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Space Robotic Experiment in JEM Flight Demonstration

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KEY WORDS AND PHRASES

Remote Manipulator System, Space Robot, Space Shuttle, Space Station

1. INTRODUCTION

Japan is collaborating on the multinational space station program. The JEM, Japanese Experiment Module, has both a pressurized module and an Exposed Facility(EF) as shown in Fig.1. JEM Remote Manipulator System(JEMRMS) will play a dominant role in handling/servicing payloads and the maintenance of the EF, and consists of two robotics arms, a main arm and a small fine arm.

JEM Flight Demonstration(JFD) is a space robotics experiment using the prototype small fine arm to demonstrate its capability, prior to the Space Station operation. The small fine arm will be installed in the Space Shuttle cargo bay and operated by a crew from a dedicated workstation in the Aft Flight Deck of the orbiter.

2. PROGRAM OVERVIEW

The major program milestones and activities are shown in Fig.2, in which the launch is scheduled in 1997. The preliminary design review was completed in Dec. 1992, and the detailed design has been conducted. In parallel with those design efforts, the phase 0 and the phase 1 safety reviews were also conducted as a payload of the Space Shuttle. Especially, the safety is a major design driver in this manned mission flight, and safety features have been incorporated according to the Shuttle safety requirements. As mentioned later, EVA compatibility will be tested using a weightless environment facility during the detailed design phase.

3. SYSTEM DESIGN FEATURES

As stated above, the JFD system basically consists of two elements, the cargo bay element and the AFD element. Fig.3 illustrates the cargo bay element, in which the small fine arm is installed with the support structure on the MPESS(multi-purpose experiment support structure) and also the robotics task components, an ORU(Orbital Replacement Unit) and a Task Panel, are also mounted. Two vision equipments, two sets of TVC and light, are provided to give the visual information on robotics tasks.

The small fine arm is deployed on-orbit using Arm Hold & Release Mechanism. The small fine arm has six joints to achieve six degrees of freedom movement and also has a tool, three fingers type of end effector, to capture and release the payload. A torque driver is incorporated into the tool to fasten and unfasten bolts installed in the ORU and the Task Panel. Once tool fingers are positioned and then engaged in the tool fixture, bolts which structurally attach ORU and Task Panel to the structure will be loosened by the torque driver. Then, the payload grasped by tool fingers will be manipulated by the small fine arm. The above robotics operation will be done by a crew from the AFD workstation shown in Fig.4. Two CCTV monitors, equipped for the Space Shuttle operation, will be used to show the video information at the work site. A dedicated workstation will be assembled on-orbit in the optimal location, relatively to the CCTV monitors from human-machine interface point of view. Translational and rotational handcontrollers are installed at both sides of the workstation for manual operation of the small fine arm with velocity command. PGSC(NASA-provided payload general support computer) will be equipped to display telemetry data including force and torque sensor data applied to the small fine arm. Preprogrammed control will be also available to deploy and to restow the small fine arm. From the safety point of view, appropriate number of inhibits and failure tolerance are provided to prevent an inadvertent release of payload and mechanism, according to the criticality of potential hazard.

Another feature of the JFD is EVA compatibility. As usual, for a deployable type of payload the capability to be jettisoned is required for orbiter safing, however, the contingency and unscheduled EVA design is also accommodated in the JFD system to minimize the generation of orbital debris. Those mechanisms for small fine arm joint, arm hold & release mechanism and ORU are EVA compatible to secure the safe return configuration.

4. MISSION OPERATION

The JFD will conduct end-to-end verification involving flight crew and has the following objectives:

a. Evaluate the small fine arm control performance with the actual behavior in space environment,

b. Evaluate the crew operational interface in micro gravity

The JFD mission operations are grouped into performance evaluation tasks and demonstration tasks. The performance evaluation tasks evaluate the JEM small fine arm control performance and operability, and they will provide the basis for the JEM operability evaluation. The demonstration tasks demonstrate the on-orbit maintenance functions and the payload operational support functions. The demonstration of replacing ORUs and the dexterous tasks using the small fine arm tool, its end effector, will evaluate the end-to-end JEM operability.

The performance evaluation tasks will evaluate the small fine arm control performance and human-machine interface through the actual operations. The followings will be evaluated:

a. Arm control performance
b. Single-joint drive control performance
c. Active compliance control performance
d. Human-machine interface.

The demonstration tasks are defined as follows:

a. Orbital Replacement Unit(ORU) replacement task
b. Hinged door opening/closing task.

A sequence of the performance evaluation and the demonstration tasks will be performed during a 16-hours mission timeline, i.e., two mission days. After the orbit injection, the JFD thermal control activation by a crew member follows the PLB door open. The workstation for the JFD operation is assembled at the Orbiter payload station by Intravehicular Activity(IVA) and then, the software to monitor and control the arm will be initialized. After the system checkout, the arm hold & release mechanism is activated to release the arm and then, the arm will be deployed. The basic system familialization task will be performed first. The crew member will operate the arm in the manual control mode and evaluate the human-machine interface. Then, the arm will be operated in all the control modes with and without active compliance control for unloaded conditions.

The crew will perform the ORU replacement task varying the control parameters to evaluate the operability and control performance. Also the task to open and close the hinged door in the task panel will be performed as a constrained motion of the arm.

After all the demonstration tasks are completed, the arm will be folded and the arm hold & release mechanism is activated to hold it. The equipments in the AFD and PLB are deactivated and the system will be shut down. The workstation is disassembled from the payload station and PGSC will be stowed in a MDK locker.

The crew deactivates the JFD thermal control after the PLB door closure.

The video and test data recorded and crew subjective comments transcribed during the mission are provided for the engineering evaluation of the small fine arm control performance and the crew interface.

5. CONCLUDING REMARKS

In this paper, the JFD ,an on-orbit experiment for space robotics, was described. The basic performance will be evaluated and some of the tasks in the future space operation will be demonstrated. Through the experiment, end-to-end space robot operational verification will be available and those results and experience will be reflected to the JEM development and operations and future applications.

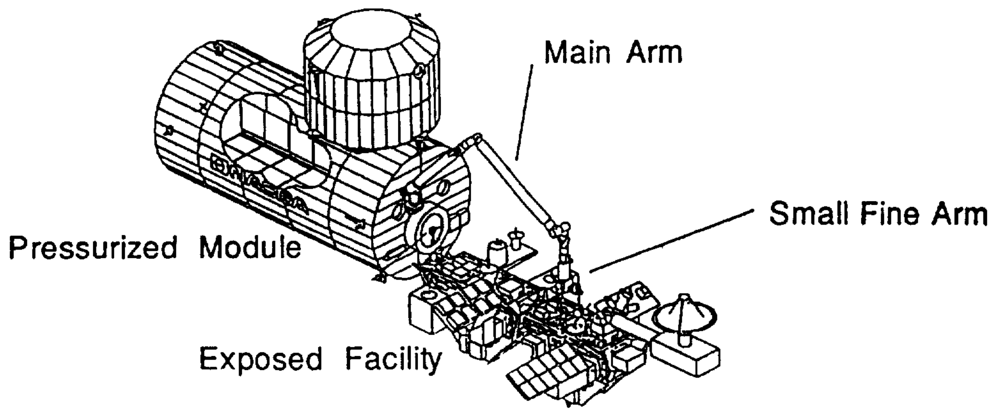

Fig. 1 JEM Configuration

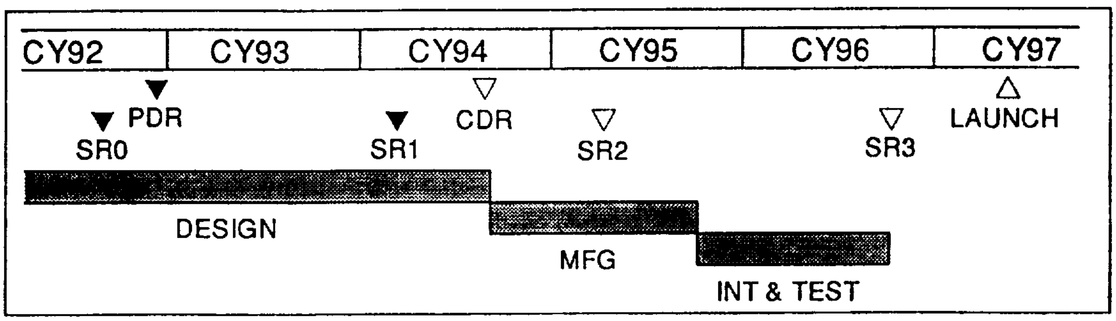

Fig. 2 Program Schedule

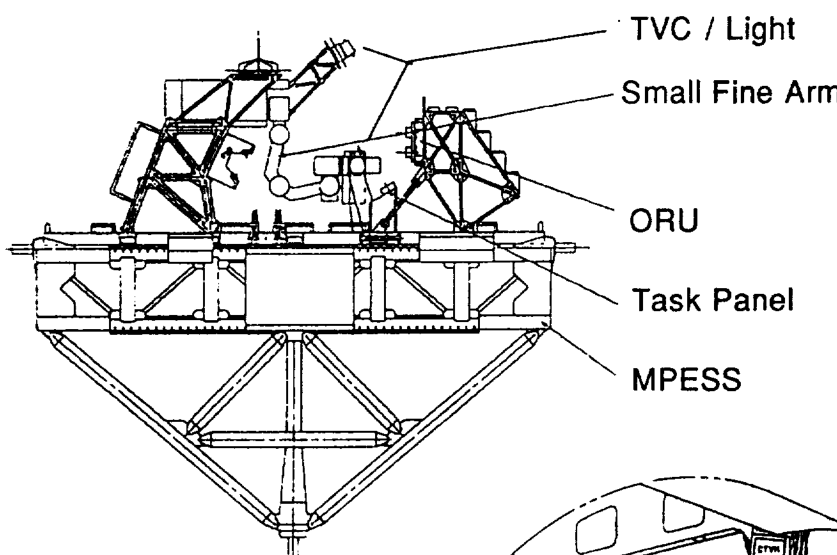

Fig. 3 Cargo Bay Element

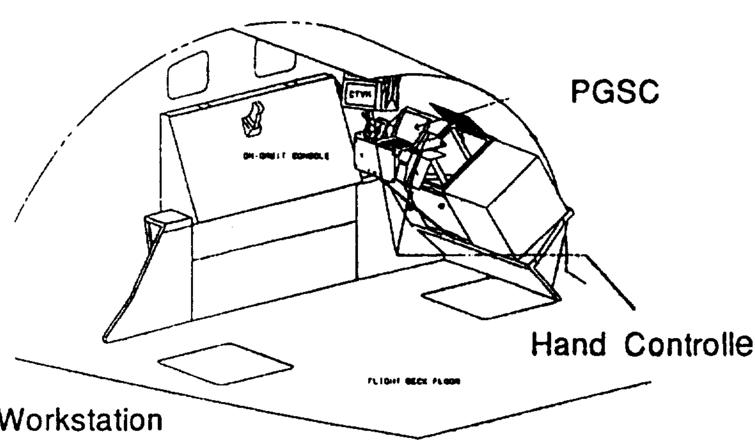

Fig. 4 AFD Workstation