INTERNATIONAL FORUM
«ATOMEXPO 2011»

# Fast reactor development program in Japan and expectations for MBIR in Russia

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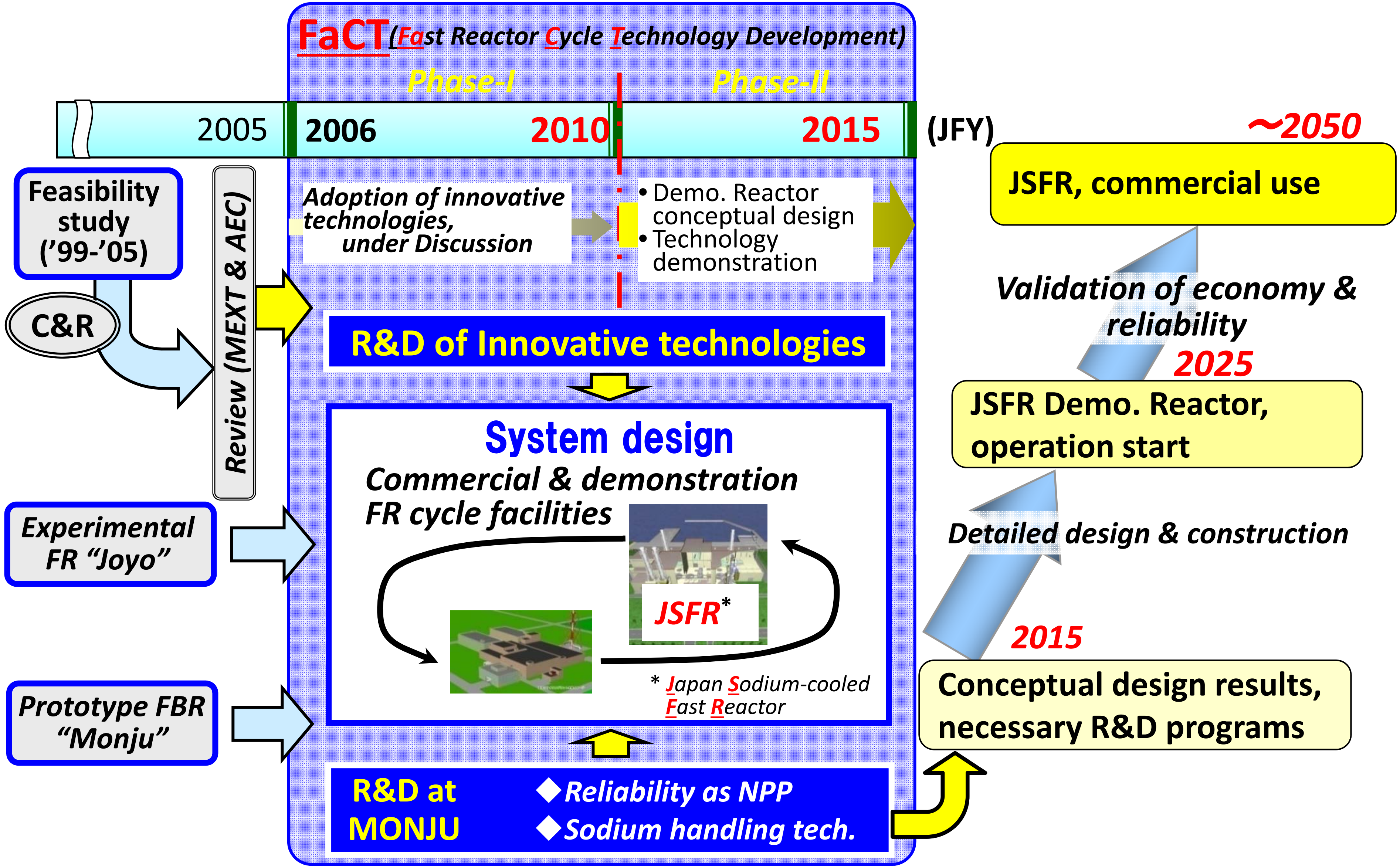
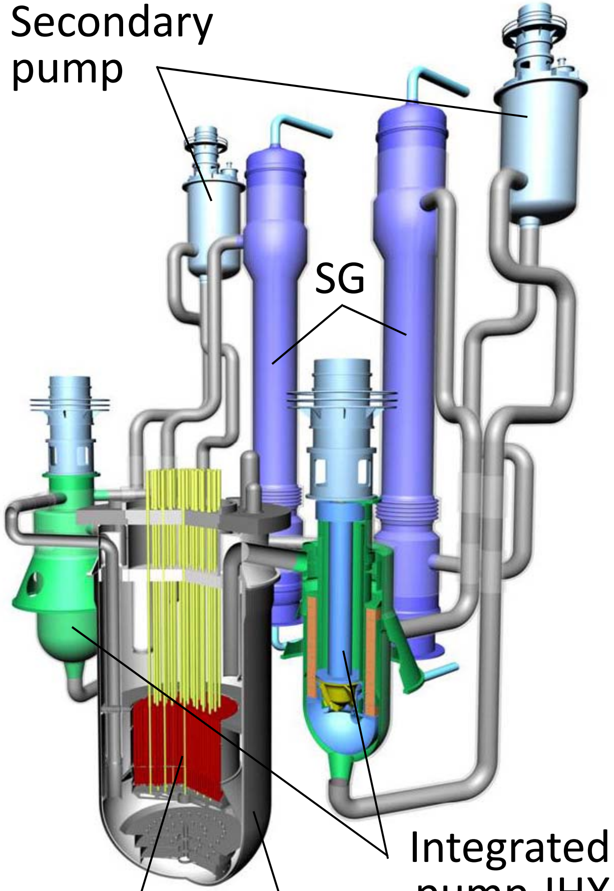
# Outline of FaCT project (Original plan)



# Basic concept for core/fuel development in JSFR




**Overview of JSFR**

**Safety**

- **Fuel safety issues related to new fuel pin design**
- **Re-criticality free core design during CDAs (Fuel subassembly with inner duct)**

**Economic**

- **Fuel burn-up : ～150GWd/t (Ave.), 230～250GWd/t (Max) (fluence(dose) : 250dpa)**
- **Coolant outlet temp. : 550℃ (Max. cladding temp. : 700℃)**
- **Long-life control rods**

**Sustainability**

- **1～5% MA bearing MOX fuel (Replaceable to [U, Pu]fuel) (Option: Metallic fuel)**

# Needs for in-pile experiments

## Fuel safety:

- Fuel pin performance under steady-state conditions (irradiation)
- Margin to fuel melting
- Margin for deterministic pin failure (under slow power transients)
- New fuel pin designs and materials (fuel, cladding)
- Use of minor actinides (MA)

## Reactor physics:

- Doppler, fuel expansion reactivity feedback
- Reactivity feedback due to sodium voiding

## Severe accidents:

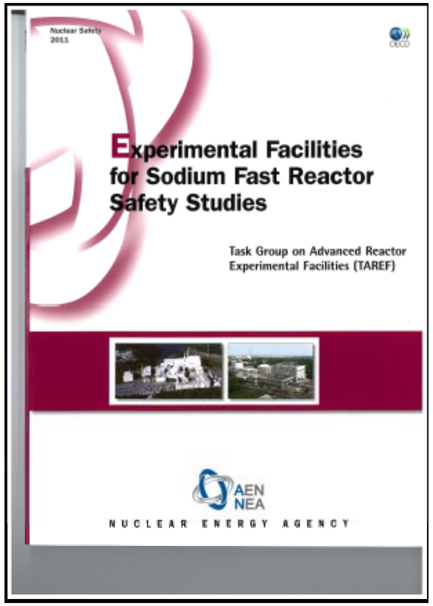
- Remained part of Unprotected Loss of Flow（ULOF) Scenario; i.e., Post Accident Material Relocation Phase and Post Accident Heat Removal Phase to ensure the In-Vessel Retention Capability
- Fission Products behavior during Severe Accidents Scenario

## Structural integrity:

- In-service inspection for in-sodium structure

## Other issues:

- Reliability and effectiveness of passive safety systems
- Fast in-core detection system




*(Main source)*
*Nuclear Safety 2011*
*NEA/CSNI/R(2010)12*

# Irradiation test program in FaCT project

## Feasibility study of high burn-up core concepts

・Fuel claddings (ODS steel, high Ni alloy) : material and fuel pin irradiation
・ Wrapper tubes (PNC-FMS) : material irradiation

## Expansion of design data

・Bundle type ODS fuel pin
・PNC-FMS wrapper tube for FCMI (Fuel-Cladding Mechanical Interaction)
・Annular fuel pins, PTM (Power-to-Melt)
・PTM for irradiated fuel

## FR advanced technology

・$B_4C$ for long-life control rod

## Minor Actinide (MA) fuel development

・Am, Np bearing oxide fuel
・Cm bearing oxide fuel (more than 40GWd/t)

## Re-criticality free core concept

・FAIDUS (Fuel subassembly with Inner DUct Structure)

# Irradiation test facilities for FR in Russia and Japan

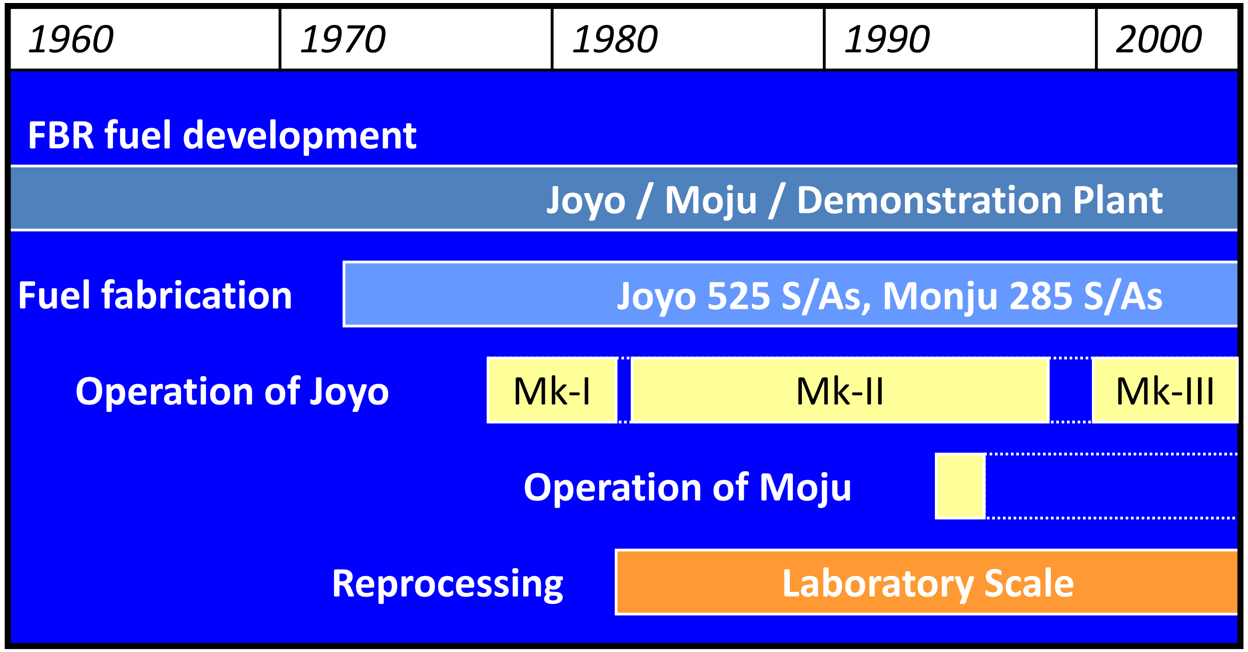
| | BN-600 (Russia) | BOR-60 (Russia) | Joyo (Japan) | Monju (Japan) | MBIR (Russia) |
|---|---|---|---|---|---|
| Thermal output | 1470MWt | 55MWt | 140MWt | 714MWt | ～150MWt |
| Neutron flux | ??×$10^{15}$ n/cm$^2$/s | 3.7×$10^{15}$ n/cm$^2$/s | 4.0×$10^{15}$ n/cm$^2$/s | 3.7×$10^{15}$ n/cm$^2$/s | 5.0×$10^{15}$ n/cm$^2$/s |
| Fuel | $UO_2$ | $UO_2$ $PuO_2$-$UO_2$ | $PuO_2$-$UO_2$ | $PuO_2$-$UO_2$ | $PuO_2$-$UO_2$ PuN-UN |
| Core dim. dia./height | 205/103 cm | 46/45 cm | 80/50 cm | 180/93 Cm | ―/55cm |
| Burnup (maximum) | 97,000 MWd/t | 176,000 MWd/t | 90,000 MWd/t | 94,000 MWd/t | ― MWd/t |
| Damage dose rate* | ～36 dpa/y | 25 dpa/y | 33 dpa/y | 47 dpa/y | 50 dpa/y |
| Remark | Under operation | Under operation | Under operation | Under operation | Under planning |

*1×$10^{26}$n/m$^2$（E>0.1MeV）＝5dpa

# Development of FR fuel

- FR fuel development with “Joyo” and “Monju”
  - Plutonium production, full MOX core
  - Accumulated experiences over 20 years in Joyo
  - Monju fuel development and fuel fabrication for initial core
  - Plutonium recycling on an experimental scale

History of FR Fuel development





Plutonium Fuel Production Facility


Experimental FR “Joyo” and Fuel Monitering Facilities


Proto-type FBR “Monju”

# Joyo – test plans

**Achievements**

- Irradiation of MOX fuels
- Irradiation of advanced austenite steel claddings
- Demonstration of Monju driver fuel pin（irradiation of PNC-316 cladding and low-density fuel pellet）
- SASS (Self-Actuated Shutdown System)
- PTM (Power-to-Melt)

**Future irradiation plan**

- ODS claddings, oxide fuel fabricated by simplified process
- MA bearing oxide fuels, metallic fuels
- Long-life control rods
- Validation of design criteria
- For preparation of fuel design standards and codes
- For Monju upgrade core

# Monju – test plans

**Purpose**

・Validation on reliability for nuclear power plant
(technical demonstration, design verification)

・Establishment of sodium handling technologies
(operation, maintenance)

**Irradiation test**

・Demonstration reactor fuel
（simplified pellet, large-diameter annular pellet)

・Subassembly scale
＊'Joyo' : fuel pins and material test pieces

・Demonstration of high burn-up and low-decontamination TRU fuel

・Np, Am and Cm bearing fuel (GACID* project)

＊GACID：Global Actinide Cycle International Demonstration

# International collaboration on FR cycle

## Gen-IV International Forum (GIF)

［Participant：12 countries and EU］

**Sodium-cooled Fast Reactors（SFR）System Agreement**

Bilateral Collaboration

**Under discussion**

Promising candidates

- Core materials
- Operation experience
- Safety issues

## International Atomic Energy Agency (IAEA)

**International Project on Innovative Nuclear Reactors and Fuel Cycles（INPRO）**

**Technical Working Group on Fast Reactors（TWG-FR）**

**Technical Working Group on Nuclear Fuel Cycle Options（TWG-NFCO）**

International standardization of philosophies for safety assurance and design criteria to achieve FR cycle technology commercialization

# Expectations for MBIR(1/2)

○MBIR will be a valuable test reactor that we can use as a field of multi-purpose R&Ds like high-precision irradiation of fuel and materials, and innovative technology to develop FR cycle.
At the same time, we can expect high operation rate and flexibility of MBIR, which permits us to push forward materials development effectively.

Concretely, followings are expected:

(1)Irradiation tests for enhanced performance (high burn-up) fuels such as MOX and TRU fuels, materials such as cladding, control rods and structural materials for acquiring irradiation data；

- swelling behavior
- Fuel-Cladding Chemical Interaction (FCCI)
- materials damage under irradiation

(2)Validation tests for confirming safety and reliability.

# Expectations for MBIR(2/2)

○When research is conducted, we expect the object should not be limited to MBIR, but open to the use of existing testing reactors in the world by considering sharing roles with those reactors.

# Conclusions

- Necessity of nuclear energy will be unchangeable even after the Fukushima-Daiich nuclear accident.
  - circumstances of long-term world energy demand
  - issues of global environment
- Fast Reactors with high performance of safety, reliability and economy as Gen-IV reactors will become more important,  so that some special test reactors for the development will be necessary.
- In the near future, the cooperative arrangement will be concluded for Fast Reactors between Russia and Japan.
- We hope we can take this opportunity to build better bilateral relations for the progress of nuclear energy.