Experiences of Safeguards Technology Development in JAEA

International Symposium on Technology Development for Nuclear Nonproliferation and Nuclear Security

Jiji press Hall, Tokyo

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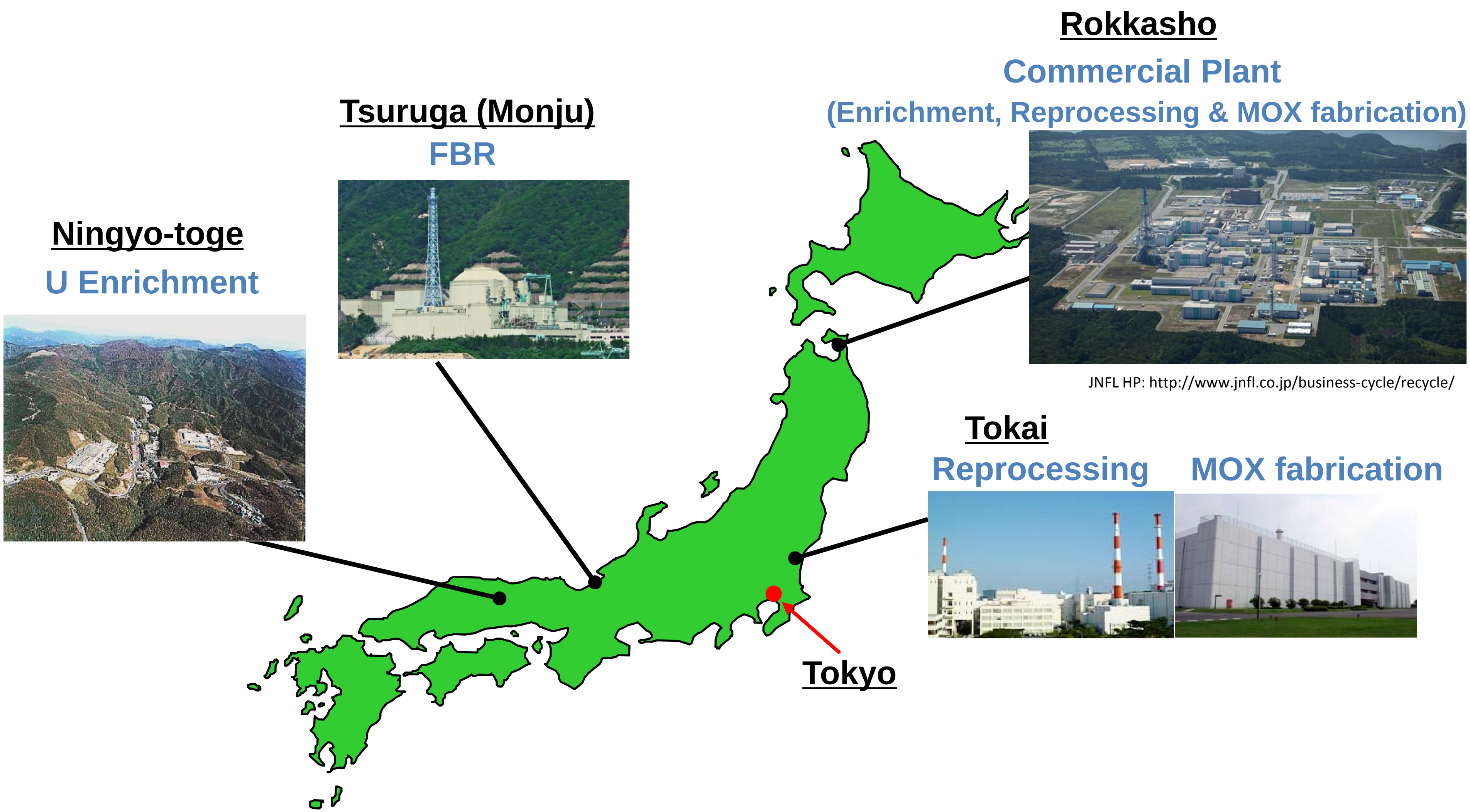
Japan Atomic Energy Agency

Nuclear Fuel Cycle Facilities in Japan



Contents

1. SG technology development for Nuclear fuel cycle facilities owned by JAEA
   - Enrichment Plant
   - Reprocessing Plant
   - MOX fuel fabrication Facility
   - Fast Breeder Reactor

2. Recent research using innovative technology
   - NDA development program subsidized by MEXT
   - Neutron Detector alternative to He-3

SG for Centrifuge
Uranium Enrichment Facilities

1975 1980 1985 1990 1995 2000 2005

Ningyo-toge Pilot Plant / Enrichment Engineering Facility

1979-1989	Operation of OP-1A,1B, 2
1993-1997	Operation of high performance GC
2000-	GC Dismantling activities

Ningyo-toge Demonstration Plant

1988-2001 DOP-1 (100tSWU/y)
1989-1999 DOP-2 (100tSWU/y)

HSP

FA

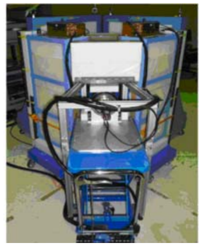
Pipe Enrichment Monitor

In-line Enrichment Monitor

Sample Bottle Enrichment Monitor

PNUH

NWAS



Rokkasho Enrichment Plant

Hexapartite Safeguards Project

In 1979, Japan, Troika (UK, West Germany, Netherland), Australia, USA, IAEA and Euratom established the Hexapartite Safeguards Project (HSP) to discuss safeguards approach for centrifuge uranium enrichment plant up to 1000tSWU/year.

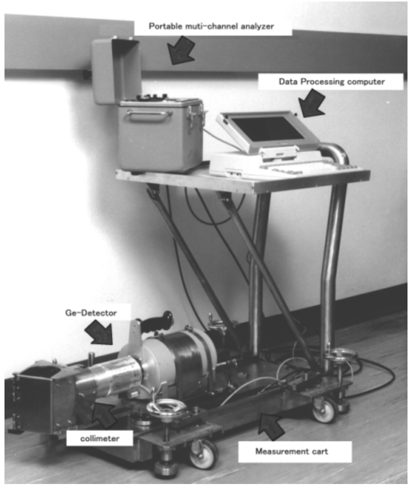
Main Inspection activities

- Verification of the declaration for NM process flow and inventory
- Verification of the declared enrichment range (e.g. 4-5%) of the product

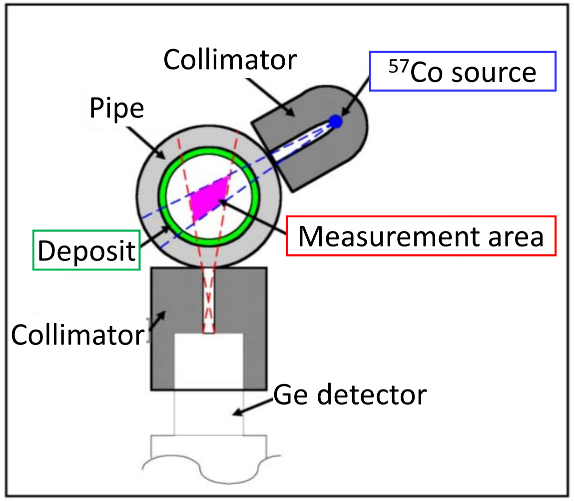
HSP concluded the maximum enrichment could be achieved by **LFUA** (Limited Frequency Unannounced Access).

Safeguards R&D at NEP

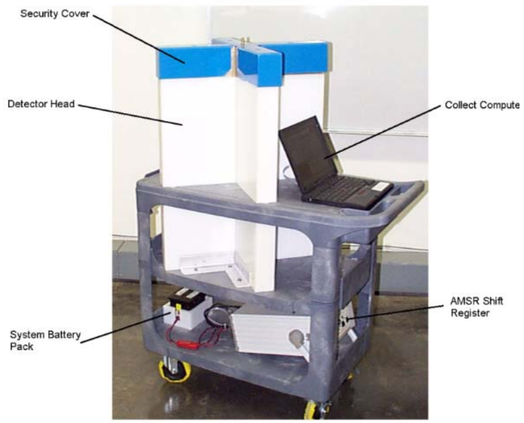
Development of pipe enrichment monitor, in-line enrichment monitor and sample bottle enrichment monitor under Japan Support Program for Agency Safeguards (JASPAS)



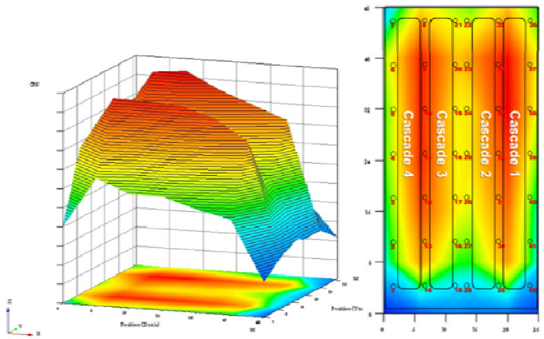
Pipe enrichment monitor



Development of Portable Neutron Uranium Holdup Counter (PNUH) to determine the quantity of uranium holdup within the Gas Centrifuges Cascade Halls.

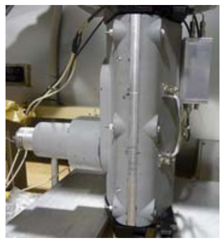


PNUH



Neutron survey data in a cascade hall (before holdup recovery)

The Advanced Enriched Monitor, which can estimate the enrichment of wall deposits and has unattended safeguards capabilities, is under testing and evaluation.



SG for Reprocessing Plant

1975 1980 1985 1990 1995 2000 2005

Tokai Reprocessing Plant (TRP)

TASTEX

TRP Improvement Plan

SRD

HMMS/VWCC

LASW measurement,
Pulse filter measurement

SMMS

K-edge、NRTA

OSL cooperation

Plutonium Conversion Development Facility (PCDF)

HBAS/WDAS/BBAS

TAMS

iPCAS

Upgrade of HBAS

Discussion with
IAEA and US

Safeguards System

Safeguards System

LASCAR

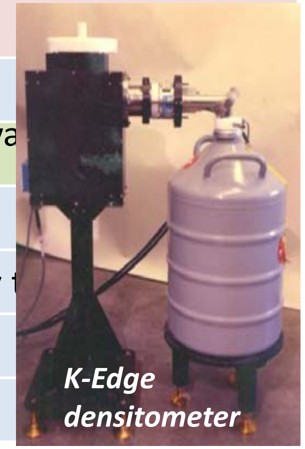
Rokkasho Reprocessing Plant

TASTEX (Tokai Advanced Safeguards Technique Exercise)

- **TASTEX was conducted from 1978 to1981 as a collaborative project by Japan, USA, France and IAEA following the US-Japan joint statement for the reprocessing in 1977.**
- **Their results were provided INFCE (International Fuel cycle Evaluation: 1977-1980) and some tasks were continued under Japan Support program for IAEA.**

TASTEX :13 tasks

	Task	Contents
A	**Surveillance measures at the spent fuel receiving area**	Surveillance camera, Underwater camera, Crane monitor
B	γ-scanning for spent fuel	Burnup estimation
C	Hulls monitoring system	Measurement for adhered nuclear material
D	Load-cell system	Solution weight at input/output accountability tank and Pu storage tanks
E	**Electro-manometer system**	Level measurement at input/output accountability tank
F	DYMAC	Near Real time Accountancy system
G	**Pu K-edge densitometer**	Pu concentration and isotope measurement
H	High resolution γ spectrometry	Pu concentration and isotope measurement
I	Pu product monitoring	Continuous surveillance for Pu product flow, tank level, va opening/closing
J	Resin bead sampling	Improvement of sampling technique
K	Isotope correlation safeguards	Verification of measurement data at Input accountability t
L	Pu input by Gravimetry	Pu/U ratio at Input accountability tank
M	Input volume by isotope spike	Calibration for input accountability tank

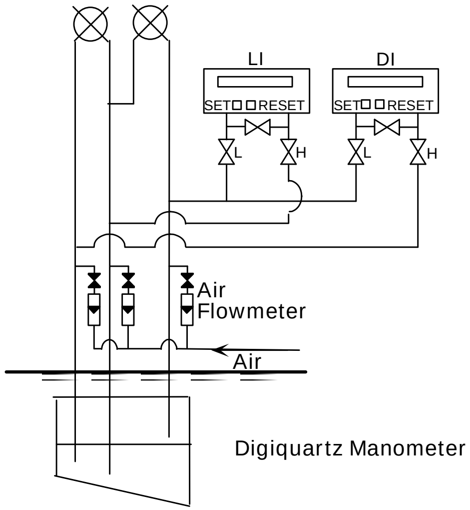

K-Edge densitometer

Improvement of Safeguards Equipment

1. More accurate Volume measurement

Water manometer

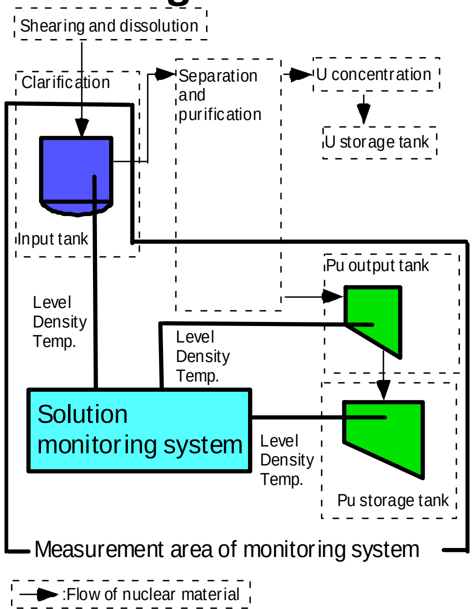
Digiquartz manometer

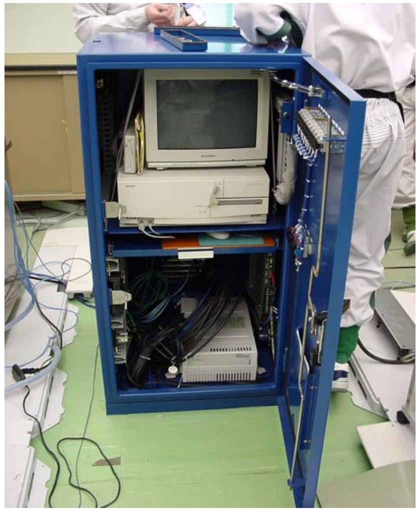


Volume measurement system by air flow

2. Solution Monitoring

Solution monitor



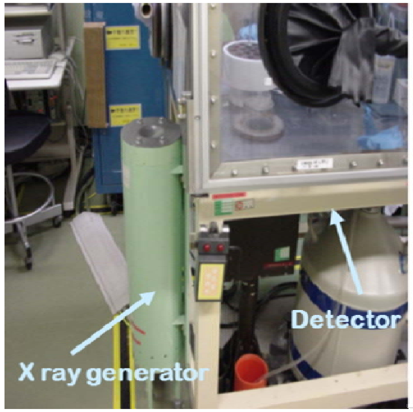


Sealed box including data collection computer

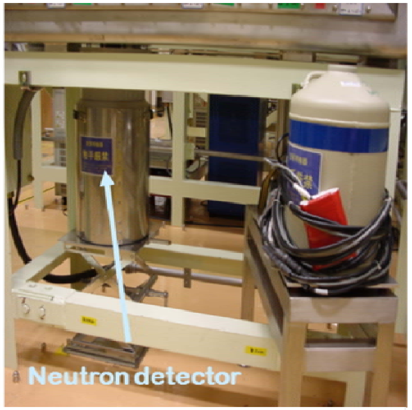
Sealed box including transformer of pressure to electric signal

Improvement of Safeguards Equipment

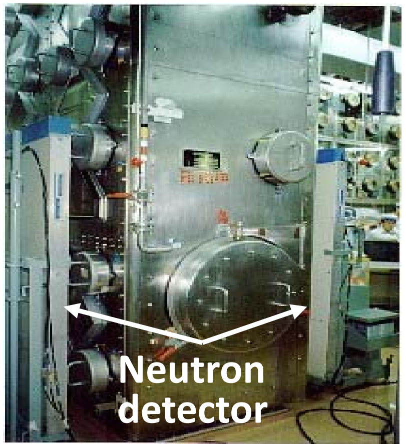
3. Nondestructive Assay



K-edge densitometer for Pu solution



Inventory sample counter for Pu solution and MOX powder



Measurement system of hold-up in glove box for MOX

4. Measurement of small amount in waste

Vitrified Waste Canister Counter

Measurement system of waste drum

SG for MOX Fabrication Facilities

1975 1980 1985 1990 1995 2000 2005

PPFF

Plutonium Fuel Fabrication Facility
(MOX fuel fabrication for ATR and FBR)

PFPF

Holdup

Discussion with IAEA and US

WCAS, SBAS

RMS, ENMC, Spike

Discussion with IAEA and US

Safeguards System

Plutonium Fuel Production Facility
(MOX fuel fabrication for FBR “Monju”)

Automated process was introduced.
Challenges;
- ***Difficulty of access to nuclear materials***
- ***Increased radiation exposure regarding the inspection activities***

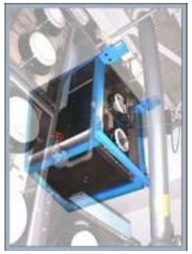
GUAM

JMOX

How to verify MOX in the process line with NDA?
Automated MOX Fabrication Plant - PFPF

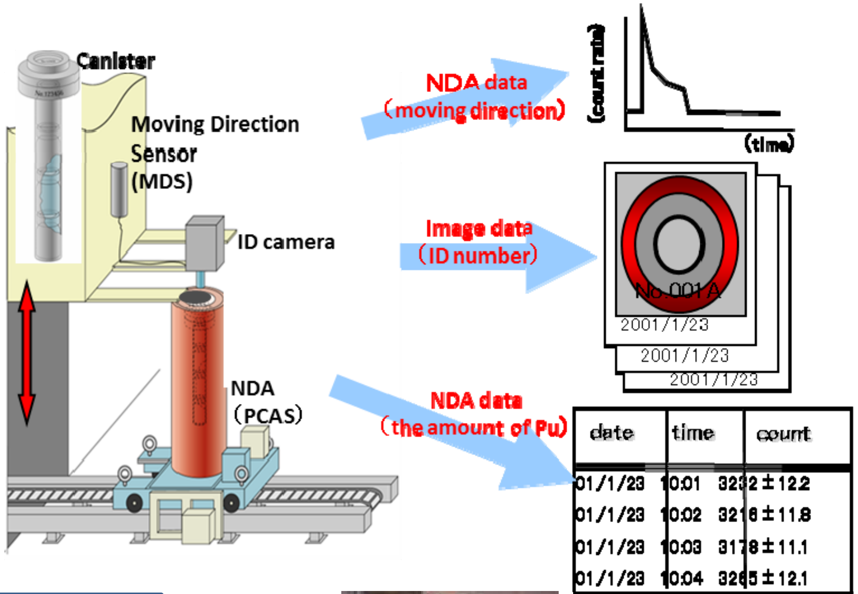
UNARM
unattended & remote

PCAS
Input MOX

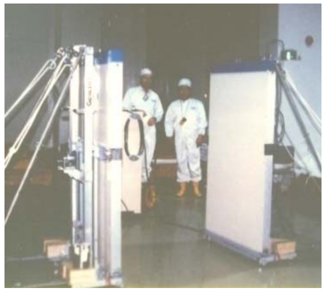


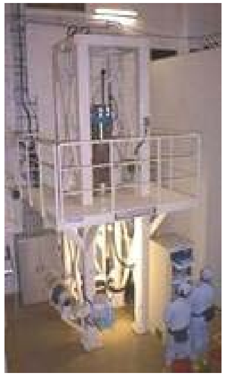
MAGB
process MOX

Unattended NDA system



SBAS
holdup MOX

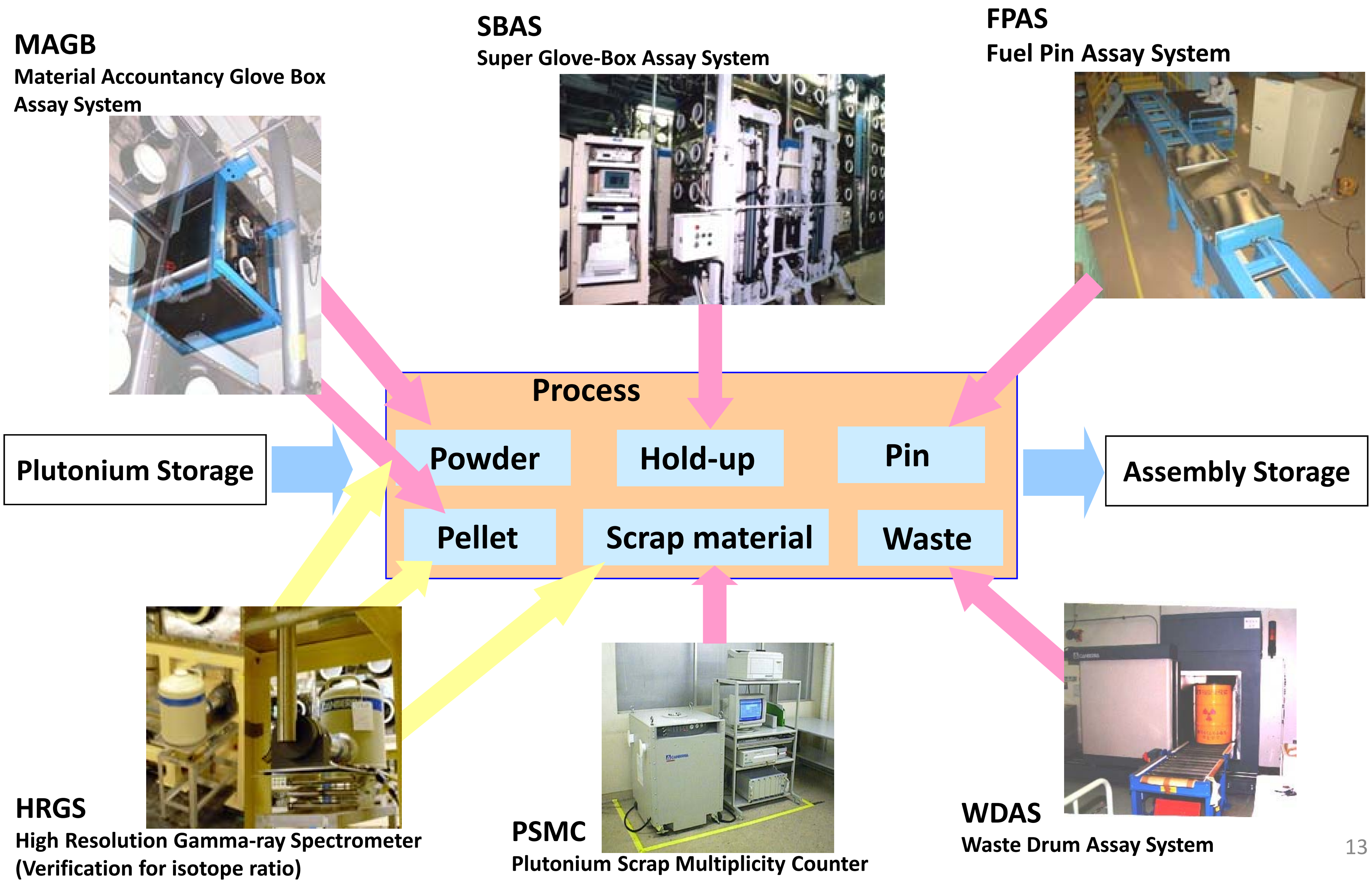




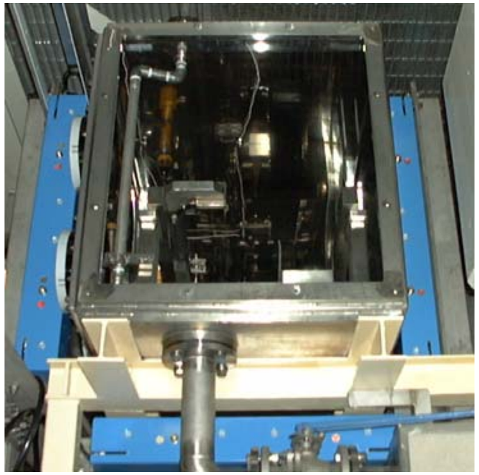
FAAS
Fuel assembly

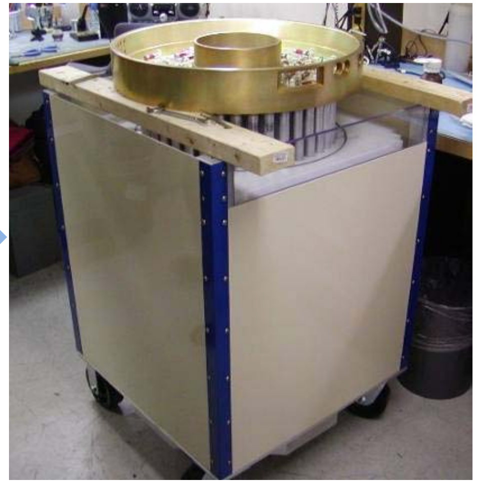
WDAS
Wastes drums

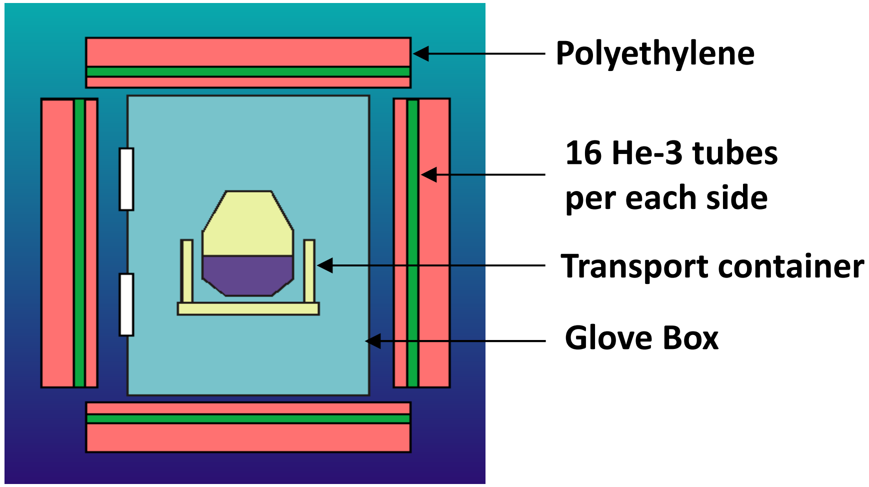
Safeguards system in the process area



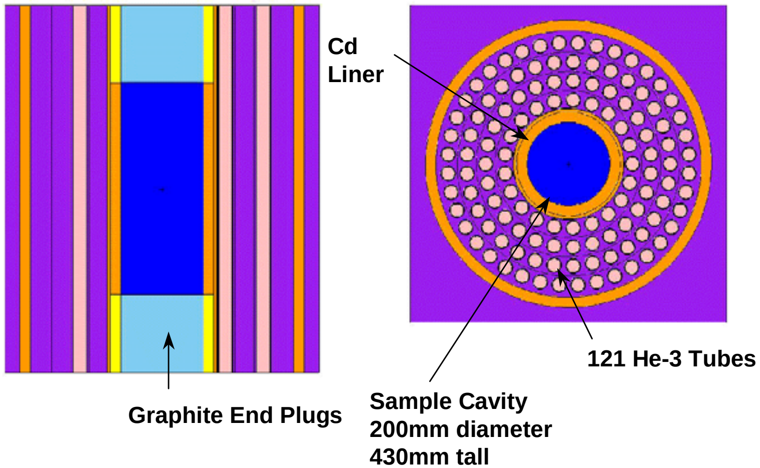
Improvement of NDA for MOX facility







AMAGB

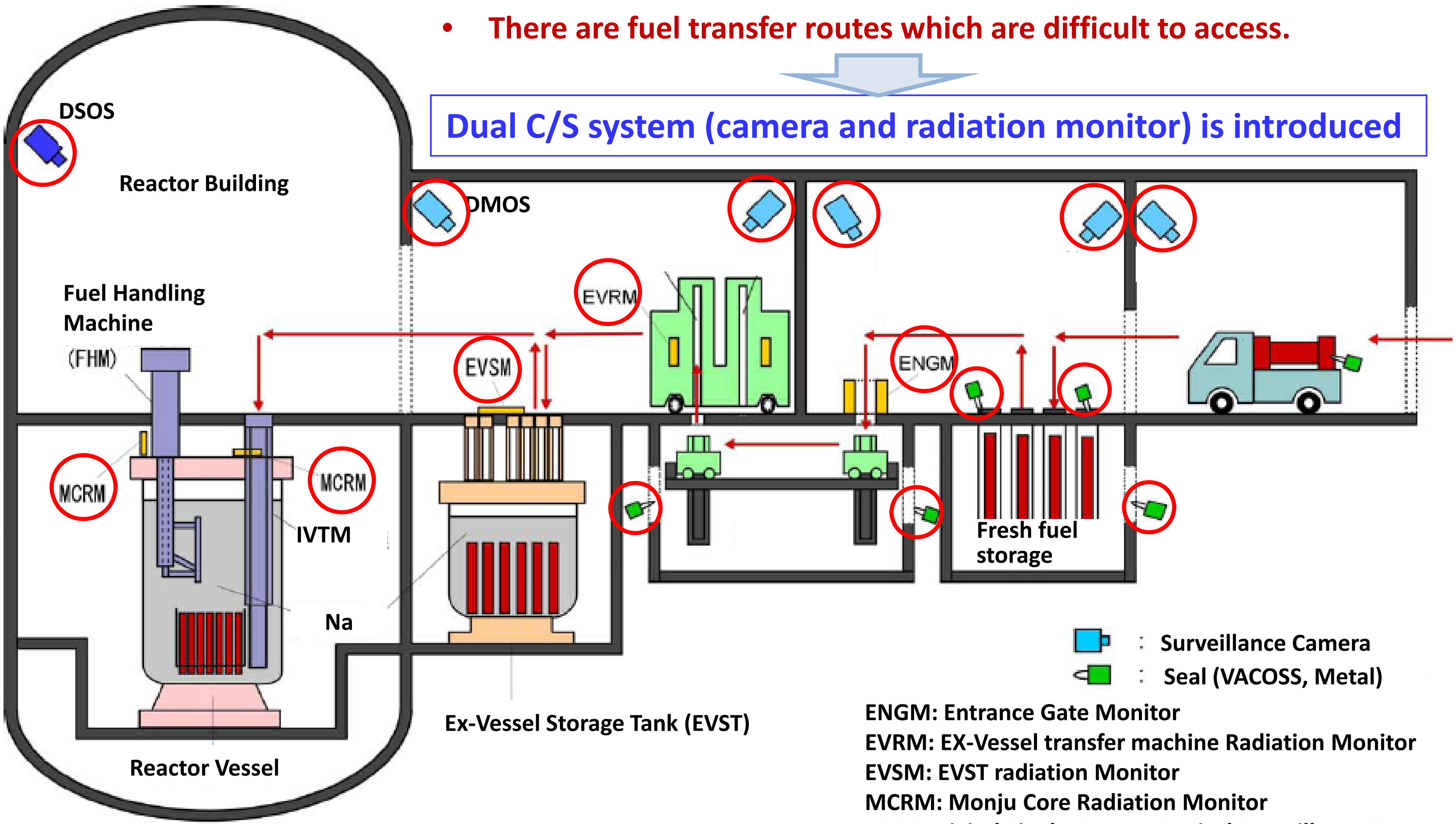


ENMC

Prototype FBR "Monju" SG equipment for fresh fuel transfer

- Core fuels cannot be observed because FBR uses Na coolant.
- There are fuel transfer routes which are difficult to access.

Dual C/S system (camera and radiation monitor) is introduced



ENGM: Entrance Gate Monitor
EVRM: EX-Vessel transfer machine Radiation Monitor
EVSM: EVST radiation Monitor
MCRM: Monju Core Radiation Monitor
DSOS: Digital Single Camera Optical Surveillance System
DMOS: Digital Multi Camera Optical Surveillance System
ITVM: In-Vessel Transfer Machine

Contribution to Rokkasho safeguards

- **Reprocessing Plant**

ISVS: Integrated Spent fuel Verification System
SMMS: Solution Monitoring and Measurement System
IHVS: Integrated Head-end Verification System
RHMS: Rokkasho Hulls Drum Measurement System
WCAS: Waste Crate Assay System
WDAS: Waste Drum Assay System
VCAS: Vitrified Canister Assay System
PIMS: Plutonium Inventory Measurement System
iPCAS: Improved Plutonium Canister Assay System
MSCS: MOX Storage C/S System
etc.

- **J-MOX plant**

GUAM: Glove-box Unattended Assay & Monitoring System
IPCA: Improved Plutonium Canister Assay system
AVIS: Advanced Verification for Inventory Samples system
AMAGB: Advanced Material accountancy Glove Box
FAAS: Advanced Fuel assembly Assay System
RSMC: Recyclable Scrap Multiplicity Counter
etc.

- **Enrichment plant**

Pipe Enrichment Monitor
PNUH: Portable Neutron Uranium Holdup Counter
etc.

Phots: JNFL web site http://www.jnfl.co.jp/

JAEA NDA Development Programs subsidized by MEXT(1/2)

(conducted between 2011JFY-2014JFY)

Development of basic technologies of advanced NDA of NM (for nuclear safeguards and security)	
(1)	Measurement test of the PNAR-NDA system for Fugen SFAs (2011JFY-2013JFY)(JAEA/USDOE collaboration)
(2)	Basic development of NRF-NDA technologies using LCS gamma-rays (2011JFY-2014JFY) (using HIgS of Duke University) (JAEA/USDOE collaboration for simulation codes) (Security)
(3)	Development of neutron detector alternative to ^{3}He using ZnS/B_2O_3 ceramic scintillator (2011JFY-2014JFY)
(4)	NRD using NRTA and NRCA (2012JFY- 2014JFY) (JAEA/JRC-IRMM collaboration)

PNAR :Passive Neutron Albedo Reactivity

LCS :Laser Compton Scattering

NRTA :Neutron Resonance Transmission Analysis

NRF :Nuclear Resonance Fluorescence

NRD :Neutron Resonance Densitometry

NRCA :Neutron Resonance Capture Analysis

JAEA NDA Development Programs subsidized by MEXT(2/2)

(conducting for next 3-5 JFYs)

Development of the following NDA technologies (for nuclear safeguards and security)	
(5)	Demonstration of NRF Non Destructive Detection of NM (2015JFY-20139FY) (using HIgS of Duke University) (Security)
(6)	Development of active neutron NDA techniques using a D-T neutron source (2015JFY-2017JFY) (JAEA/JRC collaboration)
(7)	Feasibility study on monitoring technology for Pu solution with fission products in tanks inside cell (2015JFY-2017JFY) (to be JAEA/USDOE collaboration)

An Organization Diagram of JAEA NDA R&D Programs subsidized by MEXT

（As of February 2016）

MEXT
Ministry of Education, Culture, Sports, Science and Technology

Development of Basic Technologies of Advanced NDA of NM

JAEA

ISCN

QuBS
Program: （5）
Demonstration of NRF Non Destructive Detection of NM

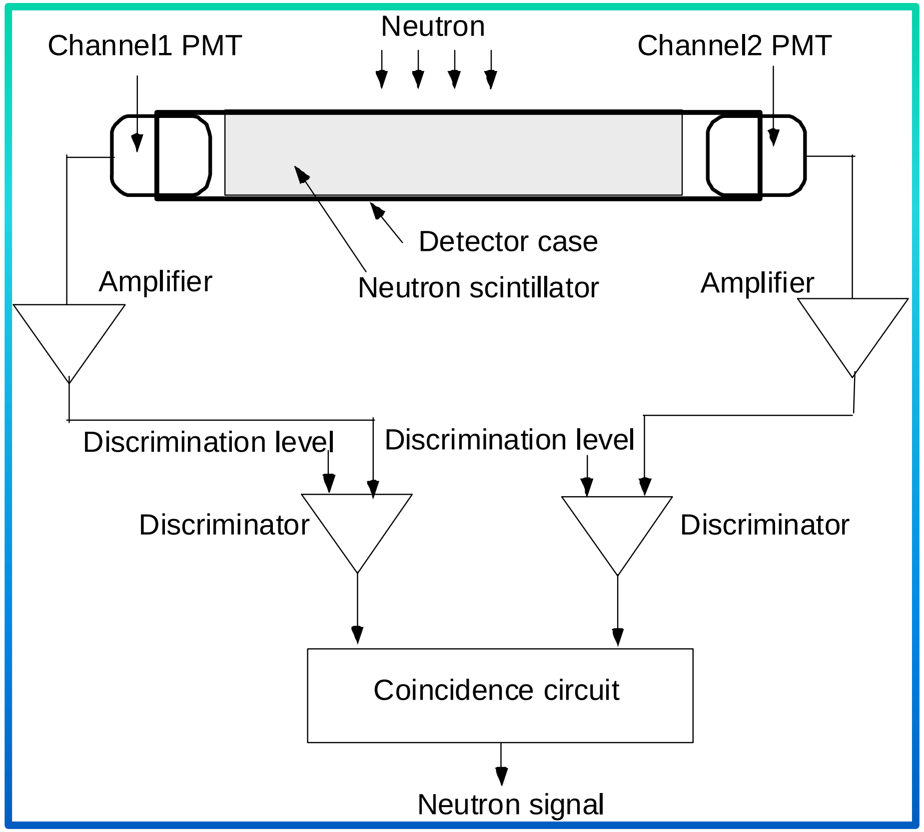
NSEC
Program: （6）
Development of active neutron NDA techniques using a D-T neutron source

TRDC
Program: （7）
Feasibility study on monitoring technology for Pu solution with fission products in tanks inside cell

QuBS: Quantum Beam Science Center
NSEC: Nuclear Science and Engineering Center
TRDC: Tokai Reprocessing Technology Development Center

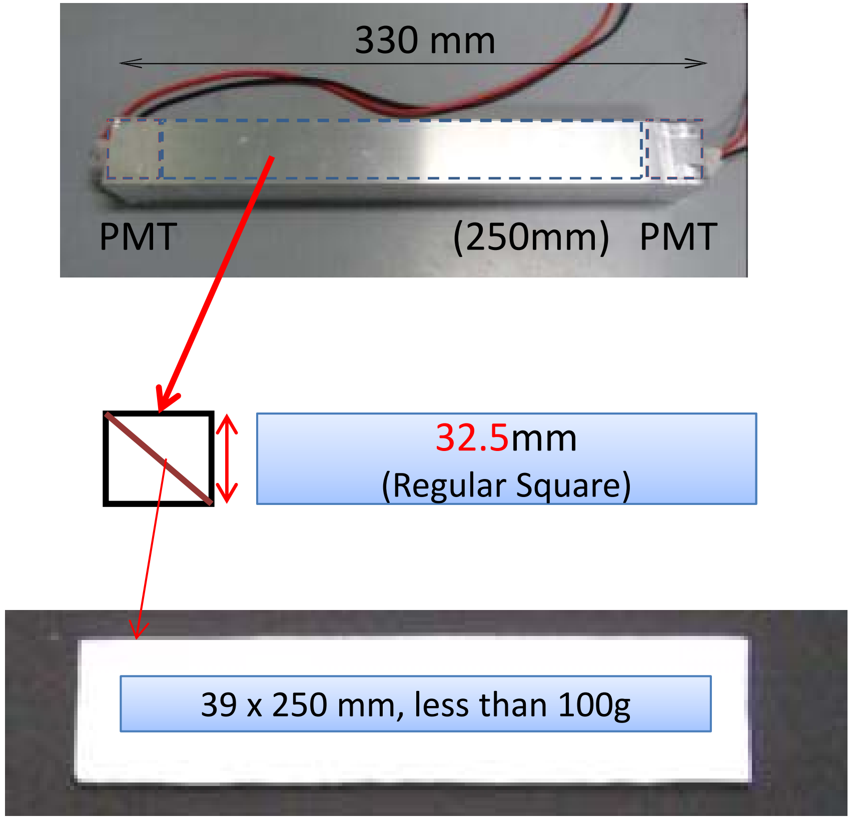
Overview of a $ZnS/^{10}B_2O_3$ Ceramic Scintillator Neutron Detector (JAEA)

Alternative neutron detector (JAEA developed)



Neutron Detection using $ZnS/^{10}B_2O_3$ Ceramic Scintillator

Neutron Detector Head



$ZnS/^{10}B_2O_3$ Ceramic Scintillator Sheet

ASAS
(Alternative Sample Assay System)

Alternative HLNCC type NDA system

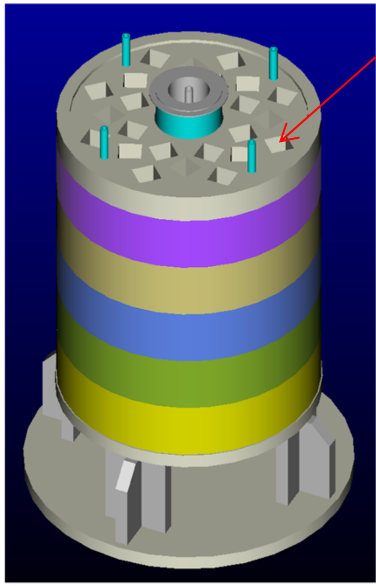
System Configuration

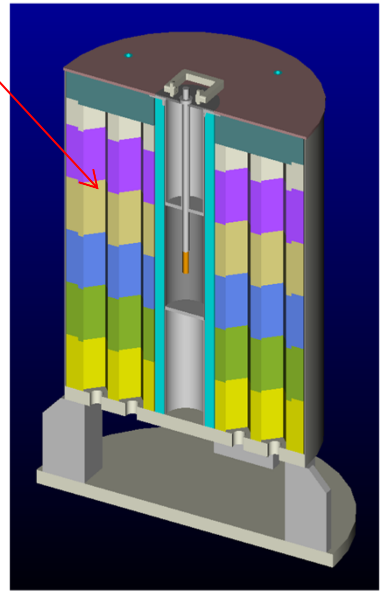
Detector

Data Processing Unit and Power Supply

Shift Register → Data Acquisition PC

$^{10}B_2O_3$/ZnS Ceramic Scintillator (24 modules)
(Rectangular Area)





Comparative Demonstration of ASAS with INVS using MOX Samples

Comparative Demonstration using known MOX Samples

	ASAS		INVS @ PCDF	
	Passive Cal.	Known-α	Passive Cal.	Known-α
Statistical Uncertainty (30min Meas.(r))	3.2%		2.2%	
Systematic Uncertainty	2.25%	2.62%	2.92%	5.3%
Total Measurement Uncertainty (TMU)	3.91%	4.14%	3.66%	5.74%

Comparative Demonstration using a unknown MOX Sample

	Pu-mass by PSMC (gPu)	Passive Calibration			Known α Calibration		
		Pu-mass (gPu)	Pu-Mass (σ)	Diff. (%)	Pu-mass (gPu)	Pu-Mass (σ)	Diff. (%)
INVS	1.353	1.343	0.012	0.586	1.367	0.005	-1.156
ASAS		1.331	0.016	1.48	1.354	0.017	-0.174

→ ASAS can be used in actual safeguards inspection

Conclusion

- **JAEA initiated to develop SG technologies mainly in order to facilitate operation for their own nuclear fuel cycle facility.**
  - ✓ **The background was bilateral or international negotiation.**
- **JAEA has been improving the technologies via their experiences of the operation for a long time. As the results, The efforts contributed to the reducing PDI of inspection, the design and operation of the commercial plants.**
- **JAEA is now moving to next stage and should develop a SG technology in order to solve an issue in IAEA safeguards inspection in collaboration with international/domestic partners**