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

Hiroyuki Daido[1], Shinji Kawatsuma[1], Hisayuki Kojima[1], Masahiro Ishihara[1], Shinichi Nakayama [2]

[1]Naraha Remote Technology Development Center, Japan Atomic Energy Agency, 1 ―22 Nakamaru, Yamadaoka, Naraha-machi, Fukushima-ken 979-0513, Japan
[2]Fukushima Research Institute, Japan Atomic Energy Agency, 7-1 Taira-aza-Omachi, Iwaki-shi, Fukushima-ken, 970-8026 Japan

Abstract

Naraha Remote Technology Development Center of Japan Atomic Energy Agency started full operation in which we mainly promote facility utilization by users on April 1st 2016. We describe the role, details of the facility including mock-ups and virtual reality system coupled with the robot simulation techniques for mainly the decommissioning of Fukushima Daiichi Nuclear Power Station. We also emphasize our own research and development to encourage and to contribute to the facility utilization. The facility is open for domestic as well as foreign users who wish to contribute to the decommissioning as well as revitalization of Fukushima.

1. Introduction

For the decommissioning of the Fukushima Daiichi Nuclear Power Station, a lot of issues to be solved still remain. One of the most important and difficult issues is retrieval of the fuel debris and relevant materials under the highly dosed and contaminated environment which was caused by the Great East Japan Earthquake followed by the serious accident at the Fukushima Daiichi Nuclear Power Station in March 2011. The pieces of nuclear fuel in the unit 1 to 3 were melted down to the Primary Containment Vessels. The key issue for safe retrieval of the fuel debris is utilization of remote technologies coupled with a mock-up which is a full-scale model of a part of the reactors for the decommissioning. In order to promote development of the relevant remote technologies necessary for decommissioning and to provide a facility for remote technology experimentation, the Japan Atomic Energy Agency (JAEA) has constructed a new facility named Naraha Remote Technology Development Center (Naraha Center) which started full operation on April 1st, 2016. The facility is also expected to contribute to revitalization of local industries. The facility is open for all the contributors of the decommissioning of the Fukushima Daiichi Nuclear Power Station as well as those of relevant activities of revitalization in this area as a user's facility where any domestic or foreign users in collaboration with JAEA staffs can organize and perform their own work according to their plan. We have arranged facility tours for more than 6500 visitors since the opening ceremony of the Naraha Center was held in October 2015 with participation of the Prime Minister Abe. We have also organized several tens of cases of the facility utilization since then. In this paper, we describe details of the facility, activities of users, those of our own research and development.

2. Facilities

The Naraha Center [1] is composed of the Mock-up Test Building mainly dedicated to the full scale feasibility test of the decommissioning and the Research Management Building both of

which are cold facilities as shown in Fig. 1. Relevant cold facility can be found at the National Nuclear Laboratory in the United Kingdom [3]. The Mock-up Test Building is large enough for installing a full-scale mock-up of a 1/8 of the suppression chamber belongs to the unit 2 of the Fukushima Daiichi Nuclear Power Station [2]. For under-water dismantling of the reactors, the development of a water sealing technology inside the suppression chamber is one of the necessary technologies for the safe decommissioning. As shown in Fig. 2, the mock-up is utilized for a series of experiments on sealing of water leakage being performed by the International Research Institute for Nuclear Decommissioning (IRID). We have also constructed and organized robot test fields including a motion capture system as shown in Fig. 3, mock-up stairs as shown in Fig. 4, a robot testing pool as shown in Fig. 5. A relevant remotely operated vehicle tested in the pool is shown in Fig. 6. Since each robot test field clarifies the robot performance levels and the necessary operator skills, users can develop a robot using these fields through the quantitative evaluation of common robot performance for the decommissioning as well as emergency response robots and other industrial applications. In the research management building, we have constructed and operated a cave type 4-sided screen virtual reality (VR) system as shown in Fig. 7. The VR provides us a stereographical virtual decommissioning work site realized on the basis of three-dimensional information of the constructions for validating of robot designs, planning of the decommissioning tasks and training of robot operators. The system also provides us a lot of suitable work sites in which well-organized preparation and hard training are needed before doing actual works. The VR system at CEA of France also made multiple applications concerning nuclear engineering [3].

Fig. 1 Bird's view of the Naraha Remote Technology Development Center located in the Naraha south industrial park. The photo was taken in June 2016. The total area is 36000 m^2.

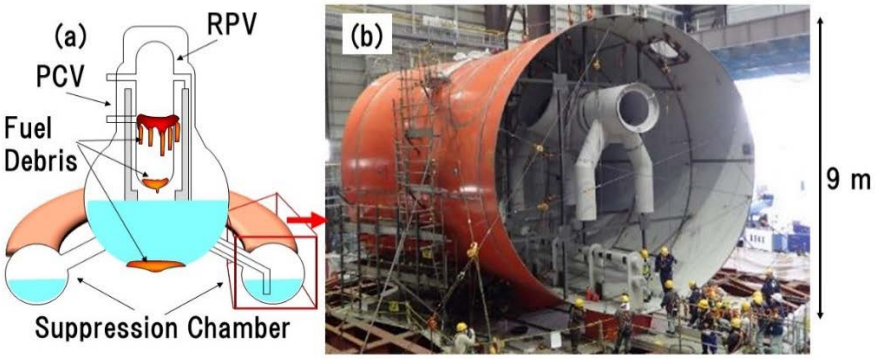

Fig. 2 (a) Cross-sectional view of the Primary Containment Vessel (PCV) and the suppression chamber of the Fukushima Daiichi Nuclear Power Station. Pieces of molten fuel debris are thought to drop down through the bottom of the Reactor Pressure Vessel (RPV) to the bottom of the PCV. (b) One eighth of the full-scale mock-up is constructed. (By courtesy of the International Research Institute for Nuclear Decommissioning).

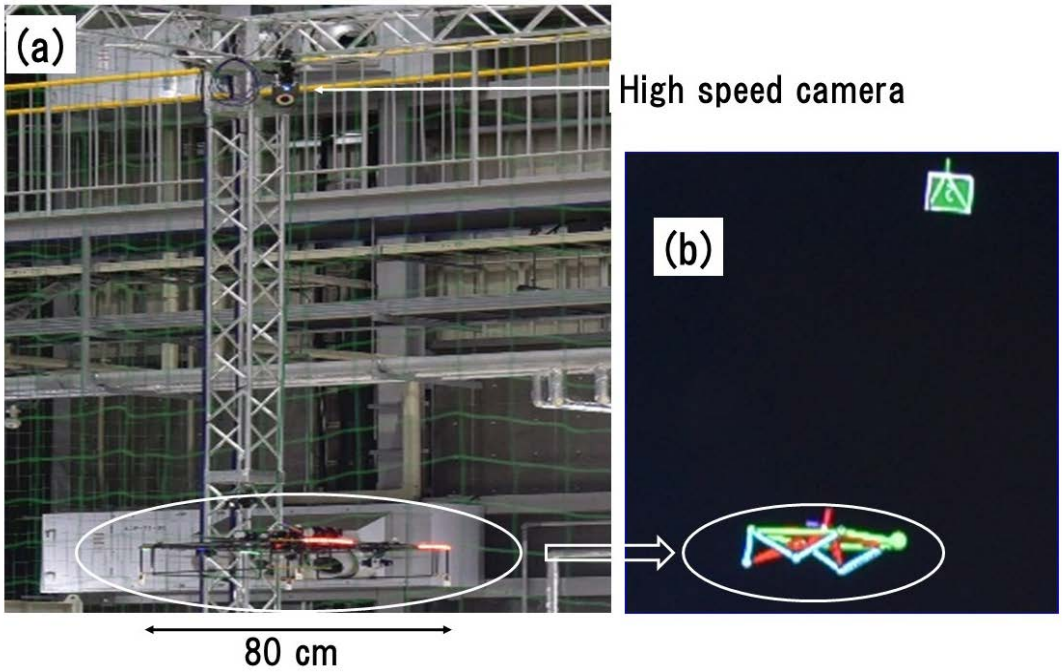

Fig. 3 (a) Photo of the motion capture system. The 16 high speed cameras (2000 frames /second) installed at the upper part of the system illuminate the object (encircled flying vehicle) having special reflectors attached on it. Available area and height for capturing the data is 10 m x 10 m and 2 m, respectively. Each reflector reflects back each infrared light to its original camera and the several cameras catch the lights simultaneously. Then the motion capture system identifies the place of the reflectors on the object stereographically. (b) The captured motion of the flying vehicle is displayed on a computer. The motion of the flying vehicle in the white circle shown in (a) is transferred into 3-dimensional digital information.

Fig. 4 Photo of the mock-up stairs (configurable stairs). A robot is climbing up the stairs. The steepness and width can be changed between 40-55 degrees and 700-1000 mm, respectively. We can use a step made of flat plate as well as that having a grating structure.

Fig. 5 Robot testing pool. The water diameter and the depth are 4.5 m and 5 m, respectively.

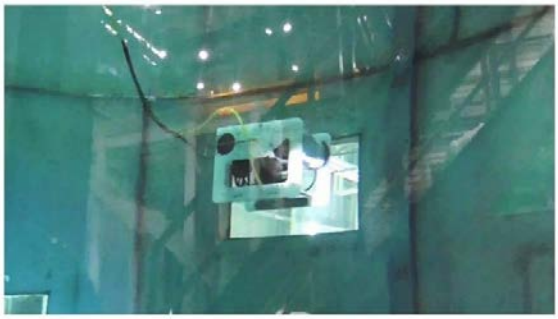

Fig. 6 Photo represents the remotely operated vehicle developed by the group of the emergency response robot which belongs to Japan Atomic Energy Agency. The size is approximately 30 cm x 30 cm x 30 cm and 20 kg in weight.

Fig. 7 Cave type 4-sided screen virtual reality system is installed mainly for the decommissioning of the Fukushima Daiichi Nuclear Power Station, unit 1 to unit 3. A stereographical movie is realized with 5 computers which make successive images on the 4 sided screens for each eye belong to an operator with special goggles. Various applications other than the decommissioning are also available.

3. Activities of users

Users are typically categorized as follows. Firstly, we should point out the national project based on the utilization of a full-scale mock-up supported by the Government, IRID, Tokyo Electric Power Company Holdings Inc., and Nuclear Damage Compensation and Decommissioning Facilitation Corporation (NDF) etc. From the point of view of our purpose, a successive mock-up project for continuous contribution to the decommissioning is indispensable. As the second category, we point out the decommissioning companies. As the third one, we point out the projects organized or assisted by the Fukushima Local Government. As the fourth one, we do universities and colleges such as Fukushima University, National Institute of Technology, Fukushima College (Fukushima College), the University of Tokyo and so on. As the fifth one, we do the local industries which directly contribute to revitalization of Fukushima in collaboration with domestic and foreign industries. In the fiscal year 2016, 38 cases of facility utilization have been accomplished. For example, on August 2016, the summer school organized by the University of Tokyo funded by the Ministry of Education, Culture, Sports, Science and Technology, Japan (MEXT) was held at the Naraha Center. The students learned how to operate robots for the decommissioning and learned simulation techniques as well. In December 2016, The Creative Robot Competition for decommissioning was organized mainly by Fukushima College funded by the MEXT. Fifteen teams from thirteen colleges were participated in the competition. Such activities contribute to the successive development of human resources for the decommissioning of Fukushima Daiichi Nuclear Power Station which lasts ~40 years.

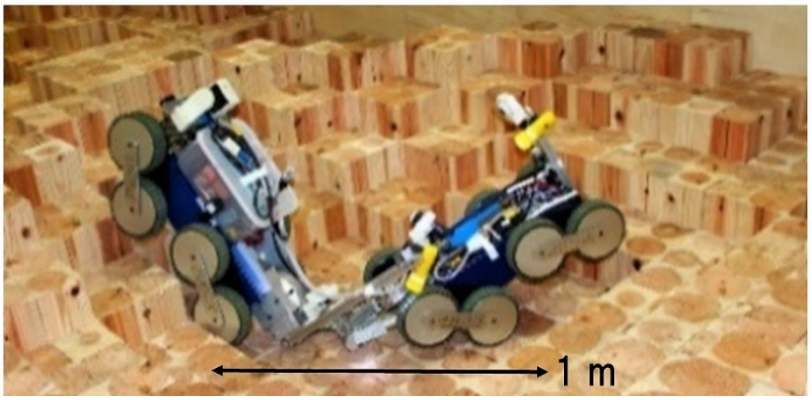

Fig. 8 Twin robots ran across a peak and valley in the standard test field at the competition. The robot belonged to Osaka Prefecture University College of Technology.

In December 2016, exhibition of robotic technology and relevant technology for the decommissioning of the Fukushima Daiichi Nuclear Power Station was organized by the decommissioning robotic technology association of Fukushima Prefecture supported by the Fukushima Technology Centre belongs to the Fukushima Local Government. More than 500 engineers and businessmen were participated. The contents of some of the fruitful utilizations are presented at a user's meeting of the Naraha Center which is held regularly.

4. Activities on research and development at the Naraha Center

We perform our own research and development using the facility. The subjects include the development of robot testing methods for the decommissioning of the Fukushima Daiichi Nuclear Power Station and the emergency response robots and relevant remote technologies which encourage and contribute to the facility utilization. Experts of the remote technology and relevant fields at the Naraha Center are willing to support facility utilizations promoted by users from all over the countries. We also hope that the utilization brings us new subjects of research and development as a feedback which also pushes the progress of the decommissioning

technologies.

Some of the examples are described as follows. Figure 9 shows a result of robot simulation [5] in which a robot is climbing up the mock-up stairs as shown in Fig. 4. The advantages include that one can try operations as many as possible before a real trial. We also note that in the simulation, we can try any task under the extreme conditions which are hardly realized in the real situation.

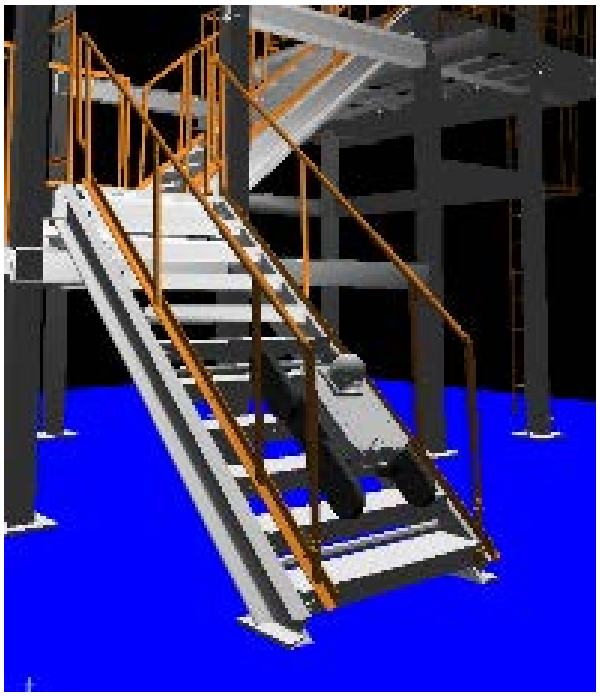

Fig. 9 Screen grab from the display of the robot simulator. A robot is working at the mock-up stairs for preparation of the decommissioning.

Development of the standard test method (STM) for the decommissioning of the Fukushima Daiichi Nuclear Power Station is important subject for our research [6]. Figure 10 shows the original STM for emergency response robots constructed at the Naraha Center, which is properly modified into the decommissioning of the Fukushima Daiichi Nuclear Power Station.

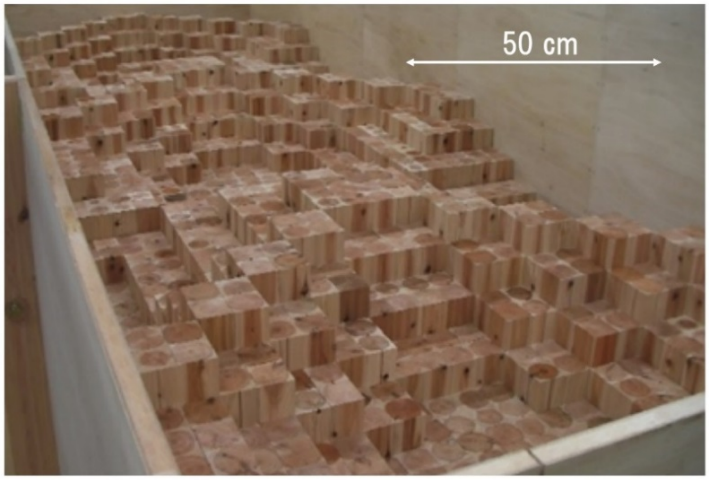

Fig. 10 Photo of the standard test field constructed at the Naraha Center for evaluation of capability of an emergency response robot. It has been originally proposed by the National Institute of Standard and Technology of the USA. We try to transfer the concept into the decommissioning of the Fukushima Daiichi Nuclear Power Station.

The retrieval of the fuel debris is one of the most difficult and important issues for the decommissioning of Fukushima Daiichi Nuclear Power Station [7]. Coupled with the remote technologies, development of laser diagnostic technologies as well as sampling, cutting, crushing and retrieval technologies are indispensable. One of the examples performed at the Naraha Center is shown in Fig. 11 in which structural integrity assessment of a concreate sample with laser driven ultrasound and sampling technology [8] with high power laser irradiation technologies are schematically shown.

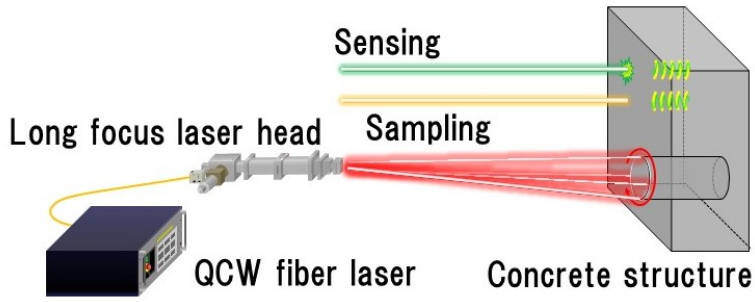

Fig. 11 Schematic drawing of a laser driven ultra-sound generation and a corresponding detection system for diagnostics of concrete property. A concrete sampling technology by a quasi-continuous wave (QCW) laser is also shown.

Remote technology for the retrieval of fuel debris has been also developed in collaboration with the private companies [9, 10]. These researches and developments encourage us to promote high quality facility utilizations for the decommissioning and the revitalization of local industries in Fukushima.

5. Summary

Naraha Remote Technology Development Center of Japan Atomic Energy Agency which is originally designed as a user's facility for the decommissioning as well as revitalization of Fukushima started full operation in April 2016 and we have promoted the facility utilizations. The research and development are also indispensable for the role of the facility. We are constructing a core competence such as development of high quality test fields of both computational and real mock-up fields equipped at the Naraha Center. The successive full scale mock-ups will contribute significantly to the progress of the decommissioning of the Fukushima Daiichi Nuclear Power Station. We believe that such a mock-up project also encourages us the facility utilization on remote technologies which will activate the local industries as well as the decommissioning companies. Such activities will attract users from all over the countries who wish to join and accelerate the decommissioning of the Fukushima Daiichi Nuclear Power Station.

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