# Overview of Remote Maintenance for ITER Blanket

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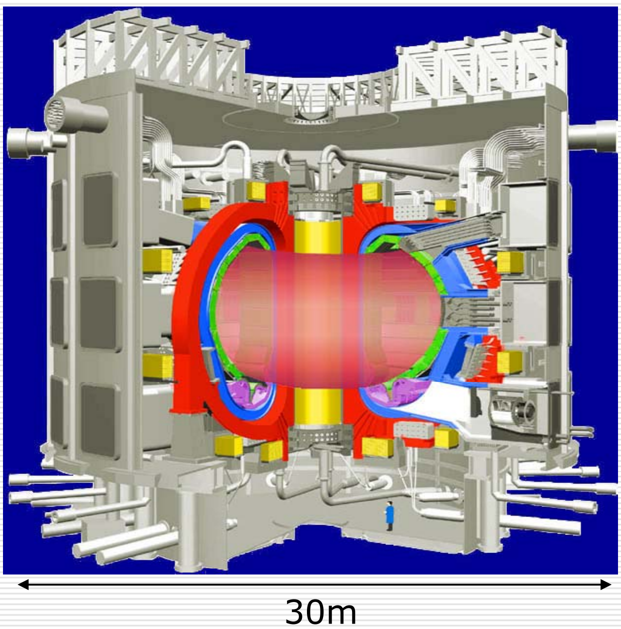
# ITER Project: Way to Fusion Energy



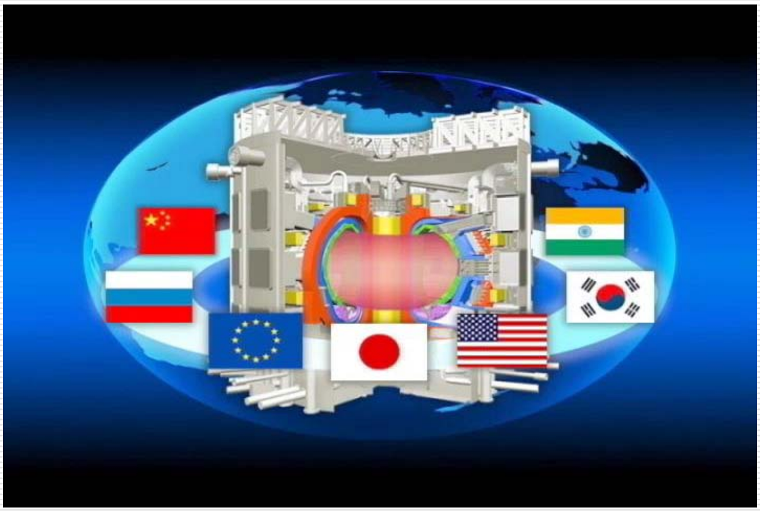

**Programmatic Objectives**

To demonstrate the scientific and technological feasibility of fusion energy for peaceful purposes

**Main Parameters**

| | |
|---|---|
| Total fusion power | 500 MW |
| Additional heating power | 50 MW |
| Q - fusion power/ additional heating power | ≥ 10 |
| Average 14MeV neutron wall loading | ≥ 0.5 MW/m$^2$ |
| Plasma inductive burn time | 300-500 s * |
| Plasma major radius (R) | 6.2 m |
| Plasma minor radius (a) | 2.0 m |
| Plasma current ($I_p$) | 15 MA |
| Toroidal field at 6.2 m radius ($B_T$) | 5.3 T |

# ITER: An International Project



- Members of ITER Project:
  - Japan
  - European Union
  - Russia
  - United States
  - China
  - Korea
  - India
- The members established an international organization (ITER organization) to operate the ITER project.



# ITER Technical Objectives [1]

- Plasma Performance
  - The ITER device should achieve extended burn in inductively driven plasmas with the ratio of fusion power to auxiliary heating power, Q, of at least 10 ($Q \geq 10$) for a range of operating scenarios and with a duration sufficient to achieve stationary conditions on the timescales characteristic of plasma processes.
  - The device should aim at demonstrating steady-state operation using non-inductive current drive with the ratio of fusion power to input power for current drive of at least 5.
  - In addition, the possibility of controlled ignition should not be precluded.
- Engineering Performance and Testing
  - The device should demonstrate the availability and integration of technologies essential for a fusion reactor (such as superconducting magnets and remote maintenance).
  - The device should test components for a future reactor (such as systems to exhaust power and particles from the plasma).
  - The device should test tritium breeding module concepts that would lead in a future reactor to tritium self-sufficiency, the extraction of high grade heat and electricity production.

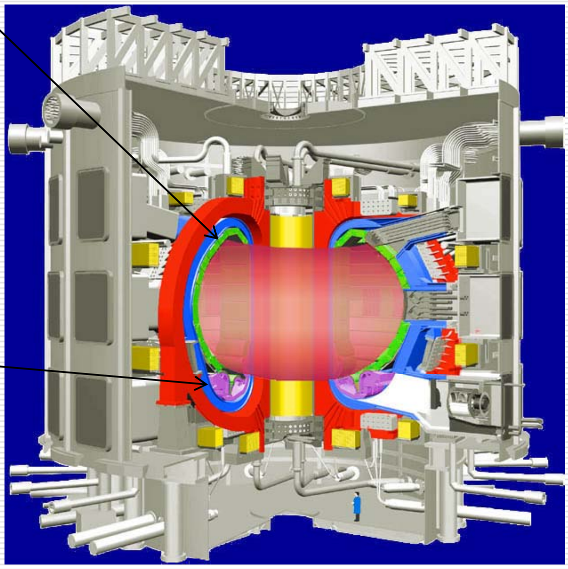
# ITER Remote Handling Classification [2]

| | |
|---|---|
| **Class 1** | those components that require scheduled remote maintenance or replacement. |
| **Class 2** | those components that do not require scheduled but are likely to require unscheduled or very infrequent remote maintenance. |
| **Class 3** | those components not expected to require remote maintenance during the life time of ITER. The projected maintenance time in case of failure may be long. |



# Two Major Components for Remote Handling (RH) [2]

- Blanket (green)
  - removes the surface heat flux and the nuclear heating within the allowable temperature and stress limits, while minimising the impurity influx to the plasma;
  - reduces the nuclear responses in the vacuum vessel structural material for the ITER fluence goal;
  - protects the superconducting coils, in combination with the vacuum vessel, from excessive nuclear heating and radiation damage.
- Divertor (purple)
  - exhausts the major part of the plasma heating power and He from the plasma, while minimising the impurity influx to the plasma;
  - must tolerate high heat loads while at the same time providing neutron shielding for the vacuum vessel and magnet coils in the vicinity of the divertor as the main interface component under normal operation between the plasma and material surfaces.



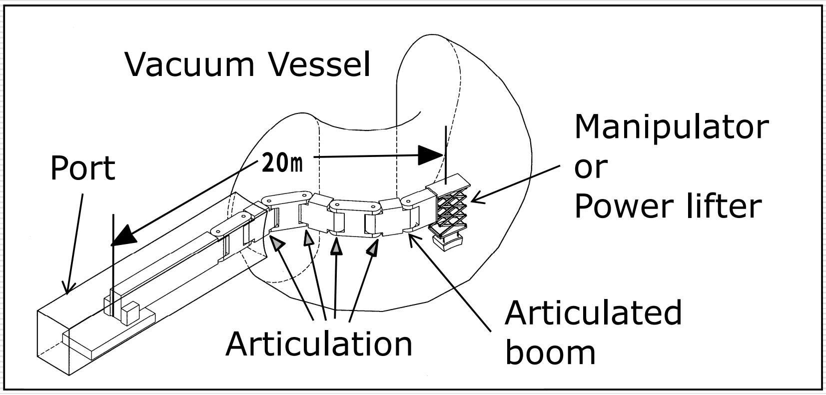
# Parameters of Blanket and Divertor [2]

| | Blanket | Divertor |
|---|---|---|
| Dose rate | 500 Gy/h | |
| Dimensions | 1.4 x 1.0 x 0.5 m | 3.4 x 2 x 0.4~0.9 m |
| Weight | 4.5 ton | 12.5 ton (central cassette) |
| Number of components | 440 | 54 |
| Dimension of opening (port) cross section | 1.7(W)×2.2(H) m | 0.7~1.4(W)×2.2(H) m |
| Maintenance time | 8 weeks (1 component)<br>3 month (1 toroidal row)<br>2 years (full replacement) | 8 weeks (1 component)<br>6 months (full replacement) |
| Maintenance frequency | 1 full replacement after 10 years<br>6 components/year (lower part)<br>3 components/year (others) | 3 full replacements/first 10 years<br>5 full replacements/latter 10 years |
| RH class | Class 2 | Class 1 |
| Procuring party for RH equipment | Japan | European Union |



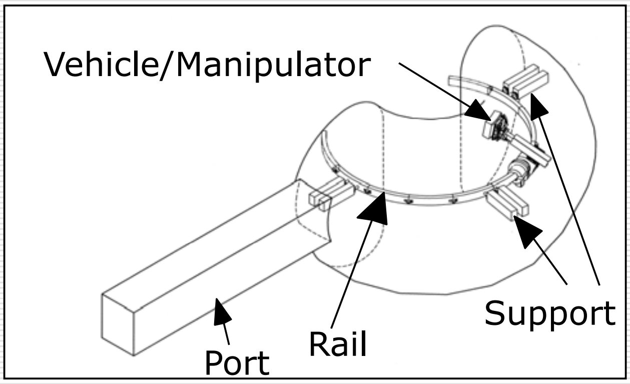
# RH Equipment: Boom Type

- Boom: cantilevered beam (deformation, vibration: large)
  ⟶ Precise positioning: difficult
- Moving speed: slow
  ⟶ Low working effectiveness
- The boom type has been adapted to the Joint European Torus (JET), which is one of largest existing fusion devices.



# RH Equipment: Rail-Vehicle Type

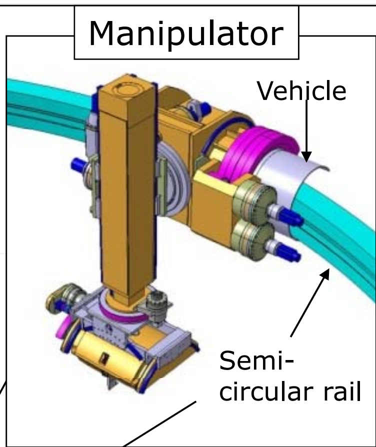
- Functions are separated: structure (rail) and vehicle/manipulator
- Rail: multiple support (high stiffness)
  ⟶ Precise positioning: available
- Moving speed: high
  ⟶ high working effectiveness
- The vehicle type is adapted as the RH equipment for the ITER blanket.

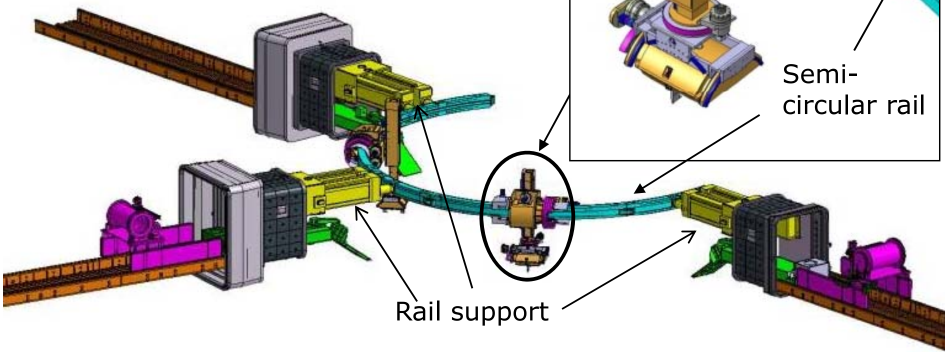




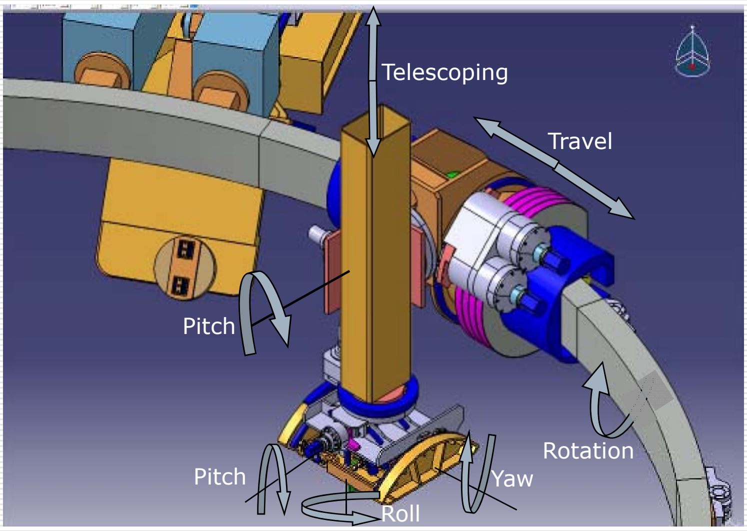

# Rail-Vehicle Type RH Equipment

- A semi-circular rail is installed in the vacuum vessel.
- A monorail-like vehicle travels along the rail with a manipulator.
- The rail is supported at three points.
- The manipulator can transport ton-level weight.



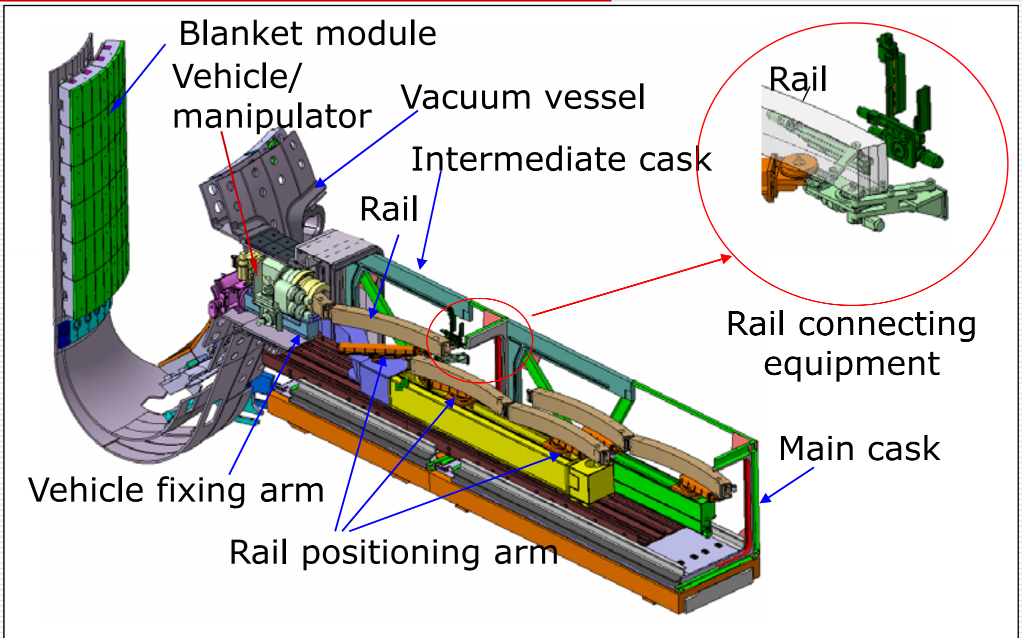
# Vehicle/Manipulator



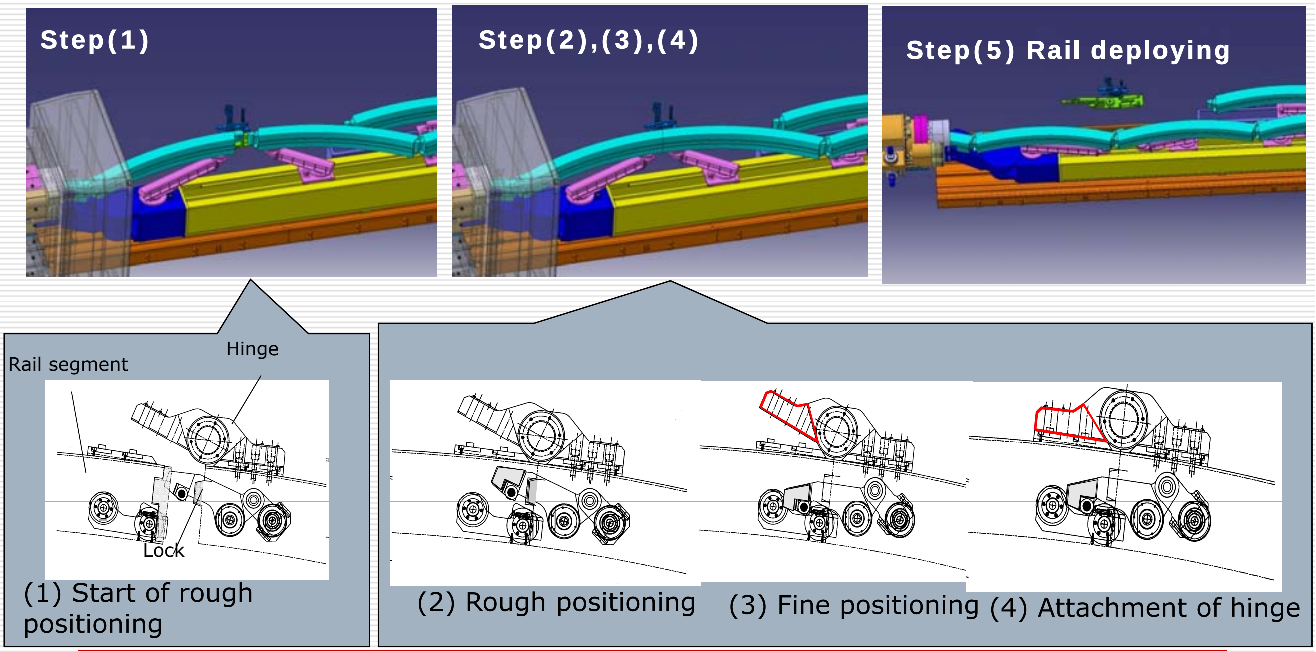

| Degree of freedom | Driving range | Output force | Output speed |
|---|---|---|---|
| Travel | 0～180 deg | 41.6 kN | 1.2 m/min |
| Rotation | ±180 deg | 145.5 kN•m | 38.8 deg/min |
| Telescoping | 2658 mm (max.) | 75.4kN (max.) | 722.6 mm/min (max.) |
| pitch | ±180 deg | 53.3 kN•m | 58.7 deg/min |
| End-effector Pitch | ±45 deg | 39.8 kN•m | 23 deg/min |
| End-effector Roll | ±180 deg | 11.7 kN•m | 102.6 deg/min |
| End-effector Yaw | ±17 deg | 43.2 kN•m | 20.4 deg/min |



# Rail Deploying Equipment

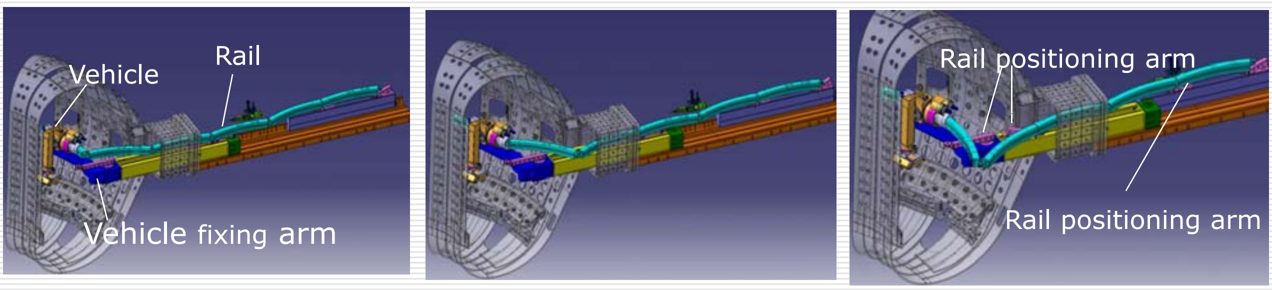


# Steps of Rail Connection






# Steps of Rail Deployment (1)

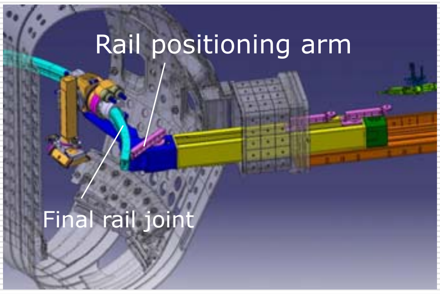



1) Support of vehicle fixing arm

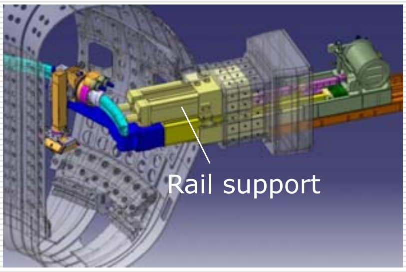
2) Deploying of rail by vehicle traveling drive

3) Arcing of rail by rail positioning arm

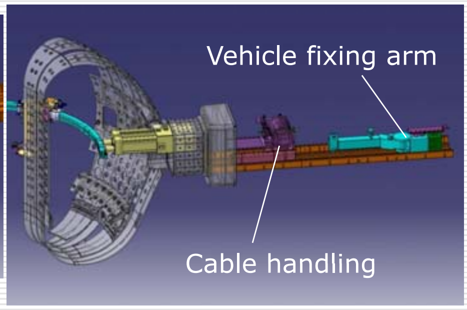
# Steps of Rail Deployment (2)




4) Deploying of final rail join




5) Installation of rail support & cable handling

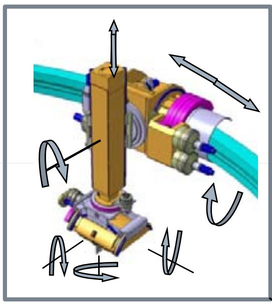


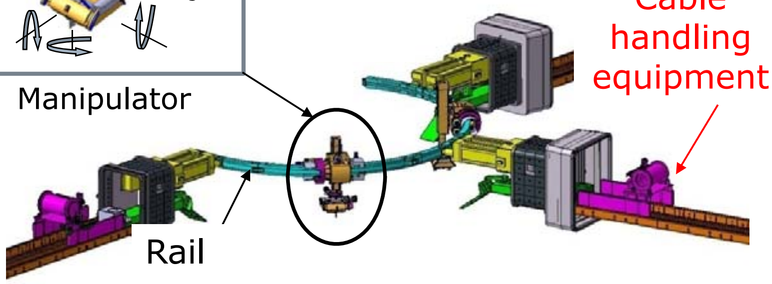

6) Removal of vehicle fixing arm



# Cable Handling Equipment

- The manipulator and its tools (20 motors) requires a multiple core cable (7.5 cm in diameter) for power supply (140 cores) and signal transmission (235 cores).
- The cable is fed by a cable handling equipment.



# Accumulator-Type and Reel-Type

**Accumulator Type**

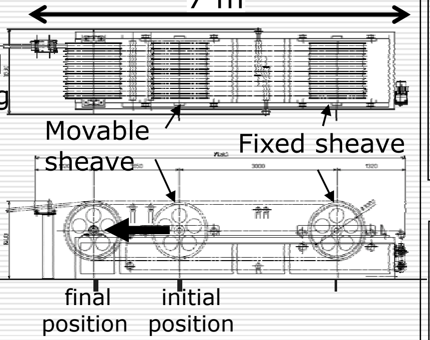
➢ The cable is accumulated by increasing the span between sheaves.

Merit:

➢ Rotating connector is not needed.

Demerit:

➢ Equipment becomes large.



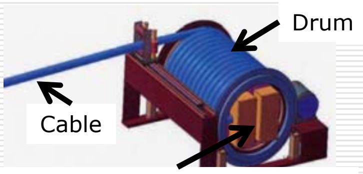

**Reel Type**

Merit:

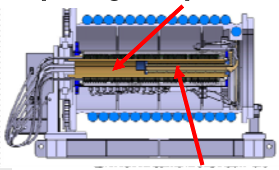
➢ Equipment becomes compact.

Demerit:

➢ It requires rotating connector (potentially noise source).




**Arrangement of slip ring**




➢ The slip ring becomes longer in the axial direction because of huge amount of power and signal lines.

➢ The slip ring is separated to two pieces, for power and for signal, and they are arranged coaxially.

-> The device becomes compact.



# Conclusion

- The remote maintenance is one of essential technologies for a fusion reactor and its demonstration is one of technical objectives in the ITER.
- The blanket is one of the major components which require remote maintenance and its RH equipment will be procured from Japan.
- The Japan Atomic Energy Agency proposed the rail-vehicle type for the blanket RH equipment and completed its design.

# Reference

[1] Project Specification, ITER_D_27ZRGH, Private Communication with ITER Organization (2008)

[2] Project Integration Document, ITER_D_2234RH, Private Communication with ITER Organization (2009)

[1] Project Requirements, ITER_D_27ZRW8, Private Communication with ITER Organization (2009)