"iRIS-V", released in the public relation movie, "JAEA Channel"[note 1].

Visualizing distribution of radioactive materials in environment in panorama

Vehicle equipped with omnidirectional three-dimensional integrated radiation imaging system "iRIS-V" has been developed.

The Collaborative Laboratories for Advanced Decommissioning Science (hereafter referred to "CLADS"[note 2]) in Tomioka Town, Fukushima Prefecture, has developed a new integrated Radiation Imaging System-Vehicle (hereafter referred to "iRIS-V"[1]) (Fig. 1). The vehicle is equipped with an omnidirectional three-dimensional Compton camera[2] system, by setting many Compton cameras that can estimate the position of radiation sources. The system integrates a sensor to measure three-dimensional distance using laser light (3D-LiDAR[3]) and a space/location information system by GPS etc.

In order to reduce radiation exposure for people working in difficult-to-return zones in Fukushima Prefecture and at the site of the Fukushima Daiichi Nuclear Power Station (hereafter referred to "1F") and to prepare the decommissioning plan, it is important to know the dose rates in the working environment and the distribution of radioactive materials scattered in the environment. Generally, distribution of radioactive materials has been measured with survey meters. However, this method is time-consuming, because survey meters cannot give any information about the direction of radiation. Therefore, measurements in wide area have been required to know the position and distribution of radioactive materials. In addition, it has been also required to monitor air dose rates and the distribution of radioactive materials in a short time, because the decommissioning and dismantling are daily progressing at the site.

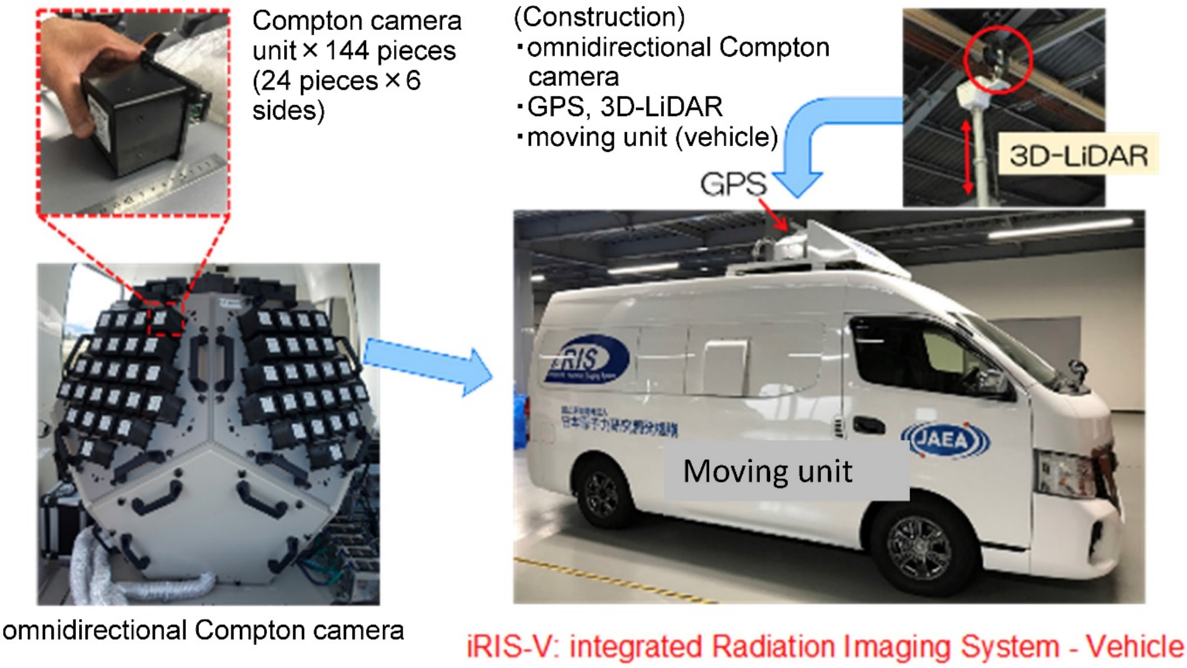

Fig. 1 integrated Radiation Imaging System-Vehicle, iRIS-V.

Distribution of radioactive materials in all sides is visualized by setting many small Compton cameras (upper left photo) on the six upper sides of the regular dodecahedron. Also, there-dimensional distribution of radioactive materials can be displayed by using a sensor to measure three-dimensional distance (3D-LiDAR) installed at the top of the vehicle.

In this vehicle, many small and light Compton cameras are placed towards the surroundings of the vehicle. Therefore, it can panoramically visualize the distribution of radioactive materials in all directions after moving to the measurement site. Also, it can display air dose rates along the route that the vehicle travelled on the map.

From now, we plan to measure the distribution of radioactive materials at the 1F site and in the difficult-to-return zones. By these measurements, the developed method is expected to contribute to the smooth progress in decommissioning and decontamination works.

Visualizing position of radioactive materials in panorama

The CLADS has developed small and light Compton cameras, and visualized there-dimensional distribution of radioactive materials by loading these cameras on drones. However, a conventional Compton camera can only measure the radiation ahead of the camera. In order to overcome this problem, the CLADS has developed a vehicle equipped with omnidirectional Compton cameras (iRIS-V). In this system, distribution of radioactive materials in all directions can be panoramically visualized with high sensitivity by setting small Compton cameras on the upper six sides of regular dodecahedron (three-dimensional figure combining twelve pentagons).

The demonstration test was conducted at the parking lot in the CLADS. As a result, we succeeded in specifying the car loading a radiation source (small sealed test source[4)]) in a short time (Fig. 2). In this figure, the position of radiation source is indicated as red contour[5)].

In the conventional system using a Compton camera, it took about 10 minutes to visualize radiation in a limited region from the front of the source. On the other hand, the present test revealed that the measurement in all directions was completed only in 80 seconds (lower figure of Fig. 2).

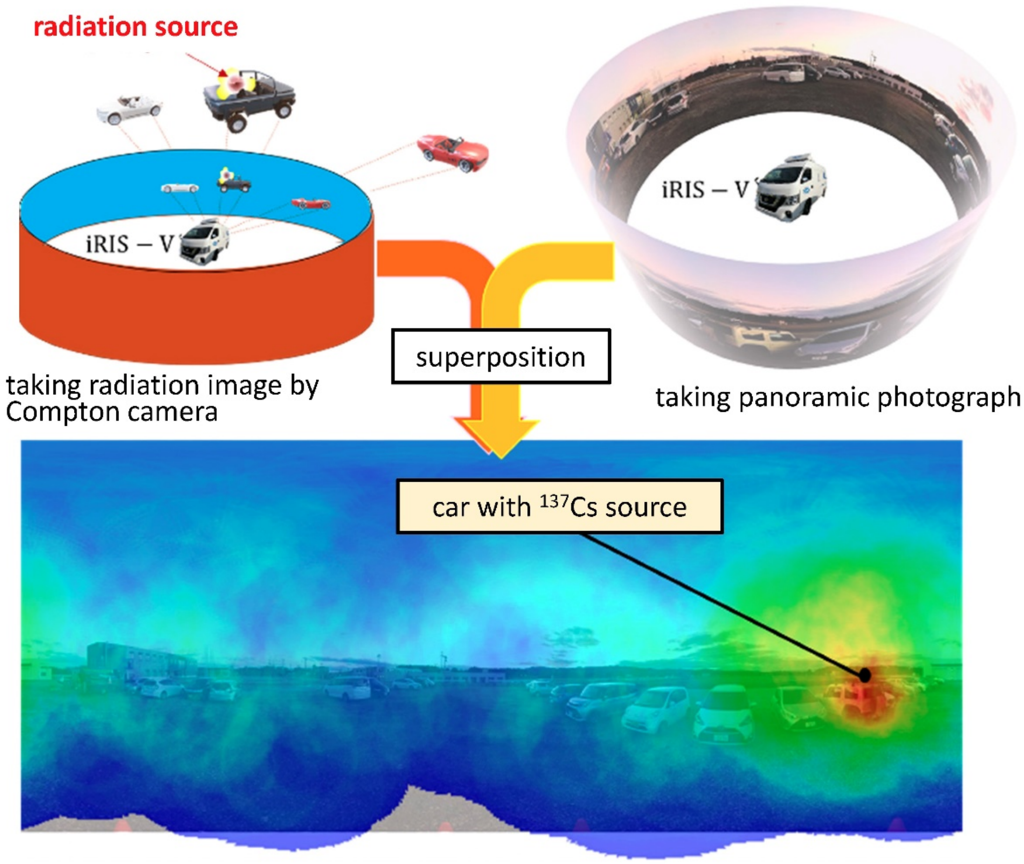

Fig. 2 Visualization of radiation source using iRIS-V (panoramic image).
The position of a radiation source is specified by measuring radiation image around the vehicle (360 degree) by Compton cameras, and superimposing the image with the all-direction panoramic image. We succeeded in specifying the car loading the radiation source among multiple cars that park around the iRIS-V. The radioactivity of the source was about 10 MBq, and the distance between the Compton camera and the source was about 5.5 m.

Environment of radiation work is reproduced in a virtual space.

We succeeded in three-dimensionally estimating the position and distribution of radiation sources by integrating a three-dimensional image obtained with a 3D-LiDAR and a radiation image obtained with a Compton camera (Fig. 3). It is also possible to three-dimensionally display the location of radiation sources from various directions and positions. In addition, since all the instruments are loaded on a car, we can visualize the distribution of radioactive materials at a site, by obtain all data after moving to the site.

Owing to the present development, it has become possible that workers simulate the contents of the work after knowing the hotspots and distribution of radioactive materials in advance. The new system is expected to contribute not only to reduce the radiation exposure of the workers but also to formulate effective decommissioning plan.

Fig. 3 Superposition of radiation image and image obtained with 3D-LiDAR sensor.

Radiation sources can be three-dimensionally displayed from various points of view by superposing radiation image obtained with Compton cameras and images obtained with a 3D-LiDAR sensor. This figure shows the three-dimensional image when a test radiation source was placed on one of the cars.

Integrated system developed by young researchers

The development of the new system described here has been promoted mainly by young researchers. The important point of the present development is that technologies in wide fields such as radiation measurements, environmental recognition and image analysis have to be integrated. For this purpose, every young researcher is making efforts in collaborating with researchers in the different fields beyond his/her own specialized field. Up to now, the research team has developed a new radiation imaging technology by combining technologies in different fields, and succeeded in detecting hotspots in severe environment such as inside of the 1F reactor buildings.

For newly developed iRIS-V, the research team aims to introduce this system in decommissioning and decontamination works by repeating the demonstration tests at the 1F site and in the difficult-to-return zones. At the 1F site, the distribution of radiation sources is changing depending on the progress in decommissioning works. Even under such circumstances, since we can immediately know the changes of the radiation distribution, the present system is considered to contribute to the safety of workers and the reduction of radiation exposure. In the difficult-to-return zones, the present system can contribute to the safer and more secure works by using it in formulating decommissioning plans and confirming the decontamination. Since the iRIS-V can give information about the position of radiation sources and their changes in a short time in addition to air dose rates that can be continuously obtained by conventional radiation monitoring vehicles, we plan to prepare iRIS-V's as next-generation monitoring vehicles.

【Terminology】

1) iRIS-V

Abbreviation of “integrated Radiation Imaging System-Vehicle”.

2) Compton camera

Radioactive materials are generally visualized by an instrument called gamma camera. Gamma cameras are roughly classified into “pinhole cameras” and “Compton cameras”. A pinhole camera is simple, but large and heavy, so it is not suitable for measurements in narrow spaces. In a Compton camera, the direction of gamma-ray is specified by the position where an injected gamma-ray (a kind of radiation) is interacted in each scatterer and absorber and the energy received. Since a Compton camera adopts a method to analytically specify the radiation source, it does not need heavy radiation shields and can be made smaller and lighter. Therefore, it can be said that a Compton camera is highly advanced technology.

3) LiDAR sensor (LiDAR: Light Detection and Ranging)

A sensor that scans an object using pulsed laser light and measures the distance from the time until the reflected scattered light returns. By loading a LiDAR sensor on a vehicle, three-dimensional terrain model in working environment can be obtained.

4) Small sealed test source

A safely designed test radiation source where radioactive materials are sealed in a container (plastic, metal, ceramic, etc.) so as not to be leaked. It is widely used for operation tests of radiation detectors, etc.

5) Contour

A line on a map that binds points having equal values. A map where contours are drawn at each value is called contour plot, which sensually shows the attributes and distribution. In order to make a contour plot easier to see, each band between two contours are sometimes colored step by step, which is called “color contour plot”.

This report is an edited version of the press released on March 27, 2020.

(Note 1)

In the homepage of JAEA, contents of the research and development at each institute are explained in the JAEA's public relation movie, "JAEA Channel", with easy-to-understand words. The contents of this report are released in the JAEA Channel entitled " " Visualize" invisible radioactive hotspots in three dimensions — Understanding the distribution of radioactive substances, and developing technology to help restore the environment of Fukushima—" (released in February 2020).

Official movie：JAEA Channel

JAEA's public relation movie, "JAEA Channel":
https://www.jaea.go.jp/english/jaea_channel/

(Note 2)

In the Sector of Fukushima Research and Development, the Fukushima Environmental Safety Center was integrated with the Collaborative Laboratories for Advanced Decommissioning Science on April 1, 2020.

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