Research on Management and Evaluation Model of Flight Test Project based on Uncertain Factors

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***Abstract*—The flight test of civil transport aircraft is an important stage for a new aircraft type to enter the aviation market. It is one of the most important scientific methods to verify the safety and performance of a new aircraft. The effectiveness and quality of the flight test mission will directly determine the decision-making and strategy of project management. The flight test is a complex project. Various uncertain events may occur causing deviations in the project schedule. Analyzing and evaluating the probability and impact of unpredictable events is an important task of project management. Based on the analysis of uncertain factors, this paper establishes the evaluation model of flight test project management, which provides feasible support for flight test project management and planning.**

***Keywords*: Uncertainty, Flight Test, Key factor, Project Management, Evaluation Model**

I. INTRODUCTION

THE flight test is the process of challenging and exploring the limits of aviation technology and products, especially new type aircraft apply with new technologies and materials. The most important goal of flight test is to guarantee safety and verify technical specifications [1]. The commercial purpose of developing civil aircraft is to put aircraft into operation and make profits. Flight test takes a very large proportion in the cost structure of aircraft development.

During the scheduled flight period of a civil aircraft flight test project, the completion of the project is one of the important conditions to achieve commercial success. As a large-scale complicated system engineering project with a long period, high risk, and complex technology, a flight test project may have various types of uncertain factors affecting the progress of the project, which can be regarded as a deviation of the project schedule. Therefore, comprehensive analysis of potential uncertainties based on past experience, statistic data, and technical analysis is crucial in project management.

II. CHARACTERISTIC ANALYSIS OF FLIGHT TEST MISSION

Generally, the main types of flight test mission for a new type of civil aircraft include research & development (R&D), compliance certification, and operational flight test [2,3].

The purpose of the R&D flight test is to determine aircraft design parameters, discover and solve problems and defects found in the design and manufacturing stage, determine the final delivery configuration of the aircraft, and confirm that the products meet the expected design specifications. Research & development flight test will run through the whole process of type flight test.

The purpose of the compliance certification flight test is to prove that the aircraft design meets the airworthiness standards, special conditions and equivalent safety requirements, and to provide basic evidence to obtain the type certification, mass production and delivery for operation.

The operational flight test is to prove that the type design and manufacturing method meets the requirement of operational airworthiness regulations, ensure the first batch of customer requirements are met and demonstrates that the aircraft has adequate operational capability and adaptability under the expected flight environments.

During the flight test process, types of flight test mission may be breakdown into flight test subjects as the basic unit. Ground tests, instrument modification, troubleshooting flight tests, etc. may be considered as attributes of test flight subjects. The main factors affecting the test flight subjects are shown in the figure below.

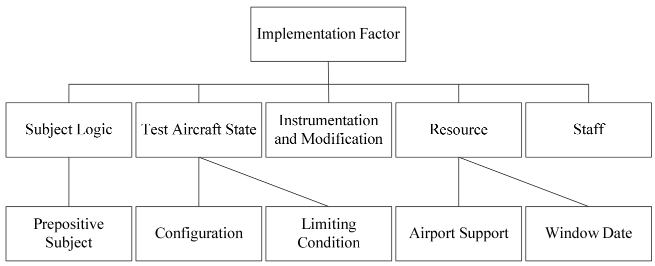

Fig. 1. Key Factor Structure of Flight Test Subject

Taking flight test subject as the basic unit to analyze project management and decision-making, it requires analyzing the key factor that affects the flight test mission. The key factors are as follow.

a) Subject logic, needs to finish specific preposition subjects as per required;

b) Aircraft status, needs to meet the aircraft configuration and restrictions required by the subject;

c) Instrument modification conditions, need to meet the test conditions of the instrument modification required by the subject;

d) Flight test resources, which need to find the requirements of subjects such as airport, window date and other conditions;

Manuscript received February 3, 2021; revised April 18, 2021.

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e) Personnel conditions, which need to assemble specialist personnel.

For example, the air data system (ADS) calibration preposition subject needs to be completed before carrying out the stall speed subject. The aircraft status needs to meet the software and hardware configurations of atmospheric data, primary flight control, power plant FADEC, and limiting factors, etc. The test the instrument modification needs to be completed such as installation of the stall recovery parachute. The resources and other conditions such as airports and personnel need to meet the relevant provisions of the airworthiness clause [4]. The example is shown in the figure below.

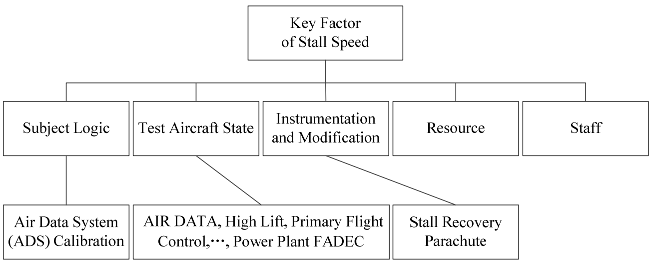

Fig.2. Key Factor Structure of Stall Speed Subject

In this subject, the flight test mission cannot proceed if any one of the above factors does not meet the prescribed conditions, it may be regarded as an uncertain factor that causes a deviation in this project.

Stall speed subject is the preposition of stall warning and other subjects, which affects all flight test tasks with relation to stall speed, thus leading to deviation in the project.

According to flight test engineering experience, based on the influence of uncertain events on the project, they can be divided into hard events and elastic events.

a) Hard event means that once an uncertain event occurs, the project schedule will inevitably produce a positive deviation, such as aircraft structural failure, etc.

b) Elastic event refers to the occurrence of uncertain events, but the adjustment of project execution plan may be used to alleviate the result of progress deviation, for example, stall speed subject cannot be completed on time due to the delay of installation of stall recovery parachute, which affects all the flight test missions with the stall speed subject as a precondition. However, it is possible to alleviate project deviation by rearranging the test sequence of other performance flight test subjects.

The flight test project is composed of a series of flight test missions with flight test subjects as the basic unit. The complexity of the flight mission process determines the complexity of flight test project management. The influence of uncertain factors on the project during the mission process can be described as resource-benefit decision-making.

III. Project Management and Evaluation Model

In large-scale project planning, it is required to complete all missions within the prescribed time limit. At present, many quantitative methods are being used for project progress control, such as the critical path method (CPM, including fuzzy critical path method), program evaluation and review technique (PERT), etc. [5, 6].

For the complex civil aircraft flight test project, control of the project schedule can be realized by distributing resources and deviations. In the top-level planning stage, the human and material costs incurred by the project can be described as quantifiable resources. Resources and project schedule per time unit can be used as key indicators for project management.

Under ideal conditions, the progress of all events in the flight test project is related to the number of resources spent, that is, increasing the input of resources may shorten the time to complete the events.

Let the total project total time as T_{Tot}. Within T_{Tot}, it consists of the time T_M required to complete all flight test missions and the waiting time T_P, such as troubleshooting time, modification time, and setting of aircraft configuration, etc.

There are n number of flight missions and m planned residual events. With

$$T_{Tot} = \sum_{i=1}^{n} T_{M_i} + \sum_{j=1}^{m} T_{P_j} \text{ , } i = 1,2,\cdots,n \text{ , } j = 1,2,\cdots,m \text{ , } n,m \in R \tag{1}$$

Let the time required for uncertain events as T_U, which contains l uncertain events and the probability of occurrence of an uncertain event is $P_U \left(0 \le P_U \le 1\right)$.

Then the influence time of uncertain events that occur during the whole project period on the project schedule is:

$$T_U = \sum_{k=1}^{l} T_{U_k} \cdot P_{U_k} \text{ , } k = 1,2,\cdots,l \text{ , } l \in R \tag{2}$$

According to the concept of hard events and elastic events, the influence time of uncertain events can also be expressed as:

$$T_U = \sum T_{U\_hard_i} \cdot P_{U\_hard_i} + \sum T_{U\_elastic_j} \cdot P_{U\_elastic_j} \tag{3}$$

Whereas, the probability of occurrence of each uncertain event may be obtained according to expert review or statistical data. If each uncertain event is composed of several key factors, $X \in \left\{X_1, X_2, \cdots X_n\right\}$, any one of which may lead to an uncertain event, then the probability of causing the event is expressed as follows [7].

$$P_{U_i} = P\left(\bigcup_{i=1}^{n} X_i\right) = \sum_{i=1}^{n} P\left(X_i\right) - \sum_{1 \le i_1 < i_2 \le n} P\left(X_{i_1} X_{i_2}\right) + \cdots + \left(-1\right)^{k-1} \sum_{1 \le i_1 < i_2 < \cdots < i_k \le n} P\left(X_{i_1} X_{i_2} - X_{i_k}\right) + \cdots + \left(-1\right)^{n-1} P\left(\bigcap_{i=1}^{n} X_i\right) \tag{4}$$

Taking the total project period T_{Tot} as the standard work period, when $T_U \le T_P$, it means that the project progress will not be affected. When $T_U > T_P$, there are positive deviations (delay) in the project progress, so it is necessary to evaluate and control the project progress.

Let the planned input resources in the total period is W_{Tot}, the resources invested per unit time during the standard work period are:

$$\bar{W} = \frac{W_{Tot}}{T_{Tot}} \tag{5}$$

ISBN: 978-988-14049-2-3
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

From Equation 1, we can get:

$$\frac{W_{Tot}}{\sum T_{M_i}} = \overline{W}_M \geq \overline{W} \quad (6)$$

In the formula, $\overline{W}_M$ can be expressed as the maximum resources that may be used per unit time.

Let the total resources required to recover from the deviation of the project schedule caused by the uncertain event as W_U .

With

$$\overline{W}_U = \frac{W_U}{T_U} \quad (7)$$

According to the above description, the unit resource factor can be used as a key factor to manage and control the project process.

When $T_U > T_P$, if $W_U \leq \overline{W} \cdot \sum T_{P_i}$, it means that the resource required for the uncertain events does not exceed the planned project resource budget, and the uncertain events can be resolved by increasing resources substantially.

If $W_U > \overline{W} \cdot \sum T_{P_i}$, it means that the resources required to solve the uncertain events exceed the planned budget. The decision-making of project management can classify the resource situation per unit required by uncertain events, to obtain the basis for decision-making.

a) $\overline{W}_U \leq \overline{W}_M - \overline{W}$, it represents that the resources consumed per unit of uncertain events is small, and the efficiency of increasing resources to solve the deviations is extremely high;

b) $\overline{W}_M - \overline{W} \leq \overline{W}_U \leq \overline{W}$, it represents that the resources consumption per unit of uncertain events is moderate, and the efficiency of increasing resources to solve the deviations is high;

c) $\overline{W} \leq \overline{W}_U \leq \overline{W}_M$, it represents that the resources consumption per unit of uncertain events is large, and the efficiency of increasing resources to solve the deviations is low;

d) $\overline{W}_U \geq \overline{W}_M$, it represents that the resources consumption per unit of uncertain events is huge, and the efficiency of increasing resources to solve the deviations is extremely low.

In project decision-making, different resource input strategies may be adopted for management and control according to the actual situation of the project progress and objectives, to select the preferred project benefit scheme.

In conclusion, for the uncertain events that may occur in the complex flight test project, the key factors of resource allocation may be analyzed, to provide the scientific decision-making scheme for project planning and management.

IV. Conclusion

Civil aircraft is the cutting-edge product of modern industrial technology, and rigorous flight tests are important to guarantee safety while occupying a large number of resources. As an extremely complex system engineering, flight test projects will be affected by a huge number of uncertain events. Based on the classification and characteristics of uncertain events. This paper analyzes the key factors, controls the project through resource allocation, establishes the evaluation model, and provides a feasible decision supporting flight test project planning and management.

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