On-orbit Construction Experiment by Tele-operated Robot Arm

AUTHORS:
Hiroshi Ueno*, Tetsuji Yoshida*, Kohtaro Matsumoto** and Sachiko Wakabayashi**

ADDRESS:
*Space Systems Division, Shimizu Corporation
No.2-3, Shibaura 1-chome, Minato-ku, Tokyo, 105-07, Japan
Tel:81-3-5441-8951, Fax:81-3-5441-8955, Email:hueno@spo.shimz.co.jp

**Science and Technology Agency, National Aerospace Laboratory
7-44-1 Jindaiji-Higashi, Chofu, Tokyo, 182, Japan
Tel: 81-422-47-5911, Fax: 81-422-47-8813, Email: matumoto@nal.go.jp

1. Introduction

On-orbit assembly technology will be one of the key roles to construct future large space structures. We have a opportunity to perform space truss construction experiments by the robot arm on Engineering Test Satellite No.7 (ETS-7), scheduled to be launched in 1997 by National Space Development Agency of Japan (NASDA). The objectives of the experiments are to establish technological basis of on-orbit assembly and construction using the robot arm remotely operated from the ground. To demonstrate truss deployment and assembly tasks, we have developed an experimental truss unit mounted on the ETS-7 satellite and a ground operation facility used for the truss construction experiments. The paper focuses on the on-orbit truss construction experiment, the experimental truss unit and the ground operation facility.

2. Truss Assembly Experiment by Space Robot

The ETS-7 is the first satellite dedicated for space robot mission in Japan. We will conduct space truss construction experiments by using the ETS-7 robot arm. To perform truss deployment and assembly experiments by operating the robot arm from the ground, we have been developing essential technologies such as handling small objects, tracking trajectories under constraints, assembling truss structure under tele-operation, and processing on-orbit camera images. These technologies will be utilized on large space structure construction in the future.

3. Experimental Truss Unit

The experimental truss unit will be mounted on the ETS-7 satellite. The experimental unit, box-shaped with 380mm width, 505mm depth and 280mm height, consists of deployable truss, truss joint assembly, and launch lock system for their truss components. The each component has own grapple fixture to be attached by the robot hand on the tip, and target markers to measure relative position with respect to the robot hand by CCD camera on the tip.

The truss unit design is highly dependent on several significant requirements from the robot such as excited force, positioning accuracy and workable area. We verified the arm accessibility to the truss, the on-board camera view and the arm collision avoidance against the truss by both computer simulations and ground tests.

The deployable truss component composing truss struts connected by hinge will be handled to be tetrahedral structure by the robot arm remotely controlled from the ground operator. The truss joint assembly component will be jointed to the node by the arm. The launch lock system will be released by the robot arm in the earlier stage of the on-orbit experiment.

We have developed the flight model of the experimental truss structure unit, performing vibration test and thermal vacuum test. At the vibration test, twenty gravitational acceleration corresponding to launching load is applied to the truss system, while the launch lock mechanism has been tested after exposed to the less than minus thirty degree centigrade for more than twenty four hours to simulate on-orbit environment at the thermal vacuum test.

4. Ground Operation Facility

The ground operation facility is designed to satisfy primary functions such as tele-operating on-orbit robot arm, handling telemetry/command data, confirming robot motion by graphics simulator and measuring the difference between arm-tip and grapple fixture by processing target marker images

The ground operation facility for truss construction experiments consists of three workstations, three personal computers and one industrial robot arm. All the computers are connected with LAN, to perform real-time experiment operation. One of the workstations called "Man-Machine-Interface computer" will play a significant role in the experiment, because almost every information will be handled by this workstation. Display designs and operator input/output sequences were carefully designed from a safety-operation point-of-view.

The facility will be used not only for actual operations, but also for preparations of the experiment, such as experiment sequence design and confirming validity of command sequence. After developing the ground facility, detailed operation sequence design (SOE design) is being conducted and actual experiment operations will be started from the beginning of 1998.