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VIRTUAL REALITY APPLICATIONS IN ROBOTIC SIMULATIONS

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The preparation for the repair of the Hubble Space Telescope (HST) by the seven member crew of the Space Shuttle Endeavour on mission STS-61 in December, 1993, provided a perfect opportunity for developing and evaluating the use of Virtual Reality technology as applied to the solution of a real-world problem. The problem, which was not unique to that flight, arises during ground-based training for space shuttle missions that involve extravehicular activities (EVA) in conjunction with Remote Manipulator System (RMS) operations, in general; and more specifically, the integrated operations that occur when an EVA person is being maneuvered around the payload bay while standing on the end of the manipulator. Current ground-based simulators do not provide complete integrated training for these scenarios due to physical limitations or safety concerns. VR provided a means to practice integrated EVA/RMS operations in the on-orbit configuration with no discomfort or risk to the crewmembers involved.

The neutral buoyancy facilities at the Johnson Space Center (JSC) and the Marshall Space Flight Center (MSFC) provide excellent training for EVA work, but because of limited volume (Figure 1) cannot encompass the entire RMS reach envelop to provide adequate RMS training. The Manipulator Development Facility (MDF) and the Shuttle Mission Simulator (SMS) at the JSC provide excellent RMS training, but do not support EVA training. Virtual Reality afforded the STS-61 crew the luxury of practicing the integrated EVA/RMS operations in an on-orbit configuration prior to the actual flight. The VR simulation (Figure 2) was developed by the Automation and Robotics Division's Telepresence/Virtual Reality Lab and Integrated Graphics, Operations, and Analysis Lab (IGOAL). The RMS Part Task Trainer (PTT) was developed by the IGOAL for RMS training in 1988 as a fully functional, kinematic simulation of the shuttle RMS and served as the RMS portion of the integrated VR simulation. The "EVA person" was tied into the system via a head mounted display system, two (2) data gloves (both right and left hands), four (4) electro-magnetic tracking sensors (1 for head tracking, 2 for hand tracking, and 1 for tracking the object being handled by the EVA person), and the software required to generate 3-D graphics, do collision detection between the subjects hands and other objects in the virtual environment, and control the flow of data from sensors-to-simulation and simulation-to-simulation. The entire simulation resides on a Silicon Graphics Onyx Reality Engine 2 System with three (3) Graphics pipelines, and six (6) 150 MHz R4400 CPU's. In this configuration, one graphics display is used by the RMS simulation, while the other two displays are used to drive the head mounted display system.

Members of the STS-61 crew used the system on eight separate occasions for a total of 16 hours of preflight work. During those sessions, the crew was able to rehearse complete EVA/RMS tasks by taking advantage of the systems capability to present the on-orbit configuration which allowed the full range of the RMS to be simulated. This allowed the EVA person on the end of the RMS to be placed in a position that would be required during the flight, but not attainable in the ground-based facilities (see Figure 1). Not only could the RMS operator see the correct RMS configuration, but the EVA person could see the configuration from the correct vantage point. By integrating the two simulation capabilities, the RMS operator and the EVA person were also able to develop the command protocol between them and have confidence that each new what the other meant when the maneuvers were performed during the actual EVA's. Because the EVA crewmember could get a realistic view of the shuttle and payload bay in the VR simulation, he/she could explore different positions and views to determine the best method for performing a specific task, thus greatly increasing the efficiency of use of the neutral buoyancy facilities. A number of task procedures and RMS positions derived in the neutral buoyancy facilities were changed when the integrated VR simulation showed them to be unsuitable for achieving the task. One other added benefit of the VR system noted by the crew was that when using VR, the EVA crewmember relies only on visual cues to determine his/her orientation (as when in space) instead of the gravity cues received in the neutral buoyancy facilities.

Similar EVA/RMS training challenges face future astronauts in preparing for the assembly of the Space Station. The Virtual Reality Training Simulation, with its present capabilities, will not replace any of the current ground-based training facilities in the foreseeable future, but will provide additional dimensions to those facilities and fill in the gaps in EVA/RMS training that are inherent in today's training scenarios.

HST Repair Mission

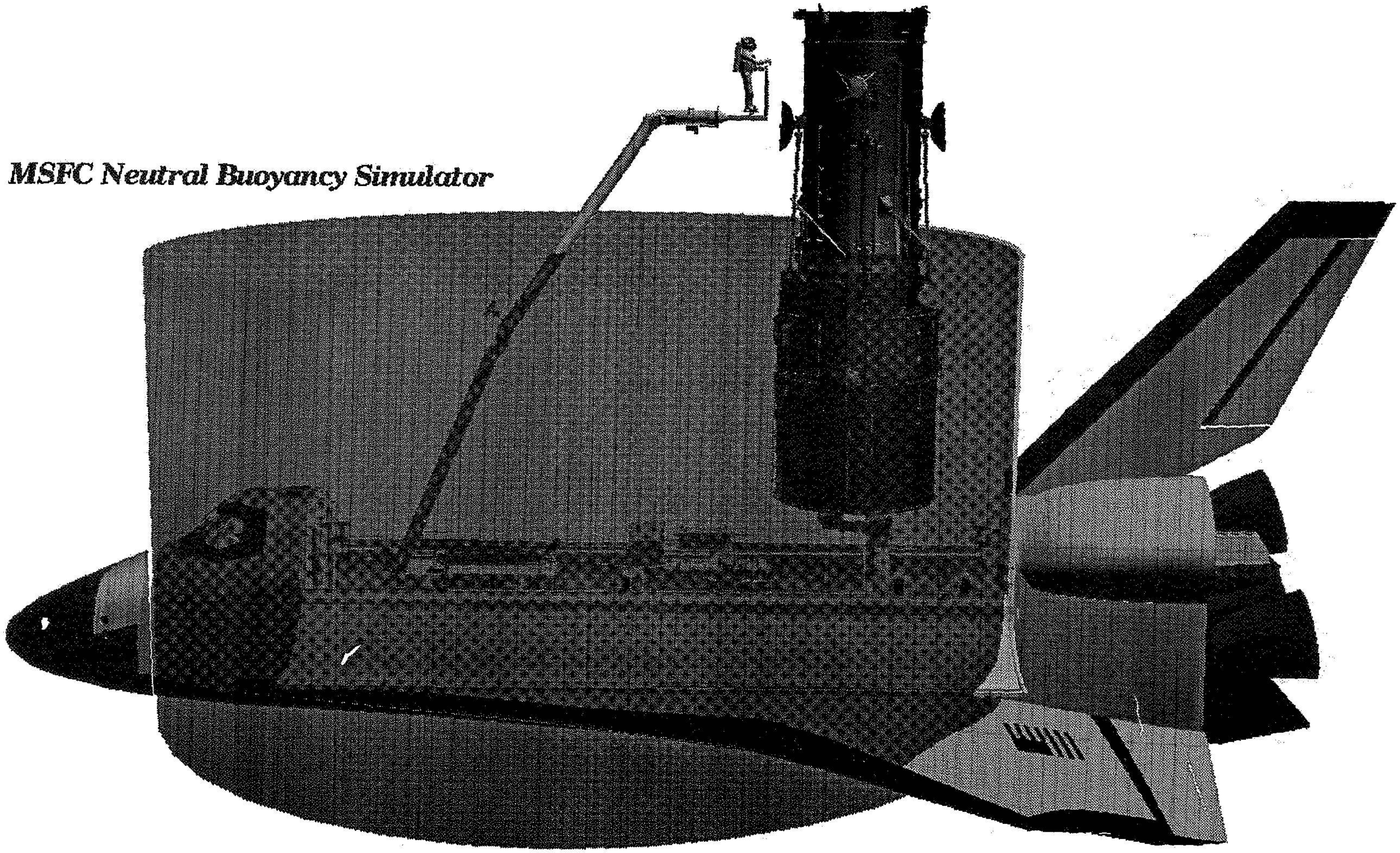

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Figure 1. Neutral Buoyancy Facility volume limitations

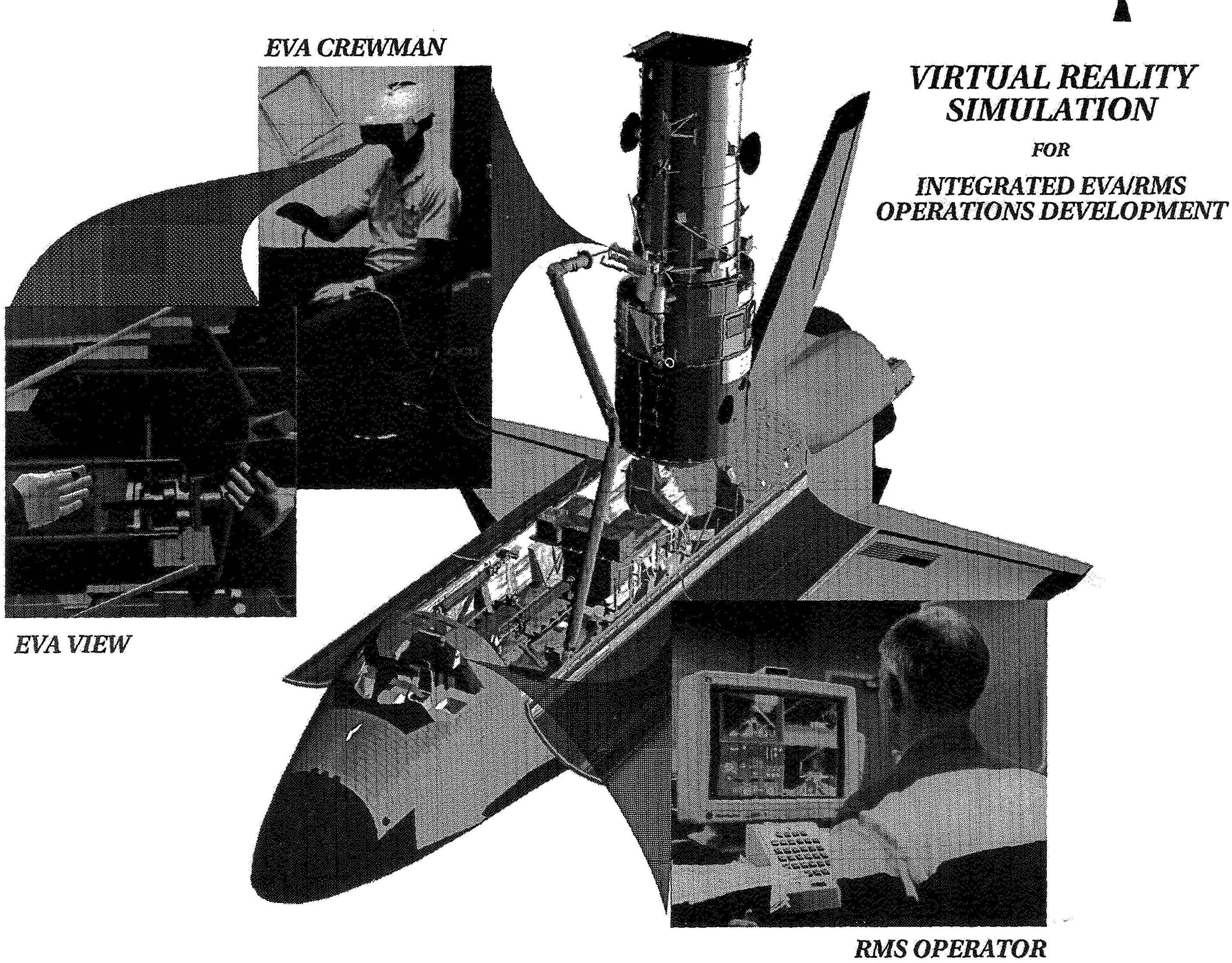

Figure 2. Integrated EVA/RMS Virtual Reality Simulation.