N85-33525

ORIGINAL PAGE IS
OF POOR QUALITY

TELEPRESENCE WORK SYSTEM CONCEPTS

Lyle M. Jenkins*

ABSTRACT

Telepresence has been used in the context of [illegible] manipulation where the operator is provided with the sensory feedback and control to perform highly dexterous tasks. The concept of a Telepresence Work Station for operation in space is described. System requirements, concepts, and a development approach are discussed. The TWS has the potential for application on the Space Shuttle, on the Orbit Maneuver Vehicle, on an Orbit Transfer Vehicle, and on the Space Station. The TWS function is to perform satellite servicing tasks and construction and assembly operations in the buildup of large spacecraft. The basic concept is a pair of dexterous arms controlled from a remote station by an operator with feedback. It may be evolved through levels of supervisory control to a smart adaptive robotic system.

INTRODUCTION

The term "Telepresence" describes a remote manipulation situation where the operator is provided with the sensory perceptions and control to accomplish intricate tasks requiring great dexterity. An extension of the concept of telepresence is a space flight system that is a combination of teleoperation and robotics called a Telepresence Work System (TWS). The TWS is an evolutionary concept that is intended to provide the operator with the capability to perform tasks in space as though the operator were at the remote site. The basic concept of a TWS is a pair of manipulator arms controlled from a remote station that provides sensory feedback of the work site conditions. Utilization of current technology with the option of including new technology as it develops is a design goal of the concept. The TWS mission and design requirements are pointed toward a general capability rather than specific or unique tasks with limited application. The primary function of the TWS would be the performance of satellite servicing and repair from the Space Shuttle. The TWS can be used for assembly tasks in the buildup of the Space Station. On the operational Space Station, the TWS can aid in the servicing of satellites and in the construction and assembly of new spacecraft.

TWS MISSION AND DESIGN REQUIREMENTS

The Space Shuttle can be expected to increase its role in the servicing, repair, and recovery of operational satellites, such as has been done with Solar Max, WESTAR, and PALAPA (Figure 1). The current and projected EVA (extravehicular activity) capability provides a basis for development of the

* NASA Lyndon B. Johnson Space Center, Houston, Texas

equipment and functions needed for working with satellites. The addition of dexterous functions greater than the current SRMS (Shuttle Remote Manipulator System) can supplement EVA for hazardous, tedious, or repetitious tasks. These dexterous functional requirements can be defined for satellite servicing, assembly and construction, and Orbiter contingency situations in terms of the capability of an EVA astronaut to perform detailed tasks.

Requirements for servicing satellites include the resupply of expendables, the replacement of modules, and the repair of damaged or inoperative components. The transfer of fluids for a resupply mission involves the attachment of fluid connectors, determination of integrity of the interface, actuation of valves, release of connectors, and verification of lack of system leakage. Resupply by tank replacement also requires the manipulation of fluid connectors as well as the handling tasks inherent in the replacement of equipment modules. Working with modules includes a variety of tasks such as removal of insulation, removal of access panels, fastener disconnection, module handling, fastener insertion, electrical connection, and verification of mechanical and electrical interfaces. Repair tasks are among the most unstructured activities that will be demanded of the TWS. The repair functions require cutting, clamping, soldering, applying adhesives, and other nonstandard operations.

The requirements to perform assembly and construction tasks in the buildup of satellites that are larger than the payload bay of the Orbiter or in the reconfiguration of satellites that are already in orbit will be similar to the operations for satellite servicing. These operations will be better defined and structured with supplemental fixtures and tooling to aid in the assembly of components into the final configuration.

Orbiter contingencies represent another area of operations that will be well structured in some instances and very poorly defined in other cases. The deployment and stowage of payloads involve the actuation of latches or the movement of mechanical appendages that have not functioned properly. With a high degree of dexterity available, the use of kits to repair damaged heat shield tiles becomes practical. The removal of icicles, as occurred on one mission, could be accomplished with ease. A TWS could provide a variety of services to aid the astronaut in EVA operations.

The design of the TWS requires certain subsystems to perform critical functions in the efficient accomplishment of tasks. The work must be stabilized relative to the TWS. The dexterous arms must have sufficient reach and degrees of freedom to place the end effectors in proximity to the work. End effectors need to interface with the equipment being serviced. Vision is an important sense in orienting for remote manipulation. Stereo viewing, while not a requirement, improves the performance of the operator in many circumstances. The interaction of the type of control system with the layout of the control station is fundamental in the case of the Orbiter. For example, the SRMS was driven to a resolved rate system because of the length of the slave arm and the constrained volume of the crew station. Shorter arms on the TWS may allow the option of a master slave controller with the proven force reflection technique to feed back reactions at the end of the manipulator arm.

ORIGINAL PAGE IS
OF POOR QUALITY

CONCEPT DESCRIPTIONS

Elements of the TWS are pointed out in Figure 2. The TWS concepts currently under evaluation are composed of the following subsystems: structural base, interface to the carrier, stabilizer arm, dexterous arms, end effectors, closed circuit television, controllers, displays, lighting, communication, and power. There are a number of options in sensors that could be incorporated to enhance the ability of the operator to perform more effectively. Stereo vision, proximity sensing, and tactile and force feedback are probable additions.

Two companies, Grumman (GAC) and Martin-Marietta (MMA), have study contracts with NASA to define concepts for the TWS. A Grumman concept, shown in Figure 3, is based on using one of the dexterous arms as the stabilizing device. The support structure is a simple arrangement for the three dexterous arms and the television camera. The control station is a portable setup in the aft deck of the Orbiter cabin. Another GAC version, illustrated in Figure 4, carries a stabilizer arm and movable cameras to get improved viewing angles. Stowage for end effectors to adapt the manipulators for specific tasks is incorporated in the structure.

A Martin-Marietta concept, as shown in Figure 5, uses 7-degree-of-freedom arms for the dexterous function and an arm with limited articulation for stabilization. Stereo vision simulates the operator eye location with the camera located relative to the two dexterous arms in an anthropomorphic representation. The initial control station concept appears in Figure 6. The controllers shown are 6-degree-of-freedom that input motion to the arms. The controllers are reindexed to keep the controller motion within the available space envelope.

SYSTEM DEVELOPMENT

The concept development will be subject to a number of trade studies. Among the more important trades are: arm length, control by position or rate, stereo or regular TV, number of arms, force reflection vs. displayed force feedback, and stabilizer arm (number, stiffness).

The initial trade results will result in a basic configuration to begin the development. The trades and technology projections are elements in the definition of an evolutionary development plan. An evolutionary program is projected that has objectives beyond the operation on the Orbiter. The OMV (Orbit Maneuver Vehicle) requires a dexterous system to perform tasks on the satellites. Similar requirements are expected for the OTV (Orbit Transfer Vehicle). These operations will be conducted at long distances from the control station. Time delay in excess of about 0.5 second becomes a factor in teleoperation; therefore, development of the TWS should include time delay compensation techniques in the selection of subsystems. Coping with time delay may include predictive graphics, rate control rather than position control, data compression and simplification to reduce communication requirements, and robotic phases in performance of an operation.

The ultimate evolutionary objective of the TWS program is the Space Station. The TWS can provide significant assistance in the initial buildup of the Station. It can conduct servicing operations similar to those that it would perform on the Shuttle. Maintenance of the Station offers another opportunity for the TWS to relieve the crew of tedious and time-consuming functions.

With these evolutionary objectives defined, the development and incorporation of technology should be selected for compatibility with the objectives. For instance, the output of a sensor should be adaptable to integration with AI (Aritifical Intelligence) systems as they become available. The crew can monitor and supervise a task. They are available to take over in a teleoperator mode. This suggests a pattern for the development of a smart adaptive robot. The TWS can be configured to do the tasks planned for a robot, including the sensory input needed to establish conditions at the work site. Telepresence provides the operator with the data to monitor the operation and, if necessary, to assume control of all or part of the task in progress.

SUMMARY

The utility of remote systems operating in a remote and hostile environment has been proven in the undersea systems that service offshore oil rigs. The concept of a TWS has the same potential for developing into an invaluable system for performing manipulative tasks in space. The TWS can be evolved into an adaptive robot that can operate autonomously in space. The robot operation can be supervised with an option to take over in a telepresence mode where needed. The TWS concept provides a focus for technology development and flight demonstration leading to operational application on the Space Shuttle and the Space Station.

REFERENCES

(1) Analysis of Remote Operating Systems for Space-Based Servicing Operations. Contract NAS 9-17066, Grumman Aerospace Corporation.

(2) Satellite Services System Analysis Study - Final Report, Contract NAS 9-16120, Grumman Aerospace Corporation, August 1981.

(3) Telepresence Work System Definition Study, NAS 9-17229, Grumman Aerospace Corporation.

(4) Telepresence Work System Definition Study, NAS 9-17230, Martin-Marietta Aerospace.

(5) Autonomy and the Human Element in Space, 1983 NASA/ASEE Summer Faculty Workshop.

ORIGINAL PAGE IS
OF POOR QUALITY

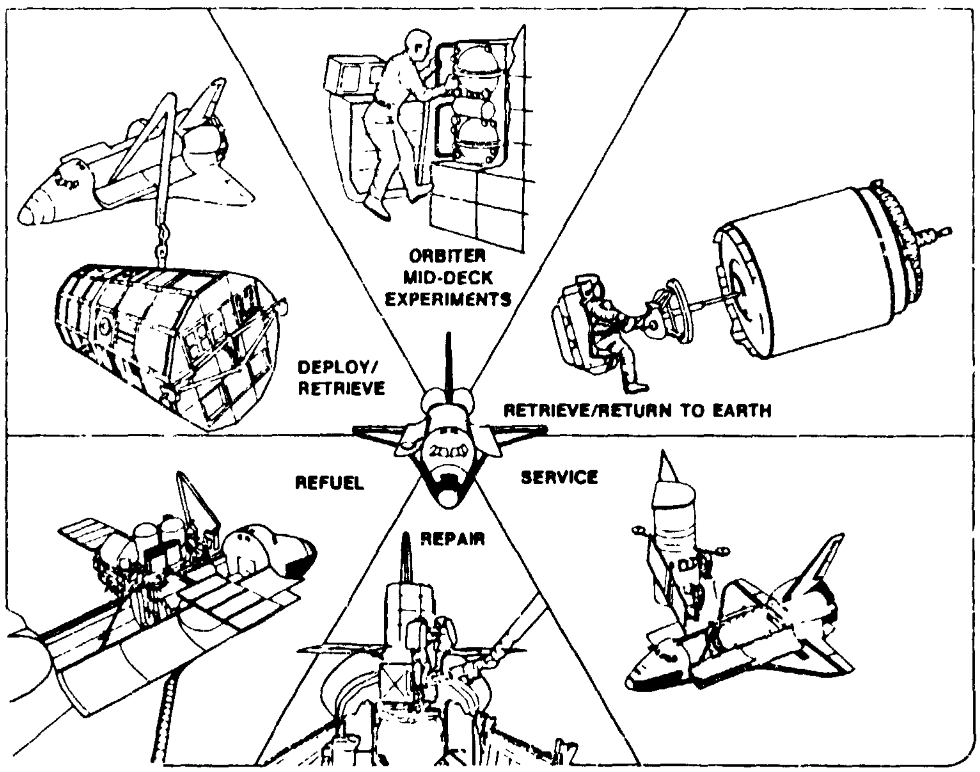

Figure 1. Shuttle Satellite Servicing Capabilities

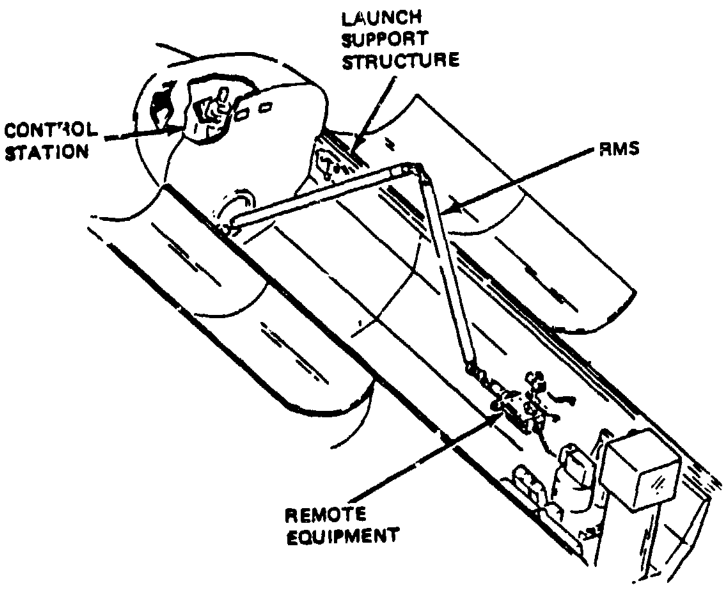

Figure 2. TWS System Elements

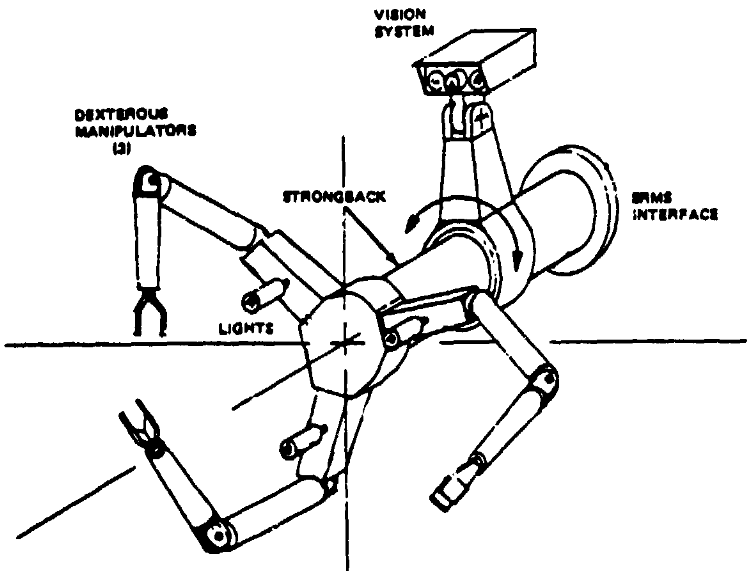

Figure 3. GAC TWS Concepts

ORIGINAL PAGE IS
OF POOR QUALITY

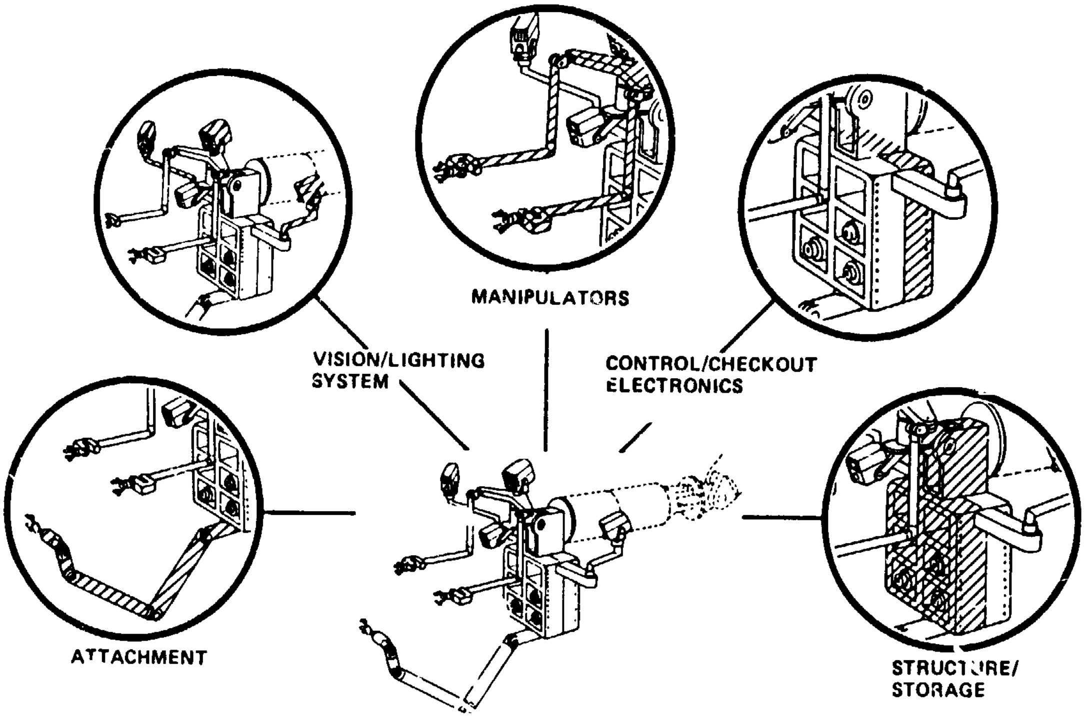

Figure 4. Alternative GAC TWS Concepts

ORIGINAL PAGE IS
OF POOR QUALITY

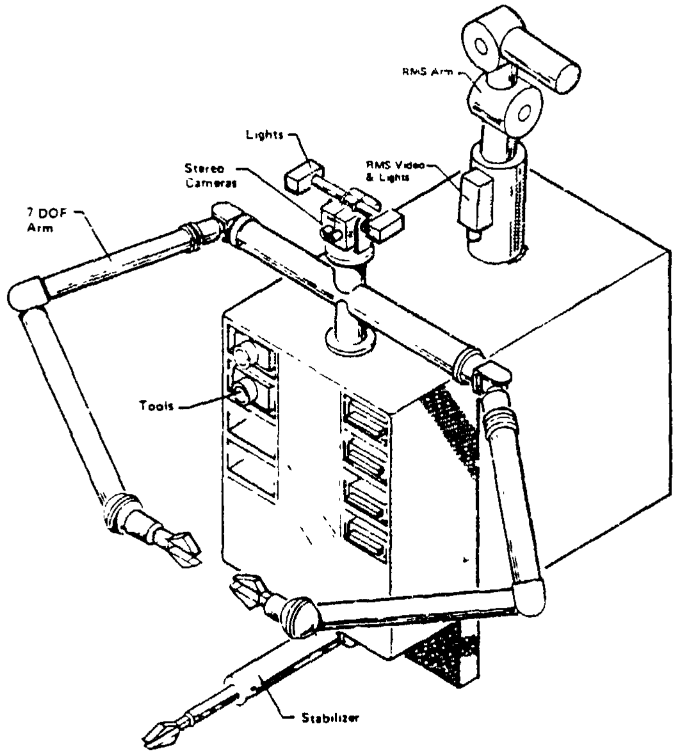

Figure 5. MM TWS Concept

ORIGINAL PAGE IS
OF POOR QUALITY

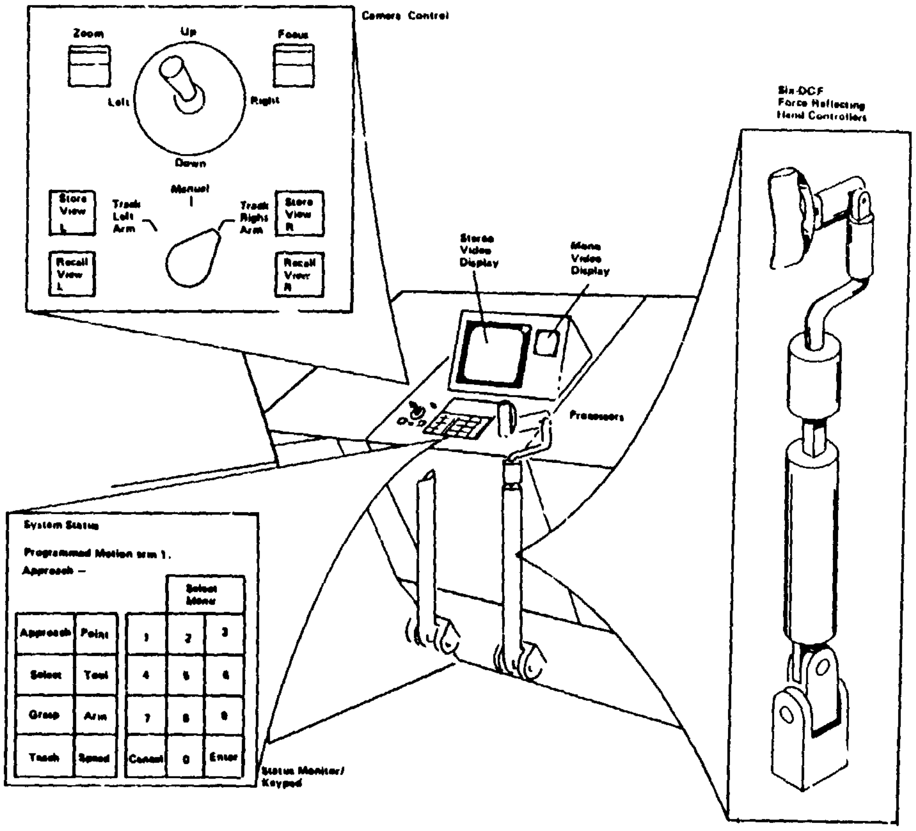

Figure 6. MM Control Station Concept