DEXTEROUS ORBITAL SERVICING SYSTEM (DOSS)

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Charles R. Price, Reginald B. Berka, and John T. Chladek
NASA/Johnson Space Center
Tel: (713)483-1523, Fax: (713)483-7580
e-mail: crprice@ctsd2.jsc.nasa.gov

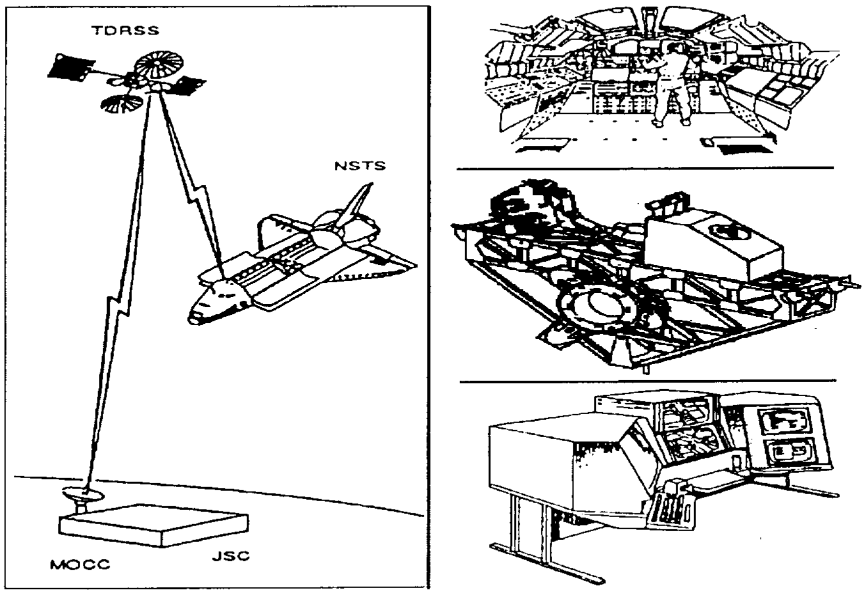

Figure 1. DOSS Concept

Summary

The Dexterous Orbiter Servicing System is a dexterous robotic spaceflight system that is based on the manipulator designed as part of the Flight Telerobotics Servicer program for the Space Station Freedom and built during a "technology capture" effort that was commissioned when the FTS was cancelled from the Space Station Freedom program. The FTS technology capture effort yielded one flight manipulator and the 1g hydraulic simulator that had been designed as an integrated test tool and crew trainer. The DOSS concept was developed to satisfy needs of the telerobotics research community, the Space Shuttle, and the Space Station. As a flight testbed, DOSS would serve as a baseline reference for testing the performance of advanced telerobotics and intelligent robotics components. For Shuttle, the DOSS, configured as a movable dexterous tool, would be used to provide operational flexibility for payload operations and contingency operations. As a risk mitigation flight demonstration, the DOSS would serve the International Space Station to characterize the end to end system performance of the Special Purpose Dexterous Manipulator performing assembly and maintenance tasks with actual ISSA orbital replacement units. Currently, the most likely entrance of the DOSS into spaceflight is a risk mitigation flight experiment for the International Space Station.

System Architecture

The DOSS is a Shuttle based flight system and consists of three major components: An aft flight deck crew control workstation, a payload bay manipulation and work space element, and a ground control workstation (Figure 1). Specifics of the DOSS workspace components have evolved from a technology centered configuration (generic task panels) and now include the ISSA specific Orbital Replacement Units and associated interfacing tools. These ORU's require a rotary drive function within the robotic gripper to loosen and tighten retention bolts, and the tools are required to access "out of the way" bolt head locations that are not accessible with the baseline SPDM end effector. The robotic function is also required to interface with three types of "handles" on the ORU's that have been accrued from specific incremental design solutions during the development and evolution of the space station.

The aft flight deck work station consists of a laptop computer, two three degree of freedom handcontrollers, a Standard (Orbiter payload service) Switch Panel, data and video recorders, closed circuit television and monitors, and cabling. The operator will be afforded direct aft window viewing of the DOSS payload bay element.

The payload bay element consists of a MPESS payload carrier, the FTS DTF-1 dexterous manipulator mounted on a base on the carrier, four ISSA Orbital Replacement Units (a battery box, remote power control module, multiplexer/demultiplexer "6B" box, and a representative Mobile Servicing System components) also mounted on the MPESS, avionics, and cabling. The grapple fixture on the DOSS is for the contingency jettison of the entire experiment via the Shuttle Remote Manipulator System in the unlikely event that a failure renders the experiment inoperative and in a configuration that is hazardous to the Shuttle.

The ground control station consists of multiple displays, a predictive kinematic graphics simulation, hand controllers, and a keyboard. The high fidelity solid model graphical simulation will be used to preview the expected results of all commands sent from the ground control station to the onboard manipulator, before the "execute" command is sent to allow the manipulator to proceed. As the manipulator then moves, joint angle data will be dowlinked to drive a "wire frame" representation of the manipulator that will "catch up" with the solid model representation of the predicted movement.

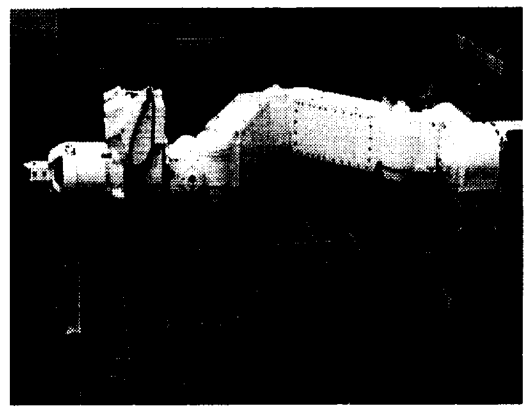

Figure 2. DOSS Manipulator on Air-Bearing Table.

DOSS Flight Experiment Objectives

- Characterize and assess the manipulator design and on-orbit task performance capabilities to improve mission success of future operational space telerobotic systems.
- Develop and evaluate an aft flight deck man/machine interface for on-orbit teleoperation with future capability to accept control from a ground-based telerobotic control station.
- Correlate fundamental engineering relationships of system performance in space with ground simulations and analysis predictions to increase fidelity of simulation models used for task assessments, mission planning, training, and recovery techniques.
- Demonstrate the functional utility of an on-orbit dexterous manipulator

- to reduce EVA operations by performing both Orbiter and Space Station tasks.
- to reduce the risks associated with Space Station first-use of telerobotics.

The Benefits

The DOSS provides valuable on-orbit manipulator demonstrations, experience, and data to the NASA telerobotics community, to the Space Station Program, and to the Space Shuttle Program. To the NASA telerobotics community DOSS is the culmination of many years of technology development in an on-orbit demonstration of our achievements and a platform for additional on-orbit demonstrations. To the Space Station Program DOSS is a vehicle to mitigate risk, gain on-orbit experience, and capture on-orbit performance data regarding dexterous manipulator technologies. The DOSS demonstrated manipulator technologies utilize similar configurations, tasks, and environments as those planned for Space Station and the SPDM. To the Space Shuttle Program DOSS is a potential tool to reduce reliance on EVA operations and reduce EVA timeliness, particularly on over-subscribed satellite servicing missions.

More specifically, DOSS:

- Delivers verification of and experience with Space Station robotic interfaces and maintenance tasks prior to SPDM deployment. Candidate interfaces and tasks include:
  - OTCM Interfaces
  - ORU Interfaces
  - ORU Changeout Operations
  - Alignment and Mating Tasks
  - Inspection/Verification that Tasks and Elements are Secure
  - Visual Surface Inspection Tasks
- Mitigates risk associated with Space Station's first on-orbit use of telerobotic technologies:
  - Impedance Control (Force/ Moment Accommodation)
  - IVA Control of Dexterous Manipulator
  - Flat Flex Cable
  - High Accuracy Manipulator Control
  - Collision Avoidance Techniques
  - Fault Tolerance and Redundancy Management
- Yields on-orbit verification data of manipulator engineering, design, modeling, and analysis prior to deployment of SPDM. Identified areas of interest are:
  - Manipulator and actuator dynamics and non-linearity
  - Manipulator accuracy and repeatability
  - Man-Machine interface (operator fatigue, lighting effects, camera views)
  - Manipulator control envelope
  - Manipulator single joint control
  - Singularity handling
  - Collision avoidance
  - Autonomous functions
  - Impedance control performance and contact stability
- Provides for near-term on-orbit demonstration of telerobotic ground control technologies:
  - Ground-based telerobotic control station
  - Time Delay Handling (e.g. predictive displays)
  - Scene Calibration Methods
  - Safety Assurance Mechanisms
  - Telemetry Interfaces
  - Data Displays
- Supports near-term use of telerobotics program technologies on-orbit for EVA time-line reductions.
- Demonstrates telerobotic technologies and capabilities to perform more elaborate servicing and maintenance tasks and provides an experience base for performing future Space Station task elements.
- Provides on-orbit data regarding performance of dexterous manipulator technologies under environmental extremes and longer duration space exposure.
- Results in re-usable flight hardware for

continued telerobotic technology demonstrations.

- Provides use of the Space Station funded FTS manipulator, cameras, end-of-arm tooling and Standard Data Processor. (see Figure 3).

The Organization

The DOSS is a partnership of three NASA Centers (JSC, LaRC, & JPL) and an expert contractor (Martin Marietta Astronautics Group - MMAG) teamed to produce a flight demonstration of dexterous robotics. The program planning, systems engineering, hardware development, and cooperative agreements for DOSS have already begun. Each participant has an agreed-upon role in providing the final product - a successful Orbiter flight experiment. In this manner, the DOSS team capitalizes upon the strengths of each participant to reduce overall costs, minimize duplication of effort, and produce a technically superior robotics flight experiment.

JSC will manage the program and be responsible for the formal Orbiter payload integration process. This process includes systems engineering, safety analysis and reporting, engineering analyses, and a Payload Integration Plan. JSC will also develop and deliver to MMAG the simplified aft flight deck workstation and the flight task panel with task elements. Engineering models for systems analysis and post-flight verification will be developed and maintained at JSC. Additionally, JSC will support engineering efforts at MMAG, ground control developments at JPL, and controls and crew training at LaRC.

MMAG will develop much of the flight systems and deliver the integrated payload bay elements. The payload bay element include the flight manipulator (currently operational at MMAG, see Figures 2 and 3), the flight avionics (partial designs complete), the aft flight deck command and display systems (partial designs complete), and the system software. MMAG will work with JSC to verify and certify these systems for flight. MMAG will take delivery of all payload elements, integrate and test them, and prepare them for shipment to KSC.

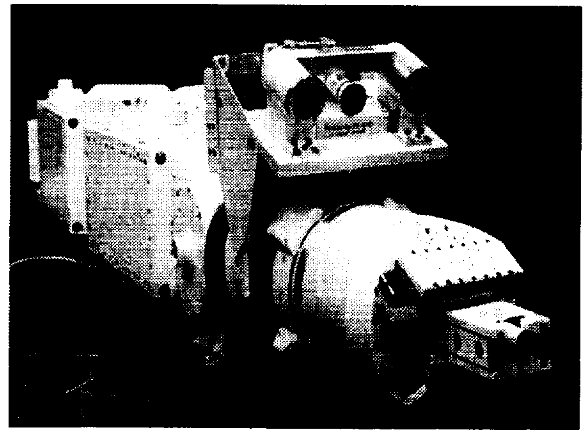

Figure 3. End-of-Arm Tooling with Wrist Camera & Lights

LaRC will use the Hydraulic Manipulator Test Bed (currently in use at LaRC) for MMAG software tests, task panel check-outs, and crew training. LaRC will monitor and direct MMAG development of control software utilizing the LaRC experience-base with manipulator controls and with the HMTB. In coordination with MMAG and JSC, LaRC will prepare the HMTB for crew training and carry out the crew training activities. LaRC will also play a key role in the development and maintenance of the engineering models used for analysis and post-flight verification of the manipulator systems.

As ground control technologies at JPL mature, JPL creates an integrated ground control system that will provide the necessary functionality of a remote POCC (Payload Operations Control Center). Anticipated key elements of the POCC include real-time video, graphic, and predictive displays, off-line task sequencing and verification, availability of autonomous actions, and high rate telemetry feedback & display.

The Space Station Servicing System

D. Hunter

THIS PAPER WAS NOT SUBMITTED.