

ASPECTS REGARDING THE QUALITY MANAGEMENT IN THE AEROSPACE INDUSTRY ORGANIZATIONS

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ABSTRACT

This scientific work was conducted with the purpose of analyzing the level of knowledge in the field of aerospace industry organizations by the perspective of management of production processes and administrative processes. In this study, aspects of aeronautical organizations are highlighted, starting from a presentation of this area and why organizations that have as their object of activity in this field are important. The attention has also been centralized on a comparative analysis of the reported earnings of companies operating in the aerospace industry. Another issue of interest is also the annual distribution of the number of passengers who have flown by airline over the last 20 years. The issue of quality and aerospace quality management has also been addressed, where the trends of the aerospace industry are presented, as well as the challenges faced by high-quality aerospace and defense managers. The last part of the paper contains the own conclusions and interpretations on the issue addressed in this study, as well as the subsequent research directions.

KEYWORDS: *aerospace industry, organization, quality, quality management.*

1. INTRODUCTION

History shows us that great inventors have approached flight technology from two perspectives. Trying to invent equipment lighter than air and equipment heavier than air, but with an aerodynamic shape to keep the equipment in the air.

After the Second World War, the commercial wing of the aeronautical field grew quite rapidly through the emergence of the demand for passenger and freight transport. This growth was accelerated by companies' approach to turning bombardiers into passenger planes like B29 and Lancaster. The first commercial jet aircraft was used by the English, called D.H. Comet.

2. INDUSTRIAL AEROSPACE ORGANIZATIONS

The making of aircraft involves organizations with different fields of activity but at the same time with a common goal, namely "making an aircraft that sails safely at a lower cost".

In the commercial field and beyond, the following types of organizations can be identified: design organizations; executives; certification organizations; aircraft maintenance organizations.

Design organizations are those organizations that develop products (aircraft) as required by customers, airlines, for commercial or military purposes. Generally, these organizations are large organizations that have access to very specific information. Modern digital design technologies help

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these organizations in a substantial way in designing products by simulating the final product, the aircraft, and simulating the operation of each individual component or system. These simulation and verification methods are required by the design standards developed by the major manufacturers. Execution organizations are divided into business areas, so that more organizations are needed to complete the final product, connected through a well-controlled supply chain of standard aeronautical requirements.

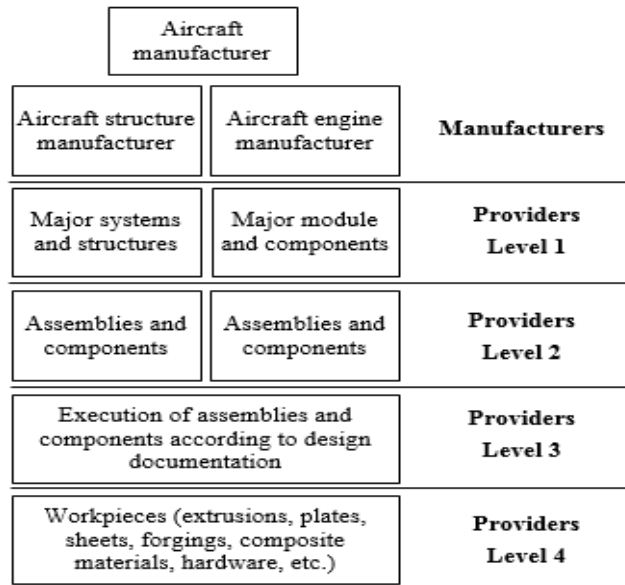


Figure 1. Aircraft configuration and classification of execution organizations

Figure 2 shows the Boeing 787 airplane configuration distribution for various vendors.

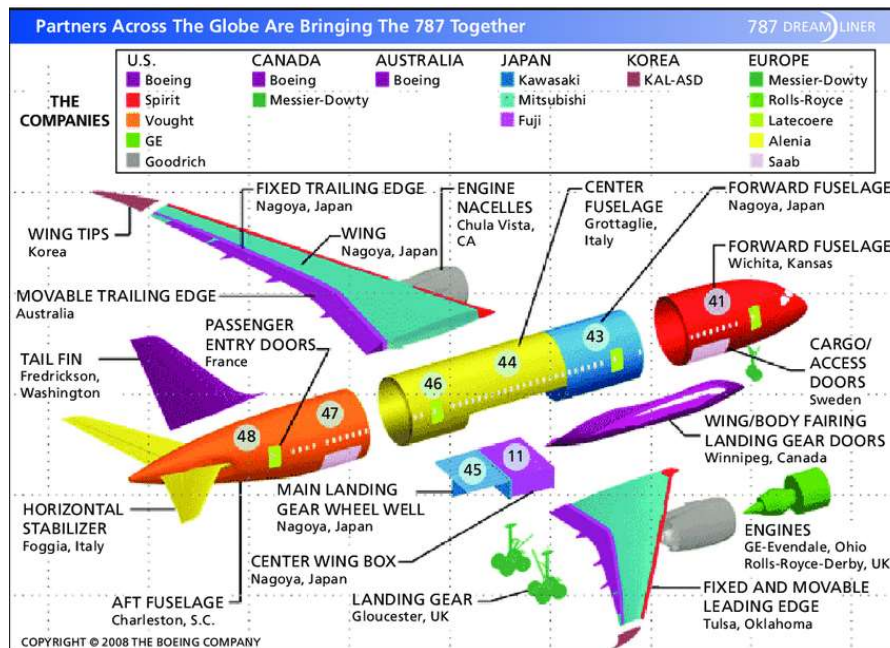


Figure 2. Boeing Aircraft Structure Configuration 787

Source: adapted from Boeings-787-Lean-Supply-Chain-Supplier-Partners_fig7_235147217 (2019)
 In figure 1 it can be seen that in the days to build an aircraft, suppliers are ranked at supplier levels according to the aircraft component configuration. It can be noticed that the organizations are

structured and specialized in relation to the aircraft configuration, the configuration of the aircraft assembly technology and, at the same time, the implementation technologies used.

Certification organizations are those organizations which, by their status, can grant to all organizations various certifications certifying the capability to achieve products or services in aeronautics in relation to the applicable standards.

Among the most frequently mentioned in the literature are:

- Certification of the quality management system (EN AS 9100);
- Certification of special production processes (NADCAP - Aerospace and Defense Contractors Accreditation Program);
- Certification by Government Authorities (EASA - European Union Aviation Safety Agency, FAA - Federal Aviation Administration).

Aircraft maintenance organizations are those organizations that maintain aircraft maintenance in accordance with applicable standards.

These organizations are very important in the life cycle of aircraft, and are equally responsible for passenger safety by applying aircraft checking procedures, each stopping them.

3. STATISTICAL ANALYSIS OF AEROSPACE COMPANIES

According to the reported annual revenues of major aircraft manufacturers, Boeing holds the first position, followed closely by Airbus (see Figure 3).

Company	Revenue				Operating Profit				Country
	2017 ⁽¹⁾	2016 ⁽²⁾	2015 ⁽³⁾	2014 ⁽⁷⁾	2017 ⁽⁴⁾	2016 ⁽⁵⁾	2015 ⁽⁶⁾	2014 ⁽⁷⁾	
Boeing	93.4	94.8	96.1	90.8	10.3	4.90	5.18	7.47	United States
Airbus	72.3	70.8	68.8	80.6	3.70	2.40	4.34	4.50	EU
Lockheed Martin	51.0	47.2	40.5	45.6	5.90	5.55	4.71	5.59	United States
United Technologies	30.9	29.0	33.1	36.2	3.83	3.84	3.00	4.57	United States
GE Aviation	27.4	26.3	24.7	24.0	6.64	6.12	5.51	5.0	United States
Northrop Grumman	25.8	24.5	23.5	24.0	3.30	3.19	3.08	3.20	United States
Raytheon	25.3	24.1	23.2	22.8	3.32	3.24	3.01	3.18	United States
Safran	17.9	16.8	16.6	18.3	2.58	2.54	1.71	2.74	France
BAE Systems	13.4	13.4	13.9	13.7	-	-	-	-	United Kingdom
Rolls-Royce Holdings	12.7	12.0	13.2	14.7	1.11	0.98	1.77	2.15	United Kingdom
Leonardo (Finmeccanica)	12.5	12.8	13.9	17.2	0.90	1.05	0.94	0.72	Italy

Figure 3. Comparative analysis of revenue of aerospace companies

Source: adapted from Aerospace manufacturer (2019)

In recent years, the challenge of these companies is given by the global trend towards reducing fuel consumption, reducing the cost of flights and increasing passenger numbers. Figure 4 shows an exponential increase in passenger numbers over the past 5 years. This growth has an impact on the entire supply chain in the aeronautics industry, where competition is getting stronger.

For aerospace manufacturers and their suppliers, the development and approach to manufacturing technologies has a major impact.

Also, design organizations work closely with manufacturing and certification organizations to develop new materials, manufacturing technologies in the shortest possible time.

To their aid, various aeronautical associations provide support and develop various standards that allow collaboration between organizations with different fields of activity.

The aeronautical field is increasingly implementing document transfer methods from design organizations to executives using product lifecycle management (PLM), PDM (product data management).

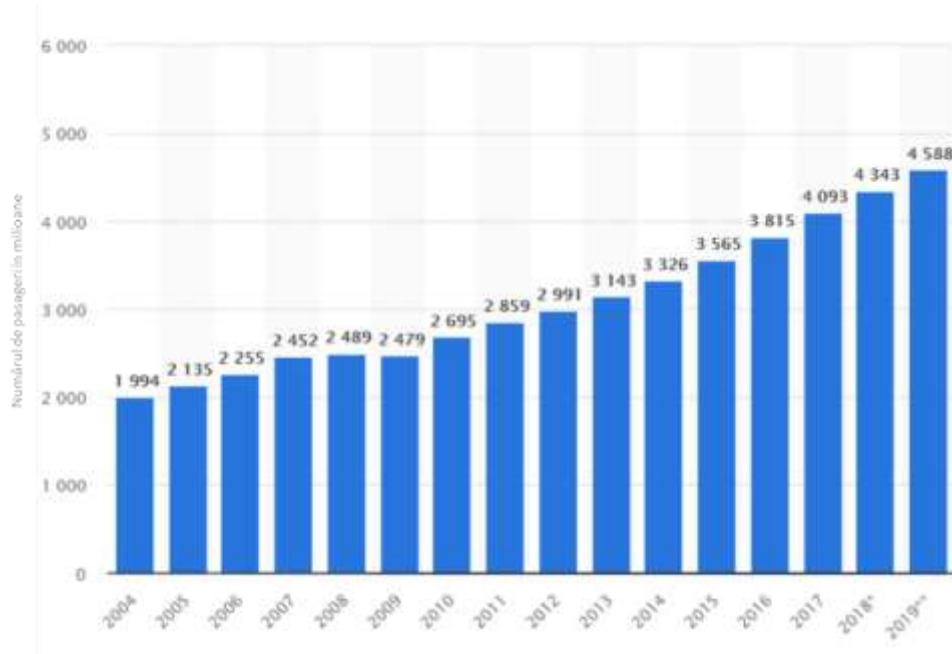


Figure 4. Annual distribution of the number of passengers flew annually, according to the airlines

Source: Global air traffic - scheduled passengers 2004-2019

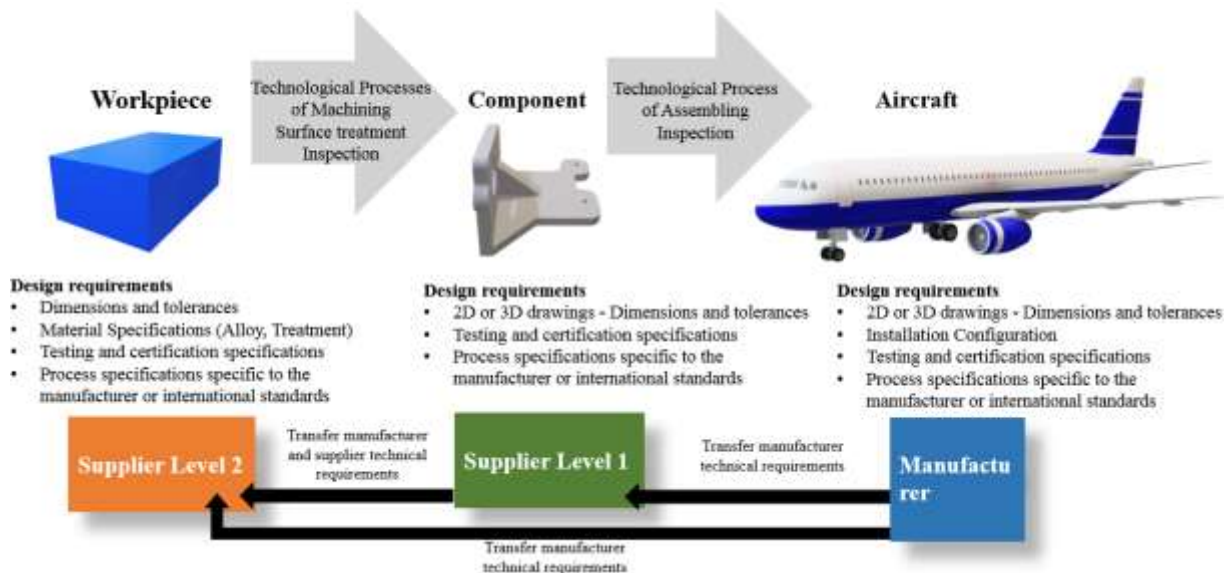


Figure 5. Transfer of technical requirements from final aircraft manufacturer to supplier

Source: Global air traffic - scheduled passengers 2004-2019

The technical documentation used in the aeronautical industry is carried out in various forms, such as:

- Classical technical documentation (2D drawings, material lists, approvals for the use of documentation for execution);
- Partial digital execution documentation (2D drawings with reduced information, 3D model, material lists, approvals for the use of documentation for execution), known as DPD (digital product data definition);
- Fully digital technical documentation (3D model with notations, materials lists, approvals for the use of documentation for execution), known as MBD (model base definition).

A big challenge for aircraft designers is to transfer technical information to companies that perform structures, assemblies and components and materials and the infrastructure they use.

The technical documentation is in line with international standards and with the standards of large companies such as Airbus and Boeing and beyond.

In order to ensure a good organization of the control of technical information, these companies have developed standardized processes for the transfer of design data.

Having a major impact on product compliance, these processes have also been introduced into international standards for management system certification.

Figure 5 highlights how the design requirements are transferred to ensure that the product is made from the final aircraft manufacturers, suppliers of raw materials and components in relation to the technological flow of the product.

4. QUALITY AND QUALITY MANAGEMENT IN AEROSPACE

The basic quality principles, how various industrial organizations use these principles may differ. Considering that industries work according to their priorities, as well as their compliance obligations and business requirements, each industry needs to understand and then apply the principles of quality in a way that defines it.

The aerospace industry is responsible for the quality of thousands of aircraft carrying millions of people around the world every day. Aircraft components have a lifespan of more than 50 years, which means that quality practices have been included in all stages of design, production, operation and maintenance in order to ensure that the processes carried out are reliable and can cope with a rigorous use.

AS 9100 – The Quality Management System was developed by the International Aerospace Quality Group (IAQG) in order to establish a general direction for the aerospace industry. AS 9100 has applicability throughout the aerospace supply chain, including even design, manufacture, replacement and maintenance. AS 9100 arose because of the previous aerospace standards that were inappropriate, including US Department of Defense MIL-Q-9858A and MIL-I-45208A standards. In 1990, aerospace manufacturers such as Boeing, McDonnell Douglas, Lockheed Martin, chose to create an aerospace application to solve the problems and shortcomings of the ISO 9001 standard. Alongside these manufacturers was the Automotive Engineers' Society (SAE) for the aviation industry, which supported them. The AS9000 launched in May 1997 by SAE has become the global standard used for aerospace quality programs.

The aerospace and defense industry take into account the civil and military needs for the production of helicopters, aircraft, satellites, missiles and other products whose safety and quality standards are maintained at the highest levels.

Manufacturers in the aerospace and defense industries and their suppliers create products using materials with very high costs and very precise processes but often operates on a short-term production environment and in production environments with high complexity and high or lower volume. Manufacturers of the defense and aerospace industry are facing industry trends like:

- Continued request for certification and quality control;
- Supply chain of increasing complexity and competition;
- Increasing demand for shorter production cycles.

To respond and meet these challenges, aerospace and defense industry managers need real-time visibility - at factories and around the globe - to be proactive through:

- Increasing quality through continuous improvement;
- Prevention and short reaction time for recalling service products;
- Ensure compliance of certification.

Globalization of the aerospace industry requires an investment in the quality management system to meet the final customer of the products.

The International Organization for Aerospace Quality (IAQG) has worked hard to support this demand and has produced a number of quality standards starting with the EN ISO 9100, based on the ISO 9001 standard.

AS 9100 is the internationally recognized industry standard for the aerospace industry.

Known as the AS 9100 in North America, the EN 9100 in Europe and the JISQ 9100 in Japan, the standard is strongly supported and joined the major aerospace manufacturers including Boeing, Airbus, Bombardier, Pratt & Whitney, Lockheed Martin, Goodrich, Messier-Dowty, Rolls-Royce and others.

The AS 9100 is a large-scale, adopted and standardized quality management system for the aerospace industry. The AS 9100, launched for the first time in October 1999 (review A) by the Automotive Engineering Society and the European Aerospace Industries Association, was a collaborative effort of the International Aerospace Quality Group (Tomić et al., 2011).

Every company wishing to implement a quality management system that meets the quality standard should improve existing documentation on operating procedures, training, and procedures for corrective actions.

5. PROCESS-BASED APPROACH

The process-based approach involves defining and systematically managing processes and interactions between them so that the results are tracked according to the quality policy and according to the organization's strategic direction. Implementing the principle of a process-based approach will lead to:

- Defining systematically the activities required to achieve the desired results;
- Establish clear responsibilities and responsibility for managing key activities in the organization;
- Focusing on the resources, methods and materials needed to improve the core activities of the organization;
- Assessing the risks, consequences and impact of actions on customers, suppliers and other stakeholders.

Adopting the process-based approach to a quality management system allows (SR EN ISO 9001:2015):

- Understanding the requirements and their ongoing compliance;
- Considering the value-added processes;
- The actual performance of the process;
- Process improvement based on evaluation of data and information.

6. INTEGRATION OF LEGAL REQUIREMENTS INTO THE QUALITY MANAGEMENT SYSTEM. EASA AND REGULATORY STRUCTURE

Legal requirements in the aeronautical field have arisen from the need to regulate aviation security requirements. These requirements have been and are being developed and verified by various international agencies, some of which are listed below:

- International Civil Aviation Organization (ICAO), is a specialized agency of the United Nations. It was created after the 1944 International Convention on International Civil Aviation (the Chicago Convention) it was ratified in 1947. ICAO's goal according to the convention is:

- "WHEREAS the next development of the international civil aviation can greatly contribute to creating and maintaining a relationship of friendship and understanding between the nations and peoples of the world, but its abuse can pose a threat to general security;

- WHEREAS it is wanted to bypass divergences and promote this cooperation between nations and peoples on whom world peace depends;

- Therefore, the governments concerned have agreed on certain principles and arrangements for international civil aviation to be developed in an orderly and safe manner and international air transport services can be established based on equal opportunities and exploited in a robust way; economic;

- Consequently, this Convention has been concluded for this purpose."

Within ICAO, 191 Member States as well as a number of aeronautical organizations around the world are collaborating to develop international standards and best practices (SIPR). These SIPRs are a reference system for those countries that define national regulations applicable to civil aviation law. An essential aspect is that ICAO SIPRs are not legally binding but they are the foundation of the national regulations that have legal status.

In this way, civil aviation regulations are harmonized worldwide, with small differences in the effective implementation of national regulations. Subsequently, these local differences are reported to ICAO and then published.

- The Civil Aviation Authority (CAA) is a generic term used in many countries, especially in China and United Kingdom. The CAA is a national regulatory body responsible for aviation. The CAA applies ICAO SARPs in national legislation and has the responsibility to oversee the regulations.

- The Federal Aviation Administration (FAA) holds the authority of US civil aviation authority, and holds responsibilities for establishing aviation regulations in the US. They are called the Aviation Federation Regulations (FAR).

- EASA is the European Aviation Safety Agency, was created in 2002 by the European Commission. EASA has taken over the functions of the joint aviation authorities of EU countries. EASA is responsible for drafting aviation safety legislation and providing technical advice to the European Commission and EU Member States, certifying the airworthiness and type of aircraft and aircraft components for aircraft operating in the EU, approving aircraft design organizations on a global scale and production and maintenance organizations inside and outside the EU.

7. TRACEABILITY OF PRODUCTS

As defined in ISO 9000, traceability is the means of determining the origin of an article and its processing history by referring to historical records to provide evidence of compliance.

In aeronautics, traceability is essential, which is why it is a mandatory requirement in the quality management system.

From the point of view of the manufacturing organizations, each piece, made, must meet the minimum identification requirements (Pop & Țițu, 2018). Some of these requirements are:

- Landmark code, according to landmark designation code assigned by the design organization.
- Production batch of the landmark;
- Batch of material;
- Mark stamp according to quality stamp

All this information must be marked on each part / piece. This information must be visible to the aircraft at the time of the maintenance inspection in order to be able to identify the process and the materials used in the event of non-compliance.

In the aeronautical industry, through the traceability process, material test values, work equipment parameters (working temperatures, processing regimes, drying temperature of painted parts, etc.) can be identified for the chemical composition of the material.

All of these requirements are identified in manufacturing processes as key product or process features. Key features are tracked and analyzed statistically to prevent the production of non-compliant products.

In the aeronautical industry, the level of inspection given by the number of key features is generated by the landmark safety class. The lower the class 1, for example, the higher the number of requirements, both of the product and of the process ones.

8. AEROSPACE AUDIT

In accordance with the ISO 9000 standard, the audit represents a systematic, independent and documented process in order to obtain audit evidence for their objective assessment in order to determine to what extent audit criteria are met (Mills, 1988).

Audits are not only undertaken to ensure regulatory compliance but also to identify weaknesses in the management system (Țițu et al., 2011). The audit process is there to serve management needs to provide feedback on existing systems, implementation and effectiveness, and provide objective data to help make decisions. For the audit process to work effectively, it needs to be managed. Audit management is a key responsibility. It has to ensure that both the audit process and the auditors themselves are aligned with the organization's needs (Huber & Glick, 1995). The audit provides a feedback mechanism that tells how well the systems work and where improvements can be made. Today, audit is recognized as an extremely powerful technique that could be used by managers alongside other management techniques.

9. ADVANCED PRODUCT QUALITY PLANNING (APQP)

Advanced Product Quality Planning (APQP) is a process developed in the late 1980s in response to the development of remote industrial automotive tools and more precisely as a reaction by major US automotive companies to production efficiency tools and the quality developed by Japanese car manufacturers by a panel of experts gathered around the American Big Three car industry: Ford, GM and Chrysler. The three major US automotive manufacturers set up this expert committee, called the Automotive Industry Action Group (AIAG), tasked with developing a standard - TS16949 - to ensure product quality improvement by making decisions in MFT teams and designing and implementing early warning systems for production process slippage. Since its implementation in the automotive industry, APQP has imposed itself as an effective methodology for eliminating losses and improving the products and services offered to customers in the automotive industry. GM, Ford and Chrysler have published the first APQP manual for the automotive industry in June 1994.

APQP borrows some risk analysis tools from the military industry. At present, APQP is a mandatory requirement in Automotive for all suppliers of the three major US manufacturers to develop new products. AIAG now has members, apart from Ford, GM and Chrysler and Japanese manufacturers like Toyota, Honda, Nissan and most of their suppliers.

The main actors in the aeronautics industry are an IAQG (International Aerospace Quality Group) and develops a similar standard applicable in the aerospace industry at the end of 2016 - AS9145 APQP / PPAP aerospace standard published in 2017.

10. CONCLUSIONS

In the latter part of the 20th century, the enthusiasm for aeronautical development has declined, with companies working more closely on digitizing aircraft equipment and investing in component manufacturing technologies. This was driven by companies' desire to reduce fuel consumption and the cost of passenger flights.

The achievement of aircraft involves organizations with different fields of activity but at the same time with a common goal, namely "making an aircraft that sails safely at the lowest cost.

Due to the complexity of the aircraft, both in terms of the number and variety of components and the complexity of the requirements, their realization depends on a chain of large suppliers, making the manufacturing process very difficult to manage.

Aeronautical organizations, from design, certification, and maintenance, are an organization that provides customers, airlines and travelers with a high-quality product throughout their life cycle.

In the direction of research, the analysis and presentation of this "organization" created from several organizations with specific fields of activity can be considered, which through the complex mechanisms make the aircrafts.

The commercial aeronautical field is on an upward trend of development due to the growing number of consumers (travelers). At the same time, organizations in this area are being challenged to reduce the cost of aircraft manufacturing, using modern manufacturing and process management technologies.

As a research direction, we can consider an analysis and study of modern manufacturing processes and management processes necessary to manage all activities from the maintenance organization to the maintenance organization.

A detailed analysis of how aeronautical industrial organizations implement digital technical documentation in the processes of manufacturing is a research direction that can develop a good practice guide in this field.

The responsibility of the aerospace industry lies on the quality of the thousands of aircraft that are intended for the transport of millions of people from all over the world.

The life of the aircraft components is over 50 years. This requires that quality practices be included in all stages of design, production, operation and maintenance in order to ensure that processes are reliable and can withstand rigorous use.

The globalization of the aerospace industry requires investment in the quality management system to meet the final customer of the products, so the International Organization for the Quality of Aerospace (AIQG) has made great efforts to support this demand and has achieved a number of quality standards starting with EN AS 9100, based on the ISO 9001 standard.

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