ITER Engineering Design Activities - R & D

In-Vessel Remote Handling

Systems near the plasma will become radioactive and will require remote maintenance, with special remote handling equipment. An in-vessel transporter system is used for the removal and reinstallation of blanket modules, multifunction manipulators for divertor cassette removal, and specialised manipulators to handle vacuum vessel port plugs. Special casks, which dock horizontally to the access ports of the vacuum vessel, are designed to house such equipment and to transport radioactive items from the tokamak to the hot-cell where refurbishment or waste disposal operations can be carried out. Docking of these casks to the vessel and the hot cell flanges is tight, to avoid spreading of contamination. Hands-on assisted maintenance is used wherever justifiable, following the ALARA principles.

The remote handling strategy for ITER has been confirmed by a comprehensive R&D programme which has successfully demonstrated that key maintenance operations such as blanket and divertor replacement can be accomplished using common remote handling technology.
Several crucial issues such as vacuum vessel remote cutting and re-welding, viewing, materials and components radiation hardness have been addressed and demonstrated.

Blanket Module Remote Handling Project (L-6)

Objective

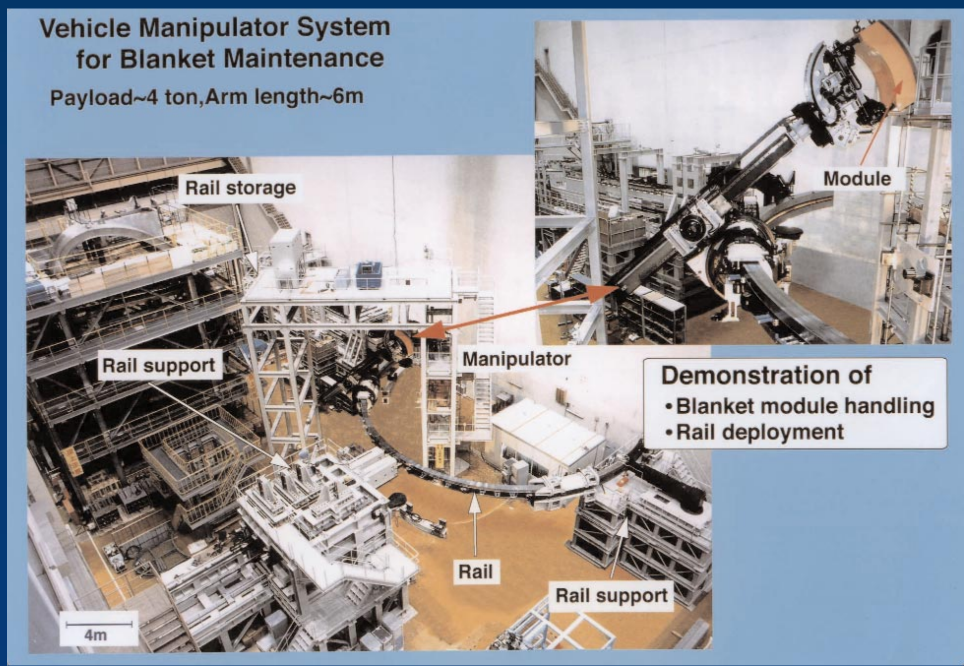
To develop and demonstrate the ability to remotely maintain blanket modules, including manipulating a 4 t module at a distance of 8 m with an accuracy of ± 2 mm. A rail-mounted vehicle system has been developed to handle the heavy blanket module within the limited space and with the required precision.

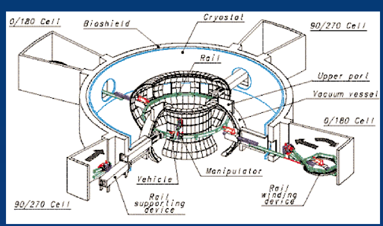
After development and prototype demonstration of the main systems and techniques, full-scale testing and verification were successfully completed in 1998 on the Blanket Test Platform (BTP) constructed at JAERI's Naka laboratory.

This platform comprises module handling equipment, port handling equipment, auxiliary remote handling tools and a blanket mockup structure to reproduce the physical environment of a 180° ITER in-vessel region. A suppression control system to reduce dynamic deflection and vibration of the arm to negligible levels has subsequently been developed and successfully tested.

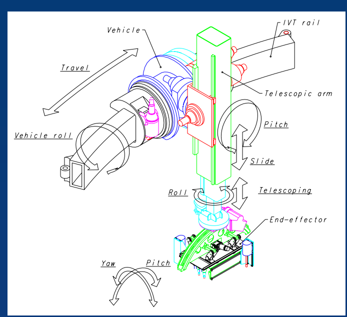
The blanket on ITER requires very precise positioning (± 0.25 mm) with respect to keys and pins. Module insertion tests have therefore been carried out to check the ability to handle misalignments between modules and keys during installation. The module has been successfully inserted with a misalignment of 10 mm, using the passive compliance of the manipulator, and chamfered keyways. Development of a sensor-based control system with this positioning accuracy is now underway.

Tests also show that the rail can be deployed 90° around the torus in about 30 minutes.





In-vessel transporter design.



Rail-mounted vehicle and telescopic arm.

Divertor Remote Handling Project (L-7)

Objective

Demonstrate that the following operations are feasible:

- *replacing and refurbishing all or individual divertor components several times during the machine life;*
- *positioning high heat flux components (HHFCs) so the maximum step between those on adjacent cassettes would be under 4 mm and the maximum variation around the whole torus would be within ± 10 mm;*
- *locking and securing the supports, making water pipe connections, assembling electrical connectors, and handling port plugs;*
- *replacing all cassettes in less than 6 months and replacing a single cassette in under 8 weeks.*

Two full-scale test facilities - the Divertor Test Platform (DTP) and the Divertor Refurbishment Platform (DRP) - have been set up at the ENEA Research Centre of Brasimone (Italy).

The key elements of the divertor maintenance procedure are

- *radial insertion of the cassettes from the chamber,*
- *toroidal manoeuvring,*
- *lowering of cassettes into position on wheeled and jacking forks,*
- *remote attachment to rail.*

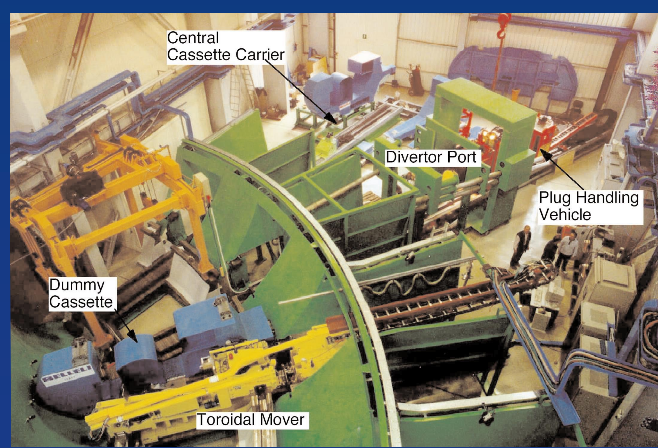
Tests on the DTP confirm

- *the maintenance concept,*
- *its integration inside the vessel,*
- *accuracy of cassette positioning,*
- *adequacy of nominal gaps and tolerances,*
- *payload capabilities.*

Improvements are being investigated to reduce costs and to implement lessons learnt in the early tests to improve man-machine interface, sensors, and timing, as well as to improve sliding components and to investigate rescue scenarios if components become jammed.

The DRP is for simulating the most critical operations to be undertaken in the hot cell. Only those parts of the mockup which are critical for HHFC mounting have been machined accurately. Tests so far show that the remote measurement system can be operated accurately enough (0.01 mm) that components can be correctly machined to fit. A target mockup has been installed on the cassette with the required accuracy, but further work is needed to streamline procedures to shorten the time taken.

Divertor Test Platform.



Divertor Refurbishment Platform.