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Dependability and Quality Satellite Telecommunication Equipment Improving at the Production Stage

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***Abstract*—This paper presents the urgent problem of improving the developed satellite telecommunication equipment reliability and quality. An analysis of the approaches used in the Russian Federation and the United States to assess the "production quality factor" is made, that directly affects the dependability and quality of the telecommunication equipment. Particular criteria are developed to evaluate the efficiency of the quality management system at the enterprises. Recommendations for the implementation of the developed criteria in the mathematical model for assessing the "production quality coefficient" for the failures category related to the systems management process factor are given.**

Keywords—quality management system; dependability; quality; satellite telecommunication equipment; artificial earth satellite.

I. INTRODUCTION

Nowadays, a promising direction in the field of formation, reception, processing and transmission of information over long distances is the use of technology based on satellite telecommunication equipment (STE) in the optical wavelength range. Indeed, there is a transition from the range of radio waves to the optical. Indeed, there is a transition from the range of radio waves to the optical [1] for communication with artificial Earth satellites (AES) [2]. There are two reasons for this: the first is the acceleration of data transmission by tens of times, the second is the compact size of optical receivers and transmitters, which indicates their low energy consumption. In order to maintain competitive advantages in the market for the provision of such communications services, satellite telecommunication equipment enterprises need to pay special attention to their dependability and quality. In fact, ensuring the STE dependability and quality is one of the priority tasks in the design and production [3, 4]. It is possible to achieve the production of dependable and high-quality STE not only by compliance the necessary actions specified in the regulatory and technical documentation (RTD), but also with the effective use of the quality management system (QMS). The QMS efficiency can be achieved only if it is introduced and maintained in working condition at all stages of the satellite telecommunication equipment life cycle, taking into account the all parties concerned needs.

However, the AES failure statistics from different countries [5] indicates drawbacks in the strategy of ensuring dependability and, consequently, quality. Not the best situation in this indicator is observed in the Russian Federation: one failure occurs in every fifth AES, at the same time, most of the failed equipment is telecommunication. Therefore, the aim of this work is to increase the dependability and quality of the STE using the QMS requirements.

II. PROBLEMS OF MODERN RUSSIAN ENTERPRISES IN THE FIELD OF QUALITY

A description of the quality management principles is given in the standard [6], similar to international standard (IS) [7]. And the standard [8] is based on the principles specified in [6, 7]. However, the principles are not requirements, but they form the basis for requirements that are established in standard [7]. There was another version of IS earlier [9]. Table 1 shows the similarities and differences in the principles of quality management (QM) in standards [8] and [9].

TABLE I. COMPARISON OF THE QM PRINCIPLES

№	QM principles according to [8]	QM principles according to [9]
1	Customer focus	Customer focus
2	Leadership	Leadership
3	Employee engagement	Employee involvement
4	Process approach	Process approach
5	–	Systematic approach to management
6	Improvement	Continuous improvement
7	Evidence-based decision making	Factual decision making
8	Relationship management	Mutually beneficial relationships with suppliers

It is known that the QMS development and implementation in the production processes at enterprises is a difficult task, but it is even more difficult to ensure its effective functioning. Indeed, after the development of documentation and the QMS introduction at electronic

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enterprises developing telecommunication equipment in general, in particular the STE, the problem of its low efficiency arises. According to experts [10, 11], about 20% of Russian enterprises that have the QMS certification, successfully use the opportunities provided by the quality management system to improve the quality of the STE.

Such measures are indicated by foreign experts in the field of dependability and quality [12]. However, a certified QMS not only does not bring benefits to manufacturing companies and does not contribute to the growth of business efficiency, but even gives negative results. This fact, in some cases, discredits the idea of the QMS creating and certifying [12].

Modern standards of quality management ISO 9000/9001 [6, 8] systematize the successful global practice of the best companies and enterprises, building on the latest developments in world management science, based on the total quality management (TQM) approaches. Over 100 international committees bringing together leading experts to take part in their development. In fact, these are the only universally recognized standards for general enterprise management. Therefore, it is necessary to draw the attention of the Russian enterprises heads to the documents [6, 8].

However, statistics suggest otherwise. In the Russian Federation, as in other CIS countries, only 20% of enterprises passed certification for compliance with the quality standard. In the EU such enterprises are about 75%, in China - about 50%.

In most cases, the term “quality” is mistakenly interpreted as “compliance with internal requirements and standards”, i.e. “quality” – is not a marketing, but a technical characteristic of a product, which is a key mistake.

This is due to the quality standards. They are formed exclusively as a system of basic concepts, requirements and recommendations (see Table 2). They is no evidence of the proposed management principles correctness. Therefore, depending on the mentality, this approach does not cause rejection in other countries, however, it is completely unacceptable for modern Russian leaders. For such leaders, in addition to credibility and the international status of a quality standard, it is necessary to provide convincing arguments regarding the benefits gained from its implementation.

TABLE II. MS VERBAL FORMS [6]

№	Verbal forms
1	“Shall” indicates a requirement
2	“Should” indicates a recommendation
3	“May” indicates a permission
4	“Can” indicates a possibility or a capability

The incompetence of external auditors is associated with the lack of proper quality of telecommunication equipment.

As a result, the causes of the ineffective functioning of the QMS in Russian enterprises are identified, which are shown in table 3.

TABLE III. REASONS FOR INEFFECTIVE QMS FUNCTIONING AT RUSSIAN ENTERPRISES

№	Verbal forms
1	Top management detachment
2	The ISO 9001 requirements are not fully implemented.
3	Incompetence in the interpretation of the ISO 9001 requirements (excluding industry specifics)
4	The organization misunderstanding of the QMS by the vast majority of staff
5	The QMS fictitious “implementation”
6	Certification processes violation
7	Non-compliance by the organization with the full ISO 9001 requirements to ensure customer satisfaction and the lack of orientation of certification bodies to verify this requirement

Based on the analysis, it could be concluded that the drawbacks that exist in Russian enterprises in the field of dependability and, consequently, the quality involved in the design and manufacture of telecommunication equipment, can adversely affect the design and manufacture of the STE. This fact will not allow creating competition for world leaders in the provision of space communications services.

Therefore, it is necessary to develop a new rational approach to improve dependability and quality. The implementation of the approach is based on the refinement of “production quality factor” K_A. With the help of K_A can be assess the attainable level of dependability and quality of the STE for AES in the design stage.

III. RESEARCH OF APPROACHES TO THE EVALUATION OF “PRODUCTION QUALITY COEFFICIENT”

This section discusses approaches aimed at assessing the “production quality factor” K_A used in the Russian Federation and the USA.

A. Approach in the Russian Federation

The approach is aimed at fulfilling the requirements of RTD to ensure a high level of quality: standards, industry standards that are established in the Regulations for the creation, production and operation of telecommunication equipment. But despite the changes in the RTD and the correctness of the fulfillment of these requirements, K_A is integral and has two constant numerical values. The reference book [13] regulates for complexes of state standards (CSS) "Moroz-6, 7" to take K_A = 1, and according to the Regulation "RK- ..." to take K_A = 0.2. The second case is related to the AES telecommunication equipment. This means that using K_A = 0.2 and substituting into expression (1), the failure rate λ_{pr} is reduced by 5 times, which increases mean operating time to failure $\overline{T}_o$ by expression (2) by 5 times.

$$\lambda_{pr} = K_A \cdot \lambda_{\Sigma}, \tag{1}$$

where λ_{Σ} is the total failure rate of the electronic devices (ED) included in the AES STE.

$$\overline{T}_o = \frac{1}{\lambda_{pr}} \tag{2}$$

However, the failure statistics provided in an open source [5] indicate the imperfection of the approach used to obtain the correct numerical values of the characteristics of a simple dependability measure - reliability.

B. Approach in the USA

The approach is described in the source RIAC-HDBK-217Plus [14] and is considered in detail in [15]. In this case, the K_A estimate is presented in the form of a mathematical model (3), after which, the result obtained by model (3) can be used in expression (1).

$$K_A = \Pi_P \cdot \Pi_{IM} \cdot \Pi_E + \Pi_D \cdot \Pi_G + \\ + \Pi_M \cdot \Pi_{IM} \cdot \Pi_E \cdot \Pi_G + \Pi_S \cdot \Pi_G +, \\ + \Pi_I + \Pi_N + \Pi_W \tag{3}$$

where each coefficient included in the model (3) characterizes a certain category of failure [14, 15]. The percentage distribution of electronic means (EM) failures by category is also presented in [14, 15].

An analysis of the source [14] allows to conclude that all the coefficients of model (3), in addition to Π_{IM}, Π_E and $\Pi_{G,}$ are estimated according to the results of expert evaluation (external audit). Consider in more detail the coefficient of model (3) Π_S - systems management process factor, which is directly related to the QMS and enterprise management. An analysis of the questionnaire (100 questions in total) regarding the Π_S coefficient is presented in Figure 1. It is noticeable, that in Figure 1, there is a distribution of questions by direction, namely staff, product, process. Most preference is given to processes with the following classification according to [16]: agreement, organizational support of the project, technical management, technical.

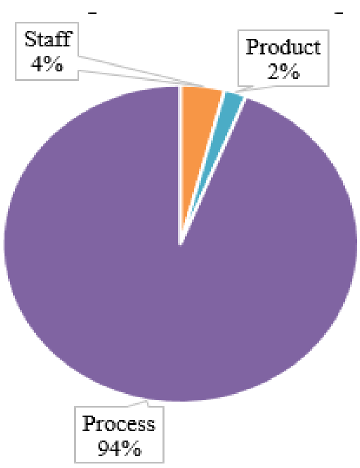

Fig. 1. The percentage distribution of the questions direction for the coefficient Π_S

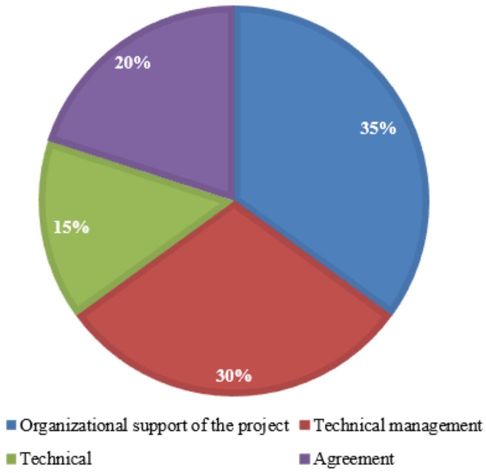

Fig. 2. The percentage distribution of the questions classification of the coefficient Π_S for the direction "Process"

However, a study of a questionnaire intended for an expert shows that the questions for each of the coefficients used are not structured and there is no indication of affiliation with specific RTD.

It is also necessary to evaluate the QMS efficiency according to certain criteria, which is not taken into account in the considered approach.

IV. Development of Criteria for Evaluating the QMS Efficiency

The quality of the manufactured STE (products) directly depends by which principle the QMS is formed and whether its potential is used to the maximum at the enterprise. It is necessary to develop criteria for numerical evaluating of the QMS effectiveness and how fully the company uses its capabilities. It is proposed to evaluate the QMS effectiveness using particular criteria R_j (see expressions (4-8)).

$$R_1 = \frac{\sum_{i=1}^{n} \gamma_i \cdot S_i}{\sum_{i=1}^{n} \gamma_i}, \tag{4}$$

where R_1 is the coefficient characterizing customer satisfaction with the quality of products manufactured by the enterprise with a weight coefficient $\beta = 1$; S_i is the value of the i indicator; γ_i is the weight coefficient i indicator; n – is the number of quality indicators.

$$R_2 = \frac{\sum_{i=1}^{m} \delta_i \cdot T_i}{\sum_{i=1}^{m} \delta_i}, \tag{5}$$

where R_2 is the coefficient characterizing compliance with product requirements with a weight coefficient $\beta = 1$; T_i is the value of the i indicator; δ_i is the weight coefficient i indicator; m – is the number of requirements.

It is proposed, using the coefficient R_3 with a weight coefficient $\beta = 0.9$, to characterize the stability of fulfilling the requirements depending on the enterprise type of activity. There are only two variations of the numerical value for R_3: in case of non-compliance with the requirements is assigned “0” and, conversely, if is met “1”.

$$R_4 = \frac{\sum_{i=1}^{l} b_i \cdot P_i}{\sum_{i=1}^{l} b_i}, \quad (6)$$

where R_4 is the coefficient characterizing the degree of fulfillment of established criteria for the effectiveness of processes with a weight coefficient $\beta = 0.9$; P_i is the value of the i indicator; b_i is the weight coefficient i indicator; l is the number of processes.

$$R_5 = 1 - \frac{K_{def}}{K_{sup}}, \quad (7)$$

where R_5 is the coefficient characterizing the quality of suppliers’ products with a weight coefficient $\beta = 0.8$; $K_{def.}$ is the defective products; $K_{sup.}$ is the total number of delivered items.

$$R_6 = \frac{C_{act}}{C_{est}}, \quad (8)$$

where R_6 is the coefficient characterizing the implementation of the quality policy and the degree of fulfillment of quality goals with a weight coefficient $\beta = 0.8$; $C_{act.}$ is the actual number of goals achieved among the established; $C_{est.}$ is the established number of goals.

Note to formulas (4-8) is: weights β_j are assigned by expert.

Evaluation of the QMS effectiveness R_{QMS} is determined by the formula (9):

$$R_{QMS} = \frac{\sum_{i=j}^{6} \beta_j \cdot R_j}{\sum_{i=j}^{6} \beta_j}, \quad (9)$$

where R_i is the value j particular criteria (total 6); β_j is the weight coefficient j particular criteria.

The main data used in the calculation particular criteria determination are:

- Generalized results of the QMS internal and external audits.
- Customer satisfaction measures of the products (STE) contained in reports on assessing customer satisfaction on complaints received, claims, consumer complaints on manufactured products.
- Quality measures of defective products: identified at the input control, during the quality control, identified at the input control, during the quality control acceptance tests of finished products (STE) at the production stage.
- Copyright data supervision during the life cycle of products (STE) for the consumer (customer).
- Product (STE) test results.
- Goal completion results in the field of dependability.
- Supplier assessment and selection results.
- Information about process efficiency measures, their dynamics.

It is worth noting that each particular criteria R_j has measures, the significance of which is determined using weights and individual values assigned by experts

V. Conclusion

The article analyzes the approaches used in the USA and the Russian Federation aimed at assessing the dependability and quality of satellite telecommunication equipment, taking into account the QMS requirements. Their advantages and disadvantages are revealed. The problems in the field of ensuring the dependability and quality required level in Russian enterprises manufacturing the STE are identified and justified. The main reason is the non-compliance with the necessary requirements (actions) specified in the QMS, in addition to RTD. The reasons of problems of quality management system introduction at the enterprises are revealed.

The paper examines the "production quality factor", a numerical evaluation of which allows to determine the characteristics of a simple dependability measure – reliability. The use of particular criteria is justified, with the help of which a numerical efficiency evaluation of the existing QMS can be carried out.

It is proposed to introduce the coefficient R_{QMS} characterizing the QMS efficiency into the mathematical model for estimating the “production quality factor” (3) for Π_S using particular R_j criteria.

A refined assessment of the “production quality factor” taking into account the QMS requirements allows to timely monitor the implementation of actions to produce dependable and high-quality satellite telecommunication equipment used to ensure the formation, reception, processing and transmission of information. Such approach could lead Russian enterprises to the world market and make them competitive with foreign leaders in the provision of space communications services.

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