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,

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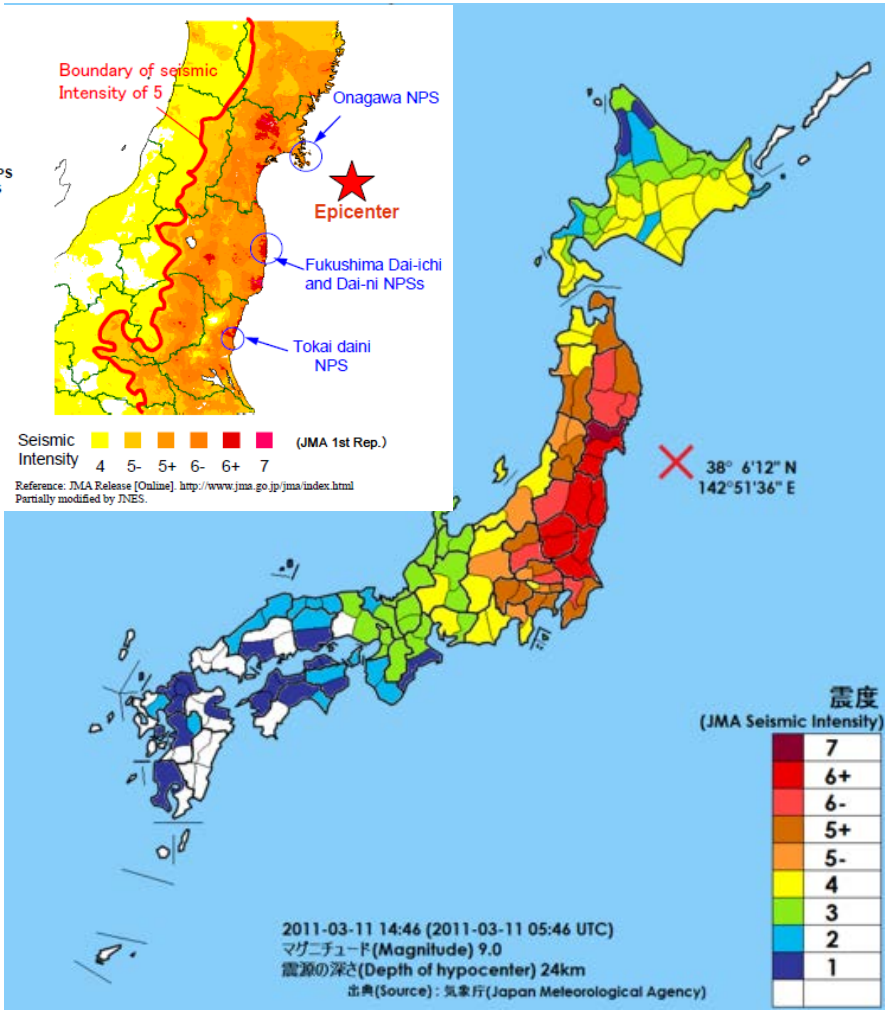
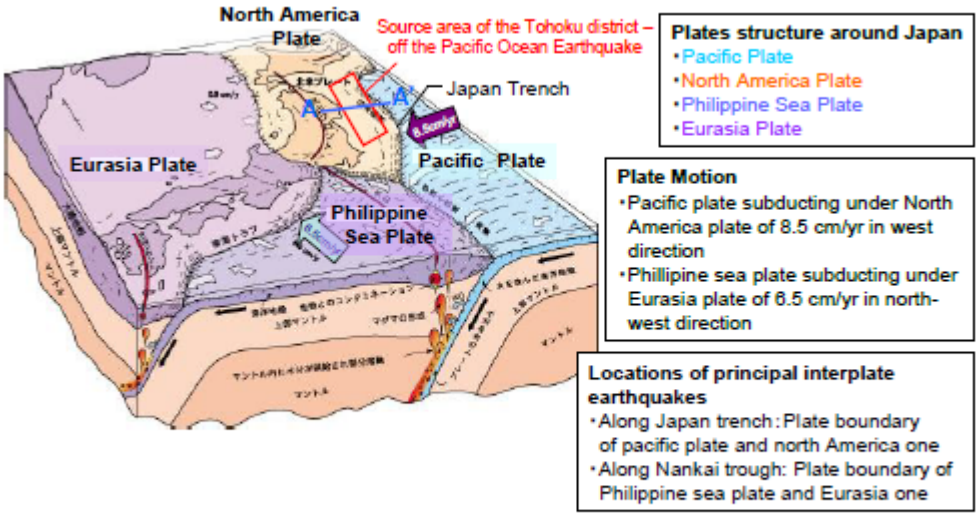
3/11/2011 Great East Japan Earthquake

- Time: 2:46pm on Friday, March 11, 2011.
- Epicenter : Offshore Sanriku coast (38ºN, 142.9ºE, 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



Reference: JGCA HP [Online]. http://www.zenchiren.or.jp/tikei/index.htm
Partially modified by JNES.

Source: Report of the Japanese Government to the IAEA Ministerial Conference on Nuclear Safety (June 18, 2011)

Fukushima Daiichi NPP after Tsunami and H_2 explosions

JAEA's Main Missions

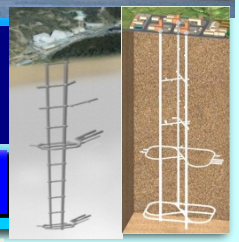
Technology Development for the Environmental Remediation and Decommissioning of TEPCO's Fukushima-Daiichi NPPs

Securing long-term energy supply
Solving global environmental issues

Nuclear Fuel Cycles

FBR Cycle Technology

Geological Disposal technology for High-Level Radioactive Waste

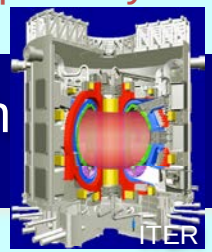


Support of LWR cycle industry

HTGR and nuclear hydrogen production

Creating science & technology Basis with international competency

Fusion Research & Development



Quantum Beam Technology Research

Activities to secure safe and peaceful use of nuclear energy

- Nuclear safety research
- Nuclear nonproliferation

Decommissioning & disposal of low-level waste

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

Universal nuclear science and technology

Basic nuclear engineering, state-of-the-art basic research, etc.

JAEA Roles

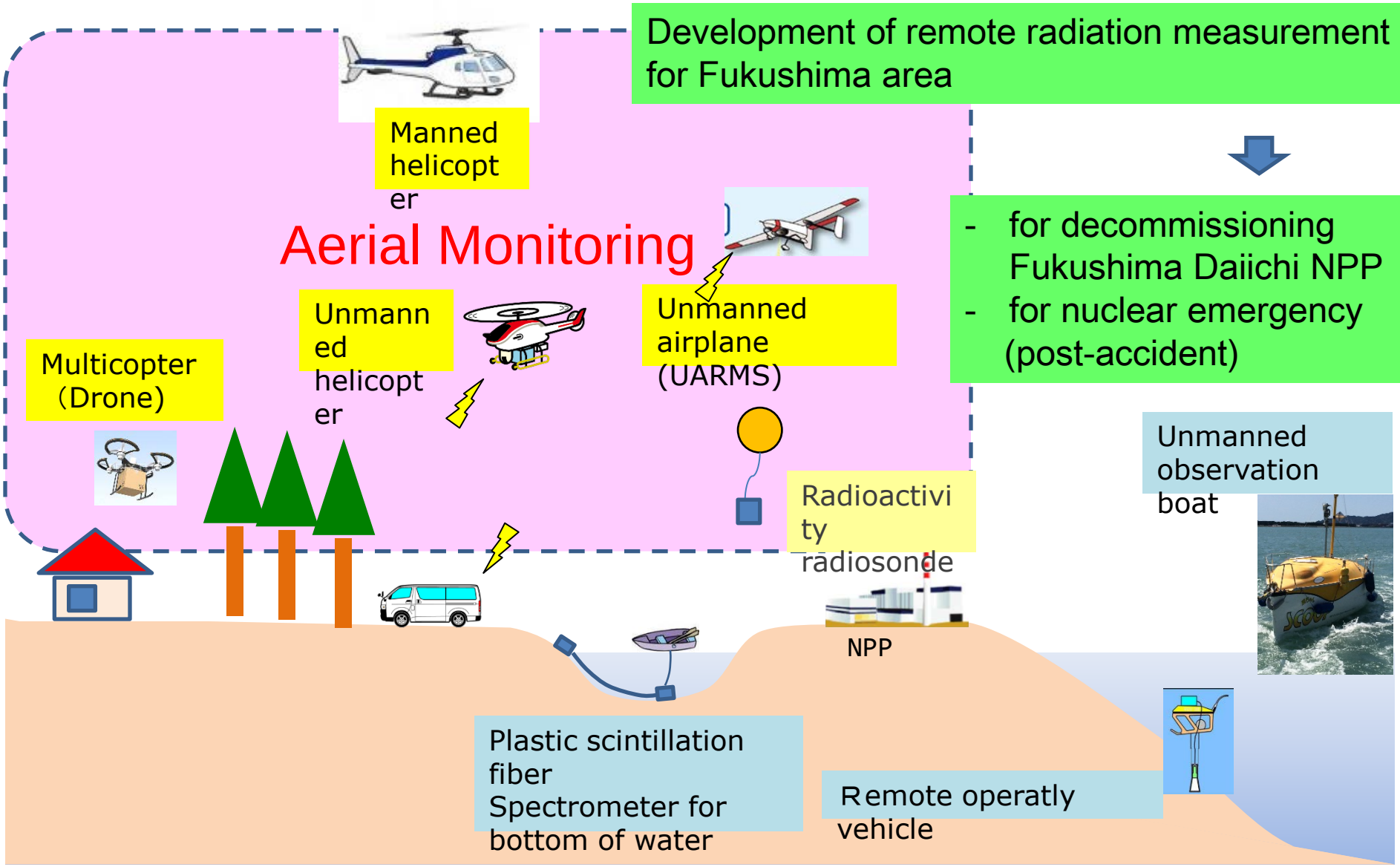
JAEA : Japan Atomic Energy Agency

- 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.

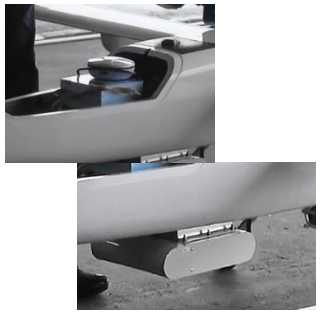
Our Activity for Fukushima Remediation

Development of remote radiation measurement for Fukushima area

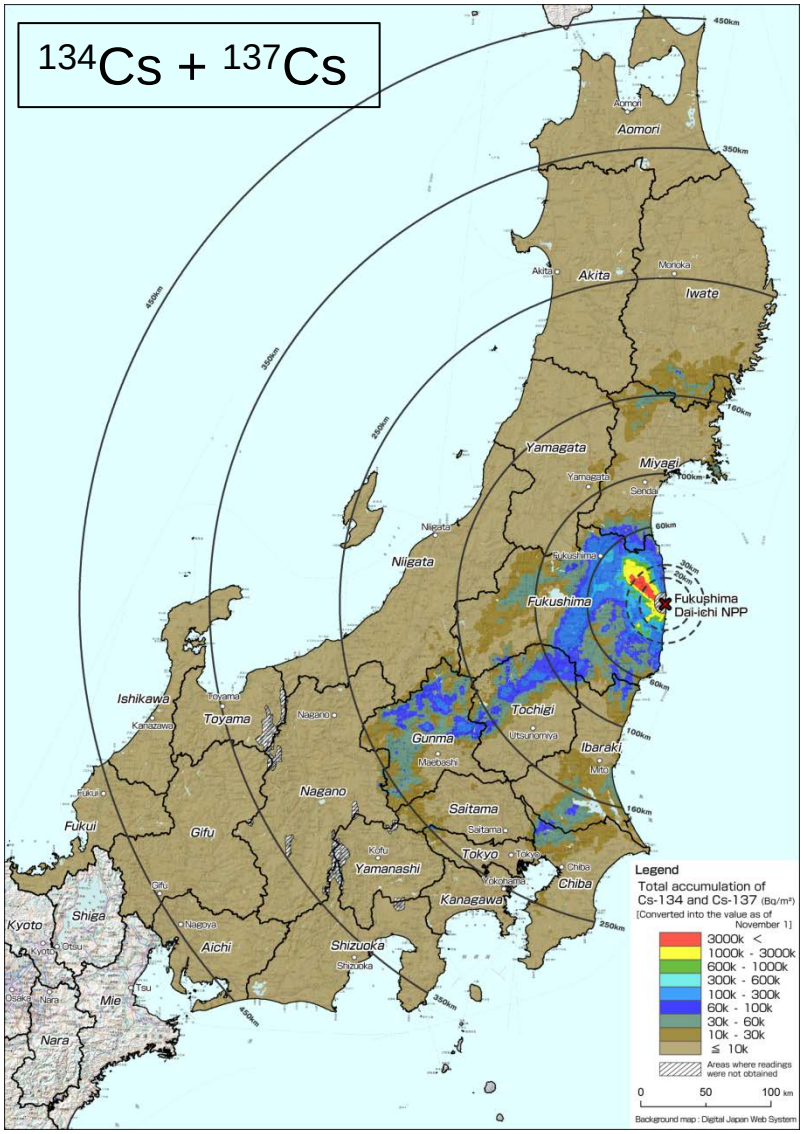
- for decommissioning Fukushima Daiichi NPP
- for nuclear emergency (post-accident)

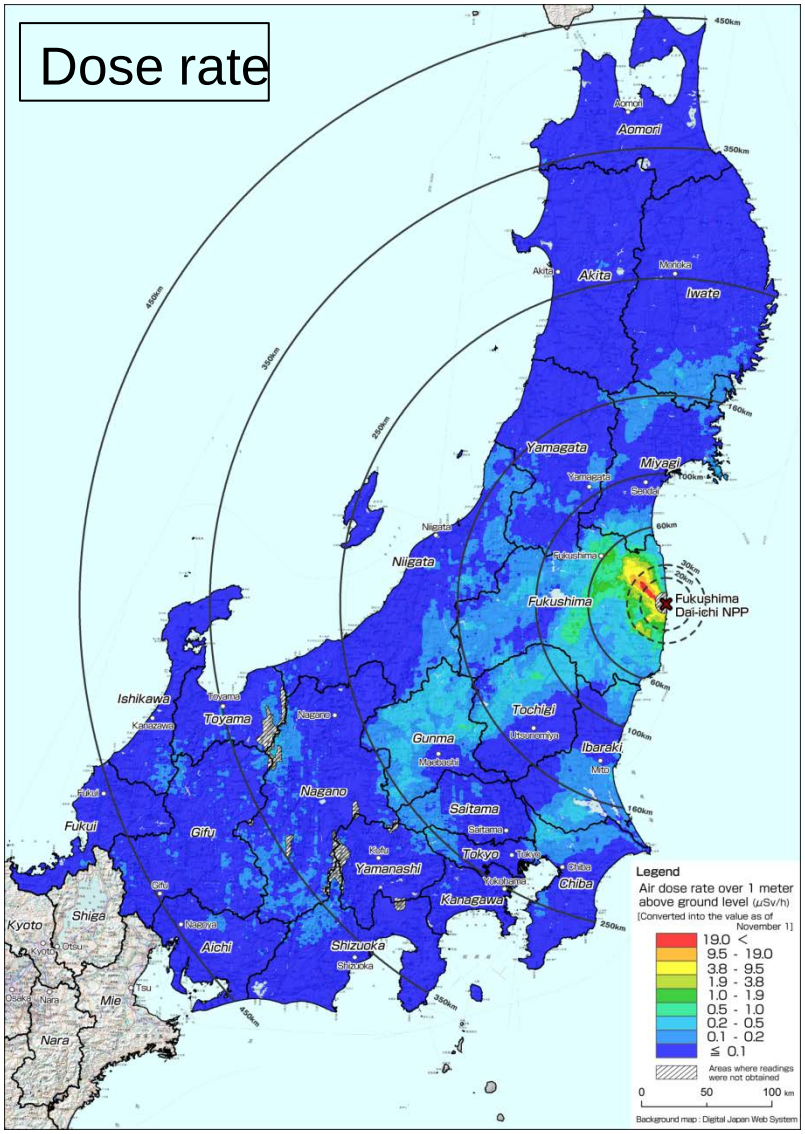


Monitoring Tools for Radiation Monitoring

	Manned helicopter	**Unmanned airplane**	**Unmanned helicopter**	**Multicopter**
				
Detector				
Standard altitude of ground level	300 m*	150 m	80 m	10 m
Air Speed	185 km/h	108 km/h	28.8 km/h	7.2 km/h
Flight Time	90 min	360 min	90 min	10 min
Max. Payload	100 kg*	10 kg	10 kg	3 kg
Flight Range	~ 100 km	> 10 km	< 3 km	< 1 km

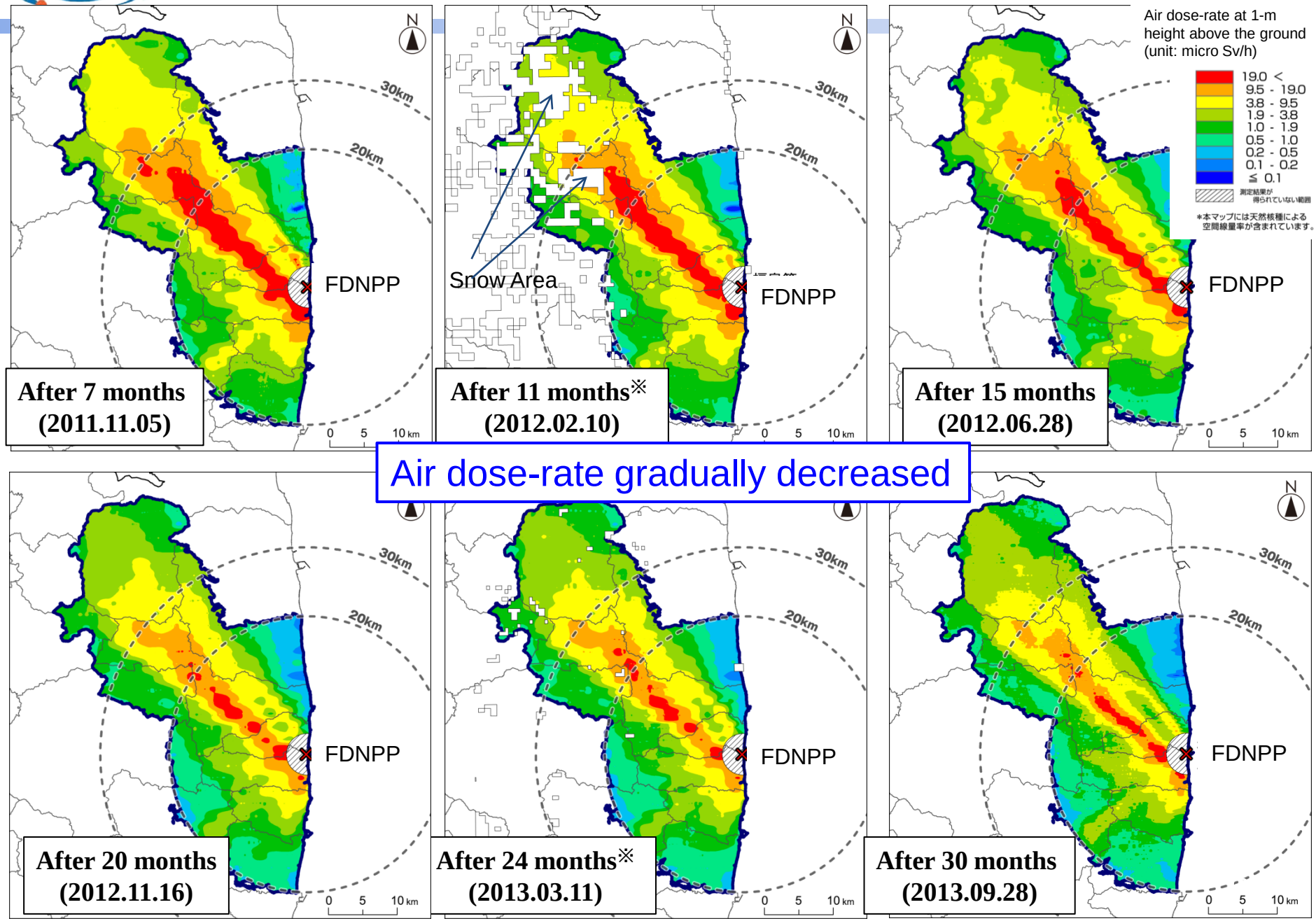
Cesium Deposition and Air Dose-Rate Measured by Manned Helicopter





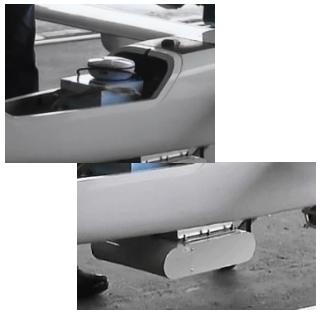
Radiation monitoring in a wide range

Time Variation of Air Dose-Rate around Fukushima Daiichi NPP



Air dose-rate gradually decreased

Monitoring Tools for Radiation Monitoring

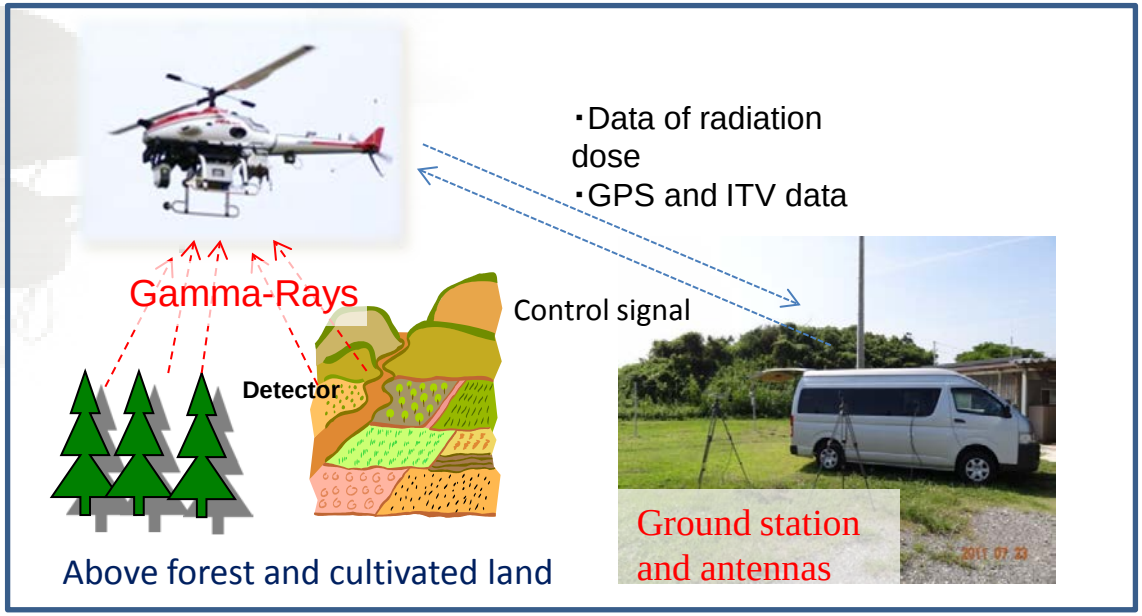
	Manned Helicopter	**Unmanned Airplane**	**Unmanned Helicopter**	**Multicopter**
				
Detector				
Flight Altitude	~ 300 m*	~ 150 m	~ 80 m	< 10 m
Air Speed	185 km/h	100 km/h	30 km/h	7 km/h
Flight Time	120 min	360 min	90 min	20 min
Max. Payload	> 100 kg*	10 kg	10 kg	3 kg
Flight Range	~ 100 km	> 10 km	< 3 km	< 1 km

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' exposure
- Small man-power

For decontamination evaluation

- It can measure repeatedly the same place by programing flight.

The AUH System

Autonomous unmanned helicopter (AUH) : RMAX G1 (Yamaha Motor Co., Ltd.)

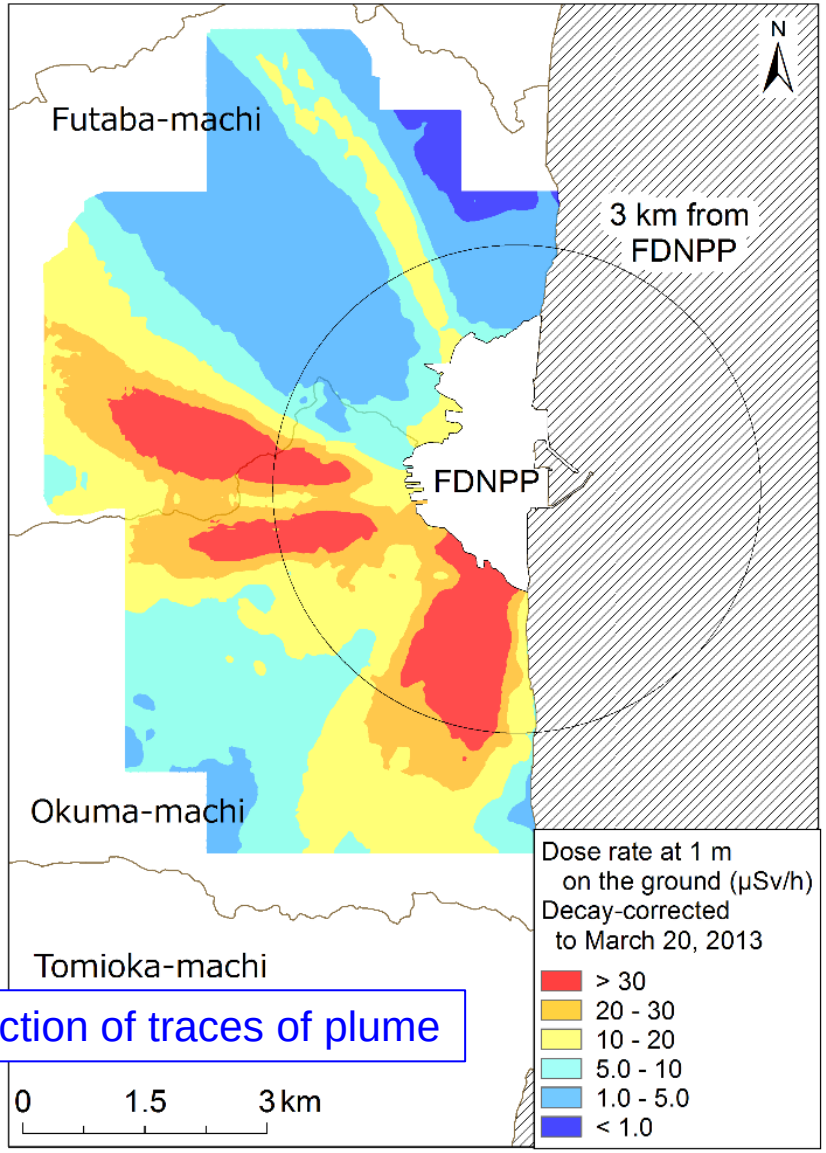
1. Body
   - Full length : less than 4 m (including rotors)
   - Weight : less than 100 kg
2. Flight performance
   - The maximum speed : 70 km/h (air speed)
     * Measurement speed: ~ 30 km/h
   - Flying duration: 60 minutes or more
   - The highest altitude : 250 m (Japanese regulation)
   - Operation 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)

The UAH

Inside the ground station

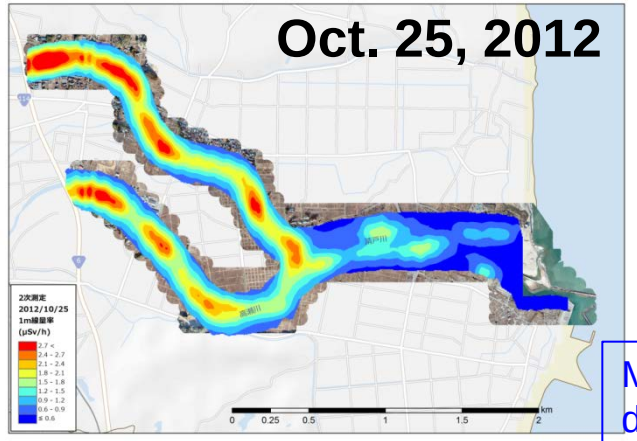
Monitoring Results by the AUH

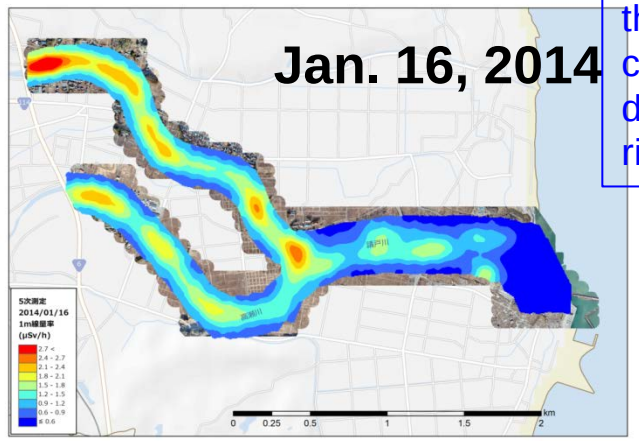
Around the FDNPP



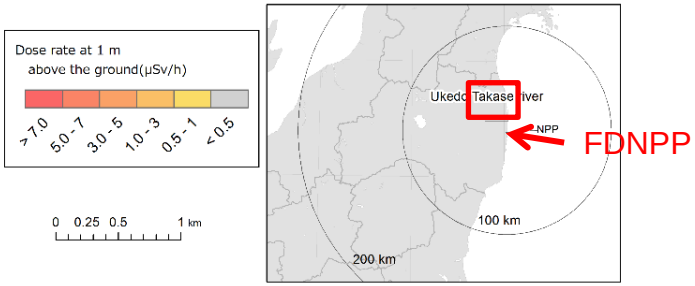
Detection of traces of plume

Around a River Bed



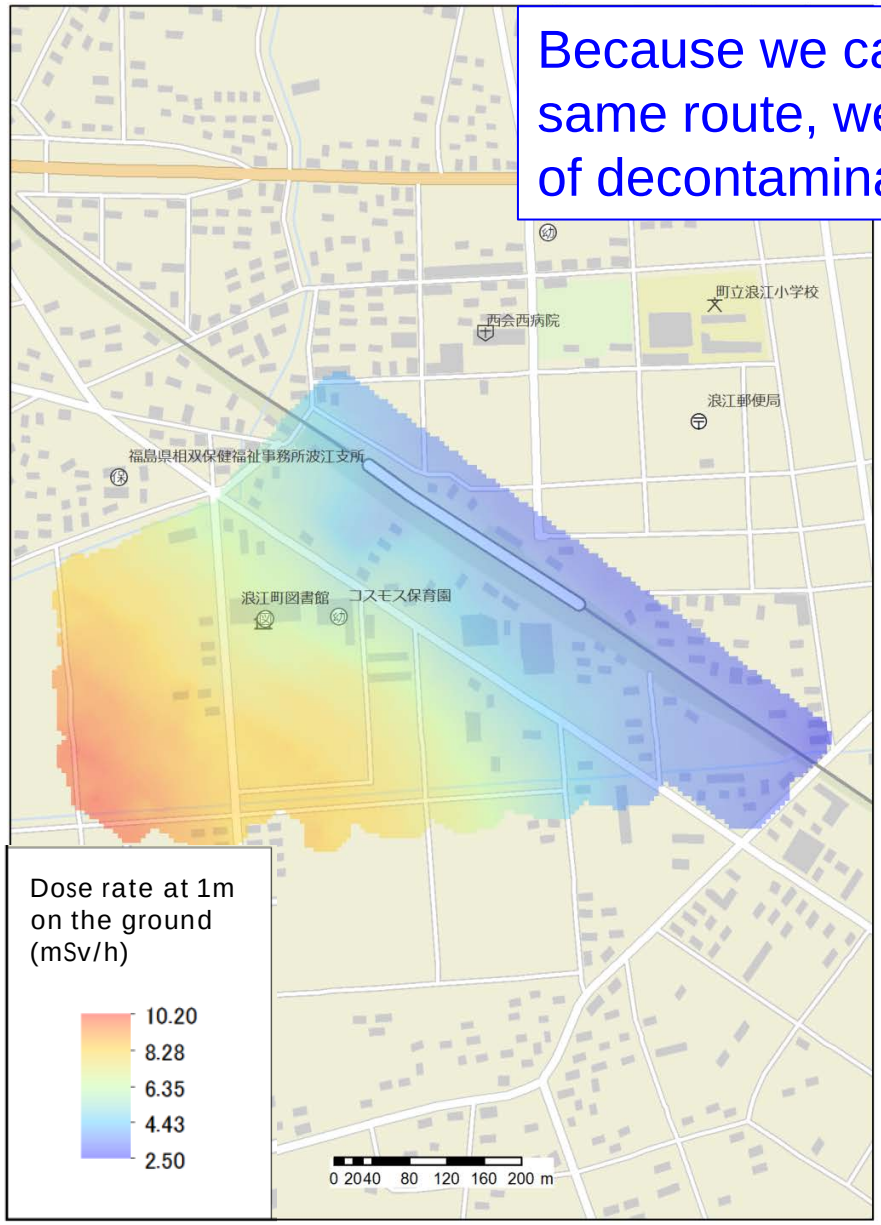


Movement and decrement of the radioactive cesium which deposited in the riverbed

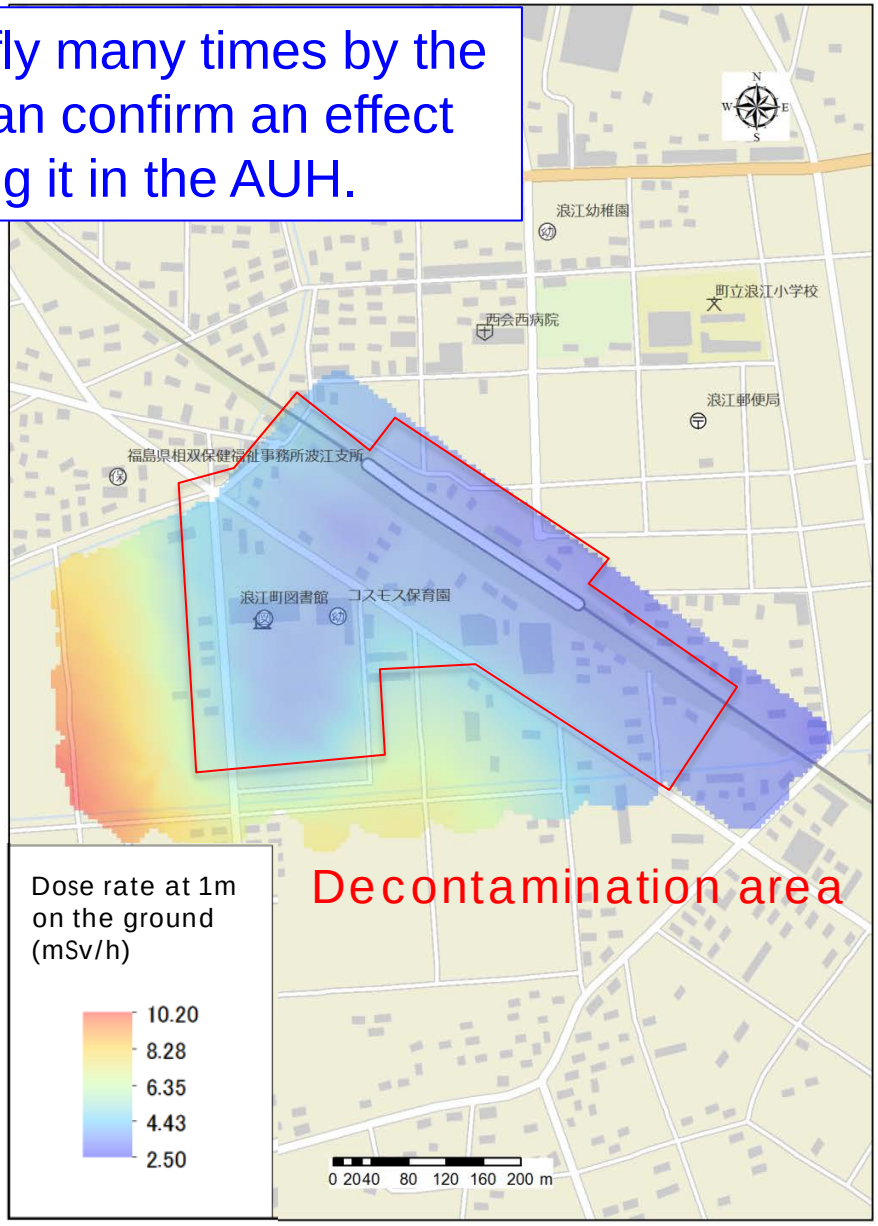


Monitoring before/after decontamination work

Before



After



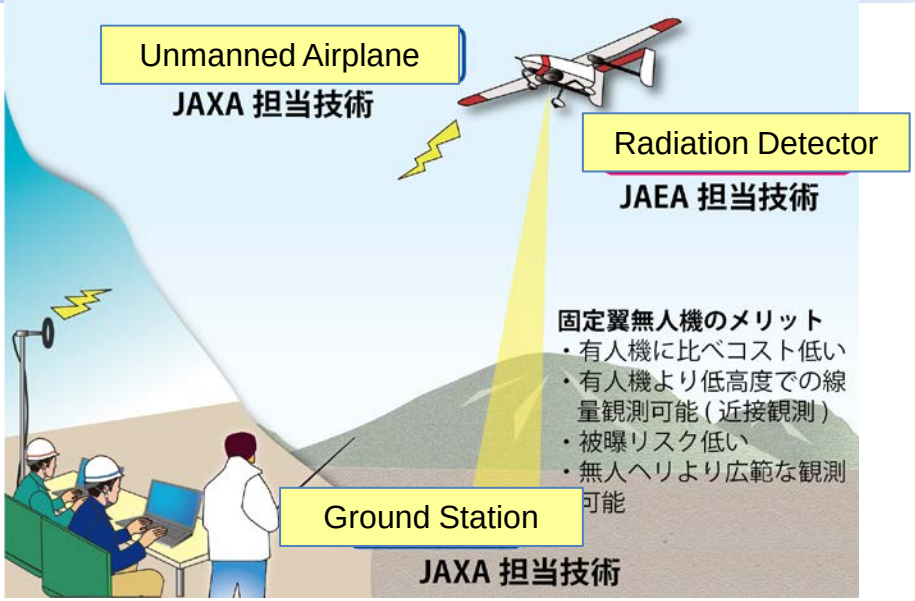
Because we can fly many times by the same route, we can confirm an effect of decontaminating it in the AUH.

Monitoring Tools for Radiation Monitoring

	Manned Helicopter	**Unmanned Airplane**	**Unmanned Helicopter**	**Multicopter**
				
Detector				
Flight Altitude	~ 300 m*	~ 150 m	~ 80 m	< 10 m
Air Speed	185 km/h	100 km/h	30 km/h	7 km/h
Flight Time	120 min	360 min	90 min	20 min
Max. Payload	> 100 kg*	10 kg	10 kg	3 kg
Flight Range	~ 100 km	> 10 km	< 3 km	< 1 km

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)



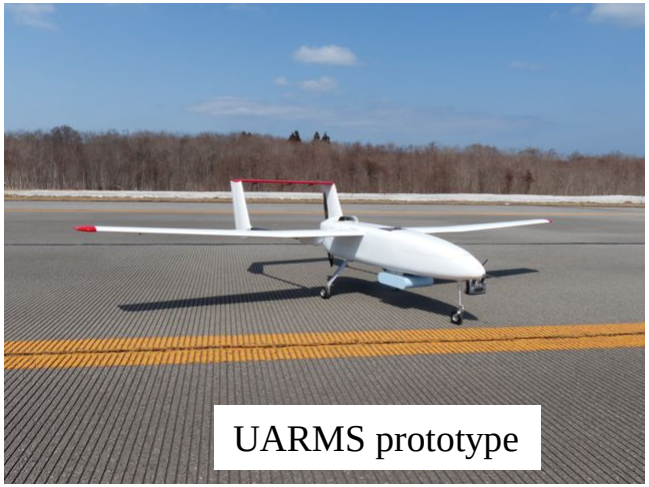
JAXA

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

JAEA

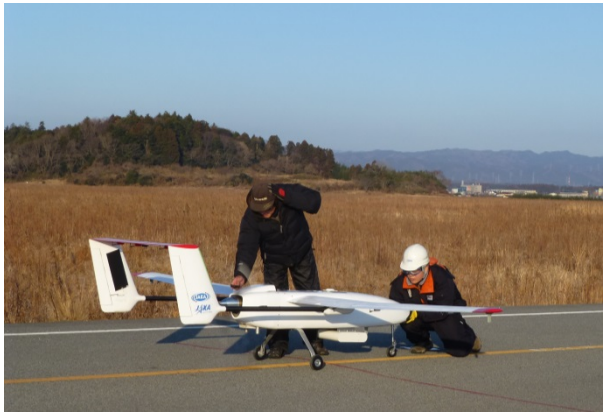
- Developing new radiation detectors for the URARMS
- Developing the analyzing and mapping method of the distribution of radioactive substances in the environment.

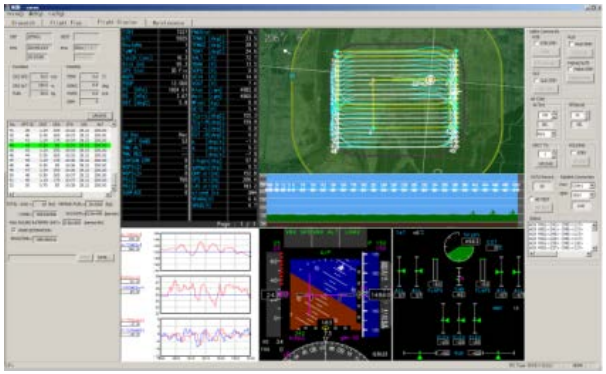
Development of the UARMS



item	spec	UARMS prototype	Additional Capability
weight	~ 50 kg	◎	
engine	Gasoline (16 L)	◎	
Flight time	6 h	○	6 h
speed	25～35m/s （90～126km/h）	◎	
Ground run	200～300m	◎	
Altitude	Around 150 m (To fly below MSA)	◎	
operation	Programmed Flight Taking-off/landing: manual operation	○	Terrain Following
Safety	Parachute, system redundant	○ (parachute, RTB)	System redundant, etc.
payload	3-10 kg	○	upgrade
weather condition	Day time, even light rain is possible, wind speed: < 15	○	same

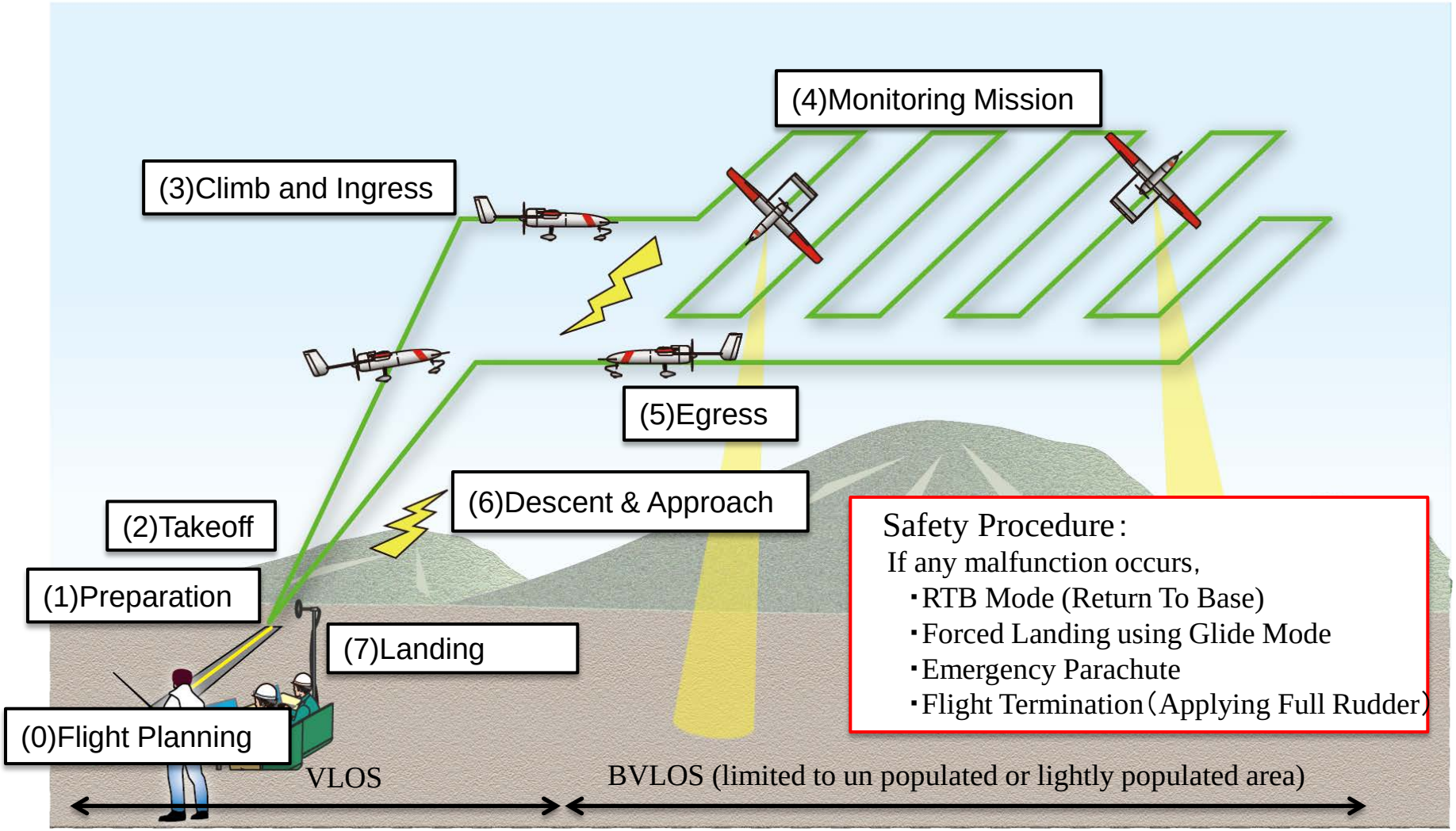
Flight Test around the Fukushima Daiichi NPP





Stricken by the tsunami

Mission Profile

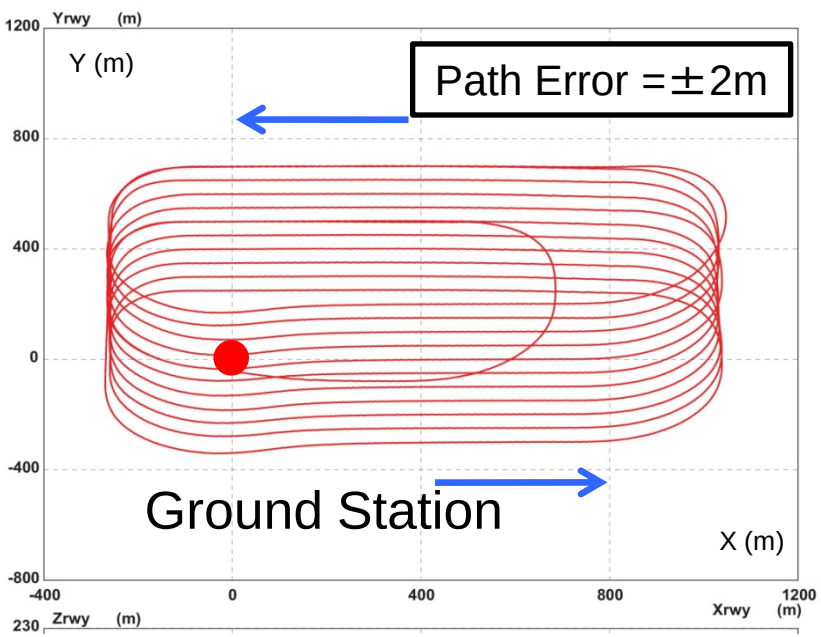


Safety Procedure：
If any malfunction occurs,
- RTB Mode (Return To Base)
- Forced Landing using Glide Mode
- Emergency Parachute
- Flight Termination（Applying Full Rudder）

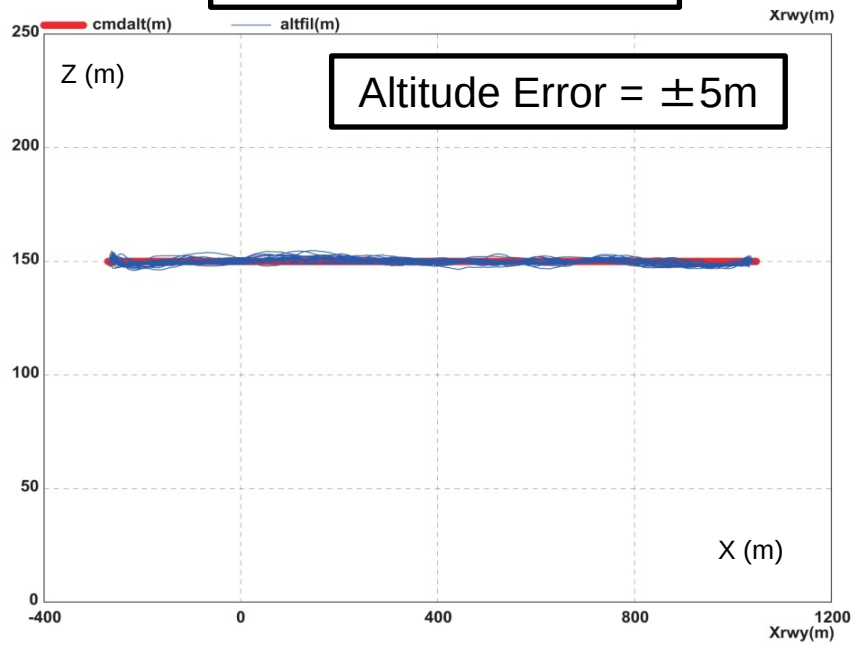
Flight Data

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

Horizontal Track

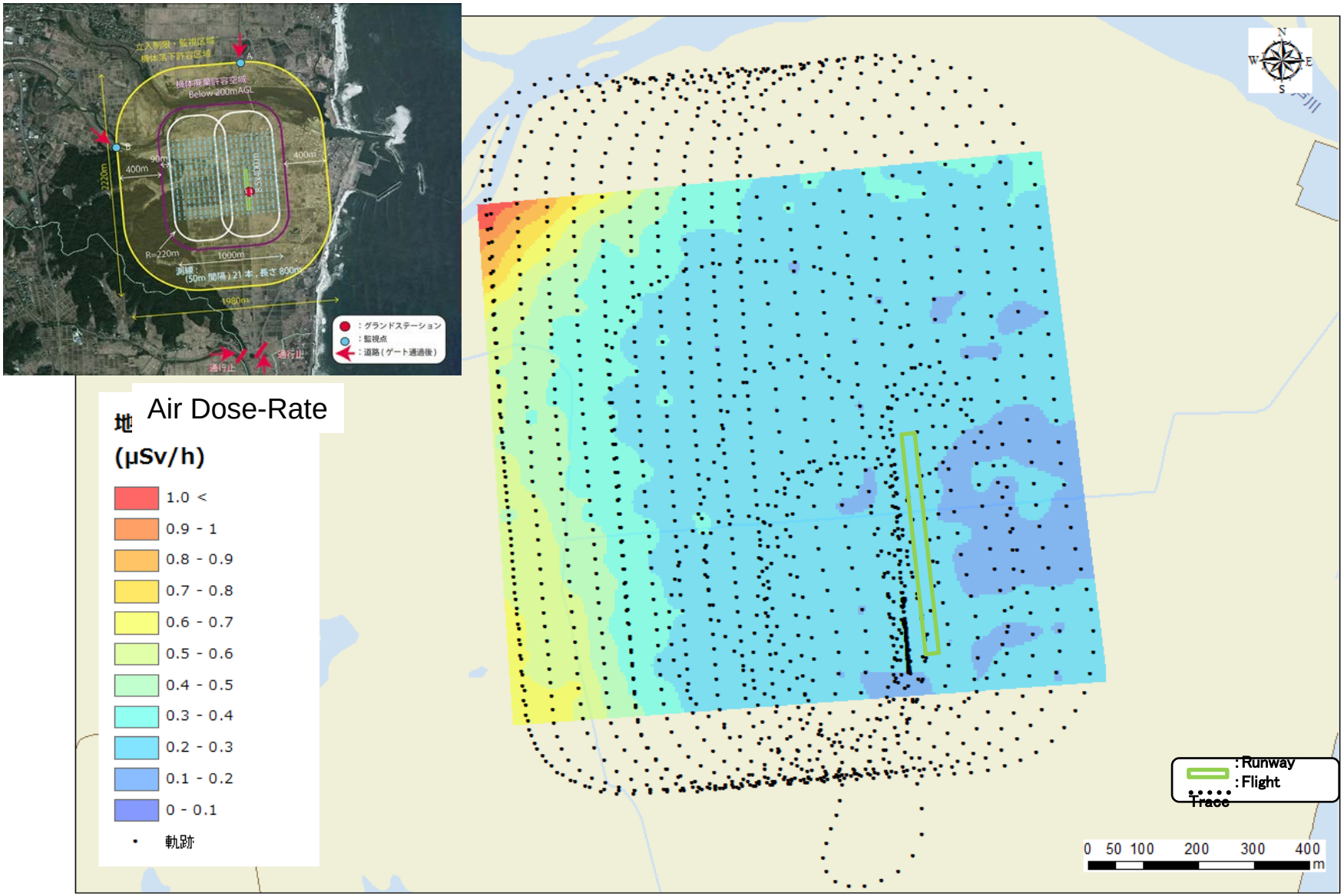


Vertical Track



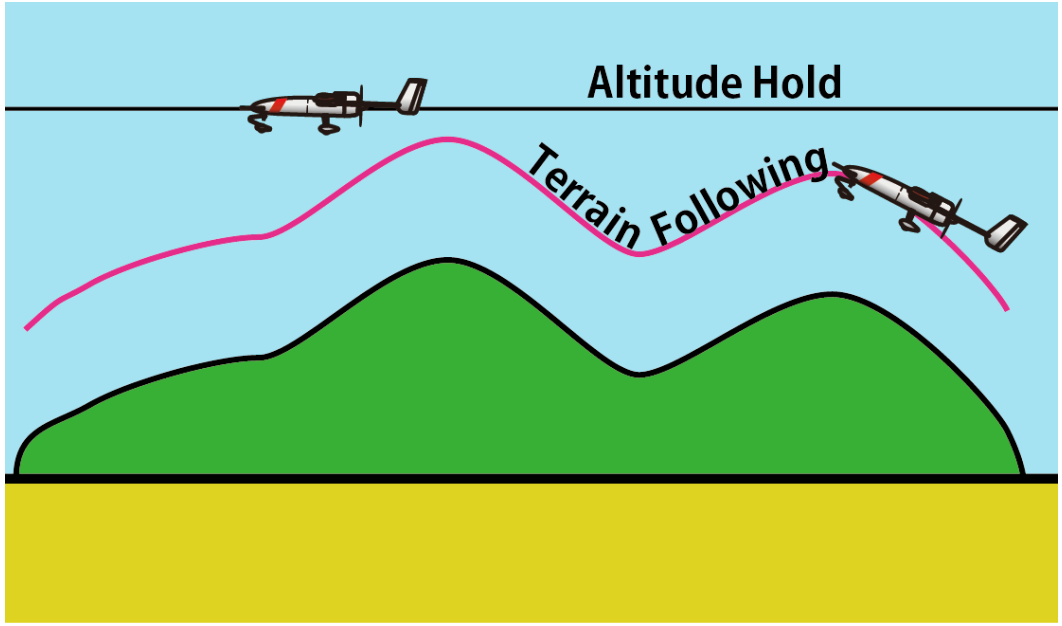
Flight On 2014.01.24

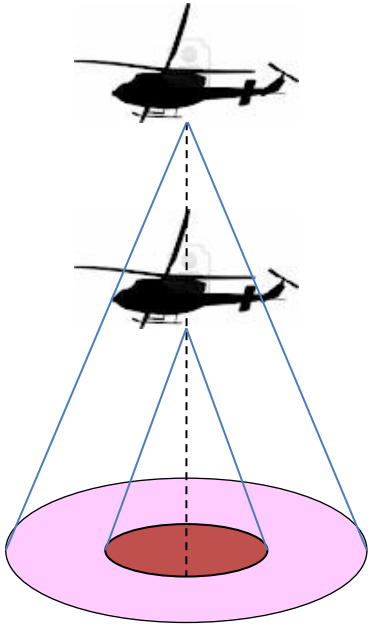
Monitoring Result by the UARMS



Flight trace and contour map of air dose-rate

Monitoring Flight followed the topography



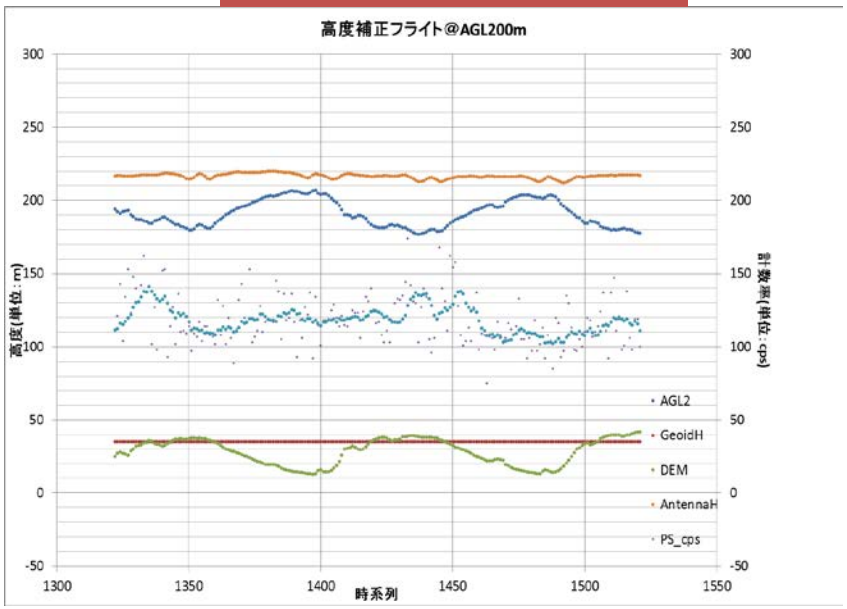


The measurement range changes by altitude.

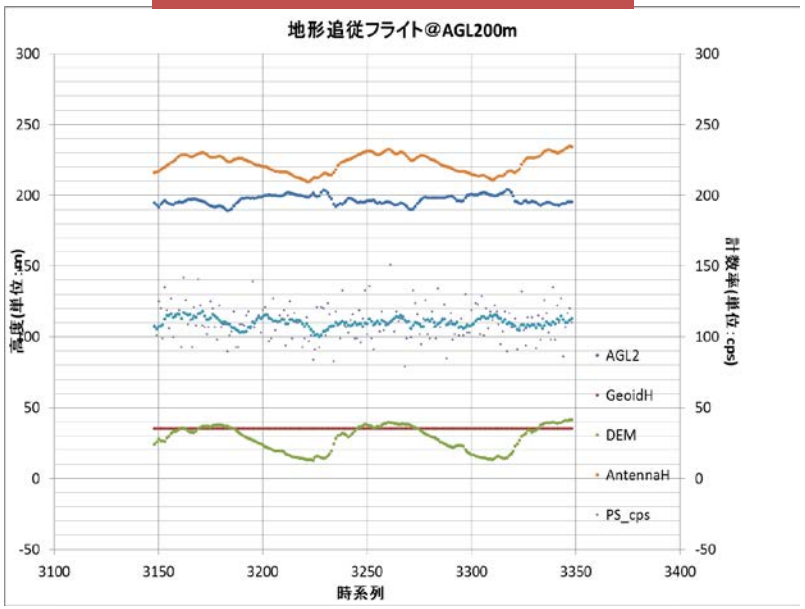
Improvement of the radiation measurement accuracy is expected by the flight that followed the topography.

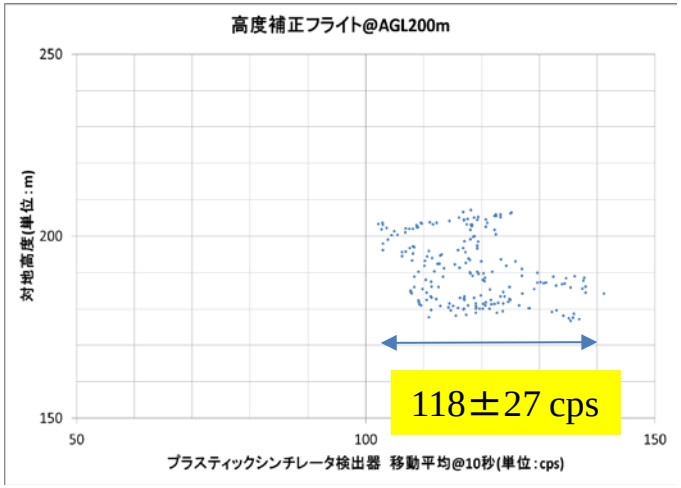
Evaluation of count-rate properties during the flight

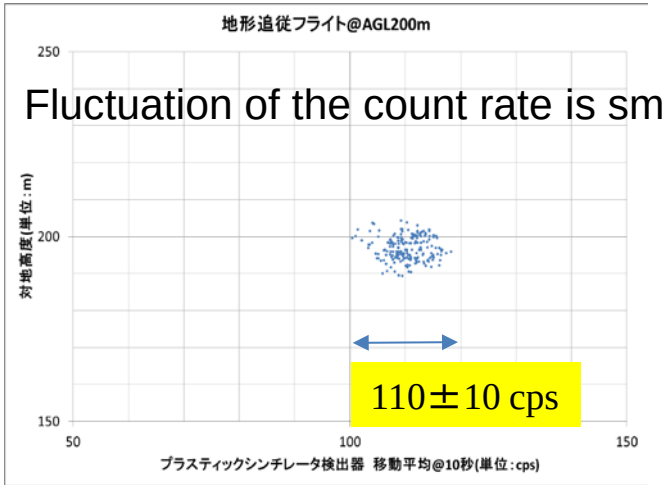
GPS Altitude Hold



"Terrain Following"







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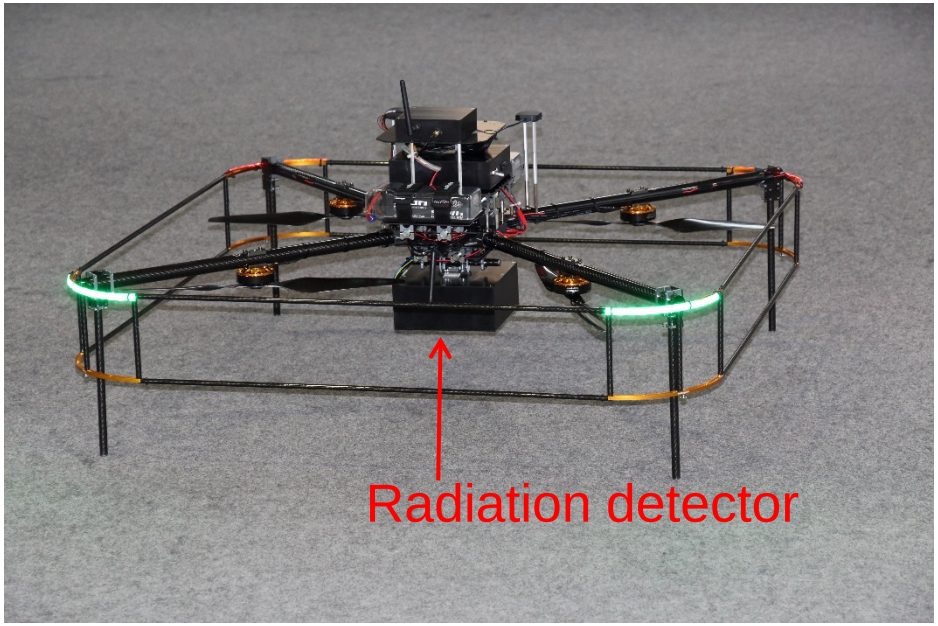
Development of a multicopter



[feature]

- Safety (to fly residental 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!