Civil Aircraft Flight Test and Airworthiness Management Mode Research

Junliang Ding[1,2,*]

[1]Northwestern Polytechnical University, Xi'an, 710072, China
[2]Chinese Flight Test Establishment, Xi'an, 710089, China

*dingjl@avic.com

Abstract. Flight testing is a comprehensive engineering endeavor that combines scientific, practical, and risk aspects, involving significant investment and technological complexity, playing a pivotal role in the airworthiness certification process of aircraft. China's aviation industry started late and faces challenges due to limited resources, resulting in various shortcomings in the civil aircraft flight testing and airworthiness management system. This article analyzes domestic and international models of flight testing and airworthiness certification flight management for civil aircraft. Addressing issues such as the insufficient knowledge base domestically and the demand for rapid development in the aviation industry, the article proposes recommendations such as strengthening the construction of research aircraft for testing to enhance fundamental research capabilities and optimizing and improving the management model for civil aircraft flight testing and airworthiness management.

Keywords: Civil Aircraft 1; Flight Testing 2; Airworthiness Regulations 3; Airworthiness System 4; Delegated Representative 5

1 Introduction

Flight testing is the process of conducting scientific research and product experimentation under actual flight conditions. Civil aircraft flight testing can be primarily categorized into several types:(1)Research Experimental Flights: These involve using research aircraft as a platform to explore new concepts and technologies.(2)Developmental Test Flights: These aim to refine configurations and optimize designs.(3)Compliance Data Collection Flights: These focus on collecting data to demonstrate compliance with regulatory requirements.(4)Certification Test Flights: These core on official inspections and compliance data confirmation by regulatory authorities[1-4].(5)Operational Evaluation and Compliance Verification Flights: These are mainly aimed at evaluating the aircraft for operational purposes, often conducted by Aircraft Evaluation Groups (AEG).(6)Additionally, there are special types of test flights such as delivery flights and training flights.

Flight testing activities for civil aircraft encompass the entire development process, from the exploration and demonstration verification of new concepts and technologies

Z. Wang et al. (eds.), *Proceedings of the 2023 2nd International Conference on Public Service, Economic Management and Sustainable Development (PESD 2023)*, Advances in Economics, Business and Management Research 273,
https://doi.org/10.2991/978-94-6463-344-3_32

to the overall flight test requirement analysis and flight test planning during the conceptual design phase. It includes integrated testing and modification design during the detailed design process, parallel in-house testing during component and assembly manufacturing stages, system integration and testing before the maiden flight, the maiden flight itself, and research and development flight testing conducted by the applicant. The process continues with compliance demonstration flights after the configuration freeze, followed by regulatory authority qualification test flights leading to Type Inspection Authorization (TIA). It extends further to operational compliance verification flights. These flight testing activities are integral to the entire aircraft development process.

Considering the airworthiness management process, flight testing consistently occupies the most critical phase of compliance verification. It encompasses various stages, from the requirement analysis for airworthiness clauses validation, establishing the approval basis based on flight safety and unique aircraft design features, confirming the approval plan, and compliance verification methods. It further extends to manufacturing compliance inspections, collecting and analyzing various compliance data, and assessing compliance. This process continues until the final closure of airworthiness clauses. Even after certification, continuous airworthiness management is vital. Throughout these stages, flight testing remains the pivotal and most demanding element of compliance verification. It involves extensive work, complex technical and managerial challenges, high risks, significant costs, and the longest duration among all activities required for certification.

Considering that flight testing spans the entire lifecycle of aircraft development and airworthiness review, and given its high complexity, high risk, high cost, and lengthy duration in terms of both technology and management, aviation powerhouses like the United States, Europe, and Russia consistently view flight testing as a crucial pillar for advancing aviation technology. They continuously optimize and refine flight test management models and airworthiness management systems to align with their national conditions and the changing landscape of the aviation industry[5]. Especially after the occurrence of two accidents involving the Boeing 737 MAX aircraft in October 2018 and March 2019, there has been a pressing need to improve and optimize flight test compliance verification and airworthiness management systems. This is essential to fundamentally achieve the goal promoted by the Chicago Convention, which is to develop aviation in a safe and orderly manner. It has become a critical issue that aviation professionals worldwide urgently need to address.

2 Current status of civil aircraft flight testing and its airworthiness management development

2.1 Overview of flight testing and airworthiness management in the United States

The United States is the most technologically advanced nation in aviation and boasts the most prominent depth, breadth, and intensity of flight testing. Its overall layout features a separation between military aircraft flight testing and civil aircraft flight testing, as well as a distinction between research flight testing and certification/qualification flight testing. Military aircraft flight testing is overseen by the Department of Defense, with the Three Military Flight Test Centers responsible for execution. Research flight testing falls under the purview of NASA's Dryden Flight Research Center (DFRC). Civil aircraft flight testing is led by the Federal Aviation Administration (FAA) in collaboration with civil aircraft flight test centers and aircraft manufacturers[6].Benefitting from a vast infrastructure for flight testing and a fleet of research aircraft, the United States maintains its position at the forefront of aviation technology development through mechanisms like military-civil integration, technology transfer, and resource sharing. As shown in Figure 1, a representative American X-series experimental aircraft was chosen for research, representing the cutting-edge level of aviation technology worldwide.

Fig. 1. Representative U.S. X-Series Experimental Research Aircraft

The U.S. civil aviation industry follows a typical pyramid structure: at the top are aviation giants, with Boeing as a representative, possessing strong technical capabilities and a significant market share. At the base of the pyramid are numerous small aviation enterprises, each with unique technical characteristics, and a diverse range of products and services[7].Benefiting from a long history, large scale, and advanced technology in U.S. civil aviation, the FAA (Federal Aviation Administration) has established the world's most comprehensive and effective regulatory framework and airworthiness management system. These regulatory frameworks have a global impact, with the majority of countries either directly referencing or learning from them to develop their own airworthiness management regulatory systems.

In alignment with the characteristics of the U.S. aviation manufacturing industry, the FAA has incorporated the pyramid-like structure of the U.S. aviation industry into its airworthiness management approach. According to FAA Regulation Part 183, the FAA allows for the delegation of certain airworthiness certification tasks to be undertaken by authorized entities, including Organization Designation Authorization (ODA) holders and individuals such as Designated Engineering Representatives (DER) and Designated Manufacturing Inspection Representatives (DMIR). This delegation of authority supports the oversight of the vast aviation industry. On one hand, for large aviation enterprises, the FAA adjusts its delegation management policies timely, enhancing airworthiness management by establishing airworthiness delegated organizations through authorizations granted to entities, transitioning from individuals. On the other hand, the FAA supports a substantial number of individual delegations, particularly for independent consultants and individuals not affiliated with a specific aviation manufacturing company. This approach helps reduce airworthiness management costs and ensures that the FAA, with its limited resources, can support the development of the numerous small-scale aviation manufacturing businesses effectively.

Despite widespread concerns about FAA's delegation of certification responsibilities to major manufacturers following the 737 MAX aircraft accidents, U.S. legislative bodies have continued to strengthen the functions of organization designation authorization (ODA). In December 2020, the United States enacted the Aircraft Certification, Safety, and Accountability Act, which aimed to enhance the ODA system, tighten certification policies, and bolster the capabilities of certification teams. These measures specifically addressed issues related to excessive authority granted to regulatory authorities and applicants concealing safety defects, emphasizing accountability in the process.

2.2 Overview of European Flight Testing and Airworthiness Management

The aviation industry in various European countries has an early start and advanced technology, but it is somewhat decentralized. Each country has its own flight test centers, including: The French Flight Test Center, which is France's official flight test organization responsible for both military and civil aircraft test missions. It is a comprehensive flight institution that combines pre-research with type certification[8-9].The United Kingdom's flight test operations, which have undergone significant reforms and are now under the privately-owned QinetiQ Group. They primarily handle research flight missions. Germany's flight test operations under the German Aerospace Center (DLR), which mainly handle research flight missions. The Netherlands' flight test operations under the Netherlands Aerospace Center (NLR), which primarily undertake research flight missions.

In the civil aviation sector, driven by competition with the U.S. aviation industry and the process of European integration, both Airbus (Airbus Group) and the European Union Aviation Safety Agency (EASA) were established. This was accompanied by the reorganization and integration of flight testing resources. The integrated structure of the European aviation industry is similar to that of the United States, with the key difference being that Europe's highly specialized aviation industry is dispersed across various European countries, each specializing in specific areas. As a result, EASA has learned from and adapted the certification regulations of the Federal Aviation Administration (FAA) to align with the characteristics of the European aviation industry. EASA's airworthiness management approach reflects the uniqueness of the European aviation sector. Airworthiness management places a strong emphasis on entry qualifications and focuses on a company's capabilities. It requires aviation companies to demonstrate their design and production capabilities by obtaining Design

Organization Approval (DOA) and Production Organization Approval (POA). The core of DOA is the requirement for applicants to have a mature Design Assurance System (DAS) and to implement this system through the creation and implementation of a Design Assurance Manual. This approach splits the airworthiness requirements for aviation products into "organization approval" and "type approval," ensuring that companies can assume corresponding airworthiness responsibilities. As the European aviation industry has developed, EASA has become an important airworthiness authority with equal standing to the FAA, playing a crucial role in ensuring the airworthiness and safety of European aviation products.

2.3 Overview of Flight Testing and Airworthiness Management in Russia

Despite being a traditional powerhouse in the aviation industry, Russia has faced challenges in the development of civil aircraft[10]. Nevertheless, Russia maintains a world-class scale and capability in flight testing, with specialized flight testing institutions concentrated in two main centers: the Air Force Red Banner Research Institute and the Gromov Flight Research Institute under the Ministry of Aviation Industry.The Red Banner Research Institute primarily handles national-level certification and operational flight testing, while the Gromov Flight Research Institute focuses on research flight testing and new aircraft development, responsible for the development of flight test technology for all military and civilian aircraft[11].Russian aircraft design bureaus also conduct some development flight testing, but these tests are conducted under the control and guidance of the Gromov Flight Research Institute. The Gromov Flight Research Institute operates a vast fleet of over 200 specialized research aircraft, which forms the foundation and prerequisite for Russia's aviation industry to maintain its technological competitiveness.

Due to historical reasons, the former Soviet Union initially developed a set of airworthiness systems and standards that differed from those in Western countries when it began developing its civil aircraft industry. It was only after the dissolution of the Soviet Union that Russia gradually started aligning its civil aircraft airworthiness standards with Western practices. Until 1991, 12 CIS countries including Russia established the Interstate Aviation Committee (IAC) in Minsk and adopted the "Agreement on Civil Aviation and the Use of Airspace," which aligned their airworthiness systems with FAA regulations. This agreement enabled these member countries to establish unified airworthiness regulations and standards, following a system similar to that of the FAA.

While Russia has advanced capabilities in the development of military aircraft, its civil aircraft industry has faced challenges in achieving technological maturity, especially in terms of safety, economics, and passenger comfort. There remains a significant gap between Russia's civil aircraft airworthiness certification capabilities and those of Western countries, due to various factors such as political, economic, and design philosophies. The transition from a self-contained airworthiness system with unique standards and management procedures during the Soviet era to the current alignment of airworthiness regulations with those of FAA and EASA demonstrates the Russian government's commitment to the development of the civil aviation industry. It also reflects the rapid growth and adaptability of both Russian regulatory authorities and the civil aviation industry to international standards and practices.

2.4 Current Situation of Domestic Civil Aircraft Flight Test and Airworthiness Management

For a long time, China's dedicated flight testing institution has been the China Flight Test Establishment (CFTE), founded in 1959. It is the only national-level certification and flight testing organization authorized by the Chinese government for military and civilian aircraft, aviation engines, airborne equipment, and other aviation products. CFTE is a national-level flight testing research institution and serves as the national "Aircraft Airworthiness Certification Laboratory." It also provides guidance for flight testing activities at aerospace industry facilities in China and has built the largest flight testing infrastructure and research aircraft fleet in Asia.As shown in Figures 2 and 3, the most representative aircraft for demonstrating and validating China's advanced aviation technologies were selected. These are the Engine Airborne Testbed and Radar Electronic Testbed, representing China's aviation industry development level in the 1990s.In 2008, Commercial Aircraft Corporation of China (COMAC) was established, and in 2012, the COMAC Civil Aircraft Flight Test Center was founded on the basis of the former Shanghai Aircraft Manufacturing Factory Flight Test Site. This center is responsible for various flight tests of COMAC's civilian aircraft models and conducts factory acceptance flight tests.

Fig. 2. Decommissioned Aircraft Engine Airborne Test Stand

Fig. 3. Yun-8 Radar Electronic Test Aircraft

Starting in the 1970s, the Civil Aviation Administration of China (CAAC) began adopting the airworthiness management model of the Federal Aviation Administration (FAA) to oversee airworthiness management for Chinese civil aircraft. With the increasing prosperity of China's aviation manufacturing and transportation industries, the airworthiness management and airworthiness system in China have continuously improved and enhanced. Especially after the complete type certification processes of the Xinzhou 60, Xinzhou 600, ARJ21-700 regional jet, and the C919 large passenger aircraft, China's capabilities in civil aircraft development, flight testing technology, and airworthiness certification have significantly improved. Furthermore, research has gradually entered into specialized areas [12-22]. Following the 737 MAX accidents, China made a decisive decision to ground all domestic 737 MAX aircraft, showcasing its technological confidence.

3 Problems in Domestic Flight Test and Airworthiness Management

Through comparative analysis, the flight testing and airworthiness management systems of various countries have their respective focuses and advantages and disadvantages based on the realities of their aviation industries. Both the FAA's management model and EASA's management model have improved review efficiency and saved review costs. However, the FAA's management model lacks a comprehensive assessment of the applicant's system and lacks third-party oversight, which could lead to transitional authorizations resulting in safety oversight gaps. EASA's management model, on the other hand, lacks delegation to individuals and may not make the maximum use of industry resources.

China, as a relatively latecomer in civil aircraft development, has embraced a diverse approach by adopting and developing the best practices from both the FAA and EASA [23-25]. For instance, China has introduced FAA's delegation authorization for organizations and individuals, as well as integrated EASA's design assurance system review mechanism, providing strong support for the growth of the civil aviation industry. After obtaining certification for the C919 large passenger aircraft, China has faced even fiercer competition in the international civil aviation market, necessitating the optimization of flight testing and airworthiness management systems. A comprehensive analysis reveals the following shortcomings in the current management models.

3.1 Weaknesses in fundamental aviation research and technology

Weakness in fundamental aviation research and technology is evident, creating a contradiction between the insufficient existing knowledge base and the continuous high-speed development. China's aviation industry started relatively late and had limited resources, initially focusing on imitation and replication. Today, there has been progress in indigenous research and development in certain areas, but comprehensive independent innovation has not yet been fully achieved. This is particularly evident in the civil aviation sector, where aircraft models like the Xinzhou series, ARJ21 regional jets, and the C919 large passenger aircraft have achieved overall technological integration but still rely on foreign expertise in key areas such as aircraft engines, avionics, flight control, and electromechanical systems.

At the level of airworthiness technical standards, due to the lack of foundational research, the absence of knowledge inheritance and accumulation, there is a prevalent phenomenon of following standards blindly without a deep understanding of the underlying logic. In comparison to Russia, we also have gaps in this aspect. For example, in Russia, the standardization of aviation materials begins with material exploration research and extends to integrated design, manufacturing, and maintenance. The key feature is having an independent testing foundation, which allows for the development of unique, advanced, and comprehensive standards that are not merely copied from foreign standards in many areas [26].

Therefore, in the current situation where there is a contradiction between the insufficient knowledge base in foundational research and the continuous high-speed development needs of the aviation industry, how can we make the leap from "tracking and imitation" to "independent innovation"? How can we bridge the "valley of death" between theoretical innovation and practical application in the aviation field? These are serious challenges faced by aviation professionals. At this point, the construction of new experimental research platforms and the conduct of research-oriented test flights and demonstration verification flights for new concepts and key technologies are inevitable pathways for the development of civil aircraft.

3.2 Lack of management and coordination in civil aircraft test flights

There is a lack of coordinated management in civil aircraft flight testing, leading to a contradiction between underutilized flight test resources and a shortage of approved flight test resources. At the current stage, this contradiction is mainly manifested in the following ways:(1)There is duplicate construction and dispersed locations of flight test experimental infrastructure, which hinders unified management and makes task coordination difficult.(2)Resources for testing prototype aircraft are not fully utilized.

In Russia, for example, 70% of test aircraft are locally modified mature aircraft used as specialized testbeds for flight experiments.(3)Organizations with mature levels of expertise in aircraft design, manufacturing, flight testing, and a large number of well-trained and experienced test pilots and flight test engineers lack sufficient delegation and authorization.

Based on national efforts to coordinate the management of flight test resources and civil aircraft flight testing models, and drawing inspiration from the FAA's organizational delegation authorization management model, authorizing qualified Designated Engineering Representatives (DERs) can provide efficient and expedited airworthiness certification services. This approach is of great significance in reducing government certification costs, ensuring flight test safety, and improving flight test efficiency.The FAA's organizational delegation authorization includes six major categories, such as major alterations and repairs, production approvals, parts manufacturing approvals, type certificates, supplemental type certificates, and technical standard order authorizations, involving a total of 150 aviation units [3]. Currently, only a very limited number of organizations in China have obtained CAAC's Designated Organization Representative (DOR) qualifications, and these are primarily limited to the fields of aircraft modifications and airworthiness inspections.

3.3 Civil aircraft flight testing and airworthiness management system is not perfected

The civil aircraft flight testing and airworthiness management system in China is not yet perfect and faces challenges stemming from the conflict between adopting foreign standards and achieving domestic adaptability. It is undeniable that China's airworthiness management model does not fully align with the characteristics of its aviation manufacturing industry. On one hand, China's aviation manufacturing industry has primarily focused on military aircraft models for a long time and has not yet developed a complete civil aviation industry chain. On the other hand, due to differences among individual entities, wholesale replication of the management models of companies like Boeing and Airbus is not suitable for the development of China's aviation industry.While the advanced flight testing and airworthiness management models and experiences from Europe and the United States can serve as references for China's airworthiness system development, adapting them to align with China's unique aviation industry development context is crucial [27-31].

Compared to countries like the United States and Europe, China's level of flight testing and airworthiness verification is still in a developmental stage and there is a significant gap when compared to the world's advanced standards. China has not yet established a relatively scientific and comprehensive set of verification methods and procedures, and there is a lack of engineering experience and knowledge accumulation in this regard. Therefore, it is essential to combine the practical aspects of civil aircraft development and airworthiness work in China, conduct in-depth research on airworthiness standards and compliance verification methods, especially focusing on research related to airworthiness regulations and standards. The goal is to develop a set of compliance verification processes that align with China's civil aviation industry, ultimately establishing a complete and efficient civil aircraft airworthiness system.

For example, Russia, while absorbing and adapting European and American airworthiness certification procedures, has taken into account its own aviation industry characteristics. They have introduced additional verification and validation at the prototype model stage and established a Prototype Model Committee dedicated to completing the certification work at this stage. Prototype models can accurately simulate various characteristics of the original aircraft, representing a partial mapping of the aircraft in virtual space. This is of significant importance for the compliance assessment of aircraft flight characteristics, structural integrity, and more.

4 Suggestions on the Development of Civil Aircraft Flight Test and Airworthiness Management

When examining the current status of flight testing and airworthiness management both domestically and internationally, several common characteristics can be observed:

1. Experimental research flights conducted using research aircraft as platforms for testing new concepts and technologies have consistently led the forefront of aviation technology development.
2. Robust foundational research capabilities are crucial for establishing airworthiness regulations and technical standards. They are prerequisites for gaining influence within the industry.
3. At the national level, coordinated management of significant flight test infrastructure and the sharing of flight test resources, avoiding redundant construction, has consistently been a guiding principle followed by various countries.
4. The technical capabilities for civil aircraft development and flight testing are often rooted in military aircraft experience, but they have developed their own systems within the constraints of airworthiness regulations, complementing each other.
5. The gradual improvement of the airworthiness system and the enhancement of certification capabilities have always accompanied the sustained growth of a nation's aviation industry.
6. Flight testing and airworthiness certification of aircraft involve highly complex systems. To improve the efficiency of certification flight testing and ensure safety, it is imperative to strengthen third-party oversight.
7. Due to the international nature of airworthiness standards, while countries borrow from FAA standards, they adapt them according to their own circumstances, establishing flight testing and airworthiness management systems that align with their unique industrial characteristics.

4.1 Strengthening the development of experimental research aircraft and foundational research capabilities is essential

Emphasizing the importance of experimental science and strengthening the development of experimental research aircraft and foundational research capabilities is crucial. For many years, China's aviation industry has followed a path of importing, surveying, replicating, and modifying products. While some technological progress has been achieved in recent years through technology transfer and collaboration, this progress is still largely built upon the research efforts of others. To transition from imitation to independent innovation in the field of aviation, China needs to verify a plethora of foundational research aspects, including new concepts, technologies, processes, and applications. These aspects have already transcended the model of imitation and require breakthroughs in experimental theory, methods, and innovation in experimental techniques. Every field is eagerly awaiting experiments guided by scientific principles to pioneer advancements. In this process, experimental science, represented by flight testing, will build the foundation for the development of aviation technology, supporting and leading continuous in-depth research in aviation fundamentals.

In the United States, nearly all significant breakthroughs and successful applications of new aviation technologies have been achieved through flight testing research and verification. In 2020, NASA introduced the Aeronautics Assessment and Test Capability Program in addition to its existing four major research programs, emphasizing the importance of flight testing and experimental science even further. Russia explicitly states that engines and onboard products cannot be used in new aircraft designs without prior advanced research flight testing. European countries also place great emphasis on leading flight testing research in aviation technology, with a focus on their key technologies tailored to their individual national circumstances.

Therefore, to support the development of aviation foundational science, increase knowledge assets, and enhance international influence in airworthiness standards, it is necessary in China to upgrade and add various new experimental research aircraft on the basis of existing ones. These research aircraft should be used for research flight testing, thereby elevating the level of technological maturity. These experimental research aircraft could encompass, but are not limited to:(1)Exploratory research aircraft for new theories and concepts such as blended-wing body, new energy, and low sonic boom.(2)Demonstration and validation test aircraft for new technologies and systems like flight control, flutter/aeroelasticity, and adaptability to complex environments.(3)Airborne laboratories for the development of systems and products like engines, onboard avionics, and electromechanical equipment.(4)Support test aircraft for various purposes including measurement/relay, ice detection/de-icing, and formation flying photography.

4.2 Suggestions on the Management Mode of Civil Aircraft Flight Test

Flight testing is a complex system engineering endeavor that combines scientific, practical, and risk-related elements. It requires substantial investments and involves highly intricate technologies. Leveraging the advantages of a new national system, pooling nationwide resources, scientifically coordinating efforts, and collaborating intensively are necessary steps to develop a "China-specific" civil aircraft flight testing management model. This model should emphasize originality, breakthroughs, and leadership to support and drive the development of China's aviation industry.

Adhering to the "main test site" principle is crucial. For significant aircraft models' flight testing, it is essential to concentrate these efforts at designated flight test centers. This approach leverages national resources, brings together specialized personnel, and treats model flight testing as a focused campaign. This strategy helps avoid dispersion of efforts to smaller locations, which can result in dispersed technical expertise and resource allocation, coordination challenges, and decreased testing efficiency. For instance, in the United States, the U.S. Air Force conducts all of its flight testing at Edwards Air Force Base whenever possible. In Russia, there are 17 flight test stations around the Gromov Flight Research Institute's airfield, which collectively utilize the nation's flight testing resources.

Adhering to the "joint flight testing and comprehensive flight testing" concept is important. Concentrated flight testing facilities provide the foundation for joint flight testing. In the context of civil aircraft joint flight testing, it involves:(1)Organizational Management: It entails discarding the backgrounds of smaller units and forming an integrated joint flight testing team that effectively manages and coordinates resources from applicants, regulatory authorities, suppliers, and other relevant parties.(2)Flight Test Design: This approach aims to conduct research, demonstrate compliance, and certify flight testing in parallel as much as possible, reducing unnecessary duplication of flight testing efforts.(3)Incorporating AEG and Operational Compliance Verification: This ensures that Aircraft Evaluation Group (AEG) and operational compliance verification flight testing activities are integrated throughout the entire qualified certification flight testing process, allowing for early aircraft delivery and operation.

4.3 Suggestions on the Airworthiness Management System for Civil Aircraft Test Flights

In 2018, the Civil Aviation Administration of China (CAAC) issued the "Action Plan for Building a Strong Civil Aviation Nation in the New Era." This plan introduced new requirements aimed at enhancing airworthiness certification capabilities. It outlined the need to improve the management system for civil aviation flight testing, optimize and refine airworthiness management measures and procedures, and take a risk-based approach to airworthiness certification project management. Furthermore, the plan emphasized the importance of ongoing development by dynamically optimizing airworthiness standards and management systems. These initiatives form the foundation for constructing a China-specific civil aircraft flight testing and airworthiness management system, allowing it to adapt to evolving industry needs and safety considerations.

Implementing the delegation of authority to Designated Organization Representatives (DORs) is a significant step in aviation regulation. The purpose of authorizing DORs is to establish a comprehensive system for delegating authority, allowing aviation enterprises that have produced mature aircraft models, possess well-structured organizations, core competencies, and expert advantages to have more autonomy. This recognition acknowledges their effectiveness in certain airworthiness verification tasks. By granting DOR qualifications to authoritative flight test organizations during the certification flight testing process, several benefits are achieved:(1)Efficiency and Cost Reduction: DORs can provide efficient services, reducing certification costs.(2)Third-Party Oversight: The introduction of third-party oversight strengthens safety management.(3) Following the "risk-based" management principle, the Civil Aviation Administration of China (CAAC) can concentrate on other areas that have a more critical impact on safety.(4)For designated organizations, more autonomy and greater delegated responsibilities instill independence and a sense of accountability. This encourages them to leverage their professional expertise and enhance their core competitiveness effectively.

It's worth noting that even after the 737 MAX accidents raised questions about the FAA's authority, the United States retained the Designated Organization Representative (DOR) system through legislation. This decision is influenced by the nature of flight testing and airworthiness verification activities, which constitute complex and adaptive systems with highly differentiated yet interdependent components. These components operate independently but require high coordination and close connections. If such a system relies solely on external forces for coordination, supervision, and enforcement, it would likely incur high costs and low efficiency. To achieve a balance between safety and efficiency, and to harness the efficiency of the emergent properties of the system as a whole, it's essential to activate the system's self-regulation and self-correction capabilities. This approach allows for both safety and efficiency and maximizes the effectiveness of the overall system.

Exploring effective mechanisms for flight test resources to support operations is crucial. Here are three key mechanisms to consider:(1)Emphasizing a flight testing approach that focuses on gathering evidence for operations can significantly enhance the efficiency of certification flight testing. This approach involves parallel activities conducted by flight test organizations, both commissioned by the airworthiness certification authorities and by flight standards authorities. These parallel activities include simulator data extraction, flight manual verification, maintenance manual verification, ground support equipment verification, master minimum equipment list verification, and human factors assessment, among others. Integrating these activities into the certification flight testing process can streamline the process and improve efficiency.(2)Flight test pilots involved in certification activities are skilled in exploring the maximum safety envelope of an aircraft beyond normal operating limits. They typically possess superior flying skills compared to line pilots. However, due to the multi-system operation and cross-departmental cooperation, their experience in experimental flight within the aviation industry system may not be explicitly recognized by civil aviation systems. Addressing this issue and allowing experienced test pilots to support the training of line pilots as instructors could enhance the aviation workforce.(3)The flight test process involves a continuous cycle of discovering, analyzing, and resolving issues, leading to the accumulation of reliability and maintainability data. Establishing mechanisms for sharing data among aircraft design, flight testing, and airline operations can be highly valuable for improving aircraft design, enhancing ongoing airworthiness, and ensuring operational safety.

5 Conclusion

The strategy for the development of the aviation industry in the United States is as follows: "To address the long-term damage to our aviation capabilities, it can be compensated for by reinitiating the X-plane program that supports research and development. This includes retrofitting existing suitable test aircraft to conduct advanced concept flight research."In the transformation process of China's aviation industry from tracking and imitation to independent innovation, there is a need for optimization in the flight testing models, the establishment of autonomous airworthiness standards, and the improvement of flight test compliance verification methods and systems. Additionally, it is essential to strengthen the research and development teams focused on experimental exploration and validation of new concepts and technologies.

We need to have a clear understanding that although China's aviation industry has achieved leading results in certain areas, the current situation of weak technological foundations and limited capabilities has not changed. Especially in the field of civil aircraft development, there is still a significant gap compared to aviation powerhouses in Europe and the United States. It is essential for us to leverage the advantages of the national system according to the actual layout and development stage of China's aviation industry. We should establish a distinctive Chinese civil aircraft flight test and airworthiness management system, contributing our efforts to the sustained high-speed development of the aviation industry.

REFERENCES

1. Zhu Fengyu. Airworthiness Management of Civil Aircraft [M]. National Defense Industry Press, 1991.
2. Civil Aviation Administration of China, Aircraft Airworthiness Authority. Airworthiness Management of Civil Aircraft in China [M]. China Civil Aviation Publishing House, 1994.
3. Philippe de Florio, Florio, Zhao Yuerang, et al. Airworthiness: An Introduction to Aircraft Certification [M]. Shanghai Jiao Tong University Press, 2013.
4. Wang Lixin. Airworthiness Regulations, Flight Quality Standards, and Design Guidelines [J]. Flight Mechanics, 2000, 18(2):4.
5. Huang Xiong. Some Thoughts on Airworthiness Management of Civil Aircraft Design Organizations [C]// Building a Moderately Prosperous Society in All Respects and the Development of China's Aviation—Proceedings of the First China Aviation Science and Technology Conference in 2013. 2013.
6. Xu Chenhua. New Developments and Technical Performance of the US MQ-9 UAV [J]. Aerospace Missiles, 2018(7):7.
7. Zheng Pai. Analysis of Recent US Legislation on Civil Small Unmanned Aircraft Control [J]. Journal of Beihang University: Social Sciences Edition, 2017, 30(5):9.
8. Zhou Ziquan. "Flight Test Engineering" [M]. Aviation Industry Press, 2010.

9. Civil Aviation Authority. EASA Aircraft With an Expired UK (National) Certificate of Airworthiness.
10. Karnozov V. Incongruent rules threaten delays to EASA certification of Russian jets [J]. Aviation International News, 2019, 50(2):49-49.
11. Zhang Bing, Zheng Shuofang, Lv Baoliang. Comparative Analysis of Aviation Standards Differences between China and Russia [J]. Aviation Standardization and Quality, 2018(2).
12. Li Chaohui, Chen Ming, Zhang Qilong, Wang Sanmin. Flight Management System Flight Test Verification Technology for Civil Large Aircraft [C]// Key Technology Forum for Large Aircraft and the 2007 Academic Annual Meeting of the Chinese Society of Aeronautics. 2007.
13. Yang Yajun, Li Yanjun. Improved Maximum Likelihood Algorithm and Its Application in Flight Test Data Processing [J]. Acta Aeronautica et Astronautica Sinica, 1997.
14. Wang Wei. Establishment and Parameter Estimation of Nonlinear Multipoint Models for DO 28 [J]. Acta Aeronautica et Astronautica Sinica, 1990, 11(7):9.
15. Feng Yachang, Wang Yong, Wang Zhanlin. Research on DFBW Aircraft Man-Machine Closed-Loop Longitudinal Landing Characteristics [J]. Acta Aeronautica et Astronautica Sinica, 1992, 13(2).
16. Su Shaopu, Chang Wenkui, Chen Xianmin. Experimental and Analytical Methods for Shear Buckling Fatigue of Typical Aircraft Panel Structures [J]. Acta Aeronautica et Astronautica Sinica, 2022, 43(5):10.
17. He Qiang, Tan Deqiang, Cheng Lin. Eye Movement and Fatigue Detection in Visual Inspection of Composite Materials in Civil Aircraft [J]. Acta Aeronautica et Astronautica Sinica, 2020, 41(5):9.
18. Dong Lei, Xiang Chenyang, Zhao Changxiao, et al. Comprehensive Evaluation of Human-Machine Efficiency of Cockpit Display Touch System for Civil Aircraft [J]. Acta Aeronautica et Astronautica Sinica, 2021, 42(6):15.
19. Li Yaohua, Gong Ziyu. Analysis of Aircraft System Safety Based on Improved FRAM [J]. Acta Aeronautica et Astronautica Sinica, 2020, 41(12):11.
20. Li Hongyun. Discussion on Airworthiness Issues of Composite Materials in Civil Aircraft Applications [J]. Aircraft Manufacturing Technology, 2009(16):4.
21. Guo Xiangdong, Zhang Pingtao, Zhao Zhao, Lai Qingren, Guo Long. Airworthiness Application Compliance Verification of Large Icing Wind Tunnel Cloud and Fog Field [J]. Acta Aeronautica et Astronautica Sinica, 2020, 41(10):15.
22. Chen Xiyuan, Shao Ziyang, Yang Jianzhong. Equivalent Method of Smoke in Aircraft Cargo Compartment Based on Reverse Design [J]. Acta Aeronautica et Astronautica Sinica, 2020, 41(11):123991-123991.
23. Chen Shan. FAA Engineering Approval Procedures for Aircraft Configuration Changes [J]. Civil Aviation Economy and Technology, 1998(09):15-17.
24. Shi Binbin. Research on FAA Individual Designee System [J]. Aircraft Design and Research, 2016(1):7.
25. Shi Binbin. An Analysis of the Authorization Functions of FAA and CAAC Designees in the Manufacturing Inspection Field [J]. Aircraft Design and Research, 2016, 000(004):61-66.
26. FAA. Organization Designation Authorization Procedures, ORDER 8100-15A.
27. Zhang Yuemei, Pu Chuanbin, Liu Xiaohua. A Brief Discussion on Airworthiness Management of Civil Aircraft [J]. Aircraft Design and Research, 2008(2):6.
28. Zhang Longdong. Analysis of Airworthiness Management Systems for Civil Aircraft at Home and Abroad [J]. Aircraft Design and Research, 2013(4):5.

29. Jiao Lianyue, Li Huaxing. Strengthening Airworthiness Management in China's Civil Aviation from the Perspective of FAA [J]. Journal of Northwestern Polytechnical University: Social Sciences Edition, 2009(3):5.
30. Zhong Zhaowen. A Brief Introduction to Airbus Group's Airworthiness Management System [J]. Aircraft Design and Research, 1998(1):4.
31. Mao Keyi, Wei Shuyou. Analysis of FAA Airworthiness Management Organizations [J]. Aviation Standardization and Quality, 2012(4):3.