Introduction of Nanosatellite Environment Test Standardization (NETS) project, Background and Objectives.

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Abstract

In order to improve the reliability of nano-satellites while keeping their advantages, low-cost and fast-delivery, a new way of thinking about environment test is necessary. There have been environment test standards internationally and domestically, which have been practiced over 40 or years. Those standards however assume large and medium class satellite using space-qualified parts and components and aiming toward high reliability in space. The nano-satellites intend to achieve the low-cost and fast-delivery by extensive use of non-space-qualified commercial-off-the-shelf (COTS) parts and components. Currently there is confusion among developers and customers about how the environment tests should be done for nano-satellites. A new government funded project started whose objective is to establish international standards of environment tests of nano-satellite system and components. The present paper briefly introduces the project's background and objectives.

1. Introduction

1.1 Reliability vs low-cost and fast-delivery

There is increasing demand of nano-satellite development worldwide among newcomers to space. The newcomers are mostly small business, universities and developing countries. They were outside the established space community made of space agencies and large prime contractors and their subsidiaries that were often dependent on government (civil and military) spending on space. To join the space community, the new comers were required to demonstrate their products satisfy the high reliability required by the customers. The requirements originated from the inherent high price of the space assets. The high hurdle against entering the space community made the industrial base of space sector stagnate or even deteriorate. Nano-satellite has a possibility of expanding the space industrial base and opening a new market of space applications, leading to a new way of thinking about how to run the space activities.

The advantages of nano-satellite are low-cost and fast-delivery. These advantages are gained by the extensive use of COTS (commercial-off-the-shelf) components and parts, and subcontracting to non-space small business manufacturers. COTS components are not meant for use in space. Therefore, the advantages are gained by sacrificing reliability against low-cost and fast-delivery. In fact, several statistics show the poor success rate of nano-satellites. Bouwmeester et al,[1] showed that only 48% of nano-satellite (defined by a weight of less than 10kg) succeeded in mission after the successful launch. Saito[2] showed that the success rate dropped significantly if the weight of satellite made by universities or non-space manufacturers exceeded 10kg.

The low success rate of nano-satellite is acceptable to a certain degree as long as the purpose is educational or technology demonstration. If the satellites are launched for commercial purpose, however, the failure is not really an option, considering the fact that the price per satellite still exceeds a million dollar.

Failure of one satellite among one hundred of satellites forming a constellation will be acceptable in future. But we are not in that stage yet. Nano-satellites are still being commercially utilized as a single or a formation flight of at most

three or four. If they keep failing in orbit at the present rate, the reputation of nano-satellite will never reach the stage to invite serious investment from outside the space community. Then, nano-satellites remain only as the platform of education or technology demonstration. No serious investment will be made to utilize a nano-satellite constellation for revolutionary space application. The space community will lose a chance to revitalize itself. Therefore, improving the reliability of nano-satellite is an urgent problem to be solved. It is a difficult problem though, as we have to find the optimum balance between the reliability and low-cost/fast-delivery.

1-2 NETS project

To improve the reliability, we propose standardization of nano-satellite environmental testing. Since September 2011, a new project, "Nano-satellite Environment Test Standardization" (NETS) project, has started under the support of Japanese government funding. The project will be promoted by four organizations, Kyushu Institute of Technology, International Standard Innovation Technology Research Association, The Society of Japanese Aerospace Industries and Astrex with participation of domestic and international stakeholders. The goal of the project is to establish an ISO standard including the following points;

(1) Environment Tests of Nano-satellite System,
(2) Documentation of Nano-satellite Environment Tests,
(3) Environment Tests of Nano-satellite Components.

A nano-satellite here is defined as a satellite mostly made of non-space-qualified COTS components. Its weight and size are typically less than 50kg and 50cm. The three standards may be eventually combined into one standard. The purpose of the present paper is to introduce the project with emphasis on background and purpose.

1-3 Needs of environment test standards

The standards can satisfy the needs from the several sectors. First, they can satisfy the needs of nano-satellite developers. Currently, if one wants to build a satellite quickly and cheaply, the easiest way is to buy components from the market. Unlike the traditional satellites, there is no time or money to visit the supplier before the developer makes decision. There are already internet shops that advertise products for nano-satellites. There is little guarantee, however, to those products. The test history is not transparent to the buyers. Even flight heritage does not guarantee that the products are made of the same parts. Therefore, if we want to make sure that the products we are buying can work in space, we tend to buy space-qualified components manufactured by well-known space manufacturer. The standards can give the minimum assurance that the products sold in the market have gone through the known environment tests.

The standards can satisfy contractual needs of satellite purchase. In the contract of large/medium class satellite, the buyer and seller both understand to what degree the tests should be done based on the experience gained through over 50 years of space activities. The nano-satellites are new to the market and buyers can be also new to the space market. There may be a gap between the buyer, those who want to do business using nanosatellites, and the seller, those who want to build satellites, about to what degree the tests should be done. The buyers may want thoroughness similar to the traditional satellites and yet much cheaper price. The seller may want to relax some of the test requirements. At this moment, there is no agreed-upon criteria about the test and verification of nano-satellites. As the time goes on, such criteria will be formed eventually. But there is a need to accelerate the formation of criteria to accommodate the rapid pace of nano-satellite development.

The standards can satisfy the needs of new comers to space that has little knowledge about the environment tests by providing a guideline of test and verification that is affordable for their purpose. It will help small business, universities

and developing countries to enter the space sector through nano-satellite development. The standard will help improving the reliability of nano-satellite made by the new comers.

2. Project approach

Figure 1 depicts the approach we take in the NETS project. There are already various environment test standards both domestic and international. Those standards were based on 50 years' experience. They are meant for very expensive satellites. But at the same time, they are meant to be highly reliable. Therefore, we take advantage of the existing standards by tailoring the requirement written there. To do tailoring, we need a certain rationale based on scientific knowledge. To obtain the rationale, in this project we carry out basic researches. The basic research will also produce new inventions that are suitable for the nano-satellite environment.

In NETS projects, we first plan to study the existing test standards, such as ISO-15864, SMC-S-016, NASA-STD-7002A, ECSS-E-ST-10-03C, JERG-2-002 for the environment test and ISO-17566 and others for the test documents. We also plan to do extensive interview with nearly 20 nano-satellite developers who have experience of developing and launching nano-satellites. In the interview, we will ask the following questions;

- What standards they used
- What tests did they do? What test did they skip and why?
- What are the anomalies found during the tests and in orbit?
- How was the documentation made?

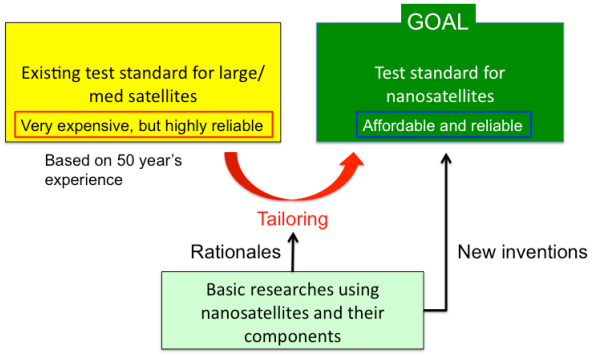

Figure 1: Approach of NETS project

For the basic researches, we prepare multiple test samples for RF transmitter (X-band solid-state amplifier with 3 W output power) and power control unit (PCU, 200W nominal power with 28 V output). We will test those samples until their performance output deviate from the nominal value beyond pre-determined limits. The tests to be carried out are thermal vacuum, thermal cycle, radiation, vibration, shock and others. Currently, in all of the environment test standards, thermal vacuum test is required for the electric and electronic components such as RF or PCU. We do thermal vacuum, thermal cycle and vacuum tests and study whether we can have the same result by a combination of thermal cycle and vacuum (room temperature) alone, leading to considerable saving in the test cost.

We also prepare dummy satellites that are made of basic satellite functions such as RF transmitter, PCU, battery, computer. Although the other components are made by dummy mass with heater inside, the components mentioned above and the satellite structure are of flight quality. The dummy satellite is a copy of 50kg-50cm nano-satellite that was previously developed for remote sensing purpose. We will put thermal and mechanical sensors inside the satellite and study the distribution of thermal and mechanical stress inside the satellite. We prepare two dummy satellites. One is tested in Japan. The other will be used for a round-robin test to be carried out at an international partner institution abroad.

The results of the basic researches as well as the document study and interviews will be examined in detail by domestic committees

formed by nano-satellite developers, component providers, space agencies, government organizations, and academia. The committees will also discuss the drafts of the standards before being presented to the international community.

In the NETS project, to form consensus among the experts of nano-satellite worldwide, we will have a series of workshops. The workshop will serve as an open forum for those who are interested in standardization of nano-satellite technologies. In the workshop, the results of the basic researches will be shared among the participants to make the scientific basis of discussion. The draft of the standards will be discussed in detail before being presented to ISO/TC20/SC14 for formal discussion. The first workshop will be held at Kitakyushu on December 14th, 2011. The purpose of the workshop is to form a consensus among experts about the needs of standardization, identify tasks, stakeholders and major players of standardization, and lay out the roadmap.

3. Milestones and roadmap

Under the current plan, the NETS project will be funded for three years until fiscal year of 2013. By the end of FY 2013 (March 2014), we anticipate the following milestones.

1. 1st international workshop, Dec. 14, 2011
2. Brief outline of the standards, March, 2012
3. Working draft ver.1, Fall, 2012
4. 2nd international workshop, Fall, 2012
5. Working draft ver.2, Spring, 2013
6. New work item proposal to ISO/TC20/SC14, Spring, 2013
7. 3rd International workshop, Summer, 2013
8. Committee draft ver.1, Fall, 2013
9. Registration of committee draft ver.2 for voting, Spring, 2014

After the end of government funding, we anticipate the following,

10. Voting of Committee Draft, Spring-Summer 2014
11. Voting of Draft International Standard Fall-Winter, 2014
12. Approval as Final Draft International Standard for editing, Spring 2015
13. Formal publication as ISO, Fall 2015

4. Conclusion

As there is a growing interest in nano-satellite development and application outside the established space sector, there is an urgent need to improve the reliability of nano-satellites so that their business use can attract serious investment. Application of nano-satellites as a constellation has a possibility of revolutionalizing the way of thinking about how to run the space activities.

International standardization of nano-satellite environment testing has merits for nano-satellite developers, nano-satellite business providers and newcomers to space by providing reliable test standards while keeping the low-cost and fast -delivery nature of nanosatellites.

A new project, “Nano-satellite Environment Test Standardization” (NETS) project has started to lead the international endeavor. The project consists of basic researches to tailor the existing test standards based on scientific data and to add new inventions to the nano-satellite tests. The research findings will be shared through a series of international workshops and research community network to improve the nano-satellite reliability. The NETS project group is ready to serve the worldwide nano-satellite community by being the focal point of the new international endeavor.

Reference

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2) *H. Satio, “Reliability Engineering considering In-orbit Failure Statistics and Cost”, (in Japanese) JSASS-2010-4050, Japan Society for Aeronautical and Space Sciences.*