

Research on Application of Lean Product Assurance System in Aerospace

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Abstract—The development cycles of models in the aerospace field are becoming shorter, and the launch missions are constantly increasing. Under these circumstances, the traditional "model-driven" product assurance management model cannot meet the current developmental needs such as "high quality and efficiency." This study explores the application and implementation of lean product assurance management methods based on total quality management in aerospace. By summarizing the development and current situation of product assurance; analyzing the existing gaps; and taking overall ideas, standards and specifications, document systems, organizational teams, and other aspects as the foothold, a lean product assurance system construction plan is proposed to adapt to the transformation of the "model and product" dual drive management mode under the productization demand. The concept of lean management is followed to improve quality governance capabilities. This study has important reference value for aerospace enterprises to improve product assurance management methods.

Keywords—aerospace, quality management, lean product assurance

I. INTRODUCTION

President Xi Jinping has stated that "We should shift the focus of development to improving its quality and efficiency." Anchoring the strategic goal of building an aerospace power, China Aerospace Science and Technology Corporation Limited proposed the developmental requirements of "ensuring success with high quality, completing tasks efficiently, and promoting the construction of national defense and aerospace power with high efficiency." It also proposed to define the transformation and development route of the quality management of the group from "fine" to "lean" and then to "excellent" and pointed out the "lean" construction direction for the implementation of total quality management [1]. However, with the shorter developmental cycles and increasing launch density of aerospace products in the new era, the aerospace quality management system cannot fully match the characteristics of multi-field, multi-user, mass and full competition. Therefore, to adapt to the new situation and new requirements, the construction of the "model and product" dual drive can be used as the premise to target, differentiate, and efficiently implement lean product assurance model. It is crucial to improve the manufacturing capacity and product quality of space equipment.

II. CONNOTATIONS OF AEROSPACE PRODUCT ASSURANCE

A. Development of Product Assurance

Product assurance originated in the United States. In 1959, the United States issued the US military standard MIL-Q-9858A "Quality Assurance Outline," as the earliest standard document on product quality assurance and proposed the definition of "quality assurance", which is "well planned, systematic and necessary measures taken to ensure that the products and services meet the specified technical requirements and achieve satisfactory performance to provide appropriate confidence." In 1986, the US Department of Defense proposed the development of the DOD-STD-2107 "Contractor Product Assurance Program", proposing the concept of "product assurance," marking the formal development of the product assurance management model [2]. Since the 1970s, the US military and industrial departments have unified the management of product development processes; including product quality, reliability, maintainability, safety, components, and raw materials, and implemented product assurance programs. NASA has developed and released the "NASA Product Assurance Manual" based on the US military standards. Subsequently, Europe gradually formed a product assurance standardization system [3] based on experiences of the United States, such as the PSS-01 and ECSS-Q series standards, which achieved good results in practical applications.

In China, the research on product assurance management modes has been relatively late. In the early 1990s, the aerospace system developed GJB1406-92 "Product Quality Assurance Outline Requirements" based on the American standard DOD-STD-2107, formally introduced the product assurance management idea, and it was applied in the practice of China-Pakistan resources, Sino-French satellite and other international cooperation projects. In order to adapt to the development of China's aerospace industry and continuously explore product assurance models that meet its own needs, a series of industry standards have been issued since 1995, including QJ2171A-1998 "Aerospace Product Assurance Requirements," QJ3076-1998 "Aerospace Product Quality Assurance Requirements," and QJ1408-1998 "Aerospace Product Reliability Assurance Requirements." As per QJ2171A, the definition of "product assurance" is "product assurance is a series of planned and organized technical and management activities carried out throughout the entire process of product development and production to ensure that the product meets the specified quality requirements" [4]. It also stipulates that the scope of product assurance includes assurances of product

assurance management, quality, reliability, maintainability, safety, component, mechanical parts material, process, and software product. Since the 21st century, the Second Academy of Aerospace Science and Industry, China Academy of Space Technology and other units have established product assurance institutions to carry out application exploration. The product guarantee model was then fully integrated into scientific research and production.

With the continuous progress of space technology and the change in market demand, aerospace product assurance is evolving and developing to meet the growing aerospace needs and challenges. In recent years, group companies have put forward new ideas and requirements for product assurance that are more suitable for current development. The Handbook of Aerospace Quality Culture in the New Era was compiled and released in 2021. In 2022, the "Aerospace Quality Management System in the New Era - Aerospace Lean Quality Management System Construction Plan" and "Guiding Opinions on the Implementation of Aerospace Lean Product Assurance Work" were issued and implemented. Lean product assurance refers to "a matrix project quality management work system that is directly responsible for product assurance teams, supported by organizational functions and specialized institutions." With technical risk identification and lean process control as the core, a series of planned and organized technical and management activities are implemented in the entire process of product design, production, test, launch, delivery, and use to ensure that the product quality meets the requirements while constantly improving the efficiency and effectiveness of the organization" [5].

B. Relationship between Quality Assurance and Product Assurance

A close relationship exists between aerospace quality management and product assurance. Quality management refers to management activities that ensure products and processes meet certain quality standards in aerospace projects. On the other hand, product assurance focuses on quality control activities in the product design process, the basic elements affecting the design such as general quality characteristics, and the basic units of components, raw materials, and other components. By conducting a series of management activities, effective measures were developed to reduce the quality risk

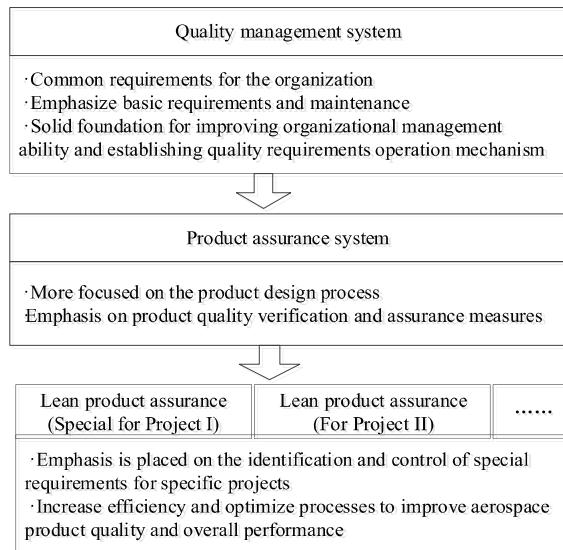


Fig. 1. Lean product assurance document system.

from the design source. Therefore, product assurance is an important aspect of quality management, and the common goal of both is to ensure that the quality of aerospace products meets specific standards and requirements for product performance, reliability, and safety. Fig. 1 depicts the differences between the two models.

- Different scope: Aerospace quality management is a broader concept that covers the entire quality management system, including quality planning, control, and improvement. Product assurance is a subset of quality management. Under the guidance of a quality management system, product assurance focuses on specific product verification and acceptance activities, product quality verification and acceptance, and related control measures.
- Different degrees of emphasis: Aerospace quality management emphasizes the establishment and implementation of an entire quality management system, including process control, standard formulation, and document management. Product assurance emphasizes the verification and assurance measures of product quality, such as design verification, acceptance testing, troubleshooting, and corrective measures. Altogether, aerospace quality management is an entire quality management system, including planning, execution, inspection, and improvement throughout the project lifecycle. Product assurance is an integral part of quality management, which focuses on verifying and ensuring product quality and performance. These two are interrelated and work together to ensure the quality and reliability of aerospace products.

Lean product assurance runs through the entire development process, aiming to improve the quality of aerospace products and overall efficiency by reducing waste, improving efficiency, and optimizing processes. The wastes may include unnecessary waiting time, material transportation and handling, repetitive work, and defect repair. Through lean principles and tools, such as a stable chemical workflow, 5S organization, continuous improvement, and error prevention, the aerospace lean product assurance method is committed to optimizing production processes and achieving high quality, efficiency, and low cost.

III. BUILDING A LEAN PRODUCT ASSURANCE SYSTEM AND IMPLEMENTING DIFFERENTIATED QUALITY MANAGEMENT

A. Construction Ideas

Lean product assurance is based on product assurance and focuses on efficient implementation of quality management to ensure that the overall performance of the product meets the minimum investment requirements. It includes lean management concepts, tools, and methods throughout a product lifecycle. At present, it is faced with the demand for product development and production of multiple types, levels, users and modes. Combined with the development requirements of aerospace products, differentiated lean product

assurance is proposed to achieve precision, process, and universality of the entire process control.

Lean product assurance takes the existing quality management system and standards as the starting point and fully identifies quality work requirements and user need at all levels to achieve an accurate and efficient management process as the basis for top-level planning. With the focus on productization/product assurance, the workflow of "model specific" and "type spectrum universal" can be built to carry out targeted product assurance activities in all stages of the product life cycle. Lean product assurance construction revolves around the three categories of "field, profession and product," and the three stages of "development, batch production and after-sales service." The overall efficiency of scientific research and production was comprehensively improved through the support of standards, document systems, and organizational teams, as shown in Fig. 2.

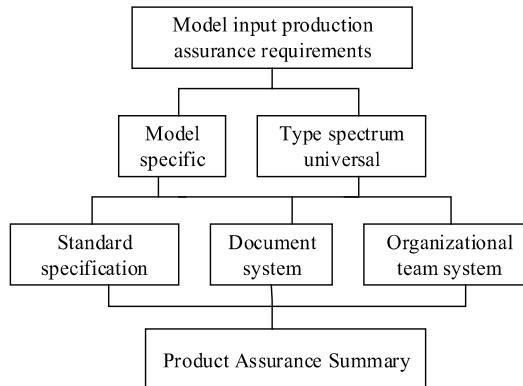


Fig. 2. Lean product assurance application.

B. Construction of Standards and Specifications

Building a lean product assurance standard specification system provides a scientific and complete basis and requirements for the implementation process, team management, and assessment evaluation of product assurance. Carrying out various product assurance management activities under the unified management mode and standardized workflow is conducive to the effective implementation of the work at the planning and execution level, and it supports lean product assurance work. First, it is necessary to comprehensively sort out the work content of the group company, the overall institute, and various units, and accurately apply the National Aerospace Industry And Institute Standards. Then, fully combined with the application of lean product assurance standards according to different product categories, product construction, and the characteristics of their own products, a product assurance standard system framework can be formed.

Product assurance standards and specifications are divided into three levels: top level, professional elements, and support execution. The first is the top-level standard for product assurance in the aerospace field, which includes relevant national, military, and aerospace standards. As a leading

standard for product assurance, it clarifies the basis for conducting product assurance work, operational requirements, and expected goals and other contents. The second level refers to the various professional element standards that guide the specific implementation of product assurance work, including product assurance work regulations, technical review work management methods, general quality characteristic work management methods, and outsourcing of general product assurance requirements. The third level is a product-oriented guiding document that supports the execution of product assurance elements in the design, production, testing, acceptance, and other stages, including product specifications, excess control, key feature identification, and control specifications.

C. Document System Construction

To promote the differentiated implementation of lean product assurance construction, it is necessary to clarify the input and output of the document system, ensure that the product assurance planning system is comprehensive, and that product assurance work is conducted in a standardized and orderly manner [6]. The lean product assurance document is shown in Fig. 3.

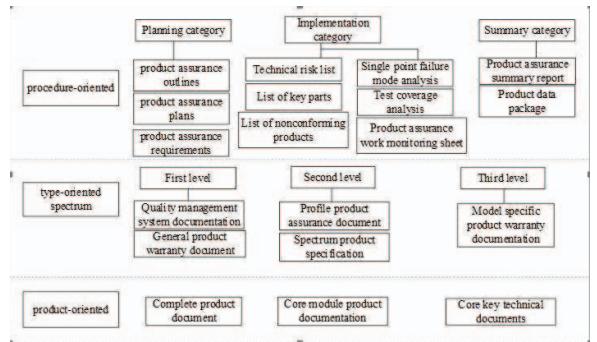


Fig. 3. Lean product assurance document.

From a process-oriented perspective, product assurance documents can be divided into planning, implementation, and summary. Planning refers to the systematic planning of various product assurance activities throughout the entire product implementation process, mainly including product assurance outlines, plans, and requirements. The implementation category is the output document of various product assurance elements in the product development process, which can reflect the implementation of the planning work, have basis and keep records, including the lists of technical risks, key and important parts, and nonconforming products. Summary documents include the analysis and evaluation summaries of the implementation of all product assurance activities specified in the product assurance outline and plan, mainly including product data packages and product assurance summary reports.

From the perspective of type spectrum, product assurance documents can be divided into general product assurance documents at the first level, consisting of quality management system documents and general product assurance outlines, which are programmatic requirements for research and production. The second level is the type spectrum product

assurance document, which is a general knowledge formed based on comprehensive analysis of the characteristics, user background, and development mode of the type spectrum product. It can guide other products of the same type to carry out product assurance work. The third level is a product assurance document specific to the model, which incorporates overall or model-specific requirements based on universality and is applicable to specific model products.

From a product-oriented perspective, product assurance documents can be planned and constructed on the basis of three aspects: complete machine products, core module products, and key core technologies. This fully integrates productization and product assurance elements into scientific research and production.

D. Organizational Team Building

Lean product assurance construction adheres to the principle of "talent is the first resource," and the product assurance team is an important component of the implementation process. We establish a product assurance team based on the concept of "field+model" and "professional+product." To realize "professional people do professional things" around model projects and spectrum products, ensure the reasonable allocation of human resources, and help the efficient operation of management processes.

The product assurance team consists of a domain product assurance chief engineer, professional product assurance manager, model system/subsystem product assurance chief engineer, product assurance manager, model product assurance engineer, professional product assurance engineer, and product assurance experts [7]. The lean product assurance team organization is shown in Fig. 4.

- The General Sports Institute established a domain product assurance chief engineer and a professional product manager. Domain product assurance chief engineers are responsible for the overall planning of product assurance work for various models in the field, and coordinate major issues such as technology, quality, and progress in the product assurance process for each model in the field. As it is responsible for ensuring the quality of various models of products within the professional field, the professional product manager focuses on promoting a series of works related to product assurance in combination with product development.
- The overall unit of the model has set up a product assurance chief for the model system/subsystem, responsible for implementing the requirements of the institute-level domain product assurance chief and

coordinating and planning various product assurance tasks such as technical status management, general quality characteristics, quality problem zeroing, and quality problem analysis for this model.

- A single unit is equipped with product assurance managers, model engineers, professional engineers, and managers. The Product Assurance Manager is responsible for the technical research of the corresponding spectrum (general) product assurance, organizing the organization of professional technical process sorting, establishing general product assurance standard specification documents, and supporting operational documents. The Model Product Assurance Engineer is familiar with the quality management system documents, quality management rules and regulations, standard specifications, product characteristics, and development and production processes. They are responsible for establishing a product assurance outline and a product assurance plan to plan the model product assurance work, organizing the review, verification, and verification of other products, and through the product assurance work dynamic monitoring table, product assurance summary report to monitor and summarize the completion of product assurance. Professional product assurance engineers are appointed among relevant personnel in the centralized departments of various product assurance specialties based on quality, general quality characteristics, software, components, processes, and materials. They carry out relevant professional product assurance research work under the organization of the product assurance manager, establish general product assurance standards and specifications, and provide support and guidance for model product assurance work. Product assurance experts are responsible for technical research, technical support, and talent development in the corresponding product assurance profession.

Through the establishment of a product assurance team with complete personnel and clear responsibilities throughout the development level of the overall institute, overall model unit, and single unit, the implementation of responsibilities is strengthened, personnel allocation is optimized, a dynamic update mechanism is established, and the assessment and incentive system is improved to fully participate in the lean product assurance process.

IV. CONCLUSION

The construction of lean product assurance systems for aerospace is an inevitable trend that promotes the transformation and development of quality management in this

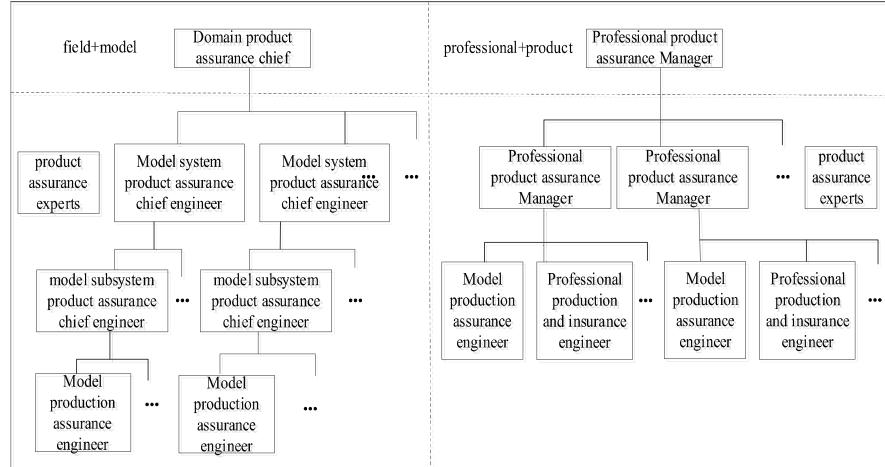


Fig. 4 Lean product assurance team composition.

new era. It is an important lever for achieving the "three high" development goals and the "double first-class" strategic goals in the aerospace field. It provides a strong guarantee of promoting the improvement of quality and efficiency in the development and production process of aerospace models. By establishing a scientifically complete standard specification, a fully differentiated document system at all levels, and a clear organizational team with clear responsibilities, we integrate product assurance elements throughout the entire development and production cycle of model products. Thus, we ensure that all requirements are implemented and effectively improve the quality level of aerospace weapons and equipment under the lean product assurance work mode.

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