Trends in the development of a digital quality management system in the aerospace industry

E Kovrigin* and V Vasiliev

Institute of Materials Science and Materials Technology, Department of Quality Management and Certification, Moscow Aviation Institute (National Research University), 4 Volokolamsk highway, Moscow 125993, Russian Federation

*E-mail: j7eka@yandex.ru

Abstract. Taking into account the analysis of the literature on the development trends of the quality management system of aerospace industry organizations, it was concluded that today there is an acute question of creating effective information-analytical systems for making managerial and other decisions in the development and production of aerospace products, in particular aircraft engines. The purpose of this article is to develop a model of information-analytical system that allows to predict the level of quality in the development and production of aircraft engines. To achieve this goal, modelling methods were used, as well as information analysis and generalization. As a result of the study, a forecasting model and a quality control scheme for the development and production of aircraft engines at different stages of the life cycle were developed and tested, allowing getting a complete picture of it.

1. Introduction

Today’s technologies in the Russian aerospace industry do not allow the creation and production of competitive aircraft that meet the high requirements of the use of aircraft. Russian-made aviation equipment has insufficiently high characteristics in terms of compliance with environmental requirements, reliability and cost-effectiveness requirements. Aircraft engines have low performance and reliability. Avionics and general-purpose equipment are inferior in functional completeness, overall weight and weight excellence, reliability and maintainability to the best examples of the world aircraft industry.

However, the whole world is experiencing a digital boom (or as it is commonly called digitalization), which is fundamentally changing the way of life of all mankind. This process is global in nature and in the next 5-10 years will affect almost all spheres of human life and society. Of course, it will not ignore the aerospace industry and such an important component of any organization as a quality management system (QMS).

Digitalization is the process of transformation of the company, aimed at forming a unified information environment throughout the life cycle of the product, combining different methods and tools of data management in the organization. Today, the formation of such an environment in the aerospace industry is ensured by the integration of modern software products: PLM (Product Life-cycle Management), MES (Manufacturing Execution System), ERP (Enterprise Recurse Planning), MDM (Master Data Management), CRM (Customer Relationship Management) [1-3]. The article [4] proposes a PLM structure based on blockchain technology, which is able to facilitate access to certain types of data on the product lifecycle. The concept of integration of industrial blockchain with Internet of things
and M2M (Machine-to-machine) technologies is proposed. The results of the study showed that the proposed structure is effective, and therefore, it can be used in industry. In the article [5], the authors first investigated various industries, such as aerospace, semiconductor, and automotive, to adapt the MES system. The authors investigated the modern, so-called Smart MES (in comparison with the usual MES), which can comprehensively and effectively cope with various situations in the workshop in real time. According to the authors of [6], enterprise resource planning (ERP) systems are considered the basis for Industry 4.0. In their article, they try to answer the following question: “Are modern ERP systems ready to integrate into Factories of the Future (FoF)?” The results of the study show that there is such willingness. However, when it comes to the interaction of the ERP system with the “machines” (M2M), certain problems arise due to the lack of a single standard and protocol. The authors of the study [7] are trying to understand (determine) which factors influence the success of CRM. As a result of the study, they came to the conclusion that the success of CRM is greatly influenced by “using information technology”, as well as “customer focus”, “organizational capabilities” and “customer knowledge management”.

The study [8] provides an overview of the benefits of introducing digital technology in the aerospace industry, which raises awareness of all recommended practices and problems that may arise, helping these organizations better implement them. Authors recommend analysing the underlying process before digitizing it so that the organization can avoid introducing bad practices. At the same time, they identified a number of problems that must be taken into account. Firstly, the aerospace industry has characteristics that create some special problems in implementing the digitalization of the organization’s management system. Secondly, investing in workflow management tools will not solve the problems associated with the underlying business process. The "digitization" of the process automates existing practices, which is the main reason why the process must be displayed and optimized before it is automated. Third, the challenge for the aerospace industry is how to integrate all of the tools, databases, and systems used. A workflow system must be able to integrate all of these capabilities. Without proper integration, it is very difficult to realize most of the benefits. Implementing a workflow management system requires active management, end-user participation, tools and system integration, and a sound implementation plan. The article [9] explores the possibilities of integrating data between suppliers, manufacturers and developers in the aerospace industry. Methodological issues of creating such knowledge bases are considered taking into account the specifics of the aerospace industry.

Thus, taking into account the development trends of digital technologies, as well as the problems that exist in the aerospace industry, there is a high need for an effective information-analytical system that allows forecasting the level of quality of developed and manufactured aircraft engines, which is the purpose of this article.

2. Methodology
To achieve the goal set in this article, logical, system, functional, and comparative methods of analysis were used; methods of analogies and generalizations. In particular, an analysis was made of the stages of the life cycle of systems given in ISO / IEC 15288: 2008 "Systems and software engineering - System life cycle processes", as well as a number of scientific articles on the product life cycle [10-12]. The following stages of the product life cycle were identified, on the basis of which a model of a quality forecasting system was built: development; mass production; exploitation. In accordance with certain stages of the life cycle, modeling was carried out (a model and scheme (algorithm) were developed), at what stage, where and how specifically, it is possible to obtain information about the quality of developed and manufactured aircraft engines.

3. Model of quality control and forecasting system
One of the important tasks in the quality management of any product, including products of the aerospace industry, is the collection and processing of information about its quality.

Under the quality of products is understood as a set of properties that determine its suitability to meet certain needs in accordance with its purpose.
Of great importance for product quality management are quality indicators laid at the stage of development and coordination of the tactical and technical specifications. The group of quality indicators includes purpose indicators, which determine the main functions for which it is intended, reliability indicators, ergonomic indicators, etc.

At the same time, since it is often not about the finished product, but about assessing the quality of laboratory and developmental prototype at the development stage, it is important to develop quality indicators – the presence of various design errors. Improving product quality largely depends on reducing the number of design errors in the development of schemes and design, manufacturing defects and product failures during acceptance and operation.

Namely, based on this, the sphere of interests of the quality service of the aerospace industry organization should include failures, defects, design errors, i.e. everything that interferes with the product is fully consistent with the purpose. Therefore, the task of forecasting quality becomes the most acute and significant for it. Because, when setting the task of forecasting, it is necessary to answer the question - what could be bad in the future, is everything done in this sense in the present?

The control and forecasting system is a system for assessing the current state of affairs on product quality and an attempt to predict the problems of tomorrow based on the elimination of today's problems.

The general scheme of this system is shown in figure 1. It is important to note that it covers the stages of development (design), mass production, and also partially the period of operation (in the case of complaints and repairs). In other words, throughout the life cycle of the product, data about it should be accumulated, which allows not only to obtain the most reliable and complete information about its quality, but also to evaluate the effectiveness of the measures taken. In essence, the above diagram shows that the development (design), manufacture and operation is a continuous and constant process of finalizing products in order to improve its quality.

Figure 1. Quality control and forecasting system.

As can be seen from the figure, quality control is carried out at each stage, in the event that developer errors, failures or product defects are detected, they are eliminated and a similar forecast is made in the next stage. Control, elimination and forecasting procedures should be included in any subsystem of the automated quality data management system.

Another important feature of any subsystem is the presence of an archive in which information on the current state of products is accumulated and stored - recorded errors, defects, failures that occurred in the past, as well as some generalized data for long-term storage, information on the causes of failures, defects and measures to eliminate them until they are implemented, generalizing quality indicators, etc.

The archive makes it possible to summarize information on various products and various units, which is important when there is a disconnect and lack of information among developers and employees of supervisory services.
The quality control and forecasting system is a common system and a common name. It represents a set of independent subsystems, determined by the isolation of the individual stages of the product life cycle:

- development of documentation (circuit, design, technological, textual);
- control of purchased materials, semi-finished products, components and elements;
- manufacturing and testing of serial products;
- adjustment of documentation of serial products;
- repair of products.

As control methods can be:

- examination (metrological and reliability) of design, technological or textual documentation;
- quality control of design, technological or textual documentation;
- various types of checks and tests;
- in some cases, at the design stage, calculation methods.

The general quality control scheme is shown in figure 2. As a result of the control, registration is carried out:

- product failures and manufacturing defects during testing and examination;
- design errors detected during the examination or approval of documentation.

![Quality control scheme](image)

**Figure 2.** Quality control scheme.

Next, an analysis of the causes of failures, defects and errors, as well as the development of recommendations for their elimination. Obviously, the more thoroughly the analysis is conducted, the
more reliable the information. In this sense, this stage is important for subsequent decisions and conclusions.

Thus, not only product failures, but also manufacturing defects, design errors, and also the most likely potential causes of failures should get into the field of view of the quality service. It is this information in its totality that can give the most complete picture of the quality of products. And only the inclusion of information on the potential causes of failures with the subsequent development of recommendations and the implementation of measures to eliminate them can allow us to talk about a proactive effect on product quality. Despite all the differences between failures, defects, errors, potential causes of failures (both semantic and origin), there is no fundamental difference in the sense that eliminating the causes that caused them is the most real way to improve quality.

4. Results and discussions

As a result of the study, a quality forecasting model was developed and tested in real practice, as well as a quality control scheme, suggesting where, when and at what stage of development and production of aircraft engines it is necessary to collect information about it. A technique is proposed for collecting information on the quality of aircraft engines being developed and produced during inspections, both technical documentation (for example, design and technological), and a specific product.

At the same time, the analysis of the proposed by a number of researchers [5–9] models of information and analytical systems in the aerospace industry has revealed the following five major unsolved problems:

- it has been found that the data, information and knowledge stored in the company's automated systems, although rich in content, do not have mechanisms that could reduce its very large size and vastness to something more focused, measurable and targeted (by basis of product or process improvements);
- there are problems associated with defining data types that can be useful in preventing defects;
- most research and industry solutions still lack the integration of supplier data and production data that contain knowledge, in particular related to manufacturing defects, which can be used to identify new design decisions;
- given the volume and discreteness of the data and the various tools used to manage it, it is not always clear how to structure diversity in such a way as to ensure its integration into the design process and informing design decisions;
- a significant amount of time is required to access, collect, restructure and reuse any kind of archival data or information to improve new designs.

In part, a number of the problems listed above, within the framework of the study of this article (table 1), were considered and their solutions were proposed.

Also, according to the authors of this article, the authors in their research and proposed models of information and analytical systems, do not fully take into account the risks associated with their implementation and use in the aerospace industry. One of them (and the most important) is the possible leakage of confidential information circulating within organizations (because their systems involve the exchange of data with external organizations, as well as providing access to certain information located in their databases). These risks are associated, including with possible cyberattacks, and as a consequence - loss of data integrity [13]. The information-analytical system of forecasting of quality offered in this article does not assume an exchange of data with external organizations (i.e. has closed character), thus considers collection of volume of information necessary for effective management of quality of production. In view of the above, it should be noted an important direction of further research in this area-the consideration of the possibilities of ensuring information security of information and analytical systems (under the conditions of data exchange with external organizations).
Table 1. Comparative analysis of the results of this article with the studies given by other authors.

| Unresolved issues                                                                 | Results of the study of this article                                      |
|----------------------------------------------------------------------------------|-------------------------------------------------------------------------|
| It has been found that the data, information and knowledge stored in the company's automated systems, although rich in content, do not have mechanisms that could reduce its very large size and vastness to something more focused, measurable and targeted (by basis of product or process improvements) | The problem was not considered / the solution of the problem was not proposed |
| There are problems associated with defining data types that can be useful in preventing defects | The problem is considered / data types (for example, detected design errors during quality control), which can be useful for preventing defects, are identified / the solution of the problem is proposed |
| Most research and industry solutions still lack the integration of supplier data and production data that contain knowledge, in particular related to manufacturing defects, which can be used to identify new design decisions | The problem is considered / due to various controls, in particular-control of incoming products from suppliers and control at different stages of the life cycle, including at the production stage, the information and analytical system is able to integrate (accumulate) the necessary data for management decisions / the solution of the problem is proposed |
| Given the volume and discreteness of the data and the various tools used to manage it, it is not always clear how to structure diversity in such a way as to ensure its integration into the design process and informing design decisions | The problem is considered / figure 2 of this article presents the scheme of information structuring / the solution of the problem is proposed |
| A significant amount of time is required to access, collect, restructure and reuse any kind of archival data or information to improve new designs | The problem is considered partially / the model presented in figure 1 takes into account the use of archival data to predict quality, but does not address the issue of time spent to access it / the solution is not fully proposed |

5. Conclusions
On the basis of the conducted research it is possible to draw the following conclusions:

- digitalization penetrates into many spheres of human life and activity, including the quality management system of organizations in the aerospace industry;
- digitalization requires a transition from descriptive to prescriptive analytics, respectively, organizations for the successful functioning and increase of competitiveness requires the introduction of effective information-analytical systems;
- To date, studies suggest the development and implementation of information-analytical systems in the organization of the aerospace industry, while the researchers themselves have noted a number of very important problems that are either not fully explored (considered) or specific measures have not been proposed to solve them;
- the model of a quality forecasting system developed by the authors of this article and tested in real practice will help to improve quality manageability in the development and production of aircraft engines in digitalization, and will also solve a number of problems that exist in the aerospace industry. However, a number of issues require further investigation and resolution.
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