# Synthetic Viewing for Remote Handling Facilities

## Introduction

The European Spallation Source (ESS) is a multi-disciplinary research facility which will be the world's most powerful pulsed neutron source. A critical component of ESS will be a facility for handling radioactive waste and preparing it for safe disposal. Safe disposal of ESS waste requires the dexterous tele-manipulation of large, highly activated payloads in a shielded chamber: a hot cell. Traditionally hot cells are built with lead glass windows to allow direct observation by operators. However, as the complexity and scale of required handling operations increases, the restrictions imposed by such windows become problematic, motivating the development of hot cells without any windows. RACE is building on its experience operating the Joint European Torus (JET) remote handling system to develop a windowless hot cell for the ESS Active Cells Facility (ACF), featuring a fully integrated remote handling system and a state-of-the-art synthetic viewing system.

What will follow is a brief background into the current state of the art in control systems for Remote Handling, followed by the proposed design of the ESS Synthetic Viewing system, concluded with a short discussion.

## Background

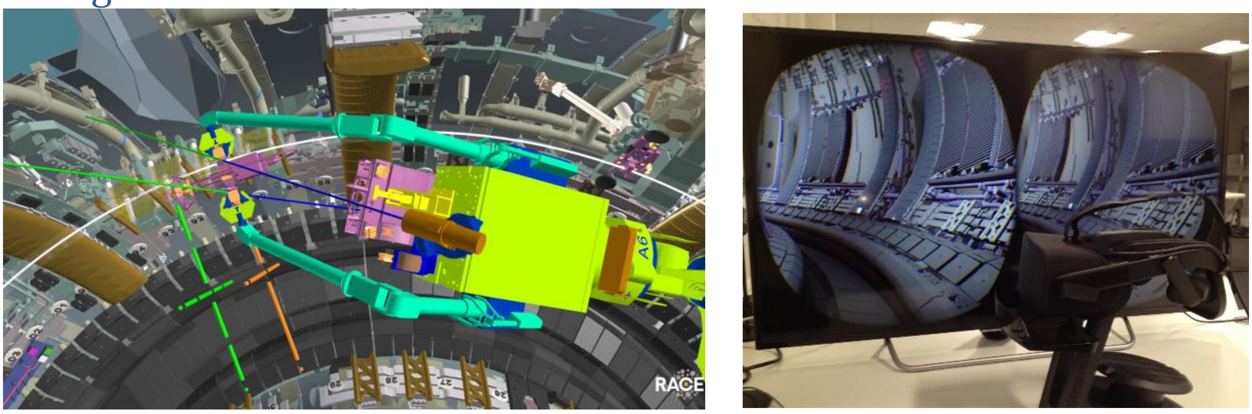


*Figure 1: Synthetic Viewing of JET*

A synthetic vision system (SVS) is a computer-mediated reality system for remote operation, that uses 3D to provide operators with clear and intuitive means of understanding their remote environment. For the operators of the JET remote handling system, operators utilise synthetic views created by a virtual reality system, which is constantly updated in real-time with position data relating to the robotic systems. This supplements a comprehensive, low-latency CCTV viewing system.

The virtual reality system incorporates a live 3D model of the environment, consisting of all robotic systems and serviceable components, as well as all the specialised tools which can be deployed. This model is continuously updated throughout operations to represent the precise configuration of JET and the RH systems as in Figure 1. The positions of remote handling robots are automatically displayed based on the position sensor data from their respective control systems, while any planned automatic moves are illustrated as semi-transparent green indicators “ghosts” of the target configuration.

The VR display is central to the JET remote handling control room, and allows the operators to clearly see the state of the robotic systems and the JET machine itself, providing views that cannot be obtained by cameras. In addition to supporting live operations in real-time, the virtual reality tools can be used in combination with simulated robotic control systems to allow operation planners to design and trial-run remote handling tasks offline in their own office, without access to the real systems. Motion path plans can be generated in this offline environment, and these are used to conduct validation mock-ups in virtual reality which are independently reviewed prior to approval for live operations.

# Synthetic Viewing


*Figure 2: Control room of a simulated ESS windowless hot cell.*

The ESS ACF contains an environment similar to JET, but with additional constraints due to the higher radiation doses that will be present. For a windowless hot-cell with limited sensors that are prone to failure, a synthetic viewing system will be critical. The system will provide an outlook to the probable state of the hot cell, allowing for more effective operations to be performed. For example, the elbows of a tele-manipulator can be monitored in three dimensions (with no camera views) for possible collision.

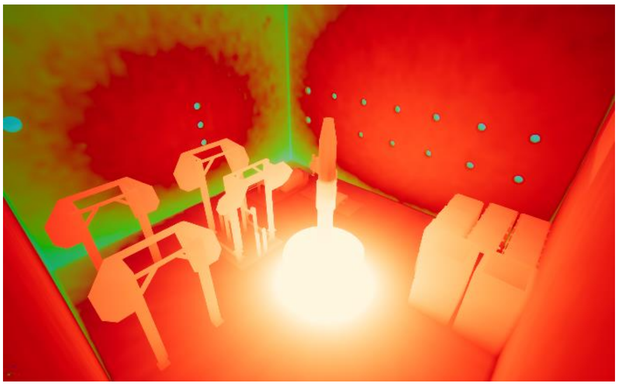

*Figure 3: Visualising Radiation in a window-less hot-cell (Credit Ras=d Data: J. Naish, CCFE).*

However, a Virtual Reality (VR) simulation has many more useful properties and functions, such as in JET, where the simulator is used for training and operations testing. A control room can be populated with simulated camera views, and operational constraints can be tested, such as reachability, lighting conditions, and radiation dose. With the use of immersive VR hardware (e.g. HTC Vive) human elements in the Remote Maintenance system can also be tested, such as operators tasked with entering the maintenance cell and carrying out operations involving the whole system. A system like this would allow for a complete Technical Design Review to include a full operation demonstration with simulated cell.

Similarly, a VR system can be easily extended to aid in the design of components. Designers can quickly and intuitively understand how their components and subsystems interact with the whole plant, without adding cost. In the ~15m$^3$ hot-cell of the ACF the scale makes this particularly important, as the components exceed the limits of normal human operations.

Finally, the current state of the art for synthetic viewing can be extended to include more information from the digital twin and control system. This can include visually indicating the state of brakes or torques on robot joints, or illustrating the currently measured radiation map or physical point cloud. Similarly, mixed reality can be employed, such that real camera views can be augmented into the VR scene to provide greater fidelity.

# Conclusion

The recent advance in simulation and VR technologies has opened many opportunities to rapidly improve the current state of the art of Remote Handling. Mixed reality technologies can extend the current Synthetic Viewing system to include advance simulation data, sensed data, and operations data conveyed in an effective, intuitive, and contextual fashion. This Synthetic Viewing solution could be used to improve all parts of the operation: from development to execution and review.