
Recycle Strategies for Fast Reactors and Related Fuel Cycle Technologies

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Satoru Tanaka

The University of Tokyo

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Japan, France, U.S.A, Russia,

India, China, Republic of Korea

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GIF, INPRO, GNEP, TWG

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1. Importance of recycling in Fast Reactor Cycle

- Efficient use of uranium, recycling of Pu
 - Fuel cycle and fuel manufacturing are essential to FR cycle
 - Recycling/burning minor actinides:
Am, Cm, Np? Homogeneous or heterogeneous
 - Management of high level radioactive waste
(reduction of heat generation, long-term toxicity)
 - Reprocessing and fuel manufacturing
 - Safety
 - Non-proliferation
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2. Development in each country

Development Status of Japan

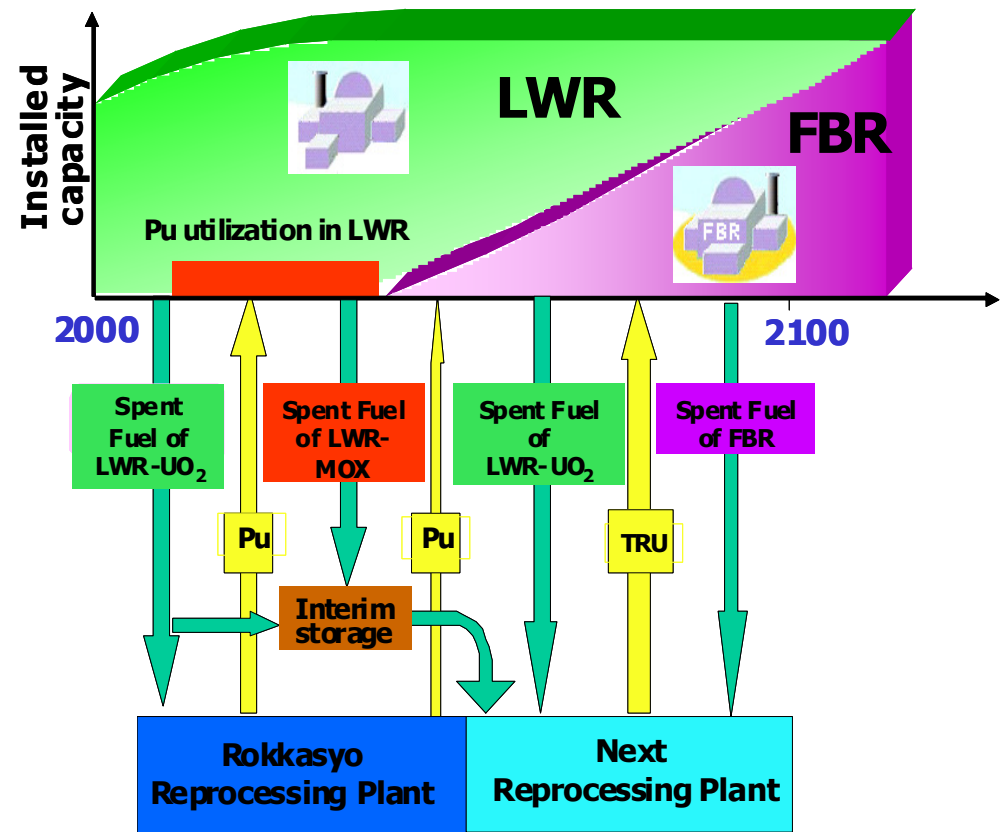


Experimental Reactor "Joyo" Prototype Reactor "Monju"

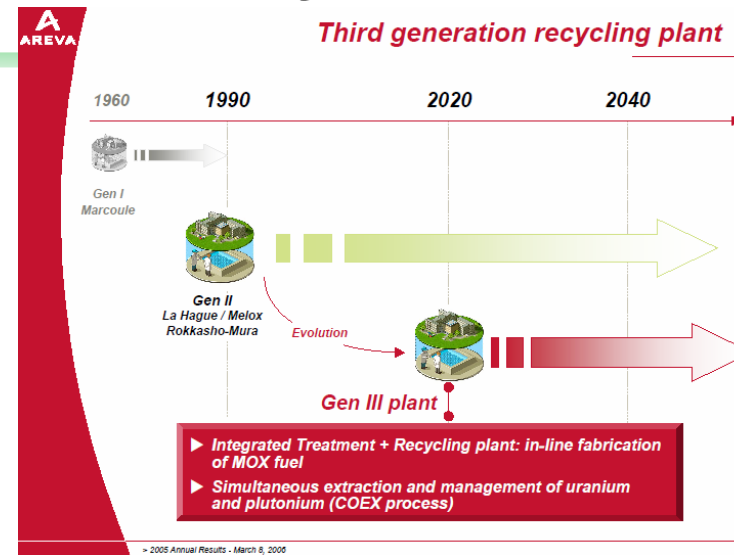
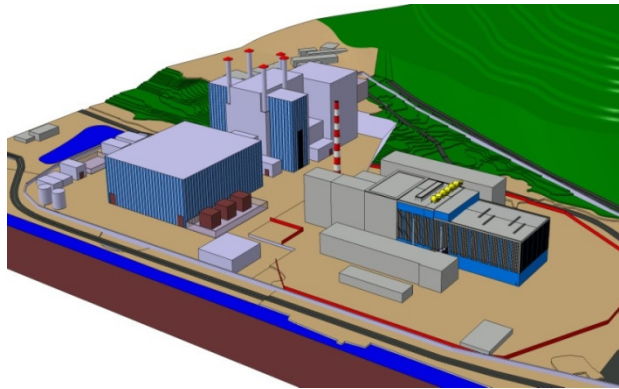
- Smooth transition from LWR cycle to FR cycle
- Five party coordinate council
- FS (1999-2005), Main concept: MOX fueled sodium cooled FR, advanced reprocessing and simplified pelletizing fuel fabrication of MOX
- FaCT (2006-2015, 2010 intermediate evaluation)
- Data from "JOYO" and "MONJU"

Investigation on Transition from LWR cycle to FBR cycle in Japan (by Funasaka)

- The discussion of the next reprocessing plant will be started in the Japan Atomic Energy Commission from around 2010.
- JAEA has been conducting the preliminary study and examination for the transition in cooperation with the related parties.
- For the transition period, it would be necessary to investigate the validity to reprocess all kinds of spent fuel at one plant and optimum process for both a large amount of LWR SF and a small amount of FBR SF.

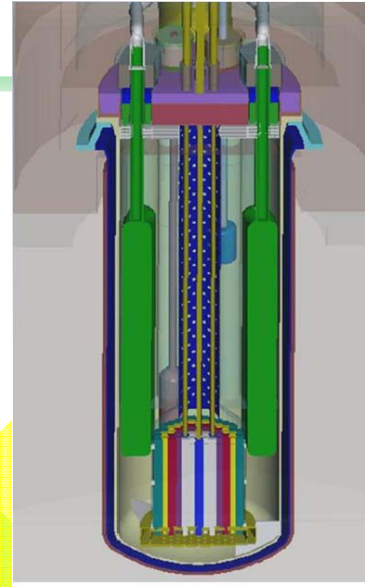


Development Status of France



- Waste management act, 28 June 2006,
- R&D of partitioning and transmutation, decision of fuel cycle technology in 2012
- COEX, DIAMEX-SANEX, GANEX: candidates of recycling technologies
- Consolidated recycling facilities (COEX +mixed fuel fabrication) by 2020
- GANEX , MA burning in Generation IV

Development Status of the U.S.



A concept diagram for an Advanced Burner

High purity uranium oxide product recovered from used nuclear fuel using the UREX+ process



- National energy policy in 2001, development promotion of the nuclear fuel cycle technology and the next generation nuclear power technology, Advanced Fuel Cycle Initiative (AFCI)
- GNEP in 2006
- In 2009, regime change, long-term R&D emphasized
- AFCI still going as an advanced fuel cycle and waste management technology
- R&D of Generation IV reactors

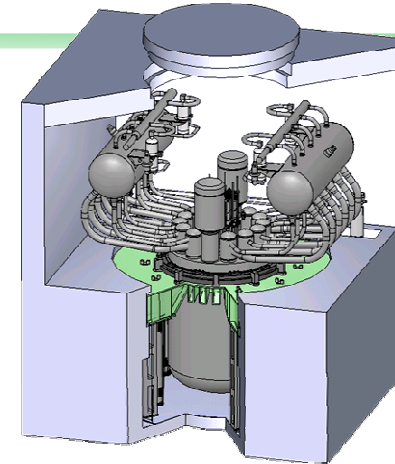
Development Status of Russia



BN-600



BN-800



SVBR-100

- BN-600(UO₂), BN-800 (MOX)
- Experience of Pb and Pb-Bi
- FR cycle with a MOX fuel planned to be completed in 2050
- Electrowinning and vibro-packed fuel fabrication

Development Status of India



-Three stage strategy

(1st :production of Pu by heavy water reactors, 2nd :FR cycle with MOX fuels to produce U-233, 3rd:thorium recycling with advanced heavy water reactors)

-Prototype SFR (PFBR: MOX fuel) in 2011

-After 2020, commercial SFRs with metallic fuels

-Has been developing fuel cycle technologies parallel to reactor development, small-scale hot testing facilities for reprocessing (CORAL)

since 2003, demonstration reprocessing plant (DERO) to reprocess PFBR fuels under construction

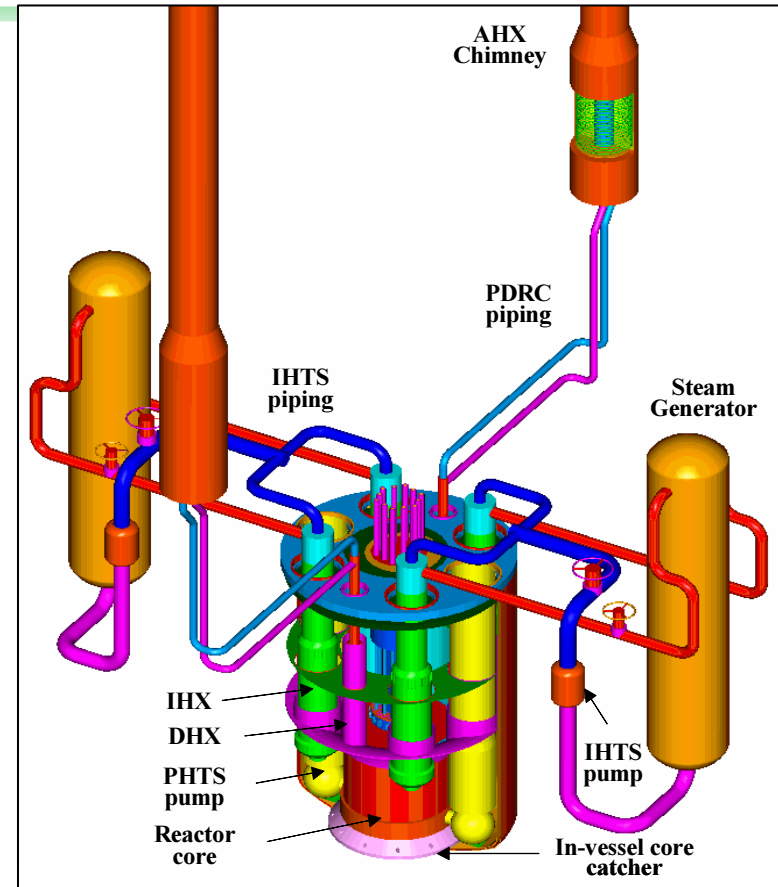
Development Status of China



- CEFR (UO₂, MOX) 2011
- Demonstration SFR with MOX fuel by 2020
- Commercial SFR 2030
- Shift from MOX fuel to metallic fuels
- Developing a pilot scale (2009) and commercial reprocessing plant (2025), and MOX fuel fabrication plant

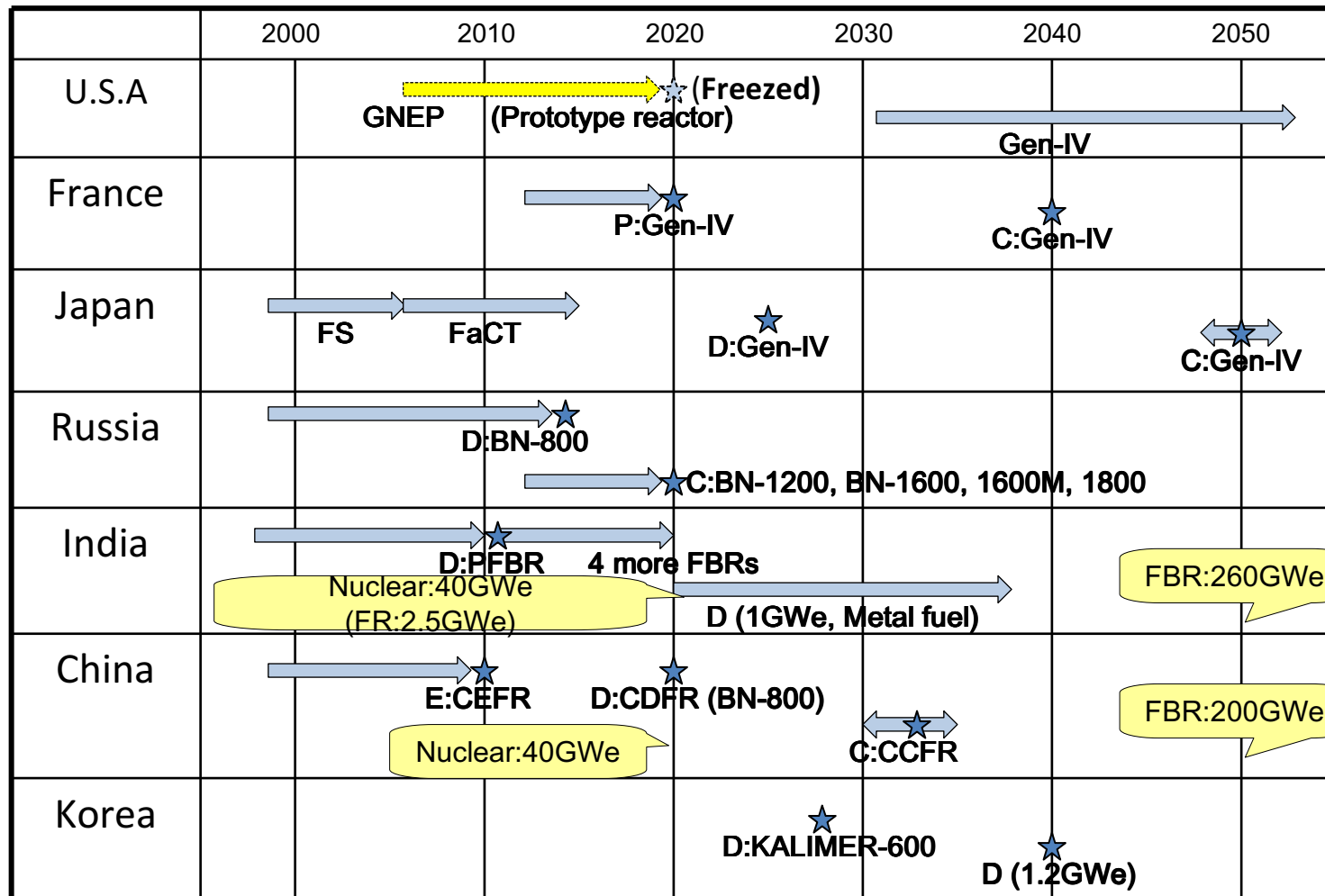
Development Status of Republic of Korea

- SFR (Korea Advanced Liquid Metal Reactors: KARIMER) with metallic fuel has been developed.
- Plan to start operation an engineered demonstration scale reprocessing facility in 2016, prototype (or a commercial scale) dry processing facility in 2025, metallic fuel fabrication facility after 2025



Conceptual design of KARIMER

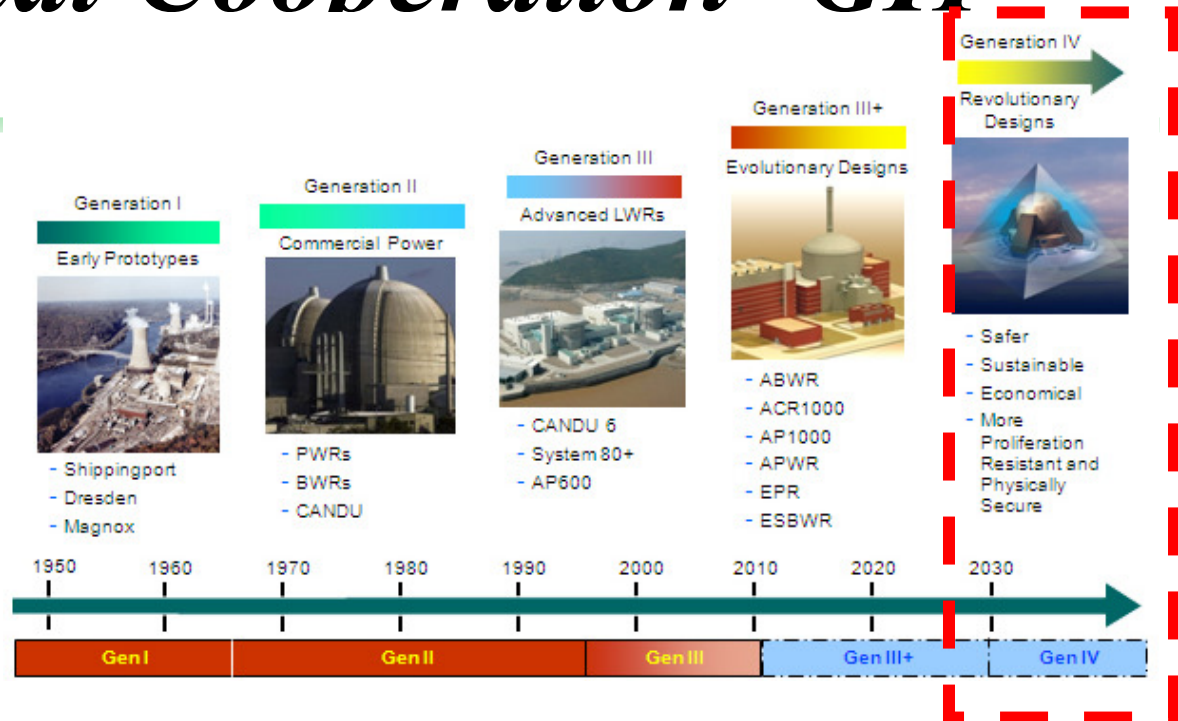
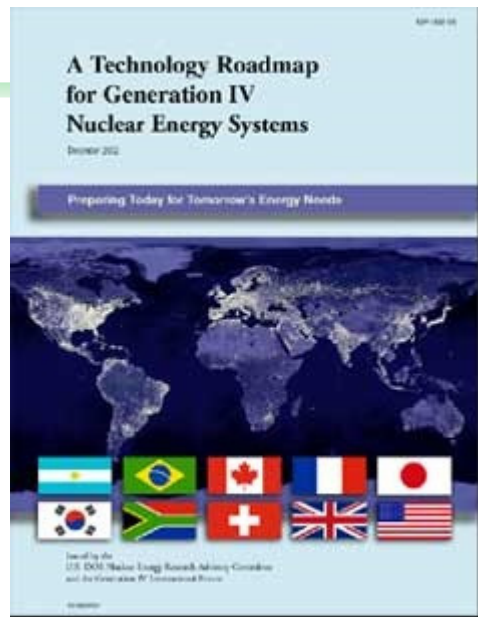
Fast Reactor Development Schedule in each country



E: experimental reactor, P: prototype reactor, D: demonstration reactor, C: commercial reactor

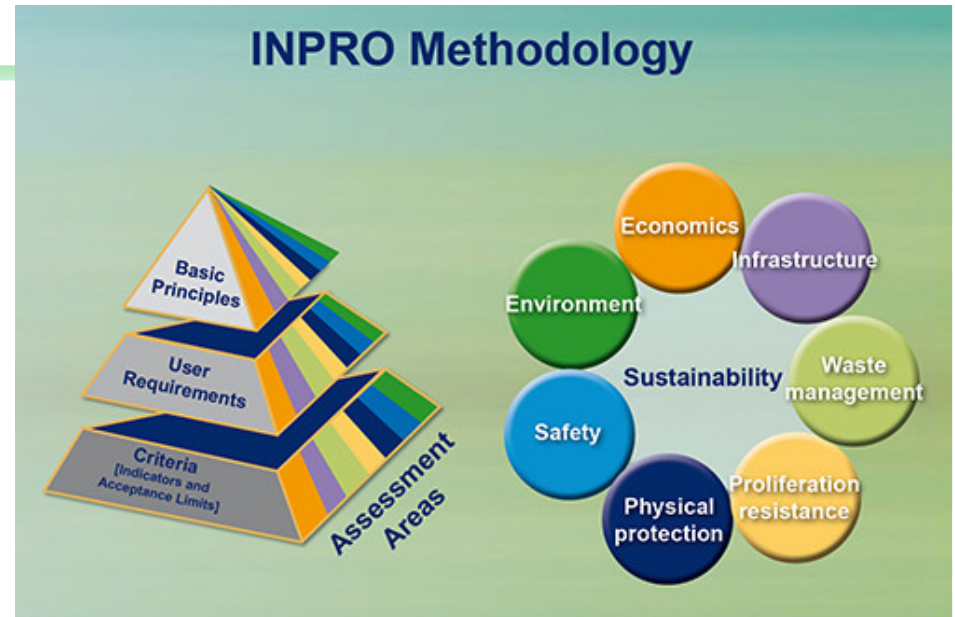
3. Current International Cooperation

International Cooperation -GIF-



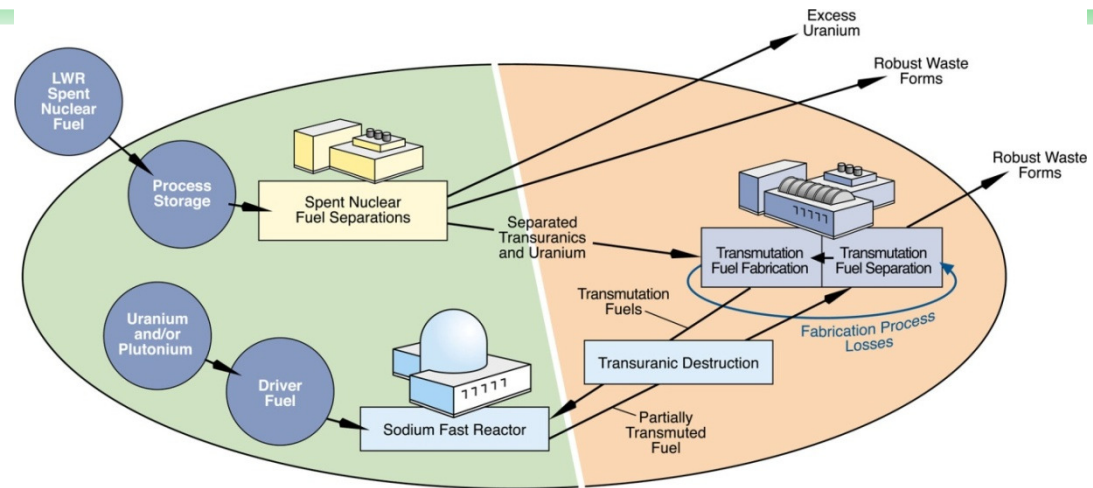
- Formed by DOE for the examination of advanced nuclear power system concepts in 2000
- Development goal: sustainability, economics, safety and reliability, proliferation resistance and physical protection
- Fuel cycle not included
- Global Actinide Cycle International Demonstration (GACID): a cooperation of GIF to develop technologies, irradiation test of MA bearing fuel needs to be carried out by US-France-Japan

International Cooperation -INPRO-



- (1) To help ensure that nuclear energy is available to contribute to meeting the energy needs of the 21st century
- (2) To bring together technology holders and users so that they can consider jointly the international and national actions required for achieving desired innovations in nuclear reactors and fuel cycles. Innovative Nuclear System (INS)

International Cooperation -GNEP-



- Started in 2006
- In 2009, regime change, long-term R&D emphasized
- AFCI still going as an advanced fuel cycle and waste management technology
- Ministerial-level meeting in October 2009: the international cooperation on nuclear infrastructure, the nuclear fuel supply guarantee, the spent fuel management service, etc.

International Cooperation in the future

- International cooperation in a specific region (the culture and the ideas are similar, the influence of distribution etc. is large)
- Political and interdisciplinary mutual collaboration is necessary to promote a sound nuclear energy development
- In Asia and Pacific-basin, more cooperation

FNCA

Forum for Nuclear Cooperation in Asia



4. Strengthening International Cooperation

(1) Common issues

- Safety
- Non-proliferation

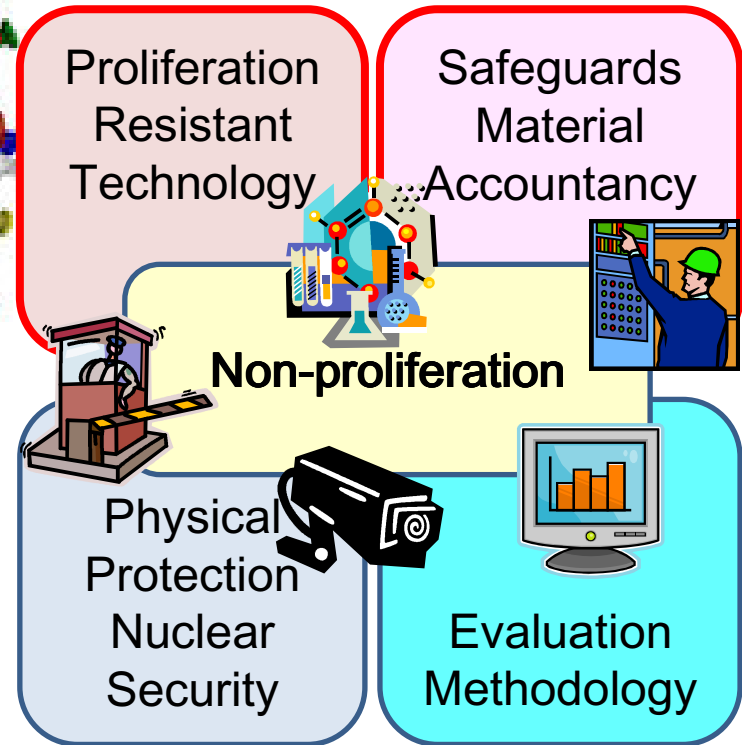
(2) Strengthening international cooperation

Common Issues

Consensus on Safety & Non-proliferation



Deployment of
FR Technol.



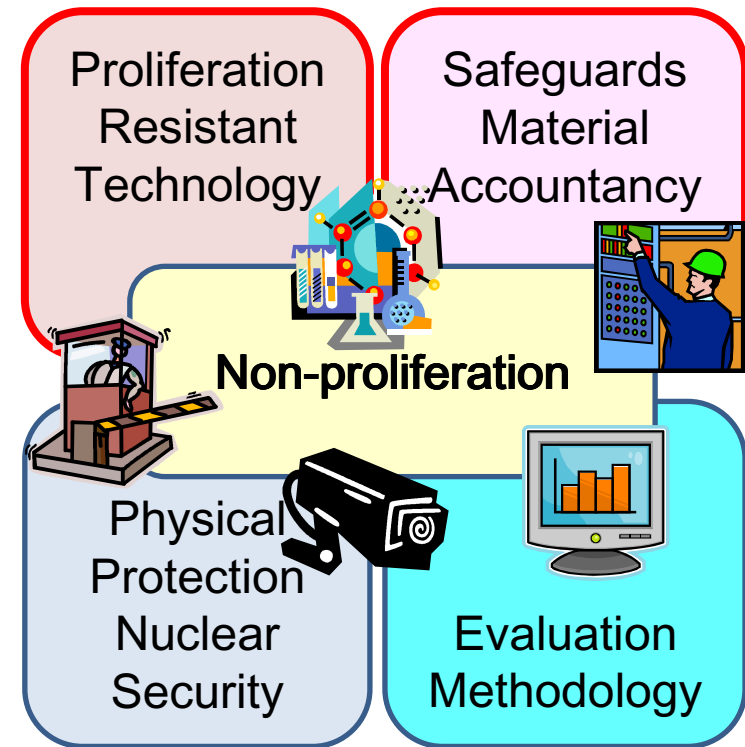
Safety Issues

- Safety is significant, if nuclear accident should occur, the damage might ranges not only public health and environment but also social and political impact.
 - Consensus of safety
 - ✓ Internationally common safety requirement
 - ✓ Harmonization of regulation
 - ✓ Sharing of knowledge on safety
 - Sophisticated SFR concept development toward commercialization
 - ✓ HCDA to be solved – Re-criticality free concept
 - ✓ Mastered Sodium Technology
-

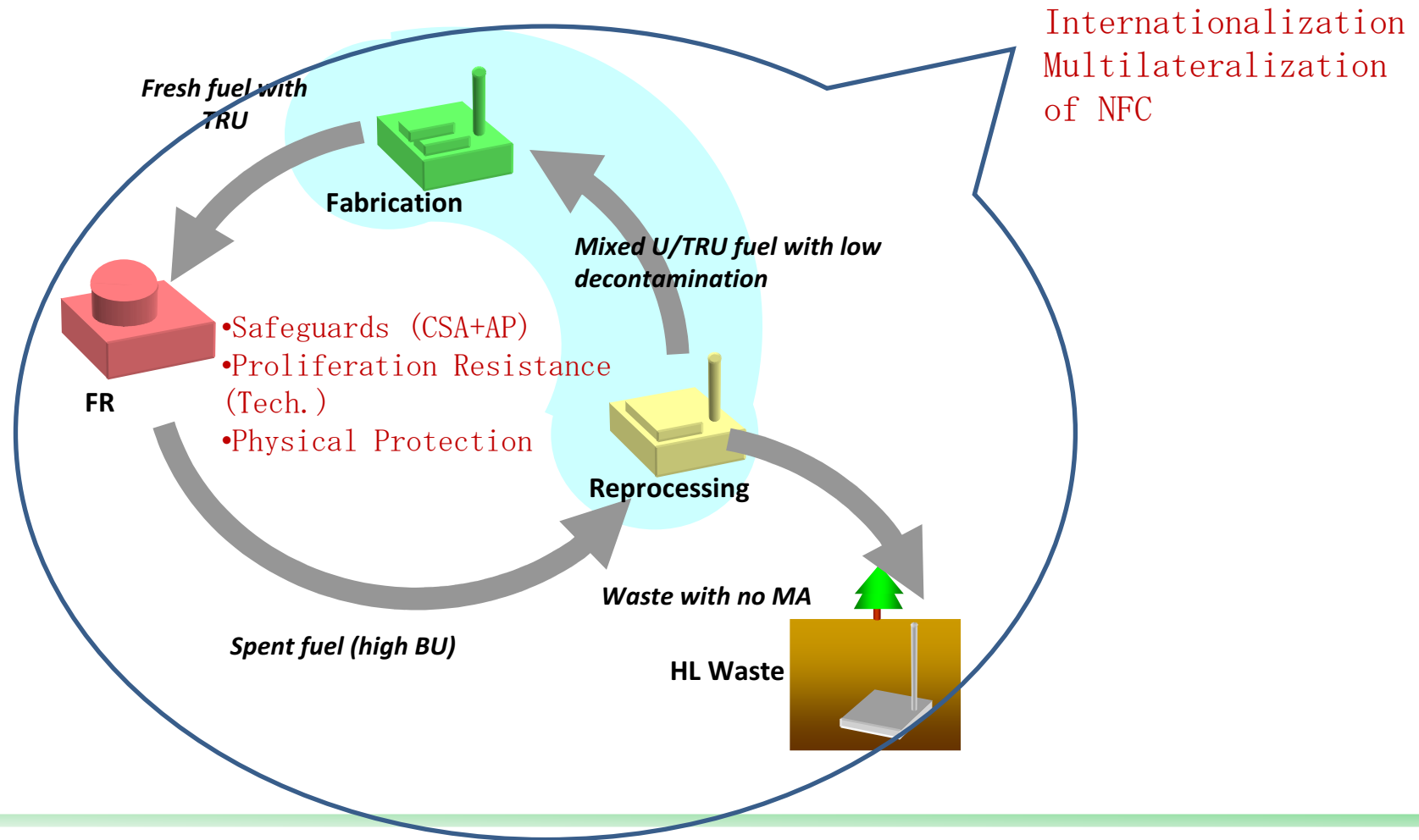
Nuclear Non-proliferation Issues

For Future FR Cycle we need

- sophisticated safeguards concept suitable for a society with lots of fast reactors and fuel cycle facilities with large inventory of plutonium,
- enhancement of intrinsic barrier to prevent pure plutonium separation in reprocessing facilities,
- study of FR core concept with proliferation resistance,
- international consensus about realistic FR cycle systems with proliferation resistance.



Effective Non-proliferation System for FR cycle (by Kuno)



Strengthening of International Cooperation

- Share development goals of idea
 - Supplement the activities among each different country without overlapping
 - The direction of these activities can be brought into one
 - Publish the result and promote the information exchange
-

International Collaboration in Japan (by Funasaka)

Trilateral Collaboration

JAEA - DOE - CEA

“COOPERATION ON SFR DEMO/PROTOTYPES”

Jan.2008 MOU → Aug.2008 revised

Gen-IV International Forum (GIF)

12 countries, 1 organization

SFR

Parties : Japan, France, US, Korea, EU, China, (Russia)

SFR Project (Broad long-term R&D items)

- System Integration and Assessment
- Safety and Operation
- Advanced Fuel
- CD · BOP
- GACID (Japan-France-US)

Cooperation

Cooperation

Information Exchange

JAEA-EDF

Technical Cooperation on the FR Systems (Oct. 2008)

JAEA-CEA

Framework Arrangement (Dec.2005)

Japan-France Collaboration

Fast Reactor WG
Fuel cycle WG etc.

JNEP (US-Japan Joint Nuclear Energy Action plan)

*Missions and Objectives were reviewed in Apr., 2009

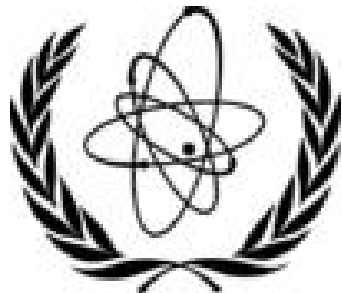
Japan-US Collaboration

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

TWG-FR (Fast Reactor Technology Working group)

IAEA

Effective Utilization of International Organizations, Academic Societies and International Conferences



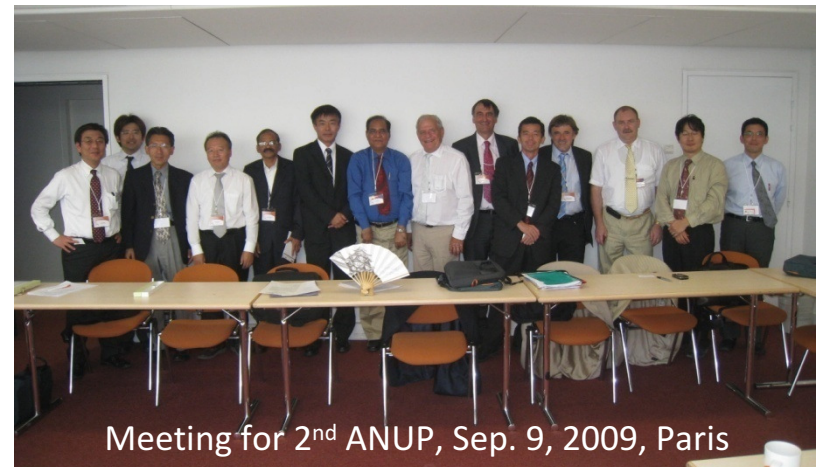
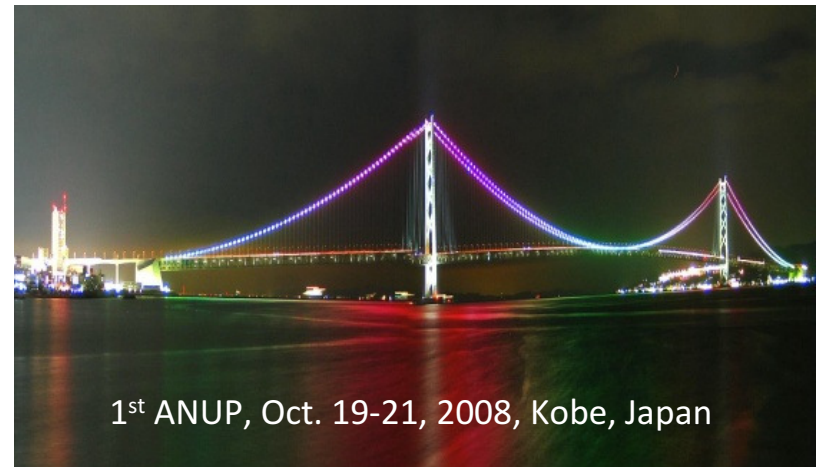
Vitalization of FR Activities in Japan

- Atomic Energy Society of Japan (AESJ) plays a key role in:
 - Fast Reactor Cycle technology development
 - Internal collaboration on FR development
- *Advanced Reactor Division* is to be established under AESJ very soon
 - Generation IV reactor and related fuel cycle technologies
 - Liaison for international collaboration in FR societies abroad
 - Cultivation of human resources and taking over the challenge
 - *Reprocessing and Recycle Division* since 2001

Global 2011, Nagoya

ANUP (Asian Nuclear Prospect) Workshop

- Nuclear energy remarkably increases in Asia, which necessitates the spent fuel management with uranium recycling. The workshop discusses this issue worldwide.
- Human resource is also important and young colleagues participation is welcome.
- 1st ANUP was held at Kobe, Japan in 2008 and 2nd ANUP will be in India in 2010.
- Then the following ANUP will be in China (2012), Korea (2014)...



Importance of human resources development



- By international collaboration
- By collaboration among research institutes, industries and universities
- By public involvement

Conclusions

Recycling strategy of Pu and MA are essential in FR cycle

International cooperation has become more important

- Safety and Non-proliferation: common issues

Strengthening international cooperation

- Specific area
 - Share development goal
 - Promote the information exchange
 - Human resources development
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Thank you
