Fuel Debris Retrieval

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The 8th International Forum on the Decommissioning of
the Fukushima Daiichi Nuclear Power Station
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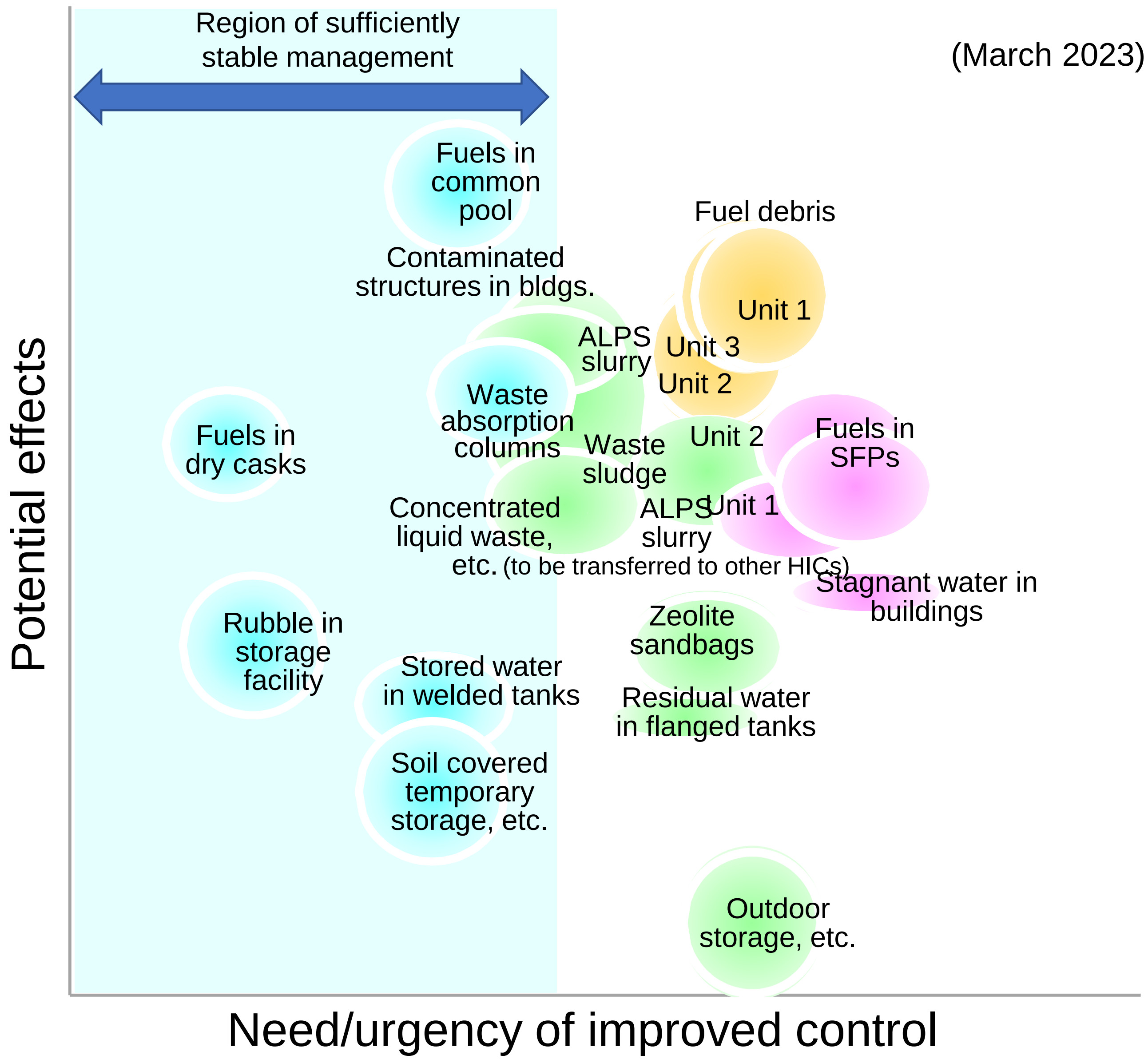
Alios Iwaki Performing Arts Center

Risk Sources at TEPCO Fukushima Daiichi NPS



- ✓ Currently, fuel debris is in a stable condition and does not require any urgent action.
- ✓ However, in the long run, it is important to retrieve fuel debris and properly bring it under control.
- ✓ The aim is to bring scattered radioactive materials to a safe state. It is also important to remove fission products (FPs) such as Cs.

Core Melts If Left Alone

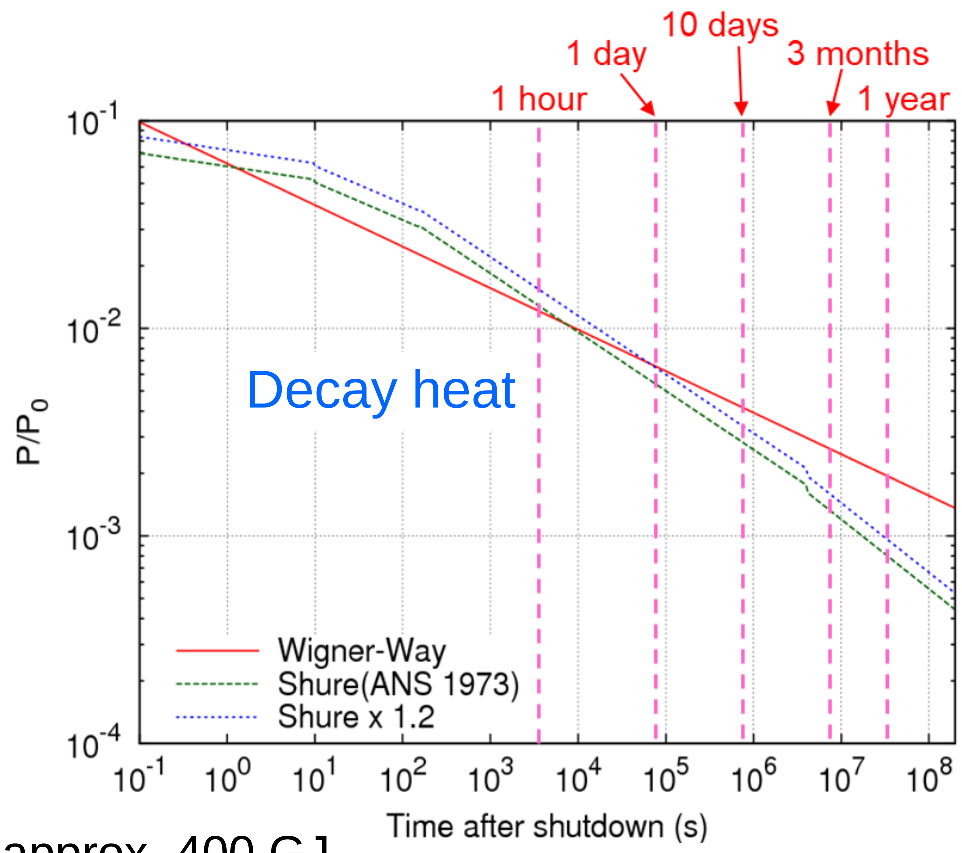
Summary of thermal balance

For 1M kWe light water reactor
Thermal power is approximately 3 GW.

1 hour to 1 day after shutdown
    Decay heat: approx. 1%, approx. 30 MW

1 month to 3 months after shutdown
    Decay heat: approx. 0.3%, approx. 9 MW

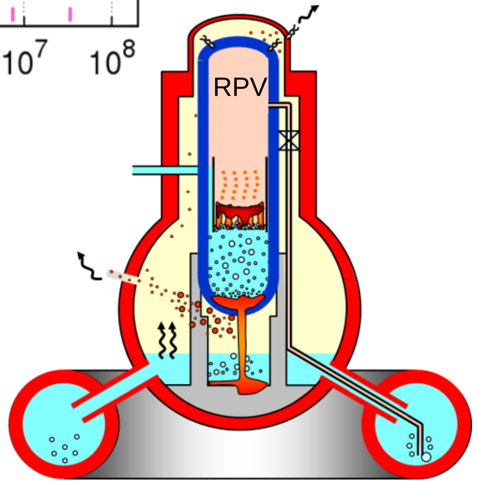
1 year after shutdown
    Decay heat: approx. 0.1%, approx. 3 MW



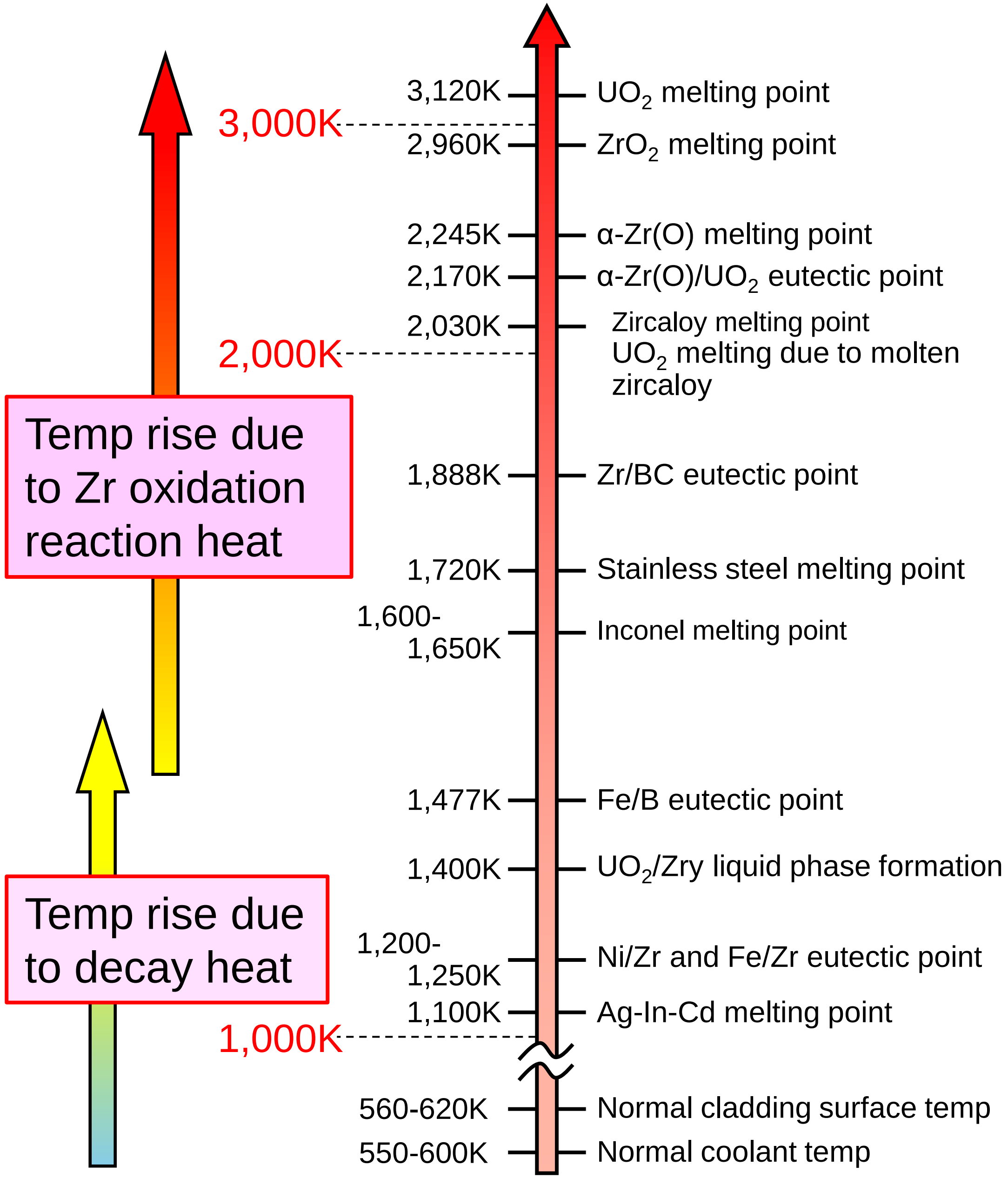
Latent heat of vaporization of 200 t of coolant: approx. 400 GJ
Approximately 4 hours for core coolant to dry up by decay heat (400 GJ/30 MW)

Heat capacity of 150 t of core: approx. 75 GJ/1000K
Approximately 40 mins for core temperature to increase by 1,000K by decay heat

Latent heat of fusion of core: approx. 45 GJ
Heat of oxidation of 30 t of zirconium: approx. 200 GJ
Equivalent to core temp increase by 2,000K (75 x 2) + total core meltdown (45)



Various Molten Substances



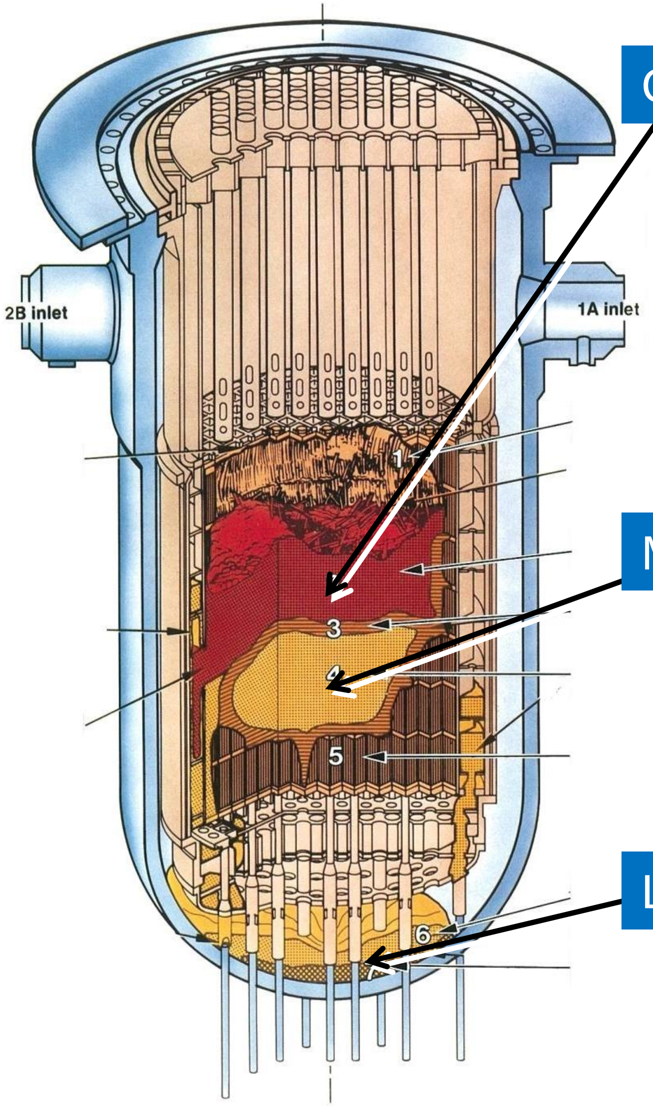
- ✓ What evaporates coolant at initial stage of accident and increases core temperature is decay heat.
- ✓ From approximately 1,500K, heat from oxidation of cladding, etc., becomes dominant.
- ✓ Rate of reaction increases as temperature rises, and temperature rises rapidly after 1,500K.
- ✓ Oxidation reaction generates H_2, which is important.

Three Mile Island Unit 2 (TMI-2) Accident

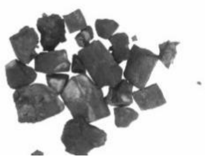
1979.3.28 4:37amEST

Approximately 45% of core got damaged, and approximately 20t fell to lower plenum

R.K. McCardell, Nucl. Eng. Des. 118(1990) 441



Core upper area



Mostly fractured fuel and resolidified molten fuel.

Control rod, cladding materials, structure materials seem to have mostly melted and moved without reacting with fuel.

Estimated max temp is approximately 2,000K in most areas.

Molten pool (approx. 3 m in diameter, central part thickness 1.5 m)

Mixture of structure materials, control rod and fuel materials. Mostly metal.

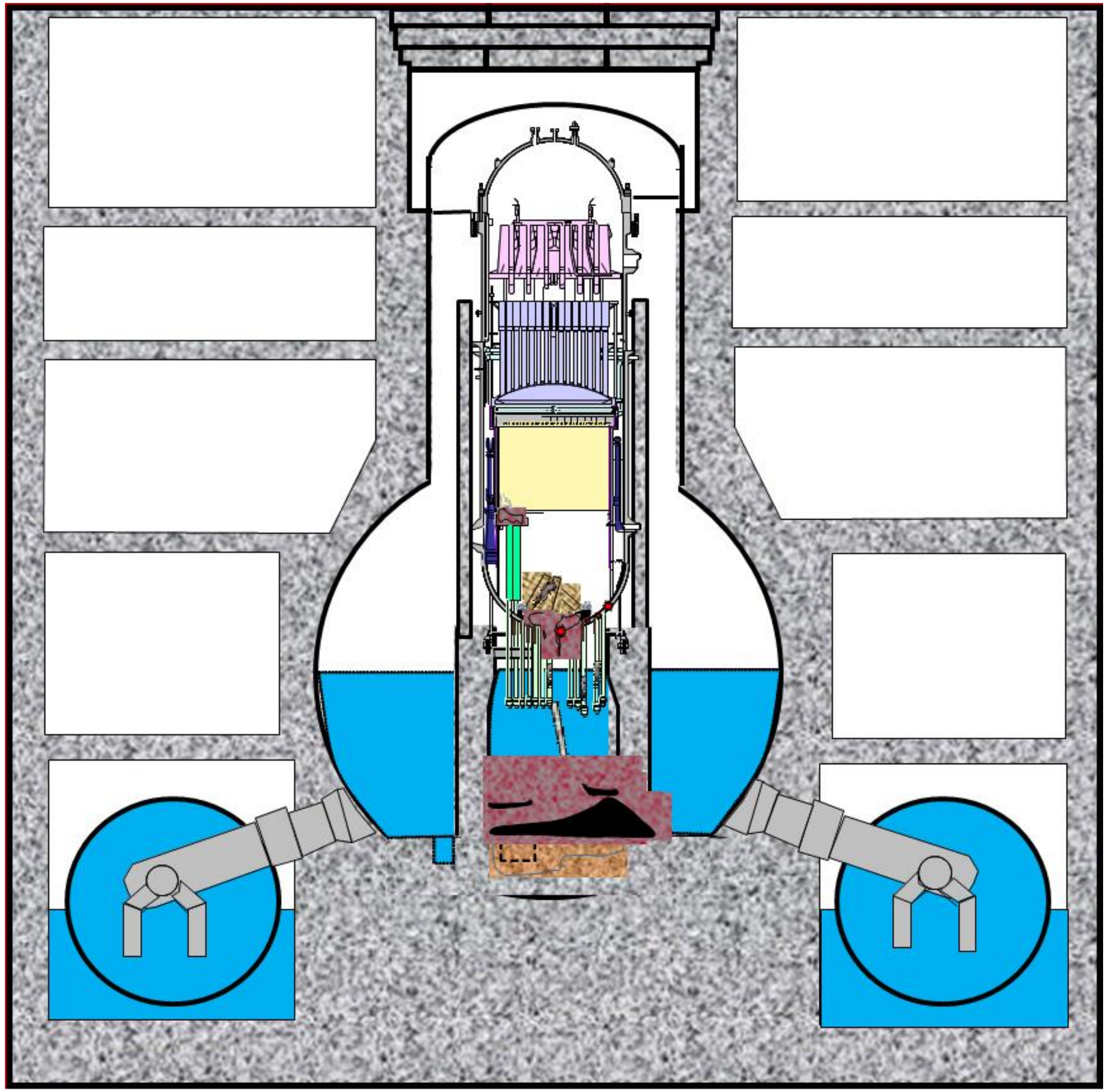
Estimated max temp is 2,700-3,100K.

Lower plenum (approx. 1 m thick deposit)

Size varies from 20 cm (rocks) to less than 0.1 mm (granules).

Resolidified molten ceramic ($(U,Zr)O_2$). Porous.

Fuel Debris at Fukushima Daiichi



Images courtesy of TEPCO Holdings, Inc.

- ✓ Full-scale retrieval starts with Unit 3.
- ✓ Properties and distribution of fuel debris greatly vary depending on the accident progression.

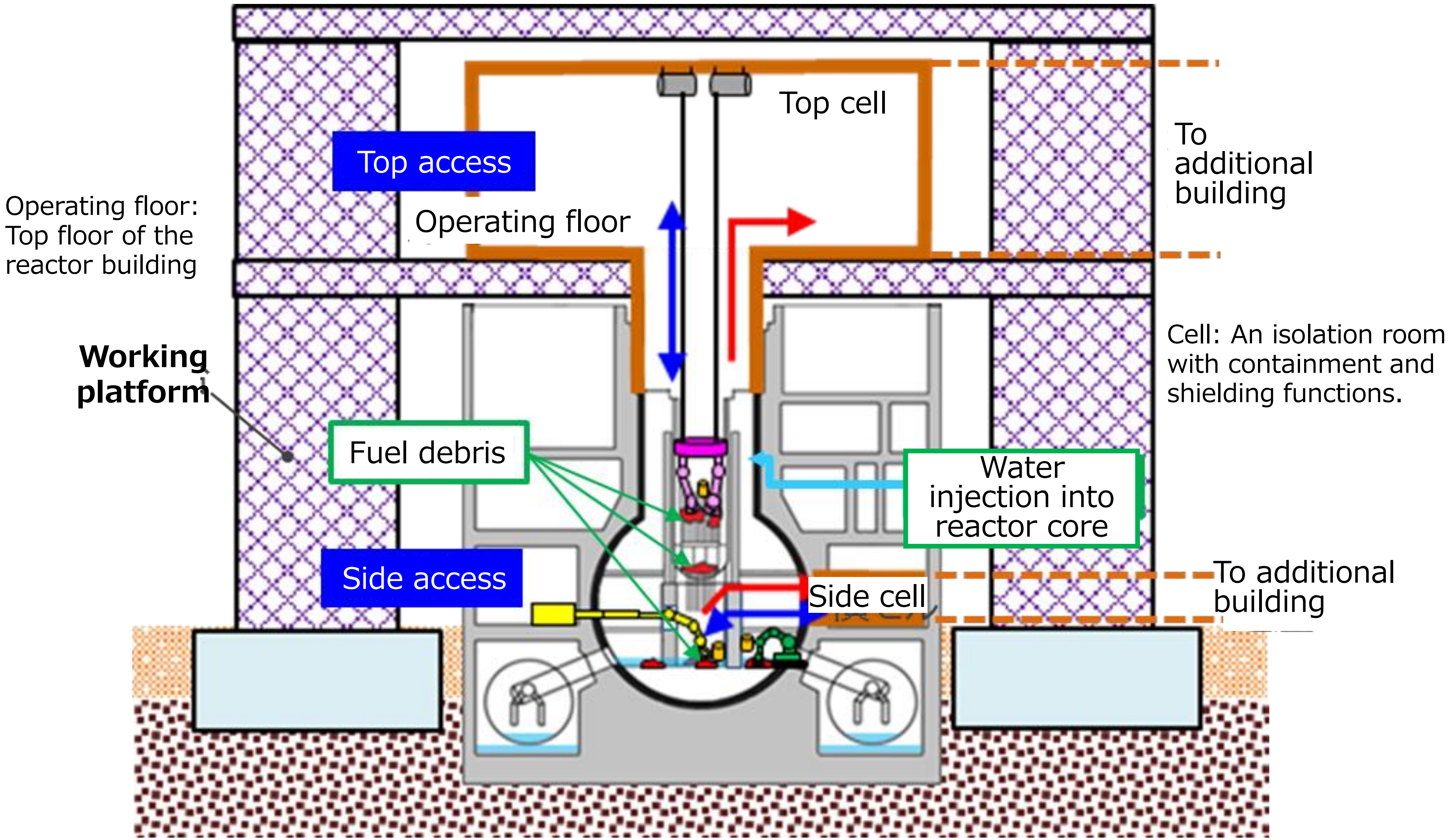
  Nearly intact stump-shaped fuel rod, fallen gravel-like fuel pellets, melted and solidified metal/ceramic materials, FP stuck in narrow segments, etc.

Study on Retrieval Method

NDF Sub-Committee for the Evaluation of Fuel Debris Retrieval Methods

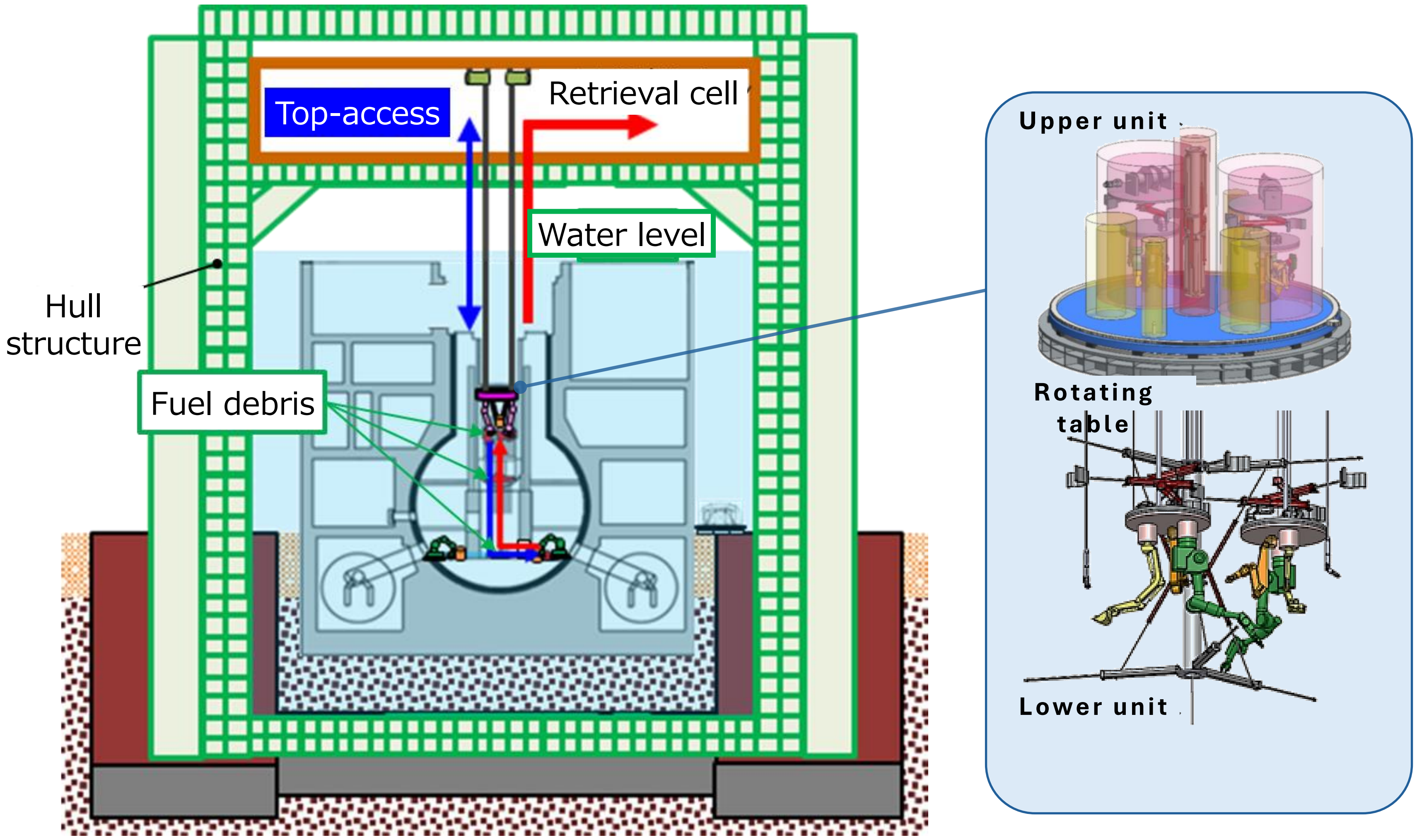
- ✓ Fuel debris retrieval methods are studied focusing on:
  - (1) Partial submersion method
  - (2) Submersion method
  - (3) Filling and solidification method
- ✓ Practicable method will be selected while placing utmost priority on safety.
- ✓ Work period is rough estimate.
- ✓ Cost is not included in the study.

(1) Partial submersion method



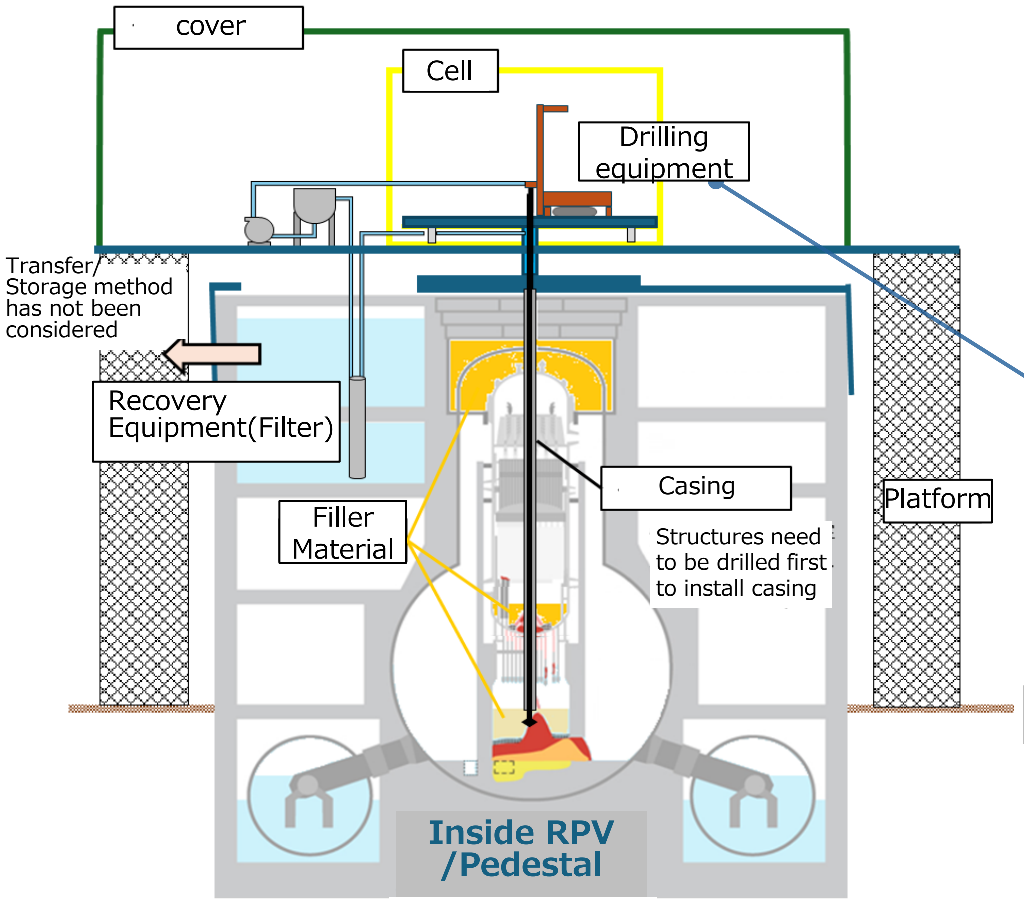
Images courtesy of TEPCO Holdings, Inc.

(2) Submersion method

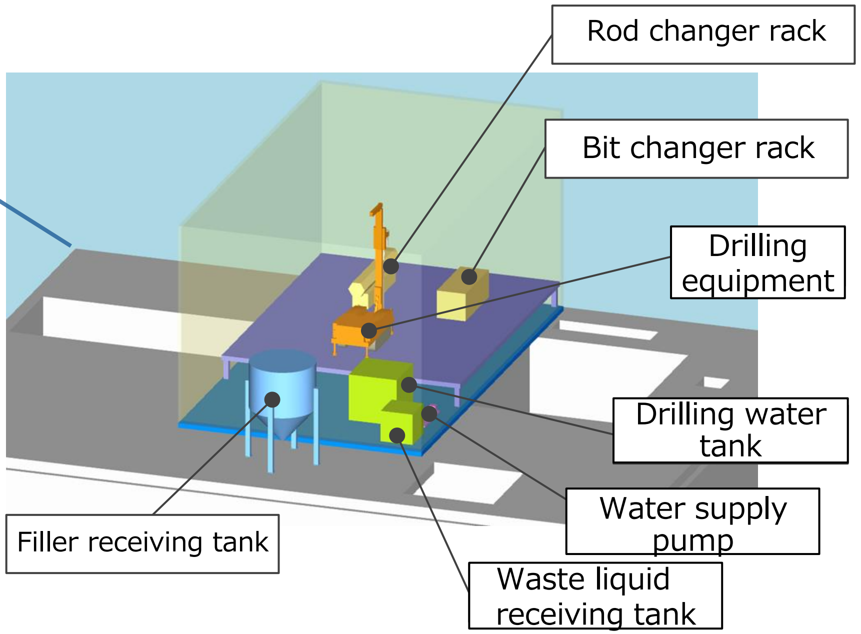


Images courtesy of TEPCO Holdings, Inc.

(3) Filling and solidification method



(Partially filled)



Recommendations for the selection of retrieval methods

NDF Sub-Committee for the Evaluation of Fuel Debris Retrieval Methods

- **Enough understandings of the situation inside the reactor are a prerequisite for its design and for ensuring its safety** at any retrieval method.
- Accelerating progress of **internal investigations** is important in the future, however, **it is essential to make parallel progresses on the selection of retrieval methods and its engineering study.**

✓ **Start design studies and research and development utilizing partial submersion method Option functions based on partial submersion method**

- In parallel with this, **internal investigations on a small-scale through top-access will be conducted.**
- **A retrieval method utilizing water shielding functions will also be studied.**

Next Step

- ✓ TEPCO is to proceed with a study on specific design based on the recommendations, and check technical feasibility;
- ✓ accelerate internal investigations and R&D at the same time;
- ✓ give shape to the plan for improving the environment (e.g., dismantling and removal of surrounding buildings) for starting fuel retrieval; and
- ✓ clarify the approach to ensuring safety as a project entity and reflect it on basic and detailed designs after discussions with regulatory authorities.

Sub-Committee will check progress of the above, but what to check is under discussion.

Internal Investigation of Unit 3 PCV

(1) Drone investigation

Old type (small drone)

Snake robot for radio relay*

(for X-6, etc.)

Better camera, lighting, duration of flight

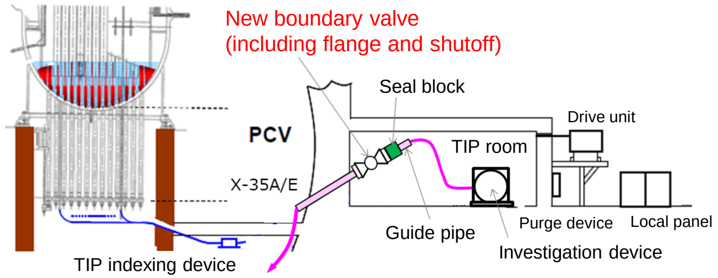
New type (improved small drone)

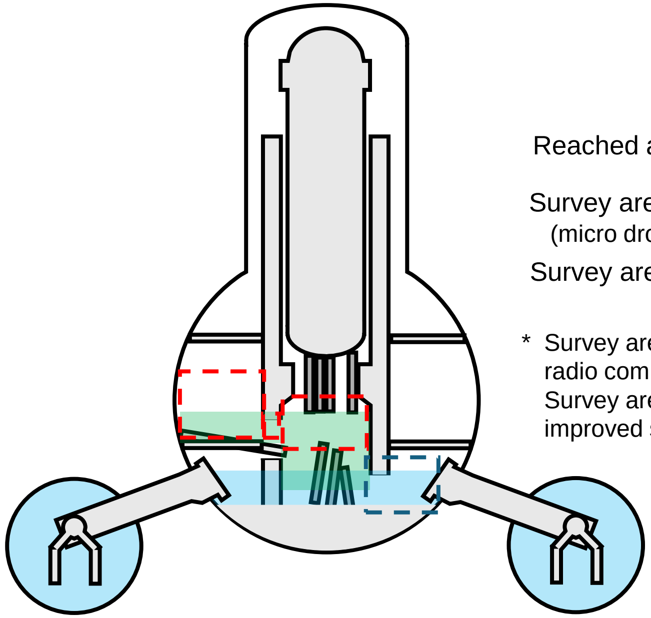
Adding measuring devices (dosimeter, thermal imaging camera) and sampling unit is under consideration.

Miniaturize (for X-53)

New type (micro drone)

(2) Endoscopic investigation (X-35)





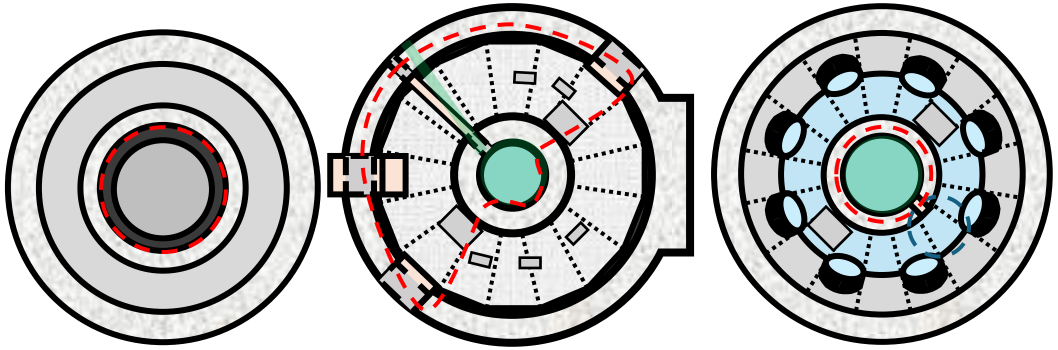
Cross-section of PCV

Reached area :

Survey area of investigation (1) : (micro drone)

Survey area of investigation (2) :

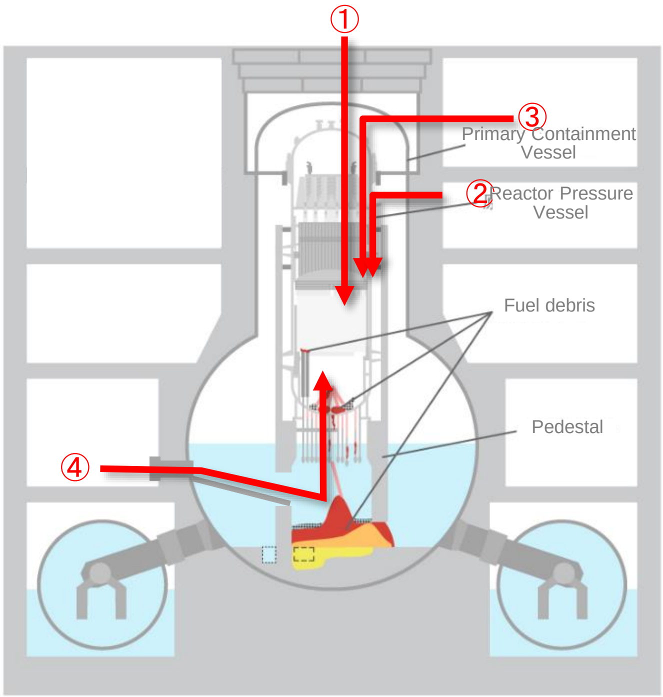
* Survey area of investigation (1) is provisional as radio communication range is under consideration. Survey area is expected to be larger with the improved small drone.

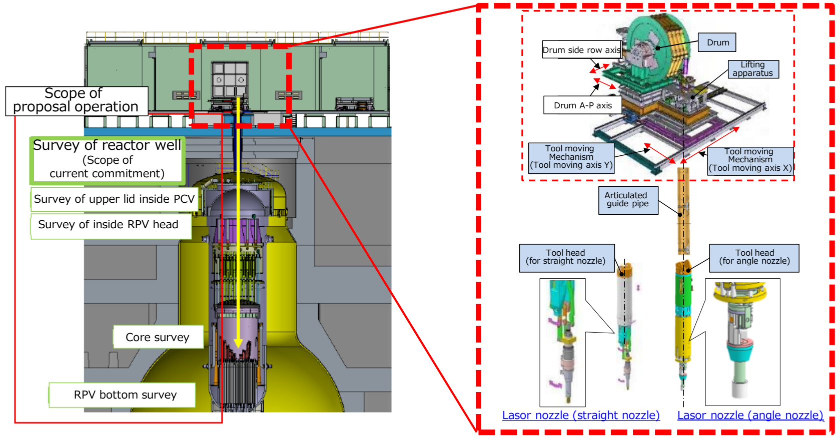


Floor map of PCV

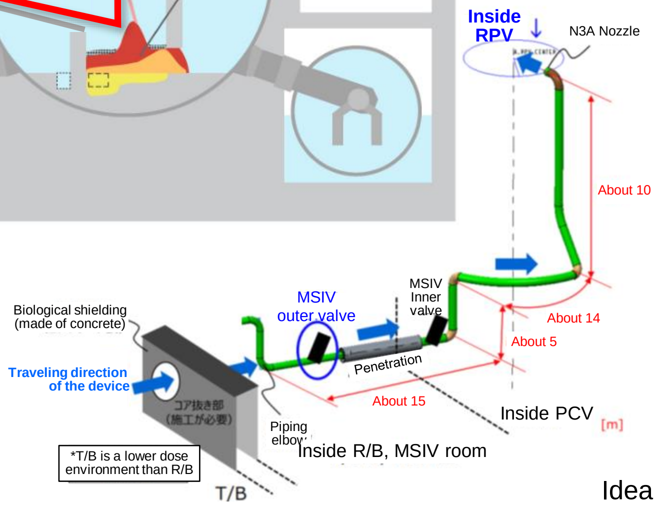
Images courtesy of TEPCO Holdings, Inc.

Internal Investigation of Unit 3 RPV

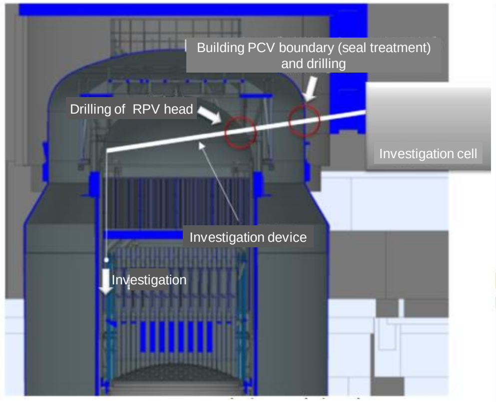




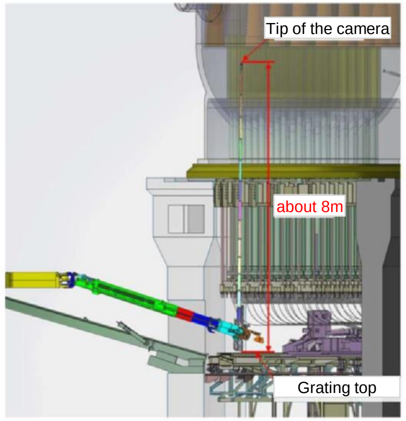
Idea (1): RPV internal investigation from directly above the RPV



Idea (2): RPV internal investigation via the MS pipe



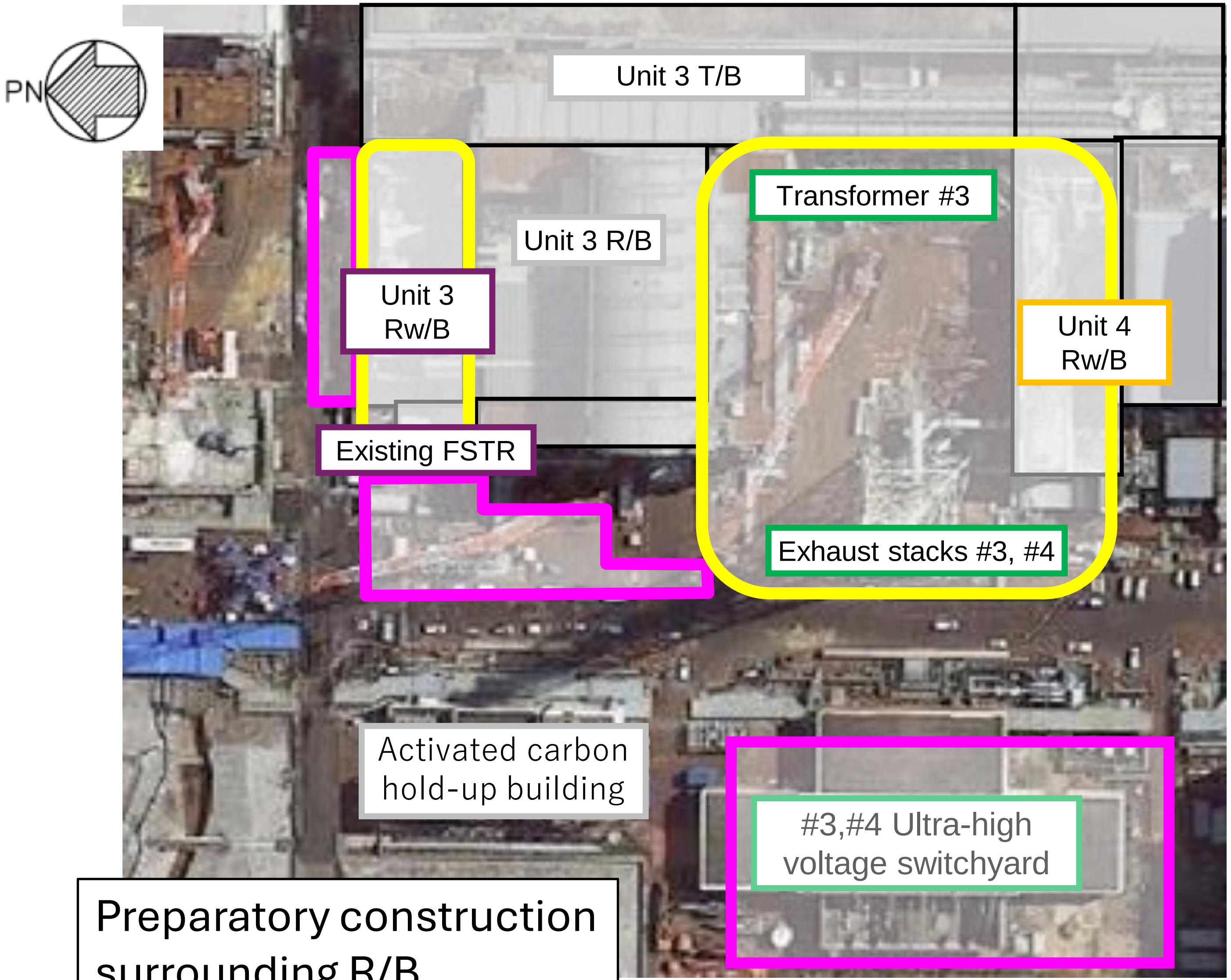
Idea (3): RPV internal investigation via the DSP



Idea (4): Investigation from the lower part of the RPV

Images courtesy of TEPCO Holdings, Inc.

General Improvement around Unit 3



Preparatory construction surrounding R/B

Images courtesy of TEPCO Holdings, Inc.

- ✓ Remove SFP cover at the top of the building, and install a new cover for retrieval
- ✓ Build working platforms to the north and south of the building to be used for top-access retrieval
- ✓ Build additional building in the south yard

(green box): Removal plan drafted
(purple box): Removal under consideration (moderate likelihood)
(orange box): Removal under consideration (low likelihood)
(grey box): Not included

Legend: (yellow) Obstacles in construction areas (buildings and yards)
(pink) Obstacles in construction yards (buildings and yards)

Proactive Decommissioning

- ✓ Utmost priority goes to ensuring safety during fuel debris retrieval.
- ✓ Both environmental risks to outside the NPS and work risks inside the NPS will be monitored.
- ✓ Purpose shared by all stakeholders is to reduce a long-term risk by the decommissioning.
- ✓ Rise in temporary risks while working is unavoidable. NRA will monitor the temporary risks to keep them at bay, and NDF will provide guidance and cooperation for steady reduction of long-term risks.
- ✓ Excessive (unscientific) fear of rise in temporary risks will significantly delay the decommissioning and cause long-term risks to remain high.

Summary

- ✓ TEPCO's plan to bring the design into shape after the report made to the Sub-Committee in March this year is yet to be confirmed. What the Sub-Committee needs to check is under discussion.
- ✓ Internal investigations are urgent also in terms of giving shape to the design.
- ✓ Environmental improvement such as dismantling and removal of surrounding buildings is an important task which greatly affects the overall work period.
- ✓ Basic approach to ensuring safety needs to be discussed and considered among all stakeholders.

Thank you for your attention.