

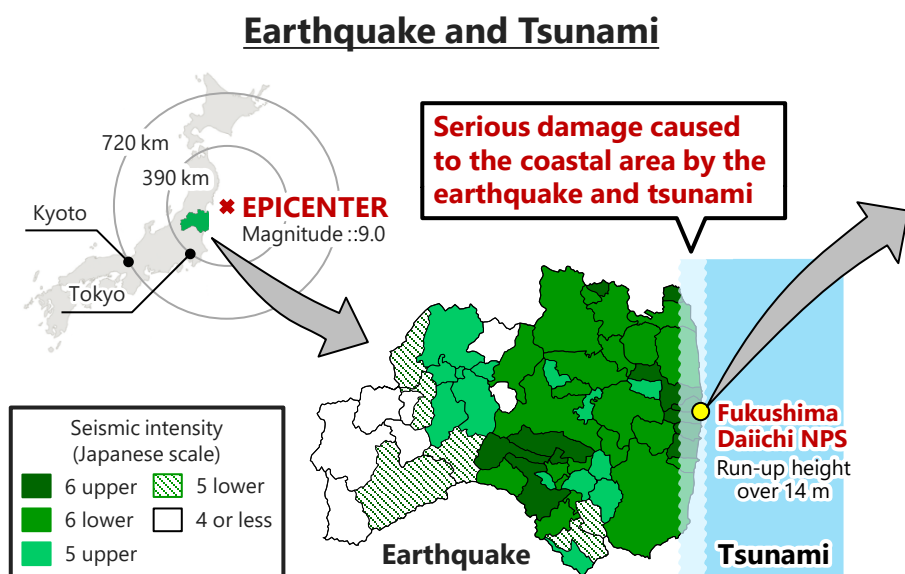


**ICRU Symposium 2023**  
**April 19, 2023, Iwaki, Fukushima**

# **JAEA R&D Efforts for Decommissioning of the Fukushima Daiichi NPS**

**Tokio Fukahori**  
**Fukushima Research Institute**  
**Japan Atomic Energy Agency**

- ◆ The 2011 Tohoku Earthquake off the Pacific coast, March 11, 2011, record high M9.0, and a tsunami struck a wide area along the coast.
- ◆ Nuclear reactors at Fukushima Daiichi NPS lost power and failed in cooling, lead to the INES 7 nuclear accident.

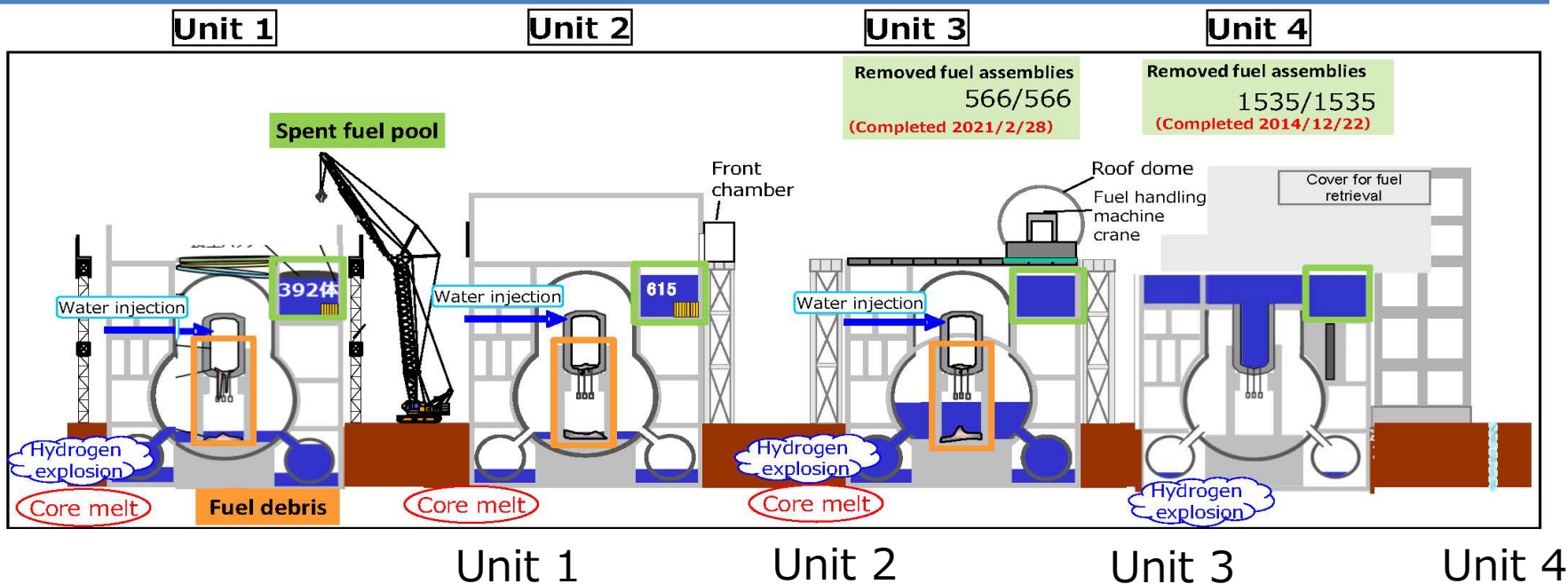


## Fukushima Nuclear Accident

- Power supply and cooling system disabled
- Core damage and hydrogen gas produced
- Hydrogen explosion
- Radioactive materials released into the air

Edited from “Steps for Revitalization in Fukushima 26<sup>th</sup> edition (Japanese ver.) <August 5, 2019>” . (Fukushima Prefecture) (accessed 2019/9/18)

(Ref.) Current status of Unit 1-4 of Fukushima Daiichi NPS



Edited from Monthly progress (July 28, 2022) (METI web-site)".

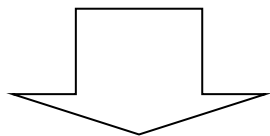
(URL) <https://www.meti.go.jp/english/earthquake/nuclear/decommissioning/pdf/mp202207.pdf> (accessed 2022/10/27)

Photos are downloaded from <https://www.tepco.co.jp/decommission/progress/about/>.

**At the Fukushima Daiichi site, some progress has been made, .....  
But, there remain unprecedended challenges ahead for the long run.**

- ✓ A large amount of radioactive materials, remaining unsealed and unknown
- ✓ Incomplete barriers for containment
- ✓ Uncertainties on the state of radioactive materials and containment barriers
- ✓ Difficulty in an access

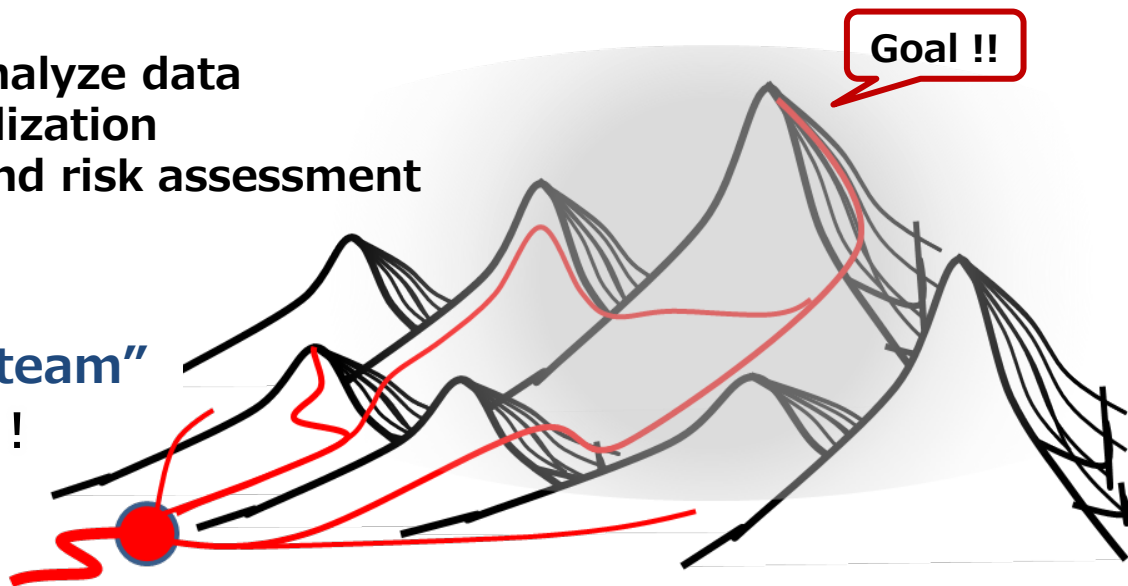
(Source: NDF Technical Strategic Plan 2021)



## R&D Needs

- **Collect, consolidate, and analyze data**
- **Characterization and visualization**
- **Methodologies for safety and risk assessment**

**“Sherpa guide” for  
“the mountain climbing team”**



## R&D for environment restoration

### CLADS at Fukushima CEC\* (2 sites)

- Environmental dynamics research
- Environmental monitoring



\*Fukushima CEC :  
Fukushima prefectural Centre for Environmental Creation

## Fukushima Daiichi Nuclear Power Station

## R&D for decommissioning

### Okuma Analysis and Research Center

- Development of analytical methods
- Characterization of radioactive waste and fuel debris



### CLADS

- Headquarter of JAEA's Fukushima R&D
- Severe accident analysis
- Waste management
- Remote visualization



### NARREC

- Mock-up test and training
- Robot simulator
- Virtual reality system

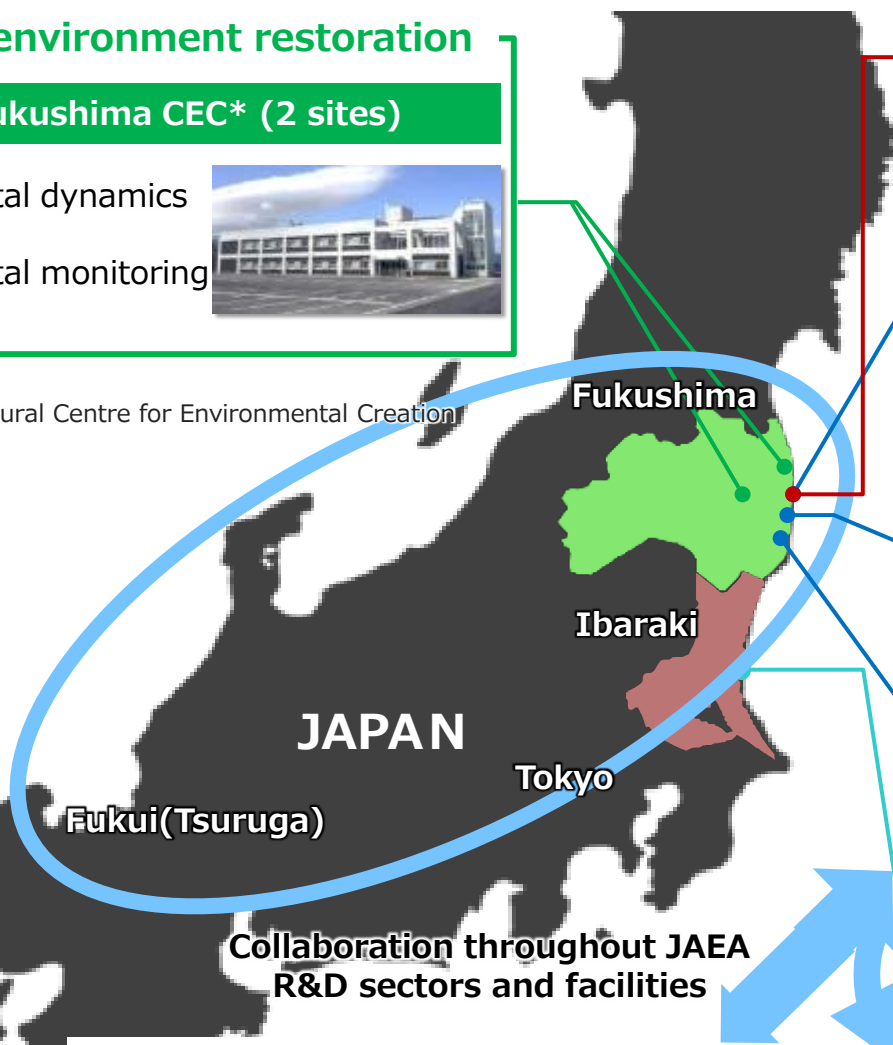


## Ibaraki area (Tokai and Oarai)

Nuclear Science Research Institute

Nuclear Fuel Cycle Engineering Lab.

Oarai Research and Development Institute



Collaboration throughout JAEA  
R&D sectors and facilities

## Other JAEA sectors/centers

Sector of Tsuruga  
Decommissioning  
Demonstration

Aomori R&D Center

Materials Sciences Research Center



### Development and Training via Integration of Physical and Virtual Mockups

- Mockup : Highly reliable and replicable testing under specific condition
- Virtual : Inexpensive evaluation under a variety of conditions



### Full scale mock-up field

Unit 2 PCV mock-up for arm-like equipment demonstration test and operator training (IRID)

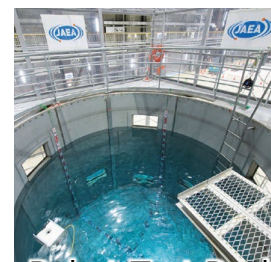


※ Source: METI official HP

### Robot test areas



Mock-up stairs

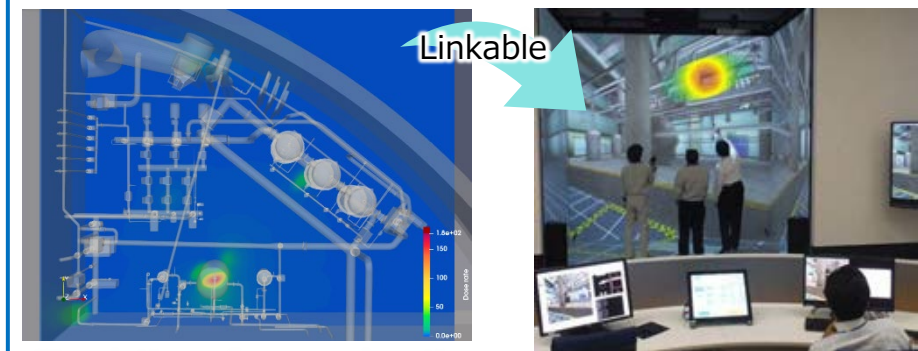


Robot Test Pool



Motion capture system

### 3D Virtual Reality System



Linkable

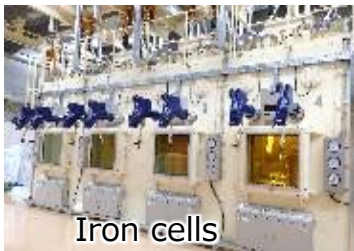
Simulation of source location

## Okuma Analysis and Research Center



### Laboratory -1

- Hot-cell operation has started in October 2022.
- Analysis of low-and-medium-dose radioactive wastes.
- Analysis of ALPS-treated water as third-party institution.



Iron cells



Glove boxes



Fume hoods

### Lab-2 (Pre-construction)

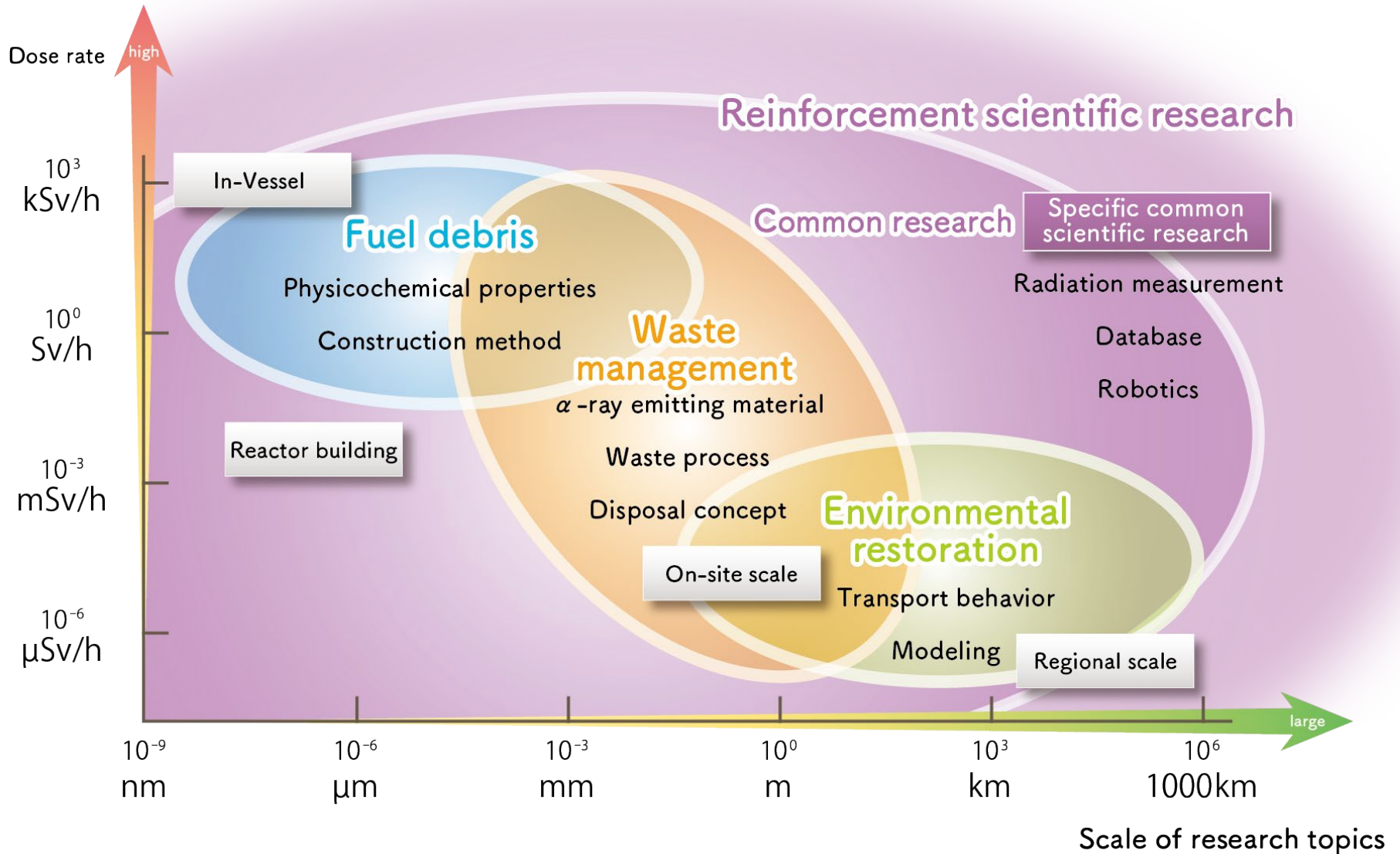
- Construction will start soon after the licensing process to be cleared.
- Analysis of high dose samples such as fuel debris.



Concrete cells

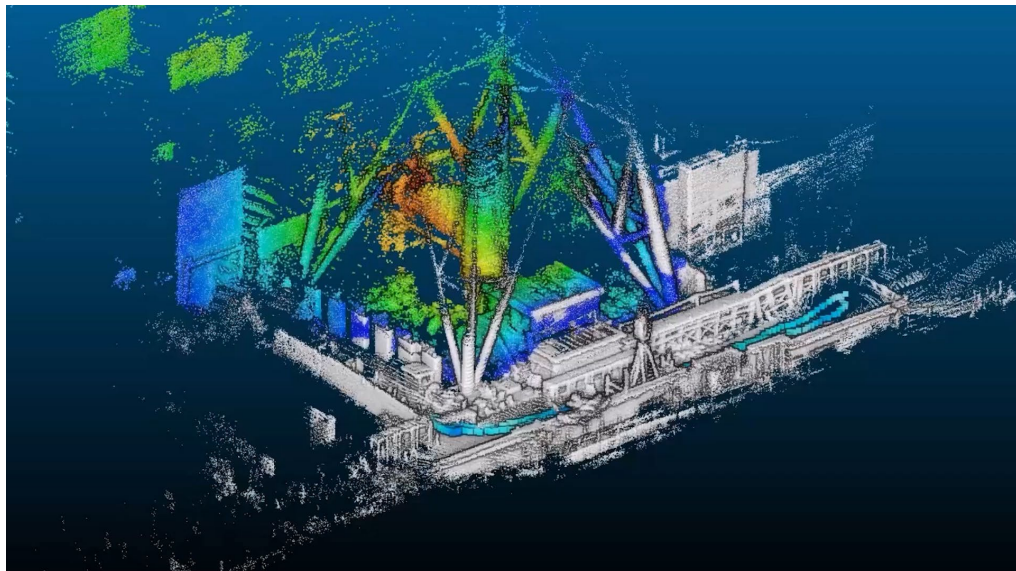
※The image shows a concrete cells at another JAEA site.







## 3D-Visualization of Invisible Radioactivity

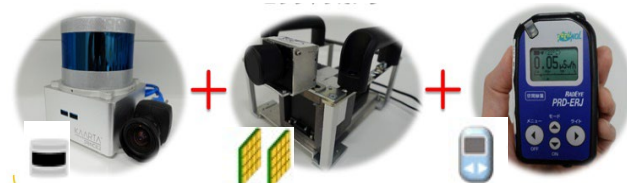


3D map visualizing radiation dose rate\*1

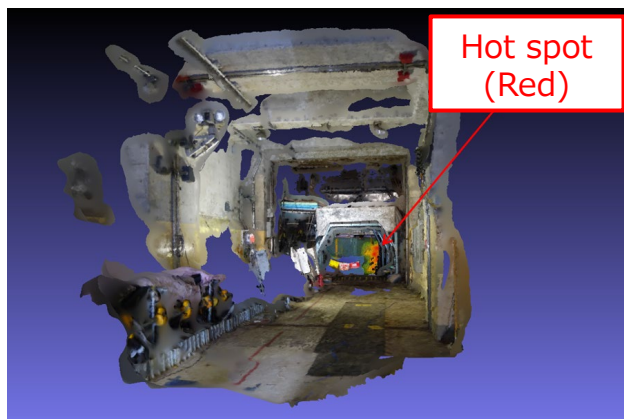
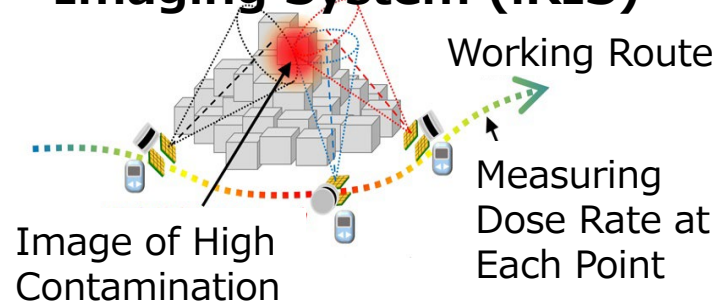
3D-Laser Scanner

Compton Camera

Radiation Survey Meter

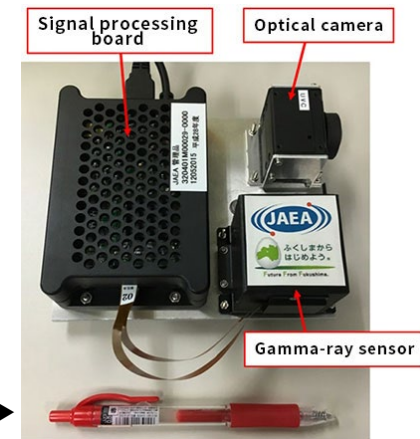


## Integrated Radiation Imaging System (iRIS)



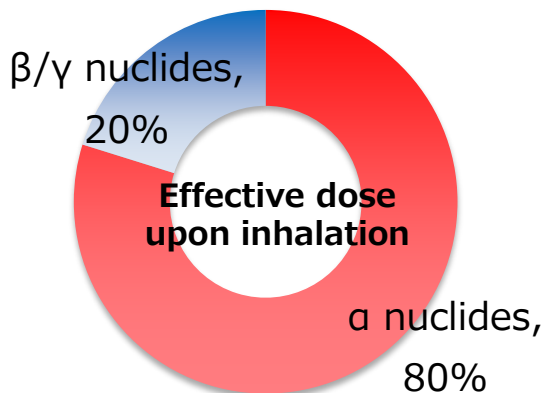
◀ Image of Hot Spots  
Compton camera  
+ 3D-Model  
+ Photogrammetry  
Technique\*2

Compact Compton camera ▶

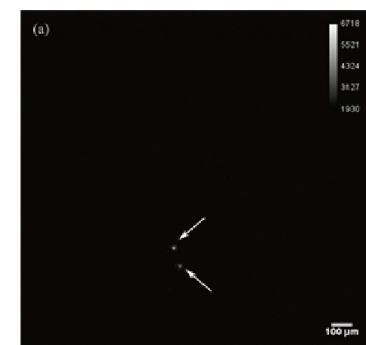
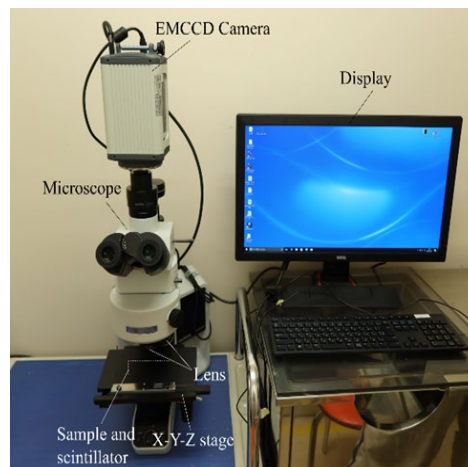


## Monitoring and Confinement Management of Alpha Nuclides

### Real-time High-resolution Visualization of Individual Alpha-emitting Particle



Effective dose estimation upon inhalation (1F-U2)



## In-situ Alpha Aerosol Monitor (IAAM)

### Inside 1F-PCVs

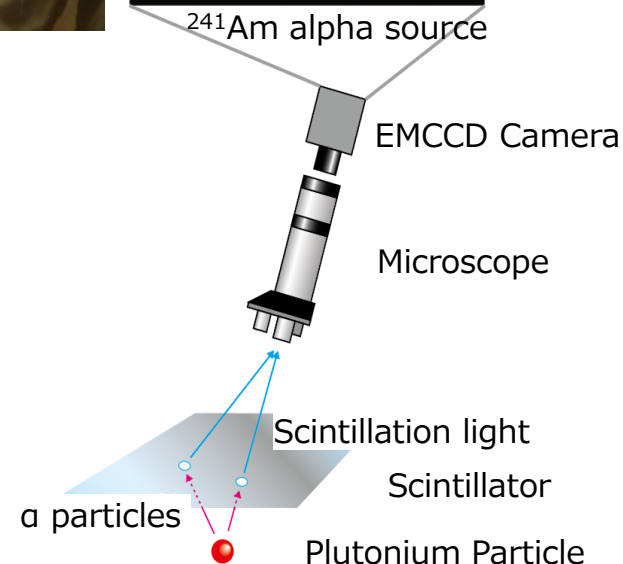
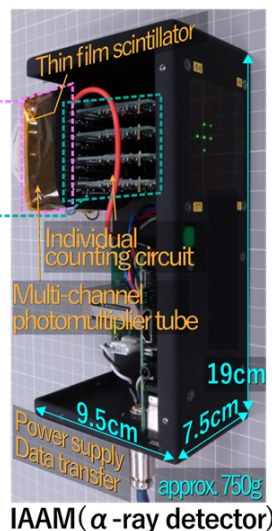
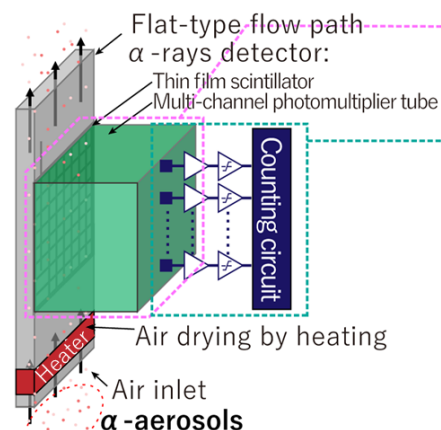
Humidity:  $\sim 100\%$   
high  $\beta/\gamma$ -rays background

### Processing of the Fuel debris

Highly-concentrated  $\alpha$ -aerosols

Fuel debris

"in-situ" monitoring by the IAAM (*in-situ* alpha air monitor)



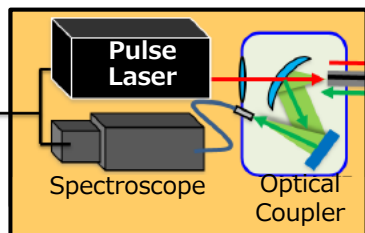
## Optical Fiber Laser-Induced Breakdown Spectroscopy (LIBS) Analysis

Elemental Analysis

Basic Type

Safe area

High dose area



Radiation-proof Fiber

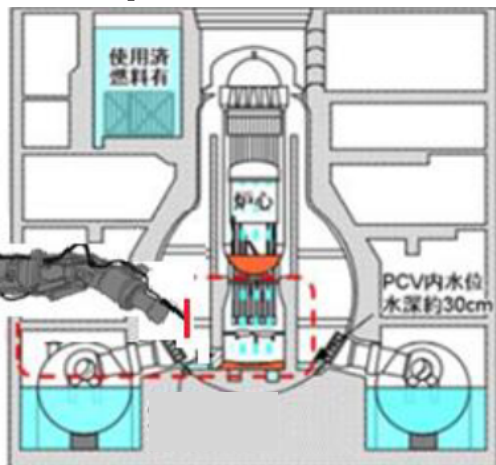
LIBS Probe Edge

Plasma Emission

Laser Light

Laser-produced plasma

Application to in-situ analysis in a reactor

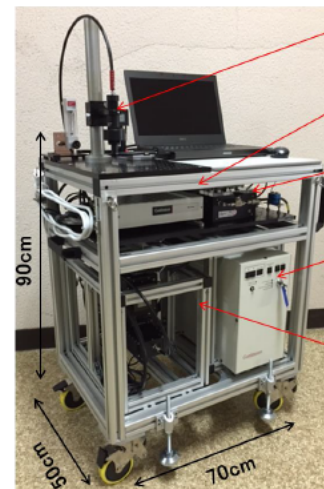


1kSv/h  
Humid Environment

φ 18 × L90



Using Basic Type



LIBS Probe

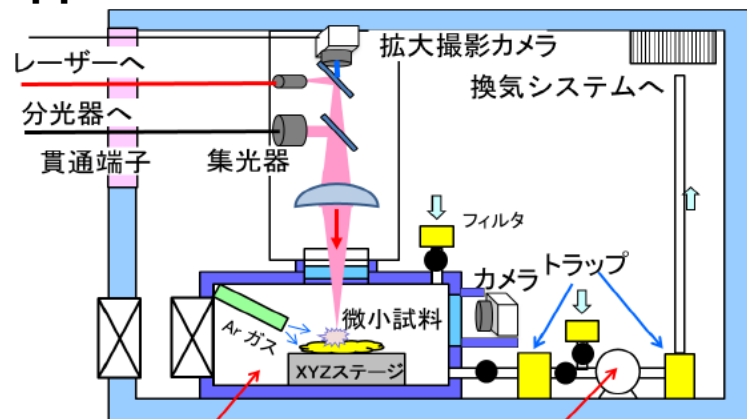
Laser Head

Fiber Camera

Laser Power Supply

Spectroscopy

Application to hot cell in-situ analysis



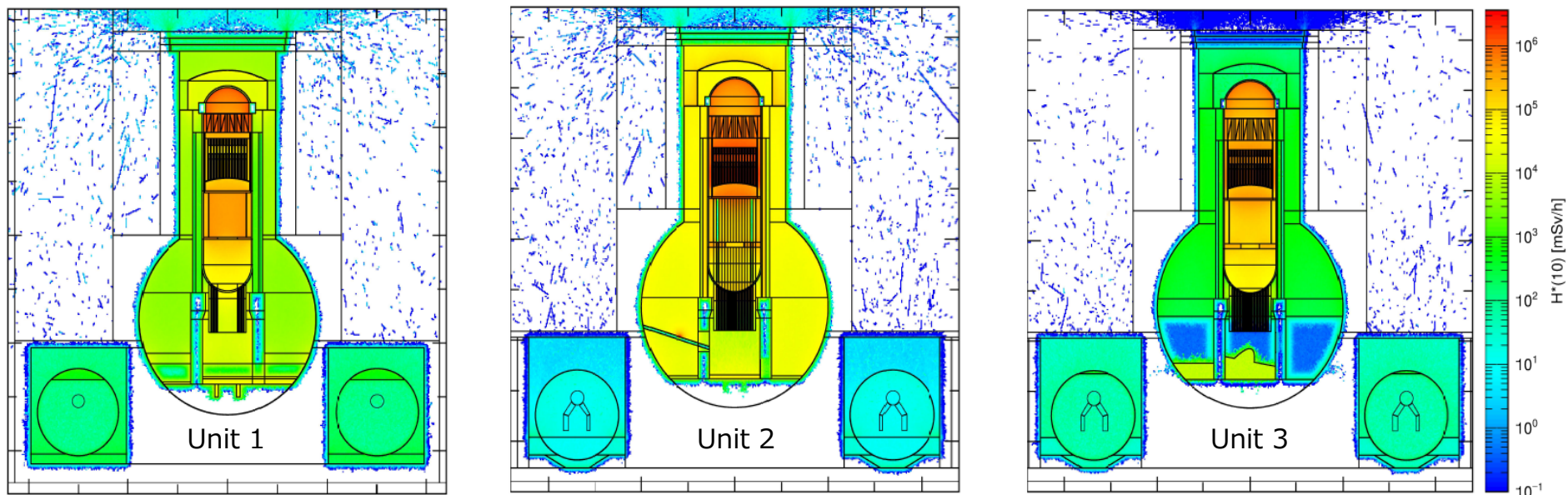
分析容器

真空ポンプ

100Sv/h  
Dry Environment



## Evaluation of spatially dose rate before the start of debris retrieval operation



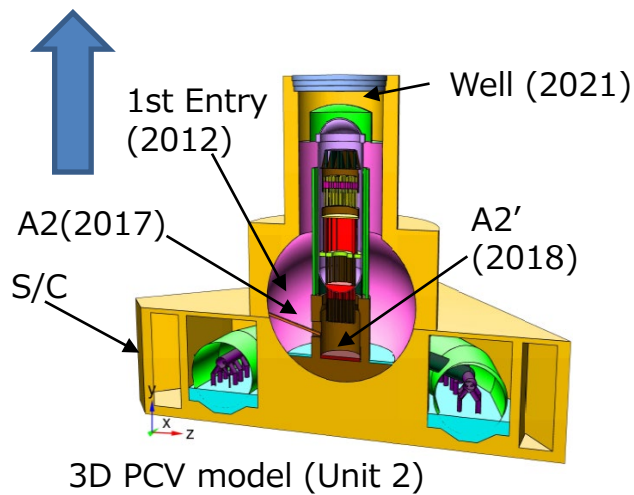
Feedback



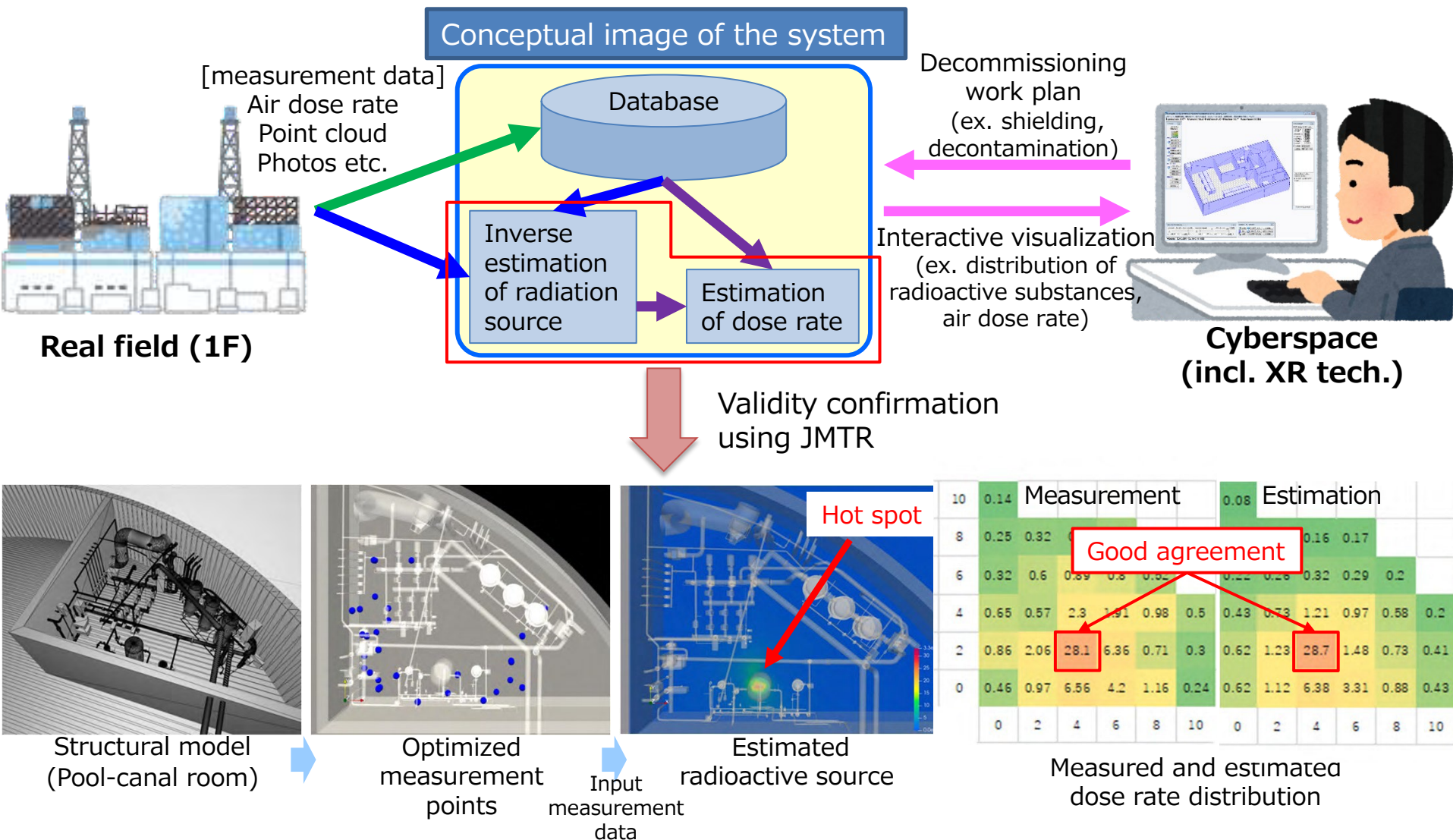
- Accident Progression Analysis
- Combustion and Radioactivation Analysis
- Fuel Debris Characterization
- Muon Imaging
- Camera (Optical) Imaging
- Radiation Dose Measurement

Simulation Model

- Source Sensitivity Analysis
- Dose Rate Analysis



## Radiation Source Evaluation System by using DX



**Thank you for your attention.**