Assurance and Evaluation Method for Reliability Requirements Completion of Aviation Product Based on CMM

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Abstract. Modern aviation product needs to meet the reliability requirements during the development process. In this paper, a comprehensive assurance system of reliability requirements completion is established and a method to evaluate the assurance system capabilities of reliability requirements completion based on CMM (Capability Maturity Model) is proposed. The evaluate index system in each level is described and AHP method is applied to determine the weight of each index factor in maturity. The evaluation results can comprehensively and effectively direct the aviation product reliability work during the development process and ultimately ensure the reliability of aviation product meets the requirements.

1. Introduction
As the complexity of modern aviation product increases, reliability work needs to be implemented. The goal of reliability work is to ensure that the aviation product meets the specified reliability requirements and maintains and improves its reliability level. Further to ensure the system can meet the requirements of operational readiness and mission success and the requirements for guaranteed resources can reduce [1]. The reliability requirements refer to a series of reliability qualitative and quantitative requirements and specific reliability work items requirements required by the ordering party in the contract. Capability maturity model related reliability have been partially studied. Researchers at the University of Maryland have used CMM to evaluate the reliability capabilities of electronics manufacturers [2-4]. The concept of reliability-centered system engineering capability was putting forward and the weapon equipment reliability-centered system engineering capability maturity model framework was established in the paper of researcher Kang Rui [5]. Li Guosheng added the maintainability and supportability to the reliability engineering capability maturity model [6]. This paper studies the factors that ensure the reliability requirements completed and builds the capability maturity model and proposes the evaluation method.

2. Assurance system of reliability requirements completion
The assurance system of reliability requirements completion refers to a series of engineering organization activities implemented in the development process which to ensure the completion of reliability requirements of aviation product. From the perspectives of organization, technology, and process, the hierarchy model of the assurance system of reliability requirements completion is shown as figure 1. The overall assurance work of reliability requirements completion of aviation product is divided into two categories which are the work of the implementation process and the work of the management process. The work of the management process is to serve the work of the implementation process. In order to establish the assurance system, the reliability requirements of product and the reliability work specified in national military standards are analyzed firstly. Then the factors affecting
the completion of reliability requirements are summarized. Finally, the correlation among the factors is considered and the structure of the assurance system is determined. With further practice and deeper learning, the assurance system will be further refined.

![Figure 1. Assurance system of reliability requirements completion.](image)

3. Assurance capability of reliability requirements completion evaluation

This paper defines the assurance capability of reliability requirements completion as the ability to develop the aviation product to meet the specified reliability requirements under the constraints on various factors of the assurance system of reliability requirements completion. A which means assurance capability maturity of reliability requirements completion is used to measure the system capability and A is a number within [0, 5]. In this paper, fuzzy comprehensive evaluation method and analytic hierarchy process (AHP) method are used to evaluate assurance capability maturity of reliability requirements completion. The evaluation system construction idea is shown in figure 2.

![Figure 2. Assurance capability of reliability requirements completion evaluation system construction idea.](image)

3.1. Maturity level

Maturity level is the core content of the capability maturity mode [7]. According to the principle of traditional capability maturity models and referring to the CMMI continuous representation model, ISO/IEC 15504 and other models [8-9], the hierarchical framework is established as shown in figure 3. Maturity level classification and level description:
Figure 3. Hierarchical framework of maturity level.

(1) Initial level. Reliability assurance activities are executed under the chaotic management state or not executed. The organization has the reliability assurance activities without corresponding norms and mature goals. Work is not performed in accordance with the principles and ideas of reliability assurance. Activities such as complete planning, tracking, analysis, improvement and experience dissemination are not implemented. Work steps are not systematic. Reliability assurance activities and the outputs obtained are partially valid. Many problems exist, including unidentified information on the collaborative process across units, geographies, and interdisciplinary, invalid of complex product development and management, and uncertainty project success.

(2) Management level. The typical project is the core at most of the time and project-level specifications are focused. The reliability assurance activity program is developed specifically including objectives, plans, and processes. The requirements for reliability assurance activities are clearly defined and activities are planned, tracked, evaluated and accepted. Reliability assurance organizations are established and organized with relevant guidelines to support and encourage. Activity resources are allocated. Appropriate corrective actions exist when there is a deviation from the operational effect and the plan or the process is not executed. The successful experience of similar projects in the past can be reproduced.

(3) Definition level. The standards-suitable reliability assurance activity process is fully established. Project-level activities are absorbed, summarized and improved. The processes related to reliability assurance activities are clearly defined at the organizational level. The project reliability assurance activities are obtained through reductions of organizational standard activities and reasonable adjustment according to the actual technical status of the project. The tailored activity contributes activity improvement information to the organization's active asset library. The biggest feature of this level is standardization.

(4) Quantization level. Reliability assurance activities are measurable and quantifiable. Statistics and other quantitative methods are used as management means and quantitative quality, process and performance indicators are used as the standard for management. Existing defects can be identified
and trends in work processes can be predicted. Measures can be implemented before problems arise to reduce costs. Good software tools are used as support generally.

(5) Optimization level. Reliability Assurance activities are able to meet current and anticipated goals and accommodate changes. Innovative methods and techniques are used centrally. It is possible to achieve continuous improvement activities by actively collecting data and screening and analyzing the data. Activity defects can be identified and defect patterns can be analyzed. The root cause of defects can be discovered and corresponding improvements can be taken. The defect prevention plan was developed and tracked. Reliability assurance staff are continuously trained and upgraded. The activity process is the result of continuous optimization.

The quantification level and the optimization level are based on the first three levels and the processes are further quantitatively predicted and controlled and analyzed and optimized according to the cost, efficiency and quality requirements of the organization's activities. Quantization level and optimization level are relatively difficult to achieve, and they are stages to realize potential by actively discovering and solving problems in an open and positive environment.

3.2. Evaluation index

The evaluation indexes are established based on the factors of the assurance system of reliability requirements completion. The evaluation indexes are shown in table 1.

### Table 1. Evaluation index

| Objective | The first-level assessment index | The second-level assessment index | The third-level assessment index |
|-----------|----------------------------------|-----------------------------------|----------------------------------|
| Basic capability | Organization | Set up independent reliability organizations and work management agencies or positions | Set up dedicated reliability information management agencies or positions |
| | | Equipped with a complete reliability team | Established a complete reliability training system |
| | | Establish a sound job evaluation system for reliability professionals | Configure the required device |
| | Equipment and facilities | Guarantee the advanced nature of the equipment | Guarantee equipment reliability |
| | | Top-level documents and requirements related to overall planning reliability work | Develop a work plan that meets product reliability requirements and characteristics |
| Assurance capability of reliability requirements completion | Plan | Establish a reliability assurance specification for applicability | Establish a reliability requirements work management requirements and control plan development |
| Management and controlling capability | Closed-loop controlling and management | Ability to carry out management control work according to management requirements and control plan system | Apply feedback adjustment mechanism to control plan during work development |
| | | reliability state identifier | Reliability state control |
| | | Reliability state review | Reliability state documentary |
| | | Establish and operate a complete reliability information system | Establish a standardized information system operation |
3.3. Weight calculation of evaluation indexes
This paper uses the AHP method to establish a weight set, which classifies various related factors in a complex problem into an interrelated and orderly hierarchy. Based on certain objective judgments, the first-level, the second-level and the third-level assessment indexes are compared and analyzed. In the weight calculation of the three layers of assessment indexes, some experts are invited to construct the discriminant matrix by comparing the index among each other. 1~9 are used as comparison scales among evaluation factors. By solving these discriminant matrices, it can be calculated that the three weights of the first-level assessment index which are denoted as \( \omega_i \) (\( i=1,2,3 \)). The weights of the second-level assessment index for the first-level assessment indexes are denoted as \( \omega_{ij} \) (\( i=1,2,3; \ j=1,2,3 \rightarrow \cdots \)). The weights of the third-level assessment index for the second-level assessment indexes are denoted as \( \omega_{ijk} \) (\( i=1,2,3; \ j=1,2,3; \ k=1,2,3 \rightarrow \cdots \)). The weight set of index is denoted as \( W_{ij} = \{ \omega_{i1j}, \omega_{i2j}, \ldots, \omega_{ijk} \} \) (\( i=1,2,3; \ j=1,2,3; \ k=1,2,3 \rightarrow \cdots \)).

3.4. Scoring criteria of index
In this paper, fuzzy comprehensive evaluation method is used to determine the scoring criteria shown as table 2.
Table 2. Scoring criteria of index

| The second-level assessment index | The third-level assessment index | Maturity level |
|----------------------------------|----------------------------------|---------------|
|                                  |                                  | Initial level | Management level | Definition level | Quantization level | Optimization level |
| Plan                             | Top-level documents and requirements related to overall planning reliability work | None or disorder | Project level management | Standardization of organization and systematization | Quantitatively management | Continuous optimization |
| Hierarchical management          | Contracts and agreements between the transferee and the supplier | Very Bad | Bad | Average | Good | Excellent |

3.5. Maturity calculating

(1) A membership function whose span is [0,1] to quantify index and experts scores are used to get fuzzy evaluating matrix with the third-level assessment index. Degree of membership $x_{ijk}^n$ indicates the membership degree of the maturity level $v_n$ of factor $X_{ijk}$.

$$x_{ijk}^n = \frac{d_{ijk}^n}{d}$$

(1)

where $d$ is the number of experts, $d_{ijk}^n$ is the number of experts whose score is $v_n$.

(2) The fuzzy evaluating matrix is shown as equation (2):

$$X_{ij} = \begin{bmatrix} x_{ij1}^1 & x_{ij2}^1 & x_{ij3}^1 & x_{ij4}^1 & x_{ij5}^1 \\ ... & ... & ... & ... & ... \\ x_{ij1}^5 & x_{ij2}^5 & x_{ij3}^5 & x_{ij4}^5 & x_{ij5}^5 \end{bmatrix}$$

(2)

(3) Maturity evaluation vector of the second-level assessment index is shown as equation (3):

$$A_{ij} = W_{ij} \cdot X_{ij}$$

(3)

(4) Maturity evaluation vector of the first-level assessment index is shown as equation (4):

$$A_i = W_i \cdot A_{ij}$$

(4)

(5) System evaluation value is shown as equation (5):

$$A = W_i \cdot A_i$$

(5)

3.6. Result analysis

The system evaluation value $A$ can reflect the level of assurance capability maturity of reliability requirements completion. The corresponding description can be found in figure 3.

4. Conclusion

This paper aims to help the aviation product meet the reliability requirements. An assurance system of reliability requirements completion and a method to evaluate the assurance system capabilities of reliability requirements completion based on CMM of aviation product are proposed. The result can not only reflect the level of assurance system of reliability requirements completion, but also expanded the application of capability maturity model in reliability. Further study will enrich the assurance system of reliability requirements completion.

References

[1] Yang Jing 2014 Review of software reliability and safety work requirements. Quality & reliability 5: 47-52
[2] Bate, Roger, et al 1995 A systems engineering capability maturity model, Version 1.1. No. CMU/SEI-95-MM-003. Carnegie-Mellon Univ Pittsburgh PA Software Engineering Inst
[3] Tiku, Sanjay 2005 Reliability capability evaluation for electronics manufacturers
[4] Tiku, Sanjay, Michael Azarian, and Michael Pecht 2007 Using a reliability capability maturity model to benchmark electronics companies. International Journal of Quality & Reliability Management 24.5: 547-563
[5] Kang Rui 2008 Research of reliability-centered system engineering capability maturity model. Engineering & technology 3: 63-66
[6] Li Guosheng 2012 RMS engineering capability evaluation based on proximity. Ship electronic engineering 32.11: 84-86
[7] Duncan Nancy Bogucki 1995 Capturing Flexibility of In-formation Technology Infrastructure: A Study of Resource Characteristics and Their Measure. Journal of Management Information Systems 12: 21-37
[8] Team, Cmmi Product 2001 CMMI for Systems Engineering/Software Engineering, Version 1.1, Continuous Representation. CMMI-SE/SW, V1.1. Continuous
[9] ISO IEC, ISO/IEC TR 15504:1998 Information technology — Software process assessment Part 3:Performing an assessment