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Space experiments on basic technologies for a space elevator using microsatellites

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ABSTRACT

We attempt to verify two basic technologies required for a space elevator using microsatellites; the tether (cable) deployment technology and the climber operation along the tether in space. Tether deployment is performed by a CubeSat called STARS-C (Space Tethered Autonomous Robotic Satellite - Cube) which will be released from the Japanese experimental module Kibo on ISS early in 2017. STARS-C consists of a mother satellite (MS) and daughter satellite (DS) connected by a 100-m tether. Its mission is focused on the tether deployment for studying the tether dynamics during the deployment with the goal of improving the smoothness of such deployment in future tether missions including space elevator. The MS and DS have common subsystems, including power, communication, and command and data handling systems. They also have a tether unit with spool and reel mechanisms as a mission system. In addition, we have been designing the next-step microsatellite called STARS-E (Space Tethered Autonomous Robotic Satellite - Elevator) under a Grant-in-Aid for Scientific Research. STARS-E is a 500-mm size satellite intended to verify the climber operation in space. It consists of a MS and DS jointed by a 2-km tether, and a climber that moves along the tether. STARS-C was launched on December 9 in 2016 and will be performed its mission early in 2017. STARS-E is in the BBM phase, and some designs are currently being fixed.

1. Introduction

A space elevator that can transport a payload using climbers along the tether (cable) connecting the earth and space stations (Fig. 1) will be the ultimate space transportation system from the earth to space, because such a system would be low cost and safe transportation method with a low impact on the environment and human body compared to existing chemical propulsion [1]. This system was initially just an imaginative idea, but the invention of new materials like carbon nanotubes [2] as well as technological developments over the past several decades, now make such a system possible. Thus, studies about technology for the space elevator become active at present [3]. To realize a space elevator, many technical issues remain, which must be solved and verified step by step. Among these, certain technologies, such as fiber formation of carbon nanotube, wireless transmission of energy to the climber, etc., are still immature. However, some can be realized with current technology, and they must be verified in space.

At the first step in the development of the space elevator, the smooth deployment of cables (tethers) in space is indispensable. An understanding of tether dynamics and control during deployment is necessary for smooth deployment. Some experiments of tether deployment in space [4–6] have been attempted in the past 10 years, but successful deployment has not yet been achieved in Japan in the space environment. Worldwide, there have been some successful tether deployment experiments in space such as SEDS, TiPS, and YES [7–9]. Further accumulation of data, however, is needed to develop an accurate tether dynamics model during tether deployment.

In such a situation, we have proposed a tether deployment experiment in space using a CubeSat called STARS-C (Space Tethered Autonomous Robotic Satellite - Cube) that improves on problems based on past experiences. With the advantages of a short development term (1–2 years) and low cost, the CubeSat is suitable for performing risky space experiments with original and new systems like tethers. STARS-C is focused on deploying a tether to allow the study of tether dynamics during deployment toward a smooth tether deployment design. STARS-C was selected as a microsatellite releasing from the Japanese experimental module Kibo on ISS in September 2014 and launched on December 9 in 2016.

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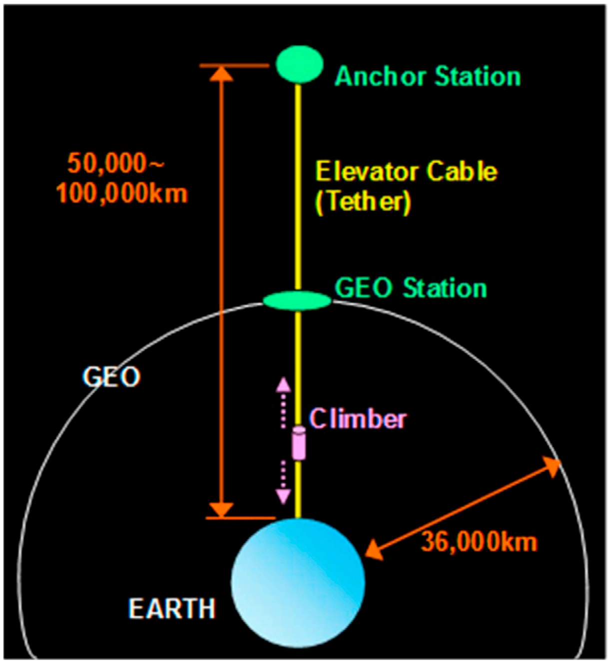

Fig. 1. Conceptual figure of space elevator.

Another important technology for the space elevator is the climber that moves up and down along the tether in space. We also have been designing the next-step microsatellite called STARS-E (Space Tethered Autonomous Robotic Satellite - Elevator) to verify a climber moving along a tether in space.

In this paper, we present the details of both STARS-C and STARS-E.

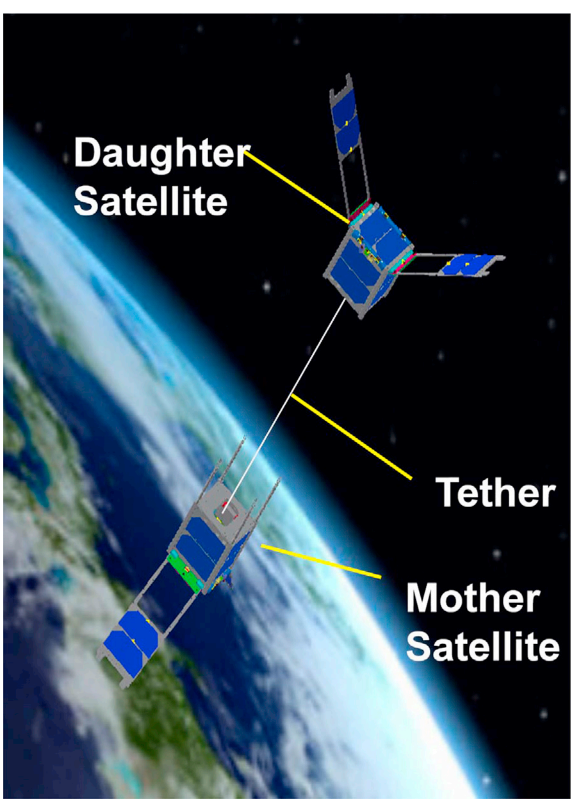

Fig. 2. Image of STARS-C.

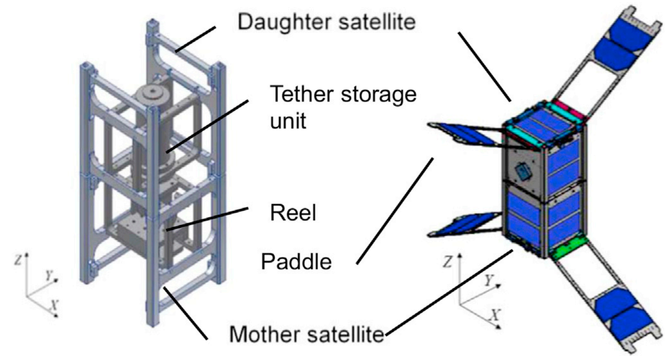

Fig. 3. Construction of STARS-C.

Table 1
Specifications of STARS-C.

Size		2U
Dimension		100×100×227 mm (Total of MS and DS)
Mass		MS: 1.5 kg DS: 1.16 kg Total: 2.66 kg
Communication	Uplink	145 MHz 1200 bps
	Downlink	437 MHz 1200/9600 bps
Orbit(Altitude/angle of inclination)		400 km/51.6 deg
Mission		Tether deployment (100 m)
Other	Amateur radio	Satellite information CW transmission
	Monitor	CMOS camera

2. Outline of STARS-C

2.1. Purpose of satellite

The purpose of the STARS-C is to demonstrate smooth deployment of a 100-m tether in space and to obtain the tether dynamics data for future design of tether deploying systems.

2.2. Satellite specifications

Fig. 2 is the image of STARS-C. It is 2U in size. It consists of a mother satellite (MS) and daughter satellite (DS), and is designed to deploy a 100-m tether between them composed of aramid fiber between them. The MS and DS have common subsystems, including power, communication, and command and data handling systems. They also have a tether

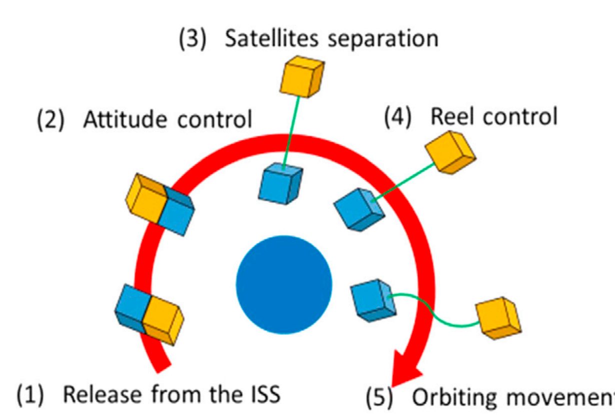

Fig. 4. Mission sequence of STARS-C.