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Overview of the CubeSat “Ten-Koh 2” scheduled to be launched on an H3 rocket

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Abstract: Ten-Koh 2 is scheduled to be launched on the first HTV-X, a new International Space Station supply vehicle, with a size of wide-6U (366.0 mm x 226.3 mm x 100.0 mm) and a mass of approximately 8 kg. Ten-Koh 2 is the successor to “Shin-en 2” and “Ten-Koh”, and its internal equipment, external equipment, and mission follow these two spacecrafts. The external structure of Shin-en 2 is made of carbon fiber reinforced thermoplastic resin CFRTP, and Shin-en 2 is the first spacecraft to adopt CFRTP for the main structure of the spacecraft. Ten-Koh was launched on October 29th, 2018, by the H2A #40 as a piggyback satellite of Ibuki 2 (GOSAT2). Ten-Koh was observing the orbital deterioration of CFRTP. The surfaces of the CFRTP samples were coated with an atomic oxygen-resistant paint and a short-wavelength-ultraviolet-resistant paint. In the future, humankind will live on bases located on the Moon and Mars. At this time, they may be molding a large space structure here with a 3D printer. A mission of Ten-Koh 2 is to investigate the space environment resistance of CFRTP molded by 3D printers in detail.

1. Introduction

The Japan Aerospace Exploration Agency (JAXA) has been developing the new international space station (ISS) transfer vehicle "HTV-X" which will be launched by a new flagship rocket H3. This HTV-X is the successor to the HTV, and is intended for in-orbit demonstrations in addition to resupplying supplies to the ISS. Even after leaving the ISS, it will remain in orbit for a maximum of 1.5 years as a technology demonstration mission phase. In the first HTV-X, a cube satellite (CubeSat) release mission is scheduled in this technology demonstration mission phase. In this mission, by releasing a satellite at a higher altitude (up to 500km) than the ISS, it is possible to extend the operating period of small satellites such as CubeSats and apply them to practical use missions. The first CubeSat to be released from this HTV-X is our Ten-Koh 2. The Okuyama Laboratory at Nihon University has just completed the development this Ten-Koh 2 to be installed in the first HTV-X. Ten-Koh 2 is a CubeSat with a size of wide-6U (366.0 mm x 226.3 mm x 100.0 mm) and a mass of approximately 8 kg. Both Fig. 1 and Fig. 2 show the appearances of Ten-Koh 2, and a 6U satellite separated from HTV-X. In the future, humankind will live on bases on the Moon and Mars. During that time, there may be a need to construct large space structures on-site using 3D printers. This paper is an excerpt from reference 1.

2. Ten-Koh 2 Spacecraft and Its Missions

The main missions of Ten-Koh 2 are the following seven, and these missions were decided based on the experience gained from Ten-Koh. Ten-Koh was developped by the Okuyama Laboratory and was launched on October 29th, 2018, by the H2A #40 as a piggyback satellite of Ibuki 2 (GOSAT 2). Ten-Koh conducted the degradation of CFRTPs. The primary of Ten-Koh 2’s missions is the material degradation observation mission, which is detailed below.

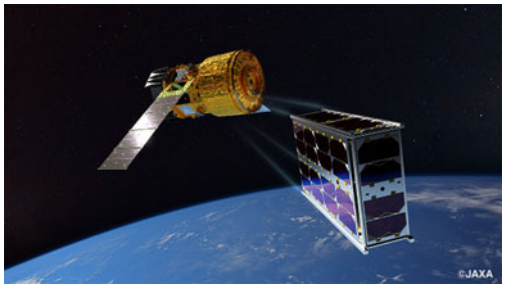

Figure 1 A 6U satellite separated from HTV-X (©JAXA).

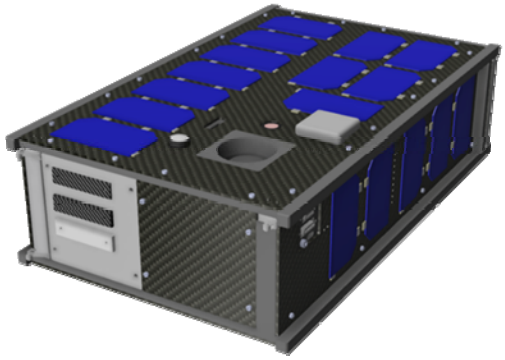

Figure 2 Appearance of Ten-Koh 2 spacecraft.

- ✓ On-orbit material degradation observation mission of 3D-printed PEEK resin and carbon fiber reinforced PEEK resin composite (PEEK/CF)
- ✓ Observe high-energy charged particles from the sun

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and galaxies and their disturbances with the Earth's ionosphere.

- ✓ Continuous operation of linear transponders
- ✓ Technical demonstration of high-speed data transfer
- ✓ Demonstration of microwave band communication technology
- ✓ Earth Observation Missions Using a High-Resolution Camera
- ✓ Space entertainment mission "N.U. Cosmic Campus" in collaboration with the Faculty of Arts and affiliated high schools

PEEK is a thermoplastic resin, which is known to be degraded by ultraviolet light, etc., although it has excellent heat resistance, mechanical strength, and radiation resistance. CFRTP is a fiber-reinforced plastic in which thermoplastic resin is used as the base material and reinforced with carbon fiber. The PEEK/CFRTP used in this study is CFRTP using PEEK as the thermoplastic resin of the base material. In this mission, we plan to fabricate these materials and observe their deterioration in a space environment using a 3D printer capable of forming complex shapes in a short period of time and controlling the orientation of fibers arbitrarily. The deterioration evaluation method is performed using three types of sensors. First, we observe the space environment where materials such as temperature are placed using a temperature sensor and a UV sensor. A strain gauge is then used to measure how much the material expands with temperature. From these results, we plan to derive the coefficient of thermal expansion of the material and evaluate the deterioration. Details of the in-orbit material deterioration observation results of PEEK/CF by Ten-Koh are shown in Reference 2.

3. Conclusion

Large space structures such as the ISS and Lunar Gateway are manufactured on the ground. Extensive ground tests are conducted many times to ensure their reliability. Once they deemed ready, they are mounted onto large rockets and launched into orbit. If 3D printers are installed at these manned bases, structures can be locally produced and utilized there. For this reason, NASA commissioned Tethers Unlimited to develop and research a "Spider-Fab" system that can manufacture large-scale space structures using a 3D printer, which is shown in Fig. 3. However, it is not well understood how large structures constructed by 3D printers deteriorate in an actual space environment. As a large structure, a 10m diameter class radio telescope installed in space, a 100m diameter class solar power sail, etc. can be considered, and high shape maintenance accuracy and relative position accuracy on the order of submicron are required. Although CF / PEEK is the most promising candidate material for realizing these large structures, it deteriorates when directly exposed to a space environment where radiation, UV-C, AO, thermal cycle, large temperature difference, and high vacuum are combined. However, there are instances where it becomes impossible to carry out the mission due to deflection and partial structural destruction. CF / PEEK has high specific strength and specific rigidity and is suitable as a spacecraft structure because it can be constructed by a 3D printer. Since it is a relatively new material, actual examples used for the main structure (primary structure) are few.

Thermoplastic CFRTP, especially CF / PEEK, is a promising candidate for the spacecraft main structure, and although it is expected to deteriorate when exposed to the space environment, the degree of deterioration progresses even after such tests is unknown. Evaluating the space environment resistance of CF / PEEK is extremely important for future space development. We believe that the efforts of Shin-en 2, Ten-Koh, and Ten-Koh 2 will be a small help in future space development. We, the Okuyama Laboratory, will continue to make the utmost efforts so that the results of Ten-Koh 2 will be utilized in the future space development of humankind.

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