# DEVELOPMENT OF THE CAR-BORNE SURVEY SYSTEM KURAMA

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*Abstract*

We have developed a car-borne survey system named as KURAMA (Kyoto University RAdiation MApping system) for the establishment of air dose rate map in Fukushima and surrounding area as a response to the nuclear accident at TEPCO Fukushima Daiichi Nuclear Power Plant on March 11, 2011. KURAMA is developed with LabVIEW. The monitoring data tagged by GPS location data are shared with remote servers over 3G mobile network, then processed by servers for a real time plot on Google Earth and other various purposes. A CompactRIO-based KURAMA-II is developed for the autonomous operation in public vehicles. More than a hundred of KURAMA and KURAMA-II now serve for the drawing up the radiation map in the East Japan by the Ministry of Education, Culture, Sports, Science and Technology in Japan. The outline and present status of KURAMA and KURAMA-II are introduced.

## INTRODUCTION

The magnitude-9 earthquake in east Japan and the following massive tsunami caused the serious nuclear disaster of Fukushima Daiichi nuclear power plant, which Japan had never experienced before. Huge amounts of radioactive isotopes were released in Fukushima and the surrounding prefectures.

In such nuclear disasters, air dose rate maps are quite important to help take measures to deal with the incident, such as assessing the radiological dose to the public, making plans for minimizing exposure to the public, or establishing procedures for environmental reclamation. The car-borne $\gamma$-ray survey technique is known to be one of the effective methods to make air dose-rate maps [1]. In this technique, a continuous radiation measurement with location data throughout the subject area is performed by one or more monitoring cars equipped with radiation detectors. Unfortunately, the existing monitoring system didn't work well in the incident. Such monitoring cars tend to be multi-functional, thus too expensive to own multiple monitoring cars in a prefecture. Fukushima was the case, and to their worse, the only monitoring car and the data center were contaminated by radioactive materials released by the hydrogen explosions of the nuclear power plant.

KURAMA was developed to overcome such difficulties in radiation surveys and for establishing air dose-rate maps during the present incident. KURAMA was designed based on consumer products, enabling a lot of in-vehicle apparatus to be prepared within a short period. KURAMA realizes high flexibility in the configuration of data-processing hubs or monitoring cars with the help of cloud technology. In the present paper, an outline of KURAMA as well as discussions regarding car-borne surveys performed by KURAMA are presented.

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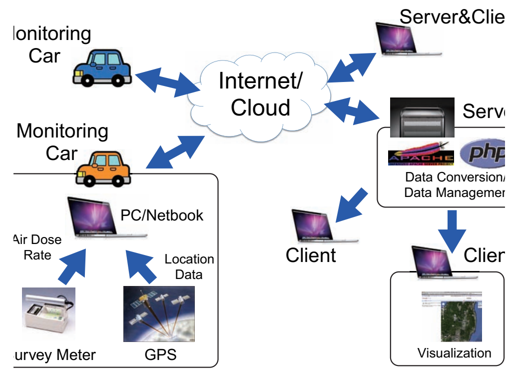


Figure 1: KURAMA system. Monitoring cars and servers are connected over the Internet by cloud technology.

## KURAMA

KURAMA is a $\gamma$-ray survey system with GPS and up-to-date network technologies developed for a primary use of car-borne surveys. A typical configuration of KURAMA is shown in Fig. 1.

An in-vehicle unit of KURAMA consists of a conventional NaI scintillation survey meter with an appropriate energy compensation, an interface box for the analog voltage output of the detector to a USB port of PC, a GPS unit, a laptop PC, and a mobile wi-fi router (Fig. 2). Its simple and compact configuration allows users to set up a in-vehicle unit in a common automobile. The software of in-vehicle part is developed with LabVIEW. The radiation data collected every three seconds is tagged by its respective location data obtained by the Global Positioning System (GPS) and stored in a csv file. The csv files updated by respective monitoring cars are simultaneously shared with remote servers by Dropbox over a 3G network, unlike other typical car-borne survey systems in which a special telemetry system or peer-to-peer radio communication is used. With this feature, the system obtains much more flexibility in the configuration and operation than other conventional car-borne systems. The radiation data is displayed in real time on Google Earth in client PCs after the dynamic generation of KML files in servers (Fig. 3).

KURAMA has served for monitoring activities in Fukushima and surrounding prefectures employed by Fukushima prefectural government and the Ministry of Ed-



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Figure 2: The in-vehicle part is compactly composed of mostly commercial components. 1) GPS unit, 2) 3G mobile wi-fi router, 3) MAKUNOUCHI, 4) NaI survey meter, 5) PC.

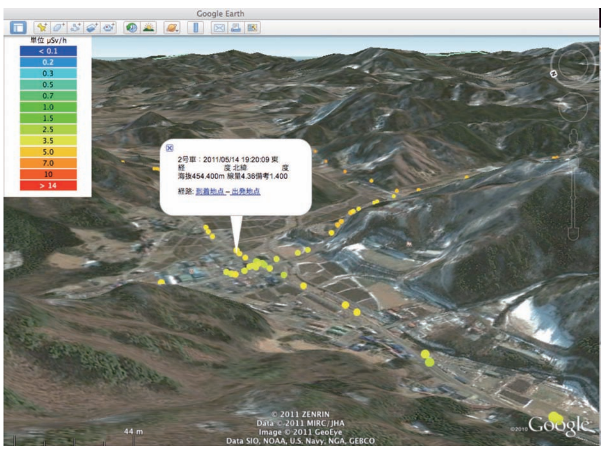

Figure 3: The data is simultaneously plotted on Google Earth. The color of each dot represents the air dose rate at respective point.

ucation, Culture, Sports, Science and Technology in Japan (MEXT). The team of Fukushima prefectural government makes precise radiation maps of major cities in Fukushima prefecture mainly for the gHot Spoth search [2], while MEXT periodically performs car-borne surveys in the eastern Japan including Tokyo metropolitan area (Fig. 4) [3].

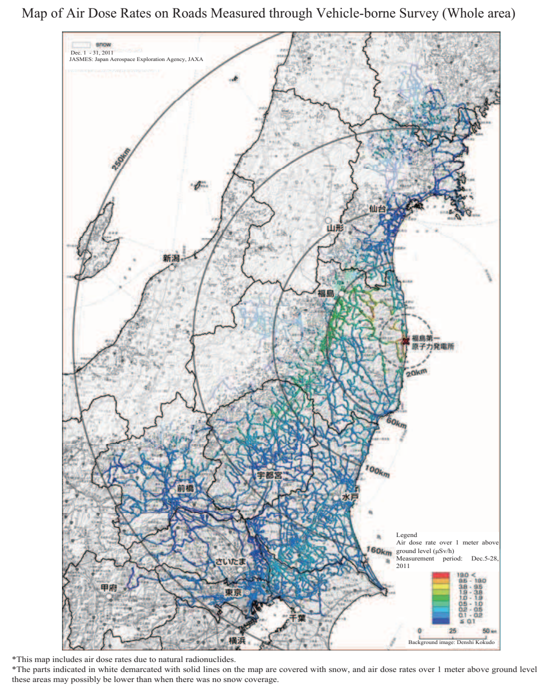


Figure 4: The air dose rate mapped by KURAMA in Dec. 2011 [3]. MEXT performed the first and second car-borne surveys of the East-Japan by KURAMA in June and December 2011, respectively.

## KURAMA-II

Long term (several tens years) and detailed surveillance of radiations are required in the living areas that are exposed to the radioactive materials. Such monitoring can be realized if moving vehicles in living areas such as buses, delivery vans or bikes for mail delivery have KURAMA onboard. KURAMA-II is designed for such purpose.

KURAMA-II stands on the architecture of KURAMA, but the in-vehicle part is totally re-designed. The platform is based on CompactRIO series of National Instruments to obtain better toughness, stability and compactness. The radiation detection part is replaced from the conventional NaI survey meter to a Hamamatsu C12137 detector, a CsI detector characterized as its compactness, high efficiency, direct ADC output and USB bus power operation. The direct ADC output enables to obtain $\gamma$-ray enegy spectra during the operation. The mobile network and GPS functions are handled by a Gxxx module for CompactRIO by SEA.

The software for KURAMA-II is basically the same code as that of original KURAMA. Additional developments are employed in several components such as device control softwares for newly introduced C12137 detector and Gxxx module, the start up and initialize sequences for autonomous operation, and the file transfer protocol.

As for the file transfer protocol, a simple file transfer protocol based on RESTful was developed since Dropbox doesn't support VxWorks, the operating system of CompactRIO. The present file transfer protocol are required to

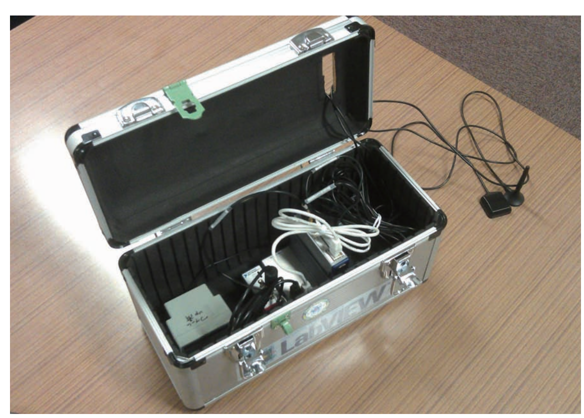

Figure 5: The in-vehicle unit of KURAMA-II. A CsI detector and a CompactRIO are compactly placed in a tool box with the size of 34.5 cm  17.5 cm  19.5 cm.

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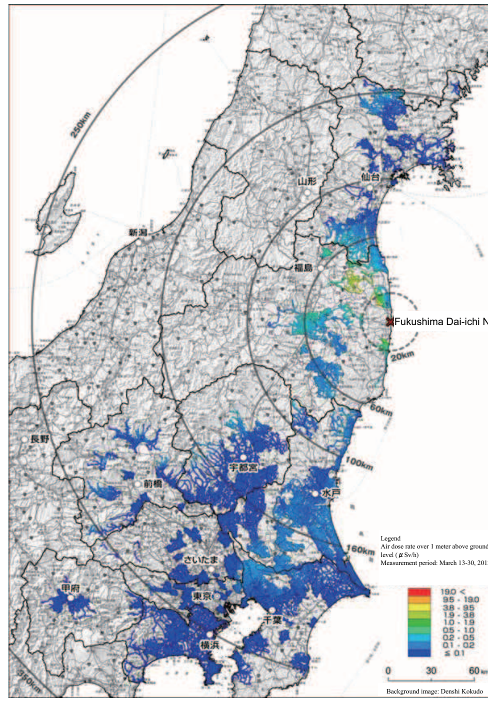
Figure 6: KURAMA-II under the field test on a city bus.

send the data without any lost under the poor coverage of the mobile network in rural part in Fukushima. In this protocol, a chunk of data as a timestamped file in csv format is produced for every three measuring points. The size of a chunk is about 400 bytes typically. Then every chunk is transferred to a remote "gateway server" by POST method. The gateway server combines received chunks to the data file, which is shared by remote servers using Dropbox as did in original KURAMA, and returns the name list of chunks which are successfully combined to the data file. The chunks in CompactRIO will not be deleted unless those names are confirmed in the returned list from the gateway server. Unsent chunks are archived at every one hundred of them as a single zip file and these are sent as soon as the network connection is recovered.

A field test on a city bus has been started since December 2011 in collaboration with Fukushima Kotsu Co. Ltd., one of the largest bus operator in Fukushima prefecture (Fig. 6). City buses are suitable for continuous monitoring purpose because of their fixed routes in the center of living area, and routine operations. Up to now, this field test is successful. We also have found that the present file transfer protocol successfully manages data transmission under the actual mobile network.

Based on the success in the field test on a city bus, MEXT introduced 100 KURAMA-II to municipalities in the eastern Japan and performed the car-borne survey for a month in March 2012 (Fig. 7). The survey was successful and proved the scalability of KURAMA-II system. The second survey in the same area by using KURAMA-II was performed in September 2012, and the result will soon be released from MEXT.

CompactRIO is designed for applications in harsh environments and small places. Therefore, KURAMA-II can be loaded on a motorcycles. This feature enables surveys by motorcycles not only for mail delivery, but also for the monitoring in regions where conventional cars can not drive, such as footpaths between rice fields, paths through forests. Also, KURAMA-II with DGPS unite is about to be used for the precise mapping by walk in rice fields, parks and playgrounds in Fukushima.




※This map includes air dose rates due to natural radionuclides.

Figure 7: Map of air dose rates on roads measured by KURAMA-II [4].

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