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Investigating Safety, Safeguards and Security (3S) Synergies to Support Infrastructure Development and Risk-Informed Methodologies for 3S by Design

M. SUZUKI, Y. IZUMI, T. KIMOTO,
Y. NAOI, T. INOUE, B HOFFHEINS

Nuclear Nonproliferation Science and Technology Center (NPSTC),

Japan Atomic Energy Agency (JAEA)

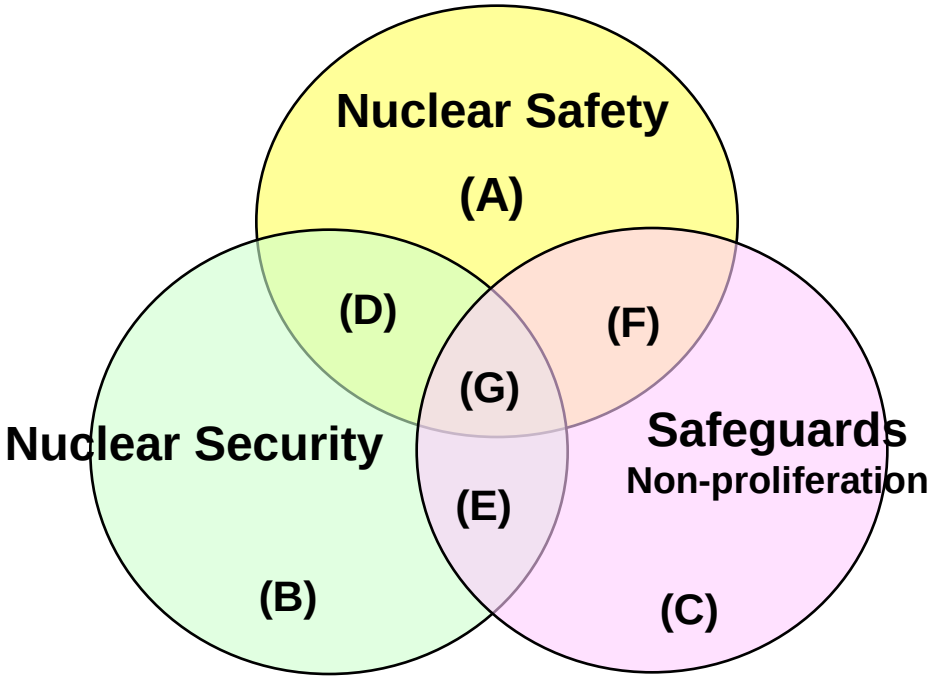
Outline

- Background of 3S activities
- Gap analysis
- Infrastructure development
- Non-proliferation culture
- Mathematical methodologies for risk-informed assessment for 3S by design
- Advanced process monitoring
- Feasibility study on the risk-informed approach
- Conclusion

Background of 3S activities

- In support of the 3S initiative raised by G8 countries in 2008, JAEA has been conducting detailed gap analyses of the promotion programs to identify possible overlaps where synergism and efficiencies might be explored.
- As an initial outcome of this study, it is realized that fostering a 3S understanding and culture is important for establishing a stable foundation from which to successfully implement and sustain nuclear energy programs nationally and internationally.
- Lessons learned in these activities can be applied to developing more efficient and effective 3S infrastructures for incorporating into Safeguards by Design (SBD) methodologies.
- A risk-informed approach regarding integration of 3S has been investigated using several mathematical methods. An initial examination of incident probability and consequence analyses, which are tools familiar to the nuclear safety, is extended to identify inherent uncertainties of proliferation risks.

Gap Analysis of 3S



(A) Emergency core cooling system for nuclear power plant, (B) Barrier at the facility entrance, (C) Authenticated apparatus

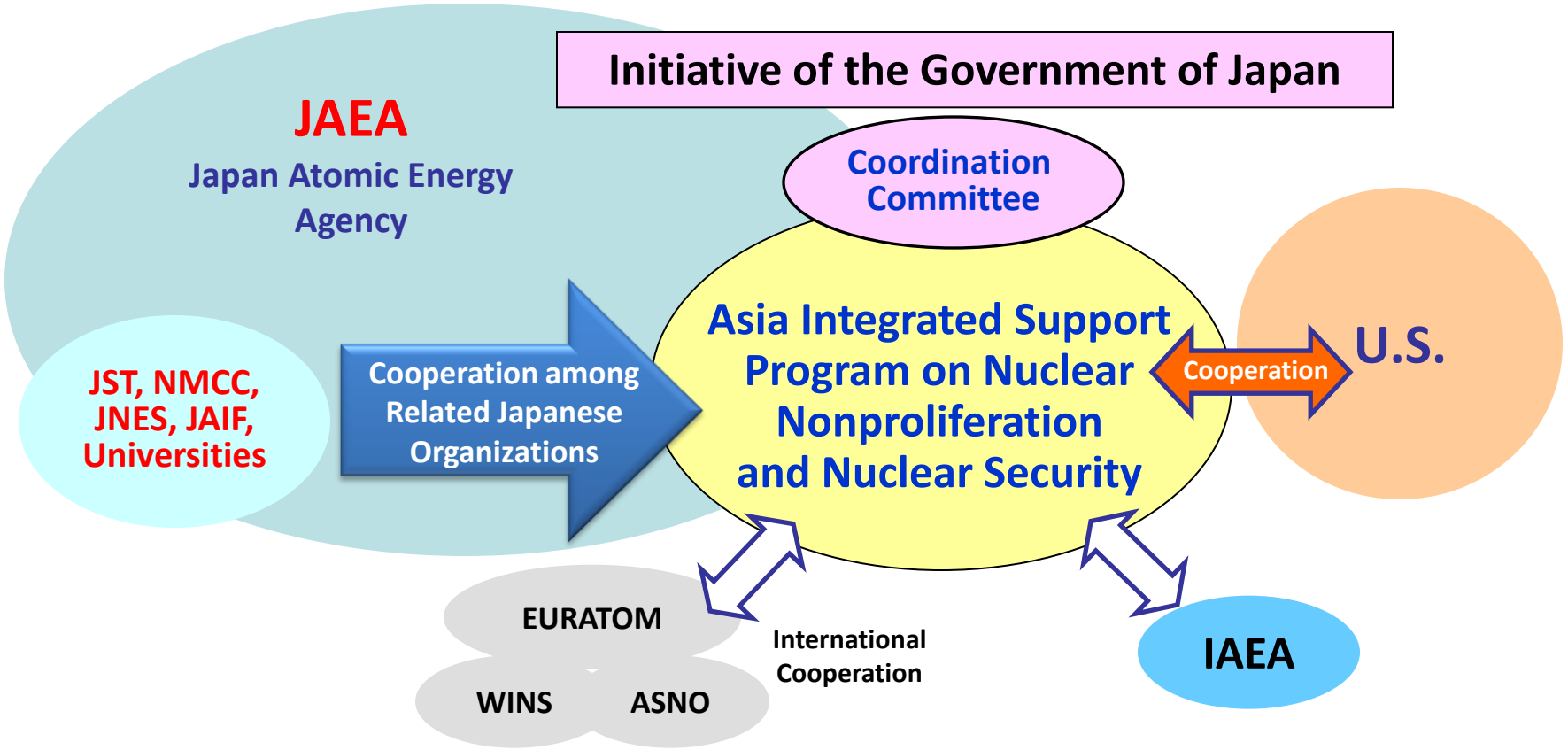
(D) Double-entry doors to keep negative pressure and prevent radioactive release

(E) Management of nuclear material using containment and surveillance and remote monitoring camera

(F) Management of nuclear material for criticality and accounting control

(G) Possible monitoring camera for multipurpose use, such as joint use of equipment

Structure of Integrated Support Centre for Nuclear Nonproliferation and Security for Asia (Tentative)

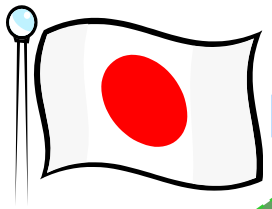


JAEA's Role on Asia Integrated Support Program

Safeguards, SSAC Training Course in JAEA

JAEA regularly provides participants from Asia, Pacific and former Soviet Union with Safeguards Training Course to initiate, operate and maintain the Safeguards and Material Control System to meet the IAEA Safeguards.

Structure



MEXT

Entrust

JAEA

Request to cooperation

NMCC

IAEA SG Support Program (JASPAS)

IAEA

Training

Program

- IAEA Safeguards
- SSAC
- Accountancy & Control
- Workshop for Accountancy & Control for Design Information
- Exercise for NDA and C/S
- Facility Visit
- etc.

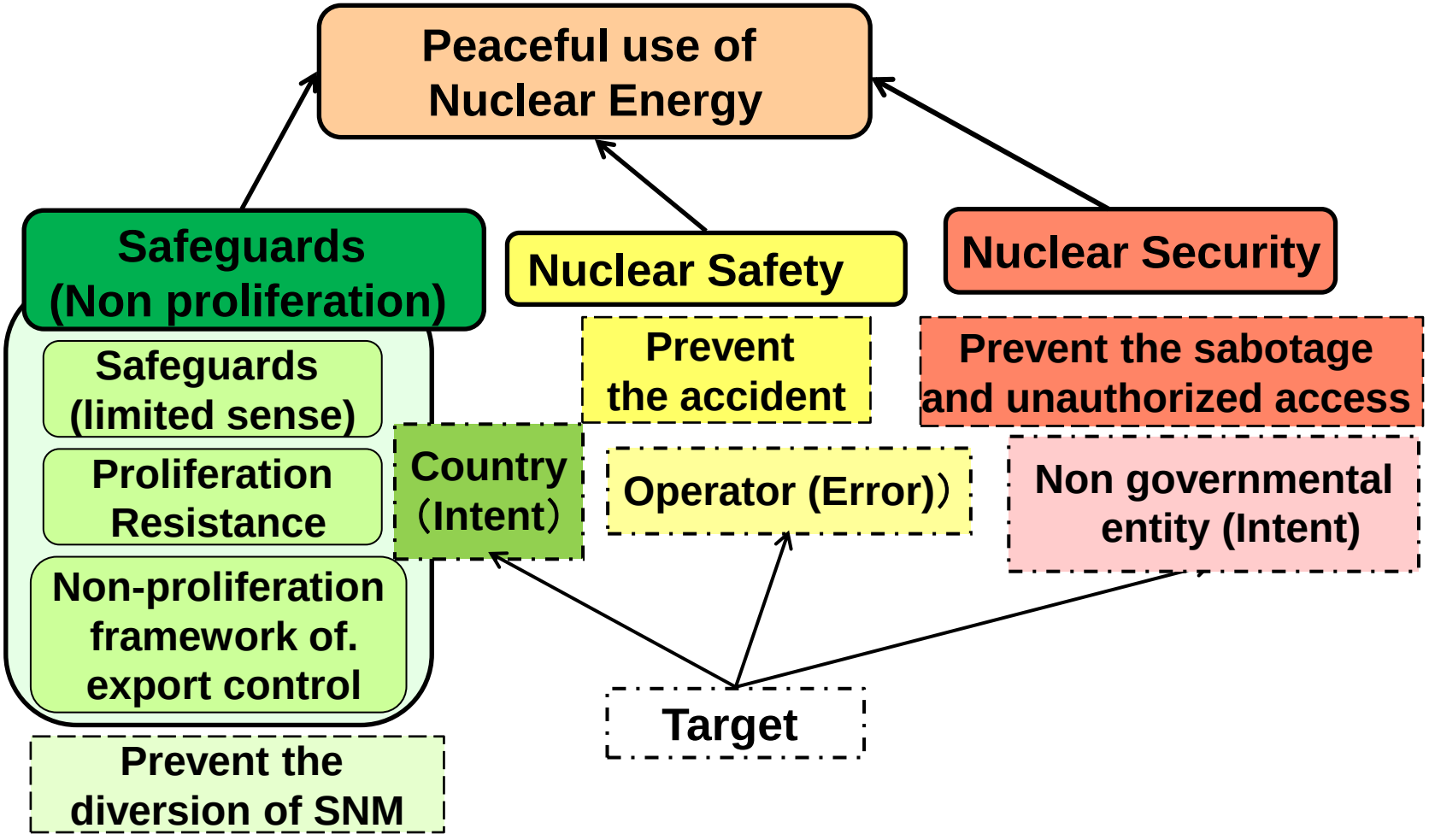
Countries

Philippine, Indonesia, Thailand, Malaysia, China, Mongolia, Myanmar, Vietnam, ROK, Japan, Armenia, Belarus, Bulgaria, Kazakhstan, Latvia, Uzbekistan, Ukraine, Lithuania, Australia

Purpose of Training

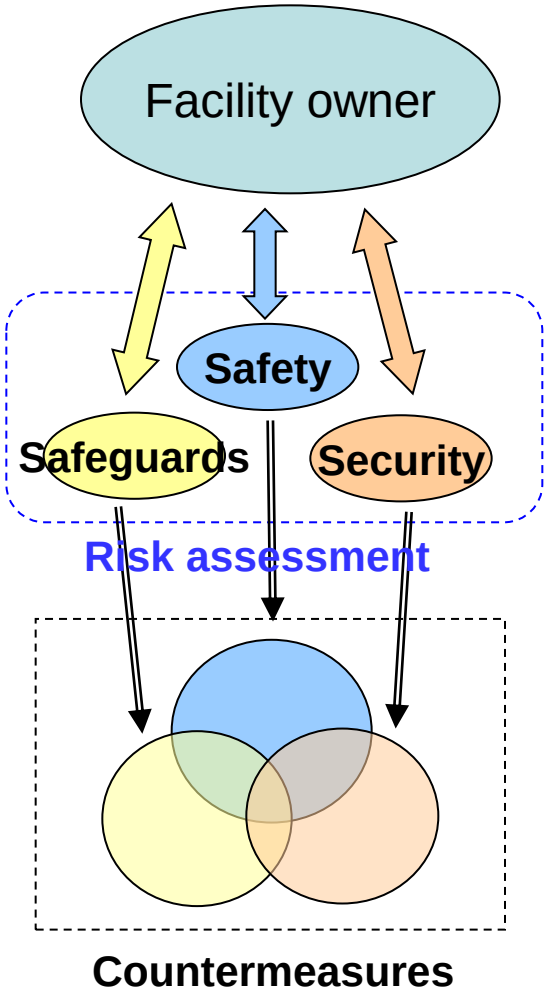
- To ensure and promote peaceful use of nuclear energy in Asia, Pacific and former Soviet Union
- To contribute to IAEA Safeguards implementation with improvement of knowledge for Safeguards and Accountancy Control
- To promote exchange of safeguards related information in the region.

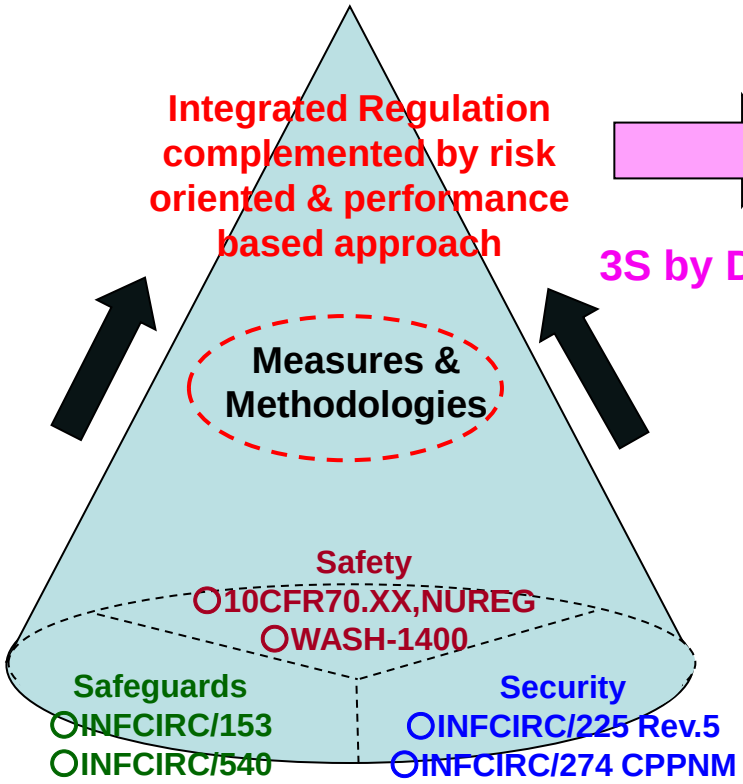
Non-proliferation culture



Non-proliferation culture to enlighten mental modality

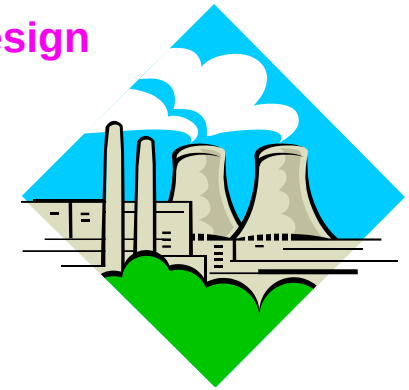
Integrated Regulation complemented by Risk-Informed Methodologies





Best Performance for All Stakeholders

3S by Design



Nuclear Fuel Cycle Facilities

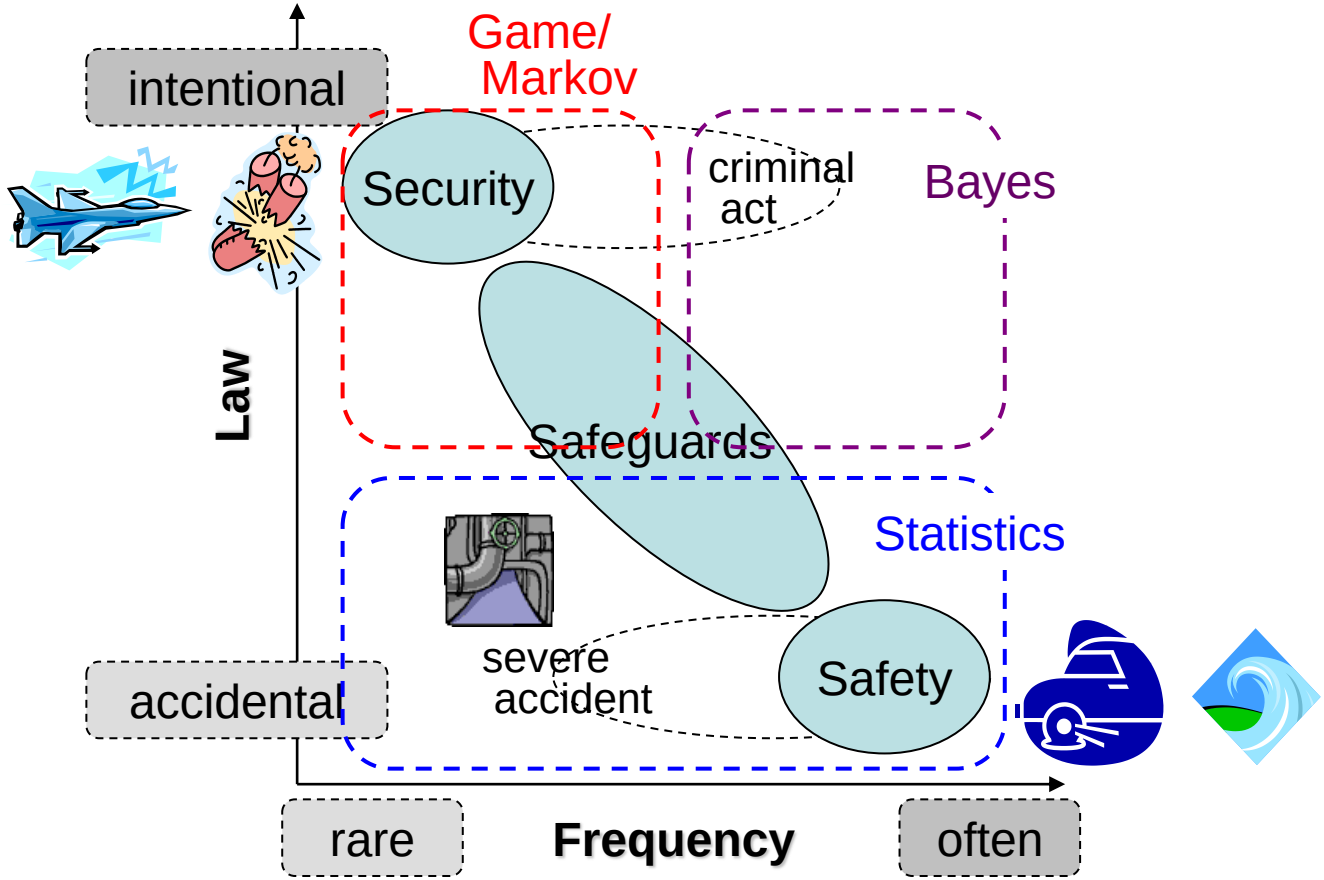
3S by Design (3SBD)

- Incorporation of 3S considerations early in the conceptual design and the system development phase is one of the most promising synergies that results in the adoption of “3S by Design (3SBD)”.
- In safety, probabilistic safety assessment has been developed by long historical trials and discussions.
- Because of the recent concerns about nuclear security, a similar probabilistic assessment has been extended for use in developing guidelines for protection of nuclear power plant against sabotage.
- The inherent difficulty in determining the frequency of terrorist attack by malicious acts is undertaken by the conservative estimate in which the initial probability is assumed to be unity as in the case of a postulated accident in safety.
- Preliminary efforts for harmonization between reliability and safety, and proliferation resistance (PR) and physical protection (PP) are initiated under the Generation IV (GEN IV) international framework.

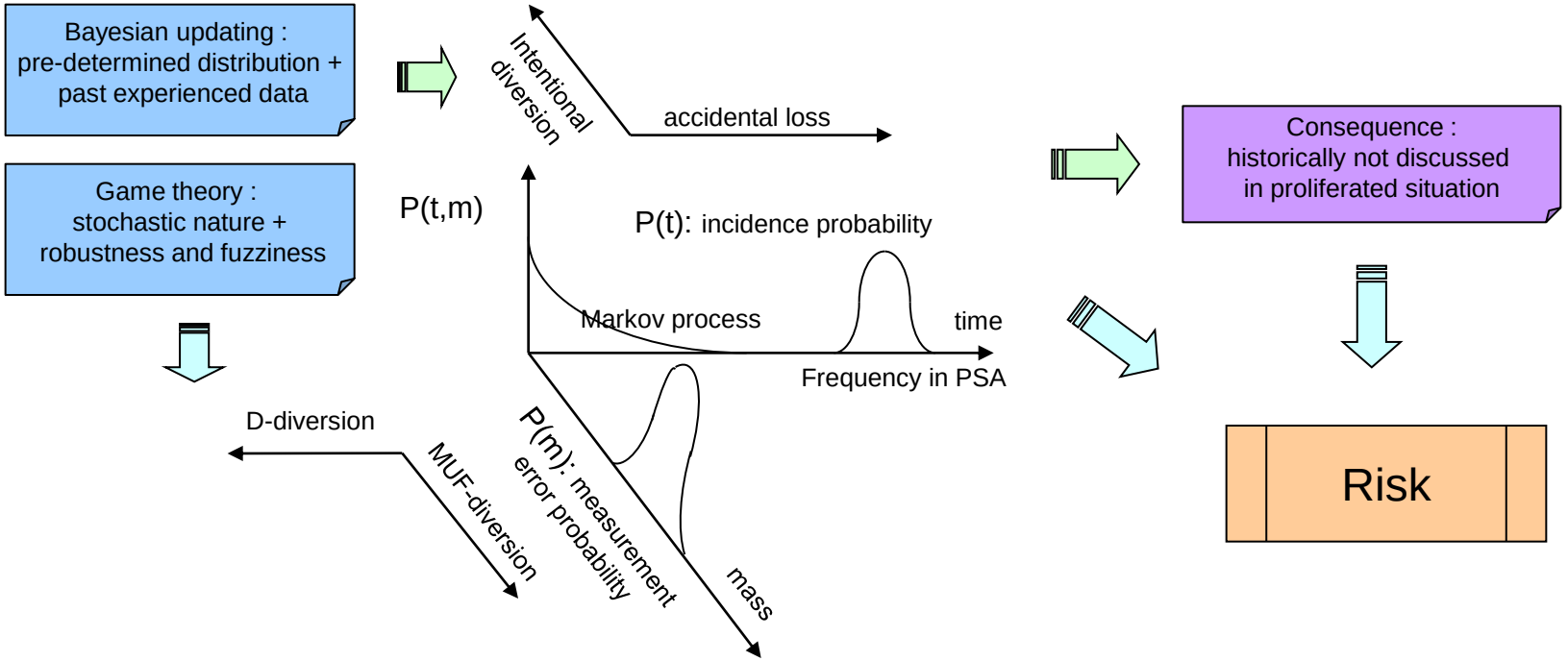
Characteristics of 3S

Past:
- ✓Purely theoretical
- ✓Criteria based
- ✓Data observation is essential

Present:
- ✓Modeling & simulation
- ✓Performance based
- ✓Powerful PC is beneficial



Uniqueness of Risk Assessment Notion Applied to Safeguards

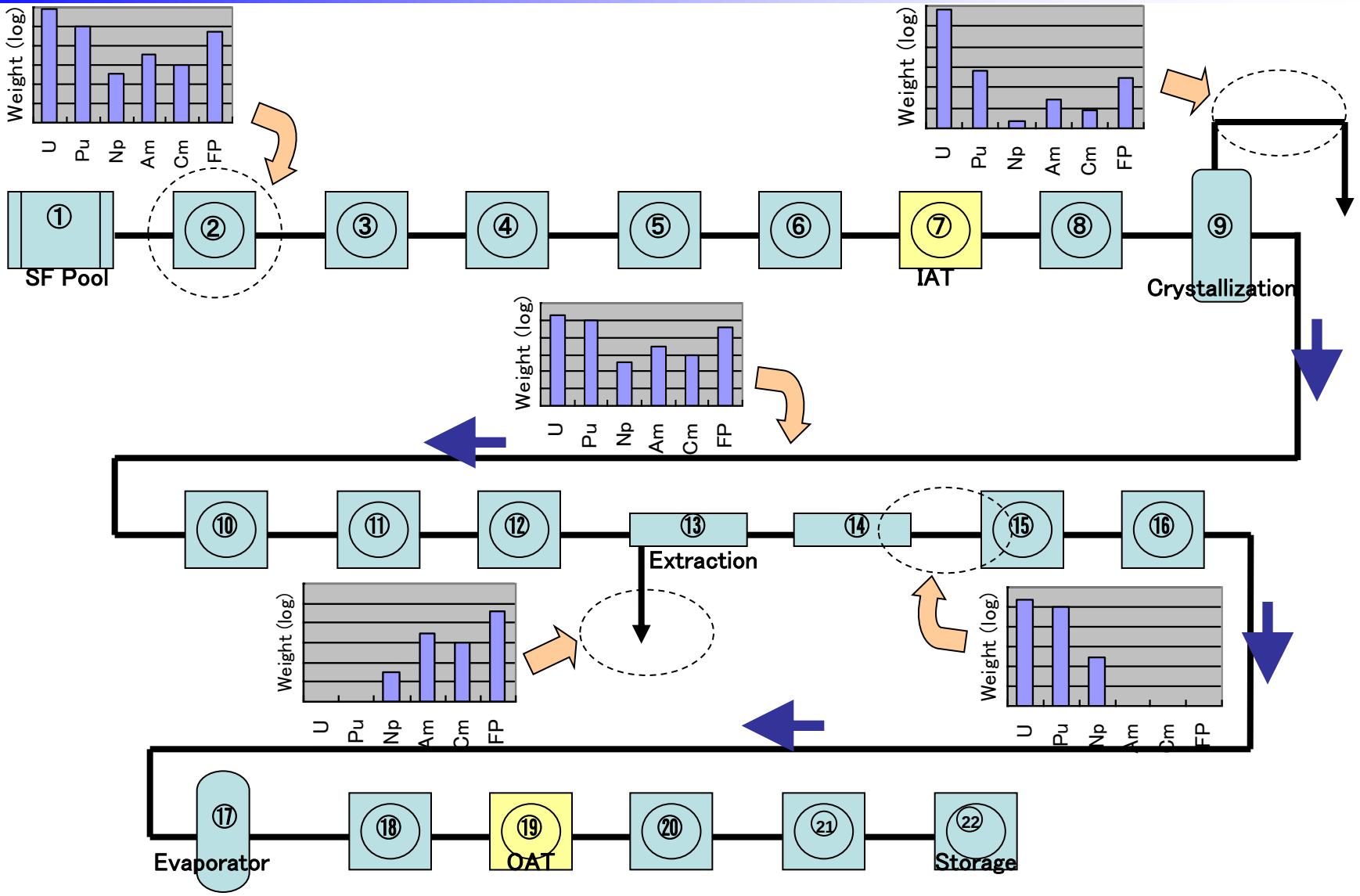


- In safeguards, the significant quantities and timeliness goals are the bases for NMA, and probability distribution of measurement error as well as time series of material balance play important roles in the deterministic criteria.
- On the contrary to an accidental loss, an intentional diversion could be estimated from an incidence probability distribution that is studied by Markov model and Game theory.
- The two-dimensional distribution of both incidence and measurement error probabilities is a unique feature of safeguards for assessing the proliferation risk.

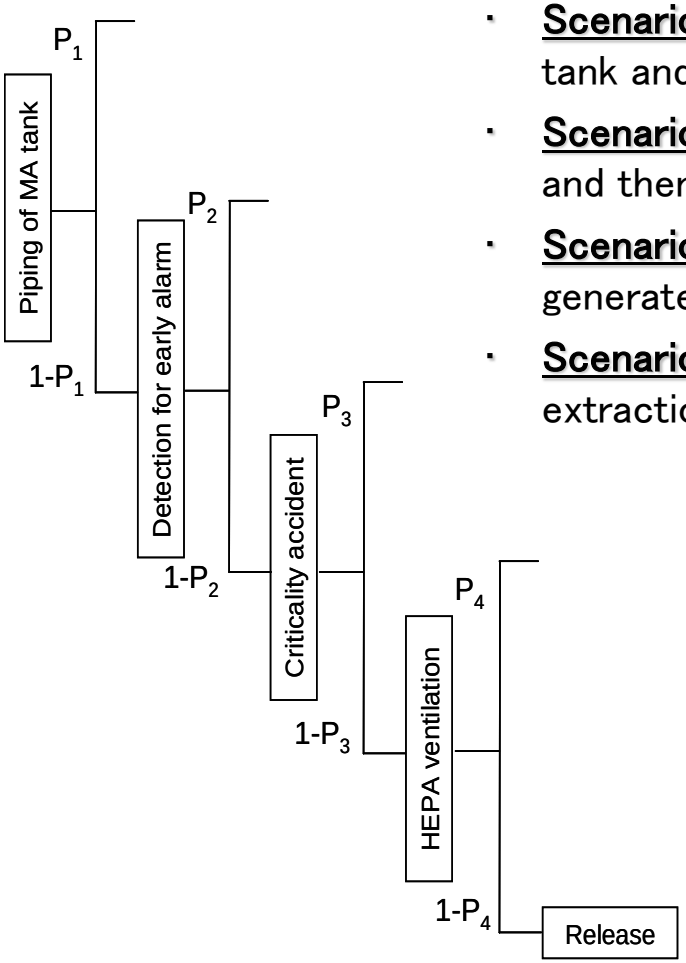
Advanced Process Monitoring

- Simulation and modeling based on proliferation pathway analysis and Monte Carlo calculation could replace the traditional NMA theory derived with a Gaussian assumption for the D-diversion.
- Multivariate statistical analysis considering historical data is used to construct false alarm rules and generate the notion of a safeguards envelope beyond which the plant is operating abnormally.
- The present PM is used as data consistency management (DCM) to check the facility operation as declared. However, extension and quantification of PM are explored for use not only as a supplementary measure but also a substitution of traditional NRTA.
- Comparative study with the present IAEA safeguards criteria is very important to enhance development of future advanced nuclear fuel cycle as well as to support more effective and efficient future IAEA safeguards to reduce overburdened inspector resources.

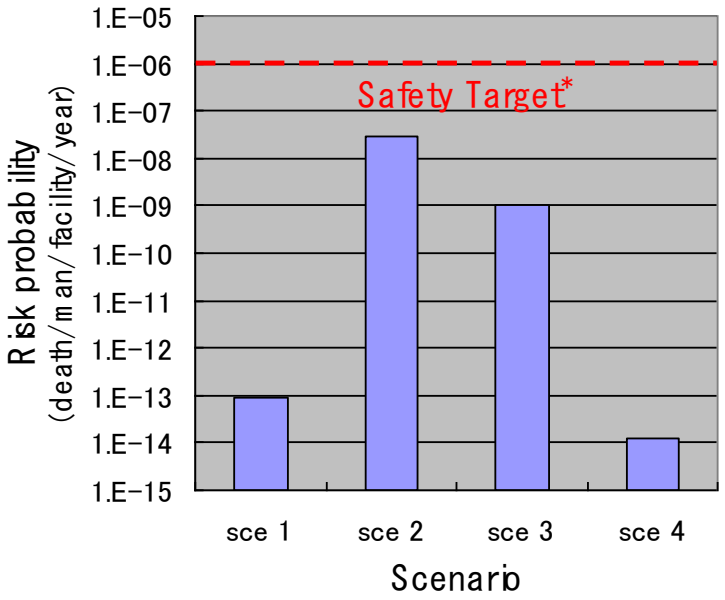
Advanced Aqueous Reprocessing Process (Feasibility Study)



Probabilistic Safety Analysis



- **Scenario1** : At outlet of 13 process, Pu is leaked into HALW tank and then critical accident is induced
- **Scenario2** : Am & Cm are leaked from outlet piping of MA tank and then the leaked waste solution is boiled
- **Scenario3** : The coolant system is failed and then heat generated tanks, HALW and MA tanks, are boiled
- **Scenario4** : Solvent is leaked from outlet piping of the extraction instrument and then fire accident is induced



* This is the FaCT safety design requirement that is one order lower than the present CFF in LWR

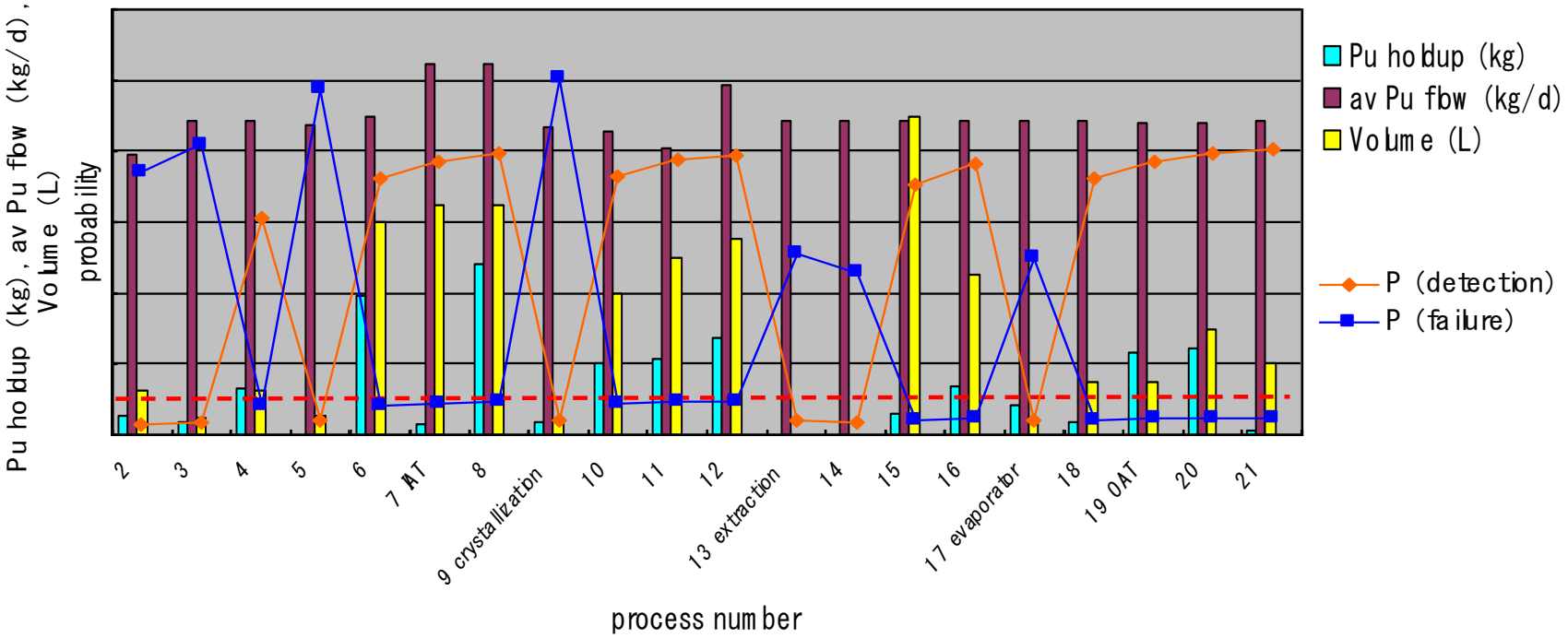
Risk probability = C × Π(1-P_i)

Proliferation Risk Assessment

- **P(m): Measurement error probability** ⇒ σMUF ⇒ Pu holdup, Pu flow rate, volume
  - Average Pu mass flow rate is greatly larger than Pu holdup comparing 1SQ.
- **P(t): Incidence probability** ⇒ Markov model approach ⇒ material type, SMMS
  - After the 13 extraction process, P_{filure} gradually decrease and $P_{detection}$ depends on SMMS

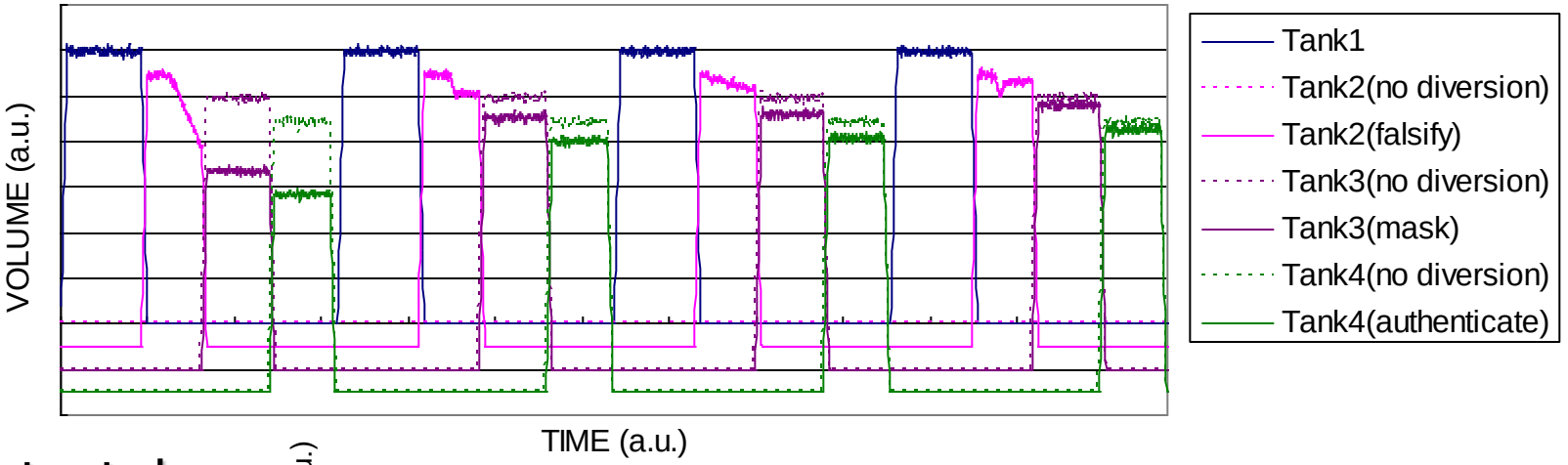
➢ For the first priority, protracted diversion from "19 OAT" and "20 process" over a day and a week before the IIV should be strictly investigated.

➢ For the process equipments without SMMS, such as "13 extraction", "14 process", and "17 evaporator", a real-time sensor should be installed to monitor any abnormal behavior.

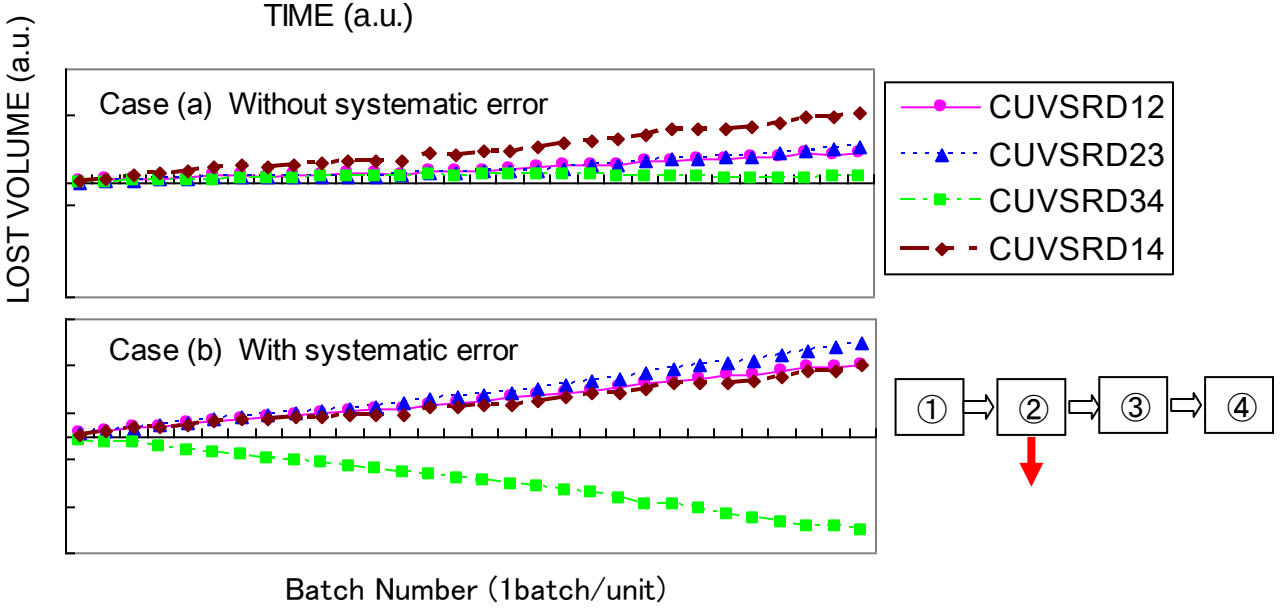


Process Monitoring Algorithm

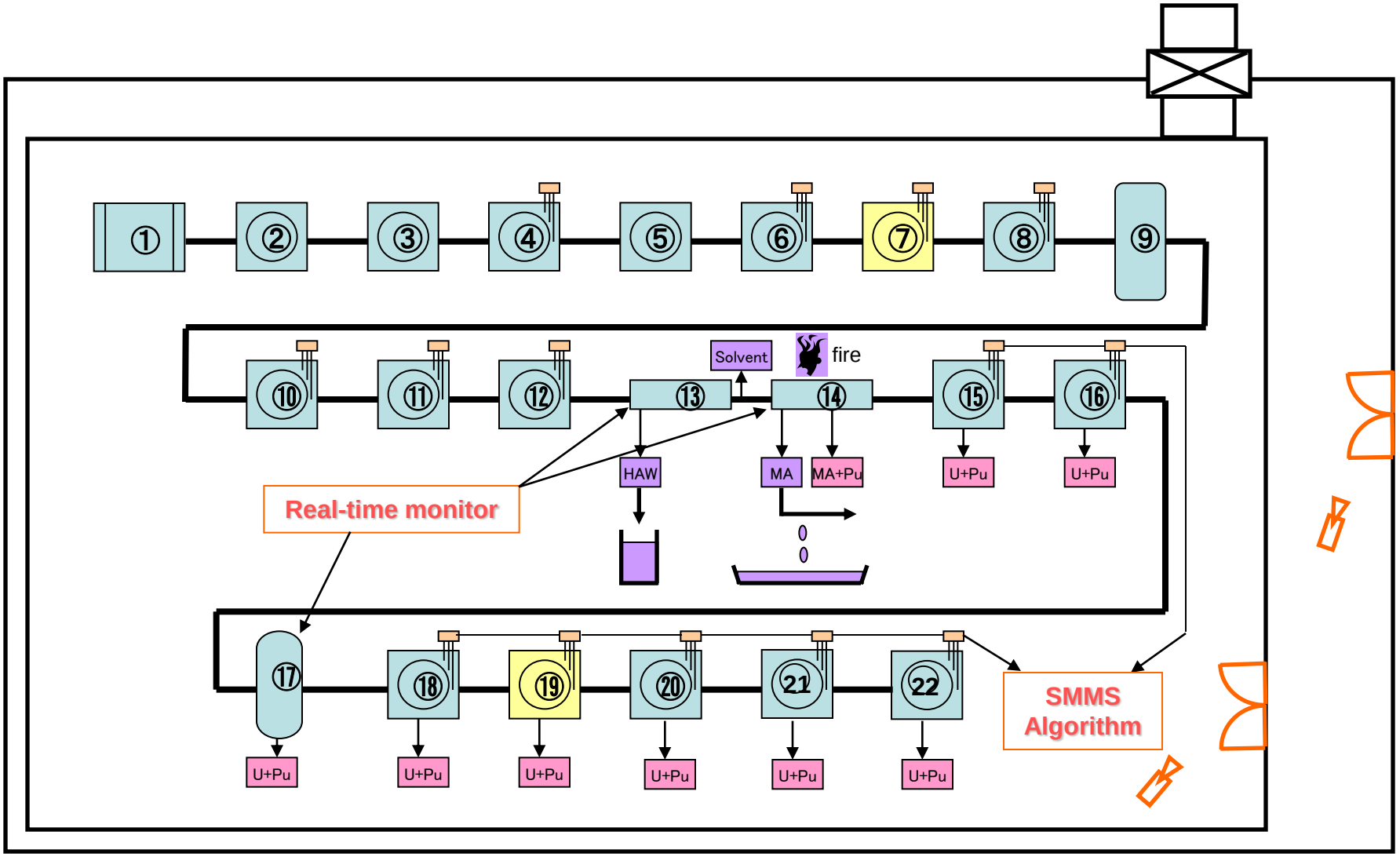
Abrupt diversion



Protracted diversion



Feasibility Study Results



Conclusions (1/2)

- It is imperative for emerging countries to accept the 3S commitment to assure transparency of and confidence in the peaceful use of nuclear energy and to obtain the understanding of the international community. Since the Japan government has launched the Integrated Support Center, we would like to contribute infrastructure support and assistance to those countries as an outcome from our 3S activities.
- In reality, culture differences among individual “S” communities may hinder the synergetic effects due to few connections in the past and inherent obstructions between them. Knowledge required in safeguards and security is almost foreign to safety experts. However, we would like to pursue establishment of the nonproliferation culture in all employees in JAEA using the presidential award system and maintain a transparent and accountable atmosphere as a nuclear energy R&D organization.

Conclusions (2/2)

- In conceptual design stage of future advanced facilities, risk-oriented assessment methodologies for 3S is one of the options to pursue more efficient and effective systems. Advanced process monitoring has been studied to extend its application beyond the present DCM. A quantitative evaluation of proliferation risk using simulation and modeling would be a modern approach for investigating diversion path analysis.
- The risk-informed design consideration as 3S synergy is still in its infancy, but the performance based assessment should be valuable for installing 3S countermeasures in the nuclear facility early in the design stage to minimize costs as well as to seek balance between detection probability and false alarms in present safeguards implementation to resolve conflicts that may arise between the IAEA and facility operations.
- Interaction and international collaboration in 3S would be a future R&D issue for nuclear fuel cycle development.

Thank you for attention

JAEA/NPSTC