Contribution to the decommissioning of Fukushima Daiichi Nuclear Power Station by JAEA Naraha Remote Technology Development Center

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Outline

1. Role of Naraha Remote Technology Development Center which is user’s facility
2. Mock-ups at the Naraha Center
3. User’s activities
4. Activities of research and development
5. Conclusion

Home page http://naraha.jaea.go.jp/ (select English)
The Center starts full operation on April 1st, 2016.

Main Role: Promotion of facility utilization coupled with our research and development

Decommissioning of Fukushima Daiichi

Innovation coast Framework

Revitalization of Fukushima

Our research and development of remote technologies and relevant decommissioning technologies

Category of users
1. (Government, IRID, TEPCO, NDF)
2. Decommissioning Companies
3. Local Government
4. Universities & Colleges
5. Local Industries

The feedback loop stimulates the research and development

IRID: International Research Institute for Nuclear Decommissioning
NDF: Nuclear Damage Compensation and Decommissioning Facilitation Corporation
TEPCO: Tokyo Electric Power Company Holdings, Inc.
2. Mock-ups at the Naraha Center

Mock-up Test Building (Width:60m × Depth:80m × Height:40m)

Research Management Building (W:35m × D:25m × H:20m)

Virtual Reality System

1/8 sector of Suppression Chamber

Test for the sealing of water leakage


Drone is operated in the Motion Capture System.

Robot is climbing up the Mock-up Stairs.
Robot is climbing up and down the Mock-up Stairs
Remotely operated vehicle is operated in the Robot Testing Pool.

Tap water, muddy water, salt water etc. Temperature <60 deg. Centigrade
Characterization of drone dynamics with the Motion Capture System
Virtual Reality System (VR) is useful for training prior to the actual works.

Cave type (immersive) VR for training the works prior to the actual works at the Fukushima Daiichi Nuclear Power Station.

Not an image of the Fukushima Daiichi Immerersive Virtual Reality system

Schematic view and an image on a screen

1. Stereographical movie for an operator gives reality of a working environment.
2. Design of an efficient work prior to the actual work.
3. Education and training for a safe and reliable work.
4. Several persons can join a training simultaneously.
5. Display dose rate, make suitable illumination, do transportation test etc. for training.
6. The VR is applicable to variety of works which need training.
At VR, visitors can experience the decommissioning work site stereographically.

This is not an image of a site at the Fukushima Daiichi Nuclear Power Station.
3. User’s activities
Full scale testing of sealing technologies for water leakage

※ The photo of the primary containment vessel (PCV) (Browns Ferry unit 1)

IRID makes series of feasibility tests followed by injection filling tests
- Sealing technology at the bent pipe
- Sealing technology through injecting filling inside the suppression chamber
- Strengthening technology for the suppression chamber

Manipulator operation for the sealing with VR

IRID: International Research Institute for Nuclear Decommissioning
Photos by courtesy of IRID
3. User’s activities: for the successive development of human resources

August 8-10\textsuperscript{th}, 2016 Summer school organized by the University of Tokyo funded by the MEXT.

December 3\textsuperscript{rd}, 2016, Creative Robot Contest for decommissioning organized by National Institute of Technology Fukushima College funded by the MEXT; 15 teams from 13 colleges participated.
4. Activities of research and development: contributing to the facility utilization

Robot simulator

Data taken at Fukushima Daiichi

Virtual reality system

Cave type 4 sided screen

Test fields

Robot

Operator

Mock-up stairs

Test field

Our core competence
- Rapid evaluation with robotic simulator
- Test using a mockup
- Combination and feedback loop
Robot simulation contributes to make a training under the serious conditions.

Functions of play-back and selecting a different viewpoint make us clear recognition.
Laser and relevant technologies for retrieval of fuel debris

Remote nondestructive testing with a laser driven ultrasound technology

Driving laser of ultrasound
Detecting system of ultrasound with laser technology

The speed in the body of a heated concrete is measured to be slower

Remote sampling technology using a QCW fiber laser

Fuel debris, concrete, metal structures of Fukushima Daiichi

Optical head
Optical fiber
Fiber laser
Catcher of samples

Concrete sample
Laser for detecting ultrasound
Ablation
Pulsed laser for driving ultrasound

T. Yamada et al. OPIC2017 LSSE Invited talk May 2017 at Yokohama, Japan
5. Conclusion

1. JAEA follows the road map of Fukushima Daiichi decommissioning. The Naraha Center will continue to contribute to the decommissioning as a mockup center of the remote technologies.

2. More than 60 cases of facility utilizations have been performed since starting full operation at the Naraha Center. Our activities on facility utilization coupled with our research and development contribute to development of decommissioning technologies as well as development of human resources.

3. The mock-ups in the facility are open for domestic as well as foreign users.
Thank you for your attention!
Following view graphs are for QA.
The Naraha Center contributes to the decommissioning of Fukushima Daiichi as well as revitalization of Fukushima together with CLADS and Okuma Center.
Short history of Naraha Remote Technology Development Center

- March 11th, 2011: Huge earthquake happened in the east part of Japan and the serious accident happened at Fukushima Daiichi Nuclear Power Station.
- March 2013: Construction of Mock-ups for remote technology has been decided by the Japanese Government. In April, JAERI started to organize the construction of a mock-up facility.
- October 19th, 2015 opening ceremony was held with participation of Prime Minister Abe.
- April 1st 2016, the Naraha Center started full operation. The Naraha Center is open for not only domestic users but also international users.
- April 1st 2017, second year started.
Mock-up stairs are useful for training of operations for robots.

Examples
Characterization and operation training of robots running up and down the stairs. Training of transportation between the down stairs and upstairs (How to do and how long does it take?).
Motion Capture System is useful for characterization of robots

For examples, the Motion Capture System is useful for characterization of robots and flying vehicles (drones).

- 16 high speed cameras Vicon T205 (Max two million pixels)
- Available area: 10m × 10m × 2m
- Precision: ±1.5mm in the area
- Frame rate: 2 kHz

Precise characterization of moving objects in the wide area
Robot Testing Pool is useful for training of Remotely Operated Vehicle (ROV)

- Diameter: 4.5 m
- Water depth: 5.0 m
  (height of the pool: 5.5 m)
- Water temperature: room temperature to 60 deg. Centigrade
- 12 observation windows

Additional equipment
Underwater cameras, illumination lights, Jib crane

Examples
- Remote control of ROVs
- Characterization of unmanned ROVs
- Training of operations
- Visibility test of robots in the water
We have made discussions with US, European and Asian scientists and engineers at the international conferences held in foreign countries as well as in Japan.

Test fields for emergency response robots originally proposed by the group of National Institute of Standards and Technology (NIST) is transferred into the test fields for the decommissioning of Fukushima Daiichi Nuclear Power Station.

Dr. Kawabata’s talk at American Society for Testing and Materials held at Virginia Beach Fire Training Center in January, 2017.

Photos listed above are for this purpose constructed at the Naraha Center.
December 7th, 2016, exhibition of robotic technology and relevant technology for decommissioning of the Fukushima Daiichi Nuclear Power Station organized by decommissioning robotic technology association in Fukushima prefecture.

More than 500 engineers and businessmen were participated.

The VR installed at Naraha contributes to how to operate the manipulator in the decommissioning as a tool for operator training, feasibility study etc. (By courtesy of IRID).

MEXT: Ministry of Education, Culture, Sports, Science and Technology, Japan
IRID: International Research Institute for Nuclear Decommissioning
For retrieval of the fuel debris at the Fukushima Daiichi Nuclear Power Station

Development of laser based technologies at the Naraha Center

Optical Head

QCW fiber laser irradiation system

3 m

0.5 m

LDV

0.2 m

YAG laser

YAG laser driven ultrasound generation system
QCW レーザーの試験システムとレーザー照射例

Concrete

Spot diameter 1 mm

NA: 0.22

Fiber diameter 0.2 mm

Optical head

High speed camera

Workstation

QCW laser

1.3 kW

100 ms

10 ms

Time [s]

Heavy concrete

30 deg.

High speed camera

Optical head

上向きドリリング

α = 50 deg.

10 ms, 10 Hz

上向き切断

V = 6 mm/s

Overlapping 45%

Concrete (50mm)

Concrete (200mm)

Concrete

Concrete

Concrete
QCWレーザー上向き加工時の溶融物除去の可視化

Upward drilling

Photon FASTCAM MC2 mono
- Frame rate: 1000 fpt
- Shutter speed: 1/20000 s
- Resolution: 512 x 352 pixels

Laser pulse 2 mm

• Laser on:
  - High plume and vaporization occurs in upward drilling.

• Laser off:
  - Downward drilling: Melt concrete mainly is expelled along sidewall of hole by vapor pressure.
  - Upward drilling: Melt ejection is enhanced by assistance of gravity. The melts drops from center of hole.

Power
10ms 90ms
0

Time [s]

Applied Laser Technology Institute
QCW レーザーを用いた上向き加工例（くり抜き）

Square cutting

V = 3 mm/s

Overlap% = 40%

1.3kW, 10ms, 5Hz

Concrete

11mm

Laser beam

15 deg.

N → 10 cycles

N → 100 cycles

Backside

100 cycles

Depth = 11 mm