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The Use of Virtual Reality and Intelligent Database Systems for Procedure Planning, Visualisation, and Real-Time Component Tracking in Remote Handling Operations

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** See annex of M.L. Watkins et al, "Overview of JET Results",
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ABSTRACT.

The organisation of Remote Handling (RH) operations in Fusion environments is increasingly critical as the number of tasks, components and tooling that RH operations teams must deal with inexorably rises. During the recent JET EP1 RH shutdown the existing Virtual Reality (VR) and procedural database systems proved essential for visualisation and tracking of operations, particularly due to the increasing complexity of remote tasks. A new task planning system for RH operations is in development, and is expected to be ready for use during the next major shutdown, planned for 2009.

The system will make use of information available from the remote operations procedures, the RH equipment Human-Machine Interfaces, the on-line RH equipment control systems and also the Virtual Reality (VR) system to establish a complete database for the location of plant items and RH equipment as RH operations progress. It is intended that the system be used during both preparation and implementation of shutdowns.

In the preparations phase the system can be used to validate procedures and overall logistics by allowing an operator to increment through each operation step and to use the VR system to visualise the location and status of all components, manipulators and RH tools. During task development the RH Operations engineers can plan and visualise movement of components and tooling to examine handling concepts and establish storage requirements.

In the implementation of operations the daily work schedules information will be integrated with the RH operations procedures tracking records to enable the VR system to provide a visual representation of the status of remote operations in real time. Monitoring of the usage history of items will allow estimates of radiation dosage and contaminant exposure to be made.

This paper describes the overall aims, structure and use of the system, discusses its application to JET, relevance to ITER and also considers potential future developments.

1. INTRODUCTION

The first RH shutdowns were managed, documented and organised using entirely paper based systems, although computerised Human-Machine-Interfaces (HMIs) were used for control of the manipulators and robots. Since the mid 1980s ([1]) increasingly advanced 3D computer models have been used to visualise and monitor live operations, and these systems have also been used to simulate operations in 'Virtual Reality' (VR) before execution, gradually taking the place of real world mock-up practice operations in the In-Vessel-Training Facility (IVTF), a full scale mock-up of the JET machine. Since 1998 there have been 5 major fully remote handling shutdowns at JET, with each successive one consisting of significantly more complex and diverse tasks, as well as a sharply rising number of tasks and a greater number of components and tools to be kept track of. The rise in number of tasks is demonstrated by figure 1.

The increased demand on RH has inevitably led to a surge in paper-work needed to plan operations and create operations procedures, track locations and radiation exposure of tooling and components, execute/carry out operations and to subsequently audit and review operations. Paper-work is also

required to ensure that operating procedures are safe and followed correctly, and that work is peer reviewed at all stages. It is therefore seen as essential that repetitive paper based systems be replaced by computerised tracking and management systems.

This paper describes the ongoing activities aimed at integrating of many of the existing computer systems used for preparation and execution of tasks at JET, including the computerised documentation and database systems used for tracking tools, components and developing procedures, the VR software, and the HMIs.

2. OVERVIEW OF THE REMOTE HANDLING TASK/OPERATION LIFE CYCLE

Modifications to the JET machine are first approved by the JET Coordination Committee before the work is split into tasks, for which plans and procedures must be developed. For each task an experienced RH engineer writes a specification or sequence description document providing

- A detailed description of the work/task
- Points where task execution flow might change, dependent on, for example, which particular tile is being installed, and the variables that this brings into the task and that must be set during the operation
- Start and end conditions for the task such as the location of robots and manipulators
- Required tooling, components and robot 'teach-repeat' files (a recorded sequence of robot movements) needed for the task
- VR model specification – what tools etc. must be configured and available in the 3D model
- IVTF mock-up requirements (if any)
- Reference drawings and documents for tooling and components

The sequence description is very detailed, however it is still an overview and there are further steps required to document the procedure before the task can be considered fully defined: A flow diagram is created that shows the start and end of the task and all the steps in between, including loops and conditional branches. Each block in the diagram (that is not a flow control block) is broken down into steps and these are detailed carefully.

The fully developed task/sequence is peer reviewed and trialled in VR and in the IVTF if necessary. A schedule is made for use of the sequence, and then the task itself is carried out according to the defined steps. Each step is individually ticked off and accounted for. A report is generated detailing the date and time that each step was completed, with comments regarding any particular issues. This must then be signed by JET management to confirm that the work has been completed to their satisfaction. Note that the steps do not necessarily take place in the order shown, and that conclusions drawn as a result of taking one step may require others to be modified or reviewed.

More detail and planning is needed to carry out and review the task than is provided by the sequence description alone, and for this purpose a collection of software applications are used to automate the planning process as far as possible. A networked database called the Operations

Documentation System (ODS) is used by many of the applications. ODS is responsible for

- Tracking locations of all components and equipment according to their unique serial numbers.
- Storing and providing fast access to specifications, and drawings of components and equipment
- Storing and retrieving procedures and flow control diagrams, including completed procedures
- Recording properties and actions associated with a certain type of equipment, for use in procedures.
- Managing and recording user access to all the stored data; who has edited a procedure, who completed a certain step of a procedure.etc.

2.1 TASK DESIGN, DEVELOPMENT AND PREPARATION

A flow diagram is created from the initial sequence description document showing graphically how the work will proceed,-using software called the ODS Process Map Editor. An example of a small part of such a diagram is shown below in figure 2.

Next the exact steps of each (pink) method block are defined using the Operations Task Development System. The method blocks titles are automatically listed in the left pane of the window when a procedure is loaded and are then detailed in the central pane using predefined (but customisable) action statements. Components and equipment -for the task can be added from the database and appear in lists on the right hand side. Figure 3 shows the 'Collect Tooling' method.

Steps/actions take several forms; flow control (case; or while), actions on tools, components or robots, or instructions that a variable must be set at this point in the procedure. Variables are used when the same procedure is used repeatedly for slightly different tasks-the operator may sometimes need to use the left arm of a manipulator and other times the right, but the rest of the procedure would be identical. So a 'set variable [manipulator_arm]' step would be used and left or right must be selected before moving move [manipulator_arm] to [location_x]'

Before new procedures can actually be used, the remote task is simulated using a digital mock-up created from configuration control (CATIA) models. This digital environment is used within the simulation tool (VR4Robots) together with 'robotised' models of remote handling robots, tools and equipment relevant to the task-. If the robots will be required to do particularly difficult or precise manoeuvres that have never been undertaken before, new teach-repeat files are also developed. VR is used to practice the procedure and check for collisions.

2.2 TASK EXECUTION

Tasks are carried out using the ODS Active Process Map application. This uses a web browser to display the process map for the task and the method steps for the block currently selected. Each time a method step is completed the box next to it is ticked and ODS records the name of the user and the date and time of completion. When additional information, such as the value of a variable, is required, the user is prompted.

While the procedure is read from the Active Process Map the robots and manipulators are used to carry out the steps using the HMIs, with camera monitors and the VR system for live visuals. One particularly useful feature of VR4Robots is that of ‘target positions’; where a translucent model of the next position of a robot is shown, allowing the users to check the move is safe before it is actually confirmed.

There are two ODS databases, one for off-line simulation and task development, and one for on-line operations, with the main differences being that the on-line version only has access to issued/approved procedures, and it is the on-line version of the system that keeps the records of which procedures steps have actually been carried out. After a task or set of tasks has been carried out a report is automatically generated from the logs, showing the time each procedure step was completed, who was responsible for the work, and any additional comments or notes made during the task.

3. INTEGRATING ODS, THE HMIS AND VR4ROBOTS

The current software suite in use at JET has proved to be an invaluable tool for RH operations. A new objective for the RH engineers is to take the logical next step in linking these systems together to further simplify operations. By allowing VR4Robots and the HMIs to query the ODS database; and to communicate with ODS applications, it will be possible to be automatically configured to the current task. This will be useful in both task design and execution. For retrieving database records VR4Robots will use the ODS ‘.Net web service’, while communication with the other ODS systems will utilise TCP/IP.

Automatic configuration of VR4Robots means that on beginning a new remote task, 3D models related to the task are inserted at their initial location, for example in an ISO container or rack etc. As one moves through the task (procedure), VR4Robots updates the locations of the objects and manipulators to match the relevant ODS ‘Step’, and will also expose or hide parts of the vessel as required for the task. If the selected step requires a movement of tools, robots or equipment VR4Robots will also show, using transparent green overlays, the target positions that the items should be in at the end of the move. When working on-line, the true real-world positions of robots and manipulators will be shown, although it will be possible to disable this feature and browse through the operation visually. Additionally, if a selected step requires a teach-repeat file to be loaded into a control-system HMI, the HMI will be able to automatically open the relevant file and move to the correct step.

Since VR4Robots is aware of whether the system is operating on-line or off-line, it will be able to examine the ODS logs and retrieve useful, time-stamped data, and it will be possible not only to reconfigure the simulation to reflect the current status of the vessel, equipment, tools etc. but also to record how long a certain tool has been in vessel and add this information to the item’s ODS record. This data is extremely useful for providing an indication of an objects radiation exposure, and such data can be presented to the user in a text box whenever the mouse pointer hovers over a particular feature or item in the simulation that has a matching ODS record.

3.1 SYSTEM DESIGN

Implementation of the features requires that several parts of the existing systems be modified, as well as adding new features. It is desirable that modifications be as minimal as possible, because the users of the system are already familiar with current working methodology, and it is essential that the hundreds of procedures that have already been developed remain compatible after the modifications are made.

Equipment records will need to store the filename and path of the 3D object so that VR4Robots will be able to retrieve it and insert the object (model) into the simulation. A field will also be added to hold the recorded in-vessel time of each item (identified by serial number).

VR4Robots will need to recognise values of certain variables used within ODS procedures, such as 'left-gripper' or 'tool tray 1 location 4'. Since VR4Robots already has a system for simulating item placement locations it will match these 'snap locations' to the relevant ODS value. ODS will need new actions for showing or hiding parts of the vessel simulation so that it can be configured or reconfigured by a procedure as the task requires. This will not affect old procedures since they will be additional functions and the old manual methods will still be available.

The system sequence diagram, figure 6, explains the interaction of different parts of the system at task initialisation and completion, and the system's response to some ODS actions after selection of an ODS task step.

CONCLUSIONS

Remote operations are a very complex environment and there are many simultaneous activities occurring. The present ODS system defines the operations steps and guides the operators. The proposed system will effectively bring together parallel activities, such as the preparation of tools and components for the next stage of the task, and allows the whole process to be visualised in real time with movements of the components, tools and manipulators recorded as the operators move through the task. The benefits of the system are many, not least the safety aspects when independent teams are controlling parallel boom systems within the same space, but nevertheless working to the same task schedule with one feeding the other with materials (i.e. tools and components) to allow completion of the task. The proposed system provides the operation's responsible officer not only with an overview of the whole environment but also with the ability to examine the next step of the task, or indeed any step of the task, prior to committing to that step.

The system will allow late changes to tasks to be visualised without manually updating the simulation, and this additional flexibility has other advantages such as providing reports on the status of the operations environment (for example in-vessel) as defined by the task. This data can be used during shift changes and to communicate shut-down status to management.

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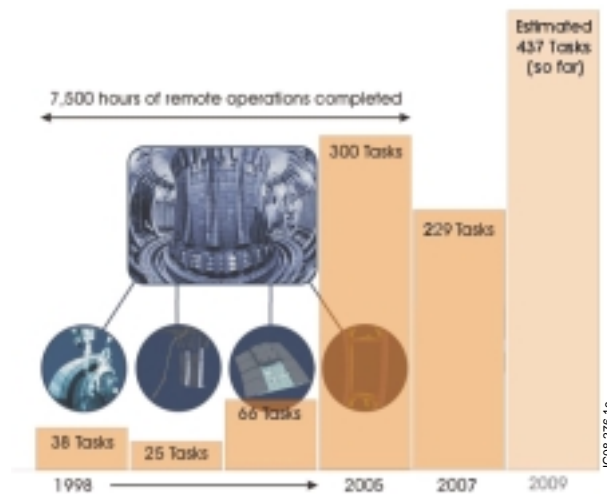


Figure 1: Number of RH tasks handled in JET shutdowns ([1])

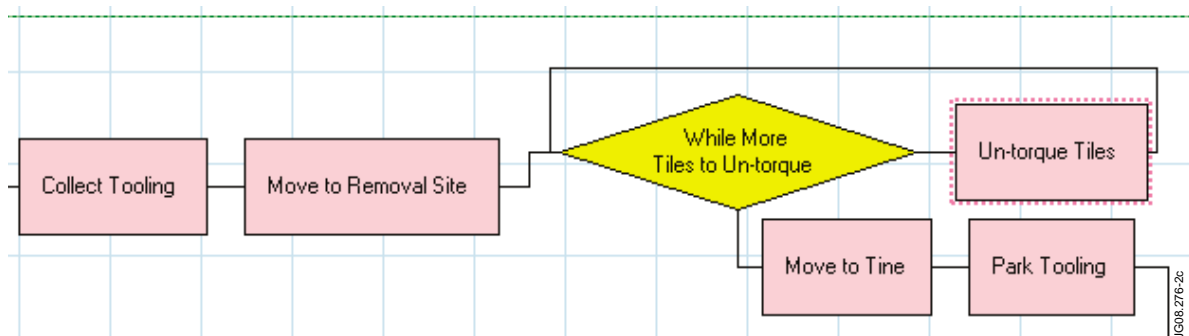


Figure 2: ODS Process Map flow diagram

Sequence		Method Steps		Equipment	
Handling of Dump Plate Halo Coil Modules [JR (v4.1 - 23/06/2008)] EDIT : Read Write					
SequenceNo INV/DIA/003					
Method Titles		Method Steps		Equipment	
No.	TM	Action	Action On	Grp.	Name
1		Select Case (TOOLING TO COLLECT)		1	Boom
2		Case (LOOSEN TILES)		2	Short Boom
3		Set Variable (Mascot)		2	MK2GB Tine
4	C	Collect	2:1 Torque Multiplier	4	Bolt Runner
5	C	Collect in Unfastening	Bolt Runner	5	Key Sns Δ/F + 70/1
6		Case (TILE REMOVAL)			
7		Set Variable (Mascot)			
8	C	Connect to Mascot fingers	Mascot Finger Adaptor		
9		Calibrate	SM07 Generic Mascot Tile Fingers		
10	C	Collect in Unfastening	Bolt Runner		
11		Case (HOLSTER)			
12	C	Collect	Bolt Runner Holster (M10)		
13	C	Collect in Fastening	Bolt Runner		
14		Case (MODULE)			
15		Set Variable (Mascot)			
16	C	Collect	Upper Halo Aray Handling Tool		
17	C	Collect in Fastening	Bolt Runner		
18		Exit Cabot			

Figure 3: Operations Task Development System

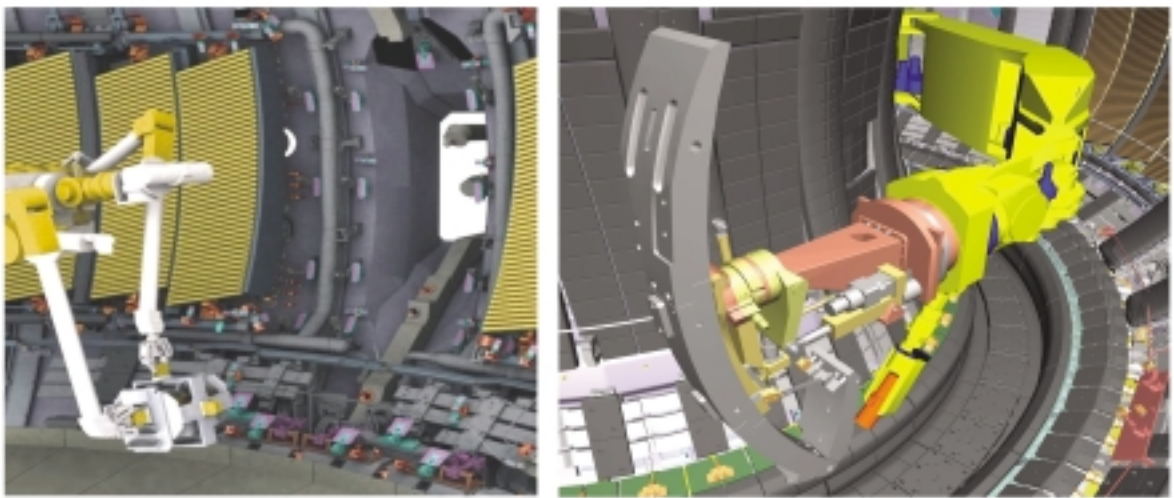


Figure 4: VR4Robots Simulation of JET and RH Manipulators

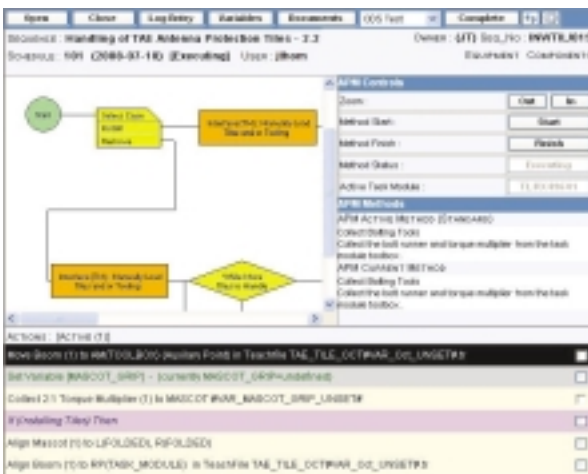


Figure 5: ODS Active Process Map

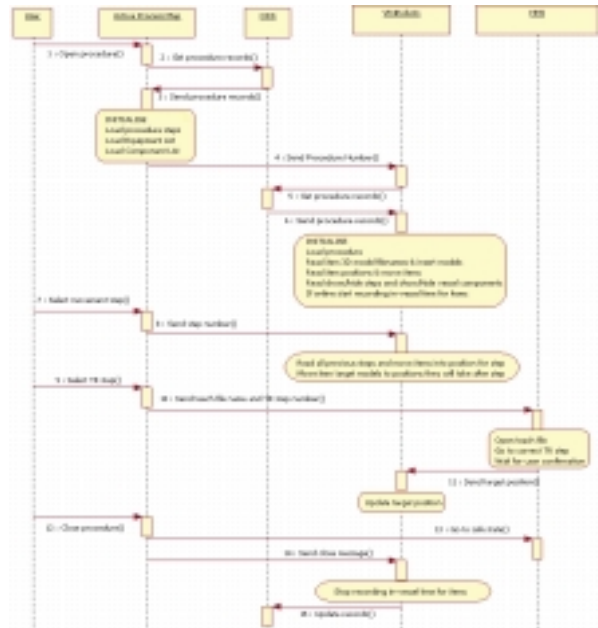


Figure 6: System sequence diagram