Japan’s Perspective on Pathways and Technology Needs

QST
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Overall picture of

Fusion power development
Steps for fusion power realization

“Phased approach”

2nd Phase
Sci feasibility

JT-60

3rd Phase
Tech feasibility

ITER

4th Phase
Tech. Demonstration Econ. feasibility

DEMO

Technology bases for DEMO

BA & national programs

Commer-
cialization
Timeline of DEMO development

2015 ~2020 ~2025 ~2035

Conceptual Design Phase

Engineering Design Phase

Milestones

<table>
<thead>
<tr>
<th></th>
<th>~2020</th>
<th>~2025</th>
<th>~2035</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ITER</strong></td>
<td>First plasma</td>
<td>DT burn at Q ~ 10</td>
<td></td>
</tr>
<tr>
<td><strong>JT-60SA</strong></td>
<td>First plasma</td>
<td></td>
<td>SS op. at $\beta_N \geq 3.5$</td>
</tr>
<tr>
<td><strong>FNT</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BB</td>
<td></td>
<td>TBM #1 safety test compl.</td>
<td></td>
</tr>
<tr>
<td>RAFM</td>
<td>~80dpa fiss. n-irrad start</td>
<td></td>
<td>DEMO design standard</td>
</tr>
<tr>
<td>A-FNS</td>
<td>Concept design compl.</td>
<td>Construction start</td>
<td>init. irrad. of BB materials</td>
</tr>
</tbody>
</table>
“Action Plan (AP) toward DEMO” was formulated to implement DEMO-relevant R&Ds in a coordinated way, being under authorization by the Fusion Sci. and Tech. Commission of MEXT.

AP defines the development timeline of 12 key technologies:

1. DEMO design
2. SC magnet
3. Blanket
4. Divertor
5. H&CD
6. Theory/ simulation
7. Core physics
8. Fuels system
9. Material codes & standards
10. Safety
11. Availability/ maintenance
12. Diagnostics and control

AP considers priority of tasks taking account of budget, resource, etc.

→ Large scale R&Ds (magnet, remote maintenance) will start after the completion of DEMO conceptual design (2025).

→ AP suggests to enhance DEMO design activity and to accelerate divertor study for a prospect for power exhaust in DEMO.
**Example of Action Plan – DEMO Design**

<table>
<thead>
<tr>
<th>DEMO Design</th>
<th>Conceptual design</th>
<th>Engineering design</th>
</tr>
</thead>
<tbody>
<tr>
<td>Establishment of phys. &amp; eng. guideline</td>
<td></td>
<td>Site asses. Const. design</td>
</tr>
<tr>
<td>Definition of safety policy</td>
<td>Preparation for regulation of safety</td>
<td>Regulation and assess. for site safety</td>
</tr>
<tr>
<td>Database(DB) of physics, engineering &amp; materials</td>
<td></td>
<td>DB update w/JT-60SA &amp; irrad. results</td>
</tr>
</tbody>
</table>

**Concept & Construction plan**

<table>
<thead>
<tr>
<th>2015</th>
<th>2020~</th>
<th>2025~</th>
<th>2035~</th>
</tr>
</thead>
<tbody>
<tr>
<td>(15)S: Basic design of concept →(19)</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>(16)S/TF: Fuel cycle strategy</td>
<td>(23)S/Q/F: Rev. of target plasma →(26)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(17)Q/N/U/S: Integrated simulator</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(18)S/D: Cost evaluation</td>
<td></td>
<td></td>
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</tbody>
</table>

**Equipment Design**

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<tr>
<th>2015</th>
<th>2020~</th>
<th>2025~</th>
<th>2035~</th>
</tr>
</thead>
<tbody>
<tr>
<td>(19)S/Q: Demo TBM targets →(19)</td>
<td></td>
<td>(27)A/S: Regulation &amp; standard →(31)</td>
<td></td>
</tr>
<tr>
<td>(17)S/D: Equip. config. w/ BOP →(19)</td>
<td></td>
<td>(after decision of standard &amp; site candidates)</td>
<td></td>
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</tbody>
</table>

**Safety Policy**

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<tr>
<td></td>
<td>(20)TF/S: Draft for safety regulation →(26)</td>
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</tbody>
</table>

**Database of Physics, Engineering & Materials**

<table>
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<tr>
<th>2015</th>
<th>2020~</th>
<th>2025~</th>
<th>2035~</th>
</tr>
</thead>
<tbody>
<tr>
<td>(16)Q/U/F/S: Eng. &amp; Materials DB</td>
<td>w/ 14MeV heavy irradiation data →(35)</td>
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Large scale R&Ds (magnet, remote maintenance) will start after the completion of DEMO conceptual design (2025).
Prospects of Ongoing Projects
National activity

- “Special Design Team” organized for all-Japan activity
- More than 80 members incl. industry

BA activity

Joint work on common design issues on DEMO

Targets by 2025:

- Conceptual design of DEMO plant
- Specs of components and facilities
- Safety design
- Waste management scenario
- Define R&D needs in the next phase

Launch large-scale R&Ds in Eng. Design Phase
Views on BB technology

- **Challenging technology for DEMO**
  - Mass production (*a set of BB: 1,150 modules, 1,600 tons*)
  - Fabrication, inspection and joint technologies
  - Various material property database for design code and standard, and for lifetime evaluation of irradiated materials

- **Needs different level approaches for development**
  - System level – T recovery, heat extraction
  - Component level – blanket, maintenance
  - Element level – structural material, breeder, neutron multiplier

Need to pursue intense study on BB technology from now on
Approaches to establish BB technology

Functional materials

ITER-TBM

Steam turbine

Heat extract.

T recovery

Mass production

Mater. properties

Small specimen testing technol.

Fission-n irrad.

Fusion-n irrad.

Irradiation

Structural materials

B$_{12}$Ti

Li$_2$TiO$_3$

RAFM ingot

Welding test
Conceptual design of A-FNS started on the premise of the 9 MeV acceleration in LIPAc of IFMIF/EVEDA.

**Specs of A-FNS**
- 40 MeV, 5 MW (CW)
- $7 \times 10^{16}$ n/s, 10 dpa/fpy
- Completion: ~2030

**IFMIF/EVEDA**
- LIPAc: 9 MeV, 125 mA

**Beam transport**
- **LIPAc**
- **40 MeV**
- **Irrad. Facility**

**Neutron intensity distr.**
- Extension
JT-60SA is being constructed under the BA activities as well as a national project.

Mission toward DEMO:
Develop steady state operation at $\beta_N > 3.5$
$\Leftarrow$ DEMO requires "steady and stable operation"

Status:
Construction in progress, as planned

Schedule:
- Completion of construction: March 2020
- First plasma: Fall in 2020
- Heating experiments start in BA Phase II (2020-2025)
Summary

- “Action Plan toward DEMO” that defines the timeline of 12 key technologies, is under authorization by the Fusion Sci. and Tech. Commission of MEXT.

- AP contributes to implementing DEMO-relevant R&Ds in a coordinated way under the cooperation of QST, NIFS, universities and manufacturing companies.

- In addition to ongoing projects (ITER and BA), Japan plans to enhance DEMO design activity, BB-related R&Ds, A-FNS conceptual design.

- Large-scale R&Ds such as magnet and remote maintenance will start after the completion of DEMO conceptual design in 2025 and the definition of targets of the R&Ds.