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# Operational experience feedback in JET Remote Handling

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**Abstract**

JET is the only operating platform within fusion where Remote Handling (RH) techniques have been developed to a stage that allows in-vessel maintenance work to be carried out fully remotely. JET's in-house team developed the methodology and a rational approach that allowed them to succeed in this task. This work clearly shows that the gap between developing the first prototypes and having an RH system ready for operational use, has a time and manpower costs which can easily be under-estimated.

After a presentation of the context of this study, this paper summarises some of the main lessons learned by the JET RH team during the development and operation of their RH equipment. Starting from the JET example, the paper then gives ITER some references for the identification of areas of improvement and for evaluation of the amount of work and manpower costs that are really needed for a complete RH system to become fully operational and reliable.


## 1. Introduction

In ITER, Remote Handling (RH) was defined by the designers at the beginning of the project as the nominal solution for the maintenance of the reactor.

Due to the introduction of a significant amount of tritium in the JET torus in 1997 and application of ALARA considerations, JET has today the only operating platform within fusion where RH techniques have been developed, tested, and improved to a stage that allows in-vessel maintenance work to be carried out fully remotely.

Even if the RH systems used in both reactors will be different, there is no doubt that ITER will have to go through the same development steps as those followed by JET before saying that its RH equipment is safe and reliable. Compared to JET, ITER has the advantage of taking RH into account in the early design of the machine. It becomes therefore interesting to take advantage of this situation and try to introduce recent operational feedback from JET into the ITER design process. EFDA, through the fusion technology task JW0-FT-5.2, asked for an external party (CEA/LIST) with knowledge of RH, fusion and ITER to gather useful lessons learned by JET in the RH field which could be relevant to the ITER case. Discussions and meetings between the JET RH team, EFDA and CEA/LIST were held. Recommendations were reported in a final

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document [1] and are summarized in the following sections.

## 2. RH philosophy

Experimental reactors like JET, are subject to changes in their configuration in order to test new components and systems. In general, this affects the RH tasks by:

- increasing the level of difficulty;
- increasing the level of detail of the task;
- increasing the number of tasks (less modularity).

To cope with this, from the beginning JET adopted a generic "man in the loop" RH strategy [2], which maximised its adaptability to the environment and minimised the need for re-configuration of the equipment from one shutdown to the next. This is not to say that all operations are controlled using a "man in the loop". In fact, the RH system is operated in an automatic (or robotic) way when there is a need for time optimisation and/or accuracy of motion and is open to manual intervention when a high level of human supervision and/or adaptability is required.

This "man in the loop" approach also lends itself well to RH tasks relating to unexpected events. What is important here is not speed or degree of automation of the task, but the adaptability of the RH equipment and procedural approach. The experience at JET is that the ability to reconfigure the RH task procedure and tooling during RH operations is an important key to its success.

## 3. Simplifying interfaces

In order for the development of RH equipment to be effective, the JET team found it essential to simplify the interfaces between the torus and the RH equipment because:

- the impact of modifications to the torus does not lead to significant changes to either the RH equipment or the RH operations Safety Case;
- only the end-effector has to be adapted to account for new operations;
- changes to tools and equipment between successive shutdowns are minimised.

In fact, at JET the only interface between the torus and the RH equipment is the size of the access port through which the RH equipment enters the vacuum vessel.

In contrast, a large proportion of the planned ITER RH equipment, in particular for divertor replacement is (arguably by necessity) heavily dependent on the machine design. The disadvantage of this has already been illustrated by the knock-on effect of the new ITER 2001 design which has resulted in a significant reconfiguration of the divertor handling equipment.

Although this situation was probably unavoidable for the case of divertor handling, the lessons learned from the JET experience should be kept in mind for other less constrained situations, e.g. use of the In-vessel transporter, port plug maintenance and hot cell work.

## 4. Additional maintenance work for fusion reactors

According to JET's experience, the nominal maintenance of a fusion reactor is not only related simply to component replacement. During the course of the various Remote Handling shutdowns, a number of supplementary tasks have become part of the nominal maintenance scheme and have often required the development of specific RH equipment: e.g. inspection for leaks, cleaning, erosion measurement, as built metrology, electrical connector replacement and checking, sampling, de-tritiation, checking and re-tightening of bolts

Installation of in-vessel services (electrical power, lighting for viewing systems . . .) should not be underestimated in terms of both design and installation time and should be considered as part of any shutdown.

## 5. Equipment development life cycle

The RH tool (or RH equipment) is of prototypical nature and after manufacture its reliability needs to be proven in order to be ready for RH operations. The general scheme used in the development of a new piece