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Fukushima Daiichi Decommissioning: *Considerations and Suggestions*

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Fukushima Daiichi Decommissioning:
Success to Date

Decommissioning of the Fukushima Daiichi site is possibly the ***most complex technical project*** in the world.

14 years after 3/11, significant progress has been made in:

- ***Stablilisation of the reactors***
- ***Site Cleanup***
- ***Water Treatment Management***
- ***Spent Fuel management***
- ***Stakeholder engagement***

While significant work remains to be accomplished in the years to come, **the foundations for safe decommissioning are firmly in place.**

Challenges Ahead

Fuel debris characterisation to support safe retrieval; waste characterization and management and long-term disposal

Fuel debris retrieval at scale

Development of long-term waste disposal strategies

Site-wide decontamination

Fuel Debris Retrieval at Scale:
A First-of-a-Kind Challenge Requiring a Stepwise Approach

A risk-informed, phased decommissioning process will reduce potential hazards

Enhanced Assessments

- Conduct deeper analyses to anticipate changes and evolving conditions over time inside the primary Containment Vessels (PCVs)

Strategic Foresight and Risk Preparedness

- Incorporate scenario planning to address uncertainties and ability to respond to potential "unknown unknowns" during fuel scale retrieval

Facility and Laboratory Infrastructure

- Design and construct support facilities capable of safely handling, analyzing, and storing fuel debris

Learning from initial operations

- Anticipate sufficient time to conduct and evaluate lessons learnt from initial limited-scale fuel debris retrieval to inform and optimize full scale retrieval operations

Remaining Work Before Full-Scale Retrieval can Begin

Scaling Up Technology

New robotic tools must be designed for large-scale, continuous operation.

Removal may require multiple types of arms, cutters, and suction systems.

Improving Characterization

Samples needed from all three units.

Continued effort to improve understanding of physical conditions inside each PCV

Current knowledge based on modeling and limited data.

Remote Operations

High radiation, narrow spaces, unstable surfaces means extreme constraints and very challenging operations.

Robotic systems must be extremely robust and highly autonomous.

Storage and Waste Management

Safe on-site waste containment systems still to be developed.

Final disposal route not yet defined.

Why International Collaboration Matters

Shared Expertise

Fuel debris removal is a global nuclear safety concern. International collaboration can accelerate safe and effective solutions.

Technology Pooling

Access to advanced robotics, imaging, and analytical tools.

Trust & Transparency

Strengthen credibility and public confidence.

Peer Review

Seek input to identify risks.

Key Collaboration Areas

Fuel Debris Characterization

- Test and demonstrate cutting/removal methods.
- Sharing of lab techniques for isotopic and materials analyses.
- Joint research on debris behavior in air and water.
- Development of potential filler materials to support partial submersion with solidification/fill method.

Robotics and Remote Systems

- Multinational development and testing of robotic arms, drones, and sensors.
- Use of AI-assisted navigation in high-radiation areas.

Modeling and Simulation

- 3D modeling of reactor internals and debris spread.
- Risk-informed planning based on international benchmark data.
- Application of 1F analyses to enhance global understanding of sever accident sequences.

Waste Handling and Disposal

- Learning from global vitrification, encapsulation, and transport methods.
- Multinational studies on long-term safety cases and disposal options.

Optimising Success:
Development of Engineering-Scale Demonstration Facilities

Large Scale Replica of reactor internals (mock-up of pressure vessel, containment structure, fuel debris)

- Simulate fuel debris retrieval operations in a safe, controlled environment to develop procedures and guidelines
- Enhance technical readiness and confidence for field operations

Hands-on training for operators and engineers with real tools and large-scale mock-ups

- Reduces risks of operational errors in high-radiation environments
- Facilitates international knowledge sharing

Test remote handling systems, robotic tools, and shielding techniques before development

- Monitors tool performance, structural interaction, failure consequences and human factors

Improve procedural reliability and safety

Conclusion

The successful retrieval of the first sample of fuel debris is a **historic and vital milestone**.

However, this is just the beginning. Moving from grams to tons requires:

- **New, large-scale technologies and verified procedures**
- **Full characterization of debris and conditions inside each PCV**
- **Long-term planning and international collaboration**

The journey ahead will take decades,
but the first, vital technical steps have been taken.

Thank you for your attention