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TELEROBOT FOR SPACE STATION

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ABSTRACT

The Flight Telerobotic Servicer (FTS), a multiple arm dexterous manipulation system, will aid in the assembly, maintenance, and servicing of the Space Station. Fundamental ideas and basic conceptual designs for a Shuttle based telerobot system resulted from the Telerobotic Work System Definition Studies performed by Grumman and Martin-Marietta. Recent Space Station studies provide additional concepts that should aid in the accomplishment of mission requirements. Presently the FTS is in contractual source selection for a Phase B preliminary design. Concurrently, design requirements are being developed through a series of robotic assessment tasks being preformed at NASA and commercial installations. A number of the requirements for remote operation on the Space Station, necessary to supplement EVA (extra vehicular activity), will be met by the FTS. Finally, technology developed for telerobotics will advance the state-of-the-art of remote operating systems, enhance operator productivity, and prove instrumental in the evolution of an adaptive, intelligent autonomous robot.

INTRODUCTION

The Space Shuttle Remote Manipulator System has been the primary means for accomplishing remote manipulation operations such as handling payloads. The RMS is severely limited in its ability to perform dexterous tasks due to its size and control mode. It is a teleoperation system that is controlled in a resolved rate mode and is not suited to constrained motion tasks. Studies of requirements for servicing satellites has defined concepts for using smaller dexterous manipulators to perform more precise manipulative tasks. The Space Station has a number of applications for remote operating systems. The requirements include dexterous manipulation for its assembly, its maintenance, in servicing satellites and for servicing remote free-flying platforms.

SYSTEM DEVELOPMENT

The concept of a telerobot is being developed in the Flight Telerobotic Servicer for the performance of a number of dexterous manipulation functions that will be needed in the station assembly, in the station maintenance, and for servicing satellites. The concept is also being examined for remote servicing operations with the Orbital Maneuvering Vehicle and for free flying platforms. The Flight Telerobotic Servicer Program is expected to provide a unique capability for supplementing the work of the EVA.

The size of the Space Station will require a number of Shuttle flights for its construction, primarily with EVA. The tasks outside the pressurized modules on Space Station are presently planned for accomplishment by the crew in EVA (extravehicular activity). The FTS can be used in early operational tasks to increase EVA timeline margins. During the period when the Shuttle mission rules restrict the use of EVA due to the potential for space sickness, the FTS can be used to unstow and deploy assembly jigs and fixtures. Launch packages for struts and nodes can be prepared for start of structure assembly. Portable EVA restraint devices can be installed in the position for the initial EVA needs. During the assembly activities, the FTS can support operations by positioning cameras, by passing and holding tools and parts and by documenting, through TV images, the as-built configuration. Post EVA, the equipment status can be checked and the status of the closeout operation reviewed and documented. Incomplete steps in final preparations for return to earth can be performed with the FTS to preclude a contingency EVA. Assistance by FTS will increase operational margins and reduce astronaut exposure to hazards.

The FTS concept is based on two dexterous manipulator arms controlled from a remote station. The term "telerobotic" describes a system that is a combination of teleoperator and robotic control. The control station (work station) will be located in the cabin of the Space Shuttle on initial missions. When the buildup of the station reaches the appropriate stage, the controlling operator will move to the interior of the Space Station at the standard work station. The FTS work station will be developed as a configuration of the standard work station.

The FTS was preceded by several conceptual studies including the Telerobotic Work System (TWS) shown in figure 1. Contracted studies by Grumman Aerospace Corporation and Martin Marietta Aerospace developed the TWS concepts illustrated in figures 2 and 3. These studies were based on the criteria of a design that would be able to perform tasks with a capability equivalent to the EVA astronaut. This EVA equivalency approach resulted in designs that are strongly anthropomorphic.

The reach and access envelope are summarized in figure 5 as functional requirements for manipulation. Additional requirements and design trades are summarized in reference [1] and [2]. A fundamental in the design approach is the use of modularity to allow effective evolution of the system as technology developed.

The current program plan for the development of the FTS consists of a technology element, a flight demonstration element, a flight system element and a ground system element. The technology element is the basis for the infusion of state of the art advancements into the initial and evolutionary FTS. A flight test of the FTS is planned to validate the telerobot design for zero-g operations. Testing in space will evaluate the task performance interface and provide a basis for the development of procedures and training. The operational FTS will be used during the initial assembly of Space Station. It will function as multipurpose tool for the maintenance of external subsystems on the station. It will have a role in the assembly, installation and servicing of payloads as well. The ground element of the program is intended to coordinate a network of telerobotic laboratories within NASA.

An evolutionary philosophy has been incorporated in the program plan for the Flight Telerobotic Servicer. The plan considers the technology base for development of the telerobot from manufacturing industry, the nuclear energy operations and undersea servicing and exploration. Although each of these areas has contributing features, the challenge of a space telerobot goes beyond the cumulative capability that has been developed in these industries. NASA's own program in telerobotic technology is a multi-center effort that is concentrated in the Office of Aeronautics and Space Technology telerobotic testbed at the Jet Propulsion Laboratory. The testbed serves as a systems laboratory for the resolution of systems issues as well as the demonstration of the functionality of various equipment combinations. The testbed has a shortcoming in the consideration of zero-g. Other capabilities for the effective simulation of the space environment exist in the flat floors and neutral buoyancy facilities at the Johnson Space Center and the Marshall Space Flight Center. Computer simulations are another way of evaluating space operations. Functional requirements are also the objective of a series of Robotic Assessment Tasks that are being conducted by the NASA centers responsible for Space Station work packages. Eventually the validity of the ground simulations will need to be correlated by flight test.

Flight tests may be categorized as research, validation of simulations, system development test and flight system verification. The human interaction with the displays and controls is difficult to simulate in system development. The operation of manipulator controllers in zero-g depends of the type of control, the actuation forces and the precision of position and movement. An evaluation of the complex interaction of the physical characteristics of the mechanical arms, controller parameters and the restraint of the operator must be provided to reduce risk in the design of the telerobot. A system with bilateral force reflection is generally acknowledged to require less training in the performance of remote manipulation tasks on earth. This has not been established for space operations. Although the benefits maybe confirmed, constraints imposed by the volume of the spacecraft may limit the application of bilateral force reflection.

SUMMARY

The FTS program is a key development in the capability to perform physical activities remotely in the hazardous environment of space. The program is planned to progress through a Phase B study to a Phase C-D design and development. With the continued application of technology, the productivity of the operator can be enhanced and the state of the art in remote operating systems can be advanced. The first space telerobot, the FTS, should prove to be an instrumental first step in the evolution to an adaptive, intelligent, autonomous robot.

REFERENCES

[1] Telerobotic Work System Definition Study. Grumman Aerospace Corporation, Contract NAS9-17229, Final Report SA-TWS-87-R002 dated April 1987.

[2] Telepresence Work Station System Definition Study. Martin Marietta Denver Aerospace Report MCR-86-528, May 1987.

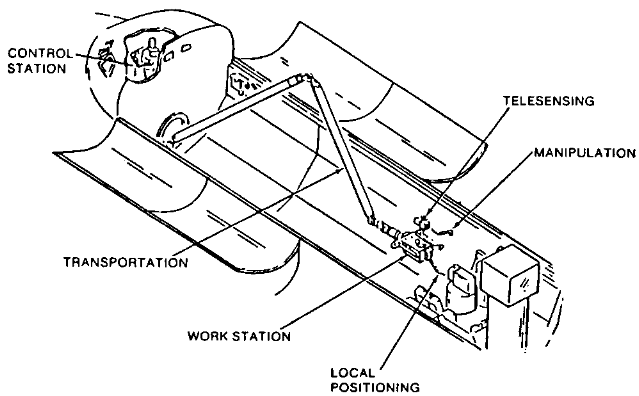

Figure 1. Definition of TWS Systems

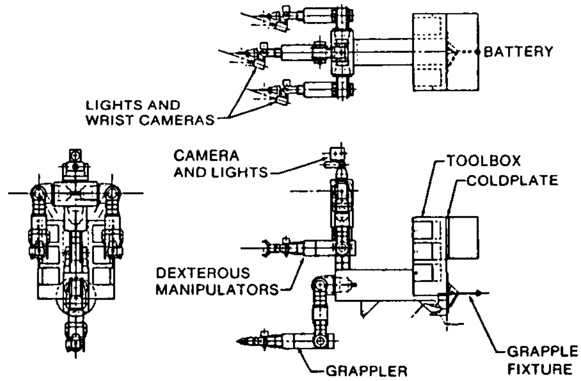

Figure 2. Grumman Telerobot Concept

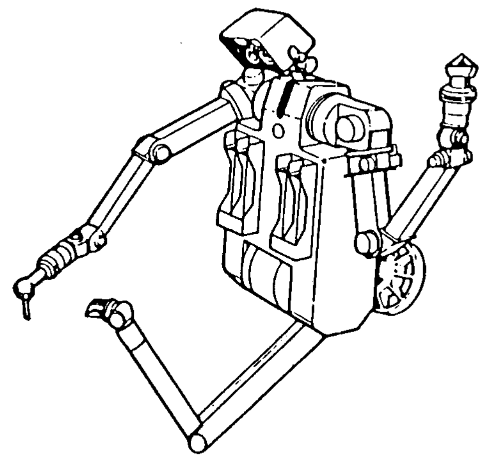

Figure 3. Martin Telerobot Concept

• DEXTERITY	
– ACCESS DEPTH	14"
– ACCESS OPENING	6' X 6'
– ORU DIMENSIONS (MAX)	36" X 36" X 72"
(MIN)	6" X 7" X 2"
– ORU MASS	3 LB TO 700 LB
• STRENGTH	
– INSERTION	20 LBS (PUSH/PULL)
– TORQUE (MAX)	2800 IN OZ
(WRIST)	576 IN OZ
(MIN)	10 IN OZ
• ACCURACY	
– TRANSLATION	.0625"
– ROTATION	±1°
• MOVEMENT	TWO HANDED OPERATION
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Figure 4. Summary of Mission Requirements for Manipulation