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ISSUES IN VISUAL SUPPORT TO REAL-TIME SPACE SYSTEM SIMULATION
SOLVED IN THE SYSTEMS ENGINEERING SIMULATOR

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INTRODUCTION

In some man-in-the-loop simulations, immediate visual feedback is essential in providing the astronauts with the real world representation of their operating environment in order to successfully complete the designed task. This is especially true in space station/space shuttle docking (Figure 1) and space station/space shuttle payload hand-off (Figure 2) scenarios. More importantly, when a remotely piloted vehicle is not equipped with radar sensors to provide data describing relative motion, the astronaut has to rely entirely on visual inputs to perform his functions. Such maneuvers are impossible without the aid of adequate visual cues.

Adequate visual coverage, the field of view provided, is also of paramount importance. The visual coverage not only provides guidance for the particular maneuvers, it also dictates the feasibility of the maneuvers themselves. Due to the complex geometrical shapes of the vehicles and their attachments, together with the number of moving parts involved, collisions between parts can happen quite inadvertently. These collisions may go unchecked if visual coverage is not available to give immediate feedback.

A third aspect of the problem is providing all the pertinent views to all participants in the simulation. In scenarios involving the Space Shuttle and Space Station working in concert there may be upwards of ten window
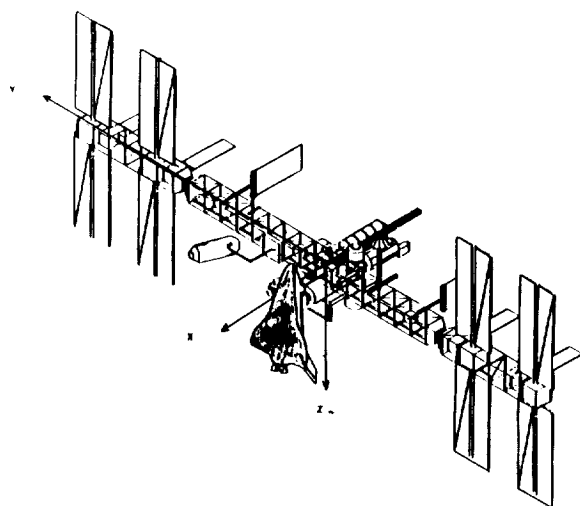

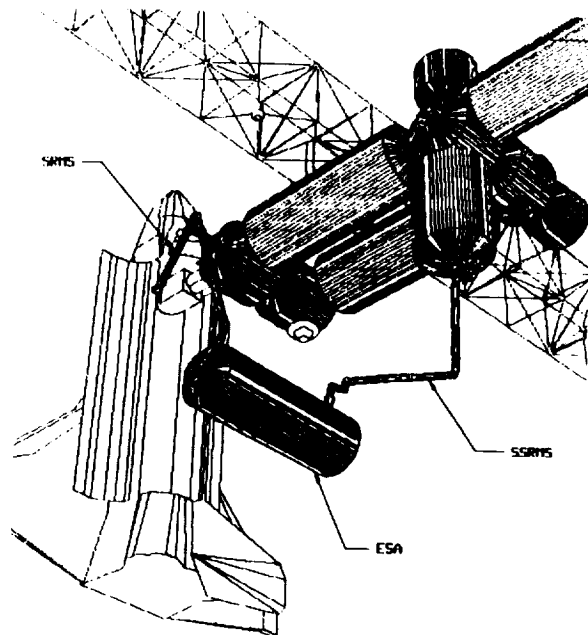Figure 1 - Space Station Freedom / Space Shuttle Docking

Figure 2 - Space Station Freedom / Space Shuttle Payload Hand-Off

views and seven closed-circuit-television (CCTV) monitors in use by the astronauts during one simulation.

Thus, the issues to be addressed in providing visual systems to man-in-the-loop simulations are : 1). providing real world representation for window and CCTV views, 2). providing adequate visual coverage (field of view) to adequately complete the task, 3). providing as many views to as many participants as possible during the simulation.

LABORATORY BACKGROUND

The Systems Engineering Simulator (SES) located at the Lyndon B. Johnson Space Center in Houston, Texas, has successfully addressed these issues in the development of its simulator complex which provides real time man-in-the-loop simulations for the National Space Transportation System Space Shuttle program and the Space Station Freedom program. The SES provides two crew stations for manned operation of the vehicles in the simulation. A Space Station Freedom workstation mockup is provided and a replication of the Space Shuttle aft flight deck is provided.
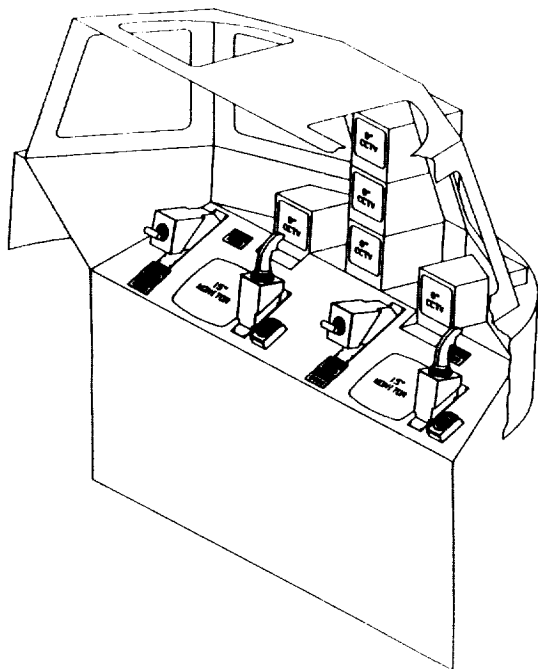
There are six windows and five camera monitors in the Space Station Freedom control mockup (Figure 3) and the Space Shuttle aft cockpit mockup has four windows and two camera monitors (Figure 4). Each window view is a virtual image projection of a two-dimensional scene projected by a television monitor. The virtual image will give the window view a three-dimensional perspective. Camera views are provided with pan/tilt/zoom capabilities, and the scene graphics are projected onto television monitors. This arrangement of different capabilities between window eye points and camera eye points is the design to map the visual simulation to the real world where out-the-window views are three-dimensional and camera views are two-dimensional.

The laboratory has three different scene generators providing a total of eleven channels of video signal. An Evans & Sutherland CT-6 visual generation system provides six channels, an Evans & Sutherland CT-3 system provides two channels, and a Redifusion Poly 2000e visual system provides three channels of video signal.

There are obviously more window and camera views than the eleven channels can support. A video distribution system has been developed to handle the video signal allocation and switching in a time-sharing fashion to provide video to windows and CCTVs as selected by the simulation operators. The system has two major components. A Scene Select subsystem allows simulation users to select which video channel is to be displayed on which window or CCTV. The other component is the Video Distribution Rack (VDR) which is responsible for routing the video signals from the three scene systems to the windows and CCTVs in the mockups.
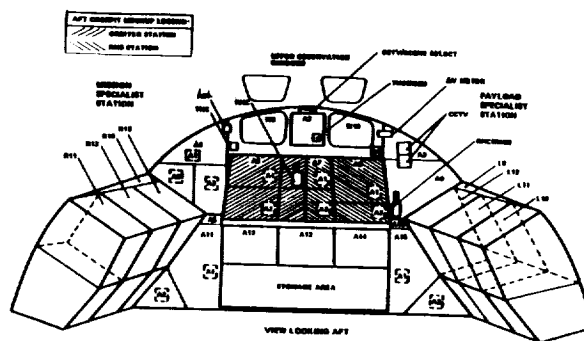

Figure 3 - Space Station Freedom Control Mockup

Figure 4 - Space Shuttle Aft Cockpit Mockup

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VISUAL SUBSYSTEM

There are five major pieces of visual scene software needed to provide the visual simulations for the SES: Scene Drive, CT3 Interface, Poly Interface, CT6 Interface and the Scene Devices Controller (Figure 5).

Scene Drive

This element provides the mathematics between the simulation and the scene systems. The Scene Drive takes inertial state vectors of the vehicles, computes the relative state vectors, and passes them onto the scene system interfaces.

An equally important issue in the visual simulation, besides the positioning of the objects, is the positioning of the eye points. Scene Drive receives inputs that indicate which eye points are currently selected and whether pan/tilt/zoom has been commanded for camera eye points. Armed with the users' requests of monitors and the availability of video channels, the Scene Drive task determines which scene system video output channels should be routed to which television monitors for display.
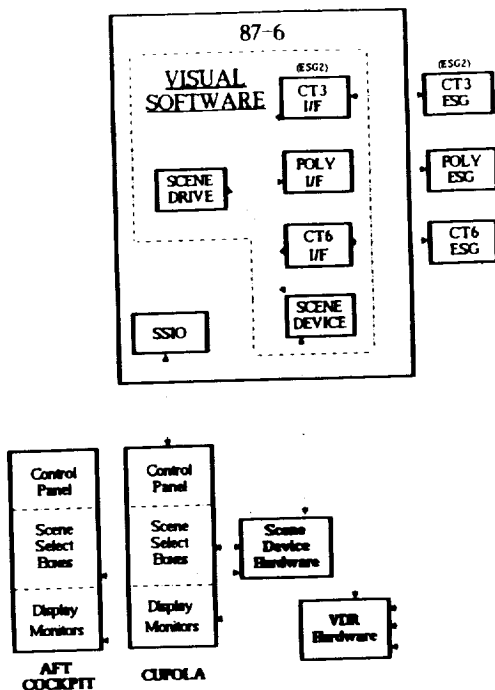
Scene Devices

The Scene Devices task is a background task supporting the simulations. It receives user requests for monitors from the Scene Select hardware and passes the requests to the Scene Drive task. It then receives the VDR and Scene Select commands from the Scene Drive tasks and passes the commands to the VDR hardware and Scene Select hardware respectively for hardware distribution of scene system outputs.

CT3, POLY & CT6 Interfaces

These three interface tasks receive relative state vectors of vehicles, eye points from the Scene Drive task, and data from the other parts of the simulation to drive the objects in the visual scene. Each of the tasks is the only link between the simulation and the corresponding scene system.

COVERAGE

Visual coverage is a major concern for SES Crew Stations. The coverage for the simulator is determined by the field-of-view of the real-world windows. Ideally, the simulator should provide the exact field-of-view to the astronaut as is available to him in the actual vehicle. The Space Station Freedom workstation creates an interesting problem in that there is almost a continual view across windows. The SES has developed a rotating optics system to fit around the Space Station Freedom workstation to provide this continual field of view (Figure 6). The optics system can rotate in a vertical manner to provide coverage overhead when necessary. This rotating capability allows the astronaut to select his coverage as a function of his interested area outside the workstation.

SUMMARY

The Systems Engineering Simulator has addressed the major issues in providing visual data to its real-time main-in-the-loop simulations. Out-the-window views and CCTV viewsare provided by three scene systems to give the astronauts their real-world views. To expand the window coverage for the Space Station Freedom workstation a rotating optics system is used to

Figure 5 - Visual Subsystem Block Diagram

provide the widest field of view possible. To provide video signals to as many viewpoints as possible, windows and CCTVs, with a limited amount of hardware, a video distribution system has been developed to time-share the video channels among viewpoints at the selection of the simulation users.

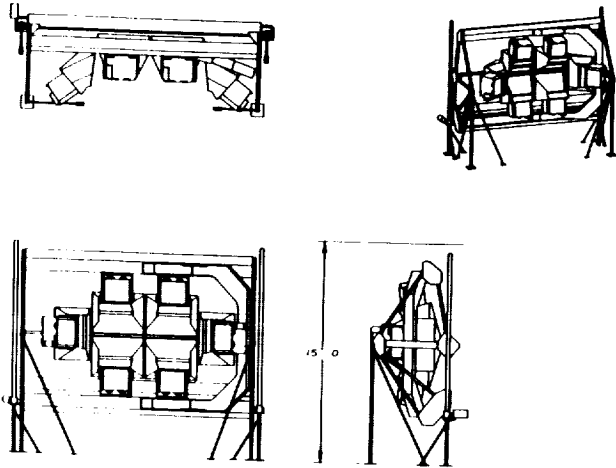These solutions have provided the visual simulation facility for real-time man-in-the-loop simulations for the NASA space program.

Figure 6 - Rotating Optics System