International Journal of Scientific Engineering and Applied Science (IJSEAS) – Volume-11, Issue 04, April 2025
ISSN: 2395-3470
www.ijseas.com

Essentials of Qualification in Aerospace Programs

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Abstract

The object of this article is to provide a critical path and fundamentals for a platform level qualification in aerospace industry. There are many sources related to subject however, it is quite hard to understand the application of these types of theoretical guidelines and match the theories and the real world implementations. The platform level development and qualification is very complex and requires an interdisciplinary approach, even if the scope of the programs/projects is a minor structural, electrical or software change on the aircraft. Since the aerospace elements such as aircraft, is so complex that any simple change may result in an unforeseen and possibly catastrophic impact on a well-integrated system. The focus of this article is to give a summary of a common development program as well as to point out some lessons learned not usually apparent in the general literature.

1. Introduction

In aerospace programs, all of the integrated subsystems must work in a wide range of hard conditions and must perform in a safe and reliable way without any conflicts therefore the platform owners utilize the qualification as the structural process to ensure these targets.

A qualification is defined as a system/product meets its predefined requirements for customer use. The qualification methods are generally test, inspection, analysis, demonstration and similarity. In addition, there might be legacy systems used in the program and the legacy systems might bring both some complexity and some simplicity at the same time. Legacy systems offer an already verified and known performance of the product. However, legacy systems bring the constraints to newly added systems since they have already completed design.

In qualification practices, one of the most essential references is INCOSE (International Council on Systems Engineering) [1]. Their frameworks and standards fundamentally put forward to the methodology to systems engineering and qualification process in aerospace industry. The qualification ground rules presented in this article mostly rely on INCOSE standards for the development lifecycle.

The ultimate output of a qualification process is a certificate of compliance that is released by the Qualification Authority. Based on the contractual requirements, the qualification authority might be related governmental departments, EASA (The European Union Aviation Safety Agency), FAA (Federal Aviation Administration) or any civil organization.

The next section includes a bird side summary of the qualification process and provides lessons learned gained some multibillion-dollar programs experiences.

2. The Qualification Process General Flow

The Qualification Process captures all requirement management, development and design and test & evaluation activities.

2.1 Requirements Management

A requirement is a statement that defines characteristics of a product or an operation in measurable and testable way. A successful requirement must have the features such that; it must be complete, unambiguous, verifiable, correct and consistent. If one of these attributes is missing; the complete design might be impacted and possibly failed.

There are many failed programs due to unsuccessful requirement management. The key point is to develop a successful set of requirements is taking into consideration of all the stakeholders, technological/technical viability, cost, regulations and standards. The main goal of a project is to achieve an acceptable product. Therefore, the performance or functional requirements of the product have to be unambiguous, testable / measurable. In addition, the requirement must include inputs from all stakeholders (including designers and manufacturers) as well as standards and regulations in the target schedule and budget.

The most commonly used sequential model for the requirement management in the aerospace programs is Vee Model. Vee Model has a structure that is shaped as “V” and its left side stands for the system definition while the right side represents system realization. Vee Model provides continuous verification and validation approach to complex design programs. In this model; all the changes must be taken into account and change control process is very crucial. In Vee Model customer level requirements are decomposed into system level requirements in terms of both functionality and performance. Then the system level requirements are further decomposed and allocated among subsystem requirements. Each level of decompositions, the derived requirements must be validated against its parent requirements and the higher-level requirements. Otherwise, the newly added requirements might contradict/conflict with the existing ones or the deleted ones might cause a design flaw or even worse system failures. Additionally, ensuring all the high-level requirements are covered by one or more lower-level requirements is very critical. At this point, a traceability matrix, which is a mapping between higher-level requirement and lower level requirements, is used.

If a need occurs for a change in the requirements, change control process is followed. The change control process is generally defined as in the following order: Issuing an Engineering Change Request (ECR), evaluation of the change impact at the Change Control Board (CCB) including the effectivity, schedule, consistency, risk and cost of the change, and then proceeding with the change with a plan and finally incorporation of the change. In certain approaches, an Engineering Change Note (ECN) is issued first and gathered feedback from all relevant interfaces before proceeding with ECR. This method improves the process robustness by systematically addressing all interface requirements before change control board discussion. Change Control Board is a formal group that review, evaluate, approve, reject or defer changes in accordance with the project’s requirements, design, scope or other resources. CCBs must have representations of engineering, project management, operations, finance, integrated logistic support, airworthiness and configuration management teams. Approved changes are implemented, monitored and tracked and all the necessary documents are updated such that: plans, requirements, test cases etc.

Following the change implementation, the requirements must be validated and a requirement baseline must be established. Requirement Baselines are established in accordance with the configuration control guidance and rules.

A simple flow chart to a change control process:

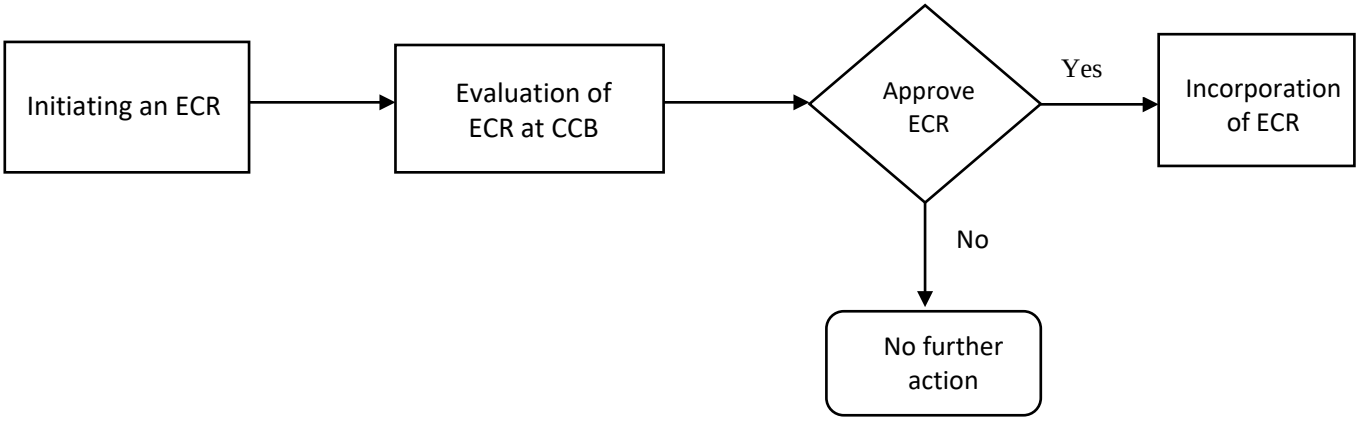

Fig. 1 Change Control Process Flow Chart

2.2 Design and Development Phase

Design and development phase starts with project planning. In accordance with the Contractual Data Requirements List (CDRL), all the plan documents are released. Project qualification plan, systems engineering management plan, configuration management plan, and quality plan are the major plan documents. Systems Engineering Management Plan, which covers all the systems engineering management lifecycle, principles, objectives, stakeholders' involvements and establishes program/project plans including technical design reviews.

The main design phases are as follows: Conceptual Design, Preliminary Design and Critical Design. These milestones are achieved via technical reviews and they are mainly: System Requirements Review (SRR), Preliminary Design Review (PDR), and Critical Design Review (CDR). In accordance with the contractual requirements, the technical reviews may be increased, as an example System Design/Functional Review may be added between SRR and PDR phases. Upon successful completion of each technical reviews, the corresponded baselines are established:

- System Design Review: Requirements Baseline,
- System Functional (Design) Review: Functional Baseline,
- Preliminary Design Review: Allocated Baseline,
- Critical Design Review: Product Baseline

Technical reviews are achieved via entry / exit criteria. CDRL document deliveries are generally entry/exit criteria for a design review. Delivery of these CDRL documents must support the program schedule. In addition, agreement with the customer on the entry / exit criteria prior to the design reviews is quite important. Systems Engineering Management Plans must cover all the technical review success criteria and this plan is mainly subject to customer approval.

The entire design process is completed when the system integration is performed. A product integration is defined as putting together of each component of a system to ensure they are functioning properly. Whereas system integration is assembling all the system and subsystems in order to ensure they are functioning as a complete system. The system architecture and the system design must be in line with each other and their consistency must be verified. Therefore, traceability between system architecture, system design and system requirements must be maintained through all design phase. Note that any system update requires re-iteration for the traceability checks. Systems are interfaced with each other via electrical, software or structural. The

interfaces between systems and subsystems are defined via interface control documents. These documents identifies how the each system and subsystem communicates properly with each other.

2.3 Verification and Validation

System integration completion prepares the system for verification and validation activities. Verification is performed in order to ensure the system meets its specified requirements. Verification may be conducted as system level or component level. During the entire project lifecycle verification is done for each system element. Verification methods are mainly as follows:

Demonstration: Observing a system operation is called as Demonstration. A helicopter firefighting system scenario flights can be categorized as Demonstration Flights.

Tests: Observing a system operation via utilizing a specific tool, equipment, instrument for collecting data is called as Test. The difference between demonstration and test can be summarized as if the result can be measured and it is quantitative, the method is called as a test. However, if the result or the operation of the system can be observed without a specific measurement tool, the activity is categorized as a demonstration. Avionics System Integration Laboratory (SIL) tests or communication flight tests utilizing records of a certain flight test instrumentation are examples for the test method.

Inspection: Visual check for the system or documentation of the artifact is inspection. Visual checks on the helicopter par numbers or visual checks of design documentations are both inspection typed verification.

Analysis: Analysis is executed as using simulations algorithms, models and examination of the processed data. Analysis of flare separation envelops for dispensing flare decoys from an aircraft for various flight conditions is a good example for analysis method.

The location of verification activities may be an aircraft (in flight or on ground), a laboratory or specific environmental chambers. In order to complete a verification activity, the results should meet the verification criteria which is predefined and agreed on prior to the verification activity. Verification success criteria and verification objectives are defined in the verification procedures.

System Requirement Verification Matrix documents are generated to define verification methods, locations and criteria for each requirement.

Validation is conducted to ensure final product meets the customer expectation and constraints or ensure that the right system/product is built.

The qualification is complete when every single requirement is successfully verified and the qualification authority has approved the compliance of the requirements through verification reports.

2.4 Lessons Learned from Large-Scaled Aerospace Programs

The main goal of a program is to present an acceptable product for customer use, These customers are mainly pilots, engineers and technicians in an aerospace program. Therefore, to achieve a successful acceptance test with end users, a user- friendly Pilot Vehicle Interface is an essential lesson learnt. As obvious as it seems, this point is usually discarded. This underestimation mainly results in a budget and schedule impact due to requested design changes during the acceptance test. In order to avoid failure during customer acceptance tests, PVI

should be handled prior to requirement development and prototypes for any new design must be presented to end users in this regard.

As another essential lessons learnt from large-scale aerospace program experiences, collecting input from both test pilots and end-user pilots from early development and design phase and establishing a robust finding management system during testing significantly increases the acceptance test success rate.

Another underestimated point is maintaining a robust and reliable communication among stakeholders. Sustaining the effective communication between the partners provides transparency and continuous alignment throughout program activity. Thus, partners may be timely notified about the issues.

4. Conclusions

The theoretical process of a qualification is very important as well as the lessons learned gained via previous programs. Based on the complexity of the program requirements there might be thousands of system and subsystem requirements. Even though the flow of a Qualification Process seems complex and requires more schedule and budget, follow of this process is inevitable in aerospace programs. Once this work flow is established and mastered well, it can be re-used in the upcoming programs. In the long run having a good structure of qualification process offers more customer reliability and satisfaction and pays off its early efforts.

References

[1] INCOSE, Systems Engineering Handbook* (5th ed.): Wiley, 2023.

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