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FLIGHT TELEROBOTIC SERVICER CONTROL FROM THE ORBITER

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ABSTRACT

This paper presents the research and work conducted at the Johnson Space Center (JSC) on the development of a testbed for a display and control panel for the Flight Telerobotic Servicer (FTS). The FTS is being developed by the Goddard Spaceflight Center for NASA. Research was conducted on both software and hardware needed to control the FTS as it has been described through the Phase B studies (ref. 1) conducted by the NASA centers. A breadboard was constructed and placed into a mockup of the aft station of the Orbiter spacecraft. This breadboard concept was then evaluated using a computer graphics representation of the Tinman FTS.

Extensive research was conducted on the software requirements and implementation. The hardware selected for the breadboard was "flight like" and in some cases fit and function evaluated. The breadboard team studied some of the concepts without pursuing in depth their impact on the Orbiter or other missions. Assumptions were made concerning payload integration because the Payload Integration Plan had not been developed to define certain constraints. Requirements like workstation cooperation, fail safe fail operational, redundancy, and autonomous control were kept in mind, but were not major drivers during the design.

Evaluations and assistance was obtained from the Man-Systems Telerobotics Laboratory at NASA's Johnson Space Center. Reviews were held with the NASA Goddard Spaceflight Center to make sure the designers were interpreting the FTS requirements properly. The lessons learned are presented in this paper and cover most of the problems that will be encountered during the development of a flight qualified control panel. Many of these problems are major in scope and will require extensive engineering and research to solve.

INTRODUCTION

The Flight Telerobotics Servicer is a robotic device that is planned to be used for space station construction and satellite repair. Early studies at the Johnson Space Center were conducted to produce a general type of display and control workstation that could be used on the ground, in the space station, or in the orbiter. During the early development phase the major emphasis was on the software, to make it portable and common for all workstations. Starting in early 1988, the development team began looking at "flight like" hardware, and how to get all the functions needed for the FTS displays and controls into the aft station of the orbiter and near a window. The development team also had to look at simultaneous operations with the Remote Manipulator System (RMS) so the only readily available space was located on panels A6 and A7. If the display and control panel could fit in this area then it would also fit in locations L10 and L11 which are on the port side of the Orbiter flight deck. There is not room at A6 and A7 for the processor so the team was looking at the possibility of putting the processor under L10 through L12. Sizing and cooling turn out to be big issues on the hardware. The Orbiter Interface Control Document (ref. 1) was consulted on what services are available and this was matched against the requirements set forth in the FTS Phase C/D Request For Proposal (ref. 2) for the FTS written by NASA. Little time was spent on the Orbiter mission kits that would be required as this would be a waste of time until the location of the panel was defined by the Orbiter program office.

Designing a panel that would give the operator maximum visibility into operations external to the Orbiter without using multiple monitors led us into researching flat panel technology, split screen imaging and sharing the orbiter video system. There was a conflict with the Remote Manipulator System operations when an attempt was made to share the Closed Circuit Television monitors on the aft deck. The physics of connecting any FTS cameras into the Orbiter Closed Circuit Television system became a research project that was not pursued. The space available behind panels A6 and A7 did not lend itself to using a very large CRT. A 9 inch color monitor and two 5 inch monitors were selected for the final testbed configuration. This created a heat problem. With each color CRT requiring about 150 watts of cooling there is a need to circulate air behind the panels.

Tentative plans were made to mount the processor(s) behind panels L13 or L14. There is sufficient space back there and cooling is convenient on the Orbiter. No significant time was spent looking at the possible attach points or cable routing while the Standard Switch Panel of other control panels were mounted in panels L10 and L11 above. When the size of the processor(s) is determined then this problem needs to be studied in more detail. Some thought was given to mounting the control panel processor(s) out in the payload bay. This is workable but would use more Orbiter payload wiring.

According to the Space Shuttle Systems Payload Accommodations, JSC 07700 volume XIV, (ref. 1) there are connectors behind panels A6-A2 and A7-A2 that we could use to route signals to the Payload Station Distribution Panel (PSDP). From there the developer could tie into the processor and route signals to the payload bay and the FTS hardware called the High Level Control Module (HLCM). All the wires would be covered under the definition of a "Mission Kit" and not require Orbiter modifications. So this part of the study although only a paper research looks as though it is workable for the flight item.

ERGONOMICS

The workstation breadboard was designed to allow for efficient human/machine interactions. Several layouts of workstation display and Control devices were studied with Human Factors engineers to insure the incorporation good human engineering practices in the design of the breadboard. These included an Alpha workstation, a portable workstation and two versions of an Orbiter panels A6-A2 and A7-A2 workstation.

THE JSC DISPLAY AND CONTROL LABORATORY

The laboratory used to develop the hardware and software covered in this research paper is located in Building 16 at the Johnson Space Center. The laboratory is run by the Teleoperator Systems Branch of the Systems Development and Simulation Division. The laboratory is used to develop Orbiter and space station display and control breadboards. It is also used for robotic studies. The laboratory has a variety of computers, mock-ups, and robot arms.

ALPHA PANEL

Early in the program the JSC team developed a panel called the Alpha panel. This panel includes an electroluminescent display with touch screen. Also on the panel is an assortment of lights, switches and programmable display pushbuttons. All this is tied into two IBM PC-AT computers through off the shelf interface boards. Software developed for this Alpha panel is used on the final Orbiter panel configuration. A data base software was developed first then the other modules were added as needed to interface with the hardware and a robotic simulation of the FTS. A software package was purchased that would run on a simulated interrupt schedule because the PCs do not support multitasking capability. The two PC computers were tied together using Ethernet TCP/IP hardware and software. The simulation computer, which is a Silicon Graphics IRIS 4D computer, was also tied into this Ethernet network. Simulations were generated on the IRIS to support each of the data and command functions, including a visual representation of the FTS on the end of the RMS in the Orbiter payload bay. Any function that would be in the HLCM was simulated in the IRIS.

A considerable amount of time was spent trying to procure a suitable data base software package to use in the PCs. Most vendor packages either had too much or too little capability, so it was decided to develop a custom data base in-house. The data base was easy to define as the programmers had previous experience in simulation data bases. The biggest task was to build support software for that data base. The software was done in C computer language.

PORTABLE WORKSTATION

The Man-Systems Department at JSC developed a portable workstation concept that could be stowed in the lower flight deck. This workstation contained one 17 inch CRT that would use windowing to give the operator multiple views. This concept was not evaluated by this team in a breadboard configuration. Some research was done into how such a control panel would be interfaced to the Orbiter. An interface panel could be built and mounted in the area of the Standard Switch Panels, (L10 thru L14), on the port aft side of the flight deck. This would allow the portable control panel to be connected into the PSDP for power and signal distribution. Cooling would be performed by dumping the heat load into the cockpit using a small fan.

ORBITER WORKSTATION

DISPLAYS, GENERAL

Due to the workstation's primary location on the aft flight deck, the operator can view FTS operations from the aft windows only on a periodic basis. Therefore, the breadboard design provides a primary display, two secondary displays, and access to the Remote Manipulator System displays. The JSC Orbiter workstation breadboard is mounted in an aft station mockup which includes two simulated Orbiter closed circuit television monitors. This allows the operator to control the FTS without the need of continuous direct viewing of the robot.

At this time the FTS simulation provides four camera views which include views from the head of the robot, a view from both the left and right wrists, and an auxiliary view. Three of the four views can be displayed at a time on any of the three monitors. This allows the operator to select the primary or secondary views according to the needs of a particular task.

PRIMARY DISPLAY

The primary display on the breadboard will be a 9 inch diagonal color monitor located on panel A6-A2. The 9 inch monitor is connected to a video digitizing board on one of the PC computers. This monitor provides a display of both text and graphics. The information displayed on this monitor include:

a. FTS health and status conditions.
b. Joint rates and positions.
c. Safety messages and system diagnostics.
d. Graphics generated review of task sequences.
e. Camera video scenes.

SECONDARY DISPLAYS

The secondary displays on the Orbiter workstation include two 5 inch monitors which display camera views only. They are connected to a video distribution unit that has inputs from both the remote cameras and the IRIS computer scene generation output.

FLAT PANEL DISPLAYS

Due to the limited depth of panels A6-A2 and A7-A2 in the Orbiter, the installation of CRTs at this location is not possible. Therefor, the monitors used in the breadboard design are of functional use only. However, flat panel technology is rapidly developing and the use of color liquid crystal displays and or color plasma displays for space applications is in the foreseeable future. These type of displays do not require as much mounting depth as conventional cathode ray tube monitors, making them better display devices for the FTS orbiter workstation at this location. The display and control laboratory has a 6.25 X 6.25 inch liquid crystal color display. Present plans are to install it in place of the 9 inch monitor for demonstrations and evaluation. The laboratory also has some small color plasma displays, however these are not of sufficient quality to use on our breadboards.

PROGRAMMABLE SWITCHES

The workstation employs a 4 X 5 matrix of programmable switches developed by Litton Systems. Each individual switch consists of a 16 by 35 array of miniature light emitting diodes, which can be pre-programmed to display text or graphic messages. Since the switches are programmable, a single switch can control several devices or functions. This effectively reduces the amount of panel space required to control the FTS. The orbiter workstation's programmable switches control such functions as:

a. Camera control, pan, tilt, and zoom.
b. FTS operation mode selections.
c. FTS position control system.
d. FTS work site lighting.

As development of the FTS continues, it may be necessary to include additional functions which are not presently included in breadboard design. Programmable switches will allow these additional functions to be implemented without redesigning the workstation.

HAND CONTROLLERS

At first two 6 Degree of Freedom hand controllers were installed on the Alpha control panel to complete the hand controller command loop. These controllers were force torque controllers. They were analog devices so they were connected to one of the PCs through an analog to digital conversion board. The commands were transferred to the IRIS computer via the laboratory Ethernet. These controllers turned out to be difficult to use because of the lack of feedback. Fingertip control switches were added to the hand controllers to activate all the necessary functions for gripper or end effector control. These switches were easy to activate, but put torque on the hand controllers causing them to issue unwanted commands.

The second set of hand controllers to be installed were 6 degree of freedom mini-master controllers. These controllers have a RS-232 interface. They were used as a stepping stone to become familiar with the new interface and the mini-master concept while waiting for the 7 degree of freedom controllers to be built.

The Orbiter panel was upgraded to 7 degree of freedom mini-master controllers developed by Schilling, Inc. These control units are a miniature replica of the Tinman manipulator arm with approximately the same range of motion as the robotic arm itself. Since the velocity and angular motion initiated at the master unit is duplicated by the slave arm, the operator is able to efficiently maneuver the robot arms. The Schilling master control unit has three separate discrete switches located on the end effectors. These switches provide the capability to open or close the gripper, and to freeze the slave arm in its current position. Once the freeze function is activated, any subsequent movement of the control unit does not affect the arms. This allows the operator to easily freeze the slave arms in order to do another task such as camera or lighting control. The operator will, however, have to take his hands off the controllers to operate other switches in the present workstation configuration.

The hand controllers are mounted in a separate panel that is attached to the Orbiter panel structure between the A6-A2 and A7-A2 panels. This configuration is not expected to be a final configuration because it is not a goal of the development team to develop hand controller configurations for actual flight.

BACKUP SWITCHES

The functions for the switches that were selected for the backup control were taken from the RMS displays and controls. Care was taken to minimize the number of switches to conserve space on the panel. When the FTS is operating using the umbilical the number of switches and switch functions will be a driving factor on the number of wires in the umbilical. There is a problem where the FTS was disconnected from its umbilical and was controlled from a communications link. The backup switches will only be hard wired into the front end of the communications network which have not been defined. The end point connections of these wires would be determined by the design of the robot. In the Orbiter testbed, the backup switches simply set a discrete or flag in the computer that is read, stored, displayed and integrated with the command data block that is sent to the simulated robot. If the switch needs to provide direct drive power to a joint motor or gripper motor in the robot, then it will take about 34 wires that are capable of carrying the required current load in the present Orbiter breadboard configuration.

CAUTION AND WARNING INDICATORS

Caution and warning indicators were installed on a common area of the workstation. These indicators are sunlight readable and have "dead legends" until activated. At this time caution and warning messages to be displayed are being researched as evaluations of the display and control of the FTS continues.

An audible alarm will also be implemented in the workstation. This alarm will sound if a condition arises which requires the operator's immediate attention.

PROBLEM AREAS

One of the big problems that the FTS project in general has run up against is the establishment of a RF communications link between the control panel and the robot when it is not on an umbilical. Because the plans include up to 4 video links as well as a high data rate for force reflective hand controllers the requirements exceed those planned by the program. If there is a requirement for the robot to be controlled by the space station workstation and have the Orbiter workstation operating in cooperative mode one workstation transmitter would have to be disabled. This also requires the cooperative workstation to now interpret RF commands from the space station workstation and display them, act on them, or at least store them in its data base. The software in the orbiter workstation would have to make an intelligent decision based upon the type of command the space station workstation has issued.

During a design review of the panel it was pointed out that one of the mission rules, 12-5 Orbiter Avoidance Maneuvers Constraint, stated that a pilot shall always be available to perform a collision avoidance maneuver during loaded RMS operations. If that pilot had to be located in the aft station to operate the Digital Auto Pilot (DAP) while the FTS is on the RMS, then there is a "people" space problem. If the pilot can be located in the pilot seat or be the RMS operator then locating the FTS panel in A6 and A7 will not pose a violation of the mission rule. Logically of course the pilot needs an aft station out the window view to do any collision avoidance maneuver with a payload in or near the payload bay. During the development of the Orbiter panel it was concluded that the emergency stop capability of the FTS would allow the FTS operator to hit the button and take over the DAP controls for an evasive maneuver if required. Further investigation of this problem will have to be conducted with the Mission Operations Directorate at JSC before the FTS panel can be mounted in A6-A2.

FOLLOW ON WORK AND APPLICATIONS

TASK EVALUATIONS

The latest version of the Orbiter FTS workstation will be used for task evaluations. There are plans to install the Orbiter panel in a high grade mockup so that it can be used by other groups for studies. Collision detection with the FTS mounted on the end of the RMS is a study that can be done with this system by adding the collision detection to the IRIS computer.

PROGRAMMABLE DISPLAY PUSHBUTTON DEVELOPMENT

As new requirements for functions to install into the Programmable Display Pushbuttons are defined they can easily be integrated into the Orbiter panel.

RELOCATION

The latest configuration of the Orbiter FTS panels are installed on rails so that they can be removed from the mockup easily and relocated into other locations.

VOICE RECOGNITION

The software was designed so that voice recognition command system could be added to the design if the need arises or financing is provided.

COOPERATIVE WORKSTATION

The team that has developed the workstation is now in the process of developing a FTS workstation for the space station. Once this workstation is developed some studies can be initiated on workstation cooperation.

ACKNOWLEDGEMENT

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REFERENCES

1 Final Report Flight Telerobotic Servicer (FTS) Tinman Concept In-house Phase B Study Vol I & II, Goddard Spaceflight Center, FS-GSF-0042, September 9, 1988.

2 Flight Telerobotic Servicer Phase C/D Request For Proposal, Goddard Spaceflight Center, November 11, 1988.

3 NASA, Space Shuttle Systems Payload Accommodations, NSTS 07700 Volume XIV, Revision 1, Johnson Space Center, Houston, 1986.