Development of A Risk Assessment System for The Creation of Space Rocket Technology

Lyudmila Zubova, Anna Yakovaleva, Natalya Tregulova, Sergey Vasenev, Natalya Zibrova

Abstract*: During the production and purchase of electronic component base (ECB) in the course of experimental design work (EDW), various risks arise that arise due to internal and external process failures. As practice shows, systematic breakdowns of EDW began to occur due to failure of ECB supplies by domestic and foreign manufacturers. In the framework of this issue, the authors developed methodological approaches to increasing the likelihood of a successful completion of the production process based on the use of preventive management in the form of a risk-based approach. The essence of this approach includes the use of the PDCA Deming cycle ("Plan-Do-Check-Act"), which is a cyclically repeating decision-making process used in quality management. Regulatory and technical documentation for assessing risks in the production and procurement of ECB will allow you to determine the level of risk in achieving the required efficiency in meeting the specified terms for the development of RST products (component parts - CP of RST products). This study substantiates the need to use a risk-based approach in the production and procurement of ECB in the course of development work (hereinafter EDW) in the development of space rocket technology (RST). This study presents a methodology for assessing risks in the production and purchase of ECBs during the implementation of EDW, based on the consideration of possible risks based on the stages of the production life cycle and delivery of foreign-made ECBs. The question has been raised about the need to develop regulatory and technical documentation for assessing risks in the production and purchase of ECBs during the implementation of EDW.

***Keywords* : risks, life cycle, space rocket technology, electronic component base.**

I. INTRODUCTION

The production of rocket and space technology, taking into account the production and purchase of ECBs of domestic and foreign production, is complicated by the fact that they are coupled not only at the EDW stages of production processes, but also at the stages of concept, outline design, etc., including supply processes. Deliveries, in turn, are subject to disruption due to the political situation and the sanctions policy against the Russian Federation. There is an urgent need to assess the impact of various nature of the occurrence of risks on the progress of the EDW with the question of the need to develop regulatory and technical documentation to assess the risks in the production and purchase of ECB during the implementation of EDW.

Currently, all industrial enterprises rely on international standards for risk assessment and quality management systems [1-6], adapting to their specific activities, developing "their own risk management and internal control systems".

In 2018, ISO 50001 was issued in a new edition of ISO 22000: 2018 (Second Edition 2018-08) [7].

The transition period to the new version is 3 years. After June 18, 2021, the ISO 22000: 2005 version is canceled with the replacement of ISO 22000: 2018, as decided by the Technical Committee ISO / TC 34, which was developing the standard.

Now ISO 22000: 2018 is brought to a single high-level structure of the ISO series of standards for management systems. In the English abbreviation, this is HLS (Hight Level Structure). This means that all sections in the new version of the ISO 22000: 2018 standard with the correct section names are the same as in the new versions of the ISO 9001: 2015, ISO 14001: 2015 and ISO 45001: 2018 standards. The main advantage of the new edition of ISO 22000: 2018 is the elimination of risks associated with the goals of the organization.

The development and procurement processes of ECBs during the implementation of EDW are complicated by the fact that they include not only production processes, but also the stages of the concept, outline design, etc., including the supply processes. Deliveries, in turn, are subject to disruption due to the political situation and the sanctions policy against the Russian Federation.

II. MATERIALS AND METHODS

There is an urgent need to assess the level of influence of various nature of the occurrence of risks on the progress of EDW. In this regard, the question has arisen of the need to develop regulatory and technical documentation for assessing risks in the production and procurement of ECB during the implementation of EDW.

Regulatory and technical documentation for assessing risks in the production and procurement of ECB will allow you to determine the risk in achieving the required effectiveness in meeting the specified deadlines for the creation and validity of the technical and economic

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indicators of RST products (CP of RST products). "ECB delivery risk situations" must be archived with their causal causes. "Results of the consequences of risks" must be archived with qualitative, quantitative and financial criteria for their assessment.

Based on the fact that at present there are disruptions in the supply of ECBs, this study presents a methodological approach for assessing risks in the development of rocket and space technology, taking into account the supply of electronic components of foreign production. Accordingly, forecasting accounting must be carried out taking into account the life cycle of RST and ECB.

When manufacturing and purchasing ECB, we highlight the risks that arise at various stages of the life cycle of an RST product:

- risks at the stage of development, approval and approval of TOR for the development of an RST product (CP of an RST product);
- risks at the stage of preliminary design;
- risks at the stage of development of the ECB list planned for use in the CP of an RST product;
- risks at the stage of development of RKD;
- risks at the stage of manufacturing a prototype CP product RST;
- risks at the stage of mass production.

When developing and supplying the electronic component base of foreign production, we suggest using a methodological approach and an additive-multiplicative risk assessment model.

For example, members of the expert commission can assess the probability of the risk Rij from the list:

0 - an almost impossible event (with a probability of not more than 0.01);

1 - an extremely unlikely event (with a probability of from 0.01 to 0.05);

2 - an unlikely event (probability from 0.05 to 0.10);

3 - an event with a probability that cannot be neglected (from 0.10 to 0.20);

4 - a fairly probable event (probability from 0.20 to 0.30);

5 - an event with a fairly high probability (more than 0.30).

Another encoding can be used, for example, instead of 0, 1, 2, 3, 4, 5, the values 1, 10, 100, 1000, 10000, 100000 are applicable. Their purpose is the preliminary orientation of experts before starting the assessment using gradations of a linguistic variable. The methodology for assessing particular risks should be modified depending on the specific statement of the problem of risk assessment and management. With the help of experts, weights are determined for risks based on their level of influence on the project (Rij is the degree of threat) and probability of occurrence (Yiji).

Then risk assessment:

$$Q_1 = \frac{Rij}{500} \times Yij \quad (1)$$

Q_1 – risk level;

Rij – probability of occurrence of risk;

Yij – weighting factor determining the degree of threat to the course of EDW;

The assessment of non-fulfillment of Q_{pr} production and Q_{Pos} ECB delivery on time will be a set (total number) of risk levels at the stages of the life cycle of the evaluated process.

The success of U_{pr} production and U_{Pos} delivery will look accordingly:

$$U_{pr} = 1 - Q_{pr} \quad (2)$$

$$U_{Pos} = 1 - Q_{Pos} \quad (3)$$

At each stage, there are certain risks. We will evaluate the risks and calculate the probabilities P1, P2, ..., P8 of the successful implementation of the above steps using their conditional names. We assume that the risks at different stages are generated by independent random causes, since they arise at non-overlapping time intervals. Then the probability P of successful development is equal to the product of the probabilities of successful stages (the multiplicative component of the model): P = P1P2 ... P8. Consequently, the assessment Q of the total risk R, i.e. the probability of failure to complete the development in a given period is Q = 1 - P = 1 - P1P2 ... P8.

We will use the additive-multiplicative model with m = 8. At each stage we single out the particular risks Rij of the second order, a total of 44 types of risks multiplicative probability innovative risk.

III. RESULTS AND DISCUSSIONS

Risk assessments by stages and total risk will be given using the additive-multiplicative model described in Section 2 above, using linguistic assessments Xij of risks Rij with six gradations, which are assigned numerical values 0, 1, 2, 3, 4, 5. Correspondence between the values of linguistic variables and probability intervals is given in Section 2.

Another expert survey made it possible to obtain linguistic risk assessments Xij for two projects (Table 1).

Phased and total risk assessments in the development of rocket and space technology, taking into account the supply of electronic components of foreign production

Table – I:Risks by stages in the selection and application of ECB at the stages of the life cycle of an RST product and expert determination of weight coefficients

№	Expert assessment of the types of private risks by stages	Private risk identification	Quantitative expert risk assessment
1.	Stage of development, approval and approval of TOR for the development of the RST product (CP of the RST product)		
1.1	Risks of submitting incorrect ECB TK requirements for RST product development	R11	10

1.2.	Risk of personnel (the risk of job disruption due to organizational problems inside the research institute) at the stage of the examination and approval of the ToR for the development of the RST product (CP of the RST product) in terms of setting requirements for ECB	R12	10
1.3.	The risk of an incorrect technical solution (global, i.e. for the product as a whole)	R13	80
1.4.	External risk (failure to work due to reasons outside the research institute)	R11	10
2.	Preliminary design		
2.1.	Risk of personnel (the risk of job disruption due to organizational problems within the research institute) when CP EDW executors develop ECB lists planned for use in CP of RST product	R21	25
2.2.	The risk of an incorrect assessment of the correctness of the choice of ECB included in the restrictive list of ECB for use in the creation of onboard equipment for spacecraft.	R22	25
2.3.	The risk of time delays by CP EDW executives sending ECB listings planned for use in the CP of an RST product by the head EDW executor.	R23	25
3.	The development stage of the ECB list planned for use in the CP of an RST product is carried out		
3.1.	Risks of delay and incorrect decision when the EDW Lead Reviewer considers and approves the ECB lists planned for use in the CP of an RST product, develops and submits to the CP EDW executors an ECB list approved for use in the RST product	R31	5
3.2.	Risks at the stages of development by the CP EDW contractor and referral to the EDW lead contractor for approval:	R32	20
3.3.	- decisions on the application of ECB in the CP of the RST product, at the request of the EDW lead contractor (see section 12)	R33	10
3.4.	- an ECB list approved for use in the CP of an RST product;	R34	5
3.5.	- Feasibility study on ECB used in CP products RST	R35	60
3.6.	- WWF models acting on the ECB used in the CP of an RST product	R31	5
3.7.	Risks of incorrect decisions and time delays at the stage of substantiating a decision by the EDW Lead Contractor on the procedure for changing ECB in an RST product, forwarding it for examination and approval to the GNIO on ECB.	R32	20
4.	RDC development stage		
4.1.	Risks when checking the selection of ECB products .	R41	10
4.2.	Risks during verification and approval in accordance with the requirements of ESKD standards, in terms of the correct selection and entry of data on ECB products, the following types of RKD (see section 13): - electrical circuit diagram (E3); - list of elements (PE3); - specifications; - statements of purchased products (VP).	R42	35
4.3.	Risks during verification and approval in accordance with the requirements of ESKD standards, in terms of the correct selection and entry of data on ECB products, the following types of RKD: - electrical circuit diagram (E3); - list of elements (PE3); - specifications; - statements of purchased products (VP).	R43	25
4.4.	Risks in the development of CRC	R44	10
4.5.	Risks in developing a decision on the order of picking	R45	15
5.	Stage of manufacturing a prototype CP product RST		
5.1.	Risks of personnel (technical errors) when purchasing ECB	R51	5
5.2.	Resource Risks When Purchasing ECB	R52	10
5.3.	Political Risks of ECB Prohibition of Procurement	R53	35
5.4.	Risks of conformity assessment purchased by ECB:	R54	25

5.5.	Risks of assessing the correctness of ECB application for CRC according to the results of manufacturing and testing of CP of a ground-based RST product provided by PON, with the conclusion on the correct application of ECB.	R55	5
5.6.	Risks of assessing the correct application of ECB according to the RRC Based on the results of manufacturing and autonomous tests (including RI) of CP of RST products (instruments, units, functional units, etc.) intended for operation in outer space.	R51	5
5.7.	Risks of conducting an incorrect assessment of the correct application of ECB with the issuance of a private opinion on the readiness of the RST product (KA) for LI regarding the correct application of ECB According to the results of NEO, comprehensive and interagency tests of the RST product (complexes and systems of the RST product)	R52	10
6.	Mass production		
6.1.	Risks of personnel during the audit of the RCD; - the risks of not resolving the identified shortcomings of the ECB;	R61	10
6.2.	Risks of personnel in the implementation of scientific and technical support for projects to create RST GNIO on ECB in the case of involvement of GNIO for the examination of RST products under development in the work provided for in this standard.	R62	10
6.3.	Risks of time delays in the development of a decision on the order of acquisition; - purchase ECB products; - confirm the conformity of ECB products to the requirements of TU for a mass-produced RST product, the requirements of the documents in accordance with which it is used, the resistance to the factors specified in the WWF model, determine the possibility of using the ECB product in an RST product by conducting VK, DI, RI and reject tests if necessary. ECB conformity is confirmed by its certification in the system of mandatory certification of space technology with the issuance of a certificate.	R63	60

Next, we will carry out step-by-step and summary risk assessments during the development and delivery of the electronic component base of foreign production (Table 2).

Table – II: Phased and total risk assessments in the development of rocket andspace technology, taking into account the production and delivery of electronic component base

Risk assessments Xij	Risks Rij	Contribution AijXij				
		Provider №1			Provider №2	
1. Concept (i = 1)		Risk assessments Xij	Weights Aij			
1	R11	0,02	3	0,06	2	0,04
2	R21	0,02	1	0,02	1	0,02
3	R31	0,16	1	0,16	0	0
Q1 risk assessment of non-compliance at stage 1				0,24		0,06
The probability of the successful completion of stage P1			0,76		0,94	
2. Draft design (i = 2)						
4	R12	0,01	2	0,02	3	0,03
5	R22	0,04	0	0	1	0,04
6	R32	0,02	1	0,02	0	0
7	R42	0,01	0	0	0	0
8	R52	0,12	1	0,12	0	0
Q2 risk assessment for non-compliance with stage 2	0,16	0,07				
The probability of successful completion of step P2	0,84	0,93				
3. The stage of development of the list of ECB, planned for use in CP products RST, perform (i = 3)						
9	R13	0,01	3	0,03	1	0,01
10	R23	0,02	1	0,02	1	0,02
11	R33	0,07	1	0,07	0	0
12	R43	0,05	1	0,05	0	0
13	R53	0,02	0	0	2	0,04
14	R63	0,03	0	0	0	0
Assessment Q3 of the risk of non-compliance in time for stage 3	0,17	0,07				
The probability of successful completion of step P3	0,83	0,93				
4. The stage of development of RKD (i = 4)						
15	R14	0,01	4	0,04	1	0,01
16	R24	0,02	2	0,04	0	0
17	R34	0,07	1	0,07	0	0

18	R44	0,05	1	0,05		
19	R54	0,01	0	0	2	0,01
20	R64	0,03	2	0,06	1	0,03
21	R74	0,01	0	0	1	0,01
Q4 risk assessment for non-compliance with stage 4	0,26	0,06				
The probability of successful completion of step P4	0,74	0,94				
5. The stage of manufacture of the prototype CP product RST (i = 5)						
22	R15	0,02	1	0,02	1	0,02
23	R25	0,02	2	0,04	1	0,02
24	R35	0,12	2	0,24	0	0
25	R45	0,01	0	0	1	0,01
26	R55	0,03	1	0,03	0	0
Q5 risk assessment of non-compliance at stage 5	0,33	0,05				
The probability of successful completion of step P5	0,67	0,95				
6. Series production (i = 6)						
27	R16	0,01	0	0	1	0,01
28	R26	0,03	2	0,06	0	0
29	R36	0,10	1	0,10	0	0
30	R46	0,02	1	0,02	1	0,02
31	R56	0,04	1	0,04	0	0
Q6 risk assessment for non-compliance with stage 6	0,22	0,03				
The probability of successful completion of step P6	0,78	0,97				

According to table 2, the probability of fulfillment of ECB by supplier No. 1 on delivery time is 0.094, i.e. this event is unlikely (a little less than 1 out of 10 chance). For this project, the probability of successful completion of the stages is not small - they vary from 0.63 to 0.84 (i.e. risk assessments range from 0.16 to 0.37). Accumulating from stage to stage, the risk assessment increases to a clearly unacceptable value of 0.906.

For supplier No. 2, the probability of successful completion of the stages is close to 1 - they vary from 0.93 to 0.97 (i.e. risk assessments range from 0.03 to 0.07). Nevertheless, accumulating from stage to stage, the risk assessment increases to a noticeable value of 0.371, respectively, the probability of successful delivery by supplier No. 2 (i.e. on time) is noticeably less than 1 and amounts to 0.629 (slightly less than 2 out of 3 chances).

Using the AM model built at the initial stages of the project (for example, at stage 1 “Concept”), it is possible to identify risk factors that make the largest contribution to the total risk. Management impacts aimed at reducing the corresponding risks may be most useful for reducing the total risk. It is at these stages that it is advisable to pay the most attention when managing projects. According to the data in Table 2, individual second-order risks make a significantly greater contribution to the risks at the stages than other types of risks at the same stages. So, for project 2, the risk at stage 3 “Development of working documentation” makes the largest contribution (0.04 out of 0.07, i.e. more than half) to risk R53 - organizational risk (the risk of job disruption due to poor organization). Thus, it is possible to single out risks for which managerial impacts can reduce the overall risk to the greatest extent.

Suppose that the cost of implementing certain managerial decisions is known. Based on the AM model, it is possible to calculate the effectiveness of a set of management decisions, i.e. risk reduction as a result of using this kit. According to the AM-model, risk is estimated by a number from 0 to 1. More advanced studies can enable a financial assessment of risks (in particular, losses from the implementation of risk situations and the costs of eliminating the consequences). Solving the optimization problem, for a given budget to reduce risks, we find the best set of managerial decisions, and also solve the dual problem - we determine the amount of financial investments necessary to reduce the risk by a given amount and further maintain an acceptable level of risk. This approach is similar to that used in the development of an automated system for forecasting and preventing accidents [14].

Using the proposed approach, on the basis of the additive-multiplicative model, conduct a risk assessment at all stages of ECB creation and select manufacturers.

IV. CONCLUSIONS

The study developed a methodological approach and an additive-multiplicative model for assessing risks in the development and delivery of electronic components of foreign production; The expert definition of weighting factors is presented when choosing and applying ECB at the stages of the life cycle of an RST product.

Using the proposed approach, on the basis of the additive-multiplicative model, carry out risk assessment at all stages of ECB creation and select manufacturers not only based on the total risks at the stage of ECB creation, but also perform a typology and classification of risk factors. This approach to the classification of risk factors will identify the most “weaknesses” of the implementing enterprises.

There is an urgent need to assess the level of influence of various nature of the occurrence of risks on the progress of EDW. In this regard, the question has arisen of the need to develop regulatory and technical documentation for assessing risks in the production and procurement of ECB during the implementation of EDW. When assessing risks in the production and procurement of ECBs during the implementation of EDW, it is necessary to develop organizational and methodological aspects of assessing threshold values for enterprises of the military-industrial complex through the developed methodology for assessing enterprise risk tolerance [14]. By setting threshold values in the form of maximum permissible risks and maximum possible risks of various nature of their occurrence (risk of incorrect technical solution, personnel risk, risk of job disruption due to organizational problems inside the research institute, external risk (political, job disruption for reasons outside the research institute) , the risk of lack of resources (temporary, human, material, financial), organizational, etc.) it will be possible to assess the level of success of EDW and the level of enterprise resistance to risks in the course of EDW.

REFERENCES

1. Risk Management Standards of the Federation of European Risk Managers Associations (FERMA).
2. COSO document (concept) "Guidelines for Monitoring the Internal Control System" (2009).
3. ISO 22000: 2018 (second edition of ISO 50001, edition 2018-08). Energy management systems
4. Zubova L.V. Definition of risk tolerance, level of risks, effect and effectiveness of their consequences, taking into account ensuring maximum risk tolerance and necessary competitiveness. Actual issues of modern economic science. III international correspondence conference: Lipetsk: "De facto", 2011. S. 109-111.
5. Zubova L.V. Methodology for substantiating entrepreneurial decisions of defense enterprises in the face of uncertainty about the consequences of risks: a monograph. Military Space Academy named after A.F. Mozhaysky, St. Petersburg: Publishing House of St. Petersburg State University of Economics. 2018.192 p.
6. Zubova L.V., Gotskaya N.R., Davydyants D.E., Karlik A. E., Petrov D.M. Comprehensive value of enterprise solutions and algorithm of risk level assessment / technical sciences. Science and Society, 2018; # 3: 111-121.
7. Zubova L.V., Kolesnik A.V., Nikolaev S.P. Features of scientific and technical risks in the development of rocket and space technology.Science and Society, 2018: 37-45.
8. Zubova L.V., Kuzmin V.N., Sherstyuk A.V. Model of administration of managerial decisions based on estimation of risk-stability of enterprises, 2018.
9. Zubova L.V. The scheme of the model of managerial decision making based on the assessment of the risk tolerance of business entities. Proceedings of St. Petersburg State University of Economics, 2018: 161.
10. Zubova L.V., Nikolaev S.P., Kolesnik A.V., Peculiarities of scientific and technical risks in the development of rocket and space technology. Science and Society, 2018; # 3: 111-121.
11. Korovin E.V. Comprehensive assessment of the effectiveness of industrial enterprise development projects. Economics of Education, 2012; # 2: 117-122.
12. Nikitin Yu.A., Korovin E.V., Kruglov D.V. Management of assortments of services for material support of state power structures. Monograph. SPb .: WATT. 2009.116 p.
13. Orlov A.I., Tsisarsky A.D. Features of risk assessment when creating space rocket technology. National interests: priorities and security, 2018; 43 (232): 114-118.
14. Charushnikov A.V., Kuzmin V.N., Dreshchinsky V.A. An innovative methodological approach to modeling and evaluating the effectiveness of space systems. Innovation, 2015; # 9 (205): 7-11.
15. Zubova L.V., Gotskaya N.R., Davydyants D.E., Karlik A. E., Petrov D.M. Comprehensive value of enterprise solutions and algorithm of risk level assessment. Science and Society, 2018; # 3: 111-121.
16. Kolesnik A.V., Zubova L.V., Nikolaev S.P. Features of scientific and technical risks in the development of rocket and space technology. Science and Society, 2018. # 2: 37-45.
17. Kuzmin V.N., Sherstyuk A.V. Zubova L.V., Model of administration managerial decisions based on assessment of risk-stability of enterprises. 8th The International Conference "Social Science and Humanity". London, 2018: 29-36.

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