Research on Open Problem Management of Civil Aircraft

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Abstract:During the full life cycle of civil aircraft, various problems are inevitable. Problems that fail to be closed and resolved in a timely manner form open problems. Reasonably judging the conditions for identifying open problems and effectively managing them—including classification, evaluation, tracking, documentation, and final closure—is of great significance for ensuring aircraft quality. Currently, there are no specialized mandatory regulatory requirements for open problem management of civil aircraft in China. By studying the open problem management schemes of EASA, SAE, and CAAC, this paper provides cases and guidance for domestic civil aircraft open problem management, and summarizes the key considerations that should be taken into account during the management process.

Keywords: Civil Aircraft; Open Problems; Problem Management

1. Introduction

Civil aircraft projects are highly complex systems engineering, characterized by high technological content, great difficulty, high risks, and long cycles. Against the backdrop of complex and volatile international situations, unprecedented opportunities and challenges have emerged for the localization of civil aircraft in China. With the increasingly refined and market-oriented development of civil aircraft, they have become more closely linked to public life. Consequently, higher requirements are imposed on the quality of civil aircraft, which correspondingly raises the standards for problem management, including open problem management (OPR).

Among the current regulations, rules, and norms issued by CAAC, a total of 27 documents mention descriptions related to open problems. Specifically, 18 documents use "remaining problems" to describe open problems, 8 directly reference "open problems", and 1 uses "disputed problems". However, none of these documents specifically regulate open problem management, and their focuses on handling open problems vary. Additionally, there are few studies on open problem management among domestic civil aircraft peers.

CAAC's ARJ21 Aircraft Certification Guidelines introduces the "Disputed Problem Resolution Procedure", which focuses on formulating solutions, reaching consensus among stakeholders, tracking problems, and ultimately ensuring their resolution. However, it does not classify the problems themselves.

CAAC's Certification Procedure for Technical Standard Order (TSO) Authorization focuses, from the perspective of the review team, on "correcting problems with potential safety impacts or non-compliance with technical standard orders/minimum performance standards before approval" for components involving software or airborne electronic hardware. It also does not clearly classify open problems.

CAAC's Civil Aircraft Airworthiness Approval Certification Procedure focuses, from the perspective of airworthiness inspection, on "whether open problems have been resolved", "the validity of design approvals, data sheets, and production certificates", and "whether alternative solutions have been agreed upon".

EASA's AMC-189 is a dedicated document describing open problem management, but other EASA airworthiness regulations also include relevant content. The FAA adopts essentially the same open problem management scheme as EASA's AMC-189. SAE also has a specialized problem management program.

Currently, CAAC does not have a dedicated document on open problem management for civil aircraft that imposes mandatory or specialized normative requirements.

The purpose of this paper is to summarize the key considerations for open problem management by studying the problem management schemes in EASA AMC-189 and EASA's airworthiness regulations for airborne electronic software and hardware, aiming to provide reference for domestic peers in conducting open problem management.

2. Necessity of Open Problem Management

Problems related to airborne electronic software and hardware may arise relatively late in the industrial development process. If these problems do not affect the safety of the aircraft/engine (and compliance with EASA certification specifications has been demonstrated), applicants may decide to certify airborne software and electronic hardware equipment with known unresolved problems.

Firstly, regarding the rationale for open problem management, for airborne electronic hardware, this scenario is covered in Section 10.9.3 of ED80/DO-254:

"Hardware Status: This section [Hardware Accomplishment Summary (HAS) generated for certification] contains a summary of unresolved problem reports at the time of certification, including statements of functional limitations.

Problems may arise due to differences in the methods used by the applicant's suppliers and sub-suppliers to track and report problem reports. Inconsistencies may exist in the reporting and tracking of problem reports and in the tools used among applicants, their suppliers, and sub-suppliers. This can make it difficult for applicants and certification authorities to accurately understand the number and severity of pending problem reports across different involved parties.

The use of suppliers and sub-suppliers by the prime contractor may also result in sub-suppliers lacking sufficient awareness and visibility of system-level requirements and considerations when evaluating problem reports and their impacts."

One of the primary objectives of the development and approval of any airborne electronic software and hardware should be to minimize the number and severity of open problem reports (OPRs) in any release. Under no circumstances should the principles and evaluation guidelines for OPR management be interpreted as a justification for applicants to deviate from this primary objective.

Therefore, it is particularly important to implement relatively systematic and comprehensive open problem management at all levels, although it poses challenges.

Open problem management serves three main purposes:

1. Clarify the roles of aircraft/engine manufacturers and equipment suppliers in assessing the limitations of an airborne embedded electronic software/hardware device due to known problems at the time of certification. It should be noted that even if the equipment supplier has sufficient knowledge to explain the functional impact of the OPR on the device, only the aircraft/engine manufacturer can evaluate or confirm its potential impact at the system/aircraft/engine level.
2. Facilitate the assessment of the acceptability of baselines released with open problem reports by defining a unified classification of business review items and appropriate methods for documenting these categories.

3. Clarify the Aspects of Problem Reporting That Should be Included in the Applicant's Supplier and Sub-Supplier Plans.

Open problems in aircraft configuration management refer to issues or change requirements arising during the design, manufacturing, and operational processes that may affect the aircraft's configuration. Effective open problem management is crucial for ensuring the safety, performance, and regulatory compliance of aircraft.

Classifying, grading, and evaluating open problems helps distinguish their severity, enables refined management, reduces civil aircraft management costs, improves management efficiency, and ensures management quality. Therefore, each open problem must be classified and evaluated.

According to the characteristics of technical problems in civil aircraft development, there are several common classification criteria, including the magnitude of the problem and its impact on project technology/schedule/cost, the urgency of resolution, the root causes, the scope of impact, and the source of the problem.

3.1 EASA's Problem Level Classification

In EASA Certification Memorandum: Development Assurance for Airborne Electronic Hardware, EASA classifies open problems into the following types:

• Type 0: Failures whose consequences have safety impacts under certain system conditions.

• Type 1: Failures whose consequences have no safety impact on the aircraft/engine under certain system conditions (this requires confirmation by the aircraft/engine manufacturer). If agreed upon by the aircraft/engine manufacturer and the equipment/hardware supplier, this type may be subdivided into:

◦ Type 1A: Failures with "significant" functional consequences; the meaning of "significant" shall be defined within the scope of the relevant system through an agreement between the aircraft/engine manufacturer and the equipment/hardware supplier (e.g., "cockpit effects").

◦ Type 1B: Failures without "significant" functional consequences.

• Type 2: Faults that do not result in failures (i.e., no system functional consequences, and the flight crew cannot detect the fault under any foreseeable operating conditions).

• Type 3: Any problems not belonging to Types 0, 1, or 2 but deviating from rules (i.e., plans, hardware development standards, or applicable CRIs). If agreed upon by the aircraft/engine manufacturer and the equipment/hardware supplier, this type may be subdivided into:

◦ Type 3A: "Significant" deviations whose impacts may reduce the assurance that the airborne electronic hardware behaves as expected without unintended behavior.

◦ Type 3B: "Insignificant" deviations from methodologies (plans) that do not affect the assurance obtained.

3.2 Problem Level Classification in FAA and AMC 20-189

To avoid disputes caused by inconsistent criteria, the FAA and AMC 20-189 have reached an agreement on a unified problem level classification scheme, which is essentially identical. The following describes the classification based on AMC 20-189:

1. "Critical" problems: Evaluated at the product, system, or equipment level. The PR (Problem Report) has actual or potential impacts on the function of the product, system, or equipment, may lead to catastrophic, hazardous, or major failure conditions, or may affect compliance with current rules.
2. "Functional" problems: Have actual or potential impacts on the function at the product, system, or equipment level.
3. "Process" problems: PRs documenting process non-compliances or defects that do not result in potential safety or functional impacts.
4. "Lifecycle Data" problems: PRs related to defects in lifecycle data items but unrelated to process non-compliances or defects.

3.3 Evaluation of Open Problems

EASA believes that root cause analysis should be conducted for all open problems whenever possible. Unless root cause analysis is not feasible under special circumstances, any such infeasibility must be justified.

All OPRs shall be classified according to the problem types defined above (see Figure 2 for the schematic relationship between OPRs and problem levels), or equivalent types may be used. If an equivalent type is proposed, each new type shall correspond to only one of the types (0, 1, 2, or 3) defined in this section of the certification memorandum. Sufficient evidence must be provided to demonstrate that an open problem cannot be closed, i.e., there is a valid reason for "opening" the problem.

For Types 0, 1, or 2, the root cause analysis should identify the corresponding errors (e.g., in VHDL code) and any related methodological deviations. For Type 3 problems, root cause analysis includes identifying methodological deviations associated with the problem.

Whether using EASA's defined OPR classification or an equivalent classification, OPRs shall be described in detail to ensure proper categorization, and all relevant information about the OPR shall be thoroughly documented.

When using previously developed airborne software or hardware, existing OPRs shall be re-evaluated in the operational environment of the aircraft/engine.

The evaluation content for problems in AMC 20-189 includes:

• Whether there are any resulting functional or operational limitations at the equipment or product level.

• Possible correlations with other existing PRs.

• For "critical" or "functional" PRs, an assessment of the potential technical causes of the problem.

PRs classified as "critical" in AMC 20-189 require sufficient mitigation measures or justifications to demonstrate the acceptability of safety impacts; "critical" problems cannot be treated as open problems.

To avoid reducing the quality assurance of certified airborne software and hardware due to an increase in open problems, the following objectives should be considered and corresponding actions taken:

1. Limit and eliminate OPRs as early as possible.
2. Restore compliance with specification

requirements promptly.
3. Correct any OPR within a timeframe consistent with the evaluation results.
Furthermore, the evaluation of the impact of open problem reports may lead to changes in the scope and depth of regulatory reviews.

3.4 Objectives for Open Problem Classification

According to SAE ED79/ARP4754 Section 9.2.2 and ED79A/ARP4574A Section 5.6.2.4, problem reports should be managed at the system level. The following objectives by type should be considered:

• Type 0: Such OPRs shall be corrected before certification, or appropriate mitigation measures (e.g., operational limitations) shall be proposed to ensure no adverse safety impacts at the aircraft/engine level.

• Types 0 and 1: Potential impacts shall be evaluated at the system level and, if necessary, at the aircraft/engine level. If required, appropriate limitations shall be identified to ensure no adverse safety impacts.

• Type 1: Any claim that the OPR has no safety impact on the aircraft/engine must be justified and documented.

• Type 2: The rationale for why the error does not result in a failure shall be documented. For simple cases, this justification may be a brief statement based on engineering judgment. In specific cases, it may require conducting additional specific verification and/or validation activities.

4. Considerations for Open Problem Management

Based on the aforementioned open problem management schemes, the following aspects should be considered when formulating an open problem management plan:

1. Establish a clear open problem management process (see Figure 1 for an example process). Develop a detailed process covering all steps from problem identification to resolution. Clarify responsible persons and relevant departments to ensure smooth and transparent information flow.

Figure 1 Example of an Open Problem Management Process

2. Classify problems and prioritize them. Categorize open problems (e.g., structural, system, software-related issues) and prioritize them based on impact severity, urgency, and resolution complexity.

3. Establish a problem database. Use a dedicated database to track open problems, recording detailed information, responsible persons, resolution status, etc. This facilitates tracking problem history, trend analysis, and future prevention.

4. Formulate change control policies. Open problems often require design changes. Ensure comprehensive analysis and evaluation before implementing changes. Establish change control strategies to guarantee the rationality and safety of changes.

5. Conduct regular reviews and reporting. Hold regular open problem review meetings to assess and update problem status, resolution progress, resource requirements, etc. Provide regular open problem reports to relevant stakeholders to ensure information sharing and transparency.

6. Strengthen team collaboration and communication. Close collaboration and communication between different departments and teams are crucial when handling open problems. Establish effective communication mechanisms (e.g., reaching consensus on OPR classification or solutions) to ensure timely information transmission and sharing.

7. Pursue continuous improvement. Regularly evaluate the effectiveness of the open problem management process, collect feedback, and identify potential improvement areas. Continuously optimize the process to improve management efficiency and quality.

8. Comply with regulations and standards. Ensure the open problem management process adheres to applicable regulations and standards to guarantee that aircraft design, manufacturing, and operation meet relevant safety and quality requirements.

9. Provide training and education. Ensure relevant personnel receive training on the open problem management process, including knowledge and skills in problem identification, reporting, resolution, and change control, to enhance their ability to manage and solve problems.

10. Collaborate with users or regulatory authorities. Maintain close cooperation and communication with relevant users or regulatory authorities when handling open problems. Comply with regulatory requirements and guidelines to ensure solutions meet applicable regulations and standards.

11. Track and close the loop. Ensure all open

problems have clear solutions, track their resolution status, and confirm thorough resolution and closure.

5. Conclusion

Effective problem management is a critical link in ensuring civil aircraft quality. Although there are currently no mandatory laws, regulations, or norms for open problem management, its importance is undeniable. Taking the open problem management schemes of EASA and SAE as examples, this paper summarizes the key considerations for conducting open problem management, providing a reference for domestic peers.

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