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ABSTRACT

The beryllium and/or tritium contamination of the JET Tokamak and auxiliary systems necessitates that many activities are carried out in air line fed pressurised suits. To enable, often complex, engineering activities to be performed, a number of novel audio and visual communications systems have been designed. The paper describes these systems which give freedom of visual and audio communication between suited personnel, supervisors, operators and engineers. The system enhances the safety of the working environment as well as helping to minimise the radiation dose to personnel. It is concluded, from a number of years experience of using the audio and visual communication systems for suited operations, that safety and the progress of complex engineering tasks have been significantly enhanced.

1. INTRODUCTION.

JET is the world's largest magnetic confinement fusion device (tokamak). It is the only operational device designed to operate with the deuterium/tritium (D-T) fuel mixture necessary for fusion power production. The first wall of the vacuum vessel is clad with CFC, graphite and beryllium tiles. To achieve the necessary high vacuum and first wall conditions, beryllium is regularly evaporated within the vessel. The use of beryllium and tritium on JET dictates that for manual engineering work, on contaminated items or within contaminated areas, the appropriate form of respiratory protective equipment (RPE) must be worn. Since the first extensive D-T campaign (DTE1)[1] some in-vessel tasks are performed using remote handling techniques[2]. These however require support from manual handling within controlled areas. The safety of personnel working within areas requiring the use of RPE is of prime importance. A number of facilities have been designed to support work in controlled areas, these include the torus assess cabin (TAC) and the controller dresser unit (CDU). In each of these facilities, a person called a "controller" takes first hand responsibility for the safety and well being of personnel working in the controlled area. Effective audio and visual communication, with and between personnel working within controlled areas, is an essential element in ensuring safety.

2. COMMUNICATING IN RESPIRATORY PROTECTIVE EQUIPMENT.

The potential risk of receiving a dose of tritium or beryllium dictates the level of respiratory protective equipment that needs to be worn in any particular area for any particular activity. Respiratory protective equipment ranges from a simple dust mask to the fully pressurised suit[3]. The ability to communicate naturally with others becomes more difficult as higher levels of protective equipment are worn. Areas requiring greater protection are progressively isolated from clean areas and are often classified as confined spaces. Wired communication is preferable to radio because of the metallic Faraday shielding in many of the controlled areas. Spiral wound electrical cables are fed around a mechanical strainer wire, through the air line, to a connector at the base of the air line fed pressurised suits. This has proven to be a highly reliable method of connecting with only a single line to the suit. Light binaural head sets (Fig.1 left) have proven to be effective within the light half suits which allow some manual adjustment of the head set. Heavier full suits are equipped with integral small speakers and a microphone (Fig.1 right) attached to the inner surface of the suit. This arrangement requires voice-switching amplifiers (VOX) to avoid feedback. Where lower levels of RPE are used, varieties of different headset, microphone and speaker arrangements have been applied.

Fig.1: Binaural head sets within half suit (left). Speakers and a microphone in full suit (right).

3. AUDIO AND VIDEO SYSTEMS.

Depending on the nature and complexity of work and in particular the number of people involved, different systems are used. Three systems from the most basic to the most comprehensive are described below.

3.1 Basic communication station

The audio communication in the basic station is purely analogue, with a single channel, so that all speech is heard by all connected persons. Colour auto-focus CCD cameras are directly wired to monitors so that a controller can have an unobstructed view of the work area. One example is the mobile pressurised suit station (Fig.2), which would normally be used to support the work of two people working in a temporary area. A similar style is used for the fixed installation of the JET beryllium handing facilities (Fig.3) where work is often performed on items which have been removed from the JET vacuum vessel.

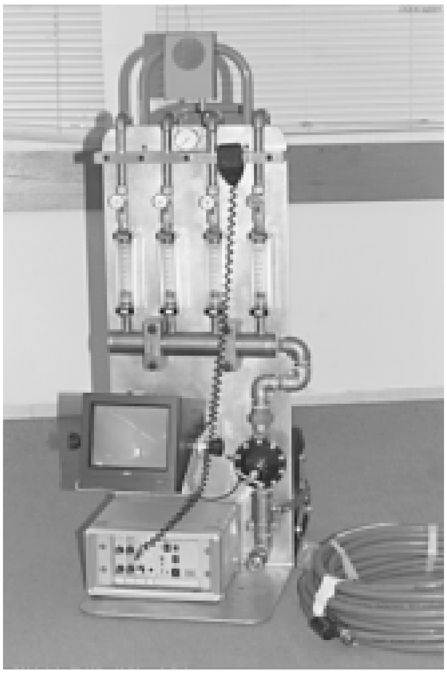

Fig.2: Mobile pressurised suit station.

Fig.3: Beryllium handing facilities control station.

3.2 Controller Dresser Unit (CDU) system

To enable work in pressurised suits in, the remote handing facilities of the Tile Carrier Transfer Facility(TCTF), Boom Enclosure, Remote Handling Maintenance Facility [4], or any other situation as required a modular service unit (CDU) was developed [5]. Each of the 3 CDUs, which have been produced, can be docked onto a facility and support 4 people working in pressurised suits. The audio communication is similar to the basic system, except that 4 separate channels, each allowing 4 connections, are available. The controller's station (Fig.4) has one speaker per channel with voice activated indicators on each. The controller has a selector panel so that he can choose the connections between channels and to which channels he speaks. External connections are available for other parties or for a number of CDUs to be linked together. Two VDUs are provided within the CDU, a selector allows views from up to 10 cameras connected to the CDU. The second VDU can be connected to the TAC video matrix described in 3.3 and through a selector allow images from up to a further 24 cameras to be selected.

Fig.4: CDU control station.

3.3 Torus Access Cabin (TAC) system.

The TAC[3] audio/visual communications system was initally developed for the Mark 2 divertor installation [6] in order to support a large number of complex in-vessel activities. The core technology of the audio and video systems was adapted from the broadcast industry. The video

system uses an electronic matrix to allow up to 24 pictures from colour CCD cameras to be routed to up to 24 monitors (Fig.5).

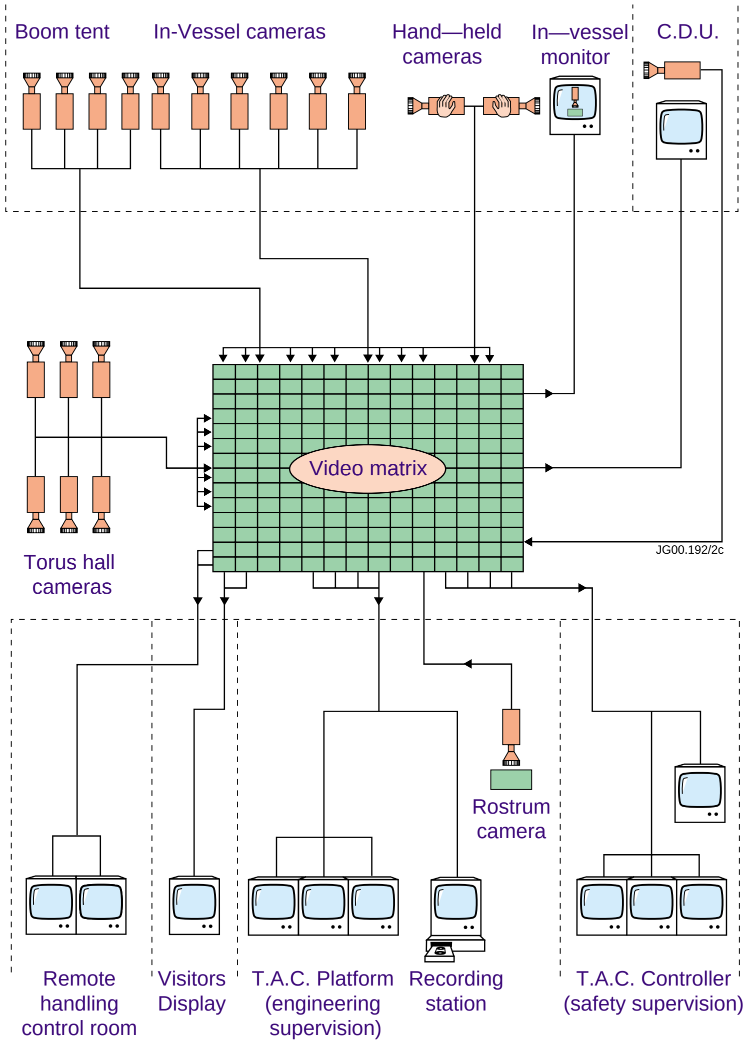

Fig.5: Typical arrangement of video matrix

Auto-focus cameras are mounted in the controlled areas to provide safety monitoring of suited operators. Further fixed and mobile cameras are used to aid engineering tasks. Images at any monitor are selected using control panels. Portable flat screen monitors, within the controlled area, can display images of drawings from the rostrum camera. Video surveys can be performed and recorded for further inspection. The audio system uses a digital audio matrix at its core. Voice signals received from up to 48 people are digitally mixed in any desired combination before being transmitted. 'Talk only ', 'listen only' or 'talk and listen' is configurable for each

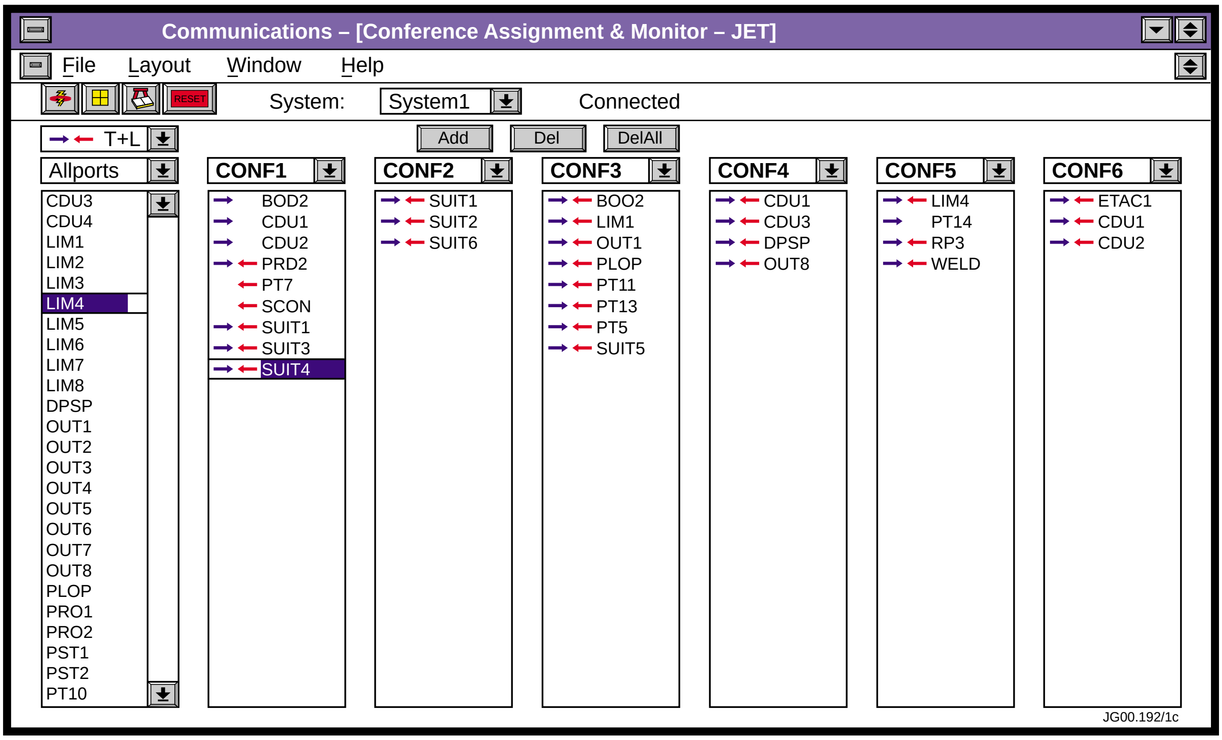

Fig.6: Audio conference control window.

channel. A specially developed real-time computer graphics interface (Fig.6) allows communications conferences to be rapidly set up and changed by the engineering supervisor (Fig.7). This allows many activities to be running concurrently and for suited personnel to switch between work groups as required. Digital linked communications panels allow those who are monitoring and controlling activities, to choose with whom they are communicating. A number of features of the systems are important to ensure the safety of the suited operators:

- The audio link between the suited personnel and the TAC controller, who has responsibility for the suited personnel's safety, are programmed to be permanently routed and can not be simply deselected.
- The TAC controller has an "announce to all" feature on his communication channel to enable important information to be communicated.
- The TAC controller has an independent high volume speaker system which can be used should communication be lost with a suited operator in-vessel.
- The audio matrix is designed with redundancy on its power supplies and processor cards, giving bump-less transition on component failure. Should there be a complete failure of the digital system, a bypass option exists, providing a basic analogue back-up system.
- To give independence from mains power, all parts of the system are supplied from uninteruptable power supplies.

Fig.7: Engineering management communications station

4. EXPERIENCE DURING THE MARK II DIVERTOR INSTALLATION SHUTDOWN.

The Mark II Divertor Shutdown from June 1995 until March 1996 involved the most extensive amount of work performed in pressurised suits to date. The Torus access cabin (TAC) communication system was used to support this work and in the later parts of the shutdown a CDU was install to support work in the Boom enclosure. The work was arranged with three shifts per day and four in-vessel entries per day. The main benefits, attributed to the communications, system were:-

- The radiological dosage to personnel was minimised by allowing supervisors and experts for particular activities to remain external to the vessel.
- The progress of engineering activities was improved by allowing the concurrent running of different tasks with the sub-set of personnel involved with each job being linked to isolated conferences. In addition, personnel could be moved between tasks and communication conferences as required.
- The continuity of long running tasks could be maintained across the 4 hour in-vessel entry shifts by ex-vessel personnel.
- In-vessel time was saved on inspections; for example, weld inspections were recorded, using a mobile in-vessel camera, for ex-vessel scrutiny.
- Complex activities, where items had to be precisely offered through ports into the vessel, were eased with all interfaces in audio and visual contact.

4.1 Experience during In-board Pellet Launcher Shutdown.

The June 1999 In-board Pellet Launcher Shutdown [7] was the first JET shutdown to combine remote handing and manual in-vessel activities. Two CDU’s were installed; one connected to the articulated boom enclosure and one on the opposite side of the torus connected to the TCTF. In the purely remote phase of the shutdown, both CDUs supported suited work in the controlled areas of the remote handling support facilities. In the later stages of the shutdown, full suit entries were made to the torus through the TCTF while remote handling activities continued in different parts of the torus. The two CDUs were linked together on one audio channel and a separate channel on each was taken to the remote handing control room, which acted as the main control centre for the work. Images from remote handling cameras were linked to the CDUs selector. Although the work performed in this hybrid shutdown was modest, it is clear that the effective audio and visual communication allowed the remote and manual techniques to be performed effectively and safely.

5. FUTURE PLANS.

It is likely that significant future enhancements to JET will be performed using a combination of remote and manual techniques. If there is large amount of manual in-vessel work a matrix system, for audio and visual communications, will help to aid work; co-ordination, flow and safety. Future higher speed computing and network technology will facilitate, effective and affordable, voice and video transmission over the Internet. This could enable greater remote participation, by Associations across Europe, in installation of future JET enhancements.

6. CONCLUSION

Audio and visual communications systems have been successfully applied on JET to support work in controlled areas over a number of years. The complexity, interfaces and number of personnel involved with a task have dictated the arrangement of the communications system. The safety and the progress of complex engineering tasks have been significantly enhanced by the application of the appropriate systems.

7. REFERENCES

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