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Evolving the JET Virtual Reality System for Delivering the JET EP2 Shutdown Remote Handling Task

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ABSTRACT

The quality, functionality and performance of the Virtual Reality (VR) system used at JET for preparation and implementation of Remote Handling (RH) operations has been progressively enhanced since its first use in the original JET remote handling shutdown in 1998. As preparation began for the JET EP2 (Enhanced Performance 2) shutdown it was recognised that the VR system being used was unable to cope with the increased functionality and the large number of 3D models needed to fully represent the JET in-vessel components and tooling planned for EP2. A bespoke VR software application was developed in collaboration with the OEM which allowed enhancements to be made to the VR system to meet the requirements of JET remote handling in preparation for EP2. Performance improvements required to meet the challenges of EP2 could not be obtained from the development of the new VR software alone. New methodologies were also required to prepare source, CATIA models for use in the VR using a collection of 3D software packages. In collaboration with the JET Drawing Office, techniques were developed within CATIA using polygon reduction tools to reduce model size, while retaining surface detail at required user limits. This paper will discuss how these developments have played an essential part in facilitating EP2 remote handling task development and examine their impact during the EP2 shutdown.

1. INTRODUCTION

During the JET EP1 Shutdown the VR software used to assist in delivering remote handling operations was PTC DIVISION Mockup. As planning began for the EP2 Shutdown it was recognised that the VR would need to provide improved real-time performance to cope with the more complex ITER Like Wall (ILW) tile carrier designs and resulting higher polygon count 3D models. Furthermore, a method of working which allowed multiple instances of the JET vessel VR model to be regularly updated was also identified as a key requirement. This was because the tile carrier designs, embedded diagnostics and associated handling tooling were still evolving in design even as remote handling engineers started preparing their component strip-out and installation procedures. VR models were required that could be remotely and globally updated on all JET Vessel VR models, so as component designs changed the engineers working on them always had the latest VR models and most accurate VR environment model.

A new VR software product was identified and purchased. This is VR4MAX created by Tree C Technology B.V. Starting from this off the shelf package a new bespoke VR application was developed through a collaboration between the OEM, Oxford Technologies Ltd (OTL) and the JET Remote Handling Group which allowed the existing JET human-machine interfaces (HMIs), which controlled the manipulators and robots both virtual and real [1] to interact with the VR environment as displayed through VR4MAX. This package is called VR4Robots.

2. MOVING FROM CATIA CONFIGURATION CONTROL MODEL STRUCTURE TO VR SIMULATION USING EXTERNAL REFERENCES

As well as improved real-time graphic performance the software allowed a new way of structuring

the JET Vessel VR model, allowing multiple engineers to have individually configurable VR models, that at the same time could have their constituent parts remotely updated as the design of component parts evolved. This ensured RH engineers were always rehearsing their tasks in the most up-to-date VR environment. To achieve this the master JET Vessel VR model was built as essentially a simple hierarchy containing links to numerous other 3D models; these links are called external references (XRefs). It is these external models that provide the true detail of the JET model. The workflow and concepts behind this new way of structuring the VR model are illustrated in Fig.1.

For each component in the JET Vessel model (or item of tooling) there would be a 'latest release' model stored in a restricted area and controlled by a VR Engineer. A copy of the master JET Vessel VR model would contain XRef links to the folder containing the 'latest release' models. A change to the 3D geometry representing a particular vessel component, or item of tooling, would lead to that model being updated in the 'latest release' area. Subsequently that component will be updated in any instances of the full JET Vessel simulation model next time it is loaded.

At any point if a component design is changed by the Drawing Office (DO) then the VR Engineer would access the configuration controlled CATIA data and use this to update the relevant 'latest release' XRef model. These design changes are often as a result of input from the RH Operations Engineer (ORO) who is checking component design in VR to validate remote handling procedures. As the ORO would start on a new remote handling task they would save off a version of the JET Vessel VR model and then configure the model to suit the requirements of the task, i.e. the installation order, by changing the display settings of the individual XRef models that are loaded in. The display settings include defining which components are visible or hidden and then within a visible component hiding or making visible individual parts, such as tiles. The engineer can then control whether group nodes are open or closed, in order to control the level at which objects are selected, apply redlining information, insert relevant tooling from a library and control the level of detail (LOD) a component displays at. These configuration settings are then saved within the ORO's personal copy of the JET Vessel VR model. Updates to source (CATIA) models are still reflected within individual ORO's saved simulations ensuring the defined task configuration is retained.

The automated up-dating of task related VR simulations has been used to considerable effect by ORO's during the EP2 shutdown resulting in productivity efficiencies throughout the task development process. Methods were developed to allow ORO's early access to design models allowing the ORO to identify design problems relating to remote handling at an earlier stage. As the design became more fixed, the VR Engineer could perform a more complete model conversion, tailoring the naming and grouping of objects for ease of shutdown use and improving model efficiency by reducing both polygons and the number of unique objects in the item.

As the project moved from the development phase into the shutdown proper, a new master release was made of the JET Vessel VR model. This was configured specifically to aid In-Vessel operations by grouping objects at the level they would be handled. This meant tile carriers, which were handled as a single item during operations, also get selected as a single object in the VR making it easier to update their visibility status and therefore reflect operational progress. In reality the tile carrier

might be formed of two or more objects which might have been individually selectable during the planning stage but during operations this would become a hindrance. During the shutdown phase, the JET Vessel VR model is saved at the end of each shift. This provides a continuous record of the changing vessel state but with the advantage of minimising disk space requirements. This again is an illustration of the advantages of using external references as each model saved is just a record of the visibility status of the XRef components rather than the physical geometry representing them. As well as using XRefs the hierarchy of the JET Vessel VR model has also changed from that used during EP1 with a move away from an octant based structure. The new hierarchy is component based rather than octant based. This allows a single model containing all geometry defining a component to be referenced within the hierarchy. Having this single model makes it easier to update and manage components through the newly developed use of XRefs. The differences in these two approaches is illustrated in Fig. 2. The new hierarchy means the model is initially structured by grouping together component XRefs with a similar function (plasma facing, vessel structure, robots etc) and then, at a sub-level of each of the above, grouping components found in a similar location (outer wall, inner wall, vessel roof etc).

Maintaining the model hierarchy used when running the DIVISION Mockup VR software would make it difficult to easily and quickly update an entire component using XRefs, as we are now able to do. This is because in the existing DIVISION Mockup hierarchy each vessel component (dump plate tile carriers for example) would get split into 8 unique octant based models appearing at different places in the model hierarchy.

Within the referenced component model there is still a division of geometry by octants but this would only be apparent when you open up the component XRef. This is beneficial for two reasons:

- a) Component parts can be named based upon the octant they are located in, making them both easy to identify and also to relate to the work schedules used by the ORO; where the division of work is still very much based around octants.
- b) The VR models require grouping in such a way so as to aid real-time performance. As an operator navigates through the model in real-time, culling operations are constantly performed to establish which scene objects need drawing on the screen. This is called the view frustum culling mechanism [2]. The division of the geometry and the resulting spatial extents of objects and groups has a major impact on the graphical performance, measureable through the refresh rate of the VR simulation (frames per second) [3]. Breaking components down into octants ensures there are objects of a size suitable for efficient real-time culling.

3. NEW METHODOLOGIES IN THE PREPARATION OF CATIA MODELS PRIOR TO CONVERSION TO VR FORMAT

As well as being able to remotely update component models so the VR simulation models could evolve through time, it was also recognized that the conversion process for getting source Configuration Control CATIA models into the VR format would need to be updated.

The new ILW CATIA models were found to be significantly larger in size, both in terms of their

physical memory size and also their polygon count, compared to models used during previous shutdowns. This was primarily due to two factors:

- a) The increased complexity of the new beryllium ILW tile carrier designs, many of which had a castellated surface, compared to the smooth surfaces of the original Carbon Fibre Composite (CFC) tiles.
- b) The move to CATIA Version 5 from Version 4 that allowed components surfaces and parts to be modelled in far greater detail and subsequently use significantly more polygons to represent each new vessel component. The result was some CATIA component models were of such a large memory size we were unable to open them in our 3D model translation application used to convert CAD solid models into surface mesh models.

A new way of preparing CATIA models was developed with the aid of the JET RH Drawing Office. This involved using the DMU Optimizer toolset within CATIA and within this the 'Simplification' function. This tool performed a global mesh reduction on the source 3D CAD model geometry. The degree of mesh reduction was controllable and after trials on a variety of components it was found a reduction factor of between 40-50% was optimum. This level of reduction removed a significant number of polygons from the model whilst maintaining the components shape to an accuracy suitable for visualisation within the VR environment. As the mesh reduction is performed the operator checks the models surface for any over simplification that would result in the VR model no longer accurately representing the form and spatial extent of the component. This could affect the ability to identify possible clashes between components, tooling and robots.

A mesh reduction process had always been carried out as part of the CATIA to VR conversion path but this had been done at a later stage using the VR tool set. Now all configuration models go through this new process to ensure the models can be handled as they move through the conversion process.

4. OEM SUPPLIED ENHANCEMENTS TO VR4ROBOTS

After initial trials of the new VR software in conjunction with the JET Vessel VR Model, several enhancements were identified to make the software more user friendly and tailored to the particular requirements of JET Remote Handling. The OEM supplied these enhancements which provided the following additional functionality to VR4Robots.

- Object Name pop-ups: - allowed easy identification of tile carriers, components and tooling by displaying an object's name next to it within the scene window if the mouse hovered for a defined period of time over the object.
- Shortcut Keys - Allowed the user to quickly carry out some frequently performed commands such as hiding or making objects visible, especially useful when in full screen mode.
- Improved behaviour menu - Tools to allow greater configuration of the Behaviour menu, a menu system to control the display of tooling.

Improved handling of XRef models by the JET Vessel VR model allowing the status of nested hierarchies of external references to be saved. This meant an XRef model could be positioned within the hierarchy of another 'parent' XRef and the status of both the XRef models and their constituent parts is recorded in the master simulation model. This enabled the use of LOD models and the resulting benefits to real-time performance.

CONCLUSIONS

Future VR models representing Remote Handling environments will most likely encounter similar problems to those we experienced during the EP2 Shutdown. VR models will evolve during the course of shutdown preparation as OROs carry out trials of procedures, highlighting handling problems. This will require re-design of tooling and components as will external factors relating for example to component manufacture or feedback from in-vessel surveys and these design changes will need to be fed back to the ORO through the VR models. Increasingly powerful CAD tools will result in more detailed and memory hungry 3D models. These will require careful translation to avoid producing geometry that is too heavy to run in real-time.

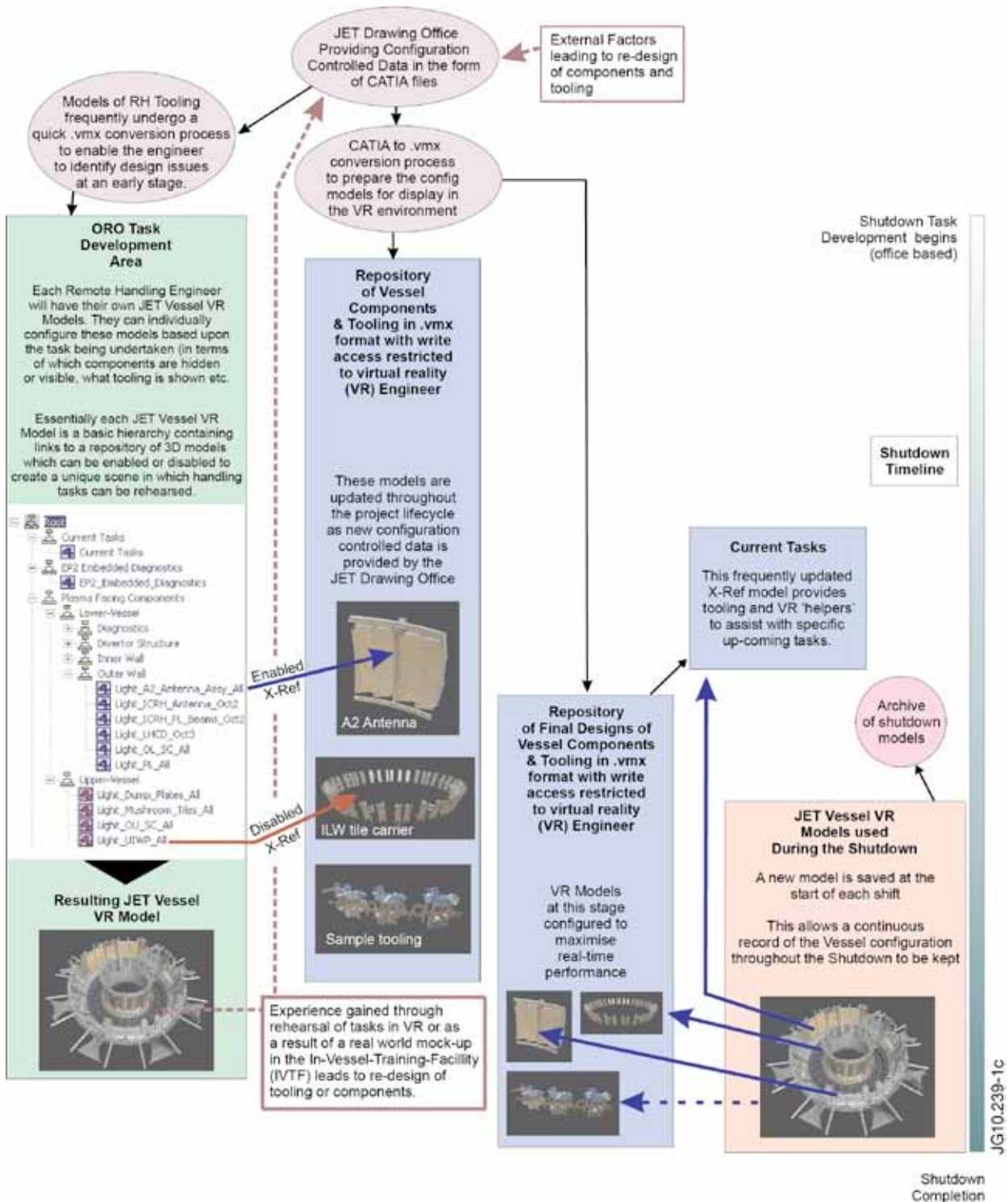
The benefits of the change in the way the JET Vessel VR model has been hierarchically structured, with a move to external references, can be seen in the greater accuracy and flexibility of the VR. This can now be constantly updated as new configuration control models are released from the JET Drawing Office. New model translation techniques allow the complex and highly detailed models coming out of the DO to be converted into VR models which are accurate but still light enough in terms of their polygon count and structure to provide acceptable real-time performance.

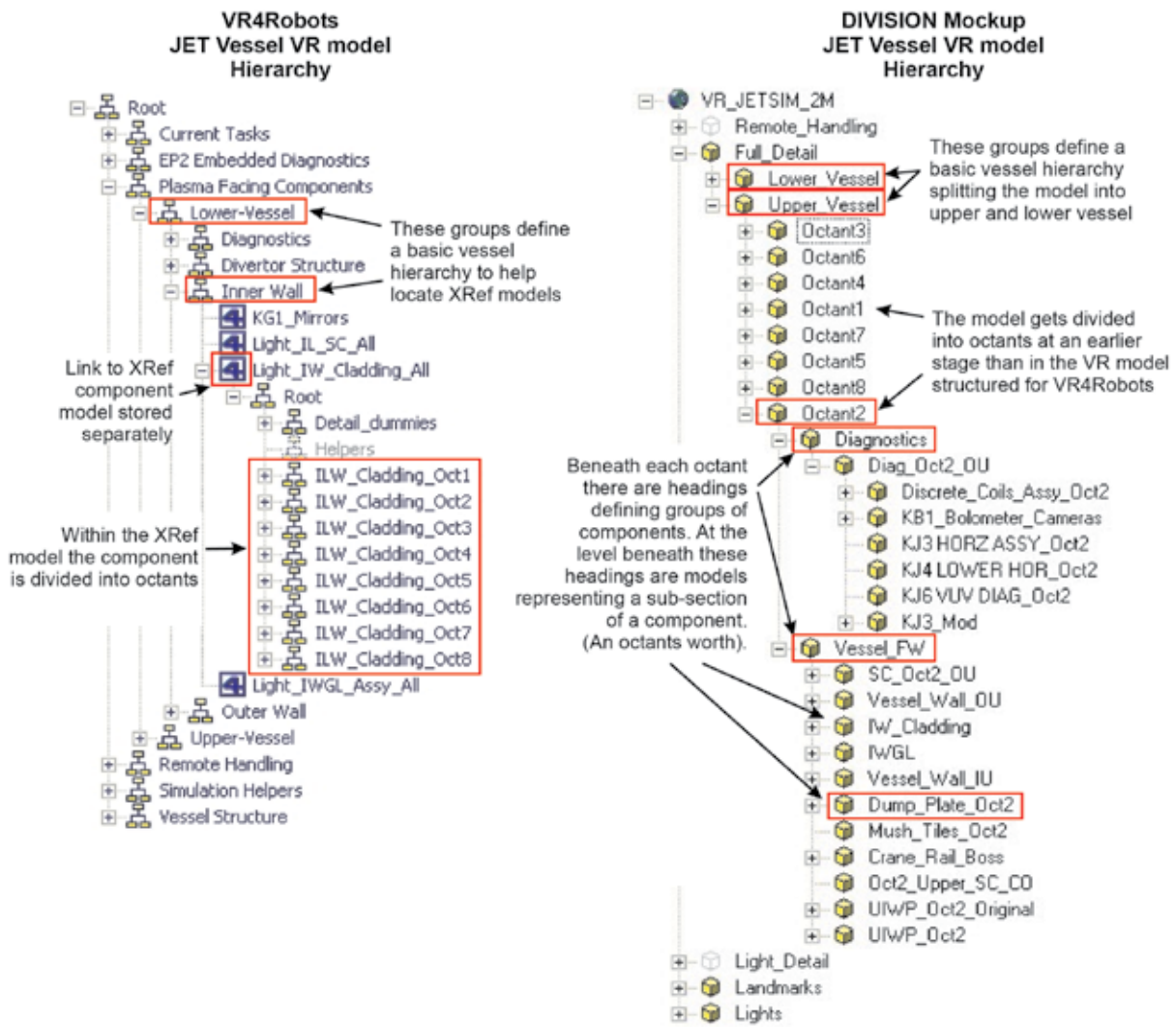
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Comparison of VR4Robots and DIVISION mockup VR model hierarchy

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