Radiation measurement by unmanned aircraft after Fukushima Daiichi nuclear power plant accident

Japan Atomic Energy Agency (JAEA)
Sector of Fukushima Research and Development,
Fukushima Environmental Safety Center,

Tatsuo TORII, and Yukihiisa SANADA
3/11/2011 Great East Japan Earthquake

➢ Time: 2:46pm on Friday, March 11, 2011.
➢ Epicenter: Offshore Sanriku coast (38°N, 142.9°E, 24km depth)
➢ Magnitude: 9.0 (maximum registered JMA intensity level was 7 at Kurihara, Miyagi prefecture)

Human damage as of March 14, 2014
➢ Deaths : 15,884
➢ Missing : 2,633

Source: Report of the Japanese Government to the IAEA Ministerial Conference on Nuclear Safety (June 18, 2011)
Fukushima Daiichi NPP after Tsunami and H₂ explosions
JAEA’s Main Missions

Technology Development for the Environmental Remediation and Decommissioning of TEPCO’s Fukushima-Daiichi NPPs

Securing long-term energy supply
Solving global environmental issues

Creating science & technology Basis with international competency

Nuclear Fuel Cycles
FBR Cycle Technology

Fusion Research & Development

Geological Disposal technology for High-Level Radioactive Waste
Support of LWR cycle industry

Quantum Beam Technology Research

Activities to secure safe and peaceful use of nuclear energy

Decommissioning & disposal of low-level waste

Nuclear safety research

Cooperation with academia and industries, international collaboration, human resource development

Nuclear nonproliferation

Universal nuclear science and technology

Basic nuclear engineering, state-of-the-art basic research, etc.
JAEA : Japan Atomic Energy Agency

- has the responsibility as the one and only institution dedicated to the comprehensive research and development of nuclear energy-related technology in the country;
- makes full use of our human resources and research facilities in responding to Fukushima-Daiichi NPPs accident, aiming at the greatest possible contribution, and
- continues to be involved in the restoration effort from the accident from a mid- and long-term perspective.
Our Activity for Fukushima Remediation

Aerial Monitoring

- Manned helicopter
- Unmanned airplane (UARMS)
- Unmanned helicopter
- Multicopter (Drone)
- Unmanned observation boat
- Remote operatly vehicle
- Plastic scintillation fiber
- Spectrometer for bottom of water

Development of remote radiation measurement for Fukushima area

- for decommissioning Fukushima Daiichi NPP
- for nuclear emergency (post-accident)
<table>
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<td><img src="image4" alt="Detector" /></td>
</tr>
<tr>
<td>Standard altitude of ground level</td>
<td>300 m*</td>
<td>150 m</td>
<td>80 m</td>
<td>10 m</td>
</tr>
<tr>
<td>Air Speed</td>
<td>185 km/h</td>
<td>108 km/h</td>
<td>28.8 km/h</td>
<td>7.2 km/h</td>
</tr>
<tr>
<td>Flight Time</td>
<td>90 min</td>
<td>360 min</td>
<td>90 min</td>
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Cesium Deposition and Air Dose-Rate Measured by Manned Helicopter

$^{134}\text{Cs} + ^{137}\text{Cs}$

Radiation monitoring in a wide range
Time Variation of Air Dose-Rate around Fukushima Daiichi NPP

Air dose-rate gradually decreased

After 7 months (2011.11.05)

After 11 months (2012.02.10)

After 15 months (2012.06.28)

After 20 months (2012.11.16)

After 24 months (2013.03.11)

After 30 months (2013.09.28)
## Monitoring Tools for Radiation Monitoring

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DEVELOPMENT OF AUTONOMOUS UNMANNED HELICOPTER (AUH) RADIATION SURVEY SYSTEM

**Feature**

1. Measurement at the places (high dose rate areas, forests, rice fields, etc.) which people cannot come into easily.
2. A ground base can be installed in a safe place (< several kilometers)
3. The image of a measurement place can also be grasped in real time.
4. Position information (GPS, video cam)
5. Programming flight.
6. Observation at a low altitude (below min. safety alt. of manned aircraft)
7. Hovering
   * Flight in the area where a person is not below

For monitoring around the Fukushima Daiichi Nuclear Power Plant
- Mapping of dose-rate distribution
- Reduction of the operator’s exposure
- Small man-power

For decontamination evaluation
- It can measure repeatedly the same place by programing flight.
Autonomous unmanned helicopter (AUH) : RMAX G1 (Yamaha Motor Co., Ltd.)

1. Body
   - Full length : less than 4 m (including rotors)
   - Weight : less than 100 kg

2. Flight performance
   - The maximum speed : 70 km/h (air speed)
     * Measurement speed: ~ 30 km/h
   - Flying duration: 60 minutes or more
   - The highest altitude : 250 m (Japanese regulation)
   - Operation Altitude: 50 ~ 100 m
   - Hovering accuracy : 3 m or less
   - Range of flight : not less than 3 km
   - When a control signal does not arrive at the ground station, it returns automatically.

3. Program flight
   - A flight schedule is drawn up on a computer display.
   - A ground image can be watched using ITV on the helicopter.
   - ITV is controllable by the ground station.

4. Payload
   - Loading weight : not less than 10 kg (at sea level)
Monitoring Results by the AUH

Around the FDNPP

Detection of traces of plume

Around a River Bed

Oct. 25, 2012

Movement and decrement of the radioactive cesium which deposited in the riverbed

Jan. 16, 2014

Futaba-machi

Okuma-machi

Tomioka-machi

FDNPP

3 km from FDNPP

Movement and decrement of the radioactive cesium which deposited in the riverbed

Dose rate at 1 m on the ground (μSv/h)

Decay-corrected to March 20, 2013

- > 30
- 20 - 30
- 10 - 20
- 5.0 - 10
- 1.0 - 5.0
- < 1.0

Dose rate at 1 m above the ground (μSv/h)

- 7-10
- 5-7
- 3-5
- 1.5-3
- 0.5-1.5
- < 0.5
Because we can fly many times by the same route, we can confirm an effect of decontaminating it in the AUH.
# Monitoring Tools for Radiation Monitoring

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Development the UARMS
(Unmanned Airplane for Radiation Monitoring System)

- Collaboration with JAXA (Japan Aerospace Exploration Agency)
- Aerial Standoff Detection (Autonomous UAV system)
- Flight duration: 6 h
- Wide range monitoring of radiation above the forest (> 10 km)
- Measures in nuclear emergency (atmospheric radioactivity)

- Developing the UARMS
- Developing Terrain Following Mode Safety System
- System Safety Design

- Developing new radiation detectors for the URARMS
- Developing the analyzing and mapping method of the distribution of radioactive substances in the environment.
## Development of the UARMS

![UARMS prototype](image1.png)  ![UARMS](image2.png)

<table>
<thead>
<tr>
<th>Item</th>
<th>Spec</th>
<th>UARMS prototype</th>
<th>Additional Capability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight</td>
<td>~ 50 kg</td>
<td>◯</td>
<td></td>
</tr>
<tr>
<td>Engine</td>
<td>Gasoline (16 L)</td>
<td>◯</td>
<td></td>
</tr>
<tr>
<td>Flight time</td>
<td>6 h</td>
<td>◯</td>
<td></td>
</tr>
<tr>
<td>Speed</td>
<td>25<del>35 m/s (90</del>126 km/h)</td>
<td>◯</td>
<td></td>
</tr>
<tr>
<td>Ground run</td>
<td>200~300 m</td>
<td>◯</td>
<td></td>
</tr>
<tr>
<td>Altitude</td>
<td>Around 150 m (To fly below MSA)</td>
<td>◯</td>
<td></td>
</tr>
<tr>
<td>Operation</td>
<td>Programmed Flight</td>
<td>◯</td>
<td>Terrain Following</td>
</tr>
<tr>
<td></td>
<td>Taking-off/landing: manual</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>operation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Safety</td>
<td>Parachute, system redundant</td>
<td>◯</td>
<td>System redundant, etc.</td>
</tr>
<tr>
<td></td>
<td>(parachute, RTB)</td>
<td></td>
<td></td>
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<tr>
<td>Payload</td>
<td>3-10 kg</td>
<td>◯</td>
<td>upgrade</td>
</tr>
<tr>
<td>Weather condition</td>
<td>Day time, even light rain is</td>
<td>◯</td>
<td>same</td>
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<tr>
<td></td>
<td>possible, wind speed: &lt; 15</td>
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<td></td>
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Flight Test around the Fukushima Daiichi NPP

Stricken by the tsunami
Mission Profile

(0) Flight Planning
(1) Preparation
(2) Takeoff
(3) Climb and Ingress
(4) Monitoring Mission
(5) Egress
(6) Descent & Approach
(7) Landing

Safety Procedure:
If any malfunction occurs,
- RTB Mode (Return To Base)
- Forced Landing using Glide Mode
- Emergency Parachute
- Flight Termination (Applying Full Rudder)

VLOS
BVLOS (limited to unpopulated or lightly populated area)
Flight Data

Track: L=800m, W=50m x 21lines, Area=1km$^2$
Altitude: 150mAGL, Airspeed: 30m/s, Flight Time: 26min

Horizontal Track

Path Error = ±2m

Vertical Track

Altitude Error = ±5m

Flight On 2014.01.24
Monitoring Result by the UARMS

Flight trace and contour map of air dose-rate
Monitoring Flight followed the topography

The measurement range changes by altitude.

Improvement of the radiation measurement accuracy is expected by the flight that followed the topography.
Evaluation of count-rate properties during the flight

- **GPS Altitude Hold**
- **"Terrain Following"**

Fluctuation of the count rate is small.

- 118 ± 27 cps
- 110 ± 10 cps
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Development of a multicopter

[feature]
- Safety (to fly residential areas)
  - Return to base
  - Urgent stop function
  - Small radiation detector
  - Rotor guard
  - Flight-log
  - 3D mapping

Flight in the forest and in the bldgs. of Fukushima Daiichi NPP
Summary

Based on the Fukushima Daiichi NPP accident:

- Aerial monitoring can grasp the distribution of the radioactive materials spread over a wide area by nuclear disaster visually.
- We can measure the distribution of radiation level quickly by using various UAV systems depending on purposes.
- As a tool measuring radiation influence in emergency, the system using UAVs which can measure radiation is effective for the safety of the researcher/engineers.
- However, operators judge the ensuring safety in an altitude of 150 m or less that UAV flies now.
- As a tool for nuclear energy disaster prevention effectively, it is necessary to build a system for safety flights and training flight crew continuously to use the UAVs.
Thank you!