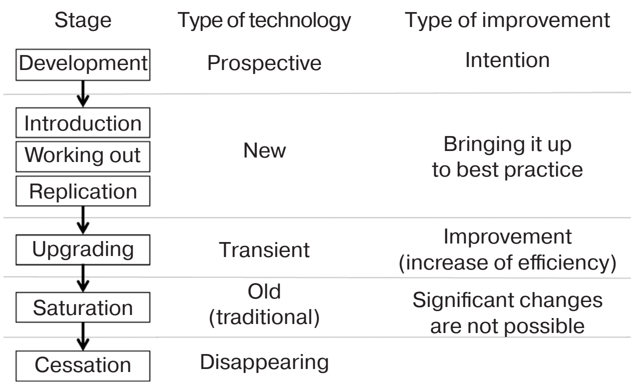

Fig. 3. Evolution of technologies according to O.S. Sukharev [14]

The formed attachments to imported technologies and standards represent one of the main obstacles to their replacement. Since this managerial effect is related to the core of technological content, domestic developers need to create such a core and put it into action in the face of fierce competition with the currently functioning—albeit at the expense of parallel imports—infrastructure [1]. As a rule, manufacturing industries try to exclude from their daily activities the risks associated with the need to improve skills, carry out research and development, and develop other time-consuming innovations. This explains the inertial reaction to the imposition of sanctions, since it is always easier to obtain parallel imports than to force elements of a complex system to localize technology and equipment.

In the context of import substitution, this represents a fundamental limitation. While technological substitution provides an opportunity to create your own product, it will continue to reduce the competitive potential of the individual industry and the economy as a whole if current patterns of economic orientation to the imported product are not altered. Therefore, centers of competence for overcoming import dependence become engineering centers, representing elements of innovative development [15].

Under contemporary conditions, the main focus of import substitution projects should be not be aimed at updating fixed assets, thus merely replicating the already achieved technological level, but instead focus on creating a basis for the rapid development and modernization of the real sector of the economy.

For most areas of manufacture of technical means of production, the creation of automatic and ACS

[6] State Council commissions discussed the idea of creating a unified service for import substitution. https://tass.ru/ekonomika/14848255. Accessed April 04, 2023 (in Russ.).

[7] On the granting of subsidies from the federal budget to the autonomous non-profit organization "Agency for Technological Development" to support projects involving the development of design documentation for components required for industries. Decree of the Government of the Russian Federation No. 208 dated 18.02.2022. http://static.government.ru/media/files/zISr7dzERAaYQY0N2HBwbN4FoBah9M6Y.pdf. Accessed April 04, 2023 (in Russ.).

[8] On providing grants in the form of subsidies from the federal budget for the implementation of projects to create and (or) develop engineering development centers on the basis of educational organizations of higher education and scientific organizations implementing projects related to the development of components. Decree of the Government of the Russian Federation No. 209 dated 18.02.2022. http://government.ru/docs/all/139438/. Accessed April 04, 2023 (in Russ.).

presents a significant challenge. The current uncertainty in maintaining the operability of production equipment in this area is a consequence of its having been characterized by its reliance on foreign microelectronic and software solutions over the past decades. Thus, the insufficient development of the Russian industrial controllers, peripherals and development tools means that problems of localization of mechanical engineering cannot be promptly solved.

The problem of creating domestic SHP solutions, comprising a set of hardware and software used to monitor and control production processes, maintain feedback, and actively influence the course of the process when it deviates from the declared parameters, as well as regulate and optimize the controlled process, is especially acute. Comprising a branched structure with distributed I/O and centralized signal processing, an SHP must ensure the physical interconnection of actuators and sensors of technological equipment. Depending on the type, the signal lines are connected to analog and discrete signal input/output modules, which are in turn connected to a programmable logic controller (PLC) via a fieldbus. To increase fault tolerance, two industrial PLC modules supporting hot redundancy can be used. In the event of a cable break or failure of one of the remote I/O devices, a minimum restoration time of the entire system should be required. Through industrial protocols such as Modbus, Industrial Ethernet, etc. The PLC provides information communication with the central control system, possibly via a fault protection system.

Integrated application development tools (e.g., *Codesys*, *ISAGRaf*, etc.) supporting all 5 IEC 61131-3 programming languages (LD, FBD, IL, ST, SFC)[9]. Thus, the PLC is responsible for receiving information from the sensors in real time through the industrial network, converting it and exchanging with other components of the automation system, as well as controlling actuators. Further data exchange between controllers and operator stations takes place via the backbone network. The operator level includes servers and user automated workstations for monitoring the operational technological and production process and, if necessary, sending commands to change parameters.

In mechanical engineering, SHP is implemented in the form of development and implementation of applied software and hardware complexes (SHC) with different degrees of universalization. The MIREA – Russian Technological University and Environmental Industrial Policy Center began a joint project to establish the functionality of such platform on the example of engineering the ACS of a glass-forming machine (GFM) (Fig. 4). Unlike the physical element of the equipment, where there are objective restrictions to achieving 100% independence (for example, natural rubber, comprising a component of many rubber products, cannot be produced in Russia for climatic reasons), the potential for import substitution of the digital element has almost no limitations and is recognized as a development priority for reasons of production and information security in compliance with the requirements of the best available technologies.

The object of engineering was selected on the basis of scientific experience, close relations with industry enterprises, first of all in the field of compliance with the best available technologies. In cooperation with one of the largest enterprises of the glass industry, an eight-section GFM became available, for which a reverse-engineering program is in the process of being developed (Fig. 5). Our potential joint development of the ACS GFM, which relates to import substitution in the field of mechanical engineering (manufacture of technical means of production), is on the priority list of industrial policy due to mechanical engineering comprising a fundamental condition for the growth and development of the country's economy.

ACS is typically considered in terms of a holistic solution for ensuring the automation of technological processes. The concept of "automated," as opposed to "automatic," emphasizes the need for human participation in individual operations, both in order to maintain control over the process and due to the complexity or inexpediency of automating individual operations. ACS ensures safety of operations by means of highly reliable alarms, interlocks and protections having a minimum response time, exact fulfillment of process regulations, elimination of erroneous actions of operating personnel, maintaining the reliable operation of equipment, and preventing emergency situations.

ACS level includes the development of a control algorithm that collects information from the primary sensors and actuators, processes the received information, automatically regulates (maintaining process parameters at the set value), manually and/or automatically controls electric drives and process equipment, transmits information from controllers and automation systems to the upper level. Industrial networks are used for information communication of all subsystems.

Within the framework of works on import substitution, the main goal consists in the development of ACS (software application part), implementation of the technical means of automation for the existing Russian fleet of sectional SFM based on the Russian element base and use of applied and system products from the register of Russian software[10]. The next step

[9] National Standard of the Russian Federation. *Programmable Controllers*. Part 3. *Programming languages*. https://docs.cntd.ru/document/1200135008. Accessed April 04, 2023 (in Russ.).

[10] https://reestr.digital.gov.ru/. Accessed April 04, 2023 (in Russ.).

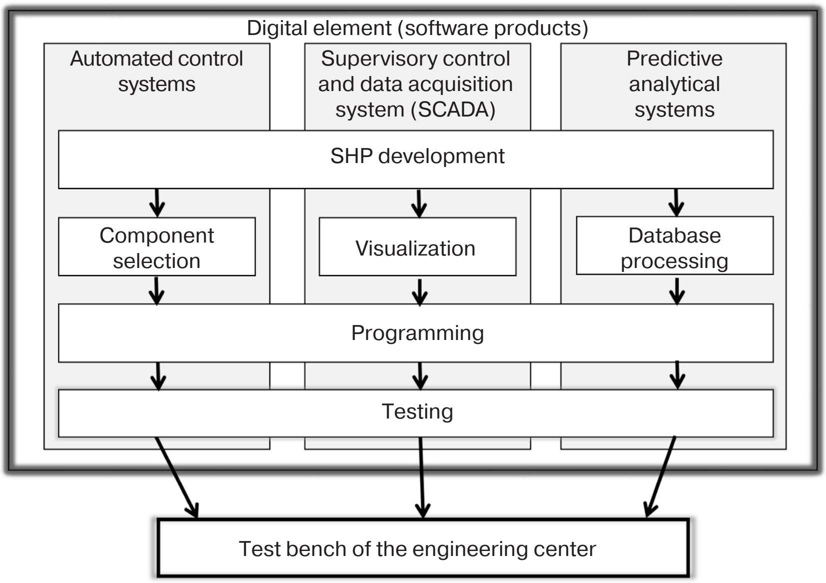

Fig. 4. Engineering center competencies

consists in the adaptation of technological equipment of the machine, including control panels, sensors of media parameters, electromechanical valves, servomotors, stepper motors, pumps, etc., with gradual transition to the use of emerging Russian products. The result of the system development will be the GFC SHC, combining application software, providing algorithms of trouble-free control of actuating mechanisms and control of machine parameters. The software will be implemented on section control PLCs (sectional controllers), devices for setting of synchronous pulse sequences by the central controller, speed and position control of frequency converters through SCADA (Fig. 6).

SCADA is a software tool whose purpose is to automate the control of technological processes, with the adjustment of parameters being carried out in real time. The operator receives comprehensive and reliable information about the objects and performs the necessary actions with the help of efficient means. In industry, the functionality of monitoring, control, archiving of the received data, alerting, and reporting, are in demand. One of the key tools of the software

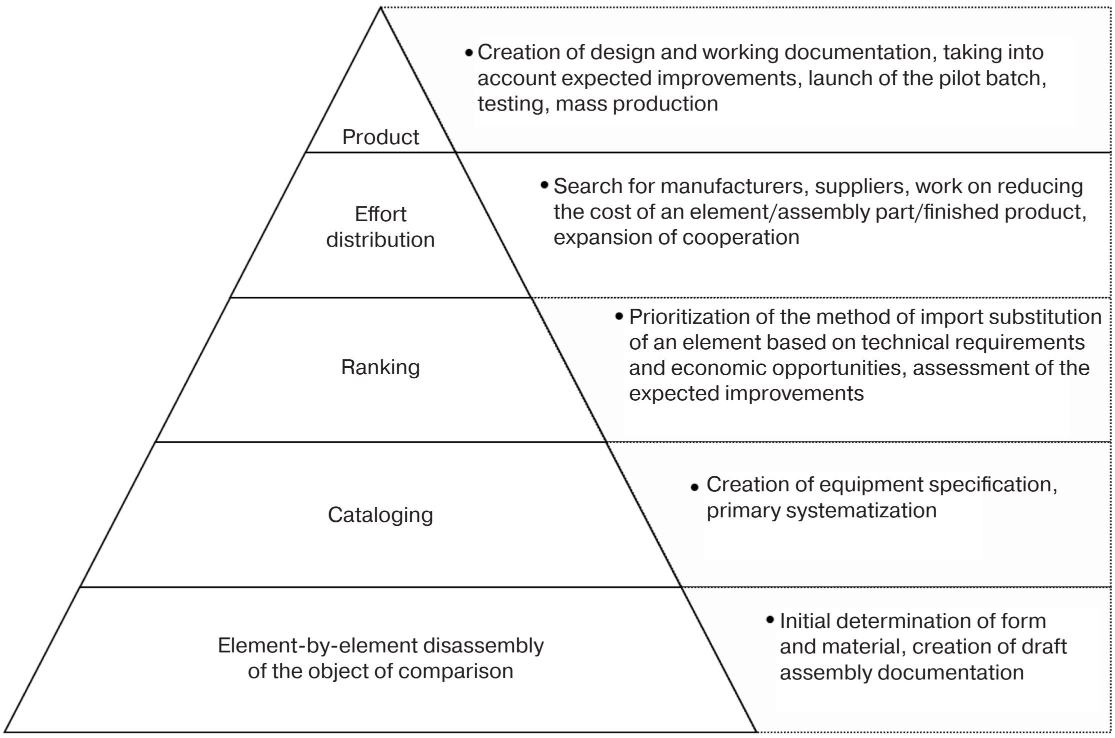

Fig. 5. Hierarchical diagram of reverse engineering

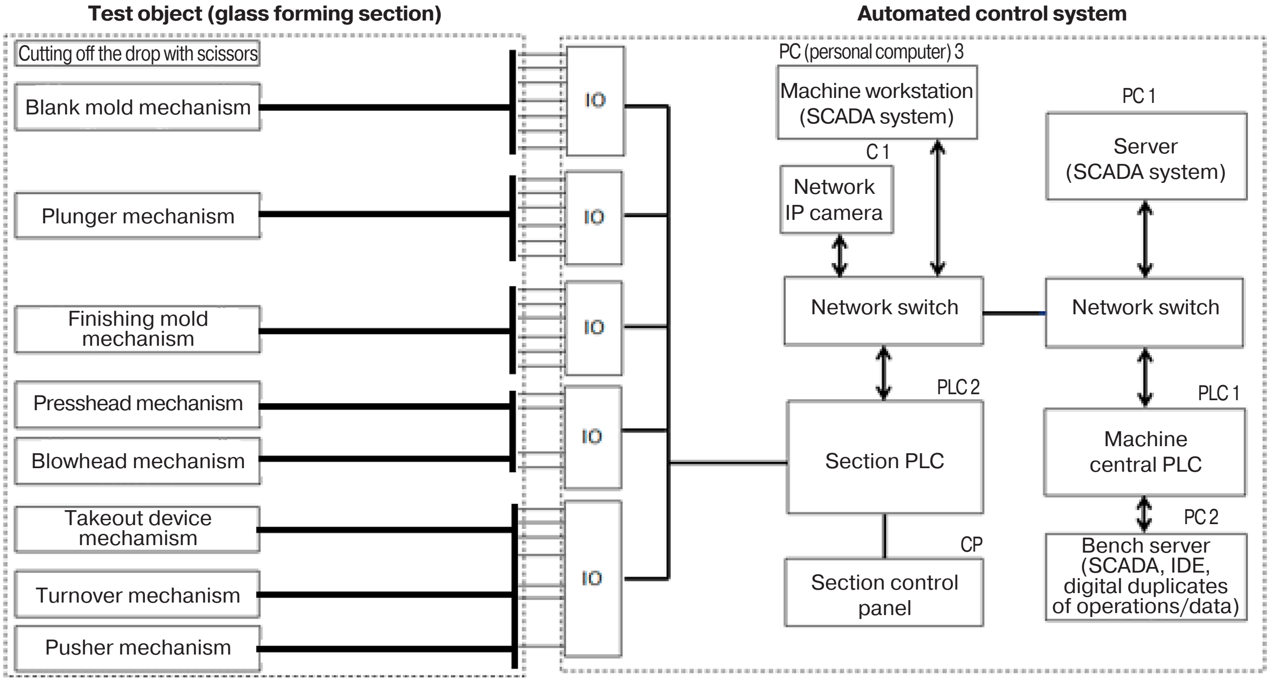

Fig. 6. Functional diagram for the development of the ACS bench. IO—input/output; IDE—integrated development environment

package consists in the hierarchy of access levels. The most common SCADAs on our market were products manufactured by Siemens[11], Aveva[12], GE Digital[13] and other companies. Currently, the functionality of Russian analogs implemented on the platform of Astra Linux[14] system is being improved, including support for object-oriented production models.

In the course of experimental (seminatural) tests of system algorithms carried out on the electromechanical bench, the fastest and cheapest stage of prototyping and testing of ACS algorithms of one section uses the elements of a digital twin to virtually simulate the work of other sections.

In the development of the systems created on the basis of the comparison object, the planned development of versions of the SHC adapted to different versions of the GFM will involve varying degrees of localization of the production of elements of the physical element of the machine. The solution of the tasks requires the combined efforts of interested parties. At the stage of SHC development, financing is provided by own funds. Since the current cost of such systems occupies a significant proportion of the cost of equipment, a substitute product has a significant commercial potential.

Importance is attributed to the possibility of providing practical training to students of Russian education institutes and the personnel of enterprises on the basis of the Engineering Center. To reduce familiarization time, the SCADA interface is designed to be visually similar to that used in the existing GFM.

CONCLUSIONS

Based on the results of research on import dependence overcoming and creating a technological sovereignty, the authors came to the following conclusions:

1. Development of the ACS GFM platform is related to import substitution in the field of mechanical engineering, which is on the priority list of Russian industrial policy.
2. Parallel imports are a temporary mitigation, but not a solution to the problem. Critical components, which include the production of electronic components and software, can and should be locked into the domestic market, recreating production chains within the country.
3. Since technology comprises not only equipment, but also carriers of knowledge, a key role is played by personnel training. Engineering centers thus become elements of innovative development, having the potential to provide additional education for students and industry specialists.
4. Technological sovereignty must be based on technologies and products that are similar or superior to the world's best examples and practices.
5. Developers of technology and equipment must cooperate and coordinate their efforts to maximize

[11] https://www.siemens.com/global/en.html. Accessed April 04, 2023.
[12] https://www.aveva.com/. Accessed April 04, 2023.
[13] https://www.ge.com/digital/. Accessed April 04, 2023.
[14] https://astralinux.ru/. Accessed April 04, 2023 (in Russ.).

the efficiency of both innovation and reverse-engineering. Since we are talking about the manufacture of the means of production rather than mass consumption products, it is inappropriate to develop the same elements (physical and digital) in parallel by different organizations. Combining production orders and their long-term planning will reduce the cost of productive machines, which will affect the economy of mass-market products.

6. Although the development and implementation of ACS of technological processes offer strong prospects for monetization, the initial stage of research in the absence of innovative investors is usually carried out at the expense of self-financing. The existing methods of state support are insufficiently coordinated with each other and characterized by a lack of production planning or the formation of centralized orders, which can affect the cost of the element and product.
7. It is necessary to raise the status of import substitution projects and, if possible, to centralize their implementation and financing, separating them into a separate national project, which establishes the achievements of individual industries and their scaling to the industry as a whole.

Authors' contributions

D.O. Skobelev, A.V. Ragutkin—the research concept, statement of the research problem, and final editing the text of the article.

D.Kh. Mikhailidi (75%), **A.B. Sukhaterin** (25%)—performing routine work on the systematization of the material, analysis of the research results and data preparation, and writing the text of the article.

REFERENCES

1. Sukharev O.S. Import substitution policy: Breaking the limits. *Upravlenets = Manager*. 2023;14(1):33–46 (in Russ.). https://doi.org/10.29141/2218-5003-2023-14-1-3
2. Nikitin G.S., Skobelev D.O. Efficiency of state and corporate investments in the development of the real sector of the economy. *Vestnik Nizhegorodskogo universiteta im. N.I. Lobachevskogo. Seriya: Sotsial'nye nauki = Vestnik of Lobachevsky State University of Nizhni Novgorod. Series: Social Sciences*. 2022;4(68):32–41 (in Russ.). Available from URL: http://www.unn.ru/pages/e-library/vestnik_soc/18115942_2022_-_4(68)_unicode/4.pdf
3. Ulin B. *Mezhregional'naya i mezhdunarodnaya torgovlya* (*Interregional and International Trade*): transl. from Engl. Moscow: Delo; 2004. 416 p. (in Russ.).
[Ohlin B. *Interregional and International Trade*. Cambridge (Massachusetts): Harvard University Press; 1967. 324 p.]
4. Porter M. *Mezhdunarodnaya konkurentsiya. Konkurentnye preimushchestva stran* (*International Competition. Competitive Advantages of Countries*). Moscow: Intellektual'naya Literatura; 2021. 948 p. (in Russ.).
5. Avdokushin E.F. *Mezhdunarodnye ekonomicheskie otnosheniya* (*International Economic Relations*). Moscow: Yurist; 1999. P. 311–315 (in Russ.). Available from URL: https://uchebnik.biz/book/111-mezhdunarodnye-yekonomicheskie-otnosheniya/ (accessed April 04, 2023).
6. Zheng X., Yu H., Yang L. Technology imports, independent innovation, and China's green economic efficiency: an analysis based on spatial and mediating effect. *Environ. Sci. Pollut. Res*. 2022;29(24):36170–36188. https://doi.org/10.1007/s11356-021-17499-y
7. Arezki R., Hadri K., Loungani P., Rao Y. Testing the Prebisch-Singer Hypothesis since 1650: Evidence from Panel Techniques that Allow for Multiple Breaks. *J. Int. Money & Finance*. 2014;42(180):208–223. https://doi.org/10.1016/j.jimonfin.2013.08.012

СПИСОК ЛИТЕРАТУРЫ

1. Сухарев О.С. Государственное управление импортозамещением: преодоление ограничений. *Управленец*. 2023;14(1):33–46. https://doi.org/10.29141/2218-5003-2023-14-1-3
2. Никитин Г.С., Скобелев Д.О. Эффективность государственных и корпоративных инвестиций в развитие реального сектора экономики. *Вестник Нижегородского университета им. Н.И. Лобачевского. Серия: Социальные науки*. 2022;4(68):32–41. URL: http://www.unn.ru/pages/e-library/vestnik_soc/18115942_2022_-_4(68)_unicode/4.pdf
3. Улин Б. *Межрегиональная и международная торговля*: пер. с англ. М.: Дело; 2004. 416 с.
4. Портер М. *Международная конкуренция. Конкурентные преимущества стран.* М.: Интеллектуальная Литература; 2021. 948 с.
5. Авдокушин Е.Ф. *Международные экономические отношения*. М.: Юристъ; 1999. С. 311–315. URL: https://uchebnik.biz/book/111-mezhdunarodnye-yekonomicheskie-otnosheniya/ (дата обращения 04.04.2023).
6. Zheng X., Yu H., Yang L. Technology imports, independent innovation, and China's green economic efficiency: an analysis based on spatial and mediating effect. *Environ. Sci. Pollut. Res*. 2022;29(24):36170–36188. https://doi.org/10.1007/s11356-021-17499-y
7. Arezki R., Hadri K., Loungani P., Rao Y. Testing the Prebisch-Singer Hypothesis since 1650: Evidence from Panel Techniques that Allow for Multiple Breaks. *J. Int. Money & Finance*. 2014;42(180):208–223. https://doi.org/10.1016/j.jimonfin.2013.08.012
8. Нуреев Р.М. *Экономика развития: модели становления и модернизации рыночной экономики*. М.: Норма; 2008. 367 с.
9. Sachs J., Williamson J. External Debt and Macroeconomic Performance in Latin America and East Asia. *Brookings Papers on Economic Activity*. 1985;1985(2):523–573. https://doi.org/10.2307/2534445

8. Nureev R.M. *Ekonomika razvitiya: modeli stanovleniya i modernizatsii rynochnoi ekonomiki* (*Economics of Development: Models of Formation and Modernization of a Market Economy*). Moscow: Norma; 2008. 367 p. (in Russ.).
9. Sachs J., Williamson J. External Debt and Macroeconomic Performance in Latin America and East Asia. *Brookings Papers on Economic Activity*. 1985;1985(2):523–573. https://doi.org/10.2307/2534445
10. Ukhanova R.M., Raiskaya M.V. Innovative Import Substitution as the Main Direction of Technological Modernization in Oil and Gas Enterprises of the Republic of Tatarstan. *Vestnik ekonomiki, prava i sotsiologii = The Review of Economics, the Law and Sociology*. 2015;4:134–136 (in Russ.). Available from URL: http://www.vestnykeps.ru/0415/28.pdf
11. Faltsman V. Import Substitution in Energy and Military-Industrial Complexes. *Voprosy Ekonomiki*. 2015;1:116–124 (in Russ.). https://doi.org/10.32609/0042-8736-2015-1-116-124
12. Panshin I.V., Yares O.B. Resursozameschenie and import substitution in solving problems of economic stability and steam-lation region&acute’s economic growth. *Sovremennye problemy nauki i obrazovaniya = Modern Problems of Science and Education*. 2014;6:511 (in Russ.). Available from URL: https://science-education.ru/en/article/view?id=16092
13. Volosatova A.A., Uchenov A.A., Skobelev D.O. Forming the concept of implementing green economy principles in the Eurasian Economic Union: the role of harmonizing resource efficiency approaches. *Vestnik Evraziiskoi nauki = The Eurasian Scientific J*. 2022;14(4):14 (in Russ.). Available from URL: https://esj.today/PDF/23ECVN422.pdf (accessed April 10, 2023).
14. Sukharev O.S. *Ekonomicheskaya teoriya evolyutsii institutov i tekhnologii* (*Economic Theory of the Evolution of Institutions and Technologies*). Moscow: Lenand; 2019. 312 p. (in Russ.).
15. Krasnyuk L.V. Essence and the structural elements of the innovative development of economy. *π-Economy*. 2010;5(107):133–138 (in Russ.). Available from URL: https://cyberleninka.ru/article/n/suschnost-i-strukturnye-elementy-innovatsionnogo-razvitiya-ekonomiki (accessed April 10, 2023).

10. Уханова Р.М., Райская М.В. Инновационное импортозамещение как основное направление технологической модернизации на предприятиях нефтегазового комплекса Республики Татарстан. *Вестник экономики, права и социологии*. 2015;4:134–136. URL: http://www.vestnykeps.ru/0415/28.pdf
11. Фальцман В. Импортозамещение в ТЭК и ОПК. *Вопросы экономики*. 2015;1:116–124. https://doi.org/10.32609/0042-8736-2015-1-116-124
12. Паньшин И.В., Яресь О.Б. Ресурсозамещение и импортозамещение при решении задач обеспечения экономической стабильности и стимулирования экономического роста региона. *Современные проблемы науки и образования*. 2014;6:511. URL: https://science-education.ru/en/article/view?id=16092
13. Волосатова А.А., Ученов А.А., Скобелев Д.О. Формирование концепции внедрения принципов зеленой экономики в евразийском экономическом союзе: роль гармонизации подходов к повышению ресурсной эффективности. *Вестник Евразийской науки*. 2022;14(4):14. URL: https://esj.today/PDF/23ECVN422.pdf (дата обращения 10.04.2023).
14. Сухарев О.С. *Экономическая теория эволюции институтов и технологий*. М.: Ленанд; 2019. 312 с.
15. Краснюк Л.В. Сущность и структурные элементы инновационного развития экономики. *π-Economy*. 2010;5(107):133–138. URL: https://cyberleninka.ru/article/n/suschnost-i-strukturnye-elementy-innovatsionnogo-razvitiya-ekonomiki (дата обращения 10.04.2023).

About the authors

Dmitry Kh. Mikhailidi, Cand. Sci. (Econ.), Researcher, Department of Resource Saving Methodology, Environmental Industrial Policy Center (38, Stremyannyi per., Moscow, 115054 Russia). E-mail: d.Mikhailidi@eipc.center. RSCI SPIN-code 6831-8043, https://orcid.org/0009-0005-6491-0710

Alexander V. Ragutkin, Cand. Sci. (Eng.), Vice-Rector for Innovative Development, MIREA – Russian Technological University (78, Vernadskogo pr., Moscow, 119454 Russia). E-mail: ragutkin@mirea.ru. Scopus Author ID 56871217700, ResearcherID AAE-4437-2022, RSCI SPIN-code 7531-7376, https://orcid.org/0000-0001-8256-1941

Dmitry O. Skobelev, Dr. Sci. (Econ.), Director, Environmental Industrial Policy Center (38, Stremyannyi per., Moscow, 115054 Russia); Head of the Department of Best Available Technologies and Regulatory Practices, Institute of Management Technologies, MIREA – Russian Technological University (78, Vernadskogo pr., Moscow, 119454 Russia). E-mail: skobelev@mirea.ru. Scopus Author ID 57205144505, RSCI SPIN-code 7830-9773, https://orcid.org/0000-0002-8067-7016

Alexey B. Sukhaterin, Lecturer, Department of Industrial Informatics, Institute of Artificial Intelligence, MIREA – Russian Technological University (78, Vernadskogo pr., Moscow, 119454 Russia). E-mail: suhaterin@mirea.ru. https://orcid.org/0009-0004-8997-4342

Об авторах

Михайлиди Дмитрий Христофорович, к.э.н., научный сотрудник, отдел методологии ресурсосбережения, ФГАУ «Научно-исследовательский институт «Центр экологической и промышленной политики» (115054, Россия, Москва, Стремянный переулок, д. 38). E-mail: d.Mikhailidi@eipc.center. SPIN-код РИНЦ 6831-8043, https://orcid.org/0009-0005-6491-0710

Рагуткин Александр Викторович, к.т.н., проректор по вопросам инновационного развития, ФГБОУ ВО «МИРЭА – Российский технологический университет» (119454, Россия, Москва, пр-т Вернадского, д. 78). E-mail: ragutkin@mirea.ru. Scopus Author ID 56871217700, ResearcherID AAE-4437-2022, SPIN-код РИНЦ 7531-7376, https://orcid.org/0000-0001-8256-1941

Скобелев Дмитрий Олегович, д.э.н., директор, ФГАУ «Научно-исследовательский институт «Центр экологической и промышленной политики» (115054, Россия, Москва, Стремянный переулок, д. 38); заведующий кафедрой наилучших доступных технологий и регуляторных практик Института технологий управления ФГБОУ ВО «МИРЭА – Российский технологический университет» (119454, Россия, Москва, пр-т Вернадского, д. 78). E-mail: skobelev@mirea.ru. Scopus Author ID 57205144505, SPIN-код РИНЦ 7830-9773, https://orcid.org/0000-0002-8067-7016

Сухатерин Алексей Борисович, преподаватель, кафедра промышленной информатики Института искусственного интеллекта, ФГБОУ ВО «МИРЭА – Российский технологический университет» (119454, Россия, Москва, пр-т Вернадского, д. 78). E-mail: suhaterin@mirea.ru. https://orcid.org/0009-0004-8997-4342

Translated from Russian into English by Lyudmila O. Bychkova
Edited for English language and spelling by Thomas A. Beavitt