Strategic Framework Design for University-based Satellites Mission Assurance

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Generally, the mission success rate of university-based satellites tends to be lower than those of governmental or commercial satellites. It is very important for human resource development to obtain a high-quality project experience built upon successful satellite missions. Therefore, UNISEC-Japan (UNIversity Space Engineering Consortium) has been working to improve the mission success rate of University-based satellites these years. This paper introduces a summary of the activities and their current status of them. The activity consists of understanding the status of current university satellite projects, analyzing the status, and designing and implementing a strategic framework for mission assurance. Our designed mission assurance activities are roughly divided into two categories; 1) encouragement of the university members' understanding of basic knowledge of mission assurance and satellite development, and 2) the construction of the supporting framework for mission assurance activities. This paper focuses on the design of a strategic framework for mission assurance, which makes proposals on how the Japanese national agency, JAXA, assists in improving the mission success rate of university satellites. The supporting system design is performed together with the investigation of the way how government or agency in other countries supports university satellite projects through online searches and interviews with the university staff and the agency people. This paper presents the details of recommendations given to JAXA, their expected effects on satellite mission assurance, and the current implementation status.

Key Words: Mission Assurance, Capacity Building, University-based Satellites, Project Management

1. Overview

UNISEC-Japan(UNIversity Space Engineering Consortium) is a non-profitable organization established in 2003 and has been supporting universities and/or technical colleges (collectively referred to as the Universities) and research institutions in Japan for the realization of practical space engineering activities. The purpose of the activities is human resource development, especially for future space engineers or researchers. Recently, the small satellite system becomes a practical system, and many practical and useful missions are realized. However, their mission success rate still tends to be low, and less than 30% of them successfully achieved their objectives[1)]. The educational effect of satellite operations is as important as the effect obtained by their development. It is very important for human resource development to obtain a high-quality project experience built upon successful satellite missions. Therefore, UNISEC-Japan has been working to improve the mission success rate of University-based satellites these years. Since 2020, our activities have been promoted more under the support of JAXA (Japan Aerospace Exploration Agency).

This paper introduces a summary of the activities and their current status of them. The activity consists of understanding the status of current Japanese university satellite projects, analyzing the status, designing a strategic framework for mission assurance, and implementing and realizing them. The phrase “mission assurance” means a series of activities to identify the factors in design, construction, operation of the satellite, etc. that may hinder mission success and to eliminate or decrease the effects of such factors. Figure 1 summarizes the mission assurance activities of this paper and their flow. This paper roughly introduces the overview of the survey and analysis, and our designed mission assurance activities. Then, a further explanation is performed for the design of a strategic framework and the current implementation status for mission assurance in improving the mission success rate of university satellites.

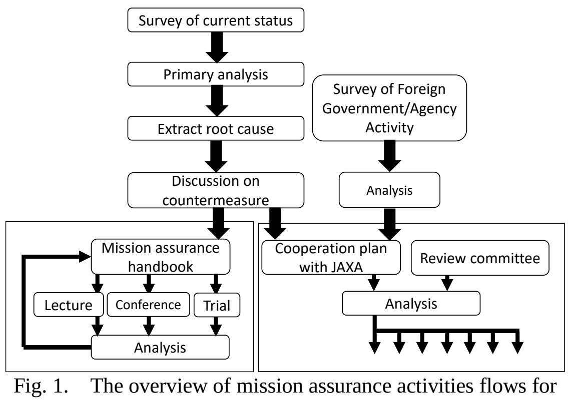

Fig. 1. The overview of mission assurance activities flows for university-based satellites.

2. Summary of the Mission Assurance Activities

2.1. Understanding Current Japanese University Satellite Projects Status and Analysis

In 2020, utilizing the idle time of the pandemic, we organized a series of online meetings to share the lessons learned from university satellite projects weekly, where more than 20 projects were discussed. A further survey still has been performed on the lessons learned among the university projects to make the best practices for mission assurance. JAXA found value in that activity and later funded a further study to do a survey on the lessons learned among the university projects, extract and analyze the success and failure cases, and extract the requirements for mission assurance. The study of the first year exacted over 200 individual success and failure cases from 36 university satellite projects. The root causes of the mission successes and failures were analyzed. The analysis results helped to extract the minimum requirements to ensure a successful satellite mission. The summary of lessons learned meeting and their analysis were published as Refs. 2 and 3. The requirements to ensure a successful satellite mission are listed in Sec. 5.2 of Ref. 2 as "Selection of Mission Assurance Requirements" .

2.2. Discussion on Countermeasures

Together with the root cause analysis, we investigated and analyzed how government or agency supports university satellite projects in other countries. The specific and detailed countermeasures were discussed to improve the mission assurance for university-based satellites based on the analysis data. The countermeasures are roughly divided into two categories: 1) that require improvement of the ability of the university project members, and 2) that require other supporters, and many activities are currently ongoing to realize the countermeasures. For the former category's example, we are developing the "Mission Assurance Handbook ", which aims to improve the project management ability of the university project members, and introduces some practical techniques for mission assurance improvement. This paper focuses on the latter part, the design of a strategic framework for mission assurance.

3. Mission Assurance Handbook

3.1. Overview

To encourage the university members' understanding of basic knowledge of mission assurance and satellite development, we performed further analysis of the failure cases to extract their root causes. The activity led to taking a handbook for mission assurance by revision, correction, and reconstruction of the requirements listed in Ref. 2 according to the system life cycle of the satellite. The analysis result of the current Japanese university satellite status showed that the mission success rate of the university-built satellite is extremely low for the first satellite. But it is also known that the success rate significantly improves for the second satellite and beyond because the lessons learned in the first satellite can be used. Failure, however, cannot be completely avoided for the second and subsequent satellites. The mission success rate can be further improved by sharing lessons learned in other satellite projects. The handbook summarized the things all the members of satellite development and operation teams in universities, including professors, staff, and students, must keep in their mind in order to improve the mission success rate.

The handbook was made as a part of a contract, "Investigation of supporting methods utilizing JAXA knowledge to improve the mission success rate of lean satellites, the fiscal year 2021" (JX-PSPS-536920A) given to the University Space Engineering Consortium by the Japan Aerospace Exploration Agency. The first version is freely available from the URL listed in Ref. 4. Based on the lessons learned, the minimum requirements for mission success were extracted and categorized as project management, satellite design, and experiments. Further analysis of the significant failure cases was performed and their root causes were also analyzed. The handbook summarized the specific countermeasures for the root causes together with corresponding development phases to realize them efficiently. In the handbook, the following four items are considered.

- The appropriate management method in the university according to the way each project is carried out
- The key points to achieve the project goals efficiently.
- The things to be done to improve the mission success rate at each phase of the project lifecycle from mission definition to post-operation
- The ideal project style: to make the university satellite program sustainable as a program, not as individual projects

3.2. Current Status

At the moment (Oct. 2022), we start activities to grow popularity and promote utilization of the mission assurance handbook.

The specific activities are follows:

- Lectures on mission assurance handbook (online / on-demand, English / Japanese)
- Introduction of the mission assurance handbook
- Trial application to the real satellite design and development and their survey (first satellite project)

We widely gather feedback on the handbook together with these activities. The handbook will be revised based on the analysis of the feedback to make it more useful and efficient.

4. A Strategic Framework for Mission Assurance

The design of a strategic framework for mission assurance is carried out together with the proposal of the framework of the JAXA's assistance. The supporting system design is performed together with the analysis of the current university's status and the survey of the other countries' support. We investigated the way how government or agency in other countries supports university satellite projects through online searches and interviews with the university staff and the agency people. The interviews were performed with not only supporters (government or agencies) but also beneficiaries (universities) to analyze their results. The surveys in 2021 were mainly performed for Europe and United States.

4.1. Survey of Other Countries Activities

4.1.1 United States of America

National Academies of Sciences, Engineering, and Medicine (NASEM) published Achieving Science with CubeSats Thinking Inside the Box[5] in 2016. It shows CubeSats have the potential as an efficient platform for obtaining high-priority science data and achieving human resource development and recommends utilization. It also encourages the improvement of suitable development methods. Based on them, NASA also puts efforts into CubeSat utilization, makes strategic plans, and many organizations and institutes performed surveys and research including mission assurance. The coverage area is from education to science implementation. The activities are roughly divided into the development support of the specific program and design/development information sharing (from Ames, Goddard, JPL, etc.)

The development supports of the specific programs are two different purposes: 1) education for beginners (CubeSat Launch Initiative, etc.)[6-12] and 2) opportunities for obtaining small satellite science results (SmallSat Technology Partnerships (STP) initiative, etc.)[13-19]. This hierarchical structure might improve the whole mission success rate of the communities. The information sharing is run by Small Spacecraft Systems Virtual Institute (S3VI) of Small Satellite Reliability Initiative (SSRI). The targets of their platform seem not only the universities but also widely related communities. Especially, their online information sharing platform are well organized and cover many kinds of related information. The system enables the users to obtain the required level of information from the lessons learned to detailed documentation.

From the interview of the university persons, inter-university cooperation is not popular and industry-academia collaboration is popular. The industries also run educational programs. Information sharing between universities is rarely performed because it becomes a competitor. Even in the same university, the information, technologies, or equipment sharing may not be performed because of the project contract limitations with different industries.

4.1.2 European Space Agency

ESA AGENDA 2025 presents an enhancement of the commercial activities by New Space, promotion of the commercialization, and increasing the number of European students in the STEM field by 20%. Space for Education 2030 program is also proposed based on the ESA AGENDA 2025, Education 2030, and OECD2018, and it is under discussion for agreement. The proposal includes the promotion of ESA academy program, which utilizes CubeSat or small satellites targeting university-level students. ESA General Support Technology Program (GSTP) has been performing technological demonstrations for important technologies for the future by CubeSat since 2019. One of the purposes of the roadmap is to maintain and improvement of CubeSat's project standards for project management, engineering, and quality assurance under reducing risks under severe constraints[20-23].

ESA promotes mission assurance to universities actively, including educational support programs for universities, the document maintenance covering mission assurance of the whole satellite project. ESA itself organizes the office for CubeSat or small satellites, aiming to obtain scientific results. There is a case that the educational supports grow up to actual scientific activities. For example, there is a case where the educational program (FYS(Fly Your Satellite)! Project, etc.) [24-27] graduates establish a startup company, and the company participates in the ESA's actual science satellite program.

The educational program is well organized and the students can select the lectures or related educational opportunities based on their level. For example, there are intensive lecture series that specialize in satellite design and development, hands-on training opportunities, satellite experimental or educational equipment utilization with technical or financial support, and design or development status review opportunities from experts. Lectures including fundamental knowledge are useful for complete beginners. The financial supports and opportunities for experimental equipment utilization with financial and technical support are useful for beginners in satellite development. The opportunities for becoming a professional project engineer after graduation help motivate students.

ESA also puts in the effort of document maintenance for CubeSat and small satellites. The main policy is the utilization of the European Coordination for Space Standardization : ECSS[28] and performs tailoring for them. It aims to realize standardized and efficient project management. It aims to manage the whole risks of the small satellite system engineering and qualification process, which realizes the mission success as scheduled under the cost requirement.

4.1.3 Canada

Canadian CubeSat Project (CCP)[29] is ongoing. The program supplies the financial support related to satellite development in the range of $200,000 to $250,000, and satellite deployment opportunities from ISS. The call for the opportunities are open in 2017, and the 15 candidates were selected in 2018. The whole projects are supported by the CSA and Canadian industries.

The information sharing platform is organized in the google group, and project-related documentation including technical documentation is shared within inter-generations and inter-universities. They also support the design review opportunities but they do not provide the utilization opportunities of the experimental equipment. The technical lecture and workshop are performed, and they can be accessed as on-demand content. The hands-on training workshop including specialized know-how sharing is also performed. The traveling fee to attend the workshop is supported by CSA.

4.1.4 Summary and Proposal

All of them promote CubeSat's utilization based on the recommendation or proposal from the government-related organization. The utilization field is both in educational opportunities and technological demonstrations. All countries also put the improvement of the quality of them as the agent and important issue and there are many kinds of countermeasures.

Their remarkable characteristics of them are the maintenance of the free launch opportunities to support educational activities. In addition, they also support the selected candidates to improve their mission assurance of the project. The support system guides them to give a successful satellite project experience, not to give just satellite development experience. The method and mind for mission success, and the experience can grow up the project member. The structure enhances and widens the future human resource of the space engineering field in a bottom-up manner efficiency. Japan also has free launch opportunities, but not for educational purposes. The opportunities are mainly for industrial development and promotion. Currently, JAXA only performs the support of safety assurance for the selected satellite project, and the mission-related points, including mission assurance, are treated only by the project member. Considering the benefit of the successful experience and other countries' support trends, we recommend JAXA support the mission assurance of the universities' project in addition to safety assurance.

To enlarge the potential human resource, it is important to support the complete beginner in satellite development. For the beginner of satellite development, the most difficult and important points of view are understanding the system engineering and system development. ESA's lecture series shows good solutions to support them as the well-organized educational program that enables students to select lectures or related educational opportunities based on their level. The fundamental lectures on system development and engineering meet demand from the complete beginner in satellite development, and help to keep potential satellite developper. It increases the number of potential satellite developers who can start the new project through their own further effort, and encourage the application of support for the actual satellite project. The actual satellite project support program can get free launch opportunities, and the opportunities can become the specific objective of student activities, and it helps keep motivate them. The project start-up support system is also well-organized. The supporting system consists of the specialist, which includes on-site supporting staff, reviewers, experimental equipment support staff, and so on. The mission assurance-related aspects are difficult to understand their necessities and practical utilization only with lecture-style knowledge. It is important to establish the framework for educational opportunities of mission assurance, together with a specific project experience.

The ideal support system is to realize the help of the developers according to the actual situation and can cover the whole development period from the mission proposal to the end of operations. Mission assurance improves significantly with the realizing support system of suitable people and timing. Young or mid-career engineers tend to achieve practical guidance of the actual situation. The reviews from the specialist at the conceptual phase enable us to prevent going back to the discussion of the further phases to the initial phase. The support system needs both on management and technical sides. In addition, pre-education of the mission assurance to satellite project members is important. The support system cannot work efficiently without understanding the purpose of the mission assurance activities.

The information sharing platform is also important for mission assurance improvement. We also propose to organize them. It can be useful not only the universities but also for industries. Other countries also recognize the importance of information sharing, and they show good examples of them. NASA constructs a database. ESA performs tailoring of the standard documents. CSA constructs an information-sharing structure in return for the financial support and free launch. JAXA also has the possibility of tailoring the standard documents (JERG), gathering the mission assurance improvement-related information and constructing an information sharing platform, and promoting inter-university information sharing.

NASA shows a good example of the experience sharing between the universities and NASA institutes, via the STP program. The experience sharing trains up the innovators of the new generation, through these two aspects: “NASA supports universities based on NASA knowledge” and “University shows the rapid and cost-effective development process grown up in the university communities”. The activities are promoted through the promotion of the collaboration program between the NASA center and university projects. There are examples that NASA's staff enters the university project on-site full-time. The university's culture has a unique ability and brand new point of view comparing the old space's culture. The trial can be realized also in Japan, and it may become a trigger for the establishment of a new development style.

4.2. Current Status

The survey and analysis results of the other counties’ activities are discussed together with analysis results of the Japanese university's status results. The discussion result was summarized as the draft recommendations plan to JAXA. The recommendations were discussed by the review board which consisted of JAXA, new space companies, and university professors, all of them are small satellite developers or operators.

The discussion results mainly consist of the followings:

- providing external reviews at the early stage of the satellite projects
- making an information-sharing platform
- improving access to relevant documents.

In addition to the above contents, the specific technical difficulties and management of the interface information were also extracted as important issues, and the final recommendation was given to JAXA for future implementation.

Currently, implementation studies are already started for some proposals:

- Feasibility of the supporting office for the university-based satellite's practical human resource development
  - review system which can support since early design phase of the satellite, starting from a primary mission design phase
- Construction of the data sharing platform
- Enhancement of the support for JAXA's standards documents utilization

5. Summary

This paper introduced UNISEC-Japan's (UNIversity Space Engineering Consortium) current activities to improve the mission success rate of University-based satellites and their current status. The activity consists of understanding the status of current university satellite projects, analyzing the status, and designing and implementing a strategic framework for mission assurance. The implementation system of the activities is gradually grown up with the support of JAXA, experts, and related communities. Specific implementation studies are already started for some proposals. We'll continue our activities of improvement based on the community's status.

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