Nuclear power in Japan, decommissioning of Fukushima Daiichi Nuclear Power Station, and UK-Japan research collaboration

4th UK Nuclear Academics Discussion Meeting
International Linkage Session

September 9, 2015

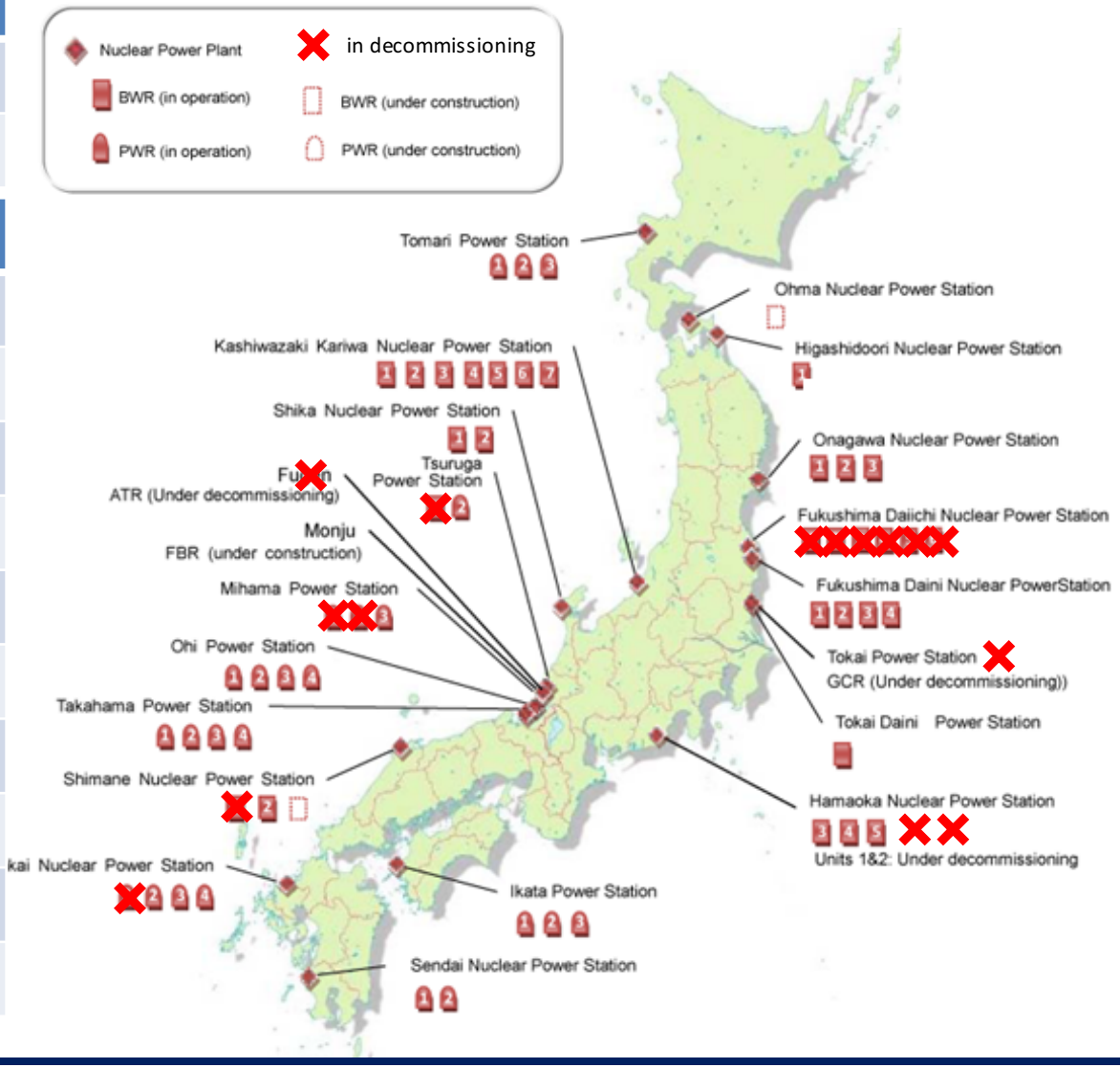
Hajimu Yamana

Nuclear Damage Compensation & Decommissioning Facilitation Corporation

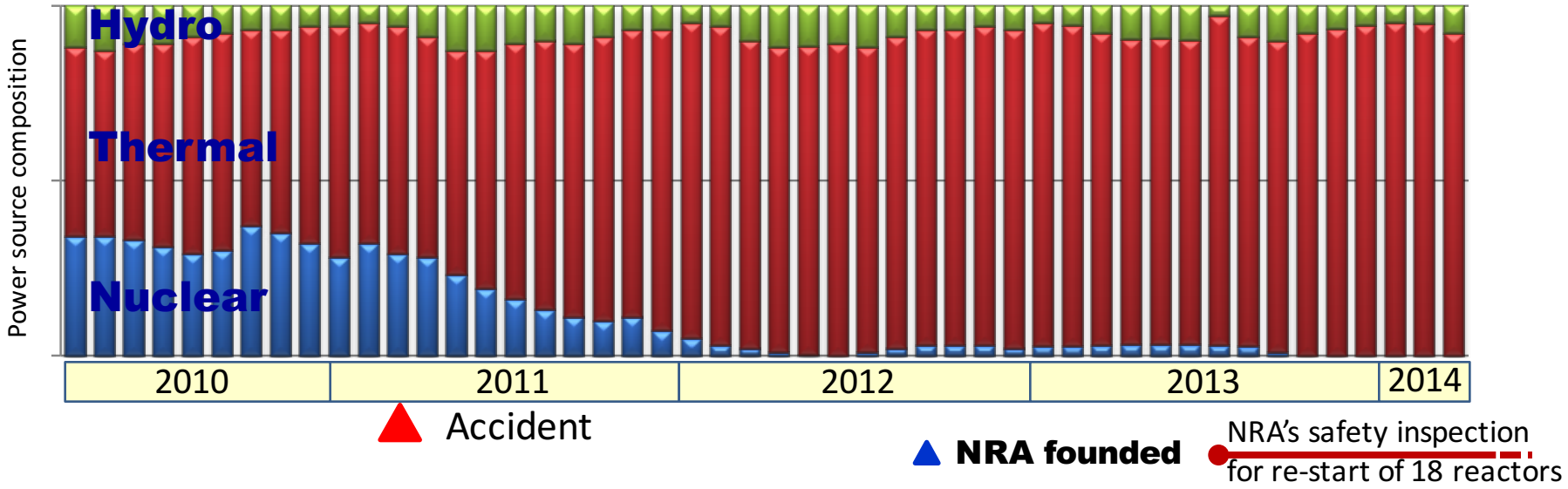
Nuclear power stations in Japan

Total capacity (GWe)	2010	2015
In operation	48.8	42.4
In decommissioning	2.6	9.0

Number of reactors		2010	2015
PWR	in operation	24	21
	in construction	0	0
	in decommissioning	0	3
BWR	in operation	26	18
	in decommissioning	2	10
ABWR	In operation	4	4
	in construction	3	3
GCR	in decommissioning	1	1
ATR	in decommissioning	1	1
FBR	In testing	1	1



Deliberation of new energy policy after the accident



Framework for Nuclear Energy Policy: AEC

New Nuclear Policy-Planning Council

Technical Subcommittee on Nuclear Power, Nuclear Fuel Cycle

Strategic Energy Plan of Japan: Cabinet and METI

DPJ administration

National Policy Unit

Advisory Committee for Natural Resources and Energy

"Zero-nuclear at 2030" proposed

LDP administration

Advisory Committee for Natural Resources and Energy

Restarted discussion

Revision by METI

Cabinet decision

Perspective of nuclear power in the new strategic energy plan

Strategic Energy Plan, cabinet decision on April 12, 2014

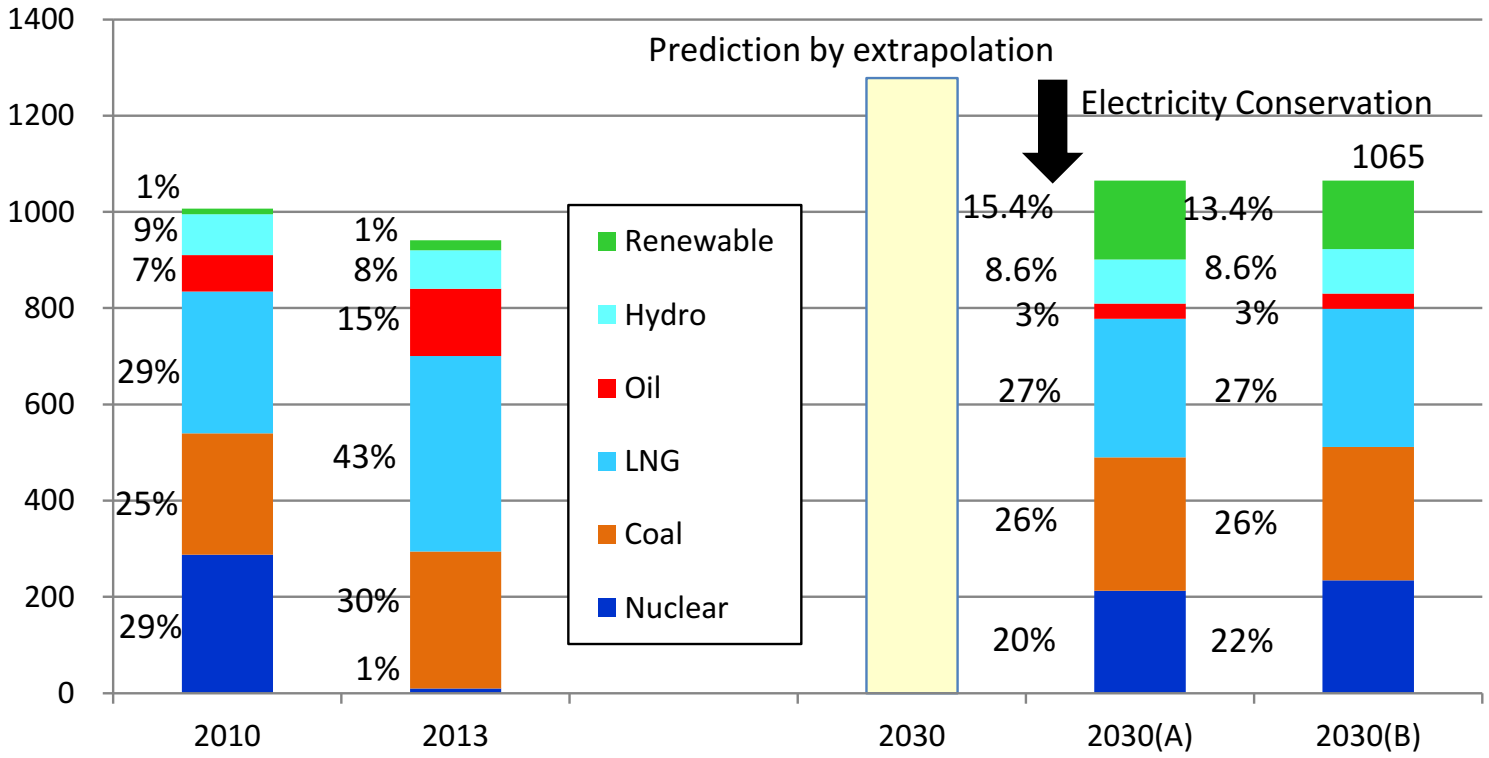
II. Principles of energy policy and perspectives for reform

(2) Nuclear power

- Important base-load power source as a low carbon and quasi-domestic energy source (contributing to the stability of energy supply–demand structure on the major premise of ensuring its safety) because of 1) superiority in stability of energy supply and efficiency, 2) low and stable operational cost, and 3) zero GHG emissions during operation
- Dependency on nuclear power generation will be lowered to the extent possible by energy saving and introducing renewable energy as well as improving the efficiency of thermal power generation, etc.
- Under this policy, we will carefully examine the quantity of electricity to be secured by nuclear power generation, considering Japan's energy constraints from the perspective of stable energy supply, cost reduction, global warming, and maintenance of nuclear technologies and human resources.

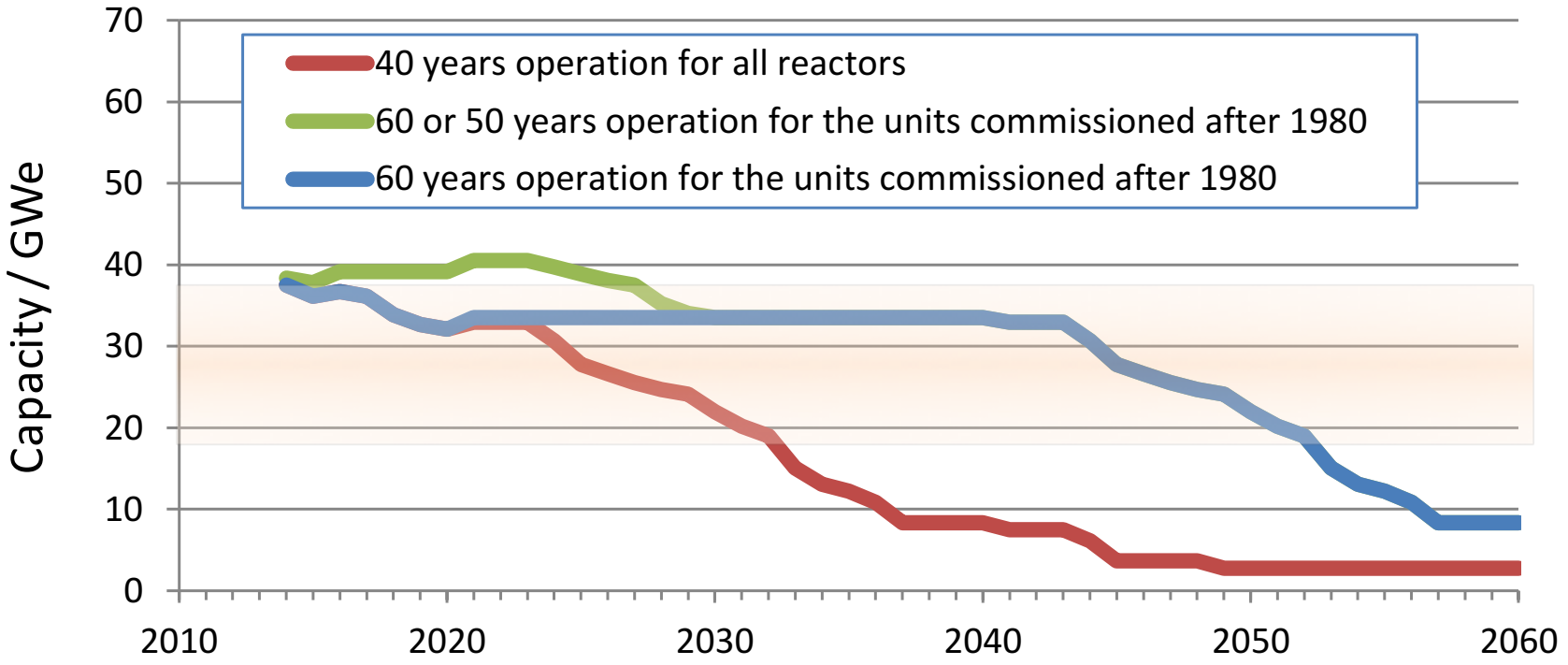
Future target of electricity supply at 2030

A plan setting a share of 20% to 22% for nuclear power in Japan's energy mix by 2030 has been approved by a consultative committee, in June 2015.



Outlook of Japanese nuclear power generation

- Nuclear power generation capacity will rapidly fall down, if there is no life-extension program of the existing reactors. Further deliberation on the future plan of new build of reactors will be necessary.
- At the same time, preparations will be necessary for the upcoming needs of the decommissioning of retiring reactors.



Nuclear fuel cycle

UOX at LWRs

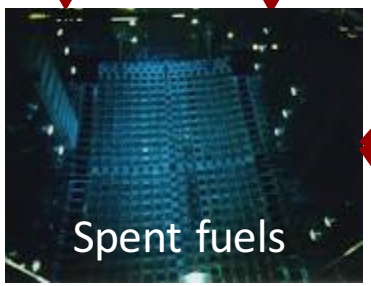
MOX reuse at LWRs

5.5-6.5 t of Pu to be consumed at 16-18 units

MOX

UOX

MOX



14,000 t stored as of 2012

SF

SF

Rokkasho RP

Process: 800t/y
Storage: 3,000 t

Pu

MOX Fab. plant

Will start in 2017

FBR R&D

Prototype FBR reactor: 280MWe

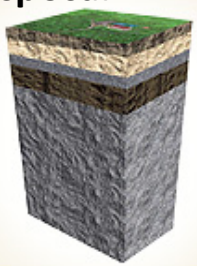
HLW

Mutsu RFS

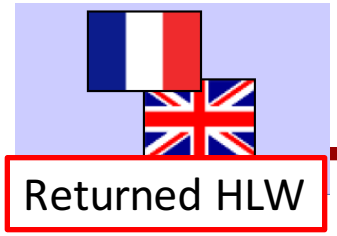
Storage: 5,000 t

LAW burial site

Deep geological disposal



Sub-surface burial site: under demonstration test



Returned HLW

HLW

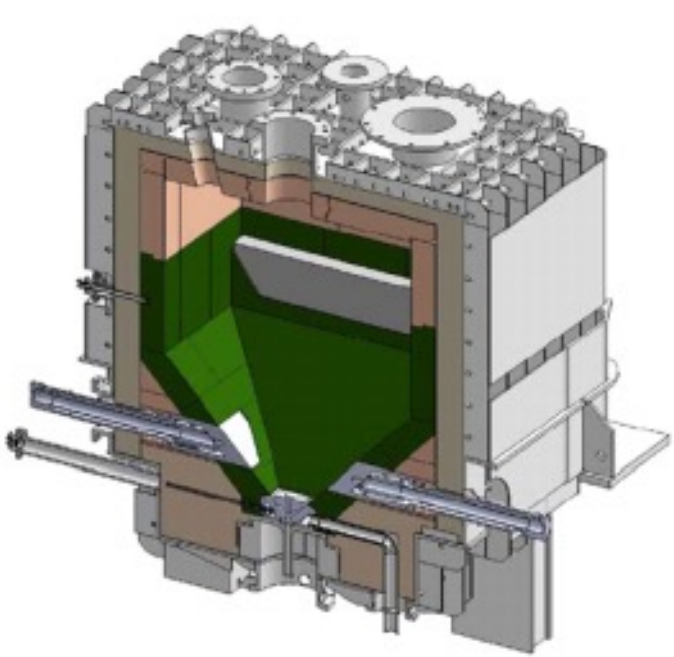
HAW storage Facility

HLW

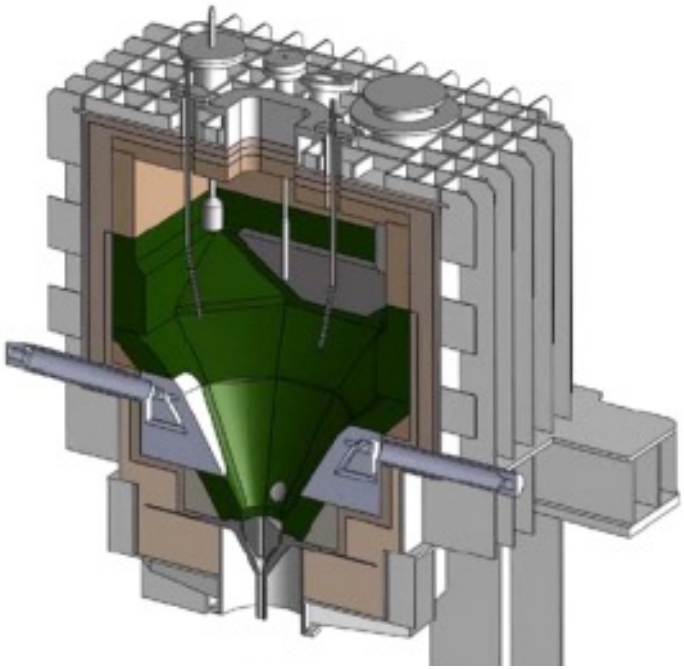
Rokkasho reprocessing plant, vitrification facility

Rokkasho Reprocessing Plant:

- Delay due to new regulatory requirement
- Vitrification process as the critical path of the performance(noble metal accumulation) has been improved



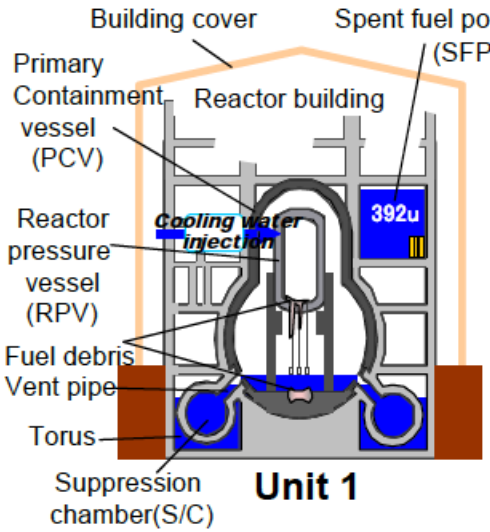
Original ceramic melter



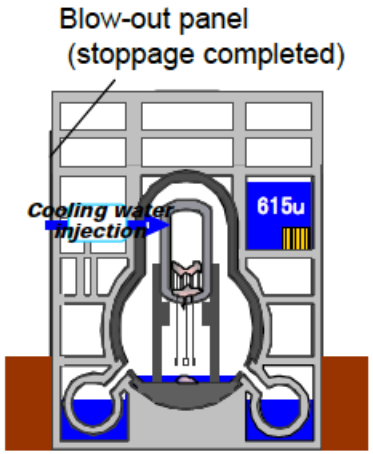
Improved ceramic melter

Latest status of Unit-1 to 4

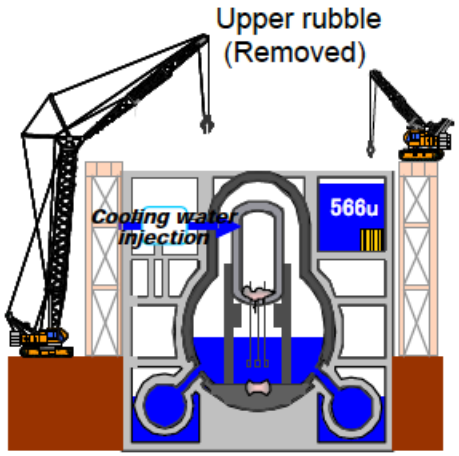
Unit-1



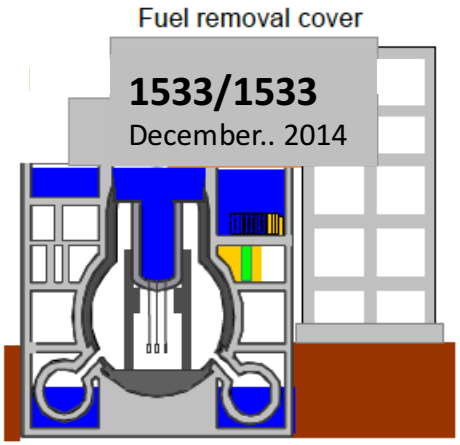
Unit-2



Unit-3



Unit-4



Organizational evolution

2011 2012 2013 2014

Cold Shutdown 2011.12.16

Roadmap

1st Road Map 2011.12.26

Road Map Revised 2012.12.26

Road Map Revised 2013.06.27

Road Map Revised 2015.06

Troubles

Contaminated Water Troubles mid-2013~

ALPS Troubles 2014.05~

Strategy

Emerging entities

IRID 2013.08.01

NDF 2014.08.18

R&D

Policy

Government

TEPCO

TEPCO D&D Co. 2014.04.01

Site Operation

Emergency Response Headquarters

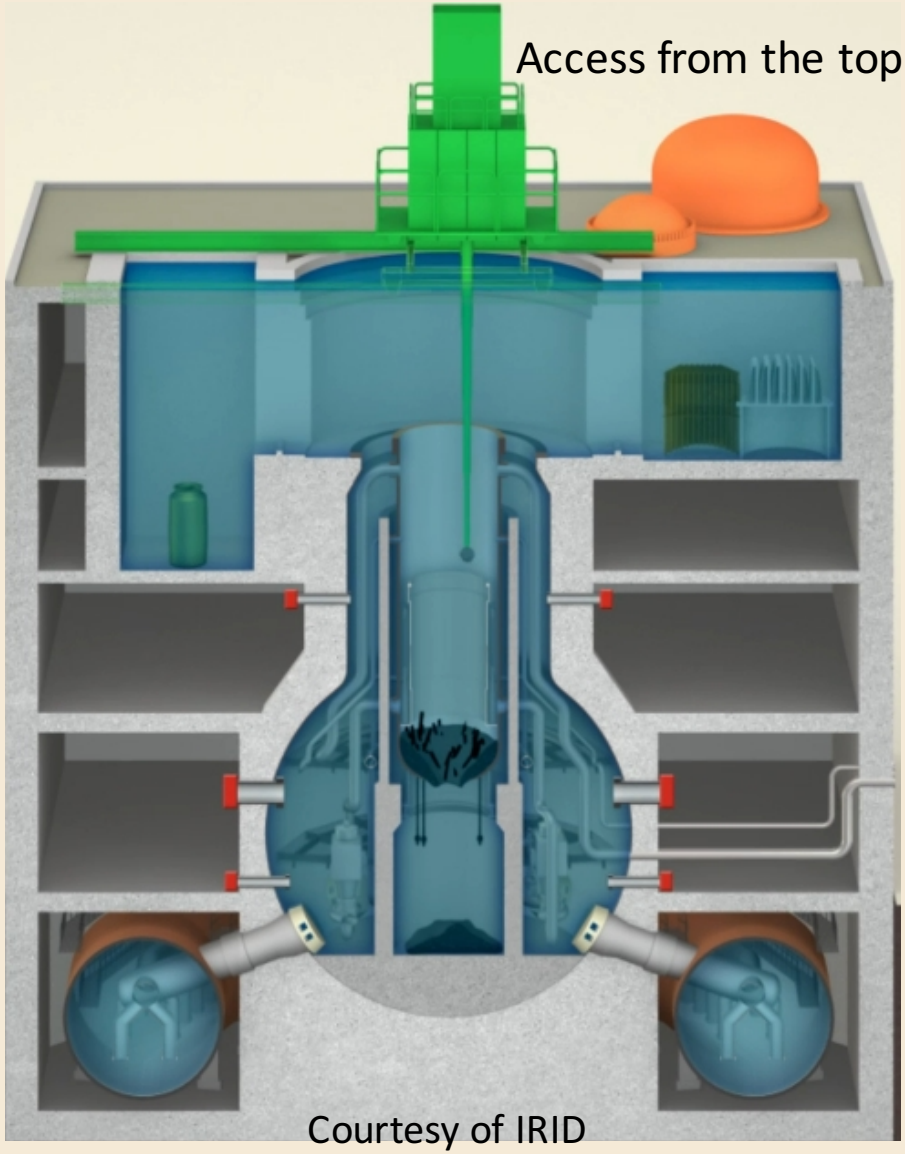
Change of Administration 2012.12

Inter-Ministerial Council for Contaminated Water and Decommissioning

Fuel-debris retrieval as the most challenging operation

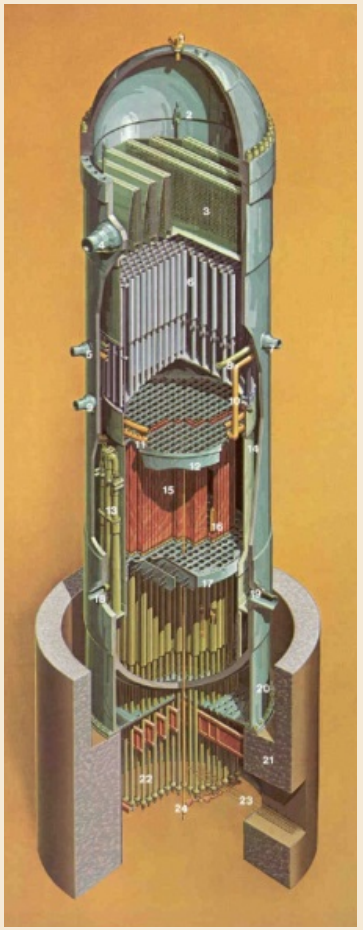
Technical difficulties

- Decontamination of rooms of the building
- Full-remote detection of leak points of PCV
- Decontamination of the inside of reactor vessels
- Full-remote fixing of leak points of PCV
- Cutting and pull-up of fuel-debris
- Encapsulation of retrieved fuel-debris
- Removal of heavy internal structures of RPV
- Safety assurance for re-criticality, radiation, and radioactive dust formation

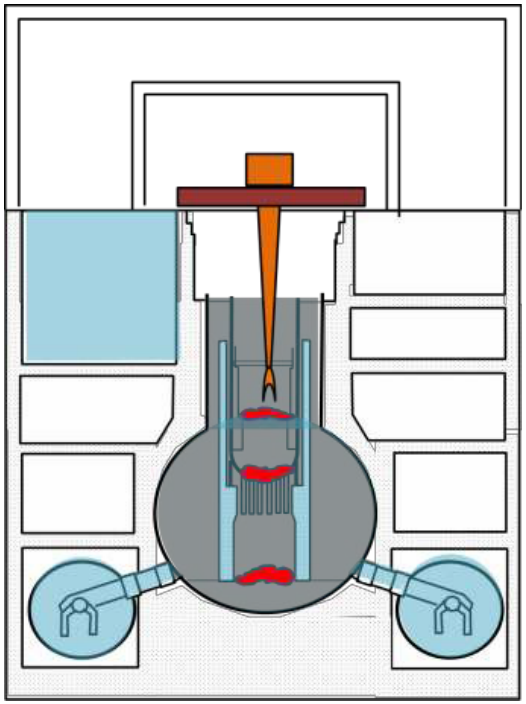


Courtesy of IRID

Access from the top with full submersion

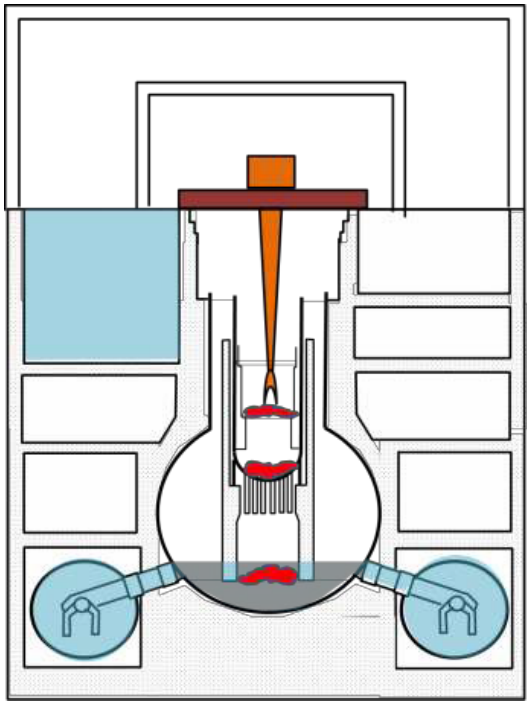


Three methods of fuel debris retrieval



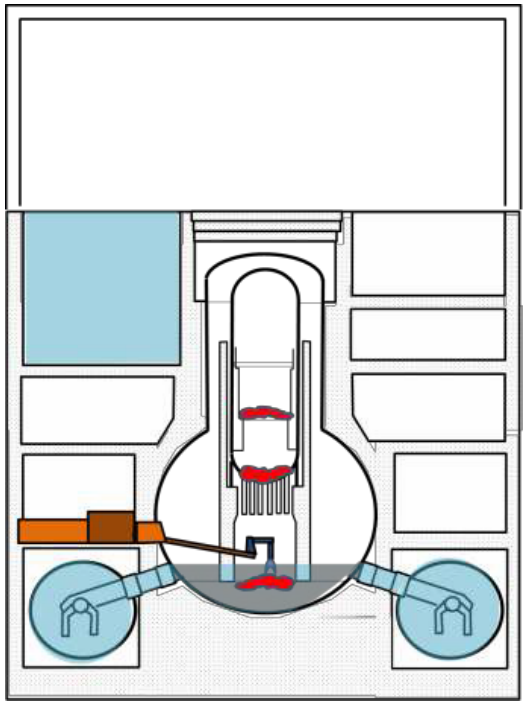
Submersion - Top entry method

Assuming the in-core structures above the fuel debris are removed



Partial submersion - Top entry method

Assuming that the in-core structures above the fuel debris are removed

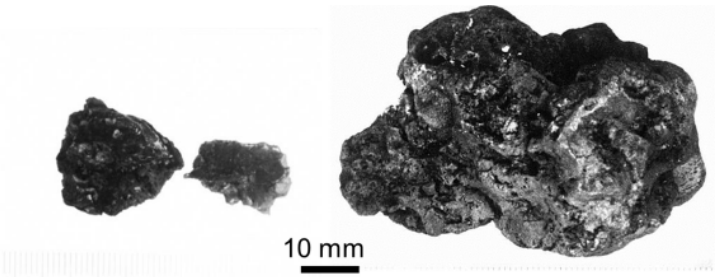


Partial submersion - Side entry method

Assuming that the equipment and other objects outside the RPV pedestal in PCV are removed

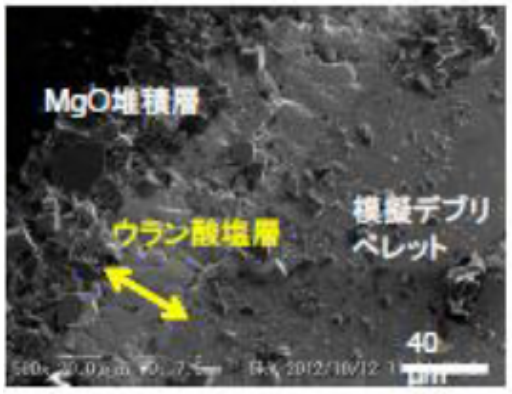
Fuel-debris

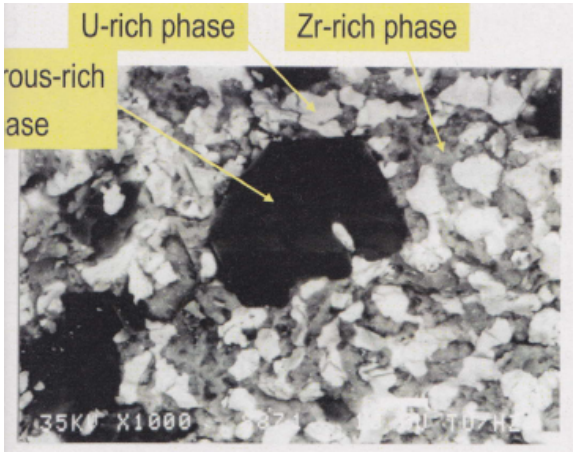
Sample of fuel debris taken from TMI-2 core (investigated by JAEA)



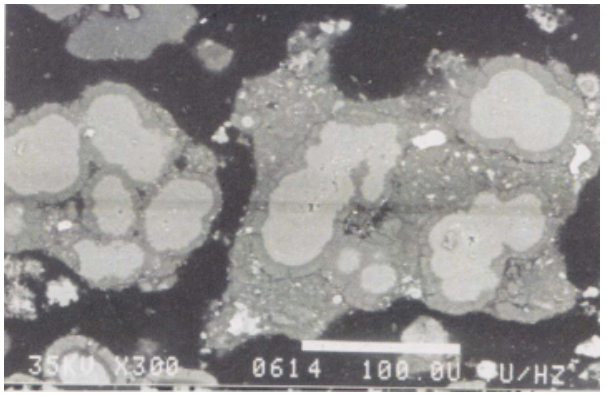
Quotation: The TMI-2 Chronicle, GPU Nuclear Communications

Sim. fuel debris studied by JAEA





TMI-2



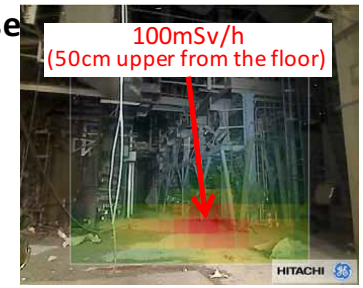
Robots implemented for inspection and clean-up

T-Hawk — **Visual survey from bird-eye view**

3u R/B
(2011.4.15)

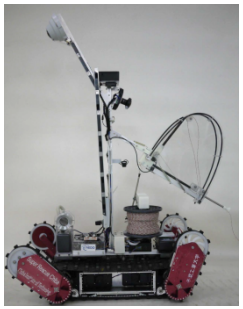
Packbot — **Visual survey and dose rate measurement**

Gamma camera



3u 1F Large-object carry-in entrance (2012.6.11-15)

Quince — **Upstairs survey**



3u 2F to 3F
(2011.7.26)

2u 5F Operation floor(2012.2.27)

Visual surveyed and dose rate was measured

Warrior — **Obstacle removal**

3u 1F Large-object carry-in entrance
(2011.11.3)

Survey Runner — **Torus room survey**

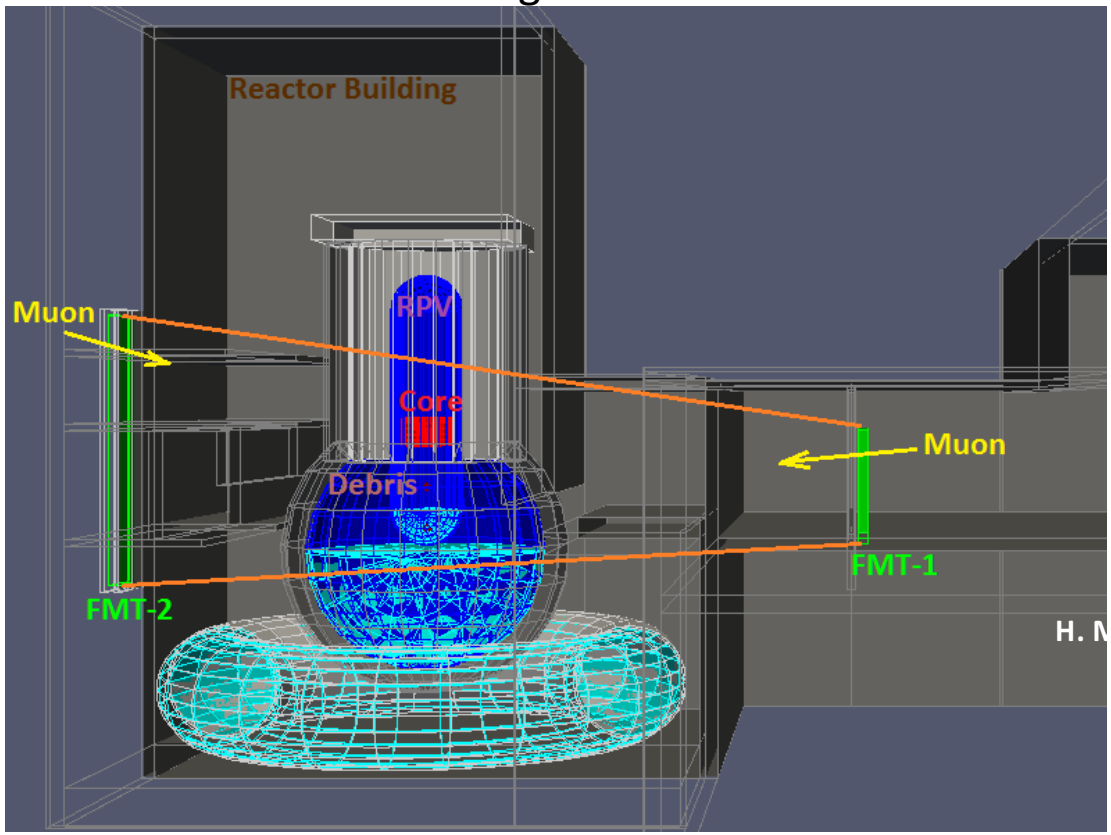
2u Torus room
(2012.4.18)

FRIGO-MA — **Small room survey**

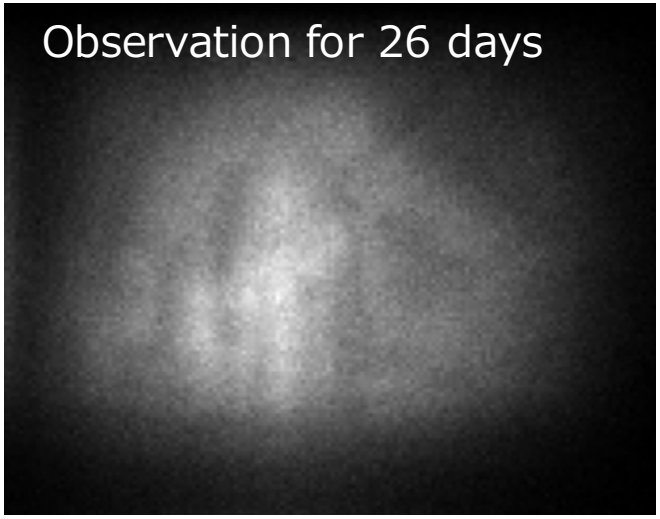
1u 1F Personal airlock room
Visual surveyed (2013.4.9)

Muon-tomography

Unit-2 Scattering method



Unit-1 Transmission method



Risk reduction strategy for the D&D

Definition of risk

(i) Risk of radioactive materials

- Risk = level of effect x probability of occurrence

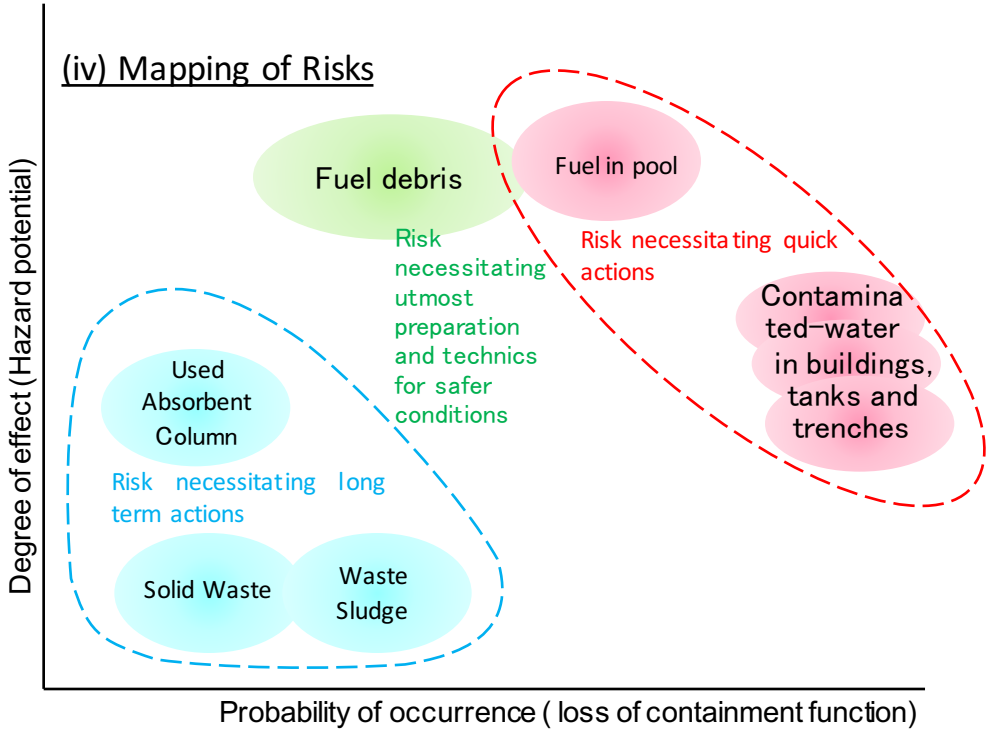
(ii) Degree of effect

- If the containment function is lost, radiation effects (exposure, environmental contamination) occur.
- Degree of effect = level of activity x physical state (solid, liquid or gas)

(iii) Probability of occurrence

- Factors for the loss of the containment function include natural phenomena, failures and improper operations.
- The vulnerability of the facility to the above factors needs to be considered.
- Probability of occurrence = possibility of occurrence of the factor x vulnerability of the facility

(iv) Mapping of Risks



(v) How to reduce risk

- Move radioactive materials to a safer and more stable facility.
  → Reduce the probability of occurrence.
- Decay of radioactivity and change in the physical state
  → Reduce the degree of effect.

Overview of R&D program for decommissioning

Government of Japan

METI

MEXT

NDF 原子力損害賠償・廃炉等支援機構
Nuclear Damage Compensation and Decommissioning Facilitation Corporation

Comprehensive management of a series of relevant R&D programs based on the NDF's Strategic Plan

Decommissioning and contaminated water management Program

Fundamental research and HRD program

Development and practical application

ex. Equipment's, devices, and system development by TEPCO and engineering companies

東京電力 etc.

R&D program (mainly application development)

<Areas and Topics>

1. Long-term management of fuel removed from SFP
2. Fuel debris retrieval methodologies
(Note: int'l RFP has been made and a couple of overseas R&D institutions is supposed to work together)
3. Radioactive waste processing/disposal
4. Contaminate water management-related
 - Demonstration of frozen-soil shielding and ALPS
 - F/S of selected technologies

IRID

東京電力 日本原子力発電株式会社 The Japan Atomic Power Company and utilities

HITACHI GE TOSHIBA 三菱重工

JAEA 産総研 株式会社アトックス

Collaboration with R&D organizations

IAE KEK 電力中央研究所

東京大学 THE UNIVERSITY OF TOKYO 東京工業大学 Tokyo Institute of Technology etc.

CEA, EPRI, NNC, KAERI, and other int'l organizations

Basic and fundamental research

- JAEA's basic and fundamental research in radioactive waste and fuel debris
- Collaborative research with Japanese and int'l R&D institutions, such as UK's

R&D Hub development

JAEA

- Mock-up test facility
- Radioactive materials analysis and research facility
- International joint research center for decommissioning

Human Resource Development

東京工業大学 Tokyo Institute of Technology ····· 東北大学 TOHOKU UNIVERSITY ····· 東京大学 THE UNIVERSITY OF TOKYO

・Awarded in 2014 as the HRD hubs, collaborating with multiple partner organization. Additional HRD hubs will be selected in 2015.

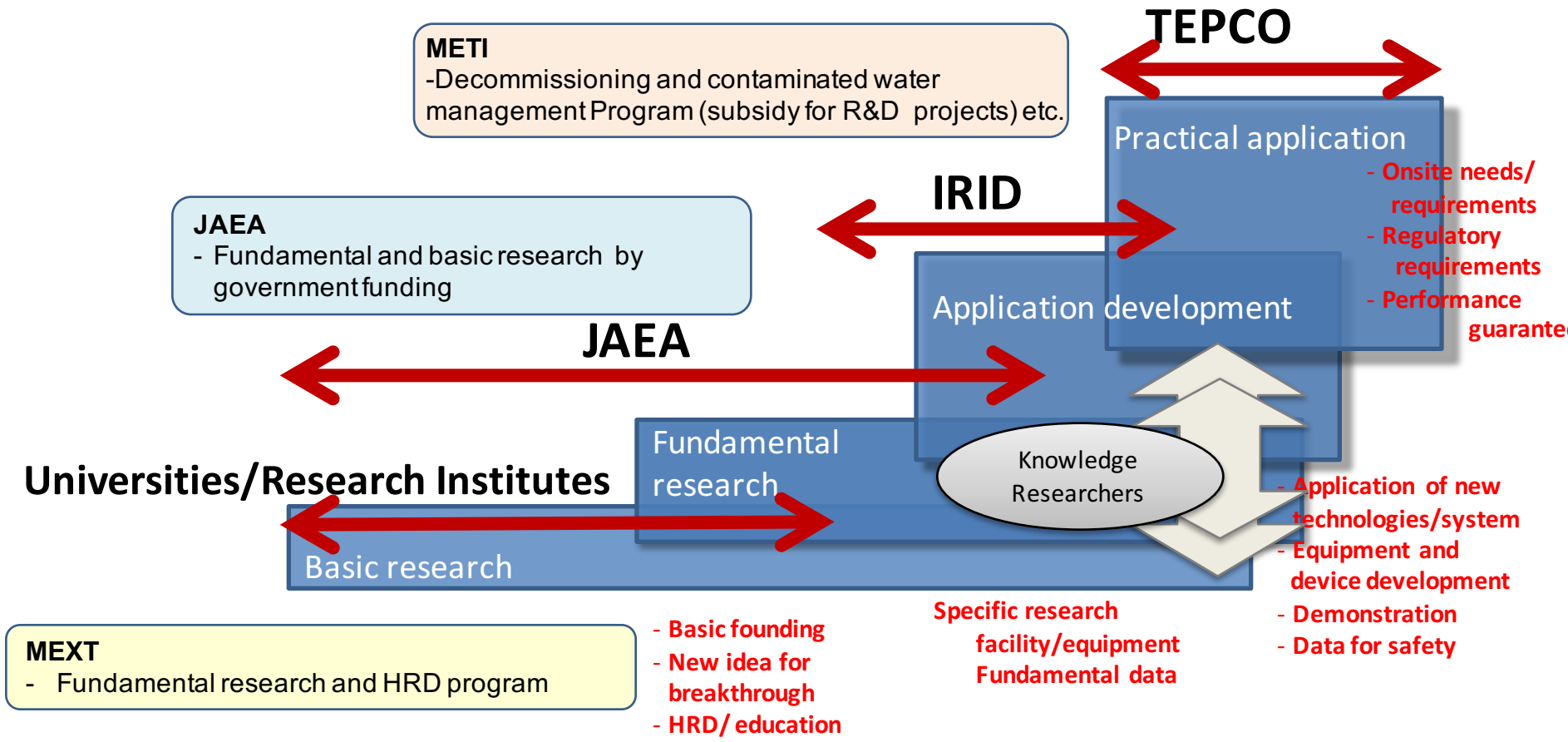
Academic Societies

ex. AESJ's "Fukushima Daiichi Decommissioning Committee"

NDF

Need of integrating all relevant R&D activities

It is important to facilitate interaction and communications among researchers and engineers involved in a series of R&D initiatives.



Collaborative Laboratories for Advanced Decommissioning Science

CLADS(JAEA): Collaborative Laboratories for Advanced Decommissioning Sciences

TEPCO, IRID, NDF

Cooperation with TEPCO, IRID, and NDF

Fukushima Pref, MOE

Environment Creation Center（2015, Apr～）
- Environment monitoring, study on environmental recovery

Fukushima Technology Centre
- Academia-industry cooperation
- Cooperation with regional industry

Cooperation

Cooperation

Joined by 100-150 domestic and international researchers

Utilization of JAEA's TOKAI and OARAI facilities（2015, Apr～）

【Acceleration of R&D on Decommissioning】
- Handling, analysis, and monitoring techniques for nuclear fuel
- Debris removal and decommissioning process
- Handling, storage and management of nuclear waste, etc.

【Utilization of JAEA's testing facilities】
- Facilities for nuclear fuel and radioactive material
- Facilities for high energy irradiation, etc.

Building of CLADS：In Fukushima（FY2016～）

【R&D in a wide variety of fields】
- A platform for R&D and HRD of 1F decommissioning
- A facility for universities and institutions in and outside Japan to collaboratively use for reactor decommissioning study
- Near 1F
- Total floor space: about2,500m²

Image

Application

Naraha Remote-Control Technology Development Center（2015～）

【Decommissioning R&D】
- Development of remote-control devices for decontamination, observation, and maintenance, etc.

Okuma Analysis and Research Center（2017～）

【Decommissioning R&D】
- Analysis of hard-to-measure nuclide, development of monitoring methods, etc.

Objective: Establish an international R&D center led by JAEA, form a network connecting human resources of universities, research institutes, and industries inside and outside Japan, and create a framework for conducting R&D by industry-academia-government collaboration and HRD comprehensively.

【Future efforts】

○Set up Collaborative Laboratories for Advanced Decommissioning Science (CLADS) within JAEA in April 2015. For the present, R&D is conducted using the existing facilities in Tokai and Oarai areas.

○Launch sequentially joint research projects using "Naraha Remote-Control Technology Development Center" (FY 2015 -) and "Okuma Analysis and Research Center" (FY 2017 -), which JAEA plans to build as R&D bases in Fukushima

○Establish "International Joint Research Facility (tentative)" in Fukushima Pref. as a platform for external researchers to share for R&D activities. (FY 2016 -)

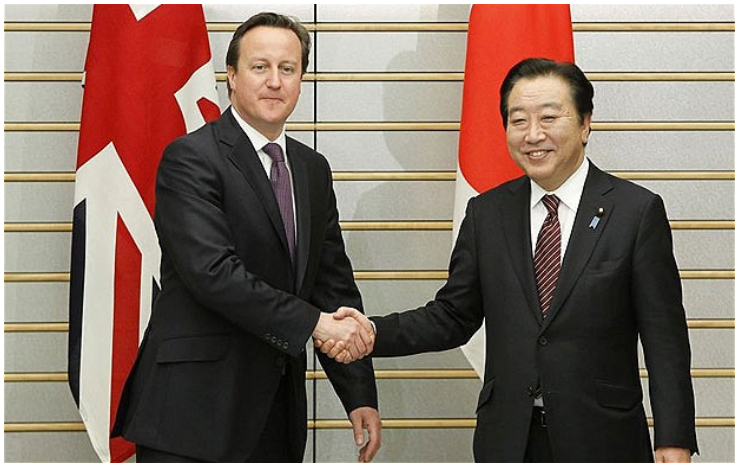
○Link fundamental R&D and on-site technologies. Serve as a place for HRD with the participation of universities, etc.

Japan-UK Dialogue

Background

Prime Minister Noda and Prime Minister Cameron held a summit meeting in Japan and produced a joint statement during PM Cameron's visit to Japan on 10 April 2012. The 'Japan-UK Framework on Civil Nuclear Energy Cooperation,' which was annexed to the joint statement, states that Japan and the UK decided to launch an annual dialogue at senior level to strengthen bilateral cooperation across the full range of civil nuclear activities.

JOINT STATEMENT
A Leading Strategic Partnership for Global Prosperity and Security
10 April 2012



Annual Japan-UK Nuclear Dialogue

1st 4th and 5th October 2012 in Tokyo.
2nd 30th and 31st October 2013 in London
3rd 9th and 10th October 2014 in Tokyo

Quotation from handouts by British Embassy Tokyo

Agenda of Japan-UK Nuclear Dialogue

Decommissioning and Clean-up
Nuclear Policy
Nuclear Safety and Regulation
Nuclear Research and Development
Public Communication

Preparatory meetings for UK-Japan Research Collaboration

UK-Japan Nuclear Safety R&D Workshop

A special meeting by leading experts on nuclear safety and engineering researches in UK and Japan

- Date 30 - 31 October, 2012
- Venue British Embassy Tokyo

Coordinator:
Prof Grimes (UK)
Prof Yamana (JPN)

UK-Japan Nuclear Safety R&D Symposium

A symposium with experts of nuclear safety researches in UK and Japan, opened to the general organizations related to nuclear business and developments

- Date 31 (afternoon) October, 2012
- Venue Koshiba Hall, The University of Tokyo

Quotation from handouts by British Embassy Tokyo

UK Japan Civil Nuclear Research Program

FY 2014

Period of application: May 2, 2014 – June 19, 2014
Funding available: Maximum Y10M per year
Maximum duration: 3 years
Proposal(s) to be granted: Two
Subject area:
(1) Joint research on severe accident studies
(2) Joint research on environmental safety

As this is a joint call with EPSRC(UK), JST and MEXT (Japan) all applications should be collaborative, with the UK partner submitting their part of the proposal to EPSRC and the Japanese partner submitting their part of the proposal to JST.

FY 2015

Period of application: May 18, 2015 – July 7, 2015
Funding available: Maximum Y30M per year
Maximum duration : 3 years
Proposal(s) to be granted: Four
Subject area:
(1) Joint research on removal of fuel debris
(2) Joint research on environmental measures including the of radioactive waste management

Prof. Yamana serves as the program director of Japanese side

Bilateral collaboration with

US-DOE
France

UK-Japan civil nuclear collaboration

Japanese perspective:

- Dependence on nuclear power will decline, but its importance will remain.
- Liberalization of electricity business is scheduled, and it may influence on the structure of the research and development.
- Decommissioning of Fukushima Daiichi NPS is a top priority subject for R&Ds, and Japan needs world's knowledge and expertise.
- It can be expected that the mood to depict the new R&D policy would come up, as the public's antipathy declines along with the successful restart of the reactors.
- UK's knowledge and competence in the basic science and nuclear engineering are beneficial to Japan. The interests of Japan may change along with the progress in the transitional period of Japanese nuclear policy.

Currently in Japan, decommissioning of Fukushima Daiichi NPS is the subject that is approved in the MEXT's funding system for UK-Japan collaboration.
But, the subject area may deserve to be expanded.