JAEA's Efforts on Safeguards for Reprocessing Facilities in the Present and Future

Mitsutoshi SUZUKI

Nuclear Nonproliferation Science and Technology Center (NPSTC),
Japan Atomic Energy Agency (JAEA)

Outline

- Brief overview of JAEA
- History and present status of SG system in Tokai Reprocessing Plant (TRP)
- Integrated Safeguards (IS) in JNC-1 site
- FaCT project in JAEA
- Future safeguards for reprocessing facilities
- Several R&D in safeguards technologies
- Conclusions

Location of JAEA Institutes

Tsuruga (Staff: 382)
Prototype FBR "Monju", Decommissioning of ATR "Fugen"

Horonobe (Staff:33)
High level radioactive waste research

Mutsu (Staff: 23)
Decommissioning of nuclear ship

Tono (Staff: 74)
High level radioactive waste research

Ningyo-toge (Staff: 96)
Decommissioning of U enrichment plants

Tokai (Staff: 2,040)
Basic research, safety studies, neutron Science, nuclear fuel cycle technologies, radioactive waste management and disposal, etc.

O-arai (Staff: 663)
Experimental FR "Joyo", HTTR and JMTR, advanced reactor R&D including FBR cycle commercialization

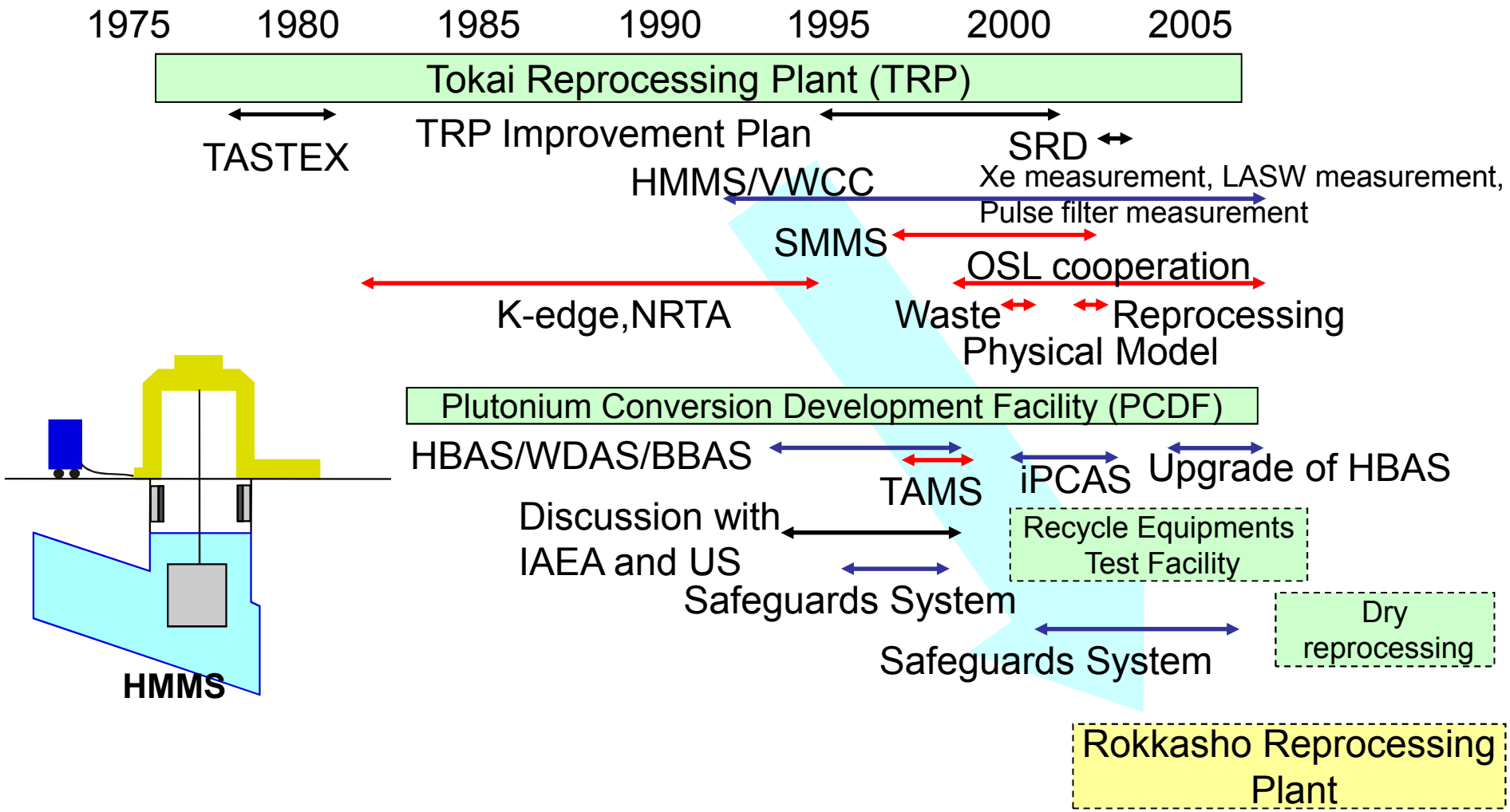
Kansai (Staff: 114)
Photon & Synchrotron Radiation Science

Takasaki (Staff: 132)
Radiation application

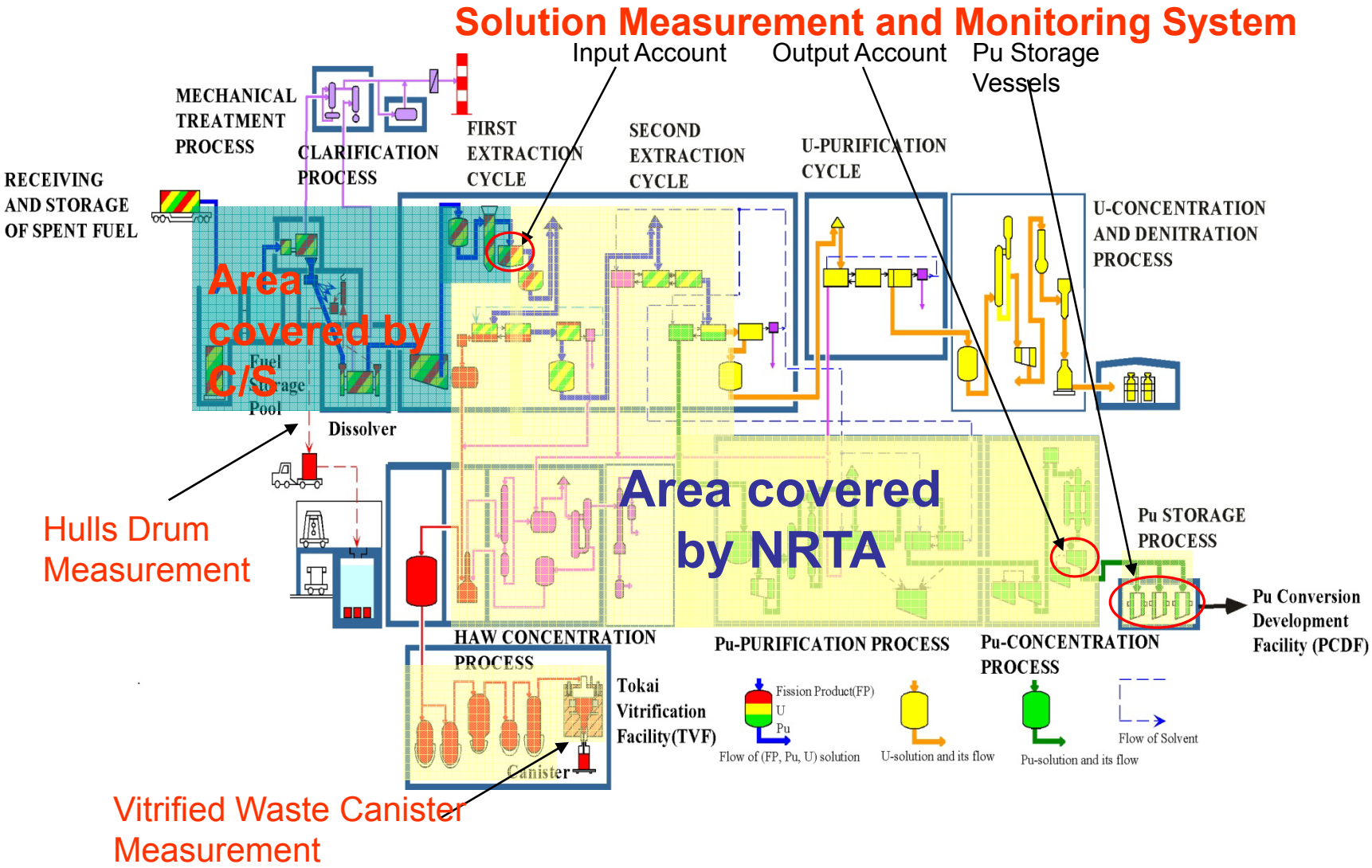
Naka (Staff: 279)
Fusion R&D, ITER support

Headquarters: Tokai
Overseas Branches: Washington DC (USA), Paris (France), Vienna (Austria)

History of Development SG System for Tokai Reprocessing Plant (TRP)



Unattended Verification and Monitoring System at TRP



Integrated Safeguards for JNC-1

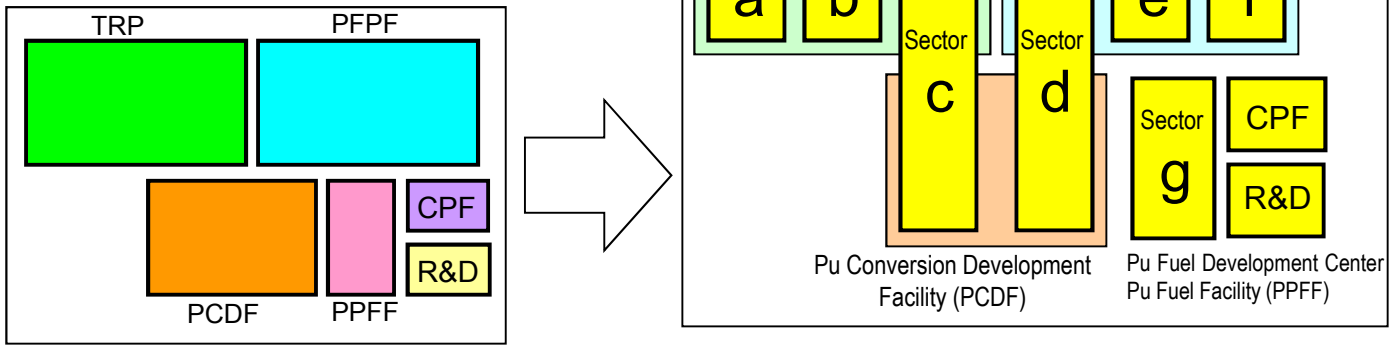
Site-level integrated safeguards were introduced to the Nuclear Fuel Cycle Engineering Laboratories (JNC-1) in August 2008.

Contributed to the implementation of effective and efficient IAEA safeguards at sites having important and/or large-scale facilities that was a first in the world. The application of integrated safeguards would allow the number of the IAEA Person-Day of Inspection (PDI) to be reduced by approximately one third.

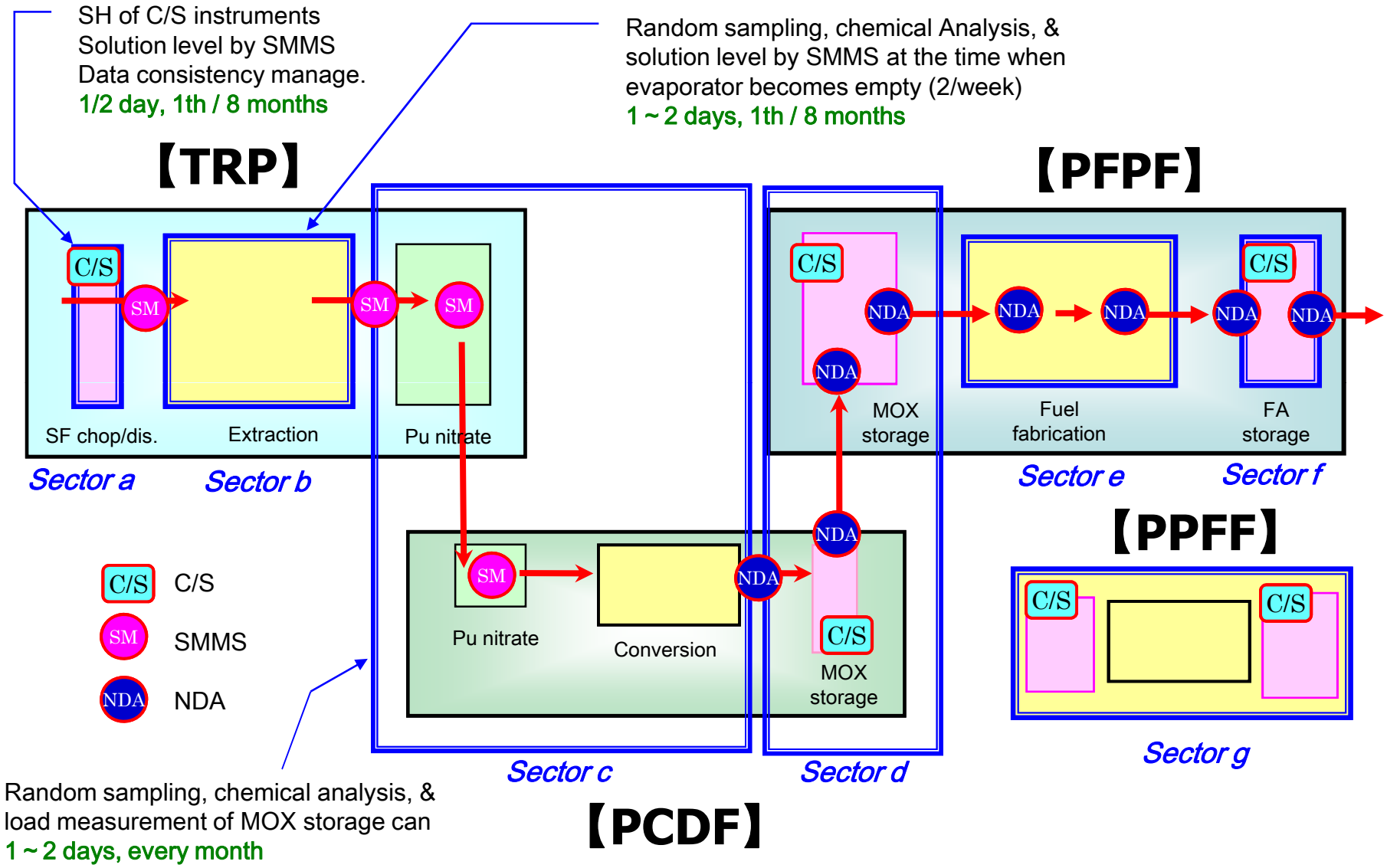
- The four facilities of TRP, PCDF, PFPF and PPFF were divided into seven Sectors (a-g) based on the physical and chemical form of the nuclear materials handled in their facilities
- Introduction of random inspections for those sectors
- Introduction of remote monitoring technologies
- Frequent provision of facility information

JNC-1: Nuclear Fuel Cycle Engineering Laboratories
JNC-2: O-arai R&D center South Area
JNC-4: Monju

National government's current schedule of IS implementation:
JNC-2: in January of 2010
JNC-4: in October of 2009



Sectors under IS for JNC-1



Framework of Bilateral Cooperation for SG Tech. Development

- <u>JASPAS</u> (Japan Support Program for the Agency)
  1981-- State Level Support Program for IAEA SG Technology
  SG System/Approach, Measurement Technique, C/S, Training, Cost Free Expert
  Approx. 60% of 92 tasks (97 tasks incl. sub tasks) were done by JAEA and its predecessors (As for 2008)

- <u>JAEA/DOE SG Cooperation Agreement</u>
  (← PNC/JNC/JAERI-DOE Coop. Agreement)
  1988-- Cooperation for SG technology development between JNC/DOE
  Total 96 programs (107 items) (As of June, 2009)

- <u>Cooperation with EU</u>
  1990-- Cooperation with JAERI
  2006-- Amendment and expansion of cooperation area

FBR Development Strategy in Japan

✓ Verification of operation reliability
✓ Establish sodium handling and innovative technology

Commercialized FBR

Commercialized fuel cycle facility

1999 Feasibility Study
✓ R&D on feasibility of candidate concepts
✓ Clarification on candidate concepts

Feasibility Study (FS) on Commercialized Fast Reactor Cycle Systems

Fast Reactor Cycle Technology Development (FaCT) Project

2006 FaCT Project
✓ Study on conceptual design
✓ Development of innovative technology

2015
✓ R&D plan for commercialization
✓ Conceptual design of economically competitive FBR

Demonstration Phase

Around 2025
Demonstration reactor comes true for verification of economical competitiveness

Before 2050
Development of commercialized FBR

Challenges for Future Reprocessing Facilities

- **Fuel cycle challenges**
  - ✓ Five goals; economy, safety, resource-utilization, waste management and nonproliferation.
  - ✓ Large throughput Pu and highly proliferation-resistant fuel cycle

- **Safeguards challenges**
  - ✓ Direct measurement of Pu by NDA at the spent fuel receipts to resolve shipper/receiver differences.
  - ✓ Process monitoring with on-line measuring techniques to respond timely verification of location and movement of nuclear material even in a large throughput facilities.
  - ✓ Increased utilization of the joint use of equipment with assuring authentication as well as early involvement of stakeholders into "Safeguards by Design" approach.
  - ✓ Harsh environment of high gamma and neutron background due to an advanced reprocessing process.

US-Japan Technology Development Cooperation of Nuclear Measurement & Detection

JAPAN

- **World-top-level technology holder of an elemental technology**
  - ✓ Original strong and monochromatic gamma source with accelerator and laser
  - ✓ Distinguished and leading technology of multiple photon ionization analysis
- **Unique country developing large and full-scale nuclear fuel cycle as non-nuclear weapon state**
  - ✓ Lessons-learned and experience from long compliance of the IAEA safeguards
  - ✓ Safeguards Technology for large reprocessing (US does not have)
  - ✓ Appropriate test-bed for demonstration test （US does not have）

USA

- **High-level technology holder of overall nuclear security field**
- **Plenty of knowledge and experience in nuclear security as nuclear weapon state**

TD Coop. Nuclear Measurement & Detection

1 . Direct measurement of Pu in spent fuel using NDA technology

- Typical technology is nuclear resonance gamma measurement with laser-compton gamma rays
- Reliable implementation of IAEA safeguards on spent fuels increasing in world-wide
- Demonstration test at nuclear facilities in Japan (TRP)

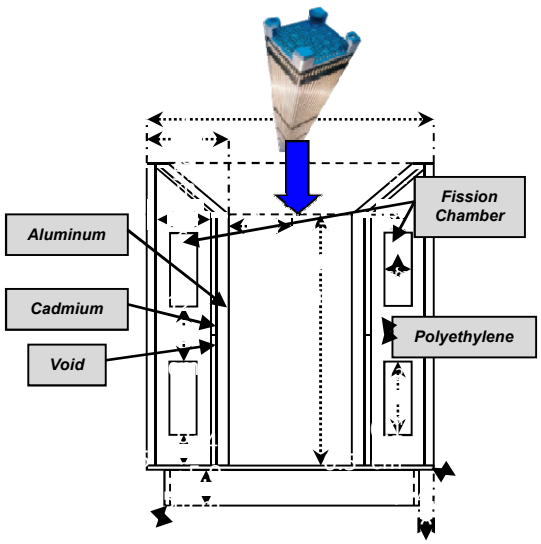
2 . Monitoring technology of Pu in nuclear fuel cycle process

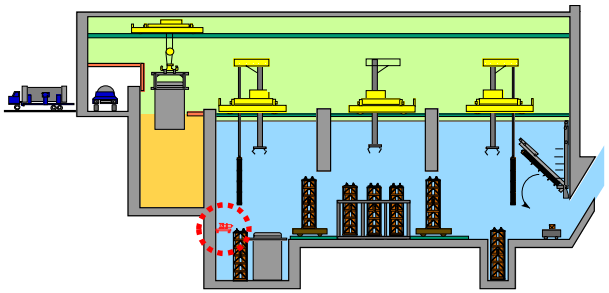
- Laser-induced breakdown spec. (LIBS) / Ablation ionization resonance spec. (AIRS)
- Weak-gamma & high resolution Pu measurement tech. with superconducting phase transition edge sensor (TES)
- Precise & accurate measurement of Pu in reprocessing and fuel fabrication process

Direct measurement of Pu using advanced NDA and LCS-gamma

- Passive Neutron Albedo Reactivity （PNAR) and Self-integration Neutron Resonance Densitometry (SINRD) are planning to be developed by LANL and these equipments will be placed to measure mass and isotopic ratio of Pu in Fugen spent fuel in Tokai Reprocessing Plant (TRP).
- Nuclear Resonance Fluorescence (NRF) with strong gamma rays generated by Laser Compton Scattering (LCS) is possible technology and this is being investigated to the possibility by both countries with NRF performance simulation.

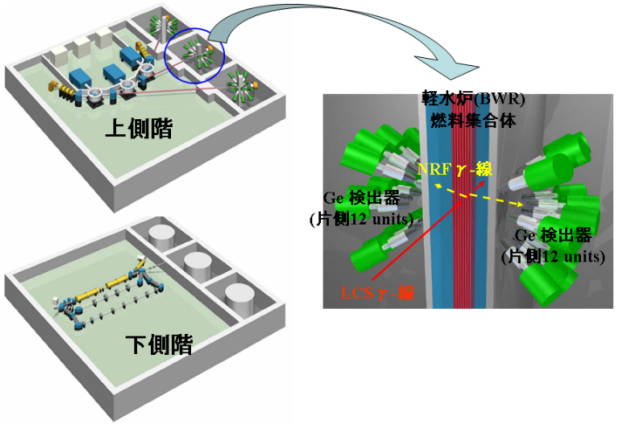
Conceptual diagram of PNAR





Test bench in the TRP pool

Conceptual layout of NRF/LCSγ



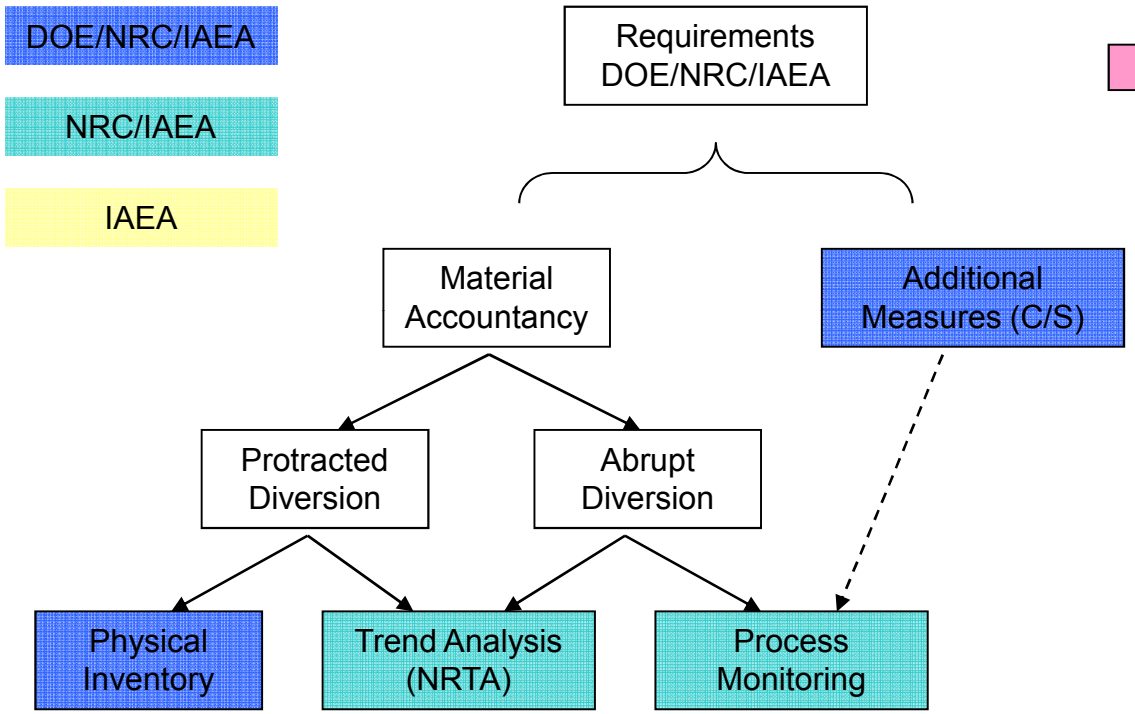
U· Pu-Acidity Real-Time Monitor

- Combination of Voltammetry + Density (+ Conductivity) provides concentrations of U/Pu/H^+.
- Voltammetry is composed of 3 Pt (or 1 Au or glassy carbon) electrodes only – maintenance-free, easy calibration.
- Maintenance free and long life time
- Accuracy/precision is expected a few % (<10%).
- Can be applied for many process solutions.

(Pt/Au Electrodes & Ultrasonic Sensor)

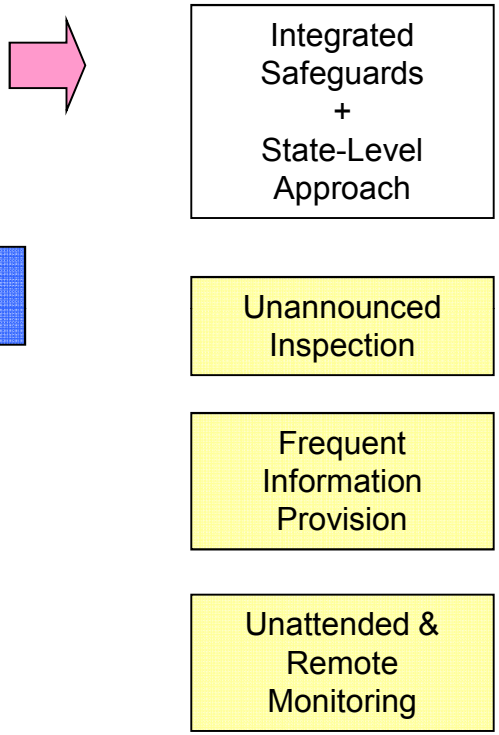
Measurement Modules

International & US Domestic SG Requirements



Advanced Process Monitoring

M. C. Miller, et al, "Safeguards Research and Technology Development for GNEP", *INMM 49th.*, (2008).

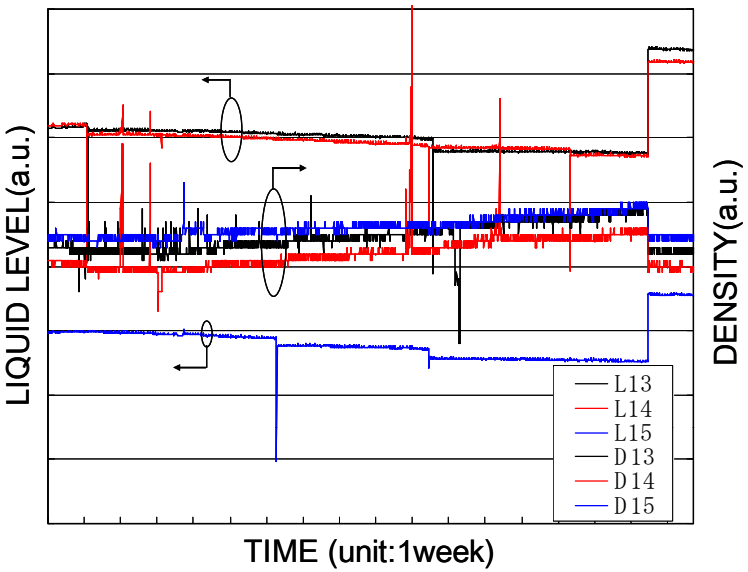


Increased Credibility

Advanced Process Monitoring

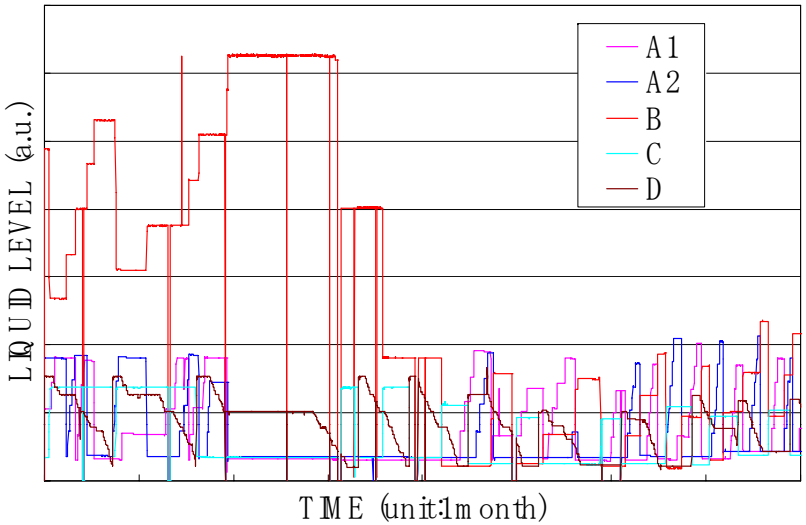
- **Simulation and modeling with proliferation pathway analysis** introduces a **risk-informed alarm rules** and sensor response is compared to self-authenticated process monitoring (PM).
- **Multivariate statistical analysis with historical data** is used to construct **false alarm rules** and generates the notion of **safeguards envelope**.
- **Quantification of PM** will be pursued to become **substitute** of traditional safeguards measures, NMA, Trend Analysis, C/S, and so on.
- **Comparative study on application of PM** with the IAEA safeguards criteria is important to enhance developing FaCT project as well as to support effective and efficient IAEA safeguards.

Demonstration of Tank Monitoring Algorithm



TRP Tank Data

Level and density tank data of tank no. 13, 14, and 15 without the solution transfer. According to the level decrease due to evaporation, the density increase gradually.



SRS Tank Data

Level tank data of tank A1, A2, B, C, and D. The solution in the tank A1 and A2 is transferred to the tank B alternately. The tank B and C operate in batch mode, but the tank D sends the solution continuously.

- In order to demonstrate the benefit of PM application, the LDT tank data from TRP and SRS are evaluated to estimate a detection probability for abrupt and protract loss with sparging, evaporation and other noise.
- Multivariate statistical analysis and precise change detection could enhance cross evaluation with the NRTA and quantified SMMS tank data.

Conclusion -Future Perspectives-

- JAEA has long been developing reliable and effective safeguards systems for nuclear fuel cycle facilities through int'l cooperation ,US ,IAEA, EU, other countries.
- JAEA's experiences and knowledge accumulated through R&D for peaceful use of nuclear energy are very important examples for IAEA promoting of int'l safeguards
- JAEA will continue the proactive efforts of contributions through safeguards technology development
  - Advanced safeguards and for the current and next generation nuclear energy system through int'l cooperation
  - Proliferation resistant technology installment from the early stage of design
- Promoting the Nonproliferation, Security, Safety and Further effective and efficient Safeguards by the synergy of "3S"

JAEA/NPSTC