Truss Structure Tele-Manipulation Experiment using ETS-VII

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Kohtaro Matsumoto, Seishiroh Kibe, Isao Yamaguchi, Takashi Kida, Sachiko Wakabayashi
National Aerospace Laboratory
7-44-1 JINDAIJI-HIGASHI-MACHI CHOFU, TOKYO 182, JAPAN
PHONE +81-0422-47-5911
FAX +81-0422-49-8813
E-mail : matumoto @asuka.aerospace-lab. go.jp

Hiroshi Ueno, Hitoshi Sato, Shigeru Aoki, Tetsuji Yoshida
Shimizu Corporation
SEVANS South 1-2-3 Shibaura, Minato-ku, Tokyo 105-07, JAPAN
PHONE +81-3-5441-0085
FAX +81-3-5441-0346
E-mail : hueno @ spo. shimz. co.j p

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Abstract

In this report, a robot experiment concept of space truss tele-manipulation by National Aerospace Laboratory (NAL) will be described in its flight model development. The experiment will be carried out on the Engineering Test Satellite No. 7 (ETS-VII) using its robot arm. The satellite is scheduled to be launched in 1997 by National Space Development Agency of Japan (NASDA). The truss flight model is composed of deployable truss system and assemble truss joint. Those truss components will be manipulated by the ETS-VII robot arm using its small Grapple Fixture type-N (GPF-N), and the experimental task operation will be executed from the ground control station .

1. Introduction

Future orbital space systems are going to be larger and more intricate in their structure. Such future space structure will be obliged to consider assemble mechanisms in space, instead existing ground-assembled systems. Space truss system will play a major part of such future on-orbit assemble systems with its high transportation performance in smaller packing volume.

For the space truss construction, two kinds of task ---link mechanism structure deployment and strut joint connection--- are considered to be an initial research issue at NAL. Recent space systems are made of rather simple deployable components for one dimensional deployment, but the future large deployment structures will take more complicated mechanism for more intricate configuration with two or three dimensional deployment.

Construction tasks for these systems will require dexterity of human or advanced autonomous systems. NAL believes the ETS-VII (Fig. 1) mission could be the first step for space truss construction.

2. Truss Experiment

NAL experiment preliminary design for ETS-VII was completed in 1993 and experiment scenario and engineering model development has begun in this April. Below is major outcomes in the preliminary design phase.

2.1 Experiment Components

On the preliminary design phase, experimental components were examined in its performance required for robot arm and space qualification. The components are to be deployable truss system and assemble truss joint independently on the task board. ETS-7 robot arm will execute truss handling

motion using its grapple fingers at the end of the arm. The arm has cameras to take visual information of robot tasks robot.

2.2 Truss System

Truss system is composed from several systems as follows;
- Deployable truss system
- Assemble truss joint system
- Launch lock system for the truss
- Task board
- Target markers for camera
- Telemetry devices (Thermisters, etc.)

Deployable truss system has rigid triangle truss and one set of struts connected each other by one degree of freedom (dof) hinge. Task board top surface has every truss system and is designed to be inclined in 20 degrees to make the arm's work smooth while robot is accessing and handling the truss. (Fig. 2, 3)

2.3 Truss Experiment Plan

Scheduled NAL experiment plan includes robot motions as follows;
- fine motion to handle small work
- follow pre-determined track
- grasp and releasing motion of the truss

For tele-manipulation from ground station, NAL is planning to introduce control technology as follows;
- time delay compensation
- graphical information processing on the ground station
- autonomous control architecture with hierarchical structure of robot task components
- operation supporting by computer models

3. Design and Development Status

3.1 Truss Operation

To confirm the function and feasibility of the truss experiment, NAL prepared the BBM (Bread Board Model) of the deployable truss and the assemble truss for its ground testbed. The robot was refined from an industrial robot so that it directly controls the angular velocity (25 ms). The robot performance is far better than ETS-VII robot arm, and it will be necessary to adjust parameters close to ETS-VII arm's in the future.

The arm is expected to use impedance control to absorb the position errors on trajectory in space. For the truss deployment test on the ground testbed, the impedance control for the three axis of both translation and rotation was applied, because the required operational force for the arm is low and the deployment 3-D trajectory is complicated.

3.2 Assemble Truss Joint

As the most of proposed space joints need twisting motion by an astronaut's hands, they may not be suitable for one hand arm task such as ETS-VII arm. For one-hand operation, Star*Bay mechanism has been introduced to NAL truss joint.

In order to use truss joint in space, it is obvious the joints have to maintain operational force lower than maximum arm force. Lever and wedge mechanism are introduced to NAL truss joint to make its force lower. The joint operation motions are; A) to insert and fix the joint into node, and B) to latch the mechanism at the beginning and end of A). A) is achieved by applying the sliding force of the robot arm, while B) is by twisting the arm.

3.3 Grasping Fixture-N (GPF-N)

GPF-N (Fig. 4) is specially designed to grasp small NAL truss system (40 mm dia. pipe). The size is approximately one thirds of standard grasping tool for ETS-VII arm (150 mm dia.).

3.4 Robot Experiment Panel

The truss system is mounted on the robot equipment panel of the ETS-VII robot mission (Fig. 5, 6). The truss location and configuration was fixed by simulation study avoiding collisions considering arm operation clearance (25 mm-45 mm) and the arm joint angle range. The range satisfies 5 degrees margin on every axis, except in the case of emergency.

3.5 Ground Operation System

The ground operation systems for ETS-Vll, including NAL mission, will be built in NASDA's Tsukuba Space Center. NAL is planning to use NASDA's station for

critical part for communication and command operation. The ground station will have functions as follows,

(1) hierarchy control teleoperation
(2) image processing and measuring
(3) orbital simulation image display
(4) tele-manipulation support information display
(5) operation and collision simulation
(6) joystick interface
(7) control and data interface to the arm

4. Future work

4.1 Development Schedule

By the fall of 1994, STM (Structural Thermal Model) and tele-operation model will be delivered to NASDA. The truss PFM (Proto-Flight Model) delivery will be in the fall of 1995. (Fig. 7)

For the limited experiment time schedule in space, NAL, NASDA and other agencies are working how to share the time, as the ETS-VII mission life is designed to be around 1.5 years.

4.2 Technical Issues

It is obvious NAL's small truss system requires higher performance in positioning and trackability however, the arm stability and capability are designed for more rough and tough space tasks using its power. Trade off study adjusting performance of the truss and of the arm is now going on.

Supporting systems on the satellite and on the ground are also being studied to relax the severe operational conditions.

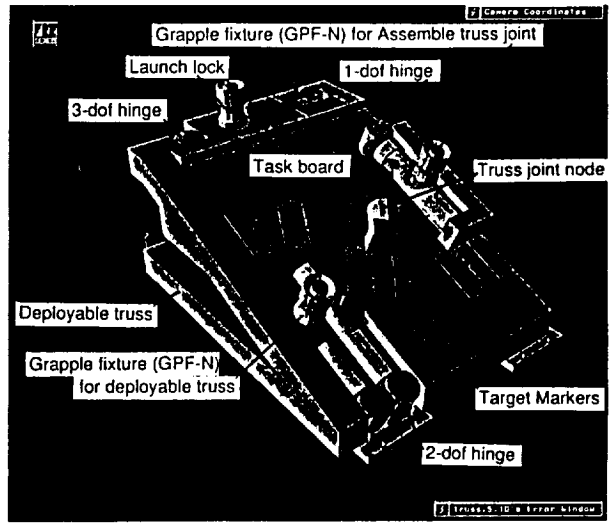

Fig.2 Truss configuration for Launching

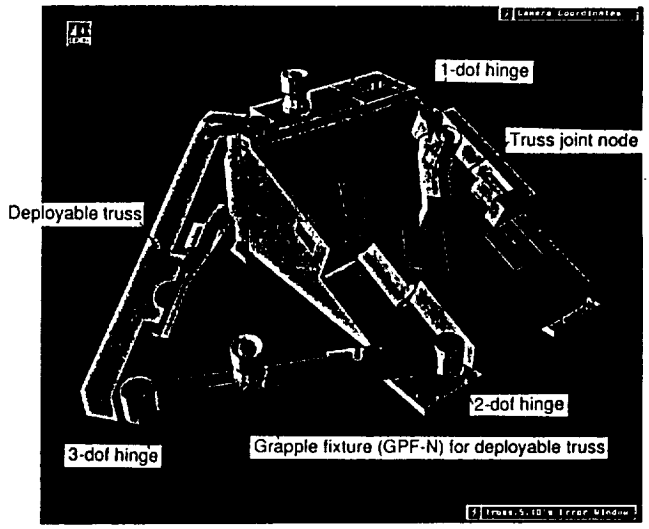

Fig.3 Deployed configuration

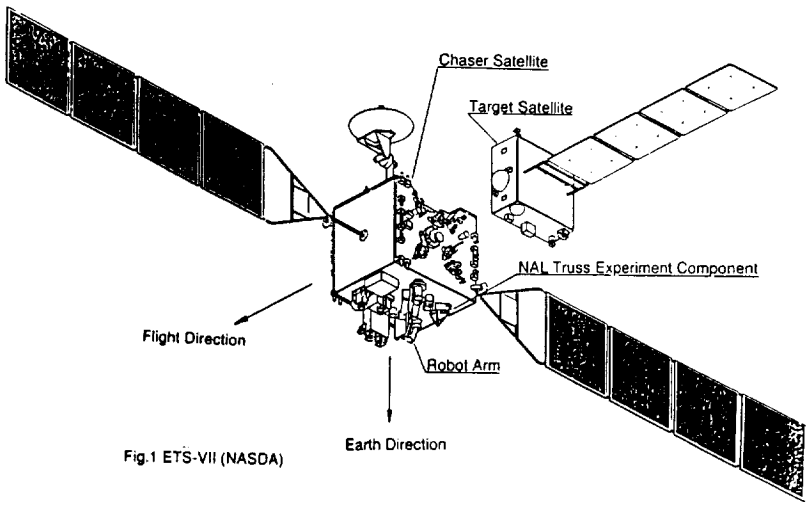

Fig.1 ETS-VII (NASDA)

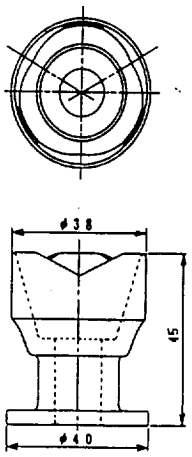

Fig. 4 GPF-N

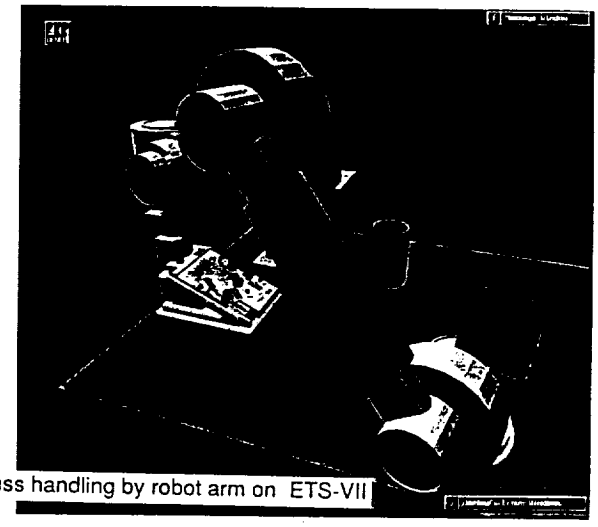

Fig. 5 Truss handling by robot arm on ETS-VII

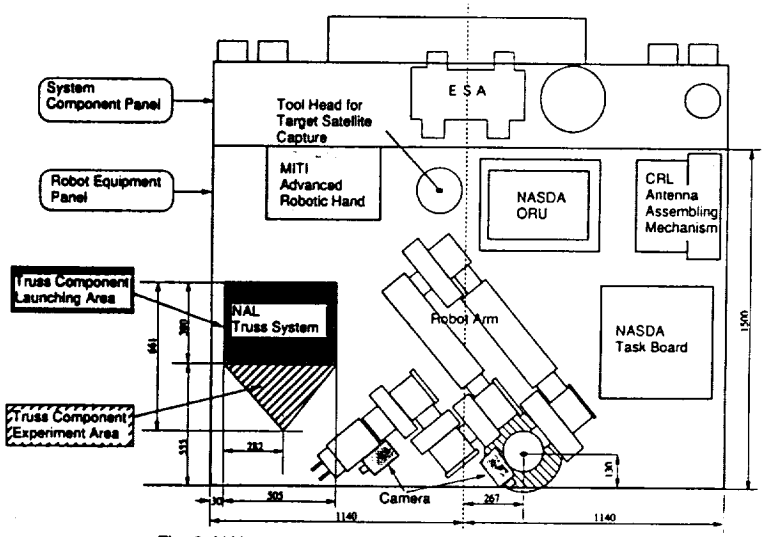

Fig. 6 NAL truss system on the ETS-VII robot equipment panel

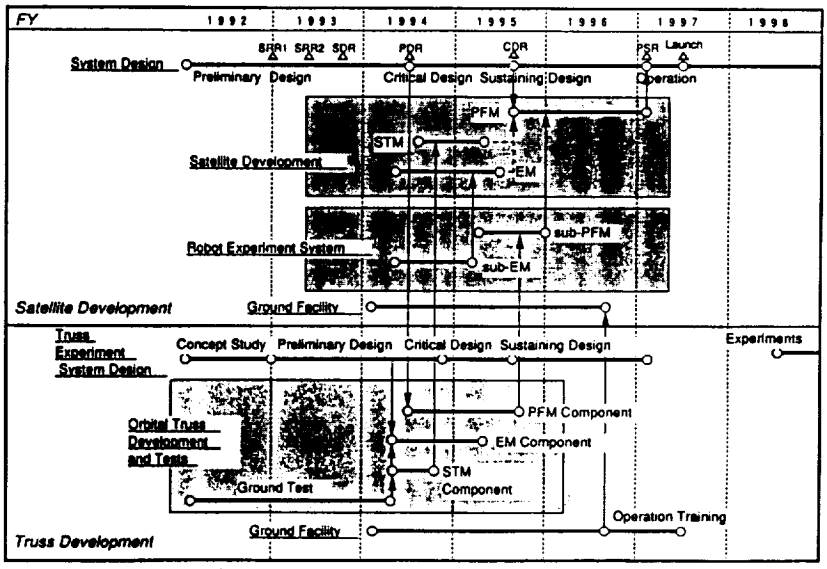

Fig. 7 ETS-VII and truss experiment equipment development schedule