Proliferation Resistance for Future Nuclear Fuel Cycle

Future Nuclear Energy World

- Nuclear power growth (number of reactors, advanced-reactors, fast reactors etc)
- Needs of nuclear fuel cycles (large scale fuel cycle, Pu recycle)
- Needs to develop safer, more economical systems
- Needs of proliferation-resistant nuclear systems against the increase in nuclear diversion risk

Measures on Proliferation Resistance

JAEA/NPSTC

- Technical Barriers (Intrinsic) as complementary measures;
  - Technical difficulty, Material type barrier

- Institutional Barriers (Extrinsic);
  - International Safeguards

    Comprehensive Safeguards Agreement + Additional Protocol, Bilateral Agreements, Export Control, Security (PP) etc

Proliferation Resistance – Detection : Based on Institutional System

High detection probability by SG and other techniques

- Design information
- Accountability
- C/S
- Detectability of material-diversion / misuse
- Operational transparency
- etc

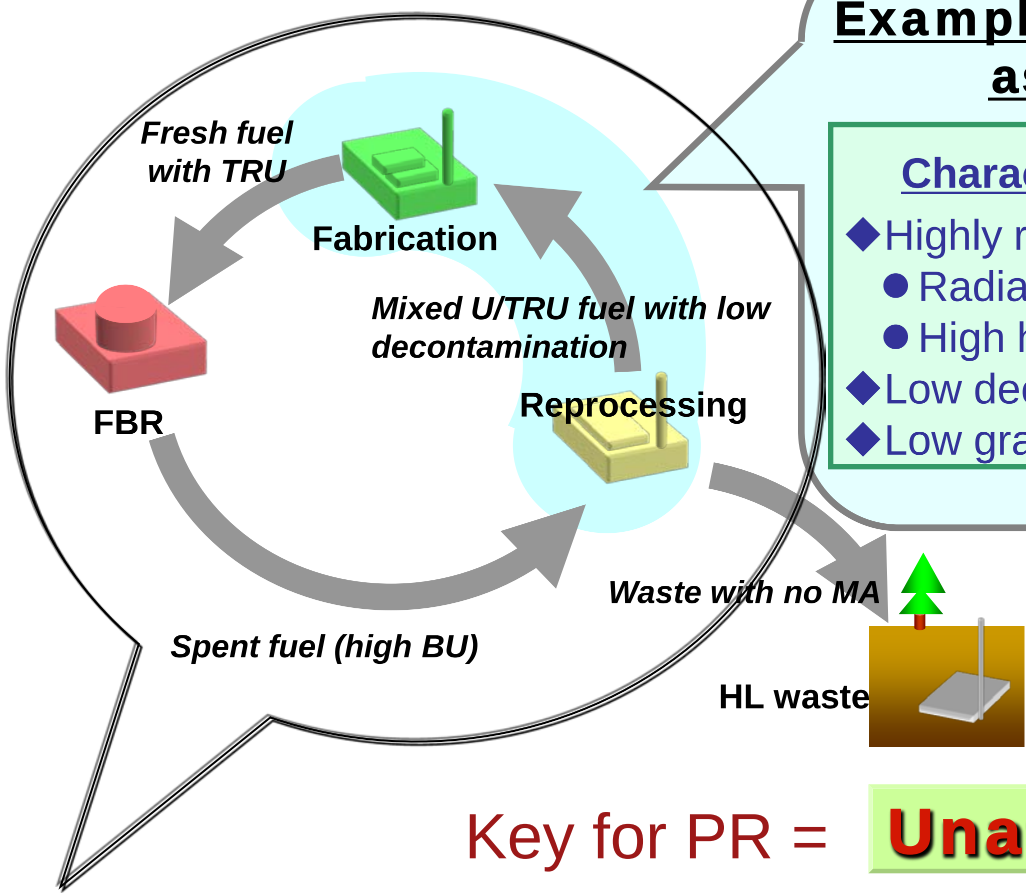
Proliferation Resistance - technical difficulty and Material type

Hard to access / Difficult to handle / Difficult to divert

- Lower Pu Grade (Isotopic Composition)
- High Radiation Dose
- High Heating Rate
- High Neutron Emission Rate
- No pure Pu; Low decontamination (chemical physical property)

Image of Proliferation Resistance (PR) of FR Cycle Fast Reactor Example

JAEA/NPSTC



Safeguards

Example of Proliferation Resistance aspects of the Fuel Cycle

Characteristics

- Highly radioactive
  - Radiation dose
  - High heating rate
- Low decontamination
- Low grade Pu

From PR&PP

- Hard to access
- Difficult to handle
- Difficult to divert

Key for PR = **Unattractive for diversion**

PR Discussion in INFCE (WG4)

- International Nuclear Fuel Cycle Evaluation, proposed by US president, Carter
  - October, 1977 – February, 1980
  - Participants: 66 States and Five International Organization
  - The first and the largest international discussion for nonproliferation of nuclear fuel cycle
- The relative PR of the different fuel cycles (Once-through, Pu recycle)
  - No single judgment can be made that is valid both now and for the future
- Assessment of Alternative Technologies
  - Alternative technology - Measures to reduce the risk of diversion

    (i) Methods of reduce the presence of Pu in the fuel cycle in separated form
    Colocation, Storage and Transport of Pu as MOX, Co-conversion, Co-processing

    (ii) Measures to use radioactivity to protect Pu from proliferation
    Pre-irradiation, Spiking, Partial Processing

    (iii) Measures to protect Pu by the use of physical barriers
- Alternative Assessment
  - Technical measures have a powerful influence on reducing the risk of theft but only a limited influence on reducing the risk of proliferation (by states).
  - Safeguards measures are more important than the technical measures.

PR & PP Methodology Features

Project	For What? (Purpose or Usage)	For Whom (Users)	By Whom (Developers)
INPRO	Better nuclear systems, Implementing better SG	Policy makers, Designers Inspectorate	Designers, Inspectors
Gen IV PRPP	Better nuclear systems, Implementing better SG, Choosing System, Export control, Public communication Tool	Policy makers, Designers	Group by different expertise
French PRPP	SG improvement, Select best nuclear system, Help designers, Public communication tool Detect weak points for system modification	Stakeholders (Decision makers, Public)	Designers
US AFCI	Diversion Theft	States Terrorist or Sub-national	Proliferation of nuclear weapons
Japan FS	Diversion, Misuse, Theft	States Sub-national	Nuclear weapons, Nuclear explosives, Other measures to do harm, Sabotage

Como Meeting in 2002 (STR-332)

- Sponsored by IAEA, October 2002
- STR-332, "Proliferation Resistance Fundamentals for Future Nuclear Energy Systems"
  - Participants: Argentina, Brazil, Canada, France, Germany, Italy, Korea, Russia, USA, IAEA
- Definition of Proliferation Resistance
  - Characteristics of a nuclear energy system that impedes the diversion or undeclared production of nuclear material, or misuse of technology, by States in order to acquire nuclear weapon or other nuclear explosive devices.
  - The degree of proliferation resistance results from a combination of technical design features, operational modalities, institutional arrangements and safeguards measures.
- Fundamentals of Proliferation Resistance
  - PR will be most cost effective when an optimal combination of intrinsic features and extrinsic measures, compatible with other design considerations, can be included in a nuclear system.
  - PR will be enhanced when taken into account as early as possible in the design and development of a nuclear system.
  - Effective use of intrinsic PR features facilitates efficient applications of extrinsic measures.
  - Extrinsic PR measures, such as control and verification measures, will remain essential, whatever the level of effectiveness of intrinsic features.
  - From a PR point of view, development and implementation of intrinsic features should be encouraged.

Structure of Terminology

JAEA/NPSTC

- Nuclear Nonproliferation
  - **Proliferation Resistance** — **Threat by (Host) State** (Diversion, Undeclared production of nuclear materials, Misuse of technology)
    - Intrinsic Features/Barriers — Resulting from the technical design incl. the features that facilitate the implementation of extrinsic measures
      - Material Barriers — Ex. Isotopic, Chemical, Radiological, etc.
      - Technical Barriers — Ex. Accessibility unattractiveness, Facility accessibility, Skill, expertise and knowledge, etc.
    - Extrinsic Measures/Barriers — Resulting from State's decisions and undertakings
      - Institutional Barriers — Ex. **Safeguards**, Additional Protocol, Export control, Bilateral nuclear agreement,
  - Physical Protection — **Threat by Sub-national groups** (Ex. Theft, RDD, sabotage)
- Nuclear Security — **Threat by Sub-national groups**
  - Physical Protection
  - Protection of Other Radioisotopes

IAEA GC(49)/17）: The prevention and detection of and response to, theft, sabotage, unauthorized access, illegal transfer or other malicious acts involving nuclear material, other radioactive substances or their associated facilities

Proliferation Resistance Measures to be considered

INPRO

- States' Commitments（UR 1）
- Attractiveness of NM and Technology（UR 2）
- Difficulty and Detectability of Diversion（UR 3）
- Multiple Barriers（UR 4）
- Optimization of design（UR 5）

GEN IV

- Technical Difficulty（TD）
- Proliferation Costs（PC）
- Detection Probability（PT）
- Material Type（MT）
- Detection Probability（DP）
- Detection Resource（DR）

Cooperation between Designers and NP Experts

- JAEA has recently started joint study for PR of future nuclear fuel cycle
  - Mutual understandings have been established.
    - System Designers understand PR features and fundamentals.
    - Safeguards experts have identified the challenges.
    - PR analysts understand those integrations and design features.
    - Established the basis for collaborative study to enhance PR of future nuclear fuel cycle

- Importance of Collaborative Study between System Designers and NP/SG/PR Experts, international manner
  - Mutual understanding among different expertise
  - Building International consensus/Fundamentals/Standard/Criteria/Guideline

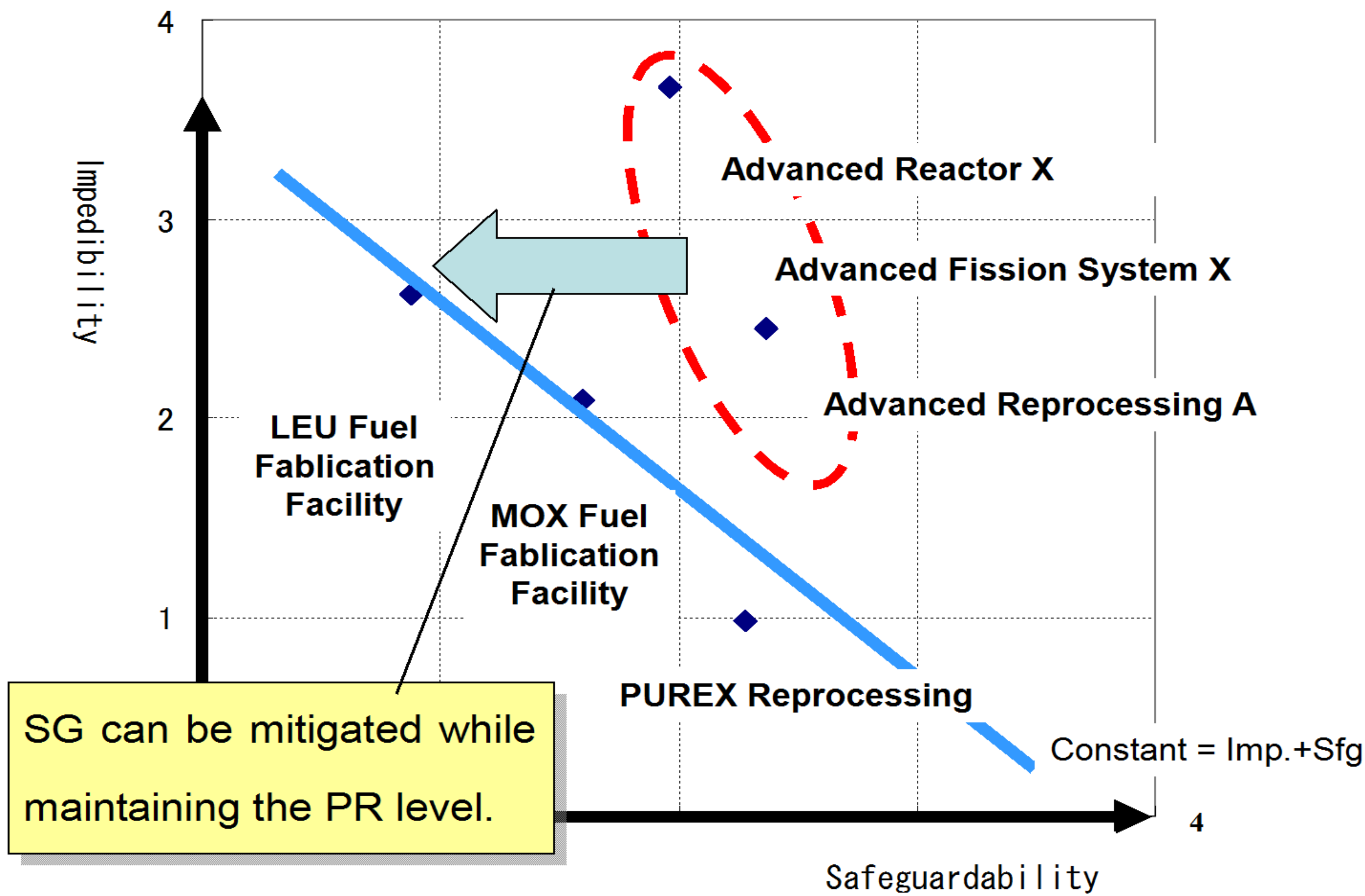


Figure -3 Examples of aggregation of typical types of facility

M.Kikuchi, presented at JAEA-IAEA WS, Nov 2007