The command and control system for JET remote handling equipment

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This paper discusses the design and development of the system for command and control of JET remote handling equipment intended to be used during the forthcoming divertor exchange. The remote handling control room provides the operators with tactile, video and audio feedback and signal based information from the local controllers. The Man-Machine Interface (MMI) has been designed to facilitate command and control of the remote handling equipment by means of a Windows NT based operating system running on a PC hardware platform. Extensive use is made of real time computer generated three dimensional images of the remote handling equipment within its operating environment. This paper describes the system and discusses the development programme from which the present command and control system has emerged.

1 INTRODUCTION

During 1997 it is planned to replace all JET Divertor tile carrier modules with new modules appropriate for the following phase of JET operations [1]. This exchange operation will be performed entirely remotely by means of the JET Mascot servo-manipulator transported around the Torus on the Articulated Boom. The Mascot will deploy specially designed tooling to release and handle modules from in-situ and will transport them to a transfer system which will remove and store them outside the Torus [2], [5].

The Mascot remote handling tasks will be performed by operators making use of its force reflection capability with video and sound feedback information provided at the equipment Man Machine Interface.

The remaining remote handling equipment is commanded through an MMI system developed at JET, which presents information and input devices to the operator in a consistent and efficient manner.

2 SYSTEM REQUIREMENTS

During the remote maintenance of the JET machine it is required that all equipment be commanded from the Remote Handling Control Room (RHCR).

The main operational requirements are as follows:

- The RHCR layout should allow the control of the in vessel and ex vessel equipment contemporaneously.
- max. transmission delay between the request of joints movement from the joystick and real movement of the joint not more than 150 ms.
- TV monitors, MMI and graphics computers to be ergonomically positioned for easy operation
- Flexibility to direct any video signal to any monitor
- Man Machine Interface to facilitate command and monitoring of the Remote Handling equipment
- Telepresence using a combination of video, sound and tactile feedback .

3 SYSTEM DESIGN

3.1 Control Room Layout

The control room layout (fig. 1) has been derived after extensive testing under operational conditions during mock-up trials [3].The operational area of the RHCR has been divided into three parts, one per transporter: Articulated Boom, Tile Carrier Transfer Facility (TCTF) and the Telescoping Articulating Remote Mast (TARM). This division of the RHCR allows the operation of the transporters to be completely independent. The remote handling operations are effected using a Mascot master station and a Remote Handling Control Station (RHCS). The RHCS is used for command and control of a transporter, cameras, tools, services, etc. and has been designed taking into account all the ergonomical requirements and with the flexibility to run any equipment MMI.

Figure 1 Remote Handling Control Room

3.2 Local Area Network

The system comprises an integration of stand alone, or local control units connected to each other and the remote handling Man-Machine Interface by means of a mixed system with Ethernet and point to point links.

One of the main requirement was to keep the transmission delay between the operator commands and the joint movement as small as possible (less than 150 ms.) After tests it was decided to connect the joystick, which is the most demanding in term of fast response and traffic on the network, directly to the Local Control Units.

All the commands and monitoring signals for all RH equipment are on a dedicated control Ethernet network. The file transfer and program maintenance from the server to the various PC are done through another dedicated file transfer Ethernet link. Fig. 2. shows a simplified diagram of the networks.

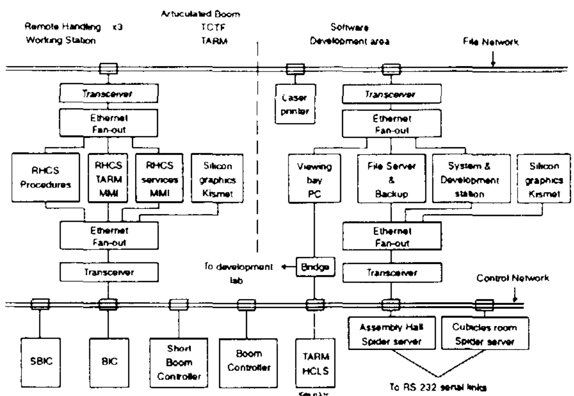

Figure 2 Remote Handling Control and File Transfer Networks

3.3 Mascot Servomanipulator Station

The telemanipulator chosen for remote maintenance of JET is Mascot IV, a microprocessor control unit based on a bilateral position servosystem .The main objective of this type of force feedback servomanipulator is to give the operator, as nearly as possible, the tactile sensation of actually doing the job. [4]. The Mascot station is completed with four TV monitors in front of the operator and one PC for the MMI.

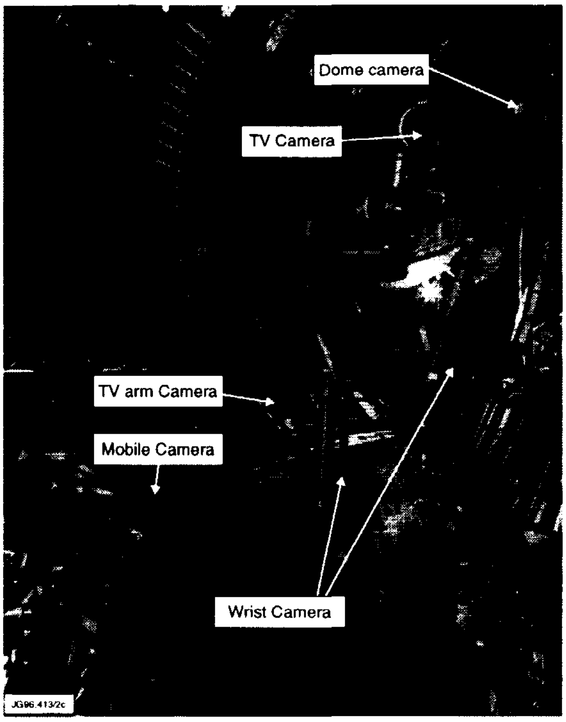

Figure 3 TV System Inside the Vessel

3.4 Video system

The RH CCTV system is the main source of visual and sound feedback information required for the remote maintenance operations. It consists of remotely controlled TV cameras, their transmission, distribution equipment and TV monitors. The deployment of the cameras for in vessel tasks is as in fig. 3. Two miniature cameras are attached to each slave arm by a flexible mount to give a close up view of the gripper, one camera is installed on the slave body between the arms and one TV arm for general viewing. The general view inside the vessel is obtained by four colour cameras housed in a protective dome (IVVS). The camera video and audio signals are connected to a central video/audio matrix. The switching of video/audio signals is implemented with commands from the video MMI. Thus any camera picture and sound can be directed to any TV monitor in the RHCR.

3.5 MMI

The MMI has been design to facilitate command and control of the remote handling equipment

The MMI software developed at JET utilises Microsoft Foundation Class (MFC) and SL-GMS software to provide a Windows look and feel for the operators. The MMI is optimised for the use of graphical and textual prompts and status information, while retaining the real time nature of equipment control and monitoring. In using this approach, the software development had a quicker learning time and allows the look to be upgraded with the operating system changes. The MFC and GMS software subsystems have a clear interface to a driver layer for communications to remote handling equipment.

Figures 4 and 5 show the TCTF [5] and Mascot MMI.

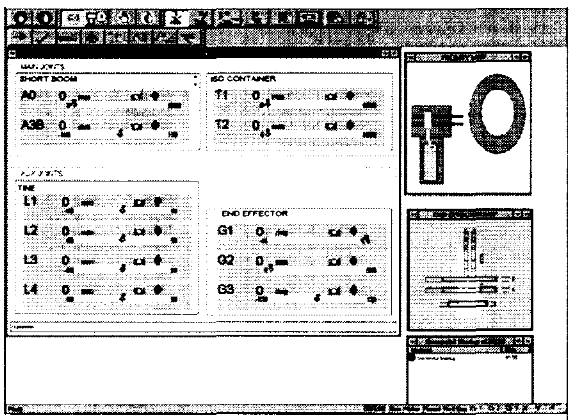

Figure 4 TCTF MMI

3.6 Graphic Workstation (KISMET)

Remote Handling operations are assisted by using KISMET, which is a real time virtual reality simulation system displaying a 3D synthetic picture. This is of great importance for the operator that can see the position of the equipment from

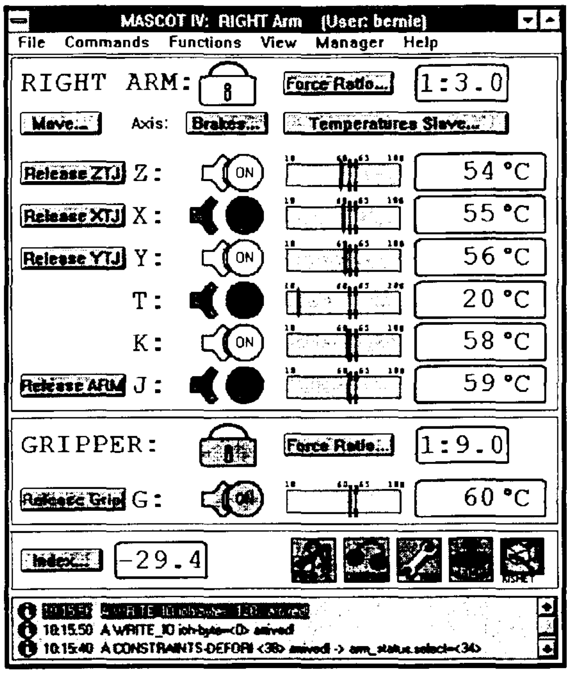

Figure 5 Mascot MMI

different point of view, hence increase confidence during manoeuvring.

KISMET is also used off-line for task feasibility studies, strategy planning, creation of robot teach files and robot operator training in simulation mode. Fig. 6 shows a 3D view of the Articulated Boom with Mascot inside the Torus.

KISMET was developed at the IAI (Institute for Applied Informatics) at FZK (Forschungszentrum Karlsruhe, Germany). At JET KISMET runs on Silicon Graphics Indigo 2 . Maximum Impact workstations. The models of the JET machine are downloaded from the CATIA database via STEP AP 203 processors.

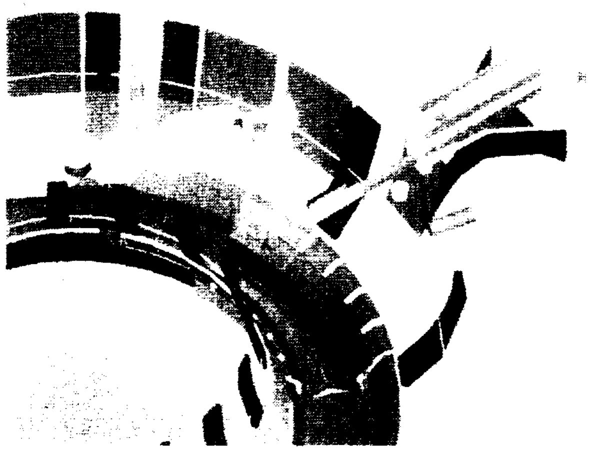

Figure 6 KISMET 3D View of the Boom inside the Torus

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