https://doi.org/10.15407/scine18.01.076

ALPATOV, A. P. (https://orcid.org/0000-0003-4411-2250),
MARCHENKO, V. T. (https://orcid.org/0000-0003-1025-2001),
KHOROLSKYI, P. P. (https://orcid.org/0000-0003-0125-200X),
and SAZINA, N. P. (https://orcid.org/0000-0002-4868-315X)
Institute of Engineering Mechanics, the NAS of Ukraine
and the State Space Agency of Ukraine,
15, Leshko-Popel St., Dnipro, 49005, Ukraine,
+380 56 372 0640, office.itm@nas.gov.ua

THE STATUS AND DIRECTIONS FOR IMPROVING THE REGULATORY AND PROCEDURAL FRAMEWORK FOR THE ROCKET AND SPACE TECHNOLOGY DEVELOPMENT IN UKRAINE

Introduction. *Based on the prospects for industrial manufacture activities in space, space industry is an important strategic resource for each country; therefore, the governments of advanced economies have been creating the necessary conditions for the dynamic development of their rocket and space industries.*

The creation and manufacture of sophisticated high-tech equipment is impossible unless there is a well-developed regulatory framework, so the task of its development is urgent.

Problem Statement. *The necessity of developing and improving a special regulatory and procedural framework for the rocket and space equipment (RSE) development is conditioned by specific features of RSE such as uniqueness, research and engineering complexity, operation of engineering systems in the outer space, unrepairability and long life cycle of such systems.*

Purpose. *The purpose of this research is to assess the status and to determine the principal directions of the priority improvement of the regulatory and procedural framework of RSE in Ukraine.*

Materials and Methods. *The research has been based on the materials on the current status and main directions of the development of the regulatory and procedural framework in the USA, France, Germany, Italy, and Russia.*

The current status of the regulatory and procedural framework for the space industry of Ukraine has been assessed by the method of analogies as a tool of the systems analysis.

Results. *The status of the regulatory and procedural framework for rocket and space technology in Ukraine has been assessed.*

Despite the shortcomings, the RSE regulatory framework in Ukraine may be considered adequate, unlike the procedural one that is unsatisfactory.

The development and certification of many methods, the most important for improving the quality of project management for the creation of RSE samples, have been proposed as a priority step to improve the procedural framework.

Citation: Alpatov, A. P., Marchenko, V. T., Khorolskyi, P. P., and Sazina, N. P. (2022). The Status and Directions for Improving the Regulatory and Procedural Framework for the Rocket and Space Technology Development in Ukraine. *Sci. innov.*, 18(1), 76—88. https://doi.org/10.15407/scine18.01.076

Conclusions. *In the upcoming years, it is necessary to develop priority computerized industry techniques that allow the decision makers of Ukraine's space industry to quickly and reasonably decide on the development of highly effective projects to create new models of RSE.*

Keywords: regulatory and procedural framework, regulatory documents, rocket and space technology, rocket and space industry, industry standards, and industry techniques.

THE CURRENT STATUSE OF THE REGULATORY AND PROCEDURAL FRAMEWORK FOR THE DEVELOPMENT OF ROCKET AND SPACE TECHNOLOGY IN THE LEADING COUNTRIES

The International Organization for Economic Cooperation and Development, which includes advanced economies, the aerospace industry is recognized as an important high-tech sector [1]. A significant part of the aerospace industry is the rocket and space component, which provides the creation of samples of rocket and space equipment (RSE).

As of today, the leaders in the field of creation and use of rocket and space technology are the following countries: the United States, the Russian Federation, France, China, India, Germany, Italy, and Japan. Until 1995, Ukraine was sharing 3rd/ 4th place with France, but today it has been outside the top ten.

The space agencies of France (*Centre national d'études spatiales (*CNES), *English* the National Center for Space Studies,), Germany (*Deutsches Zentrum für Luft- und Raumfahrt* (DLR), English the German Aerospace Center), and Italy (*Agenzia Spaziale Italiana* (ASI), English the Italian Space Agency) are developing their rocket and space technology standards based on the European Space Agency (ECSS system) standards that are complemented with country-specific characteristics. The main components of this system (in terms of creation and operation of RSE) are a system of standards in the areas [2]:

- space project management (ECSS-M-00): basic standards M 10, M 40, M 60, M 70, M 80;
- quality assurance of space products (ECSS-Q-00): basic standards Q 10, Q 20, Q 30, Q 40, Q 60, Q 70, Q 80;
- development (design) of RSE (ECSS-E-00): basic standards E 10, E 20, E 30, E 40, E 50, E 60, E 70;
- sustainable development in space (ECSS-U-00): basic standards U-10, U-20.

The MIL-STD standards of National Aeronautics and Space Administration (NASA) are analogous to the ECSS ones. This system of space standards is complemented with international standards of the ISO and IEC series.

It should be noted that the system of regulations, which currently exists in Ukraine, cannot be considered worse than that of the leading countries in the RSE field. Therefore, it does not make sense to consider in more detail the structure and content of regulations used in the RSE leaders. However, it is necessary to consider in more detail the procedural framework of the leading countries, because Ukraine lags far behind in this area. This is especially noticeable in relation to the methods for estimating the expected cost of research and development (R&D) works for the creation of new RSE models and quantifying their technical efficiency (technical level).

The modern industry database of the space agencies of France, Germany, Italy (ESA members) and the United States (NASA) has been a system of certified computerized methods for 25 years, which consists of software and user instructions to perform the necessary estimates. The current set of sectoral methods may be divided into the two groups: the procedures for engineering (technical) purpose (EP) and the procedures for technical and economic purpose (TEP).

The EP group procedures includes software packages that allow designing the structure, performing digital layout and digital testing of the structure, calculating the aerodynamic, ballistic, thermodynamic and strength parameters. They are

CATIA, PATRAN, NASTRAN, SimDesigner, DCAP, Adams, MECANO, SimPack, ThermXL, ANSYS, PowerCAP, etc.

The group of MTEP procedures includes software packages that allow estimating the expected cost of creating and operating a new model of RSE, for instance, PRICE-H, TRANSCOST, USCM, SSCM, UnSVC, FAST, SATCAV, NAFCOM, TRASIM, CEDRE, RACE Model, TIW-Q, D, ACES, and others. As of today, neither the State Space Agency nor corporations of Ukraine's rocket and space industry have possessed such software tools.

The main procedures of the TEP group perform the following functions [3—8]:

- PRICE-H (Parametric Review of Information for Costing and Evaluation) is a universal model for estimating the cost of carriers, spacecraft, equipment, devices, etc. based on a detailed cost estimate of the components (the bottom up approach);
- TRANSCOST (Transportation Cost) is a model for estimating the cost of disposable and reusable space transport systems;
- USCM (Unmanned Space Vehicle Cost Model) is a model of the cost of an unmanned spacecraft;
- SSCM (Small Satellite Cost Model) is a model for estimating the cost of development and manufacture of small (up to 1000 kg) spacecraft; its latest version SSCM19 is released in December 2019;
- UnSVC (Unmanned Space Vehicle Cost Model) is a model of the cost of developing unmanned spacecraft;
- SATCAV (Satellite LCC and Availability Model) is a model for estimating the cost of spacecraft orbiting;
- NAFCOM (NASA/Air Force Cost Model) is NASA's cost model (latest version of NAFCOM11);
- TRASIM (Transportation Simulation) is a model for estimating the cost of launch vehicle design works.

Almost all of these methods use a multidimensional parametric cost model as the dependence of cost on the main technical parameters of new RSE model. The numerical values of the parameters of this model are determined by statistical technical and economic data of previous similar samples. The analog method is used very rarely in cases where the new model is an upgrade of the existing model or in the case of an ongoing valuation.

It should be noted that the space agencies of European countries (ESA) and NASA have teams to calculate, on a regular basis, the expected cost of creating new RSE samples, which verify the correctness of the contractors cost estimates, their compliance with research and engineering (technical) level of RSE sample and keep databases of engineering (technical) and economic indicators of previous samples.

Using these computerized methods (software packages), ESA and NASA have developed the Concurrent Design Facility (CDF) that significantly reduces the design time of new RSE models and improves the quality of design documentation. This concurrent design facility makes it possible to move from document-oriented to model-oriented design. Today, CDF complexes have been available in almost all foreign space agencies of the leading countries, as well as in the world's leading aerospace corporations. Elon Musk's *SpaceX* technology effectively uses CDF as well.

In the Russian Federation, in mid-2019, the fund of RSE standards had counted 4502 applicable documents [9]. The fund of RSE regulations and standards in the space agency of the Russian Federation (*Roscosmos* Corporation) is structured as follows [5, 10]:

- *Regulations for the procedure of the creation, manufacture, and operation (use) of rocket and space complexes* (RK-11 Regulations) put into effect by the Roscosmos Order № 232 DSK dated 22.12.11, as a key document;
- GOST RV 15.002-2003 *System for developing and launching into manufacture. Military equipment. Quality assurance system. General requirements*, as a key document;
- the standards for the design and creation of RSE (about 900 documents);

- the standards for experimental method, testing, quality assurance, and reliability (about 500 documents), the key document of this block of standards is the industry standard OST 134 1028: *Rocket and space technology. Requirements for quality assurance systems of corporations involved in the creation, manufacture, and operation of the products*;
- the standards for the structure, parameters, types, brands of materials (about 2500 standards);
- the standards for standard processes, process equipment, and issues related to RSE manufacture (about 450 standards).

As of 2019, *Roscosmos* Corporation developed 205 government standards and about 4,250 industry standards (OST and RD). In 2018, 560 standards were revised/updated (12.4% of the total fund). The current level of revision of the fund of RSE standards has reached 60%, and that of their harmonization with international ones (ISO and IEC) has been about 80% [11].

In 2017, *Roscosmos* Corporation developed the *Concept for the development of a system of documents for standardization of RSE to ensure the creation, manufacture and operation of RSE for the period up to 2025* given the recent changes in the Russian Federation regulations in the field of standardization, including that for defense products. In order to achieve the target indicators of revision of the RSE standards fund, a set of measures has been planned, based on the annual target for the fund revision of at least 10%.

The Russian Federation has been purposefully creating the procedural framework for the rocket and space industry. In accordance with the instructions of the Government of the Russian Federation No. RD-P7-3706 dated 09.06.2017, *Roscosmos* Corporation has been making efforts to improve mathematical and simulation systems with the use of digital design methods, including the introduction of hardware and software platform for mathematical modeling, engineering analysis, and information technology. So, in fact, the national concurrent design facility for new RSE models has been in place.

At the end of 2017, in the organizations of the rocket and space industry of the Russian Federation, the digital technologies had been implemented for more than 90% in the development of design documentation and for 80% in mathematical modeling and engineering analysis [11].

ASSESSING THE STATUS OF THE REGULATORY AND PROCEDURAL FRAMEWORK OF THE ROCKET AND SPACE INDUSTRY OF UKRAINE

The status of the regulatory and procedural framework of the rocket and space industry of Ukraine at the early stage of its creation

The rocket and space industry of Ukraine was formed in the first half of 1992 on the basis of the USSR military industry corporations located on the territory of Ukraine. The status of the regulatory and procedural framework of these corporations corresponded to that of the Soviet Union at the end of 1991.

The core of the regulatory framework of the rocket and space industry of the former Soviet Union was special government standards GOST B that regulated the creation and operation of military equipment, and government standards of general use, such as: Unified system of design documentation, USDD (GOST 2 series), Unified system of process documentation, USPD (GOST 3 series), standards for construction materials and the Unified system of software documentation, USSD, (GOST 19 series). This system of national standards was supplemented by many (over 2,000) industry standards. At that time, such a system of regulatory documents was the most perfect in the world, as in 1970s–1980s, with the use of this regulatory framework, *Pivdenne* Design Office created:

- many strategic intercontinental ballistic missile systems (ICBMs);
- *Cyclone-2* and *Cyclone-3* space rocket systems that were the most reliable launch vehicles in the world. For the 40 years of operation (1969—

2009), 5 out of the 117 launches for *Cyclone-3* failed, and all 106 launches for *Cyclone-2* were successful [12, 13];

- more than ten types of spacecraft, among which *Tsilina-2* electronic reconnaissance spacecraft is the most notable for its design at the world level.

Such achievements show the important role played by the regulatory framework for the development of reliable and highly efficient RSE models. The main feature of the regulatory framework for the rocket and space industry was that it was a system of clearly structured and consistent specific requirements to ensure high quality fulfillment of the state defense order. The GOST B series standards and industry standards were the most high-quality and consistent. Due to this, the maximum possible quality of the design and process documentation was achieved, but however, the complexity of works on the preparation of this documentation increased significantly. From the economic point of view, increasing the complexity of works on the issue of such documentation allowed significant cost savings at the stage of experimental development of prototypes of the new RSE, because the share of labor costs in the total cost structure at that time was relatively low. On the contrary, the regulations for the development of design documentation for RSE samples in Western countries (USA, France, Germany, etc.) was a summary of the general requirements. There was a desire to minimize the cost of development of design documentation, and the required quality of the product was achieved at the stage of experimental development, because it was economically viable given a relatively high labor cost.

In the Soviet Union, the industrial procedural base for RSE consisted of the following components:

- research and procedural practice of CNDIMash Institute;
- engineering methods used at RSE design offices (method statements were practically inaccessible for employees of other corporations of the industry);
- procedural materials in the form of enterprise standards (or instructions) for calculating the cost of works on the creation of new RSE samples. It should be noted that the data that are necessary to estimate the complexity of the works were determined by industry research institute for solving economic problems of the rocket and space industry (*Agate*).

There was no single method for all corporations in the industry to estimate the cost of works on the creation of new RSE models, so there was a significant influence of subjective factors on the cost of design works and their components. However, in conditions when almost all projects related to the creation of new RSE models were determined by resolution of the Central Committee of the Communist Party of the Soviet Union and the Council of Ministers of the USSR, and any misuse of budget funds was virtually impossible, the public procurement authority did not pay much attention towards the factor of subjectivity in estimating the cost of design works.

There were no sectoral method statements of general use (even in the form of paper documents).

Assessing the current status of the regulatory framework of the rocket and space industry of Ukraine

The regulatory framework for the creation of rocket and space technology in Ukraine is based on the standards of GOST B series and domestic industry regulations that were developed by order of the Space Agency of Ukraine. At the end of 2019, the fund of sectoral regulations for the RSE development included the following main documents:

- the regulations for space activities in Ukraine (URKT series) as basic documents. Eleven applicable URKT regulations have been developed. They contain requirements for the development, manufacture, and operation of rocket and space technology; the organization, execution and provision of space launches and flights; the supervision and control over the safety of space launches and flights and the operation of space technology; the transportation, protection, and preservation of rocket and space equipment; the official investigation into incidents and emergency situations with launch vehicles and spacecraft; search and rescue operations in the space industry; the creation and use of research instruments for space exploration, utilization of space equipment; operation of spacecraft; scientific and technical evaluation of R&D projects; the limitation of contamination of the surrounding space during the operation of space equipment;

- the industry standards of organizations of Ukraine (series SOU NSAU, SOU SSA). Twenty-four applicable documents have been developed. They contain requirements for the structure, composition, presentment and requirements for the content of regulatory documents; the procedure for providing documentation marked as "O", "O1", "A"; the procedure for experimental testing; the procedure for finalization of product prototypes; the certification of terrestrial receiving stations for remote sensing of the Earth, etc. [14]. For the four SOU NSAU standards developed at the Institute of Engineering Mechanics of the NAS of Ukraine and NSAU, the first editions with terms and definitions of the basic concepts of space technology with the general technical requirements for launch vehicles, the general provisions on space parameters, and the requirements for issuing an opinion on the readiness for flight tests have been prepared, but their further elaboration has not been funded;
- the industry guidelines of the series SOU-N NSAU, SOU-N SSA. Thirty applicable documents have been developed. They contain requirements for the development of a comprehensive program of experimental testing and reliability assurance program; metrological support of development; manufacture and product testing; certification of electronic equipment for launch vehicles and spacecraft, etc. [14]. Twenty-nine regulations of SOU NSAU, SOU SSA, SOU-N NSAU, and SOU-N SSA are currently being developed;

The regulatory framework for the development of rocket and space technology in Ukraine also includes national standards of the DSTU series. According to [14, 15, 16, 17], there are 273 applicable standards with requirements for quality assurance systems, organization of works in the space and defense spheres, test procedures, information technology, etc.

Assessing the current status of the procedural framework of the rocket and space industry of Ukraine

The modern procedural framework of the rocket and space industry (by the example of European space agencies of France, Germany, Italy, and other ESA member countries) is a set of certified industry methods to ensure engineering, technical, and economic estimates for the design and testing of new RSE models with guaranteed level of correctness of the results. Computational algorithms of these methods are implemented in the form of certified computer programs with appropriate in-line documentation. The first version of the modern procedural framework of the rocket and space industry was developed in 1998 by the European Space Agency and NASA. The key components of this database (in terms of ensuring effective management of RSE projects) were methods for calculating the expected technical and economic parameters of new RSE models that were created and estimating their reliability during operation. Later, this procedural framework was constantly improved as science, technology, and information technology advanced.

The space agency of Ukraine has made almost no efforts towards creating modern procedural framework for RSE. In the period from 1992 to 2019, there were elaborated only three procedural documents of secondary importance (2006—2007) [18, 19, 20] and a method statement for assessing and forecasting technical and economic indicators of missile systems at the initial stage of their design (1993) [21]. The next step was supposed to be the creation of appropriate industry methods, but no efforts to this end have been done so far.

Even the failures to implement the two strategically important for Ukraine national projects *Cyclone-4* (2011) and *Lybid* (2012) did not become an effective push for the decision makers of the rocket and space industry, at least, to start developing industry methods for estimating the expected cost of projects to create new RSE models and the resources for their implementation and ensuring of the reliability of operation in real conditions.

As it is known from the theory of systems analysis, no project may be technically implemented unless there are necessary financial, material, manufacturing and technological, human and time resources, as well as reserves to compensate for possible risks. To this end, it is necessary to quantify the amount of resources needed and to compare them with those that are likely available during the project. To quantify the amount of resources needed for creating a space system, it is necessary to have specific numerical values of the main technical parameters of this system. Comparative analysis of necessary and available resources for such components as material, production, technological, and human resources shall be carried out only for critical components of project implementation. If there is sufficient funding, providing the space system design project with non-critical resources is not problematic.

The critical material resources include, first of all, the components that may not be purchased by making commercial agreements between buyer and seller, because permission from the government of the country of component manufacture is required for sale, which is not always possible.

The critical production and technological resources include unique specialized manufacturing and testing equipment and unique technologies that are necessary for the manufacture and experimental development of RSE and its components, but are not available at the design office involved in the design works.

The critical labor resources include highly qualified professionals who have sufficient practical experience in creating a spacecraft space system and its components, but are not available at the design office involved in the design works.

Consideration of the terms of implementation of RSE projects, financial indicators, technological support, reliability and estimate of service life requires appropriate scientific and procedural support that shall be systematic and well-thought. In *Lybid* project there is also the government component. Space communication is a dual-use technology. This project has to be implemented at Ukrainian corporations. Instead, the works were done in Canada and Russia. The results of this approach are illustrated in Table 1 [22]:

According to Table 1, the average cost of one equivalent launch duct (bandwidth 36 MHz) ranges from 4.8 to 6.5 USD million, while for the *Ly-*

Table 1. **Costs and Satellite Specifications**

Satellite	Launch date	Cost, USD million	Frequency, MHz	Number of launch ducts	Cost of equivalent launch duct, USD million
AzerSpace 1	07.02.13	233	1296	36	6.5
BRisat 1	18.06.16	230	1620	45	5.1
Chinasat 9	09.06.08	135	864	24	5.6
Hispasat 1E	29.12.10	270	1995	56	4.8
Intelsat 28	22.04.11	250	1872	52	4.8
Star One C1	14.11.07	240	1617	45	5.4
Venesat 1	29.10.08	241	1392	39	6.2
Lybid	**2014–2015**	**310**	**1026**	**29**	**10.7**

bid spacecraft, the cost amounted to 10.7 USD million. For example, the cost of creating a satellite communication system for Azerbaijan (*Azer-Space* 1) with higher technical specifications (36 equivalent launch ducts) and a higher engineering level (more reliable *Star 2* platform) totaled USD 233 million (satellite, launch vehicle, launch, insurance, control center, training, etc.).

The actual engineering level of the *Lybid* system is lower than the world one as the payload is only 29 equivalent launch ducts. As well, this concerns the engineering level of EX1000N platform of *Reshetniov Information Satellite Systems* Open Joint-Stock Company. One of the reasons for assessing this project, other than political, is the lack of sectoral methodology for quantifying the engineering level of communications satellites, which may lead to errors in making important and complex decisions on procurement by Ukraine's government.

DIRECTIONS OF IMPROVING THE REGULATORY AND PROCEDURAL FRAMEWORK FOR THE CREATION OF ROCKET AND SPACE EQUIPMENT IN UKRAINE

The general part

Creating a high-quality national regulatory framework for RSE is a very difficult task, to solve which requires the involvement of highly qualified professionals, timely and regular funding for the implementation of works in the required amount. The new Law of Ukraine on Standardization [23] has complicated the process of creating the national regulatory framework for the RSE insofar as this act completely ignores the specific features of the rocket and space industry, namely:

- Earth observation systems from space and satellite communications as we'll as space rocket systems are unique high-tech sophisticated systems that involve a large number of corporations (more than 100 contractors may collaborate). In the authors' opinion, the cost of creating such systems, in the mid-2020 prices, may range from UAH 1.5 billion to UAH 20 billion;
- spacecraft belong to the class of complex technical systems that cannot be repaired and shall operate reliably in space (solar radiation, low temperature, ionized atomic nuclei and various subatomic particles, etc.) for 5—15 years;
- to manage financial and time resources and to ensure effective quality control of design and process documentation, quality of manufacture and testing of new RSE model requires a significant number of special regulations used exclusively for the creation of RSE samples;
- RSE models are usually dual-use systems (also used as a means of solving national security and defense problems) developed in accordance with the requirements of GOST B and DSTU B standards, so they shall not be subject to WTO rules and agreements.

Proceeding from the RSE specific features and the experience of the leading countries it follows that:

- the State Space Agency of Ukraine should have a national industry regulatory framework for RSE. This does not contradict the requirements of Clause 6 of the Law on Standardization (2014) as the samples of RSE are developed in accordance with the requirements of GOST B and DSTU B standards. The Law on Standardization does not apply to the standards of these series;
- the attribution of the existing sectoral regulations to the corporation regulations category, as the new law on Standardization requires, is impossible; their assignment to the national category does not make sense because of their specificity.

From the above considerations and the experience of the leading countries in the field of RSE it follows that Ukraine needs sectoral (industry) regulatory framework in the field of RSE. At the same time, the Law of Ukraine on the Amendments to Certain Legislative Acts of Ukraine in Connection with the Adoption of the Law of Ukraine on Standardization (hereinafter referred to as the Law on the Amendments) [24] does not allow the development of industry standards for RSE (paragraph 26).

In order to take into account the peculiarities of the rocket and space industry in the Law of Ukraine on the Amendment, the following options for amending the Law of Ukraine on Space Activities have been proposed:

The first option is to remove paragraph 26 from the Law of Ukraine on Amendments.

The reason for excluding paragraph 26 is the fact that the requirements of the Law on Standardization (2014) do not apply to the GOST B and DSTU B series standards (Clause 2).

This option allows maximum use of industry standards for the improvement and development of the national regulatory framework for RSE, which requires significantly less labor and time resources as compared with the national standards. At the same time, the industry standards will be used both for the creation and operation of new RSE samples and for the certification of these samples;

The second option is to leave in paragraph 26 of the Law of Ukraine on Amendments only the text concerning the revision of Clause 12 of the Law on Space Activities. The reason for the revision is the same as in the first version.

This option is the most rational in terms of standardization of the processes of creation and operation of new RSE models. At the same time, the certification of new samples is carried out exclusively in accordance with the requirements of national standards;

The third option is to make the following replacements in paragraph 26 of the Law of Ukraine on Amendments:

- Clause 1: the text "in the ninth paragraph, the wording "standards" shall be deleted" shall be replaced by the text "in the ninth paragraph, the wording "standards" shall be replaced by "guidelines";
- Clause 6: the wording of the seventh paragraph of the first part "(shall) provide space entities in Ukraine with the necessary rules and other regulations in the field of space activities" shall be replaced with the wording "(shall) provide space entities in Ukraine with the necessary rules, guidelines, and other regulations in the field of space activities";
- Clause 8: the text "in the second part, the wording "regulative" shall be replaced by the wording "legislative" "shall be replaced by the text "in the second part, the wording "regulative" shall be replaced by the wording "guidelines, regulations and legislative acts."

The inclusion of the wording "guidelines" in the text of paragraph 26 of the Law on Amendments does not contradict the Law on Standardization, because according to Clause 6 of this Law, the State Space Agency of Ukraine shall not be entitled to issue standards, codes of practice, and specifications.

This option fully meets the requirements of the new law on Standardization, but at the same time allows issuing the necessary industry standards for rocket and space technology in the forms of industry guidelines and rules.

In this case, a minor revision of the Law on Amendments (paragraph 26) is required, and the conditions for further development of the regulatory framework for the RSE of Ukraine significantly improve;

The fourth option does not foresee any revision of paragraph 26 of the Law on Amendments provided that the Ukrainian Research and Training Center for Standardization, Certification, and Quality (UkrNDNC) officially confirms the right of the State Space Agency of Ukraine to develop and issue sectoral regulations under the titles "rules" and "guidelines."

This option is the easiest to implement, but not entirely correct. The use of this option is possible only until the revision of paragraph 26 of the Law on Amendments.

The areas of priority improvement of the national regulatory framework for RSE

The major areas for improvement of the regulatory framework for RSE shall be as follows:

ISSN 2409-9066. Sci. innov. 2022. 18 (1)

- the update of some previous national regulations and their harmonization with international standards;
- the completion of the issue of previously developed but not yet implemented regulations;
- the development and issue of regulations of DSTU B series in order to replace the applicable GOST B series standards.

For ensuring the planned and coordinated improvement of the RSE regulatory framework, it is necessary to develop a guiding document in the form of the Concept of the standardization system, the regulatory documents of which shall be used in the creation of RSE samples.

The directions of priority improvement of the national procedural framework for RSE

The proposals for the priority improvement of the sectoral procedural framework for RSE are based on the relevant experience of the leading countries in the field of RSE and the identified shortcomings in Ukraine. Given the fact that during the existence of the domestic rocket and space industry almost no industry methods have been issued, the improvement shall start with the development of several most relevant industry methods, namely:

- estimate of the expected cost of R&D works for creating a spacecraft;
- estimate of the expected cost of R&D works for creating a space system terrestrial complex;
- estimate of the engineering (technical) level of a space system;
- calculation of spacecraft reliability indicators;
- calculation of reliability indicators of a space system terrestrial complex;
- assessment of feasibility of a space system creation project;
- estimate of the expected cost of R&D works for the creation of a launch vehicle;
- calculation of the expected cost of R&D for the creation of a ground-based launch vehicle complex;
- assessment of the competitiveness of a space system;
- assessment of the competitiveness of space rocket systems.

In addition to these methods, it is necessary to develop certified industry engineering methods, based on which, in the future, it is possible to build a domestic technology for concurrent design of new RSE.

The methods currently available to RSE developers are applicable to individual cases and nontransparent. This is especially true for the methods of estimating the expected cost and quality (technical level) of new RSE samples.

The use of methods in the form of paper documents is extremely inefficient, especially for users who are not authors of these methods, because these methods are quite difficult to use and require a high level of professional training of users, in addition, paper methods cannot be certified. The problem of complexity of general use and certification of methods is quite easy to solve if the paper version is presented as a package of computer programs (computerized method). This practice has been used in the leading countries in the field of RSE since the early 1990s.

Computerized industry methods are an effective tool with the help of which the level of quality of management of space program and projects of Ukraine may significantly improve.

Conclusions

Today, the regulatory framework for RSE in Ukraine is at the stage of formation. Despite the existing shortcomings, the status of the regulatory framework for RSE may be considered satisfactory, because these shortcomings do not create obstacles and barriers to the activities of design offices and manufacturing corporations in terms of the development, manufacture, and testing of new RSE models.

The major areas for improvement of the regulatory framework for RSE shall be as follows:

- the update of some previous national regulations and their harmonization with international standards;
- the completion of the issue of previously developed but not yet implemented regulations;

- the development and issue of regulations of DSTU B series in order to replace the applicable GOST B series standards.

The status of the procedural framework for RSE in Ukraine may be considered unsatisfactory. As of mid-2020, the State Space Agency of Ukraine lacks key methods (in terms of ensuring effective management of projects to create new RSE models) for estimating the expected cost of R&D projects, quantitatively assessing the quality (technical level) of new samples, calculating the indicators of reliability of spacecraft operation in space.

The first steps to improve the procedural framework of RSE in Ukraine are the development and certification of the following methods:

- estimate of the expected cost of R&D works for creating a communication spacecraft;
- estimate of the expected cost of R&D works for creating a space system terrestrial complex;
- estimate of the engineering (technical) level of a space system;
- calculation of spacecraft reliability indicators;
- calculation of reliability indicators of a space system terrestrial complex;
- assessment of feasibility of a space system creation project;

If such methods are available, developers of new RSE models may calculate the expected technical, economic, and reliability indicators based on formalized (computerized) methods, which are transparent and uniform for all RSE developers, and the State Space Agency of Ukraine will be able to quickly and effectively control the quality of these calculations and estimates, like the space agencies of the leading countries.

In order to ensure the planned and coordinated improvement of the RSE regulatory framework, it is necessary to develop a guiding document in the form of the Concept of the standardization system, the regulatory documents of which shall be used in the creation of RSE samples.

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Received 04.12.2020
Revised 11.01.2022
Accepted 12.01.2022

А.П. Алпатов (https://orcid.org/0000-0003-4411-2250),
В.Т. Марченко (https://orcid.org/0000-0003-1025-2001),
П.П. Хорольський (https://orcid.org/0000-0003-0125-200X),
Н.П. Сазіна (https://orcid.org/0000-0002-4868-315X)
Інститут технічної механіки Національної академії наук України
і Державного космічного агентства України,
вул. Лешко-Попеля, 15, Дніпро, 49005, Україна,
+380 56 372 0640, office.itm@nas.gov.ua

СТАН ТА НАПРЯМКИ УДОСКОНАЛЕННЯ НОРМАТИВНО-МЕТОДИЧНОЇ БАЗИ РОЗРОБКИ РАКЕТНО-КОСМІЧНОЇ ТЕХНІКИ В УКРАЇНІ

Вступ. Виходячи з перспектив промислового виробництва в космосі, космічна галузь є важливим стратегічним ресурсом для кожної країни, а отже, уряди високорозвинених держав створюють необхідні умови для динамічного розвитку власної ракетно-космічної галузі. Створення та виробництво складної високотехнологічної техніки неможливе без застосування розвиненої нормативно-методичної бази, тому задача її розвитку є актуальною.

Проблематика. Необхідність розвитку та вдосконалення спеціальної нормативно-методичної бази розробки ракетно-космічної техніки (РКТ) обумовлена такими їх особливостями як унікальність, наукова та технічна складність, функціонування технічних систем в умовах космічного простору, їхня неремонтопридатність, тривалий життєвий цикл.

Мета. Оцінка стану та визначення основних напрямків першочергового удосконалення нормативно-методичної бази РКТ в Україні.

Матеріали й методи. У дослідженні використано матеріали щодо сучасного стану та основних напрямків розвитку нормативно-методичної бази для створення зразків РКТ в таких країнах як США, Франція, Німеччина, Італія та Росія. Оцінку сучасного стану нормативно-методичної бази космічної галузі України проводили з використанням методу аналогій, як одного із методів системного аналізу.

Результати. Проведено оцінку стану нормативно-методичної бази ракетно-космічної техніки в Україні. Незважаючи на наявні недоліки, стан нормативної бази можна вважати задовільним. Натомість стан методичної бази РКТ в Україні вважається незадовільним. Як першочергові кроки з удосконалення методичної бази запропоновано розробку та сертифікацію низки методик, найбільш важливих для підвищення якості менеджменту проєктів зі створення зразків РКТ.

Висновки. Необхідно в найближчі роки розробити ряд першочергових галузевих комп'ютеризованих методик, що дозволить керівництву космічної галузі України оперативно та обґрунтовано приймати рішення щодо розробки високоефективних проєктів зі створення нових зразків РКТ.

Ключові слова: нормативно-методична база, нормативні документи, ракетно-космічна техніка, ракетно-космічна галузь, галузеві стандарти, галузеві методики.