Proposal for Aviation Safety Certification System and Technical Standardization

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Extremely high levels of safety and reliability are required for aircraft that transport people and goods by air in tough environments. Moreover, because aircraft are used internationally, aviation safety systems are enacted based on international treaties and aircraft in every country need to operate in a unified way. In Japan, the development of all passenger aircraft ended with the YS-11, which was developed half a century ago. However, in Japan domestic passenger aircraft development program officially restarted in 2008, and resumed being an aircraft manufacturing country. The public and private sectors are now working on obtaining type certifications to ensure the safety of the aircraft being developed in Japan. At the same time, aircraft are becoming more complex with the full-scale introduction of computer systems and new materials, such as CFRPs (carbon fiber reinforced plastics). Safety inspections and certifications have become extremely strict by incorporating countermeasures to investigate the cause of aircraft accidents. That safety certifications and inspections are difficult is clear from the fact that Japan's passenger aircraft development program is taking a long time.

Type certification, a mechanism to provide a new aircraft to the market safely and efficiently, ensures the performance and safety of mass-produced aircraft during development by the manufacturing country and by the operating country during operation. Examinations for certification require deep expertise and experience. In Europe and the United States, governments set rules for cooperation with the private sector, and both areas are conducting joint reviews. However, as can be seen from the response to recent passenger aircraft accidents, it is not easy to ensure safety.

In Japan, the Next-Generation Sky System Research Unit (formerly the Aviation Policy Unit) has formed an industry-government-academia aviation innovation study group with the Presidential Endowed Chair for the Center for Aviation Innovation Research, and intended to conduct research on the safety certification system. The trigger for this new approach was the Boeing 787 battery accident [1, 2], and we have been studying the standardization of new technology certification methods through discussions and symposiums with standardization organizations in Europe and the United States [3–7].

With these certifications activities in mind, we summarizes the changes in the aviation safety certification system—focusing on the US, a country with advanced aircraft development —and makes recommendations for the future of the Japanese aviation industry as well as the safety certification system, which is becoming ever more complex with massive systems.

Policy recommendations

1. Expertise from the private sectors should be used to explore methods of compliance for new technologies towards type certification

Innovative technologies have been widely adopted for the development of new aircraft, including unmanned aerial vehicles (UAVs). Given these circumstances, it is difficult for government officials alone to establish a method of compliance for new technologies towards type certification, or a mechanism for ensuring safety and reliability, with respect to new technologies. To promote the development of aviation technology in Japan, a committee should be established, such as the US Aviation Rulemaking Advisory Committee (ARAC), which includes experts from the private sector. In addition, an ad hoc committee (in the United States, the Aviation Rulemaking Committee, or ARC) should be established jointly with private-sector experts according to certain themes.

2. Consensus based approach between the public and private sector should be leveraged to develop Type Certification approvals methods for new technology

It should be noted that the above discussions at the ARAC and ARC in the United States are supported by the activities of various non-profit organizations called technical standards developing organizations (TSDO) in the private sector. At TSDOs, not only companies and research institutions that develop new technologies but also airlines and airports that use them as well as regulators and academic experts participate in discussions that go beyond the interests of companies. The standardization of technology is important in the aviation industry, where safety assessments are strict, in order to employ new technologies. Collectively, this is called a technology coordination area. In Japan as well, in new fields such as small unmanned aerial vehicles ("drones") and electric vertical take-off and landing aircraft ("flying vehicles"), public-private councils have been set up to discuss policy and development goals. For aviation technology in general, technological standardization should be promoted through public-private partnerships in order to promote the practical application of new technologies.

3. A new process is required to improve the reliability and transparency of system certification

Aircraft type certification is essentially being implemented by governments, and a part of the type certification process uses the in-house certification system of the aircraft manufacturer. However, the closed environment with these parties acting alone was questioned after the near-consecutive crashes of the Boeing 737 MAX on October 29, 2018 and March 10, 2019. Every country should cooperate in designing a new system to improve the reliability and transparency of aviation safety certification processes, such as type certification.

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1. Overview of the type certification system

Aircraft cannot fly without airworthiness certifications for strength, structure, and performance that meet safety and environmental standards. In mass-produced aircraft, design and manufacturing capabilities are inspected together with various tests, as the type certification, and an airworthiness certification can be obtained for a type of aircraft. Since the type certification is issued by the country of manufacture, when operating in a country other than the country of manufacture, a type certificate for that country is also required. Although this type certification is valid after operation begins, an airworthiness certification must be continually obtained for every individual aircraft in the operating country. However, if it is determined that an improvement is necessary due to an accident or serious problems, feedback will be given for the type certification through a technical circular directive (TCD) or an airworthiness directive (AD) (Fig. 1).

A system to ensure the safety of aircraft was discussed when international operations of aircraft began after World War I, and was specified as a certificate of airworthiness and performance of aircraft at the 1919 Paris International Aviation Convention [8]. This framework had a fresh start in 1944 (during World War II) as the Chicago International Civil Aviation Treaty. In 1947, the International Civil Aviation Organization (ICAO), a specialized agency of the United Nations, was established. Airworthiness certificates for aircraft were required in Chapter 55 of the ICAO Convention, and the contents of airworthiness certification and type certification were described in Annex 8 [9]. However, since the method of airworthiness certification was defined in each country, the ICAO regulations were conceptual standards, with the details being left up to each country. In Japan, airworthiness is specified in the Airworthiness Examination Guidelines [10], but exceptional items and items that are not described there, such as new technologies, are subject to individual examinations under "special requirements," "equivalent safety," and "exemptions" .

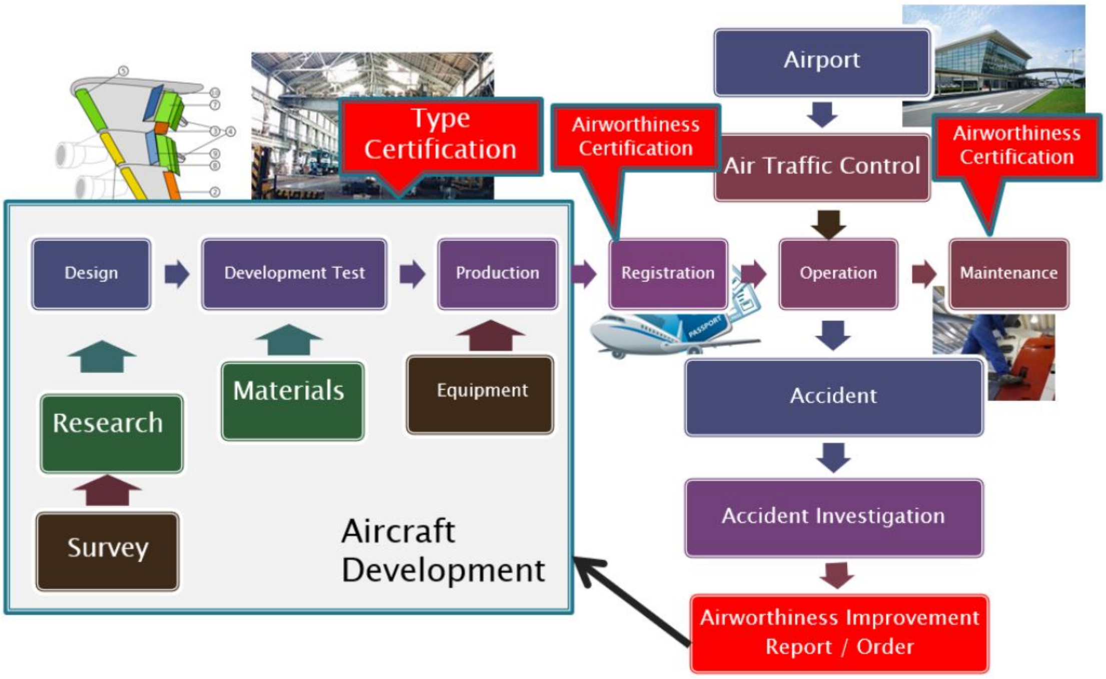

Figure 1. Aircraft type certification and airworthiness certification (Note: If the country of manufacture and the country of operation are different, type certification and airworthiness certification in the country of operation are also required.)

2. Safety certification for new technologies

The method of airworthiness certification was created during the history of aircraft development and has been formulated in each country. With rapid advancements in technological innovation, such as the adoption of computerized flight controls (“fly-by-wire”) in aircraft since the 1980s, some aircraft accidents related to this technology have occurred [11]. To deal with these circumstances, the Federal Aviation Administration (FAA) formed a standing aviation rulemaking advisory committee in 1991 to seek industry and public advice as well as recommendations on issues that could lead to safety rules. The Aviation Rulemaking Advisory Committee (ARAC) was established in 1991 for making recommendations [12]. The ARAC may also have an ad hoc committee as ARC (Aviation Rulemaking Committee), set up for investigating a specific subject for a limited period of time (Fig. 2). ARAC members are representatives of the aviation association, the aircraft industry, as well as public interest and advocacy groups and overseas civil aviation authorities. ARC committees usually include additional experts from manufacturing, the airlines, universities, and research institutions [12].

In the US, the policy of collaborating with the private sector to establish rules on aviation safety was heightened by the explosion and crash of TWA flight 800 into the Atlantic Ocean in July 1996. At that time, President Clinton set up a committee to improve aviation safety (known as the Gore Commission), calling for improvements in airworthiness certification standards. The following items were included [13]:

- standardizing certification technologies
- devising performance-based rules for adopting new technologies.

Performance-based rules formulate the performance to be achieved, but do not specify the means to achieve it, and are thought to encourage the promotion of new technologies [14].

3. Formulation of safety guidelines by technical standards developing organizations (TSDO)

In response to the Gore Commission's recommendations, European and American technical standards developing organizations (TSDO) have been developing guidelines for aviation safety design [5]. TSDOs are non-profit technical organizations such as SAE [15] and RTCA [16] in the US and EUROCAE [17] in Europe. The results of their discussions on standards have contributed to ARC in the US. SAE, launched in 1905 as the Society of Automotive Engineers, originally set standards for the supply and availability of parts during the recession of 1907–10. SAE later became a broader technical standard developing organization that included industries such as aviation and tractors. RTCA (Radio Technical Commission for Aeronautics), established in 1935 as a volunteer organization to develop technical guidelines for the aviation industry and authorities, was reestablished in 1991 as a private non-profit corporation. EUROCAE (European Organization for Civil Aviation Equipment) is a European-based organization established in 1963 to promote the standardization of aircraft and aviation equipment and air traffic control.

SAE published an analysis method for the safety of aircraft systems in 1996 called SAE ARP 4761, connected with SAE ARP 4754, for distributing safety requirements to subsystems. RTCA and EUROCAE developed DO-254 (a component-specific hardware development assurance process in 2000) and DO-178B (software considerations in airborne systems and equipment certification). The design guidelines (Fig. 3) linking these systems have become popular as industry standards, and their use is recommended in the FAA's Advisory Circulars (ACs) and other documents [18].

Figure 2. The role of standards developing organizations in the formulation of US safety rules

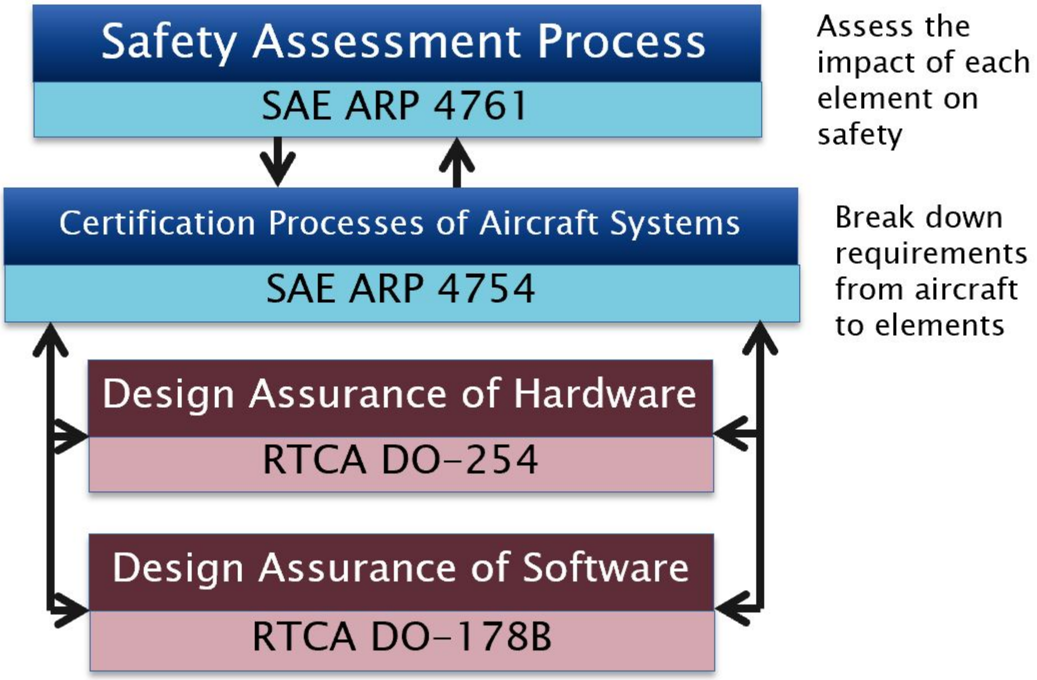

Figure 3. Safety design guidelines for aircraft systems

The role of the TSDO has been further strengthened with a major revision of the small aircraft (Part 23) certification process in the United States, largely involving the standardization organization American Society for Testing and Materials. In 2001, this organization was renamed ASTM International to reflect the internationalization of the ASTM standard [19]. Since small aircraft manufacturers are generally limited in size, the conventional method of type certification could hinder the adoption of new technologies. To specifically address the needs of smaller aircraft companies, the FAA organized the 14 CFR Part 23 Reorganization Aviation Rulemaking Committee [20]. As a result, in 2017, the FAA revised the airworthiness standards for small aircraft, Part 23, and created 63 methods based on performance-based to enable innovative and safe technologies to be efficiently applied to small aircraft. This standard for small aircraft adopted the ASTM guidelines [21, 22]. This trend is also being seen in Europe, where EUROCAE is setting the industry standard for unmanned aerial vehicles (UAVs) and electric vertical take-off and landing (eVTOL) aircraft called "flying cars" [23].

4. Situation in Japan

In Japan, the development of civil aircraft was not active until recently and the revision of the type certification method was not aggressively pursued. However, the development of MRJ (renamed the Mitsubishi SpaceJet in 2019) has progressed, and the development of some small unmanned aerial vehicles and "flying cars" has also been done in Japan. Consequently, the situation with aircraft development and certification has changed substantially. For example, the roadmap announced by the Public-Private Council on the Revolution of Air Transportation states that it is necessary in Japan to develop type certification methods in cooperation with international activities [24]. To carry out this work efficiently, a public-private partnership is essential. As well, it is necessary to immediately have an advisory committee and ad hoc committee system, similar to ARAC and ARC introduced by the FAA. In addition, to deepen the discussion, it is necessary to develop an organization that allows stakeholders to work together with authorities, research institutions, and university experts [3, 4].

5. Bilateral agreement on type certification

After a type certificate is obtained in the country of manufacture, if the country of operation is different, the type certificate of the country of operation must also be obtained. This is a double task. Since inspection and the certification of aviation safety are not limited to type certification, a bilateral aviation safety agreement (BASA) will ease these double acquisition processes [25]. A BASA between Japan and the United States was concluded in 2009. However, since there had been no Japanese aircraft type certification for passenger aircraft since the YS-11, it was necessary for US authorities to confirm the abilities of their Japanese counterparts [26]. Since then, the type certification for the MRJ (currently Mitsubishi SpaceJet) has been confirmed by US authorities, the type certification of aircraft products was officially within the scope of the BASA as of November 1, 2019 [27]. Signing the BASA has opened the way for aircraft products that have obtained type certification in Japan to go through a simplified process in the US. In that sense, an environment has been created in which the development of aircraft and equipment in Japan can be done more actively. Given these developments, it is necessary to develop a system, such as the FAA's ARAC and ARC in the US, to formulate new technical standards in Japan and to promote standardization activities.

Clearly, bilateral agreements should be concluded with countries other than the US in the future. Furthermore, there is a worldwide movement for the international harmonization of type certification methods [28], and we need to participate in these activities to develop the aviation industry in Japan.

6. Inspection and certification method for type certification

As aircraft systems have become more complex, there has been a change in the inspection and certification process. In the United States, the inspection and certification department of the civil aviation authority has been providing safety certifications, but there have been significant changes since the 1940s [2, 29]. In the 1940s, as the aviation industry grew, the Civil Aeronautics Administration (CAA) introduced a system so that individual audits could be performed to cover delays in the overall auditing process. It is the designated engineering representative (DER) who delegates airworthiness certification work.

In 1967, after name changes and consolidation, the present organization, the Federal Aviation Administration (FAA) was established. In the 1980s, the FAA responded to the demand for an increased scope of airworthiness certifications, including assigning DARs (designated airworthiness representatives) for individuals and ODARs (organizational designated airworthiness representative) for organizations. However, this system soon became complicated, and in the late 1990s, the FAA began to consider integrating certification procedures. Finally, in 2004, certification was unified under ODA (Organization Designation Authorization), and after a transition period, the new system was adopted in 2009. ODA is not certified by individual qualifications, but is carried out by manufacturers and operating companies that are recognized and entrusted by the FAA as having the ability to do certifications, while the FAA finally grants the certification.

The FAA further improved and expanded the ODA program under the FAA Modernization and Reform Act of 2012 (PL 112-95) [30]. However, in 2013, the Boeing 787 battery accident revealed the problem with this certification method. At a public hearing held by the NTSB (National Transport Safety Commission), there was a statement that, though the lithium-ion batteries were certified by the DER, the ODA were not being applied. In other words, the development of the Boeing 787 took place during a transitional period. At the end of the hearing, the NTSB chairman, in the following statement, called for another method to handle new technologies [1, 31].

The U.S. aviation community is using the same approach to certification that was *created to certify our grandparents' aircraft, and by most accounts, it has served us very well. But perhaps it is time to ask if any changes are needed to update the system that will be used to oversee the development of new and beneficial technologies on our children's and our grandchildren's aircraft.*

The US Government called for further improvements in ODA in the FAA Modernization Reform Act of 2018 (PL 115-254) [32]. However, the Boeing 737 MAX crashes—occurring nearly consecutively on October 29, 2018 and March 10, 2019—once again revealed the shortfalls of a system that delegates certification to the manufacturer. The *Joint Technical Review Report* (JATR) [33] published on October 11, 2019 by civil aviation officials in Australia, Brazil, Canada, China, Europe, Indonesia, Japan, Singapore and the UAE called for more in-depth communication between Boeing and the FAA on the certification process. In particular, this report pointed out the importance of mutual confirmation between authorities and manufacturers on whether or not all systems could be verified in a complex aircraft. The report called for Boeing to establish a certification team independent of the design and development team and for the FAA to work with other civil aviation authorities to determine the impact of system modifications on the entire aircraft. It also calls on the FAA to clarify the application of the industry consensus SAE 4754, an aircraft system safety assessment analysis [33].

7. Improving certainty and transparency in certifications

It is no longer practical for only national civil aviation authorities to conduct type certification screening for increasingly complex aircraft systems. The FAA is moving from outsourcing to individuals to outsourcing to development companies as ODA. In Japan, in the revision of the Civil Aviation Law in 2005, a review was conducted of aircraft design inspections (enforced on October 1, 2005). The intention of this review was to look into the relationship between the private sector and the government when it came to aircraft safety regulations. From the viewpoint of using private capabilities within the department, it was decided that some of the design inspections conducted by the government could be omitted for aircraft designed by government-certified companies [34].

However, the shortcomings of a closed environment (inspection and certification authorities and operators) only became evident with the recent Boeing 737 MAX accidents. A new system to improve the certainty and transparency of type certification work should be considered. One approach is to establish a certification team within the private sector that is independent of design and development, and to require Japanese aviation authorities to participate in the certification work of civil aviation authorities in other countries. However, when only a limited number of people have knowledge of the technology to be certified, such as advanced technology, further study is required. It has been pointed out that the expertise of other industry experts should be used in connection with the lithium-ion battery accident [35], and in the case of 3D printer technology (additive manufacturing), databases of universities and research institutes were certified during the certification process [36].

From the perspective of improving both the efficiency of inspections and certifications as well as transparency, it is necessary to consider the use of third-party organizations. Certifications by third-party organizations or functional safety standards—increasingly being introduced for automotive parts and robots—are standardized by the ISO (International Organization for Standardization) and JIS (Japanese Industrial Standards) [37]. In the aviation field, the introduction of such a system should be considered. In particular, the certification of small unmanned aerial vehicles and the certification of their operators and pilots require a great deal of resources. The introduction of a third-party certification process was considered by the Public-Private Council [38, 39]. In their recommendations, the main target was the development of passenger aircraft, but in air traffic control, new technologies were required to manage congested airspace, and the certification system for that is also a global issue [40].

As mentioned above, the design of a new aviation safety inspection and certification system is a global issue, and activities in collaboration with the rest of the world are important. It is urgently necessary to develop human resources who can carry out international activities in these fields.

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