ITER Remote Handling: Overview and Technical Requirements

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Remote Handling Section, ITER

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Outlines

- ITER Remote Handling Strategy
- ITER RH Operation Scenario
- Blanket RH (PBS 23-1)
- Divertor RH (PBS 23-2)
- Transfer Cask and Port Plug (PBS 23-3)
- In-Vessel Viewing System (PBS 23-4)
- Neutral Beam System RH (PBS 23-5)
- Hot Cell RH (PBS 23-6)
- RH Test Facility (PBS 23-9)
- Multi-Purpose Deployer (DCR-130)
ITER Remote Handling Strategy
ITER Remote Handling

Tokamak

PBS-23-1
Blanket RH

PBS 23-2
Divertor RH

PBS 23-4
IVVS
1a) Move TCS from lift to port plug
1b) Install or removal of Tokamak component
1c) Move back to lift
2) Lift up or down
3) Move from lift to HCF port
## RH Classifications

<table>
<thead>
<tr>
<th>Class 1</th>
<th>Those components that require <strong>scheduled remote maintenance</strong> or replacement several times during the life of the machine.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class 2</td>
<td>Those components that do not require scheduled remote maintenance but are likely to require <strong>unscheduled</strong> and very infrequent remote <strong>maintenance</strong>.</td>
</tr>
<tr>
<td>Class 3</td>
<td>Those components <strong>not expected to require remote maintenance during the life time of ITER</strong>, but <strong>whose failure would prevent ITER operation</strong>.</td>
</tr>
</tbody>
</table>
| Unclassified | Those components that do **not require remote maintenance** either because:  
  a) they are in a low or zero contamination / activation area and can be maintained hands-on. or  
  b) their failure would not prevent ITER operation |

For more detail classification procedure, see  
[*ITER_D_2FMAJY - ITER Remote Maintenance Management System (IRMMS)*](https://example.com)
ITER RH Operation Scenario
Machine Operation Scenario

ITER EXPERIMENTAL SCHEDULE: ALTERNATE

Complete
Tokamak Core
Construction

First
Plasma

Hydrogen
Helium Phase
Complete

Deuterium
Phase
Complete

Year

Events
Complete
Tokamak Core
Construction

ITER Commissioning and Operations

Start Torus Pump Down

Pump Down & Integrated Commissioning

First Plasma

End of Magnet Commissioning

Phase 2 Machine Assembly

Blankets

Divertor

Plasma Restart

Plasma Development and H&CD Commissioning

Commission, Cool & Vacuum

Nuclear License

Pre-Nuclear Shutdown & Divertor Change

D Plasmas on W Divertor

D H-Mode Studies

Trace-T Studies

100% T-fuelling capability

100% Tritium throughput capability

100% Tritium throughput capability

100% Tritium throughput capability

Q=10 Short Pulse

Q=10 Long Pulse

C1 IC1 C2 IC2 O2 C3 O3 M1 O4 M2 O5 M3

Cn: Construction phase n
ICn: Integrated commissioning phase n
Mn: Maintenance phase n
## RH Operation (Planned shutdown)

| Requirements | Activity | Freq. of Operation | RH class | C1 | C2 (12m) | C2 (16m) | IC1 (12m) | IC2 (6m) | O2 (12m) | O3 (20m) | M1 (8m) | O4 (16m) | M2 (8m) | O5 (16m) | M3 (8m) | O6 (16m) | M4 (8m) |
|--------------|----------|-------------------|----------|----|----------|----------|-----------|----------|----------|----------|---------|---------|---------|---------|---------|---------|
| PBS 23-1: IVT (Blanket RH) |         |                   |          | ✓  |          |          |           |          |          |          |         |         |         |         |         |         |         |         |
| PBS 23-2: CMM/CTM (Divertor RH) |         |                   |          | ✓  |          |          | ✓         |          | ✓        | ✓        |         |         |         | ✓       |         |         | ✓       |         | ✓**    |
| PBS 23-3: Transfer cask / plug RH |         |                   |          | ✓  |          |          | ✓         |          | ✓        | ✓        |         |         |         | ✓       |         |         | ✓       |         |         |
| PBS 23-4: IVVS (Viewing system) |         |                   |          | ✓  | ✓        | ✓        | ✓         |          | ✓        | ✓        | ✓       | ✓       | ✓       | ✓       | ✓       | ✓       | ✓       |         |
| PBS 23-5: Neutral Beam RH |         |                   |          | ✓  | ✓        | ✓        | ✓         |          | ✓        | ✓        | ✓       | ✓       | ✓       | ✓       | ✓       | ✓       | ✓       |         |
| PBS 23-6: Hot Cell RH |         |                   |          | ✓  | ✓        | ✓        | ✓         |          | ✓        | ✓        | ✓       | ✓       | ✓       | ✓       | ✓       | ✓       | ✓       |         |
| PBS 23-X: MPD (Non-baseline RH) |         |                   |          | ✓  | ✓        | ✓        | ✓         |          | ✓        | ✓        | ✓       | ✓       | ✓       | ✓       | ✓       | ✓       | ✓       |         |

### RH equipment usage

- **PB 23-1: IVT (Blanket RH)**: Usage marked ✓
- **PB 23-2: CMM/CTM (Divertor RH)**: Usage marked ✓
- **PB 23-3: Transfer cask / plug RH**: Usage marked ✓
- **PB 23-4: IVVS (Viewing system)**: Usage marked ✓
- **PB 23-5: Neutral Beam RH**: Usage marked ✓
- **PB 23-6: Hot Cell RH**: Usage marked ✓
- **PB 23-X: MPD (Non-baseline RH)**: Usage marked ✓

* GREEN operation period, GREY maintenance period.
* After DT operation, 16 months of plasma operation, and 8 months of LTM

* Blanket exchange schedule is subject to project decision.
** Divertor exchange: two more times after DT phase.
Blanket RH Equipment (PBS 23-1)
Blanket RH Equipment

- **System Functions**
  - Blanket module and/or First Wall removal from and replacement to the VV wall
  - Blanket module and/or First Wall transportation into and out of the VV
  - Bolting for fixing modules by flexible supports
  - Cooling pipe connection cutting, welding and weld inspection
  - Blanket module earthing device disconnection and re-connection
  - Insertion of NB duct liner maintenance tools

- **Requirements and Environmental Conditions**
  - **Maintenance:**
    - Replacement of all modules < 2 years.
    - Replacement of one module < 8 weeks.
  - **Load condition:**
    - Blanket: 440 Modules of 30 types, Max. Module weight: 4.5 t
  - **Atmosphere:** dry air
  - **Pressure:** ~ 1 bar
  - **Temperature:** < 50°C
  - **Humidity:** ~ 0%
  - **Gamma radiation dose rates:** (10^6 seconds after plasma operations)
    - In-Vessel: Max 500 Gy/hr
    - Inside the remote handling port: tbd Gy/hr
    - Module contact: ~75 Sv/hr
    - Between the port plug flange (in place) and the cryostat: <100μSv/hr
  - **Contamination:** tritium, activated dust (C, Be and W)
  - **Magnetic field:** < 1mT

From [ITER_D_2FMAJY - ITER Remote Maintenance Management System (IRMMS)]
Blanket RH Equipment

Vehicle manipulator
Articulated rail
Rail support equipment
Module/tool transporter
Cable handling equipment
Rail Deploying and Rail Support Equipment

- Cable Handling Equipment
- Transfer frame for Cable Handling Equipment
- Transfer mover
- Rail Support Equipment
- Sliding Beam
- Rail
- Vehicle Manipulator
Rail Support Equipment and Module Transporter

Rail Support Equipment

Vehicle Manipulator

Cable Handling Equipment

Transfer frame for Cable Handling Equipment

Tractor

Module / Tool transporter

Rail
The Rail Deployment System Configuration

- Blanket model
- Vacuum vessel
- Intermediate cask
- Rail
- Rail connecting equipment
- Sliding Beam
- Rail Storage Table
- IVT cask
- Vehicle/ manipulator
- Vehicle fixing arm
- Rail positioning arm
- CBP
- Tractor

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*Image: Diagram of the Rail Deployment System Configuration showing various components and their connections.*
Rail Deployment Sequence

1) Positioning vehicle inside VV by vehicle fixing arm
2) Deploying rail by vehicle traveling axis
3) Arcing rail by rail positioning arm
4) Deploying final rail join
5) Installing rail support equipment and cable handling equipment
6) Removing vehicle fixing arm
Prototype
Divertor RH Equipment (PBS 23-2)
Divertor RH Equipment

- **System Functions**
  - Insertion / extraction of divertor cassettes and their transport to/from a transfer cask docked at divertor level RH ports
  - Insertion / extraction of divertor level diagnostic assemblies and their transport to/from a transfer cask docked at divertor level RH ports
  - Removal / replacement of the divertor level RH port primary closure plate (PCP)
  - Dust removal in and around the divertor region during the cassette removal process
  - Cutting, welding, alignment and inspection of cassette cooling pipes, and gas injection lines.

- **Requirements and Environmental Conditions**
  - **Maintenance:**
    - Replacement of the entire divertor < 6 months
    - Replacement of one cassette < 8 weeks (varies depending on location of faulty cassette).
  - **Load condition:**
    - Standard cassette handling: ~ 9 t
    - Central (or diagnostic) cassette handling: ~ 11t
  - **Atmosphere:** dry air
  - **Pressure:** ~ 1 bar
  - **Temperature:** < 50°C
  - **Gamma radiation dose rates:** (10^6 seconds after plasma operations)
    - In-Vessel: 100 Gy/hr in divertor region.
    - Cassette contact: ~ 75 Gy/h (TBC)
    - Inside the remote handling port: tbd Gy/hr
    - Between the port plug flange (in place) and the cryostat: <100µSv/hr
  - **Contamination:** tritium, activated dust (C, Be and W)
  - **Magnetic field:** < 1mT

From [ITER_D_2FMAJY - ITER Remote Maintenance Management System (IRMMS)](http://example.com)
Divertor RH Equipment

Cryopump Port 18

Cryopump Port 6

RH Port 8

RH Port 2

Diagnostic Port 16

RH Port 14

Diagnostic Port 10

RH Port 8

Cryopump Port 6

Cryopump Port 4

RH Port 2

Cryopump Port 18
Divertor RH Equipment

Transfer Cask

Cassette Multifunctional Mover (CMM)

Cassette Toroidal Mover (CTM)
Standard Cassette Installation Sequence

1) Connect the cask to the port plug with a standard divertor cassette
2) CMM carries the cassette inside the VV
3) Connect the cassette to CTM
4) CTM moves the cassette toroidally
5) Positioning the cassette
6) Weld the pipes by using CTM MAM
Transfer Cask and Port Plug
RH Equipment
(PBS 23-3)
Transfer Cask System & Port Plug RH

- **System Functions**
  - The Cask and Plug Remote Handling Systems shall provide the means for the remote transfer of (clean/activated/contaminated) in-vessel components and Remote Handling Equipment between Hot Cell Facility and Vacuum Vessel through dedicated galleries and lift in the ITER buildings.
  - shall also provide means for transfer during Remote Handling Equipment rescue operations.
  - shall also provide means for transfer during in Vessel initial assembly and testing operations.
  - Preparatory activities, prior to initial cask docking, shall involve hands-on operations, including bio-shield plug removal, clearance of pipes, cables and other plug services, and cutting of the vacuum seal.

- **Requirements and Environmental Conditions Transfer Cask (inside)**
  - Load condition:
    - Upper port plug: 25t, Equatorial port plug: 45t
  - Dry air
  - Pressure: ~ 1 bar (min 0.95 bar - max 1.05 bar)
  - Temperature: < 50°C (tbd)
  - Gamma radiation dose rates: 120Gy/hr with 2 blanket modules, 50Gy/hr with diverter cassette.
  - Contamination: tritium, activated dust (C, Be and W)
  - Magnetic field: <1mT
Transfer Cask System

- About 50 t empty
- Size: 3.7m x 2.7m x 8.5m,
- Confine tritium, no

~ 100 persons city bus

In-Cask Equipments
Port Plugs & In-Cask Equipment (1)

• Components to be transferred
  • Plugs
    - Diagnostic Plugs (PBS 55)
    - Electron Cyclotron Heating (ECH) Plugs (PBS 52)
    - Ion Cyclotron Heating (ICH) Plugs (PBS 51)
    - Lower Hybrid Heating (LHH) Plugs (PBS 54)
    - Test Blanket Module (TBM) Plugs (PBS 56)
  • NB cell upper port diagnostic tubes (PBS 55)
  • Blanket RH Equipment (PBS 23 01) (& 2 Blanket Modules)
  • Divertor RH Equipment (PBS 23 02) (& 1DIV K7)
  • In-Vessel Viewing System Plugs (PBS 23 04)
  • Torus cryopumps (PBS 31)

• 21 dedicated transfer casks with 7 different types

<table>
<thead>
<tr>
<th>Type of casks</th>
<th>UPPER PORTS</th>
<th>EQUATORIAL CASK</th>
<th>PORTS</th>
<th>LOWER PORTS CASK</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main cask system</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td>4</td>
<td>14</td>
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<tr>
<td>Rescue cask sys</td>
<td>(1)</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>7</td>
</tr>
</tbody>
</table>
Port Plugs & In-Cask Equipment (2)

NB Cell Upper Plug Diag. central tube

Upper Plug

Eq. Plug

Divertor
Docking Transfer Cask System to a Port

1) Entering into a port for maintenance operation.

2) Approaching to the port.

3) Supporting by the pallet system, and removing the ATS outside of the port.

4) Positioning of the cask for connection to the port.

5) Connection to the port.

6) Opening the double seal door.
In-Vessel Viewing System (PBS 23-4)
In-Vessel Viewing System (IVVS)

• **System Functions**
  – shall allow for in-vessel inspection of plasma-facing surfaces to look for possible damage caused during plasma operations.
  – shall also be used for metrology measurements of the plasma chamber and its components.

• **Requirements and Environmental Conditions**
  – Maintenance:
    • Visual Inspection of one ITER sector: < 2 hrs
    • Dimensional survey of one ITER sector: < 8 hrs
  – Performance:
    • shall provide viewing images with a spatial resolution better than **1mm at target distances of 0.5m-4m** and better than **3mm at target distances up to 10m**.
    • shall be capable of providing metrology at key points of the divertor and first wall regions with a reference **accuracy of better than ±0.5mm at 5m target distance**.
  – Atmosphere: Vacuum @ **10^{-3} Pa**
  – Temperature: **120°C (240°C for baking)**
  – Gamma radiation dose rates: **5000 Gy/hr**. Total dose 10 MGy.
  – Magnetic field: < 1 milli Tesla

From ITER_D_2FMAJY - ITER Remote Maintenance Management System (IRMMS)
ITER_D_29NC9X - SRD-23-04 (In-Vessel Viewing System) from DOORS
In-Vessel Viewing System (IVVS)

IVVS Port

Cryo pump port

Triangular support

Divertor

Six installation port: #03, 05, 09, 11, 15, 17
## Coverage of IVVS Inspection

<table>
<thead>
<tr>
<th>Probe Position</th>
<th>Coverage Incident angle of 60deg (70deg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Out board</td>
<td>54.82% (73.91%)</td>
</tr>
<tr>
<td>Mid</td>
<td>56.29% (70.84%)</td>
</tr>
<tr>
<td>In board</td>
<td>56.29% (70.15%)</td>
</tr>
</tbody>
</table>

**Coverage of whole VV surface**

**Coverage of divertor area**
Prototype

- Metrology results at 3.75m and 0 deg
- Scanning time: 60 minutes
- **Resolution < 1mm**
  until 70 deg incident angle
Neutral Beam System
RH Equipment
(PBS 23-5)
Neutral Beam System RH Equipment

• **System Functions**
  – Removal and replacement of the caesium oven fuelling system
  – Removal and replacement of the beam source
  – Removal and replacement of the beam line components
  – Removal and replacement of the NB gate valve and duct bellows (tbc)

• **Requirements and Environmental Conditions**
  – **Maintenance:**
    • Time required for removal and replacement of the caesium oven fuelling system – 7 days
    • That of beam source, the beam line components, the NB gate valve and duct bellows - tbd
  – **Load condition:**
    • NB Injector assembly weight: 26 t
    • Passive Magnetic Shield large end plate weight: 6 t
    • Beam Source Vessel end plate weight: 7.5 t
  – **Atmosphere:** Air
  – **Pressure:** ~ 1 bar
  – **Temperature:** Ambient
  – **Gamma radiation dose rates:**
    • Around ion source: < 0.4 mGy/hr
    • Outside the ion source vacuum boundary: < 0.01Gy/hr
    • Outside the beam line: < 0.01 Gy/hr
    • Outside the magnetic shield: < 10-4 Gy/hr
    • Around the fast shutter: < 0.1 Gy/hr
  – **Contamination:** tritium, activated dust (C, Be and W)
  – **Magnetic field:** ~ 0.1 Tesla

From ITER_D_2FMAJY - ITER Remote Maintenance Management System (IRMMS)
Neutral Beam System

(1) Beam source maintenance

(2) Beam line components maintenance

(3) Duct liner maintenance
Deployment of RH system

- Monorail crane
- DNB
- HNB #1
- HNB #2
- HNB #3
Beam Source RH (1)

1) Exchange the caesium oven (RH Class 1)

2) Opening the BSV end plate

3) Disconnection of beam source service

4) Removing the beam source
Beam Line Components RH (2)

1) Opening the BLV lid
2) Moving the manipulator
3) Maintaining the beam line components
Duct Liner RH (3)

1) Move duct liner into VV from transfer cask

2) Transfer the DLM from the RH port to the NB Port in inside of VV by using IVT

3) Positioning the DLM and inserting it to the NB port.

4) Service connection for the DLM
Hot Cell
RH Equipment
(PBS 23-6)
Hot Cell RH Equipment

• **System Functions**
  - Transfer of component within, in an out of the Hot Cell,
  - Storage of machine components and RH equipment.
  - Cleaning and dust removal.
  - Repair or refurbishment operations, including removal/installation of parts, minor machining operations, welding.
  - Inspection of components (such as Visual/Ultrasonic/leak testing).
  - Maintenance of the Hot Cell infrastructure and equipment located in the red zones (including RH equipment).
  - Remote maintenance inside the Hot Cell building for the following ITER components:
    - Divertor Cassettes system.
    - Blanket modules system.
    - Vacuum vessel port plugs and diagnostic systems.
    - Neutral beam cell upper port diagnostic tubes.
    - In-Vessel and HC RH equipment.
    - In-Vessel Viewing System.
    - Torus Cryopumps.

• **Requirements and Environmental Conditions**
  - The pressure is 1 bar absolute
  - Maximum environmental temperature of 35°C
  - The relative humidity is 25 % Max
  - No magnetic field
  - The contamination comprise mainly tritium, but possibly also activated dust (C, Be and W)
  - Typical maximum environmental radiation dose rate of 460 Gy/hour (possible changes as ITER design progresses).
Hot Cell Layout
Hot Cell RH Equipment

The HC RH system shall comprise the following equipment:

- Boom-style RH transporter(s)
- Jib cranes transporters
- Lifting jigs
- Dexterous telemanipulator(s) end effectors
- Direct viewing telemanipulators
- Inspection equipment (including weld NDT, visual inspection, metrology)
- Cleaning equipment (Vacuum cleaner).
DIVERTOR CASSETTES REFURBISHMENT:
on-line for 54 divertor cassettes, all available requirements at the time have been taken into account

Divertor cassette testing & tools support
PLUGS REFURBISHMENT: some requirements available at the time have been taken into account.
Limited provision for plug testing.
TBM REFURBISHMENT:
1. TBM plug fully inserted into Hot Cell
2. Spare TBM plugs
RH Test Facility
(PBS-23-9)
RHTF Requirements

- Test Facilities Required for all (IRMS) elements:
  
  (ITER Remote Maintenance System)
  - In-Vessel Transporter (IVT), transfer casks, end effectors & tooling
  - Cassette Multi-Function Mover (CMM), casks, end effectors & tooling
  - Cassette Toriodal Mover (CTM), umbilical & tooling
  - In-Vessel Viewing System (IVVS) – transfer cask based
  - Cryopump system – transfer cask based
  - Upper plug system – transfer cask based
  - Equatorial plug system – transfer cask based
  - NB Duct Liner – transfer cask, transporters, manipulators & tooling
  - Hot Cell systems – transporters, manipulators & tooling
  - NB Cell systems – transporters, manipulators & tooling
  - Multi-purpose Deployer (MPD), transfer casks, end effectors & tooling*
  - ELM Coils – transfer cask, transporters, manipulators & tooling*

* TBC
## RHTF Functions

<table>
<thead>
<tr>
<th>Task Ref.</th>
<th>ITER Remote Maintenance System Facilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1</td>
<td>In Vessel Component first installation</td>
</tr>
<tr>
<td>T1.1</td>
<td>Validation of assembly procedures</td>
</tr>
<tr>
<td>T1.2</td>
<td>Training of assembly personnel, rehearsal</td>
</tr>
<tr>
<td>T2</td>
<td>ITER Plant</td>
</tr>
<tr>
<td>T2.1</td>
<td>As build new plant RH compatibility check</td>
</tr>
<tr>
<td>T2.2</td>
<td>Interface checks of existing plant which do not fit in situ on installation</td>
</tr>
<tr>
<td>T2.3</td>
<td>Interface checks of repaired (active/contaminated) plant to IRMS</td>
</tr>
<tr>
<td>T3</td>
<td>IRMS Equipment</td>
</tr>
<tr>
<td>T3.1</td>
<td>New IRMS equipment Initial assembly.</td>
</tr>
<tr>
<td>T3.2</td>
<td>Integration interface checks of new IRMS sub-systems (eg. E/E’s, Tools....)</td>
</tr>
<tr>
<td>T3.3</td>
<td>Site acceptance testing new IRMS equipment</td>
</tr>
<tr>
<td>T3.4</td>
<td>Reliability proving of new IRMS equipment</td>
</tr>
<tr>
<td>T3.5</td>
<td>SOR testing prior to RH op’s IRMS equipment (new &amp; old)</td>
</tr>
<tr>
<td>T3.6</td>
<td>Qualification testing &amp; commissioning after repair, maintenance or modification of IRMS equipment (post first deployment)</td>
</tr>
<tr>
<td>T4</td>
<td>RH Operations</td>
</tr>
<tr>
<td>T4.1</td>
<td>Validation of RH procedures</td>
</tr>
<tr>
<td>T4.2</td>
<td>Training of RH personnel, rehearsal</td>
</tr>
</tbody>
</table>
Hot RHTF & Cold RHTF

HOT RHTF host by HC building

Cold RHTF host by Assembly Hall building
Example of RHTF
Multi-Purpose Deployer
(DCR-130 accepted)
## In-Vessel Requirements (Non-baseline in RH)

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Activity</th>
<th>Expected Frequency of Operation</th>
<th>RH class</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mandatory</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dust accumulation monitoring and removal</td>
<td>Dust sampling</td>
<td>16 months*</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Dust removal</td>
<td>16 months*</td>
<td>1</td>
</tr>
<tr>
<td>Tritium inventory monitoring</td>
<td>Tritium sampling</td>
<td>16 months*</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Tritium removal</td>
<td>Main system is baking</td>
<td>2</td>
</tr>
<tr>
<td>Vacuum vessel inspection</td>
<td>Periodic inspection</td>
<td>every 40 months</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Periodic requalification</td>
<td>every 10 years</td>
<td>1</td>
</tr>
<tr>
<td>Defined at a certain extent</td>
<td>Vacuum vessel leak identification</td>
<td>Leak localisation</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Expected few times in ITER operation</td>
<td>1</td>
</tr>
<tr>
<td>In-Vessel diagnostics maintenance</td>
<td>Calibration, alignment, inspection, replacement, cleaning</td>
<td>16 months</td>
<td>TBD</td>
</tr>
<tr>
<td>Definition on going</td>
<td>• VS and ELMs coils</td>
<td>Maintenance</td>
<td>TBD</td>
</tr>
<tr>
<td></td>
<td>• Maintenance</td>
<td>Assistance</td>
<td>TBD</td>
</tr>
<tr>
<td></td>
<td>• NB Duct Liner Tile replacement</td>
<td>Rescue operation</td>
<td>TBD</td>
</tr>
<tr>
<td></td>
<td>• Rescue operation of the other RH systems</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Based on hypotheses of dust (and tritium) inventory growing-up, to be validated through R&D on going and H, D phase. Safety Authority will ask to do that at any shutdown for ALARA principle.
MPD System

MPD Transporter

Transfer Cask System

MPD Manipulator

Task Module
MPD Requirements

- **MPD Transporter**
  - **Installation:**
    - Deployment from a standard and an intermediate transfer cask through 4 designated IVT entry ports (N° 3, 8, 12 & 17).
    - Shall be deployed without IVT because of space limitation.
  - **Load capability:**
    - Deployment of end effectors with 100kg self weight plus a 250kg payload within the access zone.
    - Deployment of bilateral manipulator arms with a 100kg payload within the access zone.
    - Additional payload capacity of 2 tonnes for all accessible position in VV.
  - **Kinematic performance:**
    - Reach over a segment of VV of ±50°.
    - Maximum Point of Reference (PoR) speed of 100 mm/s.
    - PoR positional accuracy of ±10mm.
  - **Others:**
    - Possibility to recover the MPD following a single point failure
    - No hydraulic power to be used

- **MPD Manipulator**
  - Force reflecting servo-manipulation
  - Bilateral configuration
  - Long-term load capacity in three DoF of 30kg per arm
  - No hydraulic power to be used
### MPD Requirements

- **MPD Task Module**
  - Provides constant availability of tools (and/or components) anywhere within VV.
  - Contains following tools:

<table>
<thead>
<tr>
<th>MPD RH Equipment Specification</th>
<th>In-Vessel tools</th>
<th>Cask Based Service Packs</th>
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<tr>
<td></td>
<td>Width (in)</td>
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<tr>
<td>End Effectors</td>
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<td>Abrasive Cleaning Tool</td>
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<td>Sanding Tool</td>
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<td>Nitrogen Inlet</td>
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<td>Viewing</td>
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<td>Inspection &amp; Test</td>
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Sub-total 0.755 Sub-total 4.0 14.0 Sub-total 1.18
MPD Requirements

- MPD Transfer Cask
  - Standard Transfer Cask
    - MPD main cask based on an Standard Equatorial Cask
      - Same pallet, same ATS, same enclosures, cooling system and DSD.
    - A specific in-cask handling equipment
      - Carriage for the transporter with 2 rails on the cask’s base plate
    - Designed for a maximum payload of 45 T
  - Intermediate Cask
    - MPD intermediate cask based on the IVT intermediate cask concept
      - Same shorter pallet, same shorter ATS, same enclosures, cooling system and DSD.
    - A specific in-cask equipments (OTL data)
      - For tools (gas blower, He sniffer, He spray, TIG weld and calibration source),
      - For camera inspection tool (radiation hardened),
      - For umbilical (electrical, pipe and special cable)
    - Docking at the rear side of the standard TC.
  - Recovery Cask
    - MPD recovery cask based on the MPD transporter cask
      - To mate with the transporter cask after removing the intermediate cask
    - A specific in-cask handling equipment which can grip the transporter to pull it back into the cask
Deployment of MPD Transporter

1) MPD stowed inside transfer cask
2) Passage through the port
3) Rotate axis 4 to deploy inside VV
4) Rotate axis 8 to deploy inside VV
5) Unfold the arm
6) Full extension of the arm: access to 50° sector
MPD Operation Concept - Collaborative working

- Operation of the MPD will require a number of tools which must be made available ideally at the manipulator work site for operation time efficiency.
- For this reason a second MPD is deployed with the concept Task Module mounted upon it.
Conclusion

- Remote Handling (RH) of the tokamak components is an essential part of the overall ITER experiment, and relies on the close interaction between the ITER Remote maintenance System (IRMS) and the ITER components.

- ITER Remote Handling is composed of as follows:
  - Blanket RH (PBS 23-1)
  - Divertor RH (PBS 23-2)
  - Transfer Cask and Port Plug (PBS 23-3)
  - In-Vessel Viewing System (PBS 23-4)
  - Neutral Beam System RH (PBS 23-5)
  - Hot Cell RH (PBS 23-6)
  - RH Test Facility (PBS 23-9)
  - Multi-Purpose Deployer (DCR-130)