FLIGHT EXPERIMENT CONCEPTS

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FLIGHT EXPERIMENTS IN TELEROBOTICS-ORBITER MIDDECK CONCEPT

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Abstract

Most uncertainties of operation of a telerobot in the space environment relate to the absence of gravity effects and not to the vacuum effects. A flight experiment concept is proposed for the middeck of the Space Shuttle that provides direct access for the crew. Telerobot dexterous manipulation issues in task performance, mechanism response, system duty cycles and operator interface can be effectively addressed. A pair of replica-type master controllers would be adapted for slave manipulator functions. A variety of test setups and control modes can obtain data on zero g operation of a telerobot.

1. Introduction

The operation of a telerobot in the space environment will bring up a number of issues that cannot be effectively addressed in ground-based simulations [1].

The difficulty and expense of flight testing is an effective deterrent to research in the vacuum and zero g. Even so, the risk in applying telerobotics to dexterous manipulation tasks can be reduced by validating simulations and answering questions of task performance, mechanism design, system flexibility and interface with the operator in a flight test. The majority of flight test issues relate to zero g and not to vacuum effects. This provides an opportunity to experiment in the middeck of the Space Shuttle cabin. The proposed concept involves replica-type master controllers, developed for good bilateral force reflection, adapted for slave manipulator function. Through a variety of control modes, many significant test objectives can be resolved. With direct access to the task site, the crew can change the test setups and accommodate mistakes in task performance to reduce the probability of test failure.

2. Experiment Objectives

The objective of a flight experiment is to develop data for resolution or support of research issues that cannot be adequately simulated in ground-based laboratories. For a telerobot, these issues can be categorized as task performance, manipulator characterization and operator interface. Tasks involve some degree of dexterous manipulation. Maneuvering and positioning orbital replacement units (ORU), attachment of structural fasteners, electrical connectors, fluid transfer lines, and handling of tools are examples of tasks. Operations in zero g may also involve unique provisions for object retention, containing contaminents or dealing with large surface areas such as insulation.

The mechanical functions of a manipulator may change in zero g, affecting positional accuracy and repeatability and cannot be effectively simulated in ground-based tests. The interaction of joint and arm flexibility with control may be significant in response to forces generated in task performance. The direction and magnitude of force application may change to a degree that will affect the accomplishment of a specific task. Dual-arm activities are certainly a question when gravity is not acting on the arms and workpiece.

The operator's control of the manipulators in zero g cannot be adequately simulated on Earth. Position control modes and bilateral force reflection control are particularly sensitive to operator restraints and controller configuration. Data must be developed on these interactions including dual-arm control. Viewing the worksite, whether direct or by TV, has not been evaluated under space flight conditions.

There are integrated telerobotic system issues that exhibit a high degree of uncertainty in the transition from ground to space flight operations. The manipulator duty-cycles with power requirements and heat dissipation should be measured when performing tasks in zero g. Actual flight testing should also develop the realities of training and operations integration in the use of a remote operating system for dexterous manipulation.

3. Concept Description

Several potential experiment concepts are described in reference [2]. These include a fixed-base telerobot attached to a carrier structure in the orbiter payload bay (Figure 1), a telerobot positioned by the Space Shuttle remote manipulator system (RMS) (Figure 2), and a telerobot representation in the middeck of the orbiter. The middeck flight experiment concept is derived from the performance of a force-reflecting "mini-master" controller and extrapolating that performance to zero g (Figure 3). The flight experiment uses two of the controllers set up in the middeck of the orbiter cabin. The controllers are modified to operate in a slave mode as well as in a master control mode. Three combinations of operation are proposed:

1. A workstation with dual arm controllers that controls a computer simulation with synthetic force input fed to the controllers (Figure 4).

2. Master controller driving the other controller as a slave in a bilateral force reflecting mode (Figure 5).

3. Dual-arm slave manipulators controlled by computer (Figure 6).

The test combinations would be set up in various combinations of workstation and worksite configurations to evaluate task performance.

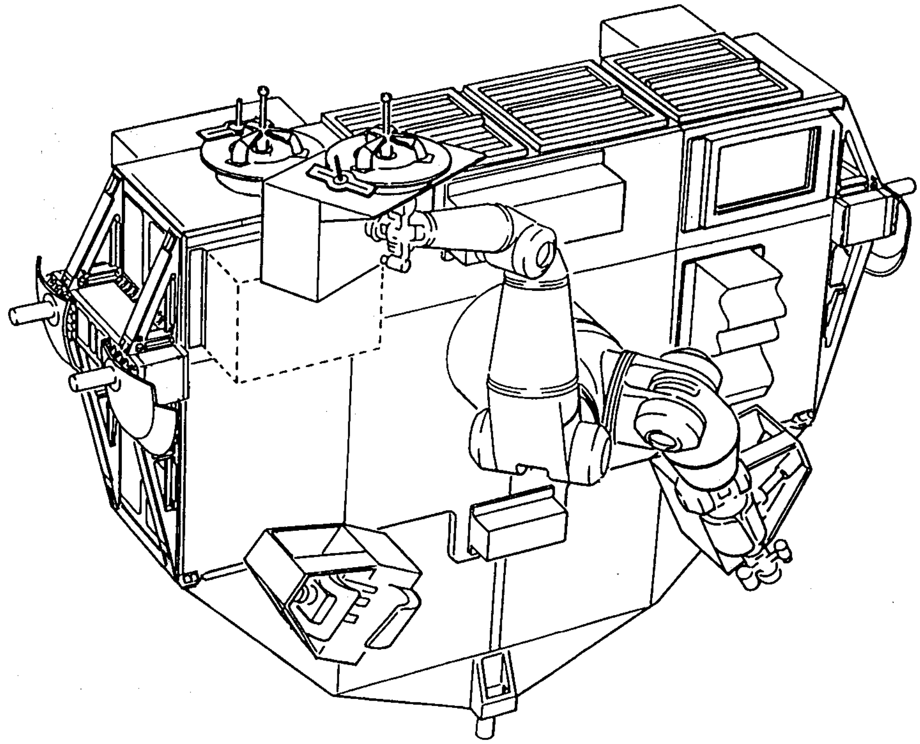

Figure 1.- Fixed-base telerobot in Orbiter payload bay.

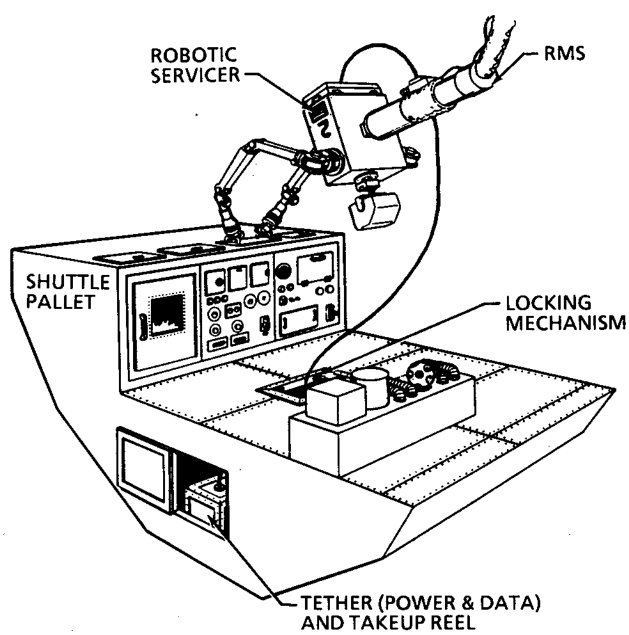

Figure 2.- RMS-positioned telerobot.

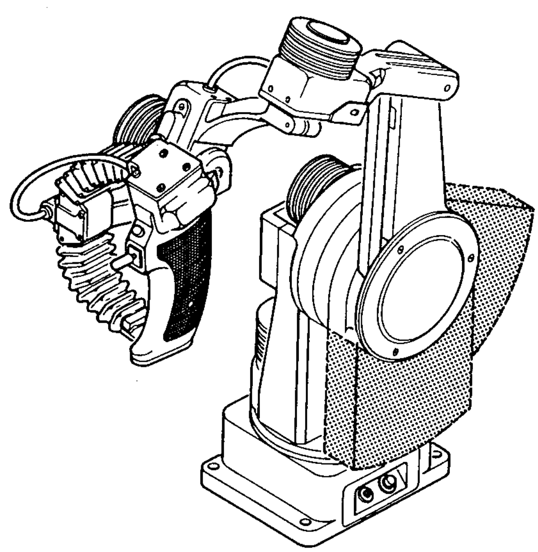

Figure 3.- Force reflecting mini-master controller.

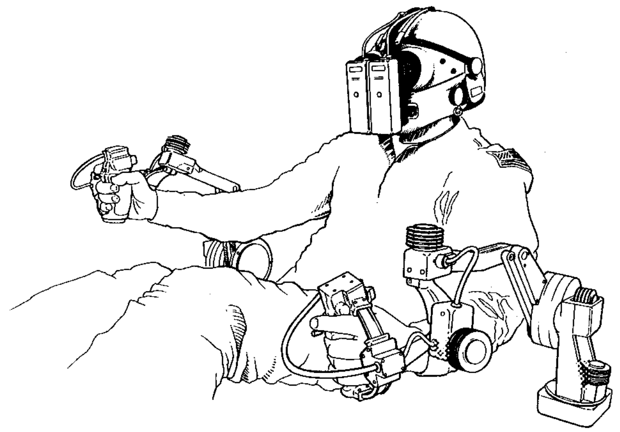

Figure 4.- Dual-arm controllers.

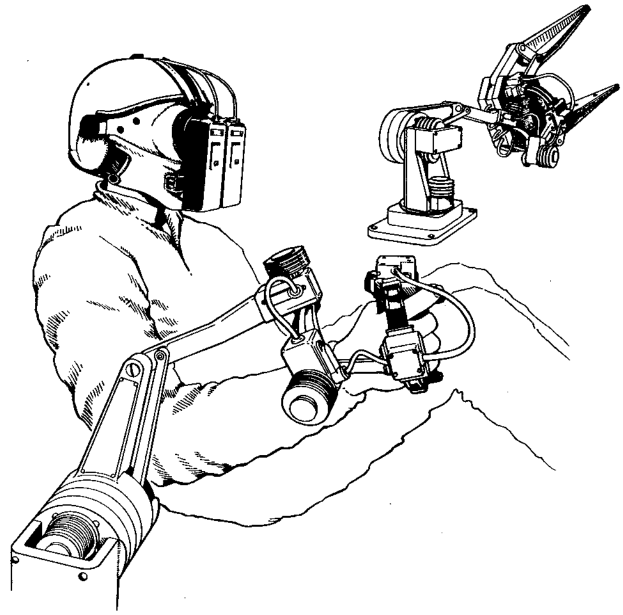

Figure 5.- Master controller and slave arm.

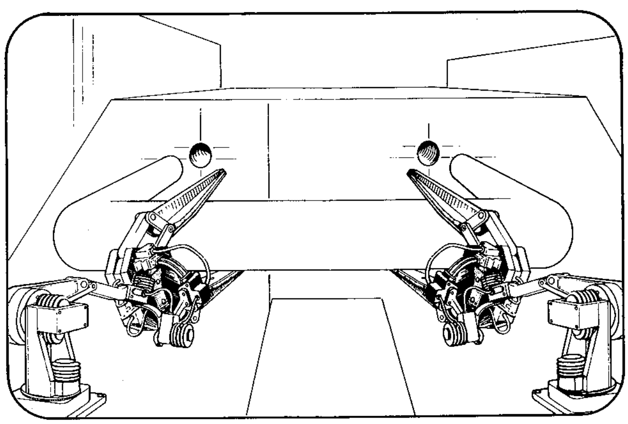

Figure 6.- Dual-arm slave manipulators.

4. Experiment Equipment Requirements

The primary equipment needed is a pair of mini-masters and their supporting electronics as controller/manipulators. End effectors must be installed on the controllers for the slave manipulator mode. A computer supports the controller/manipulators as well as an interface for the dual arm control simulation and a driver for the dual slave arm setup. Displays for the operator may be incorporated in a helmet for portability (Figure 7). Restraint systems for the operator should include several variations to provide a comparison of degrees of support for reacting controller loads (Figure 8). Closed circuit television functions to provide indirect viewing for the operator as well as to document most of the test results (Figure 9). The final piece of primary equipment is the task board.

Secondary equipment to support the experiment includes the power supply and structural interface adapters. Structural interfaces are required for the controller/manipulators, operator restraints and the task board. Lack of convection cooling may dictate the need for fans to circulate air past the controller/manipulators and the electronic equipment.

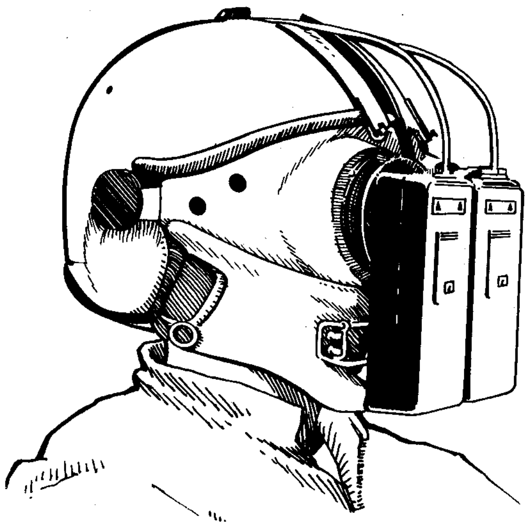

Figure 7.- Helmet mounted displays.

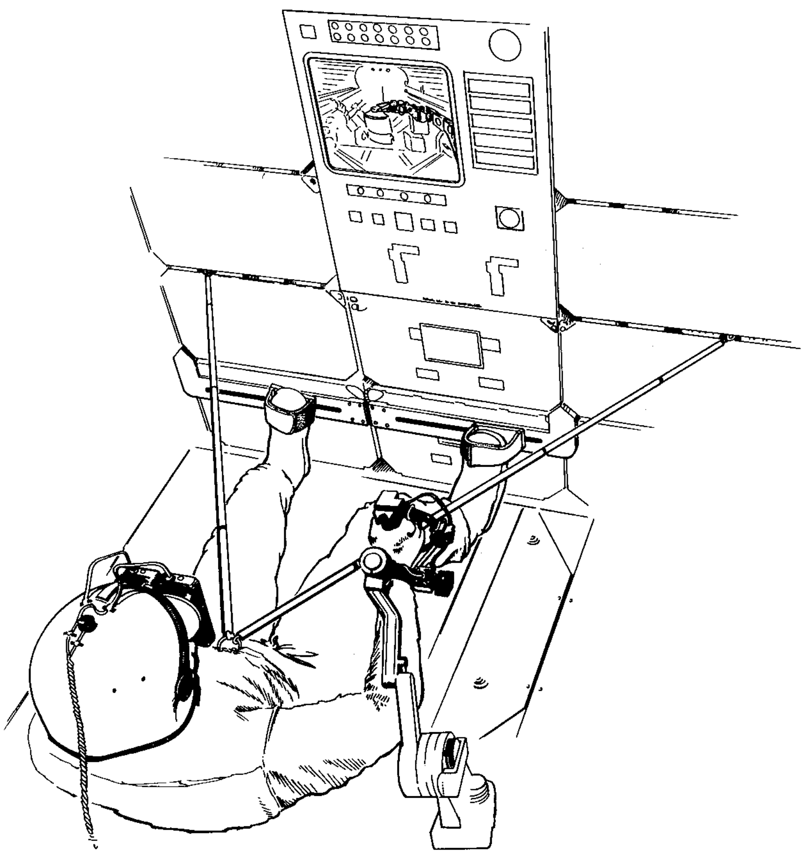

Figure 8.- Operator restraints.

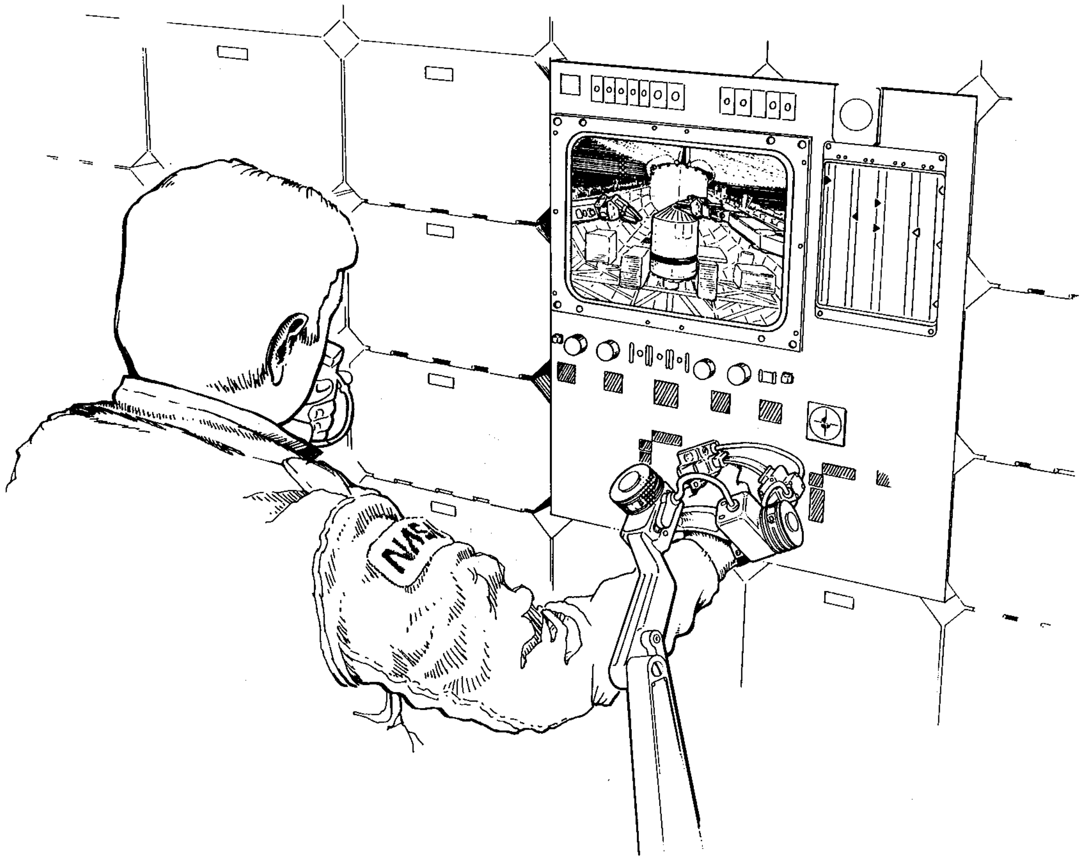

Figure 9.- Indirect viewing with CCTV.

5. Concept Analysis

The concept of a simple middeck test of dexterous manipulation in different telerobotic control modes has numerous advantages over a test setup in the cargo bay of the orbiter. The equipment, materials and function do not have to be certified for vacuum operation. The materials need only meet flammability and toxicity standards for use in the crew cabin. The small low-force manipulator arms do not represent a significant safety hazard for injury to the crew or damage to orbiter equipment. Tests, not under direct operator control may need safety isolation with light weight netting or simply avoidance of the test zone. The cabin location of the test setup allows hands-on access to alter test setups or to accommodate testing errors. This assures that useful data will be obtained. Repetitive testing with several operators can provide some degree of statistically significant results. Repeating tests using direct vision and television views of tasks gives an indication of the validity of similar testing in Earth-bound simulations.

A potential psychological disadvantage of the concept is the size of the manipulators. Most Earth-bound manipulators are massive to support payloads in the gravity field. Space manipulators can handle massive loads with low levels of force; therefore, they can be lighter than manipulators for Earth application. The perception of the small manipulator may detract from the impression of capability that is inherent in the test. The small manipulators will be mechanically different from the conventional design approach for manipulators. This will require careful design and test analysis to obtain duty-cycle test results that can be extrapolated to larger vacuum-rated manipulator designs.

6. Summary

Flight testing of telerobotic technology onboard the Space Shuttle can provide answers to uncertainties and issues that are a concern with the development of a telerobot system for space. The proposed middeck experiment provides a relatively low risk, low cost approach to early definition of telerobot system functions in space. The benefits of an operational space telerobotic system, such as the flight telerobotic servicer (FTS), in enhancing astronaut productivity and reducing the risk of extravehicular activity, deserve the greatest chance of success that can be achieved.

REFERENCES

[1] R. deFigueiredo and L. Jenkins, "Space Robots," International Encyclopedia of Robotics, Dorf.

[2] L. Jenkins, "Telerobot experiment concepts in space," SPIE 1987 Symposium on Advances in Intelligent Robotic Systems, November 1, 1987.