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## Technical Specifications (In-Cash Procurement)

# RH Telem manipulator Procurement - Technical Summary

Technical Summary for the Call for Tender process of the RH Telem manipulator System



# TECHNICAL SUMMARY

## RH Manipulator Supply Framework

### Call for Nomination

#### Abbreviations and Acronyms

Abbreviation	Description
ART	Agile Robot Transporter
BRHS	Blanket RH System
CMM	Cassette Multifunction Mover
COTS	Commercial Off The Shelf
CTM	Cassette Toroidal Mover
DA	Domestic Agency
DRHS	Divertor RH System
HNB	Heating Neutral Beam
IO	ITER Organization
LAN	Local Area Network
MAM	Manipulator ArM (DRHS)
MTBF	Mean Time Between Failures
NB	Neutral Beam
NBRHS	Neutral Beam Cell RH System
NB	Neutral Beam
PE/NPE	Pressure Equipment/Nuclear Pressure Equipment
PIC	Protection Important Component
QARO	Quality Assurance Responsible Officer
RH	Remote Handling
Gy	Gray

For a complete list of ITER abbreviations see: ITER Abbreviations (ITER\_D\_2MU6W5).

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## 1 Purpose

The purpose of this document is to provide summary information for a Call for Nomination for the tender of a contract to supply a two arm Remote Handling (RH) Telemanipulator System to the ITER Organization.

**This Call for Nomination is to seek companies interested in participating in the tender for the subject Contract.**

## 2 Scope of the Contract

RH telemanipulators are a key component of the ITER RH System, and they are required in several of the RH task specific sub-systems. The different RH sub-systems can have different telemanipulator requirements in terms of size, reach, and payload.

The scope of this contract is for the supply of a two arm, radiation tolerant, electrical telemanipulator system that will initially be used for RH mock-up trials, and later will be integrated into the RH System for remote maintenance of the ITER machine. The specifics of the telemanipulator specification for this procurement will be derived from the RH ART (Agile Robot Transporter) sub-system requirements (see Annex A – 7.2.4).

The telemanipulator system will need to satisfy ITER customisation requirements (described below). It is expected that the supplier has the ability to configure and tailor its telemanipulator product to meet the IO requirements. The contract scope, therefore, will cover:

- Detailing of the manufacturing design of the customised telemanipulator system,
- Manufacturing and testing of the telemanipulator system,
- Delivery and installation of the telemanipulator system at IO premises.

## 3 Background

ITER is a large-scale scientific experiment intended to prove the viability of nuclear fusion as an energy source, and to collect the data necessary for the design and subsequent operation of the first electricity-producing fusion power plant.

Once nuclear plasma operations have begun, the in-vessel environment will become a highly hazardous environment prohibiting human access, and the in-vessel maintenance tasks will be carried out fully remotely using remote handling systems. The operation of the RH systems will take place from a fully remote control room located outside the nuclear buildings.

ITER is being constructed in Europe, at Cadarache in the South of France (see [www.iter.org](http://www.iter.org) for an overview of the ITER project). The ITER Organization (IO) is the nuclear operator, complying with the relevant French Laws and regulations, authorization, codes and standards applied to Basic Nuclear Installation (INB). IO is responsible for integrating the activities from the early stage of design, to the procurement, the assembly, commissioning and operation. Further background information is provide in Annex A.



## 4 Tendering Information

### 4.1 Required Capability and Experience

The company or consortia of companies selected shall be recognised for their capability and experience in providing Telemanipulator Systems for use in nuclear environments. Some of the criteria important for the selection will be:

- Established product line for telemanipulator systems,
- Telemanipulator product that is proven to be highly dextrous for carrying out a wide range of remote maintenance tasks,
- Ability to provide customization of the standard product to meet ITER constraints (notably reach, payload, stowage space),
- Ability to customize the control system to be compatible with the ITER distributed architectural needs,
- Extensive track record of deploying telemanipulator arms in nuclear facilities,
- Proven radiation tolerance of manipulator up to 1MGy,
- Proven reliability of manipulator under real working conditions,
- Design that allows for high level of decontamination of the manipulator arms,
- Compatibility with deployment and operation in a clean environment (no leakage of oil/grease, flakes of paint, etc).

### 4.2 Quality requirements

The ITER Quality class of the Telemanipulator System is QC2. The Contractor or Consortium members shall all have an ISO 9001:2015 certified quality system or alternatively a QA Program approved by the QARO.

If a Consortium quality plan is issued for IO approval, this should clearly state who is the consortium leader with consensus of all members that they shall follow this quality plan.

### 4.3 Safety requirements

The Telemanipulator System is classified at ITER as Safety Relevant (SR). No specific safety requirement related to PIC and/or PIA and/or PE/NPE components apply.

### 4.4 Candidature

Participation is open to all legal persons participating either individually or in a grouping (consortium) which is established in an ITER Member State. A legal person cannot participate individually or as a consortium partner in more than one application or tender. A consortium may be a permanent, legally-established grouping or a grouping, which has been constituted informally for a specific tender procedure. All members of a consortium (i.e. the leader and all other members) are jointly and severally liable to the ITER Organization. The consortium cannot be modified later without the approval of the ITER Organization.



The groupings shall be presented at the pre-qualification (PQ) stage. The consortium cannot be modified later without the approval of the ITER Organization after the pre-qualification.

Legal entities belonging to the same legal grouping are allowed to participate separately if they are able to demonstrate independent technical and financial capacities. Bidders' (individual or consortium) must comply with the selection criteria to be clarified at the PQ stage. IO reserves the right to disregard duplicated references and may exclude such legal entities from the tender procedure.

**Special attention:**

**In addition to the nomination (candidate list) submitted by each Domestic Agency to the IO,**

**Interested tenderers are kindly requested to register in the IO Ariba e-procurement tool called "IPROC". You can find all links to proceed along with instruction going to: <https://www.iter.org/fr/proc/overview>.**

**When registering in Ariba (IPROC), suppliers are kindly requested to nominate at least one contact person. This contact person will be receiving the notification.**

## 4.5 Reference

Further information on the ITER Organization procurement can be found at: <http://www.iter.org/org/team/adm/proc/overview>

## 5 Timetable

The duration of the contract is estimated to be 20 months from the signature date. The tentative timetable for setting up the contract is as follows:

- Call for Nomination            November 2023
- Pre-qualification                January 2024
- Call for Tender                 March 2024
- Award of Contract             July 2024
- Completion of Contract      March 2026

## 6 RH Telemanipulator System Summary Specification

### 6.1 Telemanipulator System

The Telemanipulator System shall consist of a two arm haptic master unit controlling a remote two arm slave unit.

The Telemanipulator System master and slave shall be physically separate units with control cabinets that communicate over a digital network.

The Telemanipulator System shall be configured and tuned to allow man-in-the-loop dextrous handling with force reflecting capability to the operator.

The Telemanipulator System shall have suitable safety controls to ensure safe operations.

The Telemanipulator System shall be issued with a certificate of inclusion for CE marking.

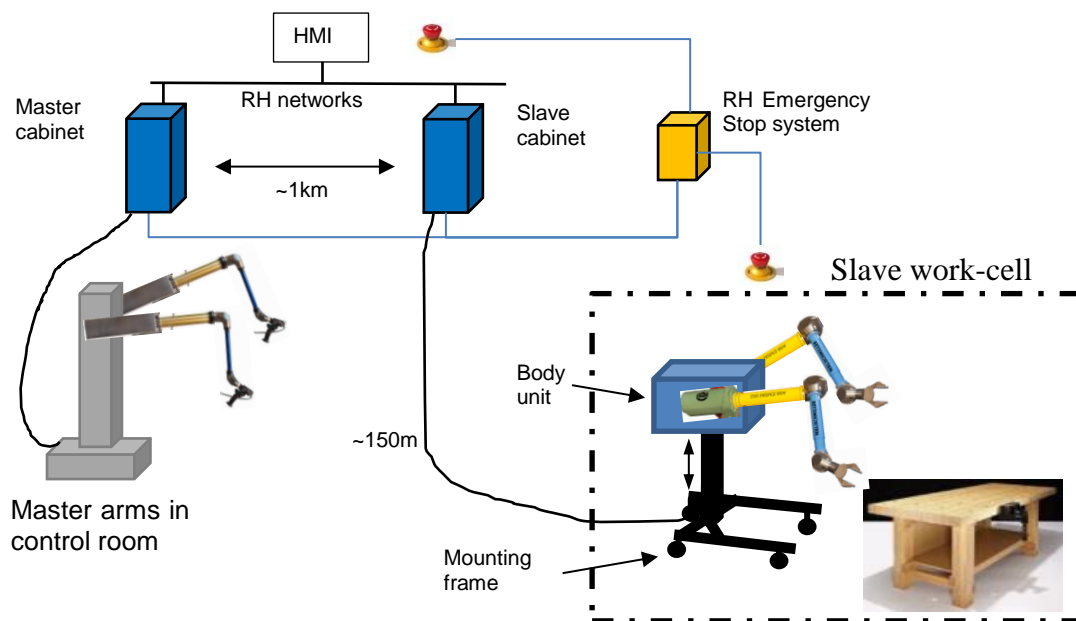


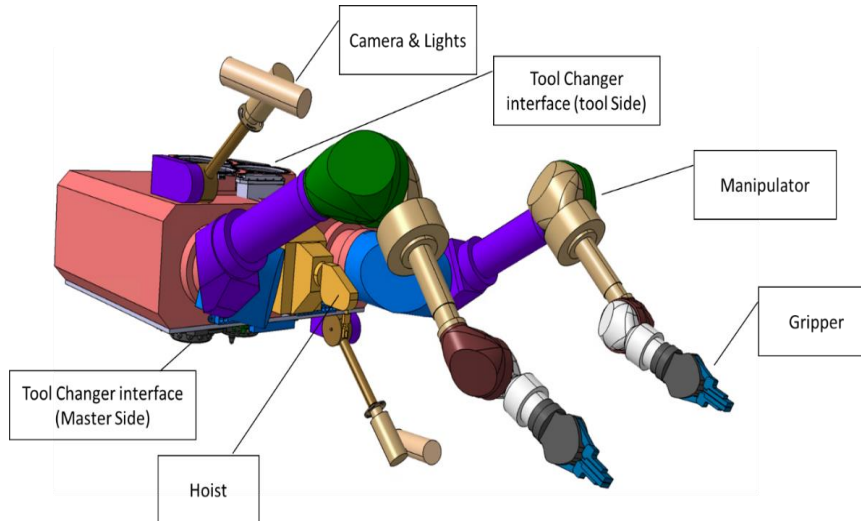
Figure 1. Schematic of an electrical master-slave telemanipulator system

### 6.2 Slave Manipulator Unit

The slave manipulator unit shall consist of two manipulator arms connected to a body unit.

The body unit shall allow the fitting of additional elements **not in the scope** of the procurement:

- Tool changer interfaces on top and bottom of body unit,
- Camera arms on top and bottom of body unit,
- Tooling connector on bottom of body unit,
- Hoist arm on front of body unit.



**Figure 2. Concept of the ART Manipulator**

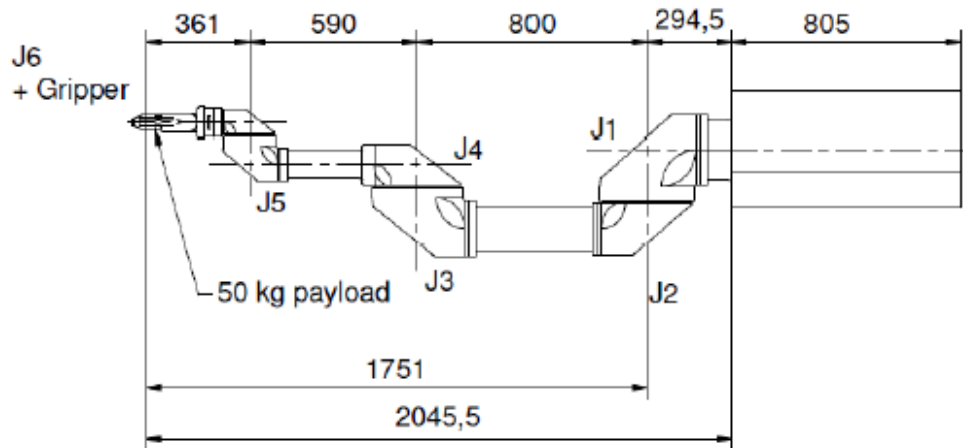
The slave manipulator arms shall have 6 degrees of freedom (excl. grippers), 50kg payload capacity, and the bespoke dimensions as shown in the drawing below.

The slave manipulator arm workspace shall envelope a 1m sided cube.

The slave manipulator arms shall have grippers consistent with the handling of 50kg payloads.

The slave manipulator shall require electrical power only.

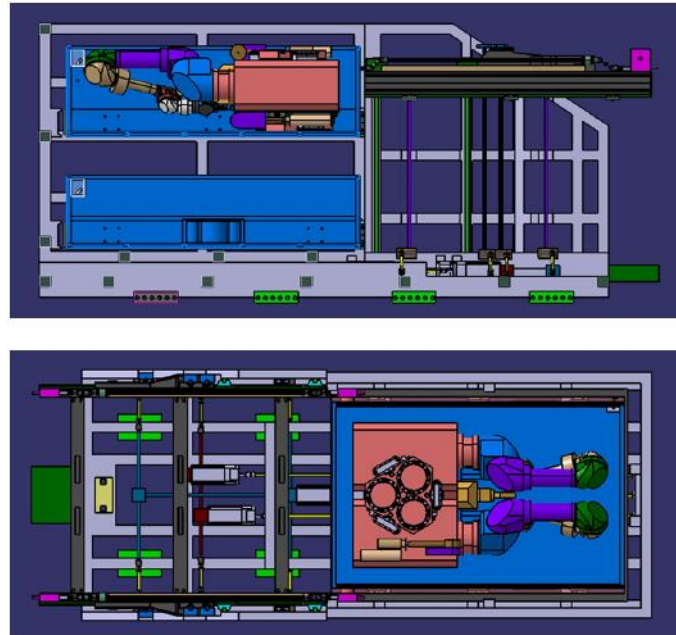
The slave manipulator arms shall provide means for rescue in case of single point failure.



**Figure 3. Required dimensions for the ART manipulator arms**

The slave manipulator unit shall be capable of being folded to fit within the ART end-effector transfer trolley drawers (Internal LxWxH = 2000x1200x650mm).

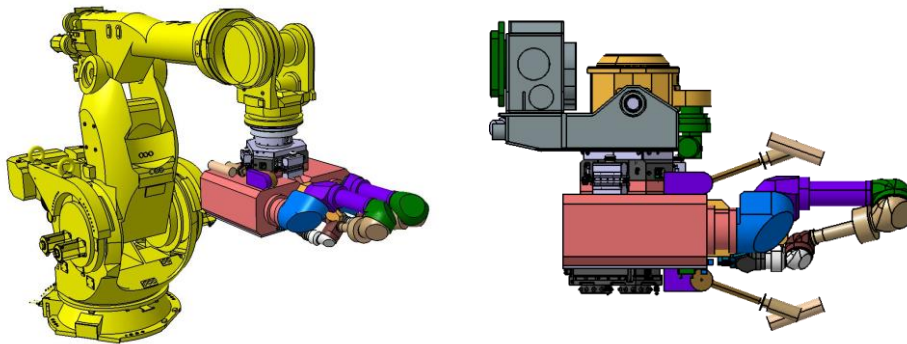




**Figure 4. Schematic showing the slave manipulator unit in an ART transfer trolley drawer**

The slave manipulator shall be delivered to IO with a mounting frame (not shown) suitable for initial operation and bench trials.

The slave manipulator structural design shall allow the future IO operating scenarios whereby the manipulator is handled and positioned by transport devices (industrial robotic transporter, Agile Robot Transporter (ART)).



**Figure 5. Manipulator unit positioned by Transporter devices**

### 6.3 Master Manipulator Unit

The Telemanipulator haptic master unit shall consist of two haptic arms on a mounting frame.

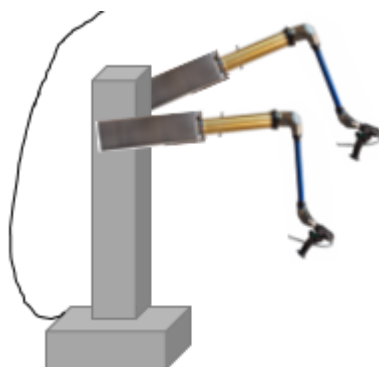
The master arms shall provide for man-in-loop positioning of the slave arms.

The master arms shall provide force-feedback from the slave arms physical interactions with their environment to the operator.

The master arms shall have control over the slave arm gripping function.

The master arms shall be kinematically similar to the slave arms to allow whole arm control by the operator.

The master unit shall be configurable for a seated or standing operator.



**Figure 6. Schematic of Telem manipulator master unit**

## 6.4 Control System

The Telem manipulator shall provide bilateral master/slave control.

The Master and Slave units shall have separate control cabinets that communicate over digital network fibres.

It shall be possible to separate the Master and Slave cabinets by up to 1km as a minimum.

The Slave arms shall stop motion and hold load in the event of a power cut.

The Slave arms shall be able to be restarted without homing operation after power shutdown.

The control system shall provide the following functions as a minimum:

- Man-in-loop positioning control of slave arms with force-feedback,
- Indexing function to allow re-positioning of master arm to comfortable position,
- Operation of the slave arm in robotic mode (playback of defined positions or motions),
- Operation of the slave arm in either joint mode or Cartesian mode,
- Selection of the Tool Control Point in Cartesian mode,
- Control over the gripping function,
- Adjustment of master-slave force ratio,
- Adjustment of master-slave position ratio,
- Ability to constrain operator defined degrees of freedom,
- Weight compensation of self-weight and tools.

## 6.5 Telem manipulator Parameters

The ability for a telem manipulator to perform remote maintenance tasks is difficult to capture in a set of performance parameters. A basic set of telem manipulator requirements is recorded in table 1.

Basic Requirement	Parameter
Kinematics	Min. 6 degrees of freedom plus gripper
Radiation hardness	Min. 1 MGy

Environment conditions	Between 20°C and 50°C, Relative humidity up to 60% Residual magnetic field up to 1mT
Power source	Electrical
Distance between master and slave	Up to 1 km
Communication between master and slave	LAN
Force reflecting	Essential
Reach	Minimum of 2m
Payload per arm (centre of gripper)	50kg
Stowage space for the integrated Dual Arm Manipulator	2000 x 1200 x 650mm
Maximum weight of the integrated two Arm Manipulators on their supporting structure, excluding ancillary systems (Payloads, Camera arms, Tool Changers (male+ female), RH Tool connectors, hoist)	1200Kg
Decontaminability	High (sealed against contamination ingress) Grippers remotely removable
Tip maximum velocity	Up to 1 m/s
Force sensitivity	< 5kg
Teach-and-repeat function	Essential < 1mm repeatability error on path
Master arm max force	6kg
Master workspace	Min $\phi$ 0.5m sphere

**Table 1. Indicative Basic Telemanipulator performance parameters**

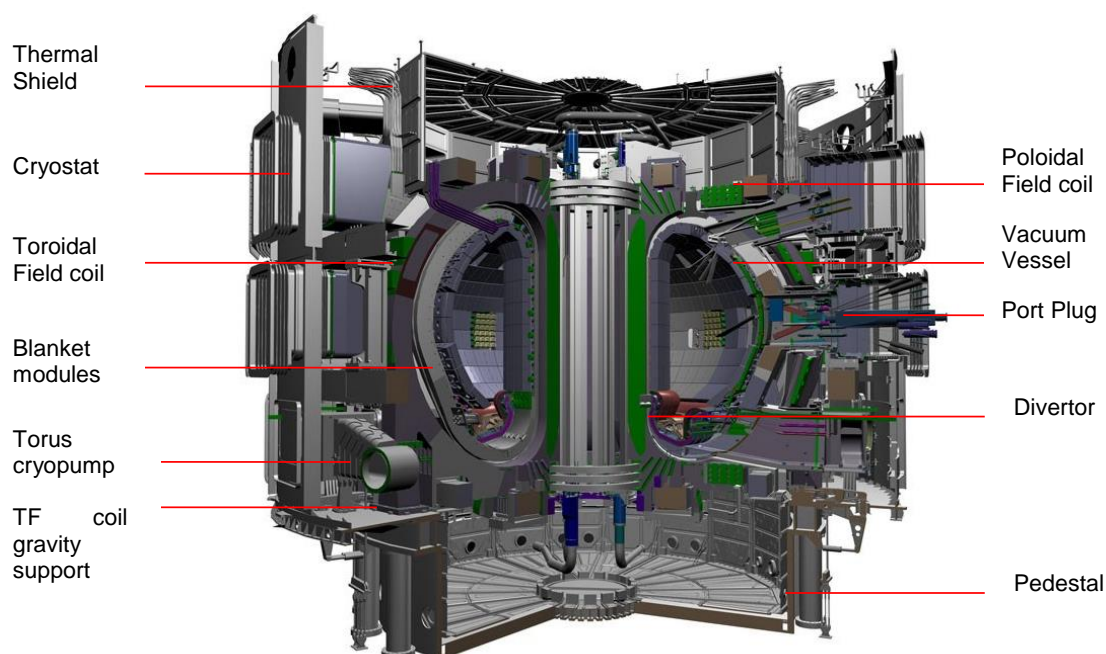
## 7 Annex A – Background Information

### 7.1 The ITER Project

ITER is a large-scale scientific experiment intended to prove the viability of nuclear fusion as an energy source, and to collect the data necessary for the design and subsequent operation of the first electricity-producing fusion power plant.

The ITER Agreement was signed by **China**, the **European Union**, **India**, **Japan**, **Korea**, **Russia** and the **United States**. The Members of the ITER Organization will bear the cost of the project through its construction phase and its operational phase before decommissioning.

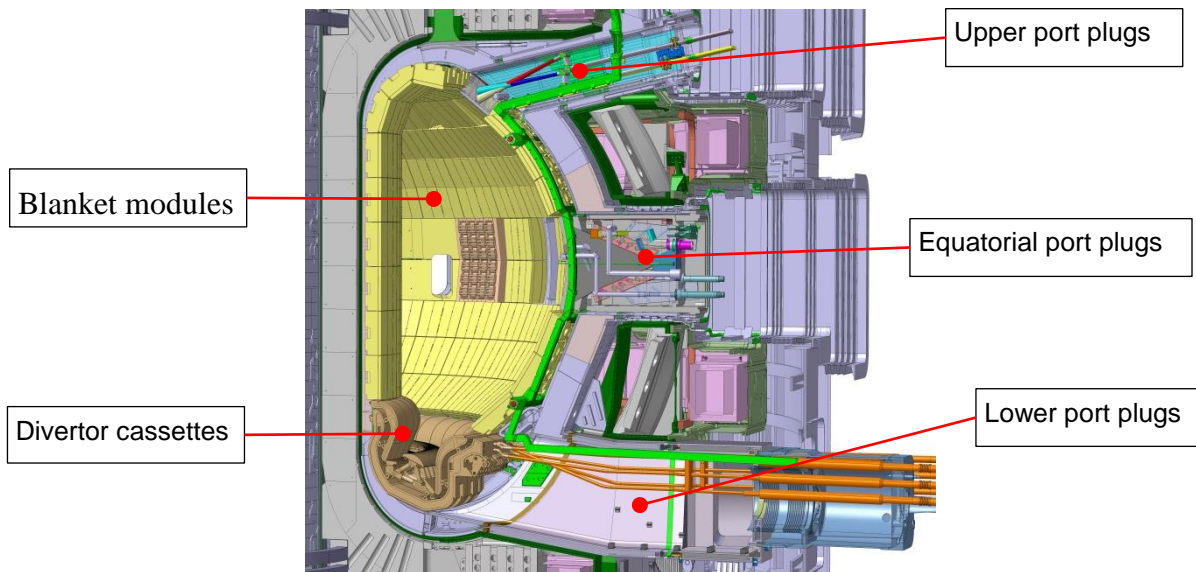
ITER is being constructed in Europe, at Cadarache in the South of France (see [www.iter.org](http://www.iter.org) for an overview of the ITER project).



**Figure 7. The ITER machine and selected components**

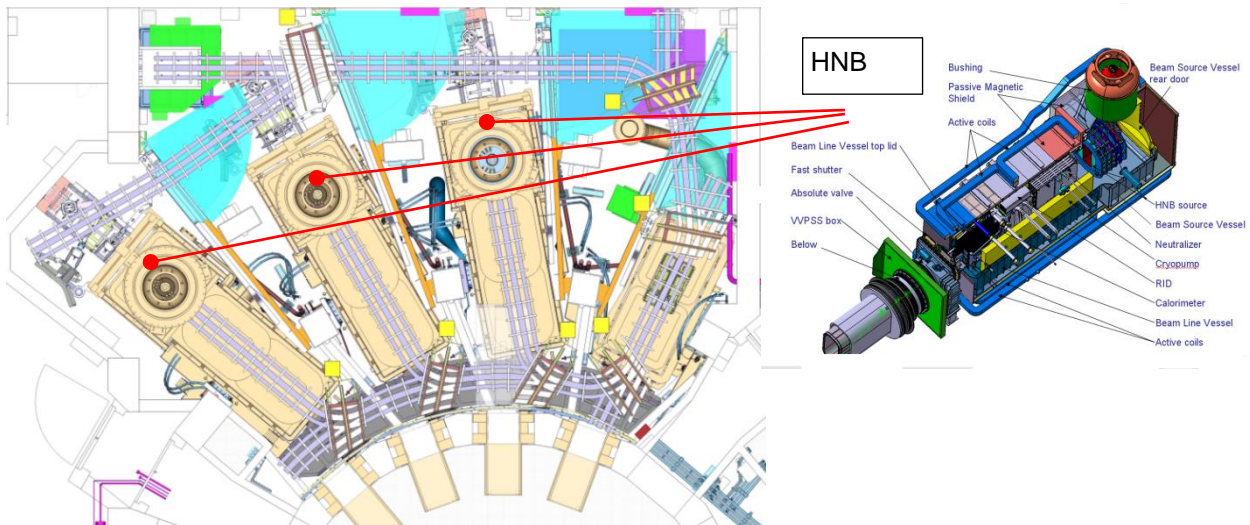
Once plasma operations have begun, the in-vessel environment will become a highly hazardous environment prohibiting human access, and the in-vessel maintenance tasks will be carried out fully remotely using remote handling systems. Some of the maintenance tasks will be carried out in-situ, but many will be done by removing the components to the Hot-Cell and carrying out the maintenance there. The list of in-vessel maintenance tasks includes, but is not limited to:-

- Replacement of Blanket first wall panels and shield modules,
- Replacement of Divertor cassettes,
- Upper level port plug maintenance,
- Equatorial level port plug maintenance,
- Lower level port plug (cryopump, In-vessel viewing system) maintenance
- Diagnostic rack maintenance
- Vacuum vessel in-service inspection,
- Dust sampling and removal,
- Leak localization,
- Diagnostic calibration.



**Figure 8. Identification of some in-vessel components requiring maintenance**

On the north side of the vacuum vessel, the Neutral Beam (NB) Cell contains multiple NB injector systems. The maintenance of these systems and other equipment in the NB Cell will also require the use of remote handling systems.



**Figure 9. Identification of some NB Cell components requiring maintenance**

## 7.2 ITER Remote Handling System

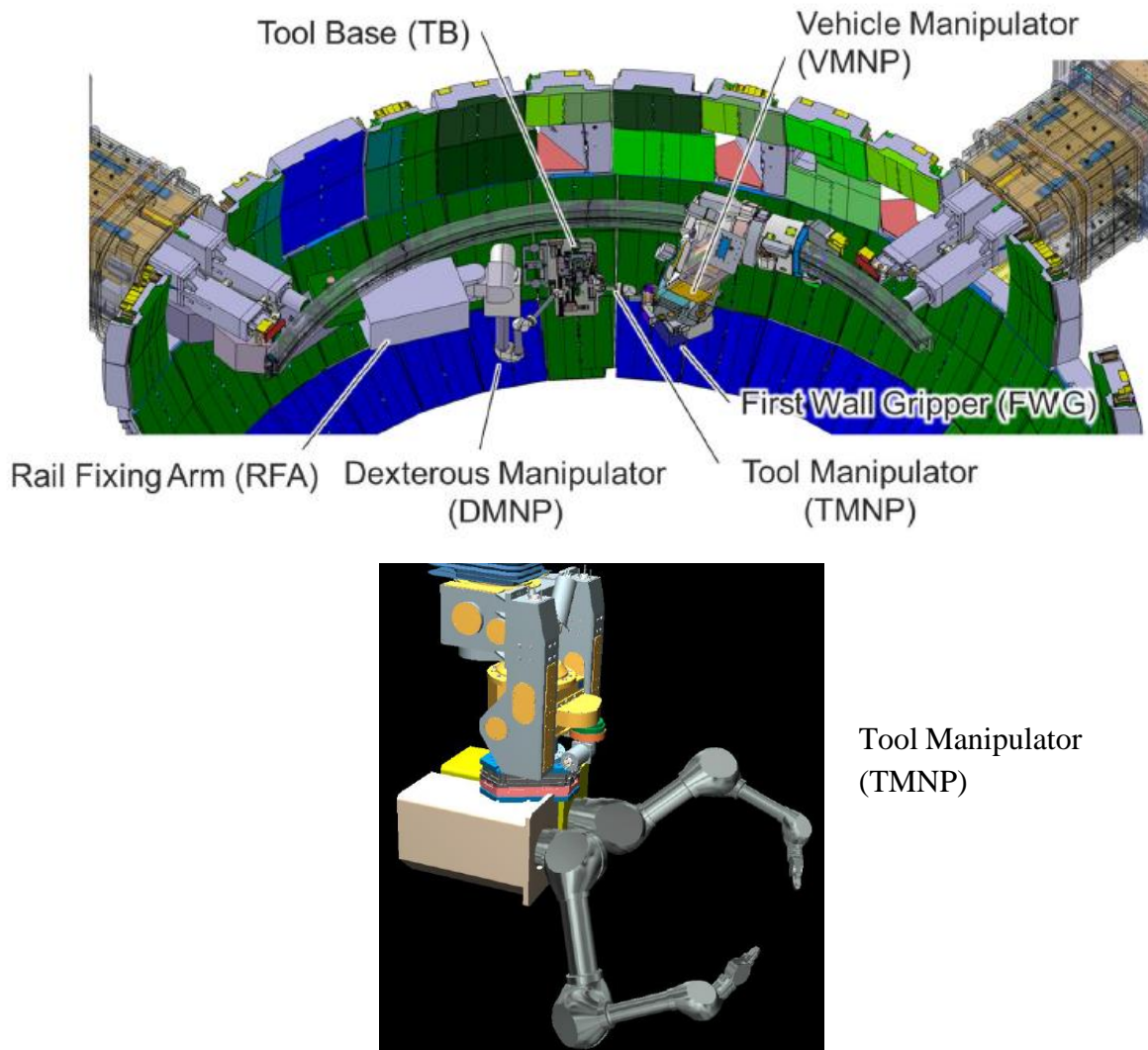
The ITER in-vessel RH System is made up of several sub-systems that have manipulator requirements:

- Blanket RH System: Targets the maintenance of the ITER blanket system,
- Divertor RH System: Target the maintenance of the ITER divertor system,
- NB Cell RH System: Targets the maintenance of the systems in the NB Cell,
- ART RH System: Multi-purpose in-vessel RH system – diagnostic calibration,

The procurement of the ITER RH System involves 3 parties: the ITER Organization, the European Domestic Agency (F4E), and the Japanese Domestic Agency.

### 7.2.1 Blanket RH System

The Blanket RH System (BRHS) is used for the in-vessel replacement of the Blanket first wall and shield block modules. The Tool Manipulator sub-system is a dual arm manipulator that is transported inside the vessel by the Vehicle Manipulator.

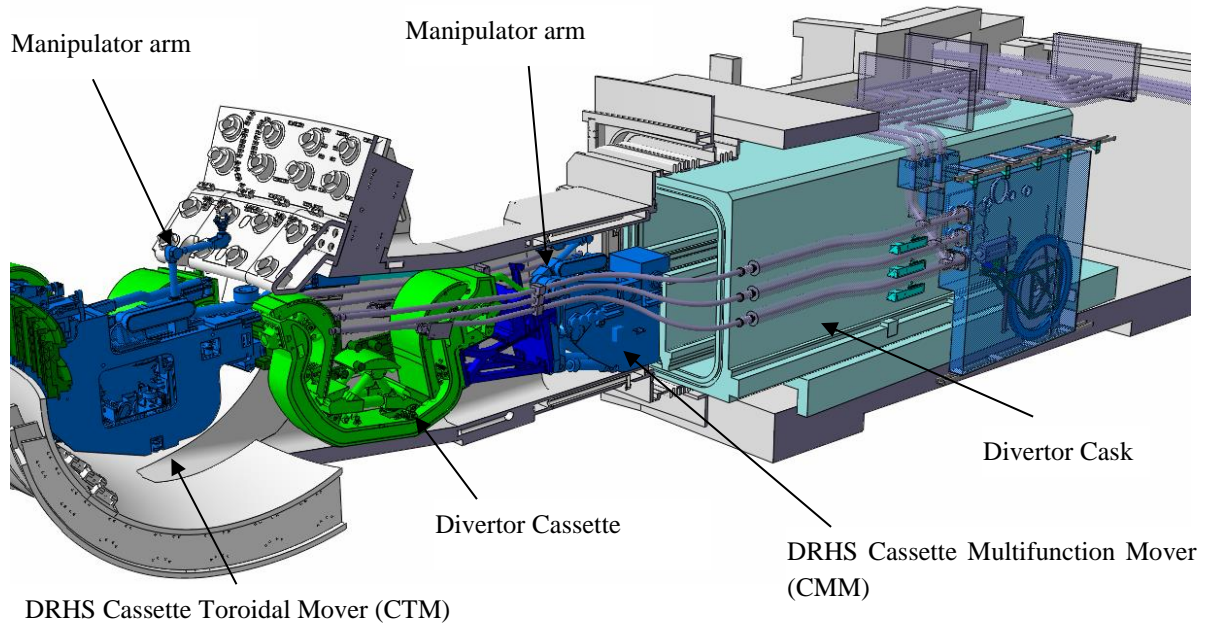


**Figure 10. Overview of the Blanket RH System**

### 7.2.2 Divertor RH System

The Divertor RH System (DRHS) is used to replace Divertor cassettes at the bottom of the Vacuum Vessel. The DRHS has two cassette mover sub-systems, each requiring an integrated manipulator arm:

- Cassette Multifunction Mover ( CMM),
- Cassette Toroidal Mover (CTM).

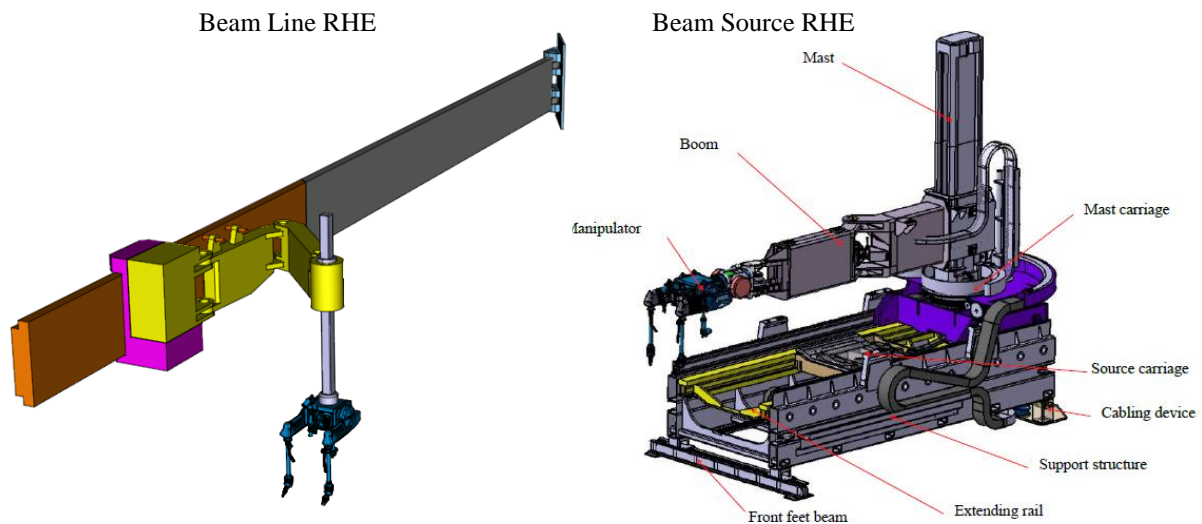


**Figure 11. Overview of the Divertor RH System**

### 7.2.3 NB Cell RH System

The NB Cell RH System (NBRHS) is used to perform numerous remote maintenance tasks on the NB injectors and other system in the NB Cell. Two of the NBRHS sub-systems are designed to deploy a dual-arm telemanipulator:

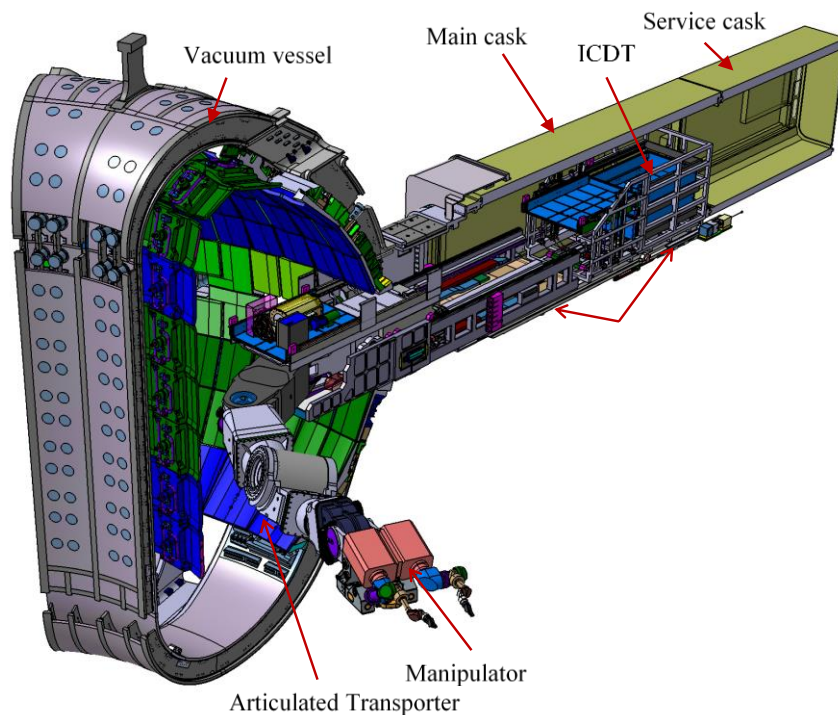
- Beam Line RH equipment,
- Beam Source RH equipment.



**Figure 12. Some elements of the NB Cell RH System**

### 7.2.4 Agile Robot Transporter

The Agile Robot Transporter system (ART) provides a generic capability for carrying out inspection and light maintenance tasks inside the vessel. Diagnostic calibration and dust removal are some of the tasks to be performed by the ART.



**Figure 13. Overview of ART system with Manipulator as End-Effector**

## 7.3 Telemanipulation at ITER

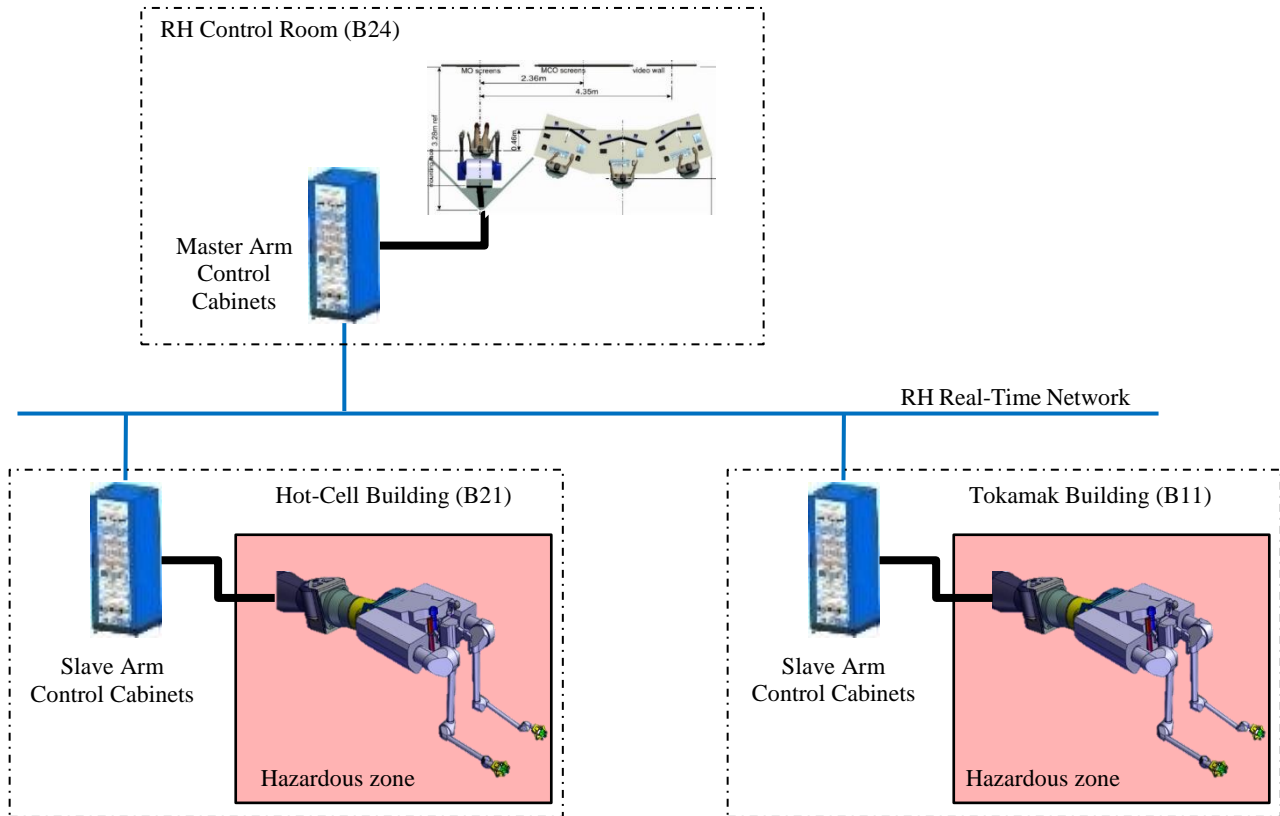
### 7.3.1 Control System

The Telemanipulator is the key RH tool for carrying out dextrous operations in a remote environment. At ITER the remote environments are spread over the Tokamak building (B11) and the Hot-Cell building (B21), and the control is from a fully remote control room in the Personnel Access Control Building (B24). The ITER Telemanipulator system is, therefore, an electrically linked master-slave device rather than a mechanically linked master-slave device.

The ITER Project has multiple potential remote maintenance activities at many different locations in the nuclear buildings, and the ITER RH System will contain a large set of devices to have the capability to perform these tasks. For any one shutdown campaign, only a sub-set of the maintenance activities will be needed, and only a sub-set of the RH System will be deployed. The RH System and RH Control Room need to have the flexibility to be configured to operate the required sub-set of the RH System needed for a specific ITER maintenance shutdown. Specifically, this means that the RH Control Room will have standardized work-cells, with standard hardware, that can be configured to operate any of the RH sub-systems.

The figure below shows the required distributed control system architecture in simplified form. The only communication between the different ITER buildings is through digital networks. The overall system will contain multiple master and slave devices. The ITER RH System will require a range of slave manipulators as each RH sub-system can have specific requirements in terms of space, kinematics, reach, load capacity. In the RH control room, however, it is highly desirable to have a standard master arm device.



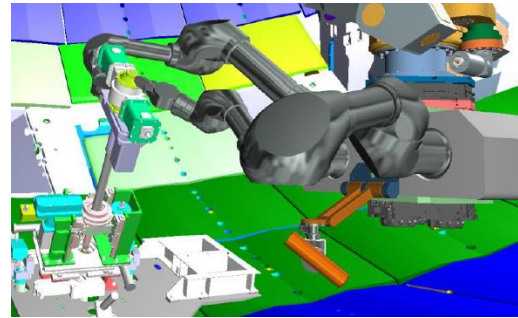


**Figure 14. Distributed architecture for the ITER RH Telemanipulator system**

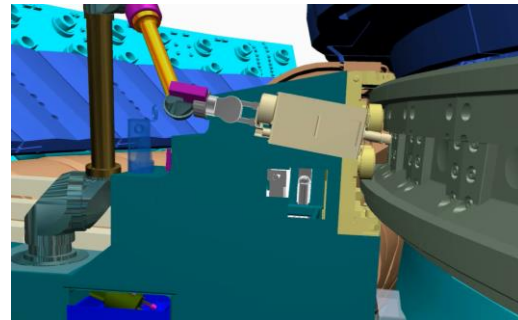
### 7.3.2 Operations

The general objective of the Telemanipulator system is to provide human maintenance capabilities in the remote hazardous environment. The man-in-loop operation allows for a wide capability and flexibility for doing maintenance tasks and coping with variations in the task conditions. Typically a ‘transporter’ device will position the telemanipulator close to the maintenance task and the force-feedback telemanipulation system, together with a remote viewing system is used by the operator to perform tasks requiring interaction with the remote environment. The positioning of the telemanipulator does not need to be very precise since the operator can perform the tasks based on the relative positioning of the manipulator to the task. In some cases, automated motions may be used once a datum is established.

BRHS Tool manipulator deployment and operation



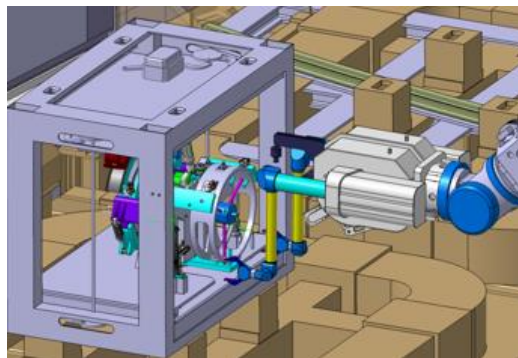
DRHS manipulator tool deployment and operation



First Wall sample removal using ART manipulator



NBRHS tool deployment and operation on VVPSS



**Figure 15. Sample manipulator operation tasks**

The ITER RH manipulators should be considered as general operation tools that can be used for a wide range of tasks. While the main tasks can be identified now, the details will evolve as the operations and handling tools are developed, and this is a continuous process. The selection criteria will consider some specific parameters such as radiation hardness, stowage space, reach, and load capacity, and will then focus on achieving good telepresence and operational performance for undertaking general RH compatible tasks.