August 29, 2022
The 6th International Forum on Fukushima Daiichi Decommissioning (DAY 2)
Iwaki City Art and Culture Exchange Center "Alios"

Analytical Competence and University Initiatives in Japan

Japan Nuclear Damage Liability and Decommissioning Corporation

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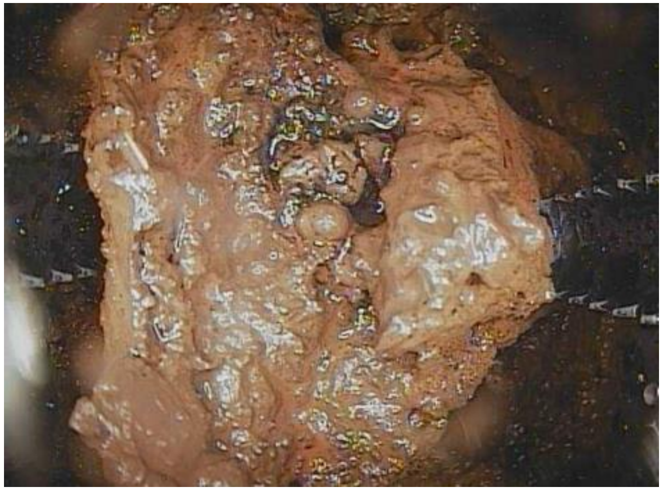
Lecture Contents

- Characteristics of samples and objectives of the analysis
  - What is the sample to be analyzed?
  - What is the purpose of the analysis?
  - What is needed for the analysis?
- Existing analytical facilities, methods, and personnel
- Issues related to analysis for 1F decommissioning
- Measures to resolve the issues
- New university initiatives
- Summary

What is the sample to be analyzed?

- Debris, accident-derived waste
  - The first core meltdown accident at a BWR in the world
  - No records of many plant parameters due to loss of power at the accident
  - Unclear operational status of the safety equipment
  - Injection of seawater to bring the accident under control
  - Many uncertainties regarding the state inside the reactors, the state of the debris, fission products release paths, etc.
    - What you don't see in normal decommissioning
    - Unconfirmed properties
    - Many with high doses
    - A wide variety of subject
    - Difficult-to-measure nuclides
    - High timeliness to be required
    - Huge number of samples
    - Limited sample volume

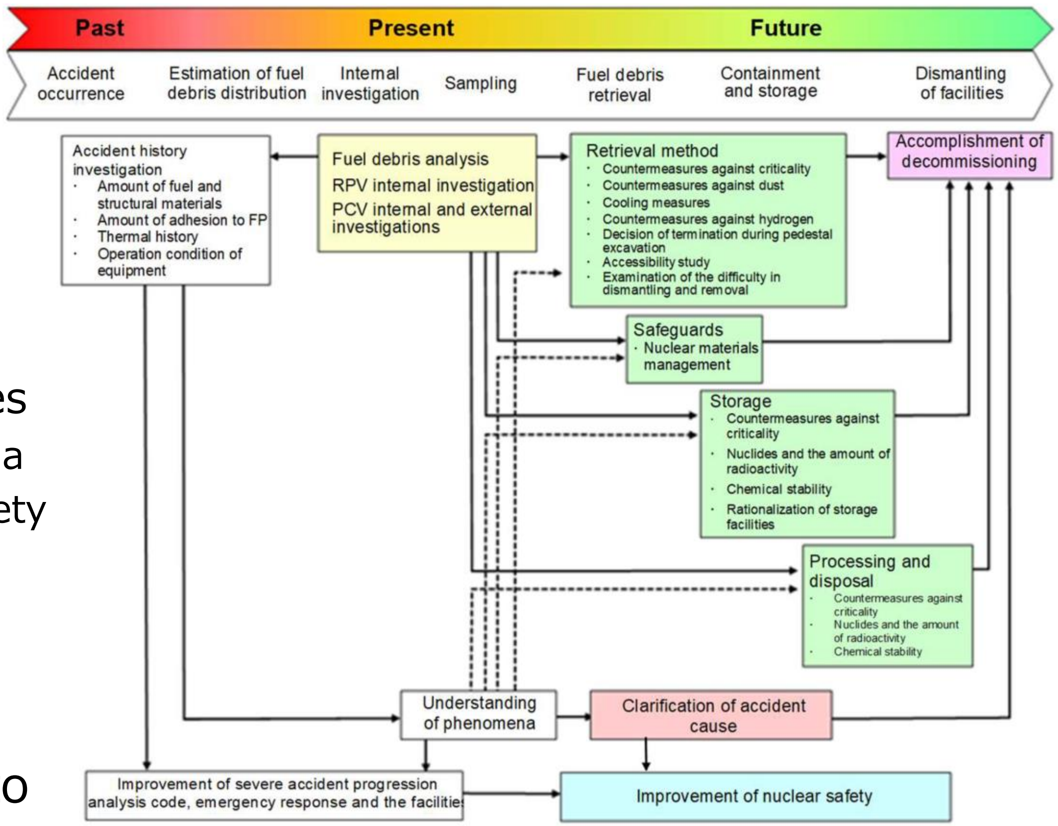


Pebble-like deposits at the bottom of the pedestal of Unit 2 of 1F

(Courtesy of TEPCO)

What is the purpose of the analysis?

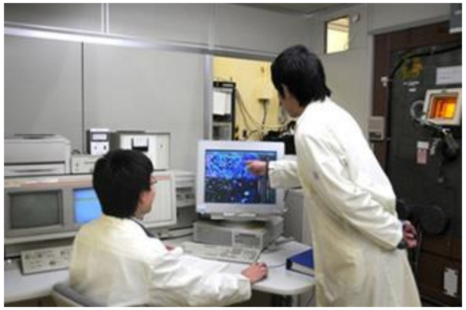
- Quick identification of basic properties
  - Nuclide inventory, chemical composition, chemical form, density, etc.
- The results of the analysis are important basic information and applied in several areas
  - Decommissioning work
    - Retrieval method
    - Storage management
    - Processing and disposal
  - Clarification of accident causes
    - Understanding of phenomena
    - Improvement of nuclear safety
- The analytical results are one of the important criteria for decisions for reducing the range of uncertainty in order to facilitate 1F decommissioning



Incorporation of analyses and investigation results, and their relationships (Technical Strategic Plan 2021)

What is needed for the analysis?

- **Facilities**
  - Facilities and equipment capable of handling debris and accident-derived waste
- **Methods**
  - Analytical methods, techniques, and equipment applicable to debris and accident-derived waste
  - New analytical methods, technologies, and equipment required for debris and accident-derived waste
- **Personnel**
  - Analytical technicians
  - Analytical specialists who evaluate and interpret the results of the analysis
  - Analytical engineers who develop new methods, techniques, and equipment



(Courtesy of JAEA)

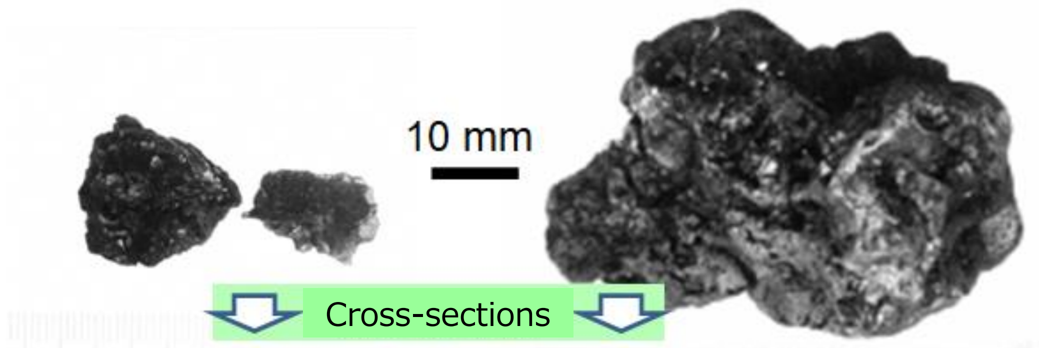
Existing analytical facilities, methods, and personnel (1/7)

- Do we have facilities, methods, and personnel for the analysis?
  - Handling of debris and accident-derived waste
    - The same manner as irradiated fuels and materials/radioactive wastes is required
      - Radiation controlled area (nuclear fuel handling, radioisotope handling)
      - Hot cell, glove box, hood
  - Existing irradiated fuels and materials examination facilities/radioactive waste handling facilities, analytical methods, and personnel are available
    - Nuclear Science Research Institute, Japan Atomic Energy Agency (JAEA-NSRI)
    - Oarai Research and Development Institute, Japan Atomic Energy Agency (JAEA-ORDI)
    - Nuclear Fuel Cycle Engineering Laboratories, Japan Atomic Energy Agency, (JAEA-NCL)
    - Nippon Nuclear Fuel Development Co., Ltd. (NFD)
    - MHI Nuclear Development Corporation (NDC)
    - (University facilities and equipment)
- Conducted analysis of 1F samples immediately after the accident using these facilities, methods, and personnel

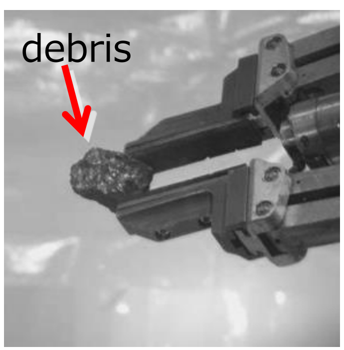
Existing analytical facilities, methods, and personnel (2/7)

■ JAEA-NSRI

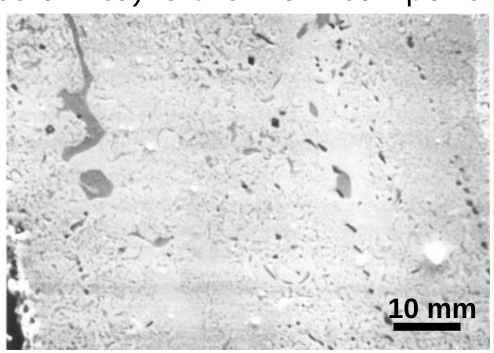
- Analysis of the debris of TMI-2 (Three Mile Island Unit 2) in the US
  - Part of the OECD/NEA international joint research
  - About 60 pieces of debris were shipped to Japan in 1991
  - Results contribute to clarification of accident progression, etc.



Cross-sections



Uranium and zirconium oxides (ceramics) is the main component



Mixture of zircaloy and inconel (light brown)

UO_2 (green)

Mixture of zircaloy and stainless steel (white)

Ag-In-Cd control material (dark brown)

Analysis of the debris of TMI-2 at JAEA-NSRI

(Courtesy of JAEA)

JAEA-NSRI

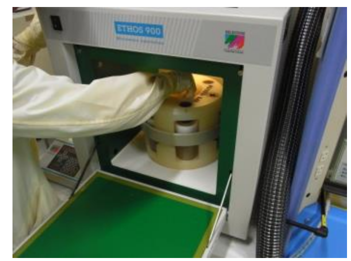
- Analysis of rubble, contaminated water, etc. of 1F
- Analysis of simulated debris

Sampling of rubble

Sampling of felled trees

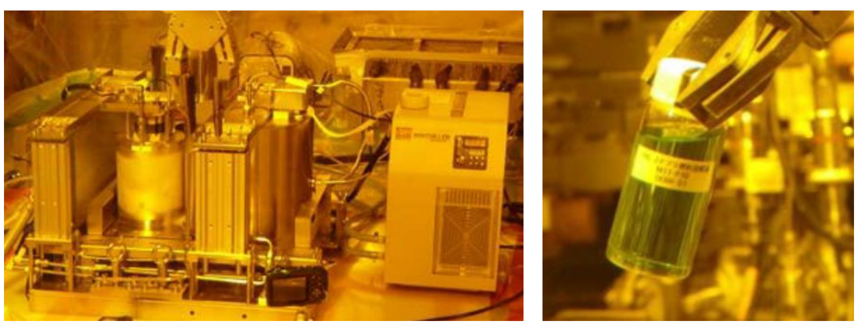
Glove boxes

Hot cells



Pretreatment of sample

Analysis using solid-phase extractants



Debris Dissolution Tests in Hot Cells

- Cooperation with TEPCO on radioactivity analysis
- Technical guidance to TEPCO Power Technology

Analysis of rubble

(Courtesy of JAEA)

JAEA-ORDI

- Analysis of rubble, contaminated water, etc. of 1F
- Analysis of deposits, smear samples inside the PCV, etc.
- Analysis of simulated debris

Hot cells (Steel cells)

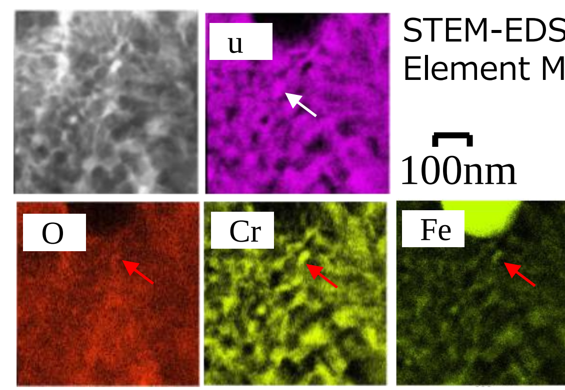
FIB
(Sample thinning for TEM observation)

TEM (Transmission Electron Microscope)

Hot cells (Concrete cells)

FE-SEM
(Field Emission Scanning Electron Microscope)

STEM-EDS
Element Mapping



Analysis of deposits inside the PCV

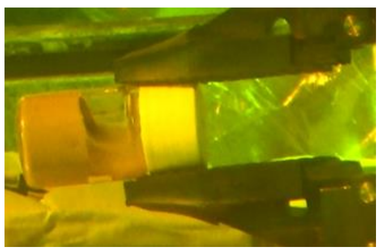
(Courtesy of JAEA)

JAEA-NCL

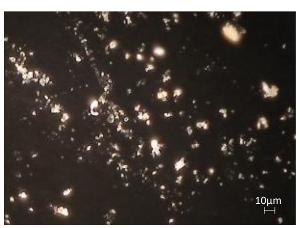
- Analysis of rubble, contaminated water. etc. of 1F

Hot cells

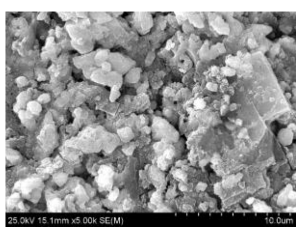
Appearance



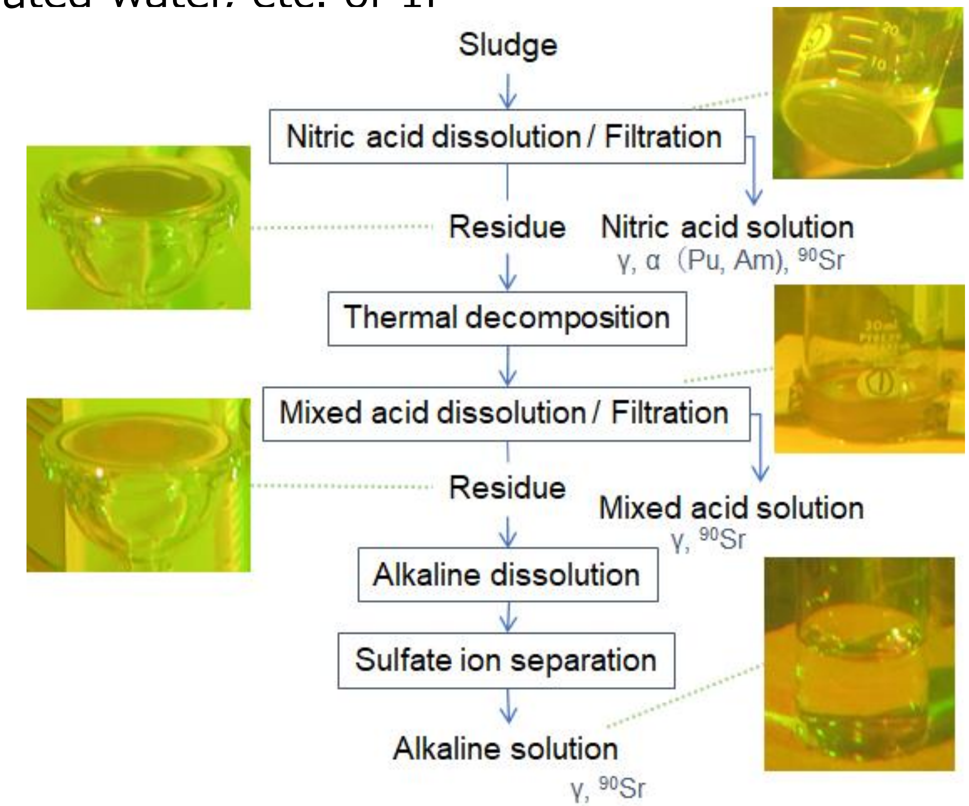
Observation in a hot cell



Optical microscopy



SEM-EDX analysis



Development of analytical method of the sludge

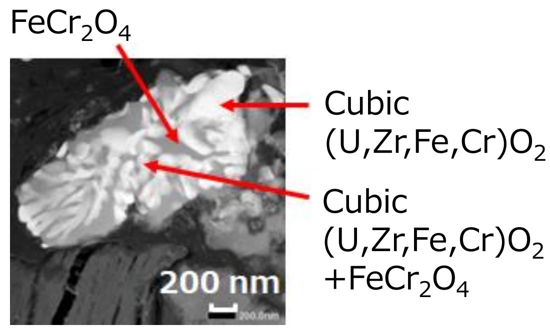
Analysis of secondary waste from water treatment
(Sludge accumulated in decontamination equipment)

(Courtesy of JAEA)

Existing analytical facilities, methods, and personnel (6/7)

NFD

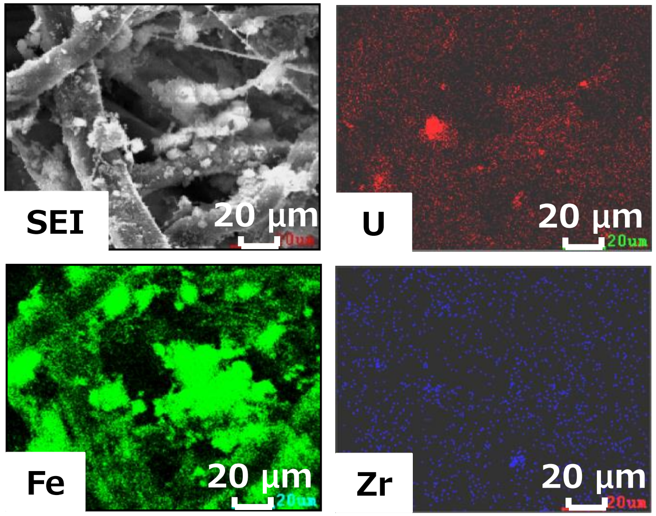
- Analysis of rubble, contaminated water, etc. of 1F
- Analysis of deposits, smear samples inside the PCV
- Analysis of simulated debris



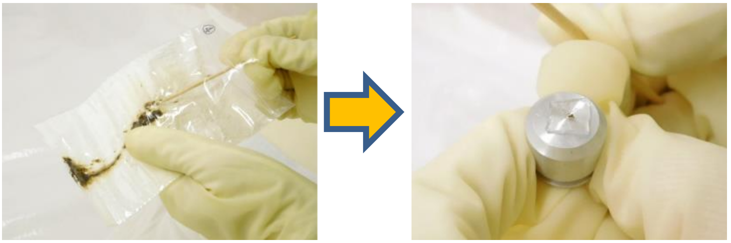
Detailed structure of U-bearing particle observed on the deposits from Unit 2 (STEM-HAADF image)

Hot cells

TEM (Transmission electron microscope)



U-bearing particles observed on the smear sample from Unit 3 (SEM-EDS)



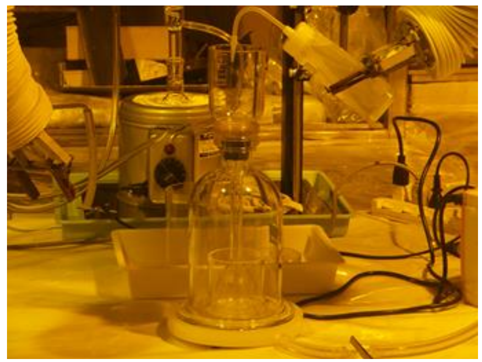
Sample preparation for SEM (Scanning electron microscope)

(Courtesy of NFD)

NDC

- Analysis of rubble, contaminated water, etc. of 1F
- Analysis of simulated debris

Hot cells

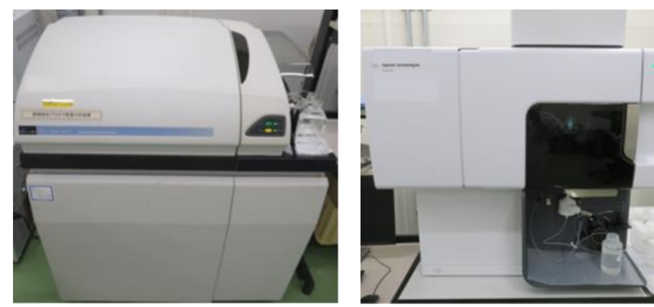


Nitric acid dissolution of simulated debris in a hot cell

Equipment of pretreatment for radionuclide analysis

Before dissolution | Addition of nitric acid | After dissolution | After solid-liquid separation

Nitric acid dissolution of simulated debris in a hot cell



Chemical Analysis instruments
(Left: ICP-MS; Right: ICP-AES)

(Courtesy of NDC)

- Are the existing facilities for analysis sufficient for 1F decommissioning?
  - Other tasks, not able to concentrate on analysis for 1F decommissioning
  - Located in Ibaraki area away from 1F, poor timeliness
  - Insufficient capacity for analysis required for 1F decommissioning
- New facilities are under construction and planned adjacent to the 1F site and on the 1F site
  - Analysis and Research of Radioactive Materials Laboratory-1 (completed, preparing to set up a controlled area)
  - Analysis and Research of Radioactive Materials Laboratory-2 (under construction)
  - TEPCO Comprehensive Analysis Facility (under planning)

Image of facilities for Analysis and Research of radioactive materials (Courtesy of JAEA)

Issues related to analysis for 1F decommissioning (2/3)

- Are the existing methods of analysis sufficient for 1F decommissioning?
  - What is required for 1F decommissioning
    - To accommodate a huge number of samples
    - Efficient analysis for the decommissioning process
    - Field-oriented analysis for the decommissioning process
    - Analysis that leads to the determination of the cause of the accident
    - Effective use of limited analytical human resources
    - Reducion of the burden on analytical work

- New analytical methods, techniques, and equipment need to be developed.
  - Accelerated and automated analysis
  - Simplified and efficient analysis
  - Increased accuracy and sophistication of analysis
  - Specialized analysis for the decommissioning process
  - A statistical approach to estimating the whole from a small number of samples

NDF

Issues related to analysis for 1F decommissioning (3/3)

- Is the existing personnel for analysis sufficient for 1F decommissioning?
  - Existing facilities require existing personnel for analysis
  - New facilities require new analytical personnel

- Need to develop, secure, and retain new personnel for analysis
  - Need personnel with a wide range of knowledge and skills
    - General chemical and instrumental analysis
    - Properties of various types of radiation and measurement methods
    - Physical, chemical, and biological properties of radioisotopes
    - Radiation protection, laws and regulations related to nuclear power and radiation
    - Chemical reactivity of fuels and materials, etc.

- JAEA and others have accumulated sufficient knowledge and experience in the handling of alpha nuclides and fuel analysis techniques
  - Personnel exchange between TEPCO and JAEA is important
  - Analytical specialists who evaluate and interpret the results of the analysis are rare, and it is important to work on increasing this number

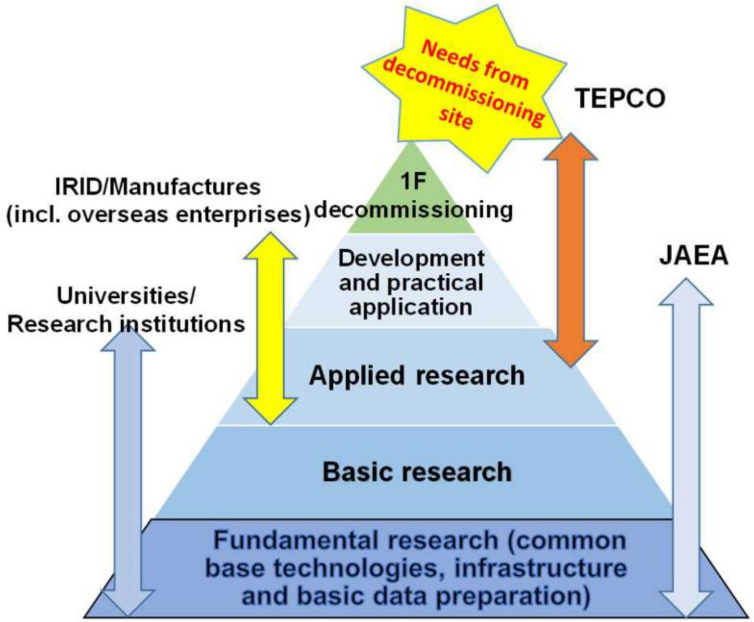
Measures to resolve the issues

Government Assistance

- Project of decommissioning, contaminated water and treated water management
  - Targeting applied research, practical application research, and on-site demonstration of high difficulty
- Nuclear energy science & technology and human resource development project
  - Targeting domestic and foreign universities and research institutions that promote fundamental and basic research and human resource development initiatives

Initiatives by various industrial-academic-governmental institutions

- Fundamental, basic and applied research by domestic and foreign universities, JAEA, and other research institutions
- Practical application research, and on-site demonstration by IRID, manufacturers including overseas companies, TEPCO, etc.



Scope of R&D for decommissioning and implementation entities
(Technical Strategic Plan 2021)

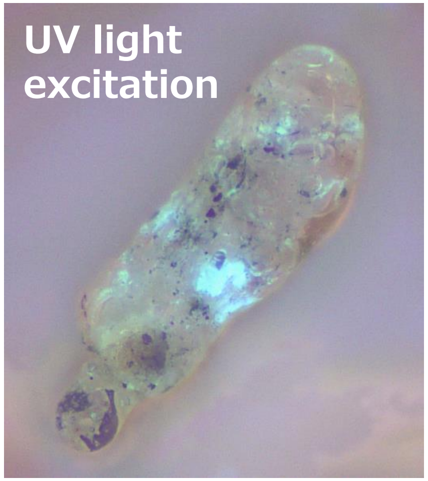
New university initiatives (1/4)

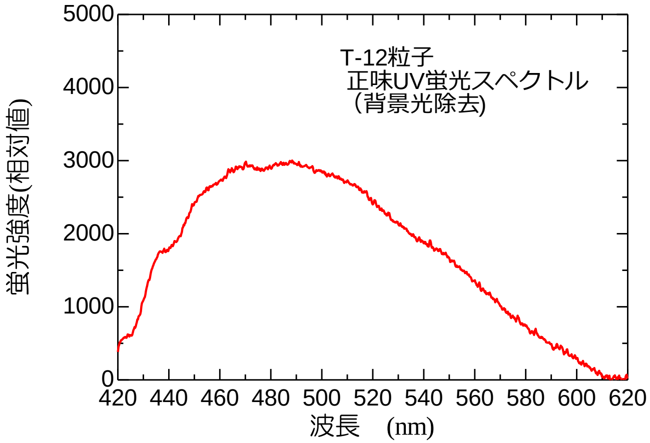
Elucidation of basic property of radioactive microparticles

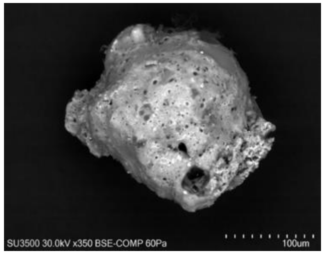
(Results of a group led by Professor Igarashi of Kyoto University (then Ibaraki University))

- Insoluble radioactive microparticles released into the environment were found and a foresighted study was initiated
  - Elucidation of basic properties by various analytical methods
- Discovery of induced fluorescence
  - Detectability of Cs-containing glassy materials by fluorescence
- Contribution to risk reduction in decommissioning work and deepening of accident progression scenarios

Particle a few μm in diameter with high Cs concentration (Type A; derived from Unit 2)







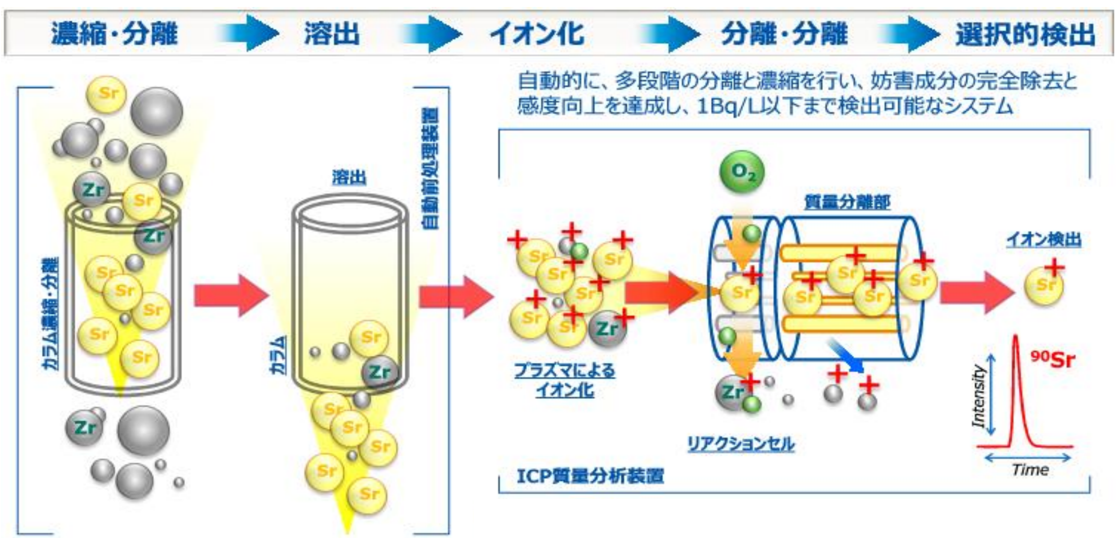
Particle tens to hundreds of μm in diameter with low Cs concentration (Type B; derived from Unit 1)

Fluorescence emitted from Type B particle irradiated with UV light

(Courtesy of Prof. Igarashi, Kyoto University)

New university initiatives (2/4)

- **Development of a rapid analytical method for strontium-90**
  (Results of a group led by Professor Takagai of Fukushima University)
  - Analytical method based on inductively coupled plasma-mass spectrometry (ICP-MS)
    - Complex analytical work and skilled techniques
      ⇒ Automatic pretreatment, automatic control and measurement systems
    - Long time (2 weeks to 1 month)
      ⇒ Measurement time: 23 minutes, detection limit: 0.3 Bq/L
  - Practical use at the 1F site from December 1, 2014



Overview of Rapid Analytical Methods for ^{90}Sr

The first practical use technology applied to 1F site developed by university

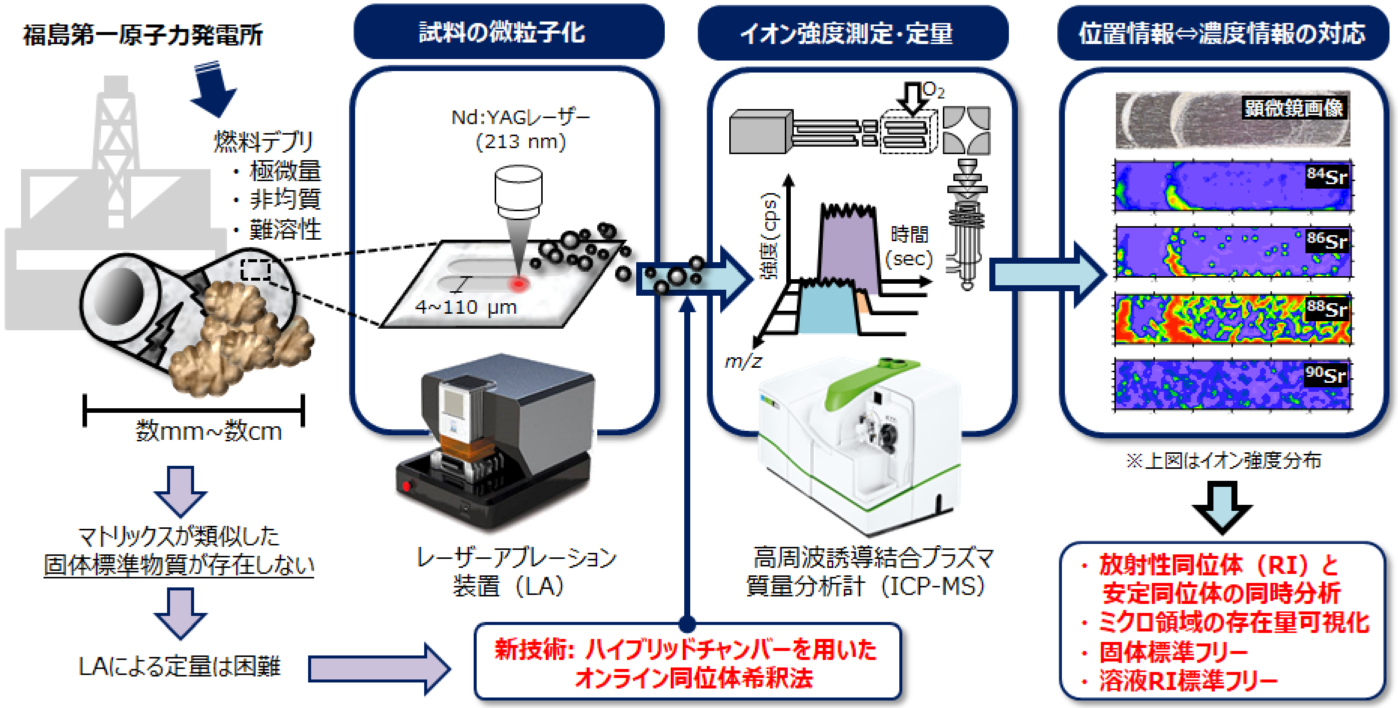
(Courtesy of Professor Takagai, Fukushima University)

New university initiatives (3/4)

- Technological development of micro-domain quantitative imaging of solid samples

(Results of a group led by Professor Takagai of Fukushima University)

- Laser Ablation - Inductively Coupled Plasma Mass Spectrometry (LA-ICP-MS)
  - Development of a simultaneous determination method for stable and radioactive isotopes without the use of solid reference materials, and its application to mapping

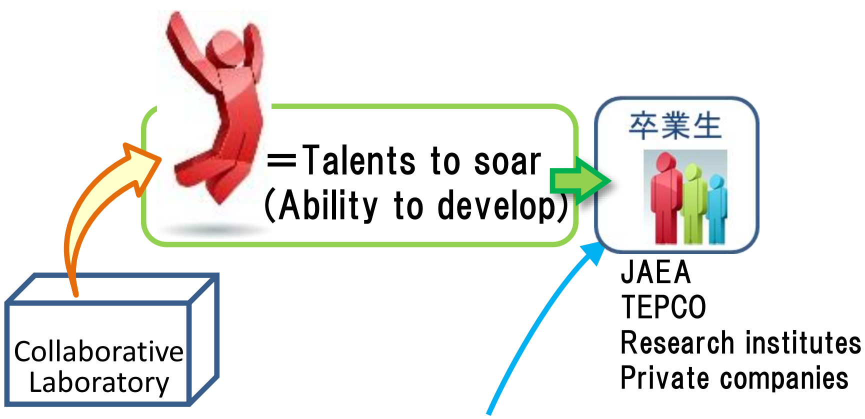


(Courtesy of Professor Takagai, Fukushima University)

Tie-up type human resource development

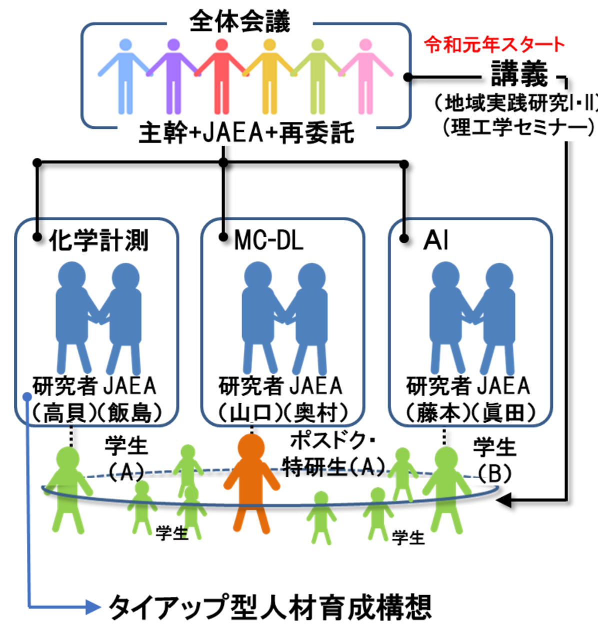
(Efforts by a group led by Professor Takagai of Fukushima University)

- Tie-up between Fukushima University and JAEA researchers
  - Graduate students, postdocs, and cross-appointment members staying at JAEA (Miharu) to conduct research
  - Course credit for lectures and practical training by JAEA researchers at Miharu
  - Lectures for students in collaboration with TEPCO for both research promotion and education
  - Volunteer education in cooperation with private companies, government agencies, and TEPCO



- Analytical engineers who can analyze both chemical and physical analysis
- Simulator with a background in physics and chemistry
- Analytical engineers who handle big data
- Physical and chemical engineers capable of handling AI

Image of human resources to be developed through this project



(Courtesy of Professor Takagai, Fukushima University)

Summary

- The analytical results are one of the important criteria for decisions for reducing the range of uncertainty in order to facilitate decommissioning of the 1F
  - Debris and accident-derived waste are not found in normal decommissioning
  - Quick identification of basic properties that is useful for decommissioning work and clarification of accident causes
- Existing analytical facilities, methods, and human resources are not sufficient for 1F decommissioning in a timely manner
  - Need new analytical facilities for 1F decommissioning
  - Need to establish an analysis system with shared roles, taking advantage of the characteristics of the existing and new facilities
  - Need simplified, efficient, accurate, sophisticated analytical methods to meet the purpose of analysis
  - Need to develop, secure, and retain new human resources for analysis
- Young people are eagerly awaited to participate in the decades-long decommissioning of the 1F reactors
  - Need to support activities at universities that can be a source of human resources