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Report

Market Survey - RH Telemanipulator Summary Specification

Background information and outline of IO/RH Telemanipulator specification in support of a Market Survey

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Table of Contents

1 PURPOSE ... 3

2 SCOPE OF FRAMEWORK CONTRACT ... 3

3 BACKGROUND INFORMATION ... 4

3.1 THE ITER PROJECT ... 4

3.2 ITER REMOTE HANDLING SYSTEM ... 6

3.2.1 Blanket RH System ... 6

3.2.2 Divertor RH System ... 6

3.2.3 NB Cell RH System ... 7

3.2.4 Agile Robot Transporter ... 8

3.2.5 Cask and Plug RH System ... 8

3.3 TELEMANIPULATION AT ITER ... 9

3.3.1 Control System ... 9

3.3.2 Operations ... 10

4 RH TELEMANIPULATOR SPECIFICATION ... 11

5 FRAMEWORK SCHEME ... 13

5.1 FRAMEWORK CONTRACT ... 13

5.2 SCHEDULE OUTLINE ... 14

Abbreviations and Acronyms

ART	Agile Robot Transporter
BRHS	Blanket RH System
CMM	Cassette Multifunction Mover
COTS	Commercial Off The Shelf
CTM	Cassette Toroidal Mover
DA	Domestic Agency
DNB	Diagnostic Neutral Beam
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
RH	Remote Handling
Gy	Gray

1 Purpose

The purpose of this document is to provide general information to the Market Survey.

The ITER Organization aims to place a new framework contract to supply Remote Handling (RH) Telemanipulator's for the ITER Project. The following sections explain the current planning of the ITER project. The contents are not binding and they may be subject to change.

2 Scope of Framework Contract

The scope of the framework contract would be to provide Telemanipulator solutions and associated services for the different Remote Handling sub-system needs on the ITER Project:

- Supply of Telemanipulator Systems & Equipment
  - Supply of Telemanipulator master arm devices,
  - Supply of Telemanipulator slave arm devices (multiple configurations),
  - Supply of Telemanipulator support body/frames,
  - Supply of integrated Telemanipulator master-slave systems
    - Different slave arm configurations possible,
    - Bespoke body unit and support frames possible,
    - Control system compatible with integration with ITER/RH architecture.
- Supply of Telemanipulator Services
  - Supply of Telemanipulator research services,
    - Task studies, performance studies, new feature studies, platform migration studies
  - Supply of Telemanipulator development services,
    - Mechanical, hardware, & software feature development
  - Supply of Telemanipulator integration services,
    - Supply of interfacing and integration data/documents
    - Kinematic calibration of slave arms
    - Integration of Telemanipulator system into robotic work-cell
    - Upgrade of components of previously supplied Telemanipulator system

The scope of the framework would be to cover the Telemanipulator needs for the ITER in-vessel and NB Cell remote handling sub-systems, which are under the procurement responsibilities of both the IO and DAs.

The ITER Hot-Cell Telemanipulator needs are **not** considered to be in the scope of this framework.

3 Background Information

3.1 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 for an overview of the ITER project).

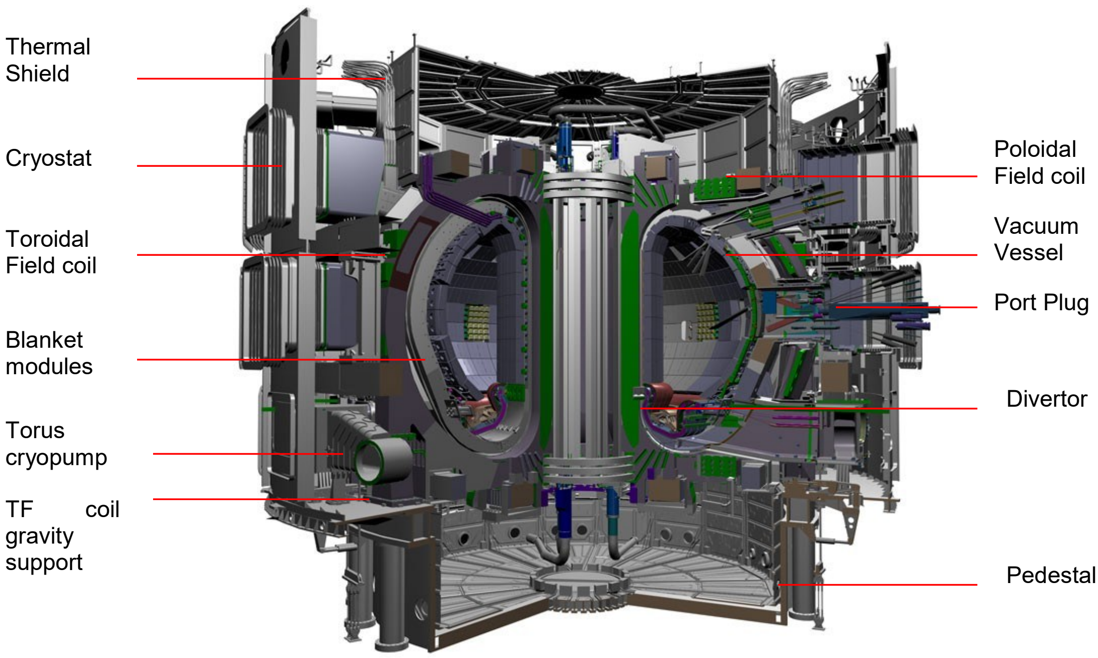


Figure 1. The ITER machine and selected components

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
- Replacement of NB duct liner,
- Diagnostic rack maintenance
- Vacuum vessel in-service inspection,
- Dust sampling and removal,
- Leak localization,
- Diagnostic calibration.

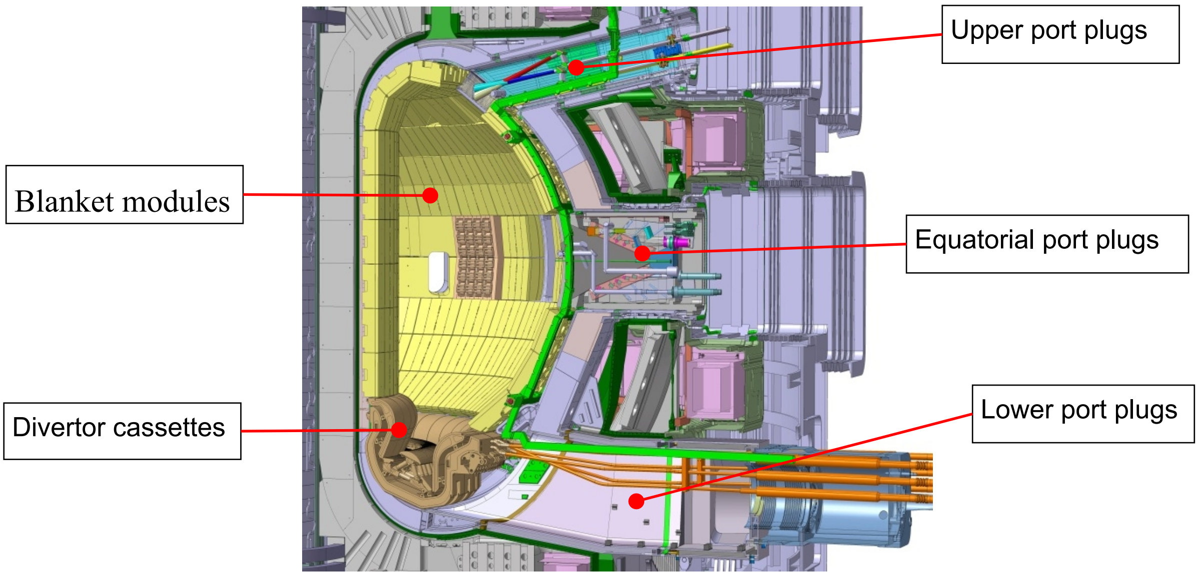


Figure 2. Identification of some in-vessel components requiring maintenance

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.

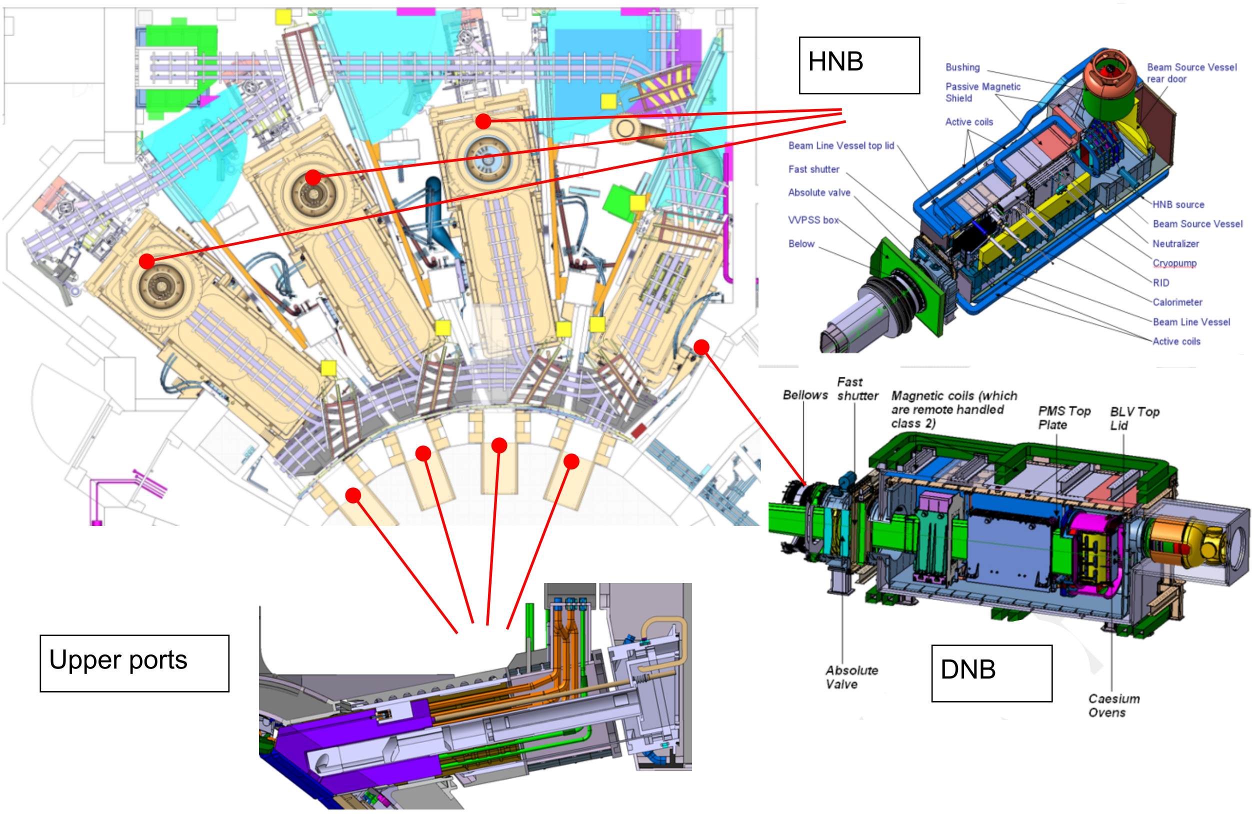


Figure 3. Identification of some NB Cell components requiring maintenance

3.2 ITER Remote Handling System

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

3.2.1 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.

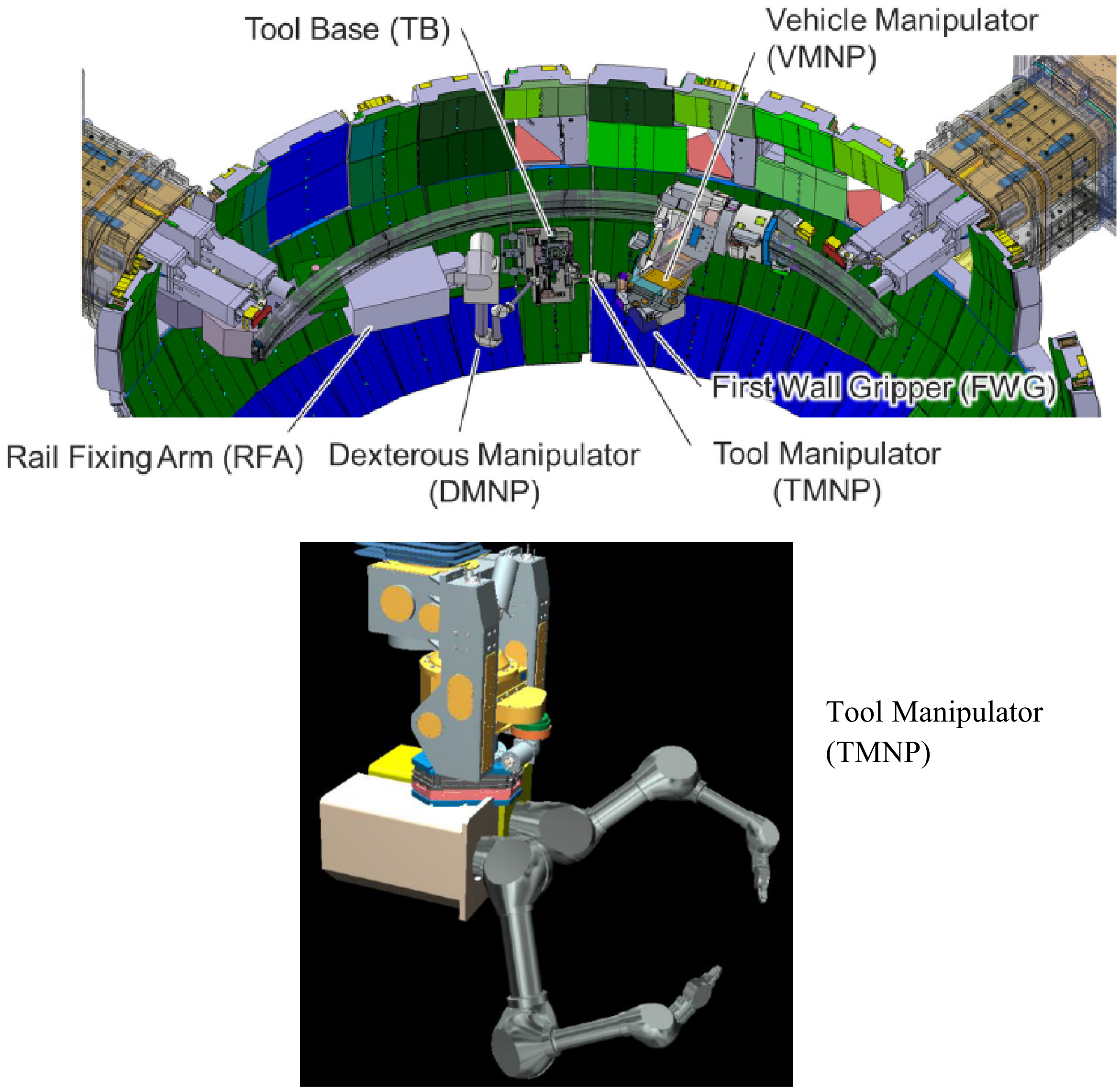


Figure 4. Overview of the Blanket RH System

3.2.2 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).

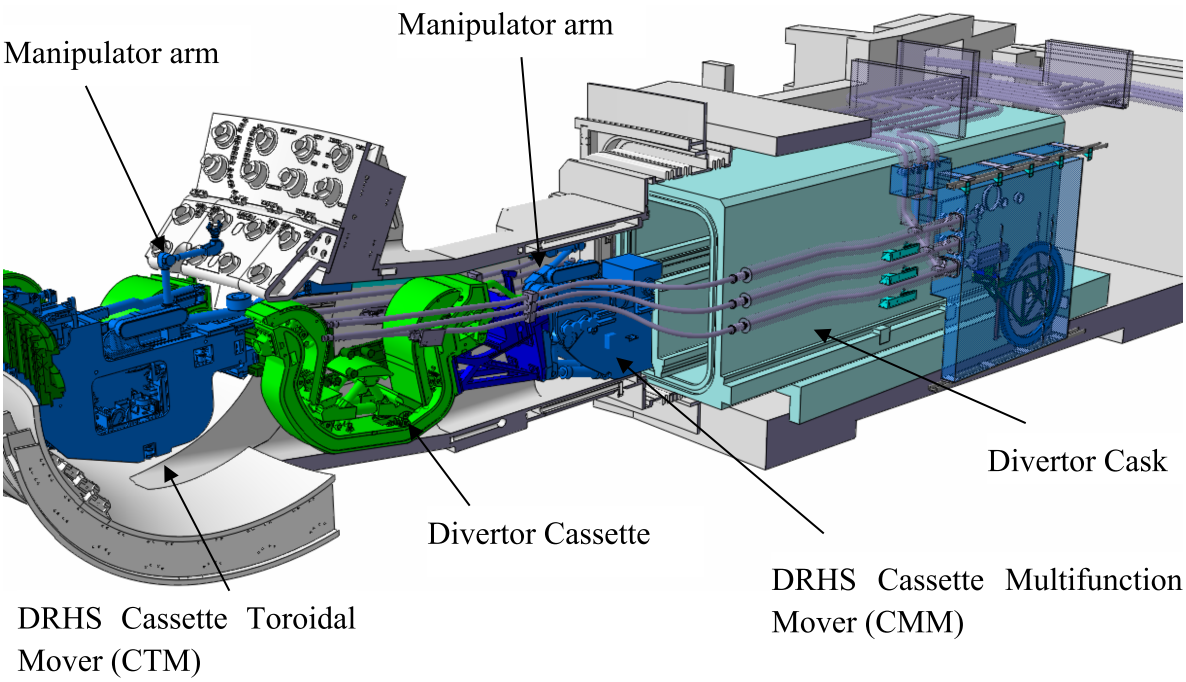


Figure 5. Overview of the Divrtor RH System

3.2.3 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.

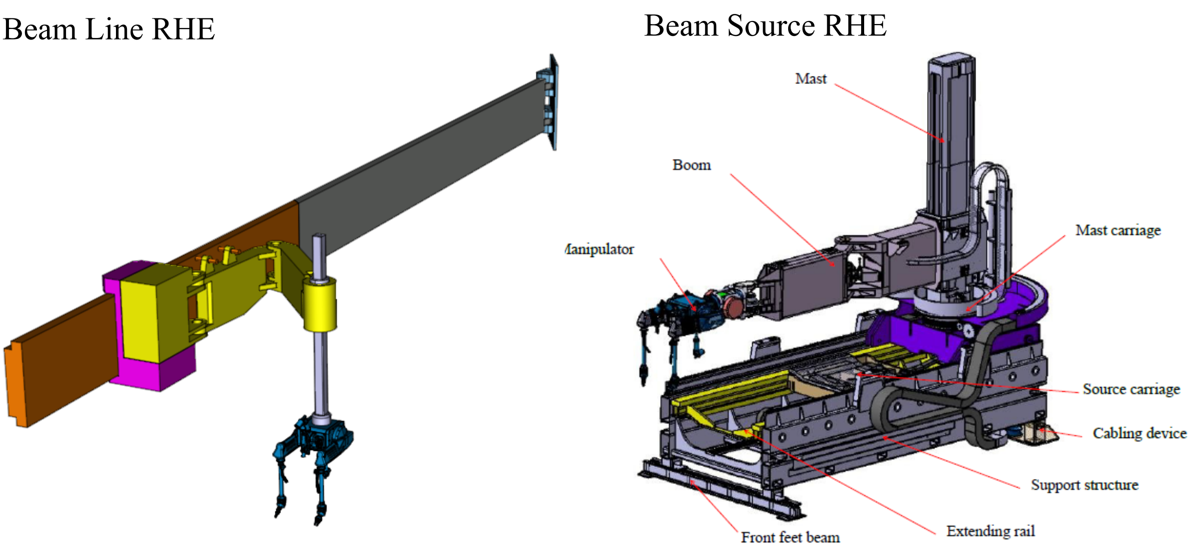


Figure 6. Some elements of the NB Cell RH System

3.2.4 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.

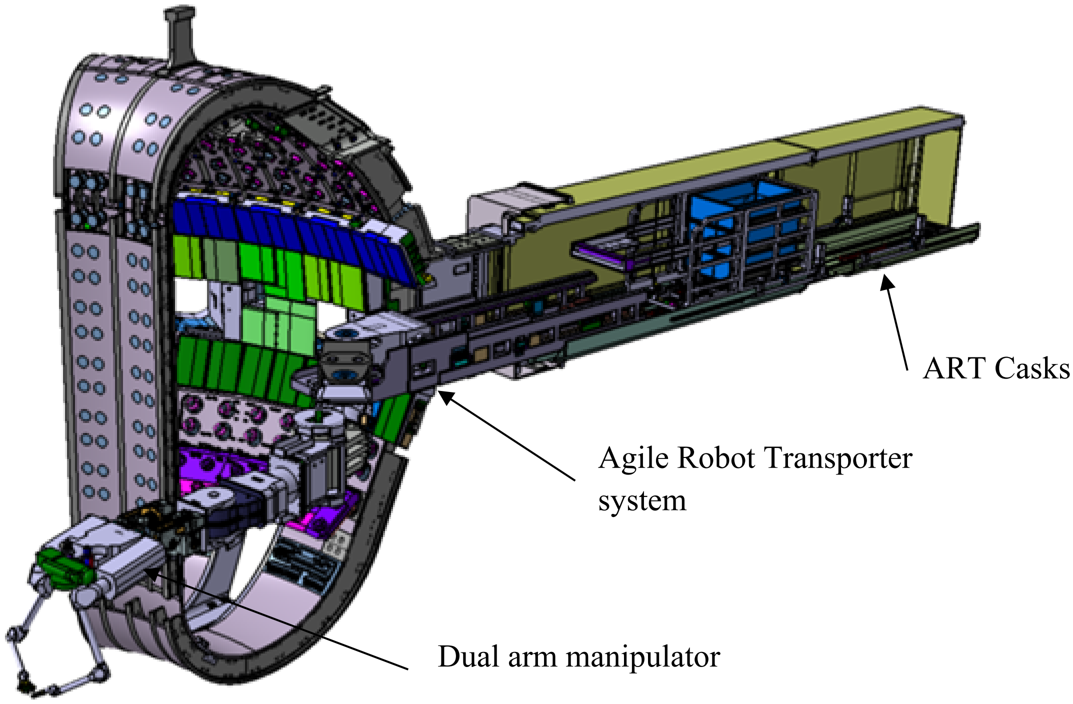


Figure 7. Overview of ART system

3.2.5 Cask and Plug RH System

The principle of the ITER in-vessel remote maintenance is to use a 'Cask' vehicle to transport RH equipment and in-vessel components between the vessel and the Hot-Cell. Maintenance of the component is then carried out in the Hot-Cell.

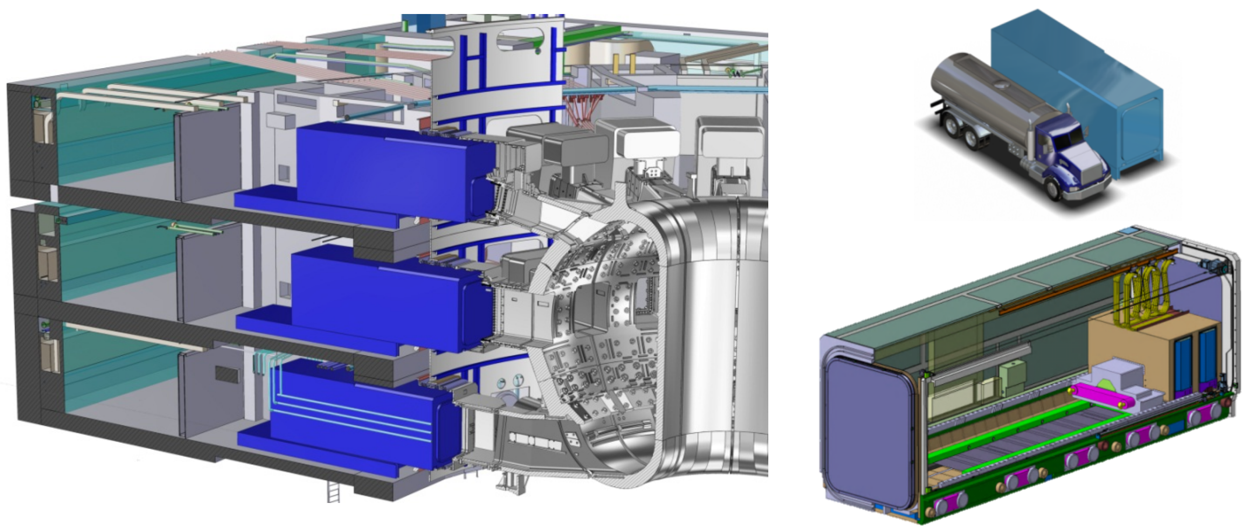


Figure 8. Overview of RH Cask system

3.3 Telemanipulation at ITER

3.3.1 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.

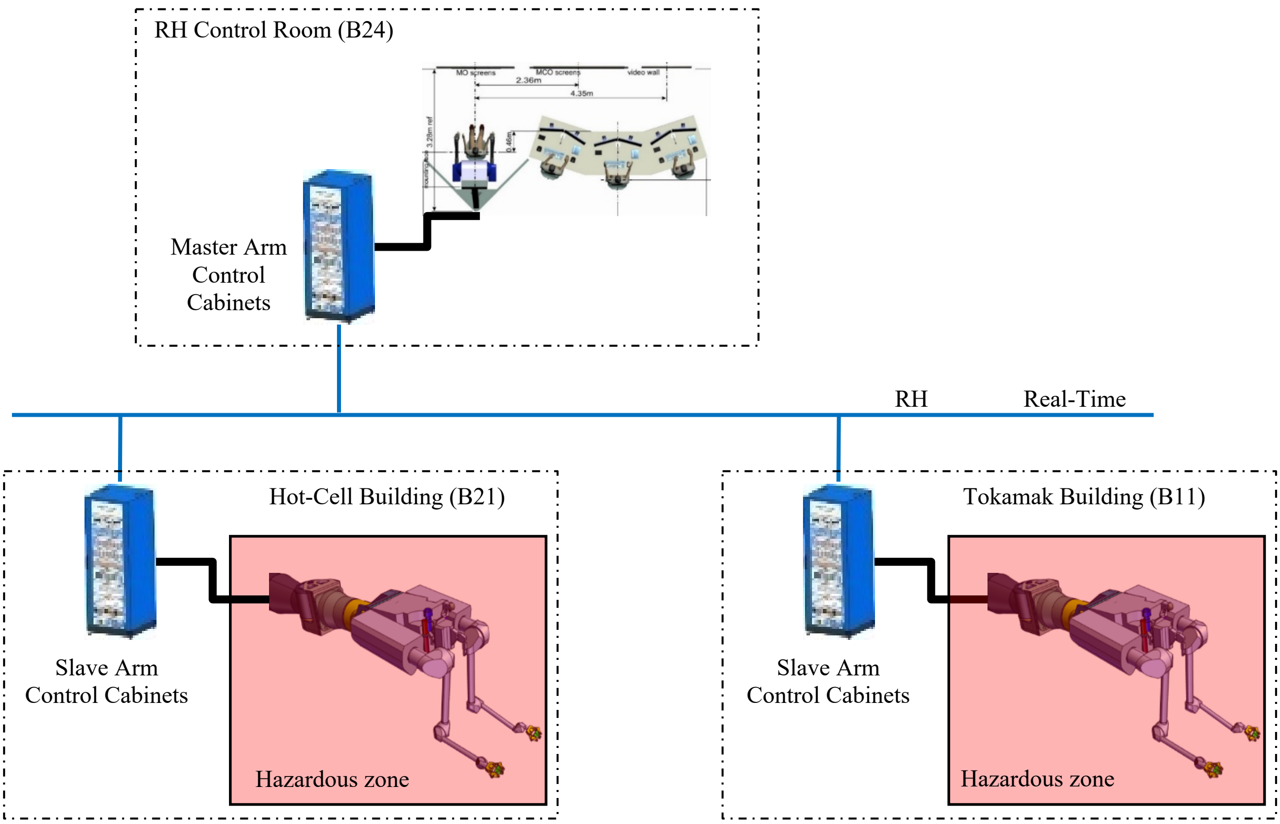
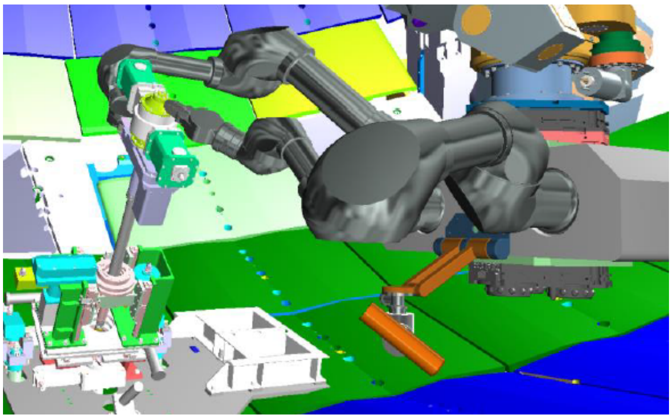


Figure 9. Distributed architecture for the ITER RH Telemanipulator system

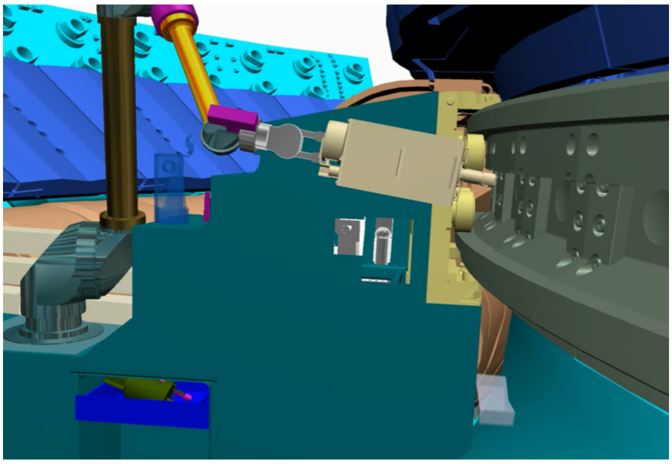
3.3.2 Operations

The general objective of the Telemanipulator system is to strive 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



NBRHS tool deployment and operation on VVPSS

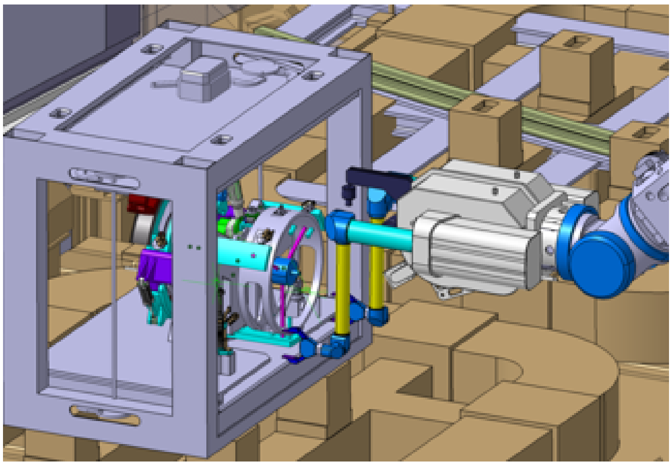


Figure 10. Sample manipulator operation tasks

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.

4 RH Telemanipulator Specification

The ability for a telemanipulator to perform remote maintenance tasks is difficult to capture in a set of performance parameters. A basic set of telemanipulator requirements is recorded in table 1, and a set of demonstration tasks is recorded in table 2. The Supplier and manipulator devices track record will also be an important part of the evaluation (table 3).

Basic Requirement	**Parameter**
Kinematics	Min. 6 degrees of freedom plus gripper
Radiation hardness	Min. 1 MGy
Power source	Electrical
Distance between master and slave	Up to 1 km
Communication between master and slave	LAN
Force reflecting	Essential
Reach	Up to 2.6m (application dependent)
Payload per arm (centre of gripper)	20kg to 75kg (application dependent)
Stowage space	Application dependent
Decontaminability	High
Tip maximum velocity	Min 0.75 m/s
Friction reflected to operator	Low
Reflected inertia	Low
Force sensitivity	< 1kg
Teach-and-repeat function	Essential - < 0.5mm repeatability error on path
Master arm integration	Can link to different slave devices
Master arm max force	1 to 6kg
Master workspace	Min ϕ0.5m sphere

Table 1. Indicative Basic Telemanipulator performance parameters

Demonstration Task	Required outcome
Pick and place throughout workspace	Tasks performed smoothly and without difficulty
Peg-in-hole tests	Peg is inserted and removed without difficulty without any scoring of its surface
Block insertion tasks	Block is inserted and removed without difficulty without any scoring of its surface
Force sensitivity test (threading M12 bolt)	The bolting operations are performed successfully without damaging the threads
M6 bolting test with ratchet tool	The bolting operations are performed successfully without damaging the threads
Electrical connector test	The connection operations are performed successfully without damaging the pins
Dextrous handling test (Jenga™ block game)	Pieces are successfully removed without toppling the stack
Controlled gripping tests (empty soda can)	The handling operations are performed successfully with minimal can distortion
Mobility tests across workspace	The telemanipulator system does not get stuck in any configurations

Table 2. Indicative Telemanipulator demonstration tasks

Track record	Response
Customized Telemanipulators based around COTS products	Product line description, Examples of delivered customised projects
Deployment in nuclear facilities	Extensive track record
Used for wide range of real world maintenance tasks	Yes
Proven operation up to 1MGy	Yes
Proven reliability under real working conditions	High MTBF
Positive endorsement from nuclear clients	Yes
Demonstration of decontamination to hands-on maintenance levels.	Yes
Ability to tailor product to client needs (link lengths, load capacity, interface plate)	Demonstrated through examples
Ability to provide bespoke support frames	Demonstrated through examples
Ability to adapt basic product to client needs	Yes

Table 3. Indicative real world experience criteria

5 Framework Scheme

5.1 Framework Contract

The concept of the Framework contract is to select the Supplier of the RH Telemanipulator solutions to the ITER parties.

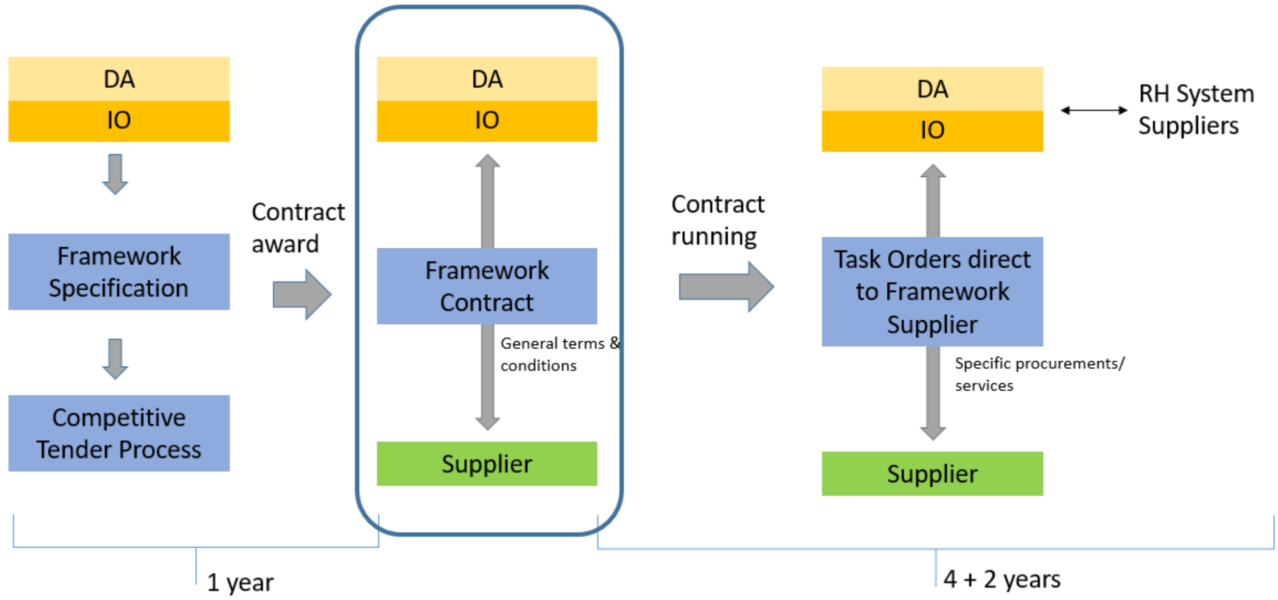


Figure 11. RH Manipulator Framework Scheme

The selection of the Supplier will be based on a set of detailed evaluation criteria established by the IO and DAs, and covering technical, schedule, and financial aspects.

The framework contract will establish general terms and conditions for the supply of equipment and services such as:

- Supply of Telemanipulator Systems & Equipment
    - Range of equipment types and configuration parameters covered by Framework
    - Specification of general technical requirements for equipment types
    - Specification of general procurement requirements
        - QA, CAD, documentation, certification
        - Acceptance testing
        - Shipping, installation
    - Costing formula for the COTS products
    - Costing formula for the bespoke products
    - Indicative list and schedule of the IO/DA supply needs covered by Framework
- Supply of Telemanipulator Services
    - Range of types of services covered by Framework
    - Breakdown of requirements/deliverables for types of services

- Specification of general rules for provision of services
- Rates for calculating cost of services
- Breakdown of cost of some sample services

Once the framework is signed, the ITER parties will use Task Orders to directly procure equipment/services from the Supplier, with additional specific requirements. In general, the supplied Telemanipulator equipment would then be integrated into the RH sub-systems being procured by the party.

The framework contract is expected to have a duration of 4 years, with an option to extend for an additional 2 years.

5.2 Schedule Outline

The framework contract is expected to cover the procurement of approximately 10 slave manipulator arms and related other equipment over a 6 year period. This figure is subject to optimization of the IO needs.

The framework contract also covers the supply of services, and it is expected that several development task orders would be placed to tailor the Telemanipulator solutions to the IO needs. These developments would then be integrated into the subsequent manipulator procurements.

An indicative outline schedule of Task Orders is shown in the figure below.

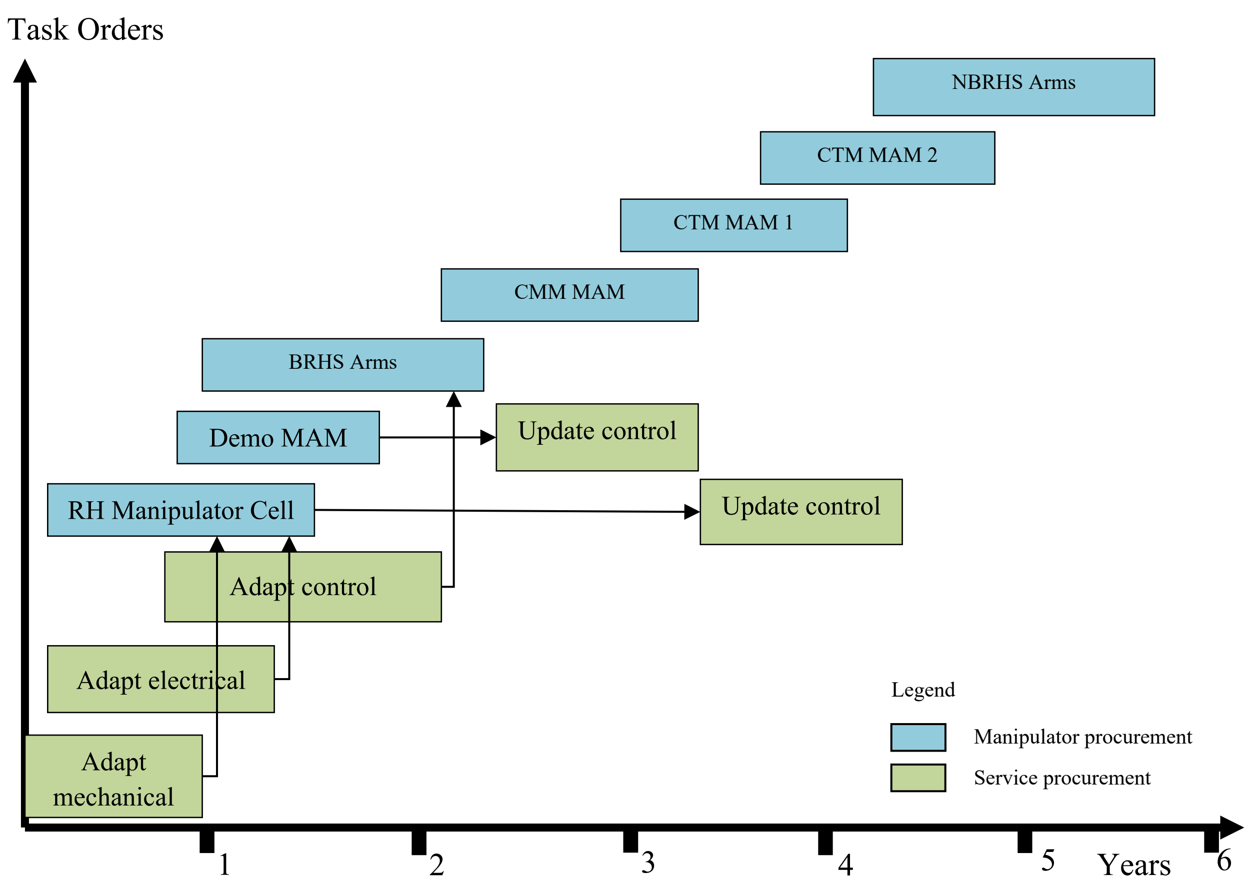


Figure 12. Indicative schedule of Task Orders