

Planning for Emergency Field Environmental Radiological Monitoring

Mark L. Miller

Principal Member of the Technical Staff, Sandia National Laboratories

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Emergency Planning Purpose

- **Emergency Planning BEGINS with Background/Routine Monitoring**
- **Sources, Baseline Concentrations, Fate and Transport, Impact and Early Warning**
 - Data Collection Objectives
 - Data Quality Objectives

Failing to PLAN means PLANNING to Fail?



Useful Reference Documents

- [NCRP Report No. 161](#), *Management of Persons Contaminated with Radionuclides*
- [NCRP Report No. 159](#), *Risk to the Thyroid from Ionizing Radiation*
- [NCRP Report No. 116](#), *Limitation of Exposure to Ionizing Radiation*
- [NCRP Report No. 154](#), *Cs-137 in the Environment: Radioecology and Approaches to Assessment and Management*
- [NCRP Report No. 109](#), *Effects of Ionizing Radiation on Aquatic Organisms*
- [NCRP Report No. 52](#), *Cs-137 from the Environment to Man: Metabolism and Dose*

Useful Reference Documents (cont'd)

- [Commentary No. 19](#), *Key Elements of Preparing Emergency Responders for Nuclear and Radiological Terrorism*
- [Commentary No. 10](#), *Advising the Public about Radiation Emergencies*



Topics to Address

Texts should be available to convey basic facts, *i.e.*, potential hazards and options for radiation protection. Other recommended topics include the following:

- description of radiation types
- radiation sources
- interactions of radiation with matter
- radionuclide generation
- radioactive decay
- environmental movement of radioactive materials
- modes of exposure (external, inhalation, ingestion)
- behavior of radiation radioactive materials within the body
- levels of measurable effects on humans and the environment
- limitation of exposure by time, distance and shielding

Exposure Pathways

(Data Collection Objectives)

(Not all pathways may be of concern. Prioritize target pathways to fit budget.)

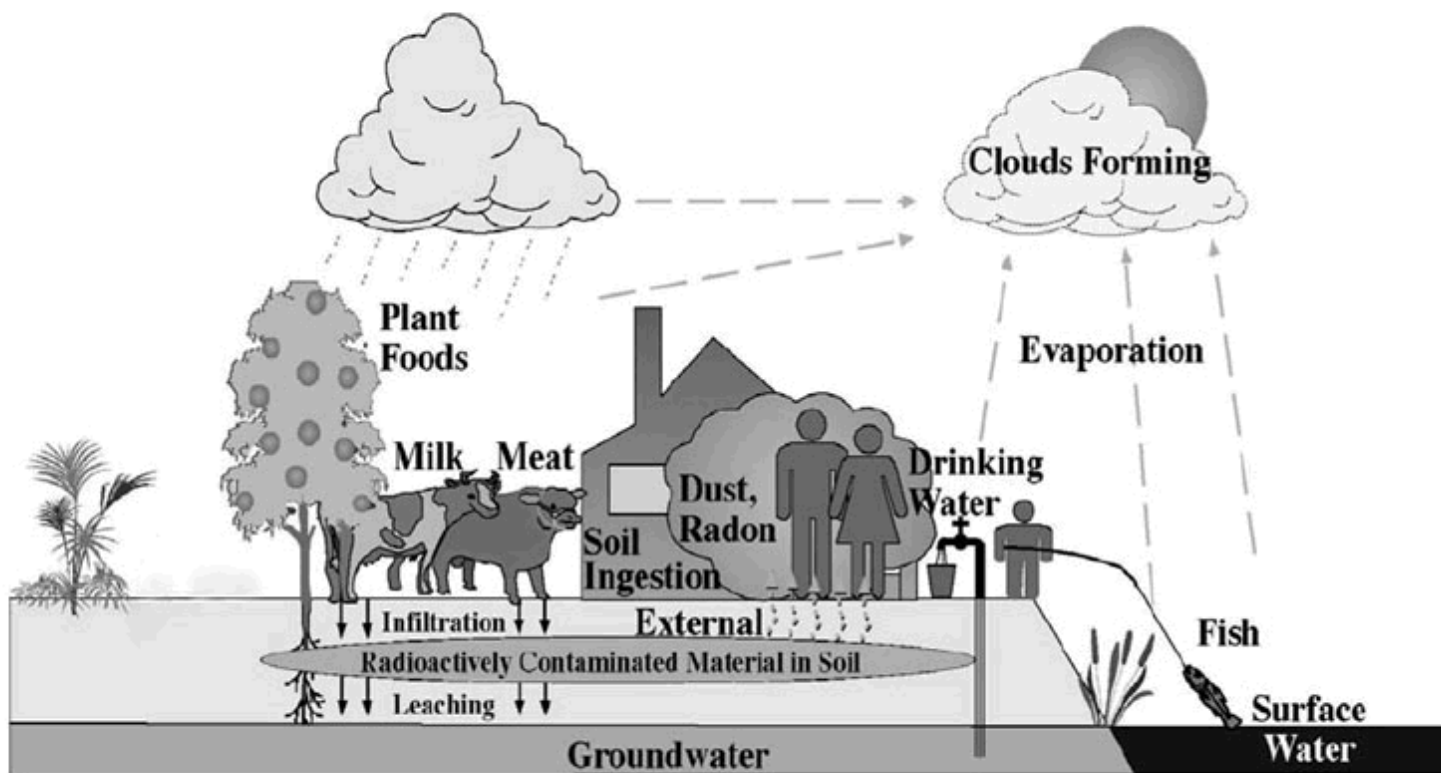


FIGURE 1.1 Exposure Pathways Considered in RESRAD



Exposure Pathways

(Data Collection Objectives)

- **Direct exposure to external radiation from the contaminated soil material;**
- **Internal dose from inhalation of airborne radionuclides, including radon progeny; and**
- **Internal dose from ingestion of**
 - Plant foods grown in the contaminated soil and irrigated with contaminated water,
 - Meat and milk from livestock fed with contaminated fodder and water,
 - Drinking water from a contaminated well or water body,
 - Fish or shellfish from a contaminated water body, and
 - Contaminated soil.



Radionuclides of Concern

- H^3
- Zn^{65}
- Co^{60}
- Sr^{90}
- Cs^{137}
- Ra^{226}
- U^{235}
- U^{238}
- Pu^{239}
- Others? (MAPEP list?)

Potential Accident Radiation Release Inventory

Nuclide	Ci	Nuclide	Ci	Nuclide	Ci
Ba-137m	1.1E+06	La-140	4.4E+05	Tc-99m	2.0E+05
Ba-140	6.0E+06	Mo-99	2.0E+05	Te-127	3.7E+05
Ce-144	1.5E+05	Np-239	2.2E+06	Te-127m	6.5E+02
Cs-134	2.0E+06	Pr-144	1.5E+05	Te-129	4.0E+05
Cs-135	1.0E-02	Pr-144m	2.7E+03	Te-129m	5.3E+05
Cs-136	6.1E+05	Pu-239	2.2E-01	Te-131	1.5E+05
Cs-137	1.3E+06	Rb-87	3.2E-08	Te-131m	6.6E+05
Cs-138	2.4E-07	Rb-88	4.5E+04	Te-132	9.5E+06
I-129	3.2E-04	Rh-103m	1.8E+05	U-235	4.2E-14
I-131	1.7E+07	Rh-106	4.9E+04	Xe-131m	3.3E+05
I-132	1.7E+07	Ru-103	1.8E+05	Xe-133	5.4E+07
I-133	1.6E+07	Ru-106	4.9E+04	Xe-133m	1.7E+06
I-134	8.2E-02	Sb-127	4.9E+05	Xe-135	1.1E+07
I-135	2.2E+06	Sb-129	5.4E+04	Xe-135m	3.8E+05
Kr-85	2.3E+05	Sr-89	3.7E+06	Y-90	5.1E+03
Kr-85m	1.5E+05	Sr-90	1.8E+05	Y-91	2.1E+05
Kr-87	1.5E+01	Sr-91	6.8E+05	Y-91m	2.7E+05
Kr-88	4.4E+04	Tc-99	2.4E-03		

Radionuclides of Concern Assay Techniques

- **H³ – Liquid Scintillation Counting (LSC) – activation product**
- **Zn⁶⁵ – Gamma Spec – fission product**
- **Co⁶⁰ – Gamma Spec – activation product**
- **Sr⁹⁰ – Radiochemistry – fission product**
- **Cs¹³⁷ – Gamma Spec – fission product**



Radionuclides of Concern Assay Techniques (cont'd)

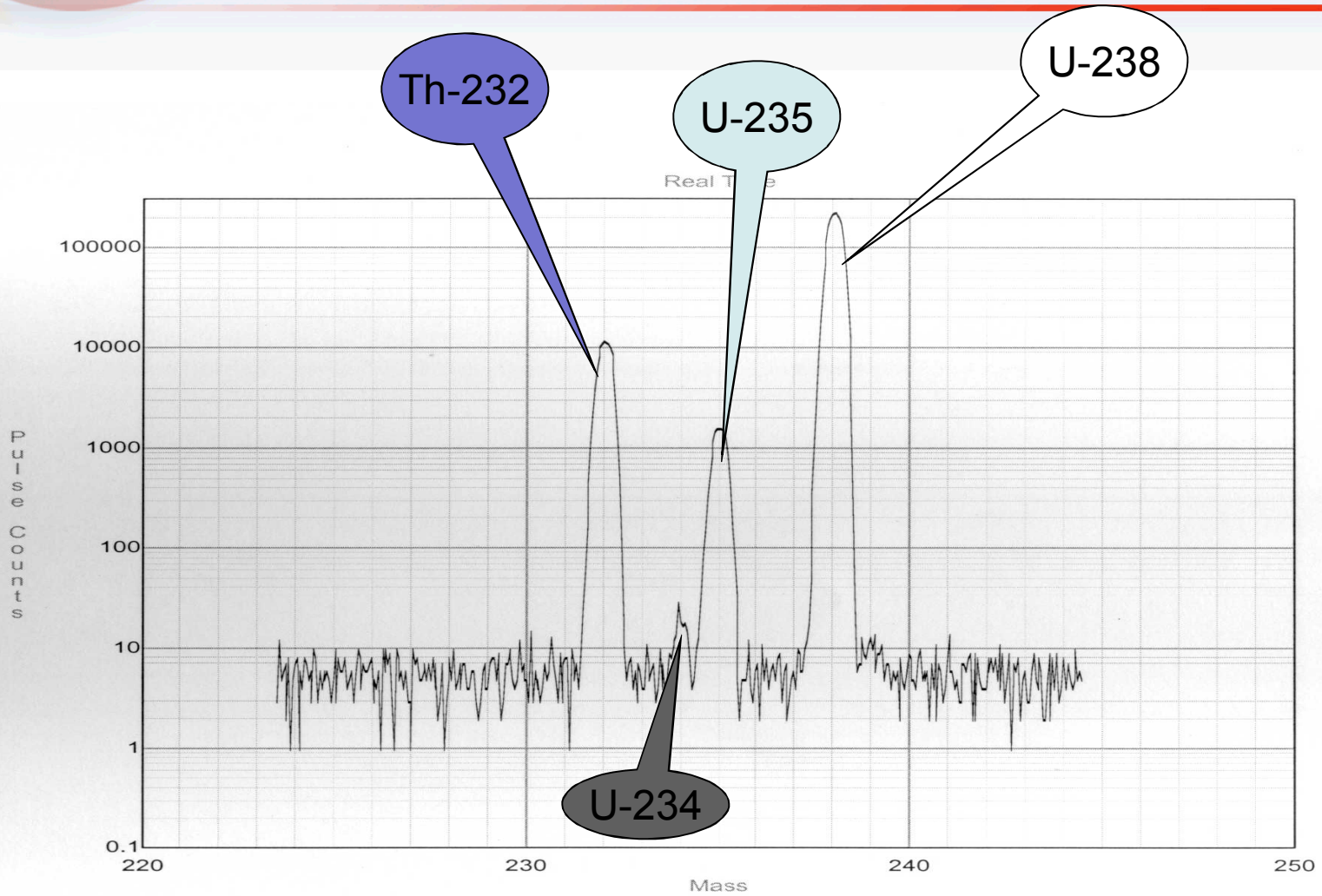
- **Ra²²⁶ – Gamma Spec - NORM**
- **U²³⁵ - ICP-MS – fuel component**
- **U²³⁸ - ICP-MS – fuel component**
- **Pu²³⁹ – Alpha Spec or ICP-MS – fuel component / activation product**
- ❖ **Other radionuclides may be identified via gamma spec or LSC software during assay**
- ❖ **Additional (or fewer) target radionuclides in successive sampling**



Non-radiometric Assay

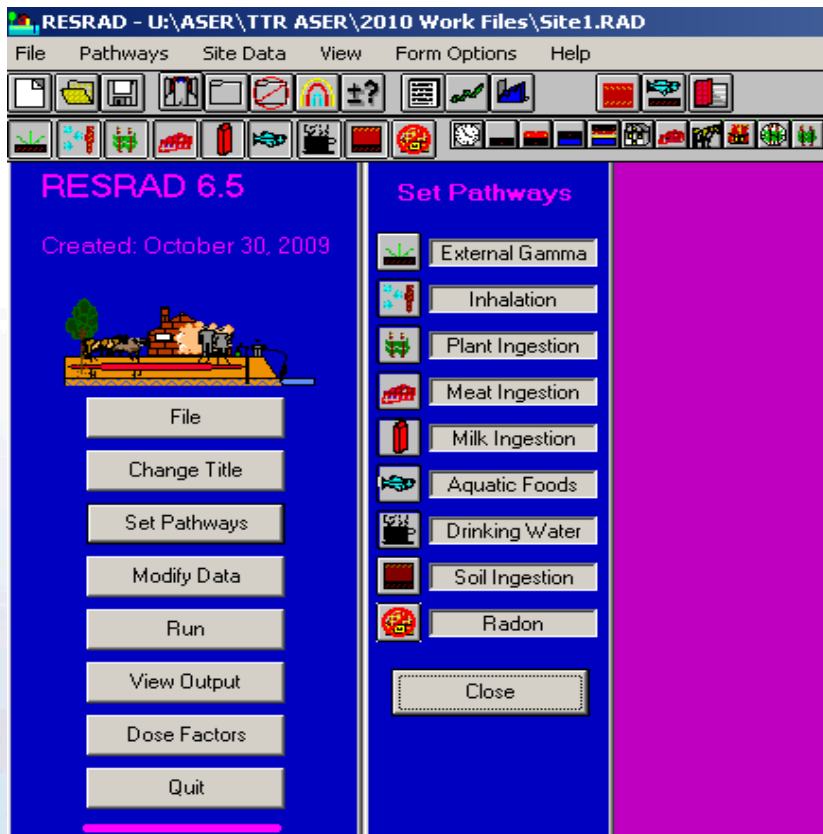
- **Even though U & Pu are radioactive, they have LONG half-lives and LARGE atomic numbers**
- **LARGE atomic number lends itself to ICP-MS (or other non-radiometric assay)**
- **Advantages: Low detection limits and accurate isotope ratios for long-lived isotopes**

ICP-MS Spectrum for U / Th / Pu



Related Input Parameters Needed

- Seafood Consumption Rates
- Meat / Dairy / Vegetable Consumption



» Many Others (RESRAD provides default values than can be overridden by user.)

» <http://web.ead.anl.gov/resrad/home2/>

Example of RESRAD Parameters

Ingestion Pathway, Dietary Data

Fruit, vegetable, and grain consumption:	160	kilograms/year
Leafy vegetable consumption:	14	kilograms/year
Milk consumption:	92	liters/year
Meat and poultry consumption:	63	kilograms/year
Fish consumption:	5.4	kilograms/year
Other seafood consumption:	.9	kilograms/year
Soil ingestion:	36.5	grams/year
Drinking water intake:	510	liters/year

Contaminated fractions	Drinking water:	1
	Household water:	1
	Livestock water:	1
	Irrigation water:	1
	Aquatic food:	.5
	Plant food:	-1
	Meat:	-1
	Milk:	-1

Source

Radiological Units

Activity: Dose: Basic Radiation Dose Limit: mrem/yr

Nuclide Concentration: pCi/g Nuclide List:

Ac-227	0	<input type="button" value="Add Nuclide"/> <input type="button" value="Delete Nuclide"/> <input type="button" value="Transport"/> <input type="button" value="OK"/>	Pu-241
Co-60	100		Pu-242
Cs-137	100		Pu-244
H-3	100		Ra-226
Pa-231	0		Ra-228
Pb-210	0		Rb-87
Pu-239	100		Re-186m
Ra-226	100		Re-187
U-235	0		Rh-101

Perform Uncertainty or Probabilistic Analysis on Transfer Factor

Cover and Contaminated Zone Hydrological Data

Cover depth:	0	meters
Density of cover material:	1.5	grams/cm ³
Cover erosion rate:	.001	meters/year

Density of contaminated zone:	1.5	grams/cm ³
Contaminated zone erosion rate:	.001	meters/year
Contaminated zone total porosity:	.4	
Contaminated zone field capacity:	.2	
Contaminated zone hydraulic conductivity:	10	meters/year
Contaminated zone b parameter:	5.3	

Humidity in air:	8	grams/m ³
Evapotranspiration coefficient:	.5	
Wind Speed:	2	meters/s
Precipitation:	1	meters/year
Irrigation:	.2	meters/year
Irrigation mode:	<input checked="" type="radio"/> Overhead <input type="radio"/> Ditch	
Runoff coefficient:	.2	
Watershed area for nearby stream or pond:	1000000	square meters
Accuracy for water/soil computations:	.001	

Occupancy, Inhalation, and External Gamma Data

Inhalation rate:	8400	m ³ /year
Mass loading for inhalation:	.0001	grams/m ³
Exposure duration:	30	years
Indoor dust filtration factor:	.4	
External gamma shielding factor:	.7	
Indoor time fraction:	.5	
Outdoor time fraction:	.25	
Shape of the contaminated zone:	<input checked="" type="radio"/> Circular <input type="radio"/> Non-Circular <input type="button" value="Shape"/>	



Data Quality Objectives

- **NRC Regulatory Guide 4.1, “Programs for Monitoring Radioactivity in the Environs of Nuclear Power Plants”**
- **NRC Regulatory Guide 4.15 – “Quality Assurance for Radiological Monitoring Programs – Effluent Streams and the Environment”**
- **EPA Data Quality Objective (DQO) process (EPA QA/G-4-2006)**
- **MARSSIM**
- **MARLAP**
- **MAPEP**
- **DOE Order 458.1 “Radiation Protection of the Public and the Environment”**
- **DOE/EH-0173T, “Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance”**
- **HASL-300 - EML Procedures Manual, 28th Edition**

Typical Laboratory Sensitivities

Data Quality Objectives

Table 7.3 Typical Measurement Sensitivities for Laboratory Radiometric Procedures

Sample Type	Radionuclides or Radiation Measured	Procedure	Approximate Measurement Sensitivity
Smears (filter paper)	Gross alpha	Gas-flow proportional counter; 5-min count Alpha scintillation detector with scaler; 5-min count	5 dpm 20 dpm
	Gross beta	Gas-flow proportional counter; 5-min count End window GM with scaler; 5-min count (unshielded detector)	10 dpm 80 dpm
	Low energy beta (³ H, ¹⁴ C, ⁶³ Ni)	Liquid scintillation spectrometer; 5-min count	30 dpm
Soil Sediment	¹³⁷ Cs, ⁶⁰ Co, ²²⁶ Ra (²¹⁴ Bi) ^a , ²³² Th (²²⁸ Ac), ²³⁵ U	Germanium detector (25% relative efficiency) with multichannel analyzer; pulse height analyzer; 500-g sample; 15-min analysis	0.04-0.1 Bq/g (1-3 pCi/g)
	²³⁴ , ²³⁵ , ²³⁸ U; ²³⁸ , ²³⁹ , ²⁴⁰ Pu; ²²⁷ , ²²⁸ , ²³⁰ , ²³² Th; other alpha emitters	Alpha spectroscopy with multichannel analyzer - pyrosulfate fusion and solvent extraction; surface barrier detector; pulse height analyzer; 1-g sample; 16-hr count	0.004-0.02 Bq/g (0.1-0.5 pCi/g)
Water	Gross alpha	Gas-flow proportional counter; 100-ml sample, 200-min count	0.04 Bq/L (1 pCi/L)
	Gross beta	Gas-flow proportional counter; 100-ml sample, 200-min count	0.04 Bq/L (1 pCi/L)
	¹³⁷ Cs, ⁶⁰ Co, ²²⁶ Ra (²¹⁴ Bi), ²³² Th (²²⁸ Ac), ²³⁵ U	Germanium detector (25% relative efficiency) with multichannel analyzer; pulse height analyzer; 3.5L sample, 16-hr count	0.4 Bq/L (10 pCi/L)
	²³⁴ , ²³⁵ , ²³⁸ U; ²³⁸ , ²³⁹ , ²⁴⁰ Pu; ²²⁷ , ²²⁸ , ²³⁰ , ²³² Th; other alpha emitters	Alpha spectroscopy with multichannel analyzer - solvent extraction; surface barrier detector; pulse height analyzer; 100 ml sample, 30 min count	0.004-0.02 Bq/L (0.1-0.5 pCi/L)
	³ H	Liquid scintillation spectrometry; 5-ml sample, 30-min count	10 Bq/L (300 pCi/L)

^a Indicates that a member of the decay series is measured to determine activity level of the parent radionuclide of primary interest.

MARSSIM, Revision 1

7-20

August 2000

Sampling and Preparation for Laboratory Measurements



Data Quality Objectives

(Examples used for SNL Terrestrial Surveillance)

Table I. Required Gamma Spectroscopy Radionuclides and Minimum Detection Amounts (MDA) by Matrix.

Radionuclide	MDA				
	Water pCi/L	Solid pCi/g	Air Filter pCi/sample	Urine pCi/L	Vegetation pCi/g
⁶⁰ Co	10	0.03	20	20	0.03
¹³⁷ Cs	10	0.04	20	20	0.04
²³⁵ U	TBD	TBD	TBD	TBD	TBD
²³⁸ U	TBD	TBD	TBD	TBD	TBD
²⁴¹ Am	30	0.3	25	20	0.5

Table II. Alpha Spectrometry Radionuclides and Required Critical Levels (L_c) by Matrix

Radionuclide	L _c (Concentration Corrected)					
	Water pCi/L	Solid pCi/g	Air Filter pCi/sample	Urine pCi/L	Vegetation pCi/g	Feces Ash pCi/g
²⁴¹ Am	0.05	0.03	0.01	0.05	0.01	0.04
²⁴⁴ Cm	0.05	0.03	0.01	0.05	0.01	0.04
²³⁷ Np	0.05	0.03	0.01	0.05	0.01	0.04
²¹⁰ Po	0.5	0.5	0.1	0.1	0.01	0.04
²³⁸ Pu	0.06	0.03	0.01	0.05	0.01	0.04
²³⁹ Pu	0.06	0.03	0.01	0.05	0.01	0.04
²²⁶ Ra	0.5	0.2	0.5	0.5	0.2	0.2
²²⁸ Th	0.08	0.04	0.01	0.05	0.01	0.04
²³⁰ Th	0.08	0.04	0.01	0.05	0.01	0.04
²³² Th	0.08	0.04	0.01	0.05	0.01	0.04
²³⁴ U	0.1	0.1	0.02	0.05	0.01	0.05
²³⁵ U	0.1	0.1	0.02	0.05	0.01	0.05
²³⁸ U	0.1	0.1	0.02	0.05	0.01	0.05

Data Quality Objectives

(Examples used for SNL Terrestrial Surveillance)

Table III. Gas Proportional Counting Radionuclides and Required Critical Levels (L_c) by Matrix

Radionuclide	L_c (Concentration Corrected)			
	Water pCi/L	Solid pCi/g	Air Filter pCi/sample	Vegetation pCi/g
Gross α	1	1	1	1
Gross β	1	1	1	1
^{89}Sr	1	5	2	5
^{90}Sr	1	0.5	2	5
^{131}I	2	5	5	5
^{210}Pb	1	5	2	5
^{210}Po	1	1	2	1
^{226}Ra	1	1	2	1
^{228}Ra	0.5	0.5	1	0.5
^{99}Tc	1	1	1	1

Table IV. Liquid Scintillation Counting Radionuclides and Required Critical Levels (L_c) by Matrix

Radionuclide	L_c (Concentration Corrected)			
	Water pCi/L	Solid/Soil pCi/g	Air Filter pCi/sample	Swipe pCi/100cm ²
^3H	200*	200** (pCi/L)	10	10
^{14}C	500	10	20	20
^{99}Tc	1	2	20	20
^{210}Pb	1.0	5	10	10
^{222}Rn	200	200		

[†]For tritium the specified solid L_c applies to the distilled water. For waste samples the required L_c is 0.01 pCi/g. ^{*}For tritium the L_c of the distilled water pulled from environmental soil or groundwater.

Data Quality Objectives

U.S. Department of Energy
Washington, D.C.

ORDER

DOE 5400.5

2-8-90

Change 2: 1-7-93

SUBJECT: RADIATION PROTECTION OF THE PUBLIC AND
THE ENVIRONMENT

- PURPOSE.** To establish standards and requirements for operations of the Department of Energy (DOE) and DOE contractors with respect to protection of members of the public and the environment against undue risk from radiation.

DOE 5400.5
2-8-90

III-6

Radionuclide	f ₁ Value	Ingested Water DCG ($\mu\text{Ci}/\text{mL}$)	Inhaled Air DCG ($\mu\text{Ci}/\text{mL}$)			U-235	2.E-03	5.E-06	-	-	9.E-14
			D	W	Y						
Co-56	3.E-01	1.E-05	-	-	-	5.E-02	6.E-07	5.E-12	2.E-12	-	
Co-57	5.E-02	2.E-04	-	7.E-09	2.E-09	2.E-03	5.E-06	-	-	1.E-13	
Co-58m	3.E-01	1.E-04	-	-	-	5.E-02	5.E-07	5.E-12	2.E-12	-	
Co-58	5.E-02	2.E-03	-	2.E-07	2.E-07	2.E-03	6.E-06	-	-	1.E-13	
Co-60m ^{3/}	3.E-01	2.E-03	-	-	-	5.E-02	5.E-05	6.E-09	4.E-09	-	
Co-60	5.E-02	3.E-01	-	3.E-09	2.E-09	2.E-03	5.E-05	-	-	4.E-09	
Cs-137 _{2/}	1.E+00	3.E-06	4.E-10	-	-	5.E-02	6.E-07	5.E-12	2.E-12	-	

**Note: Only Air and Water DCGs
Soil/Sediment/Food will depend
on RESRAD calculations**

**** DCG = "Derived Concentration Guide"**



Source Term Considerations

- **Bushehr Reactor in Iran 400 km N**
- **Braka Reactors in UAE 240 km miles SE**
- **Ocean Currents?**
- **Meteorological Patterns?**
- **Source depletion with distance?**
- **Water release?**
- **Air Release?**

Nuclear Facilities in Gulf Region



Bushehr Reactor Location

-The Bushehr nuclear facility is located near Halileh which is about a dozen kilometers to the south of Bushehr proper, along the Gulf coast.



A Real World Example

The M9.0 Tohoku Earthquake and Tsunami of 11 March 2011 Impact on the Fukushima Nuclear Power Station

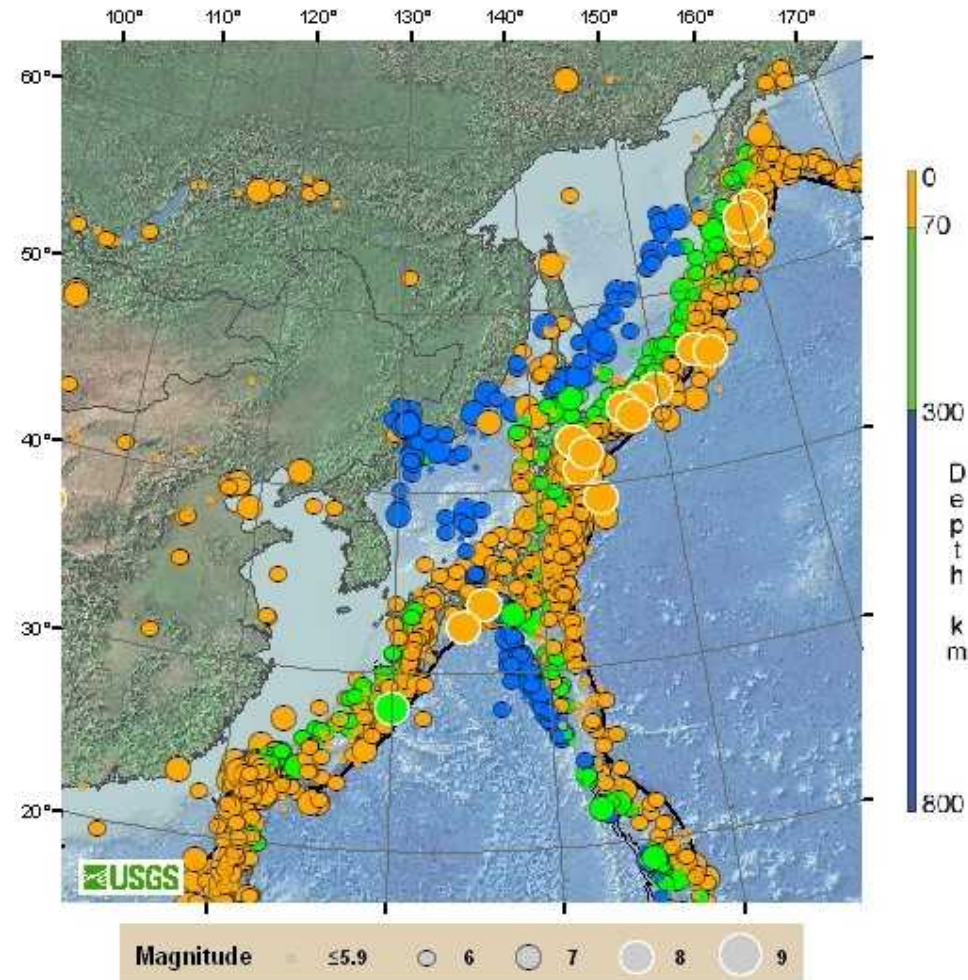


Historical events

Japan is one of the most seismically active areas in the world, has a long subduction zone plate boundary, and many 7+ earthquakes have occurred there in the past. 9 events of magnitude 7 or greater since 1973.

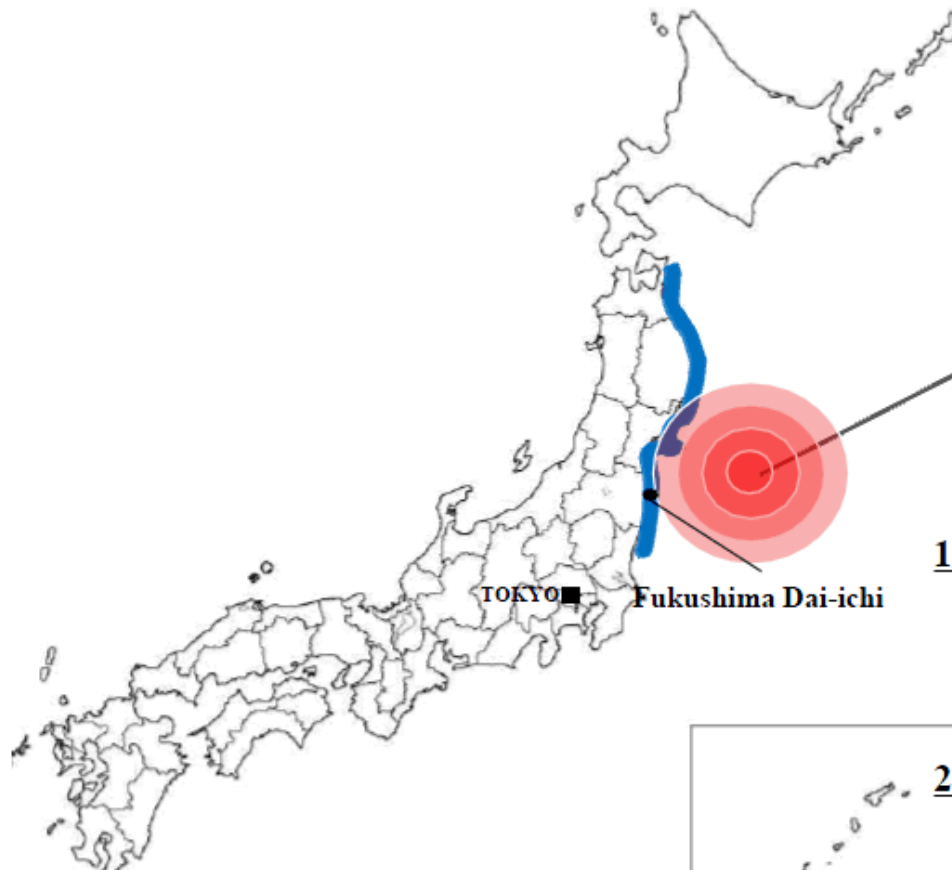
Large off-shore earthquakes have occurred in the same subduction zone in 1611, 1896 and 1933 that each produced devastating tsunami waves on the Sanriku coast of Pacific NE Japan.

Historically, it was known that a great earthquake associated with a huge tsunami occurred in 869 and killed more than 1000 people.



Fukushima Overview

A. Japan Faces an Unprecedented Challenge (Enormous Earthquake, Tsunamis and Nuclear Accident)



Earthquakes:

M - 9.0 quake (March 11)
M - 7 class 5 times
M - 6 class 72 times
M - 5 class 423 times

1. Casualties : over 27,000

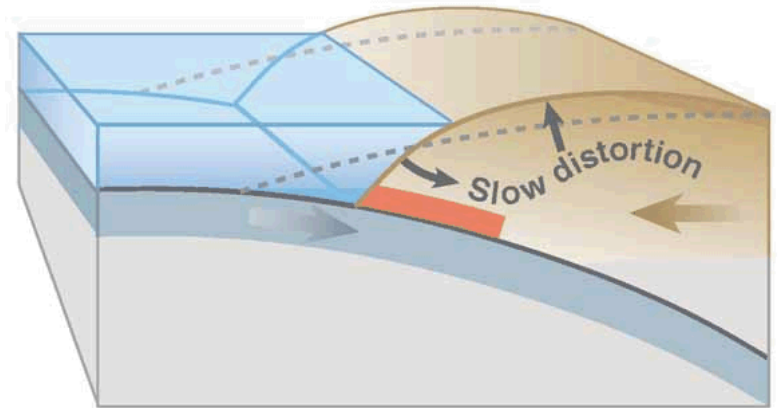
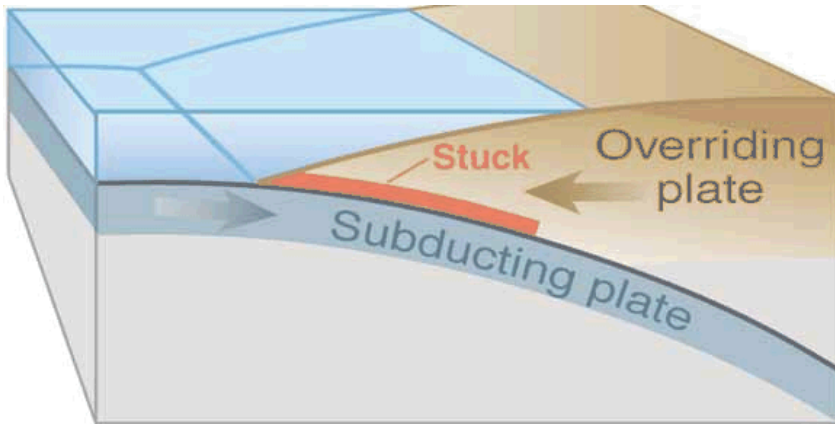
Dead	over 13,000
Missing	over 14,000

2. Evacuees : over 136,000

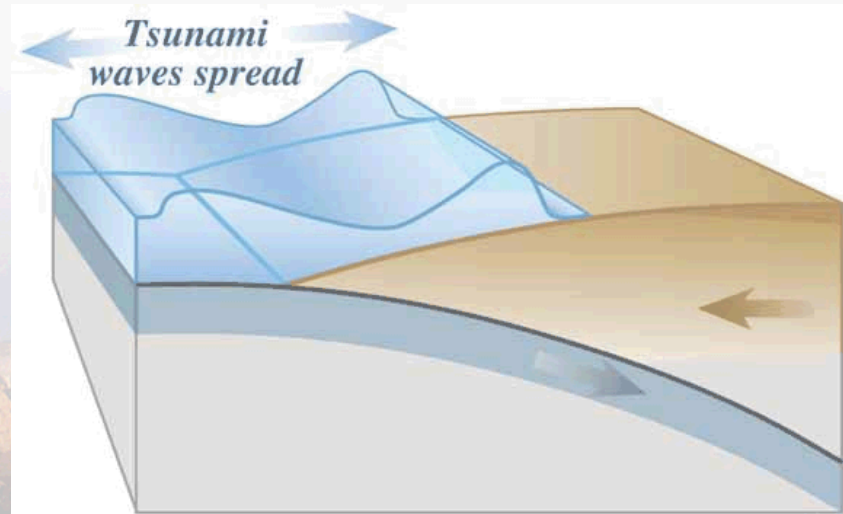
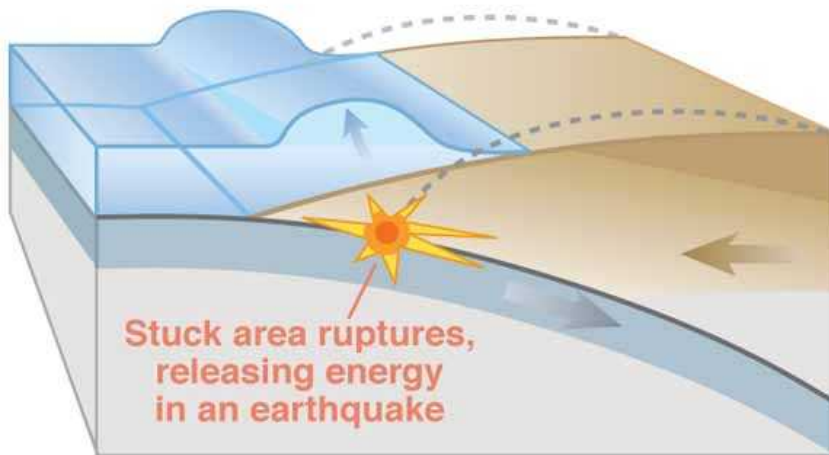
(As of April 17th)

Tsunami Generation

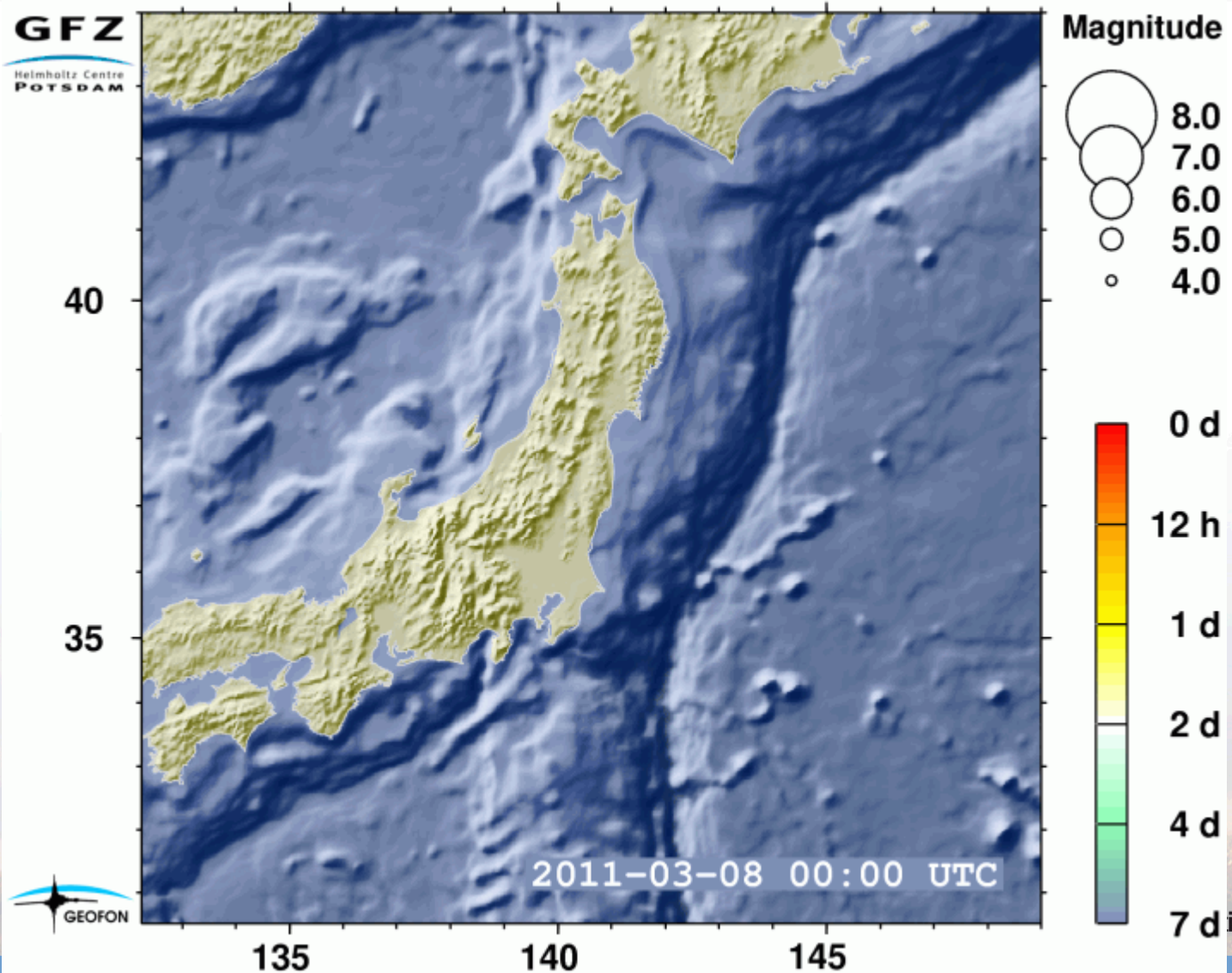
Note: These are **WEST** coast U.S. schematics. Reverse for Japan Tohoku quake.



Earthquake starts tsunami

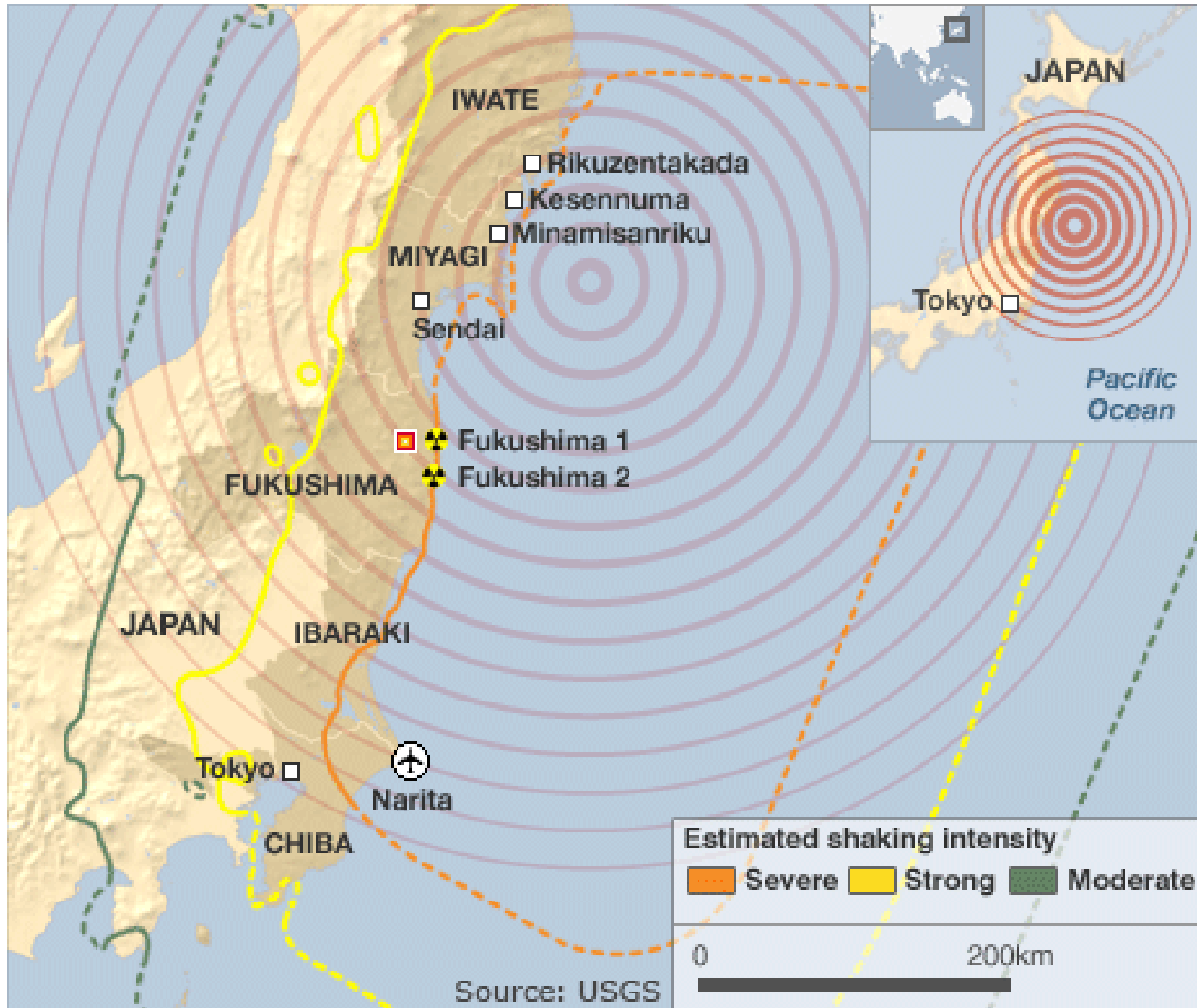


Seismicity Animation



Map View of Area

Areas affected by the quake





Tsunami Statistics

- **Original Design Basis was ~3 meters based on 1900 Chile earthquake/tsunami**
- **Upgrade in 2000 to 6 meters based on more modern data**
- **Actual 3/11/11 tsunami was 14 meters!**
- **Ground level at Fukushima Dai-ichi in 10 meters.**
- **You can't out guess Mother Nature?**



NUCLEAR PLANTS IN JAPAN

Kashiwazaki-Kariwa

Shika

Tsuruga

Mihama

Ohi

Takahama

Shimane

Genkai

Tomari

Higashidori

Onagawa

Fukushima I

Fukushima II

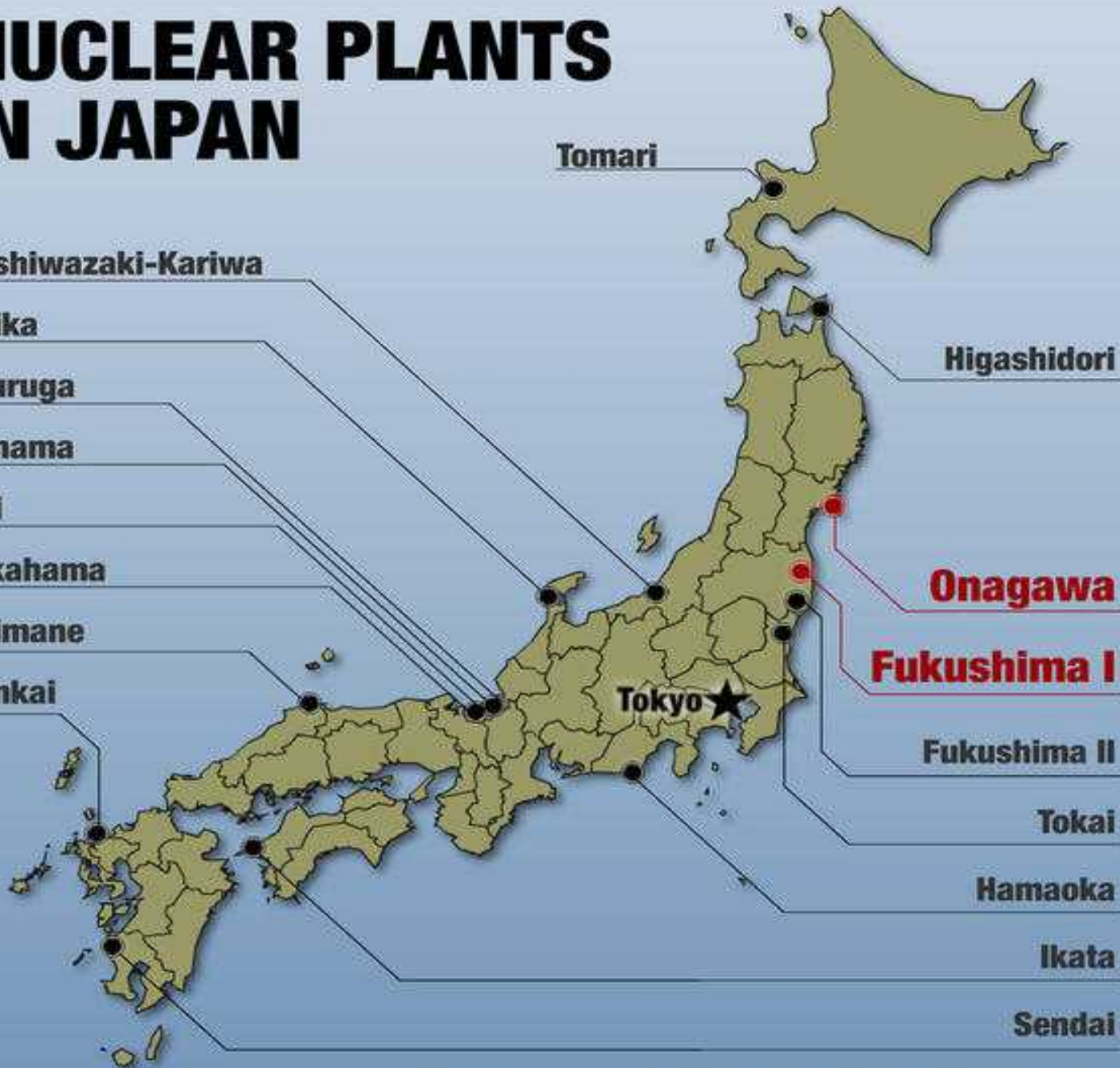
Tokai

Hamaoka

Ikata

Sendai

Tokyo ★





Fukushima Event Evolution



“Before Earthquake” Photo



Emergency Generator
Diesel Storage Tanks





All Emergency Shutdown Systems WORKED (Initially)

- **Reactors Automatically Shut Down**
- **Emergency Core Cooling Initiated**
- **All Systems Under Control**

Post-quake Tsunami Hits Coast

- **Massive Damage**
- **Destroys Electric Power Grid (which supplied power for “routine” plant operations)**
- **Emergency Diesel Generators Started, as Designed**
 - **HOWEVER, tsunami washed diesel fuel storage tanks away! Pumps ran ~ 8 hrs on battery backup.**



The Nightmare Unfolds

Had the (electric) ventilation fans been working, most/all of hydrogen gas generation would have gone out the tall stack shown in the following pictures.



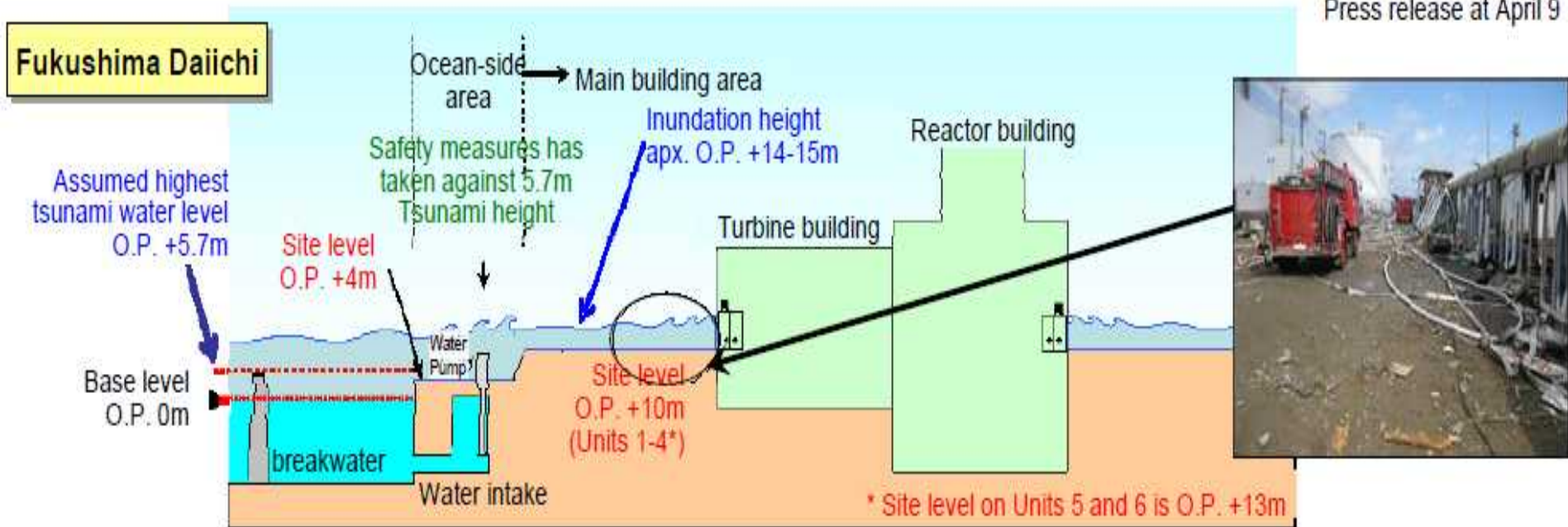
**Emergency Generator
Diesel Tanks GONE!**





Height of Tsunami

Press release at April 9



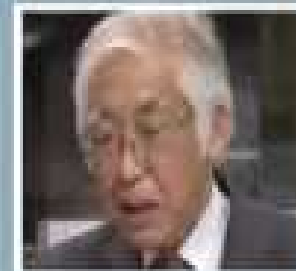
O.P. : Onahama bay construction base level

View of explosion / Steam venting

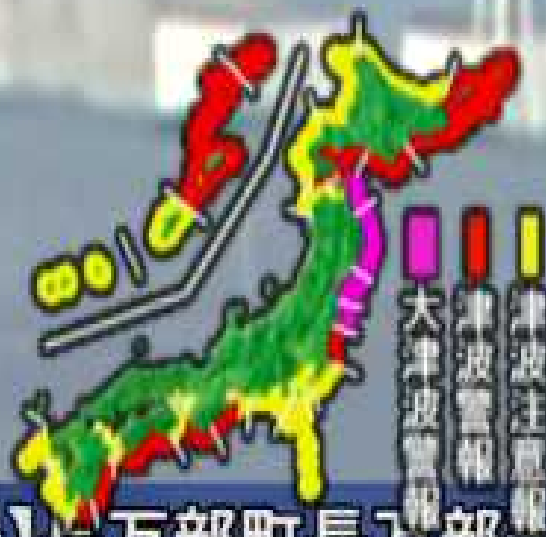
5:06

福島第一原発
炉心 溶融の可能性

福島第一原発
午後3時半ごろ



津波情報



道路

小牧市錦岡一室蘭市東町【37号】長万部町長万部一黒松内E

Monday, March 14

Monday's blast destroyed the containment building but the reactor is still intact. Japanese officials also said cooling systems have failed at a third reactor.



In this image made off NTV/NNN Japan television footage, smoke ascends from the Fukushima Dai-ichi nuclear plant's Unit 3 in Okumamachi, Fukushima Prefecture, northern Japan, March 14. The second hydrogen explosion in three days rocked Japan's stricken nuclear plant Monday, sending a massive column of smoke into the air and wounding 11 workers.

NTV/NNN Japan/AP

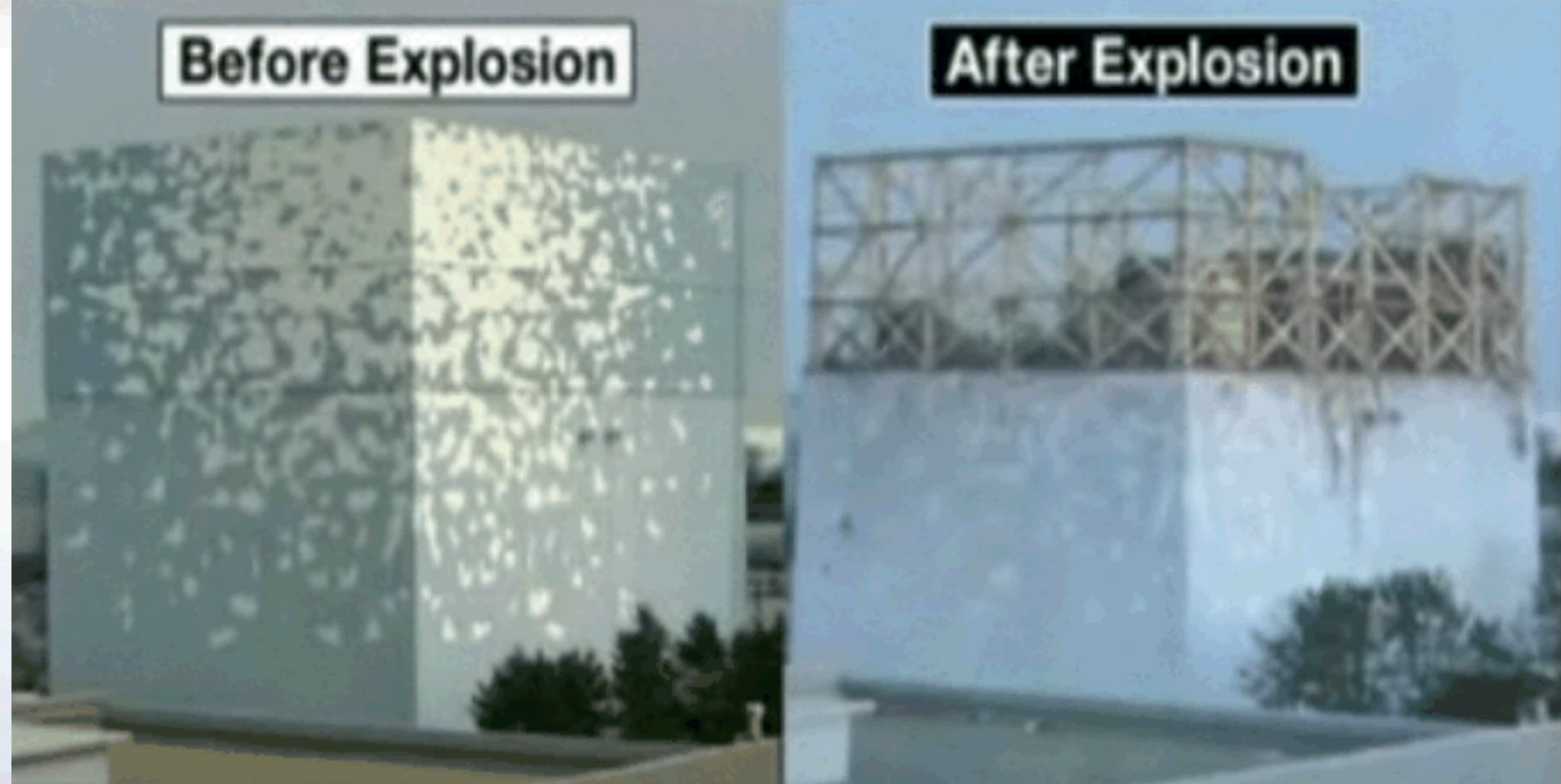
View of explosion / Steam venting

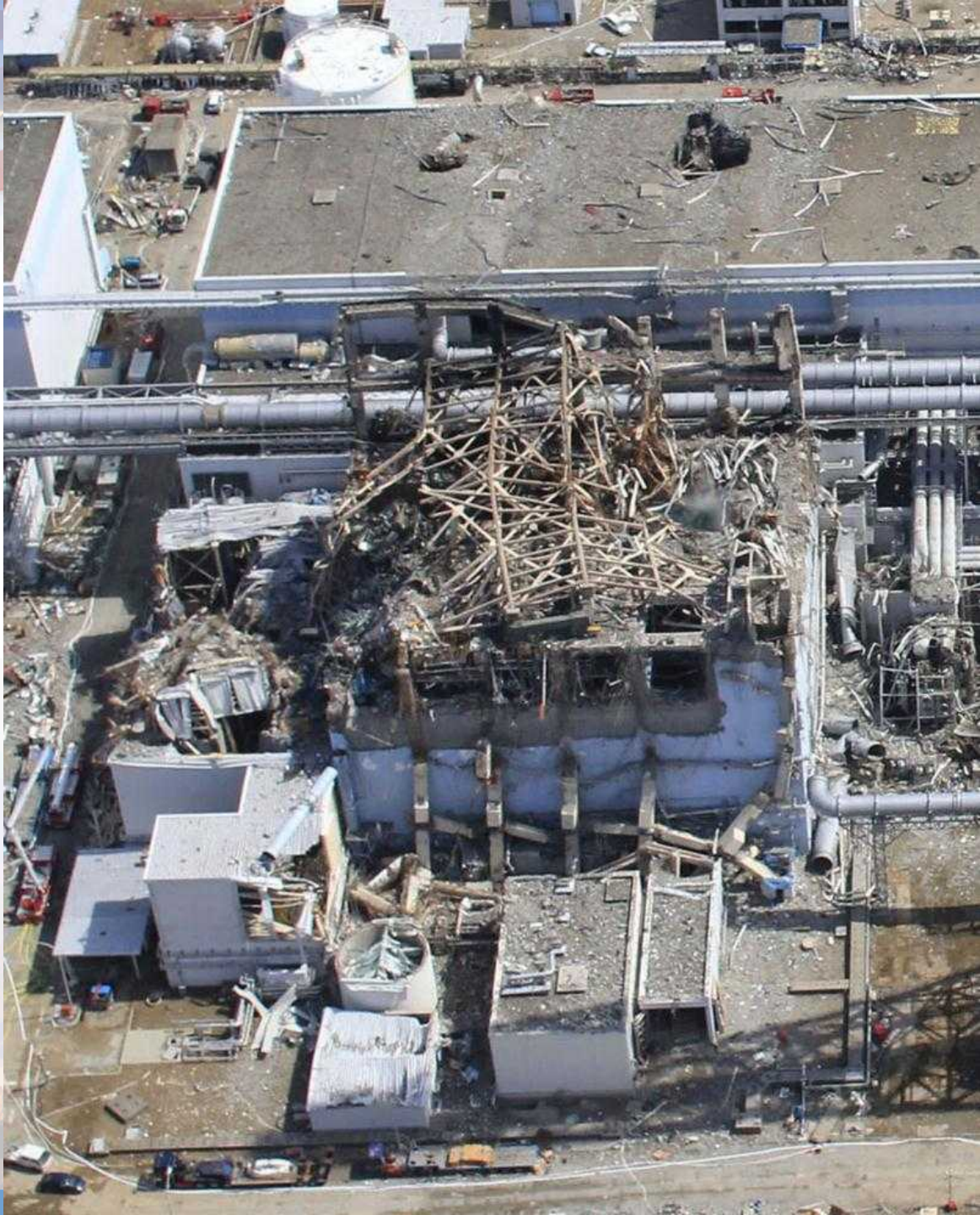


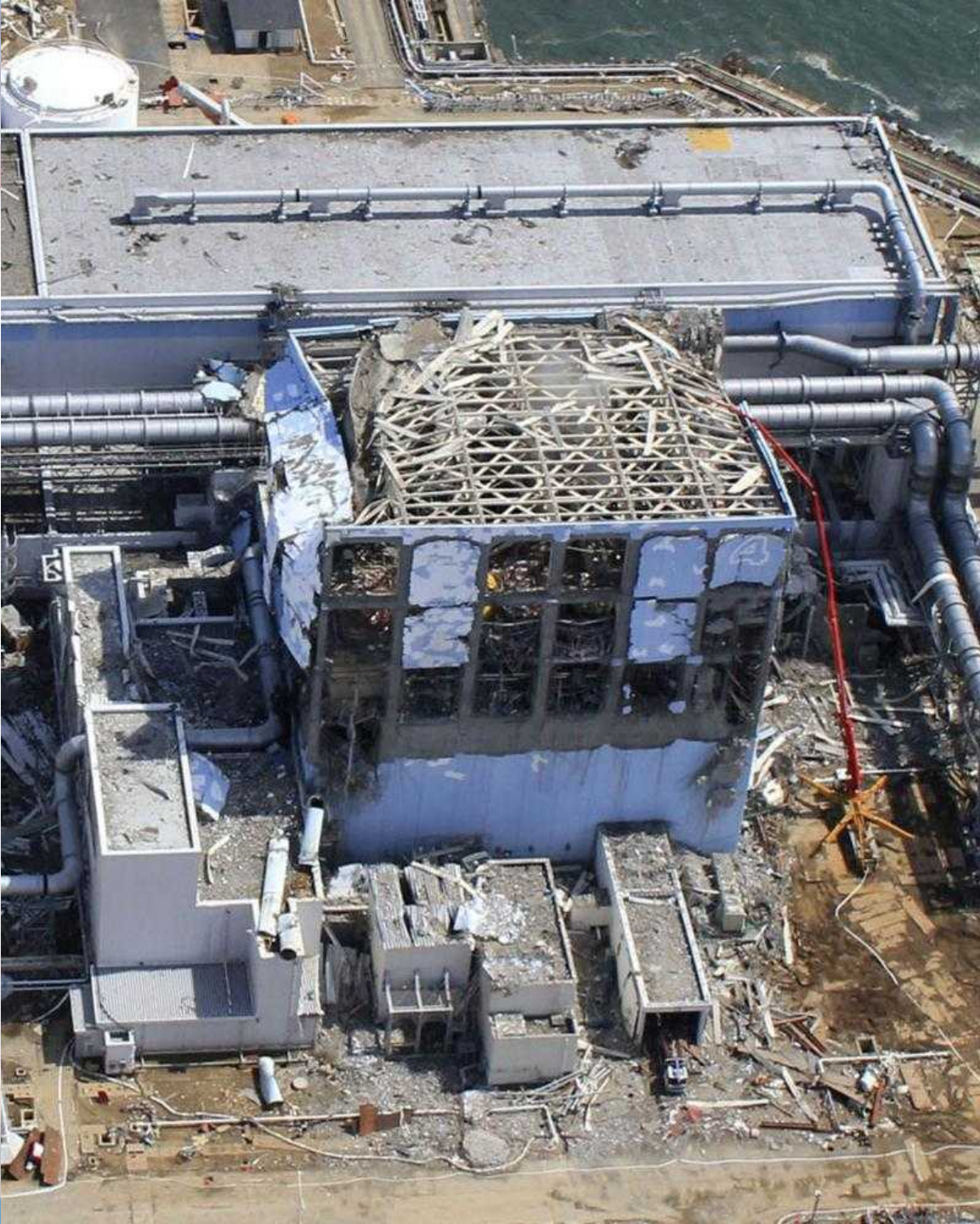


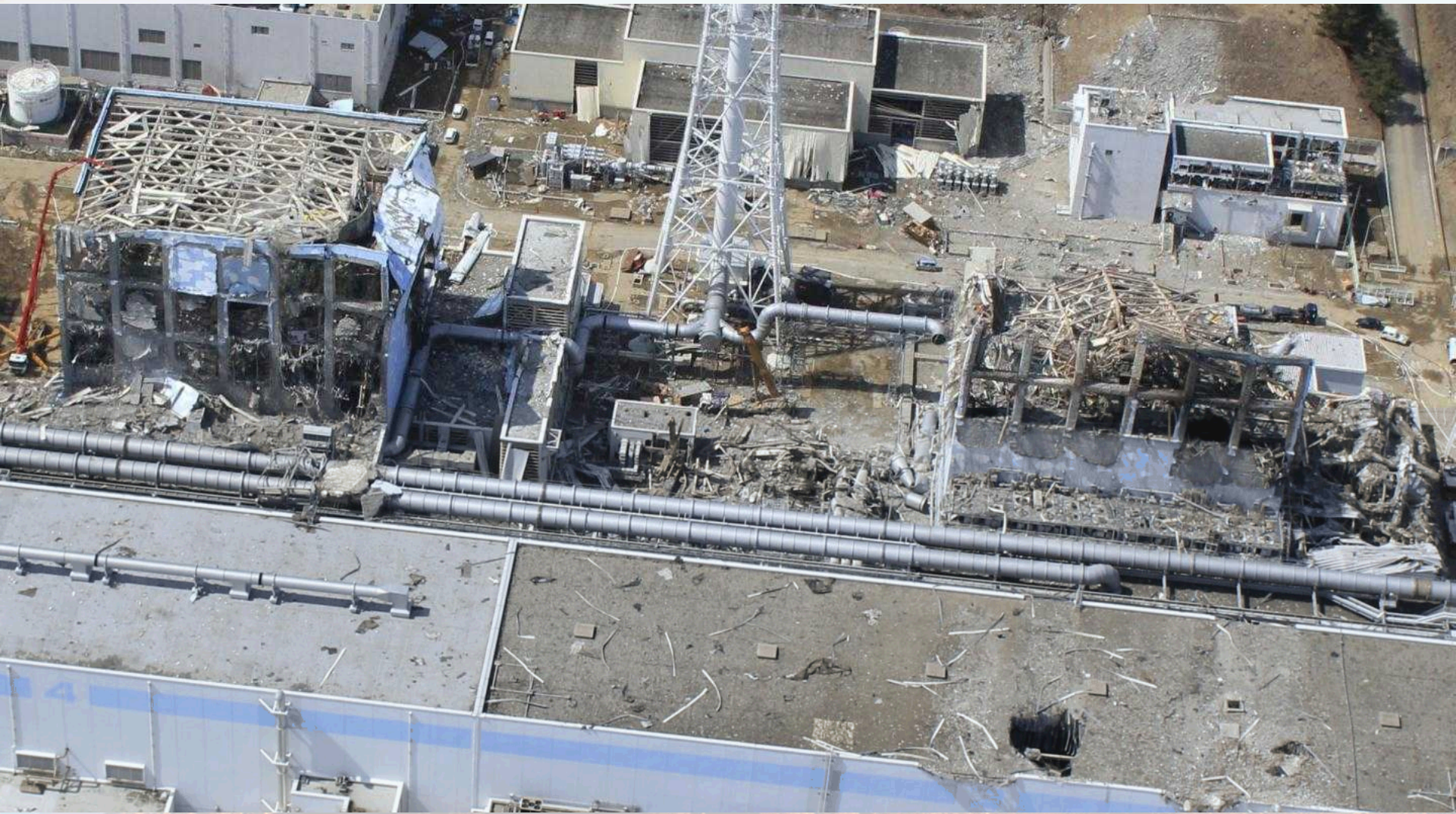
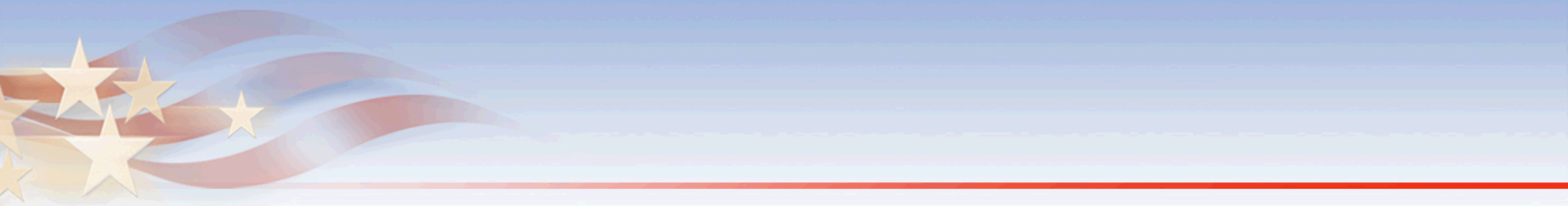
Before Explosion

After Explosion







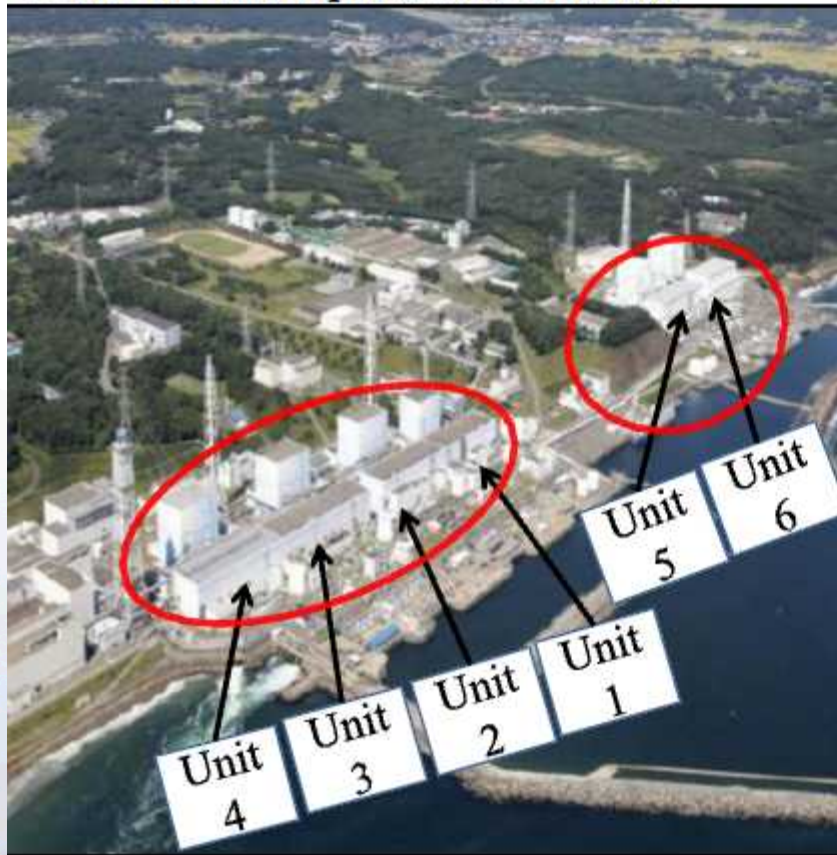




3. Nuclear Power Stations

Fukushima Dai-ichi Nuclear Power Station

Before the Earthquake and Tsunamis



TEPCO

After the Earthquake and Tsunamis



Air Photo Service Inc (Myoko, Niigata Japan)







Fukushima Daiichi Nuclear Power Plant

Okuma, Japan

37 25 18N 141 01 56E



Japan



**3 Minutes After Unit 3
Reactor Building Explosion**

**Damaged Unit 3 Reactor
Building
(Visible Smoke/Dust Plume
Drifting East Approx 2
kilometers)**





Fukushima Daiichi Nuclear Power Plant

Okuma, Japan

37 25 18N 141 01 56E



Japan



**3 Minutes After Unit 3
Reactor Building Explosion**

**Damaged Unit 3 Reactor
Building
(Visible Smoke/Dust
Plume Drifting East)**

**Damaged Unit 1
Reactor Building**



Fukushima Daiichi Nuclear Power Plant

Okuma, Japan

37 25 18N 141 01 56E



Japan



**3 Minutes After Unit 3
Reactor Building Explosion**

**Damaged Unit 3 Reactor
Building
(Roof Blown Off; Panel
Walls Blown Out)**

**Damaged Unit 1
Reactor Building**

Trucks

FUKUSHIMA DAIICHI

Switchyard for Reactor Units 5 and 6

Reactor Unit 6

Diesel generator building

Reactor Unit 5

Fukushima Daiichi, Reactor Unit 5 and Reactor Unit 6,
no blast or fire damage observed

18 MAR 2011, 10:19am local time



Fire Trucks

3. Nuclear Power Stations

Fukushima Dai-ichi Nuclear Power Station

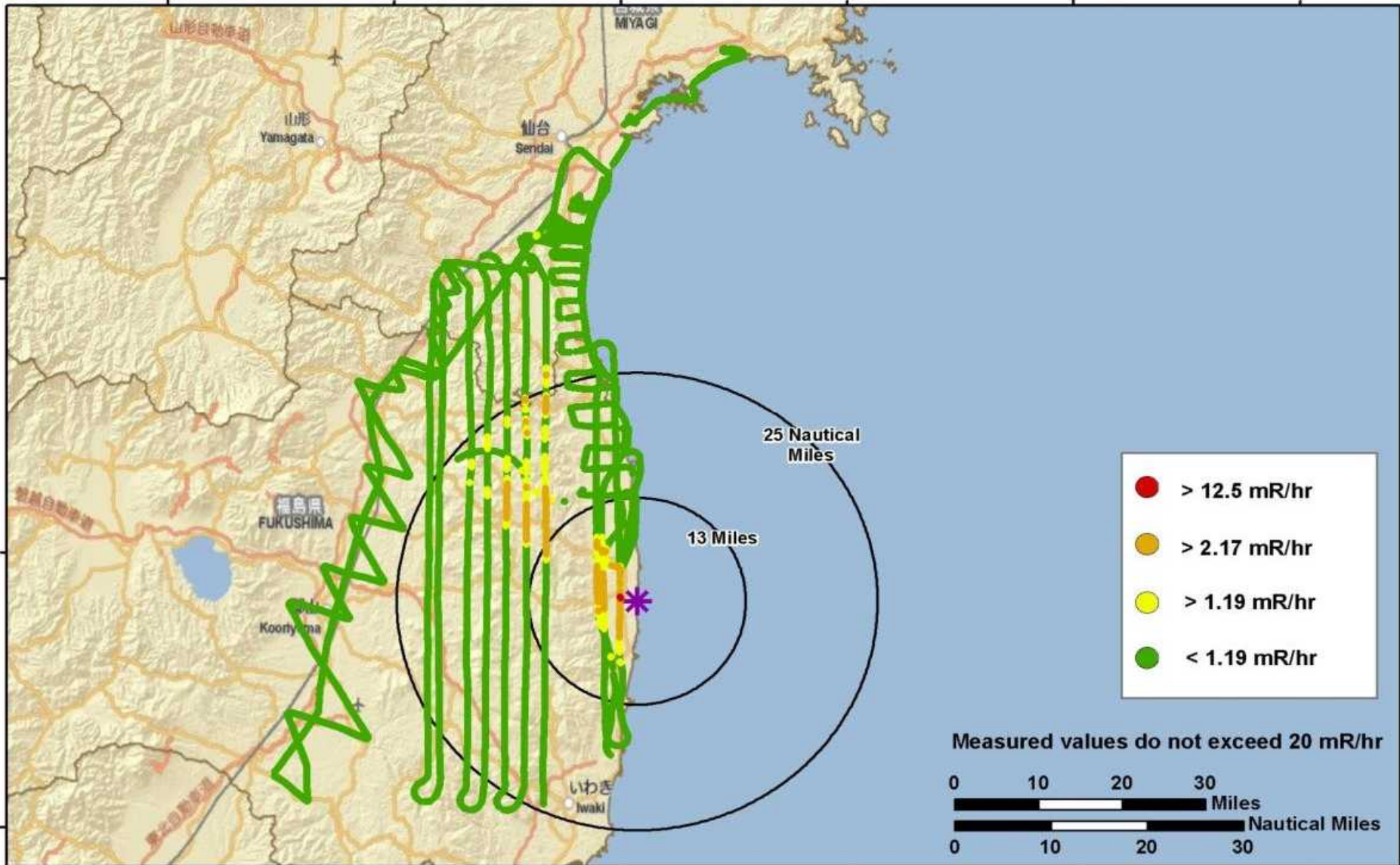


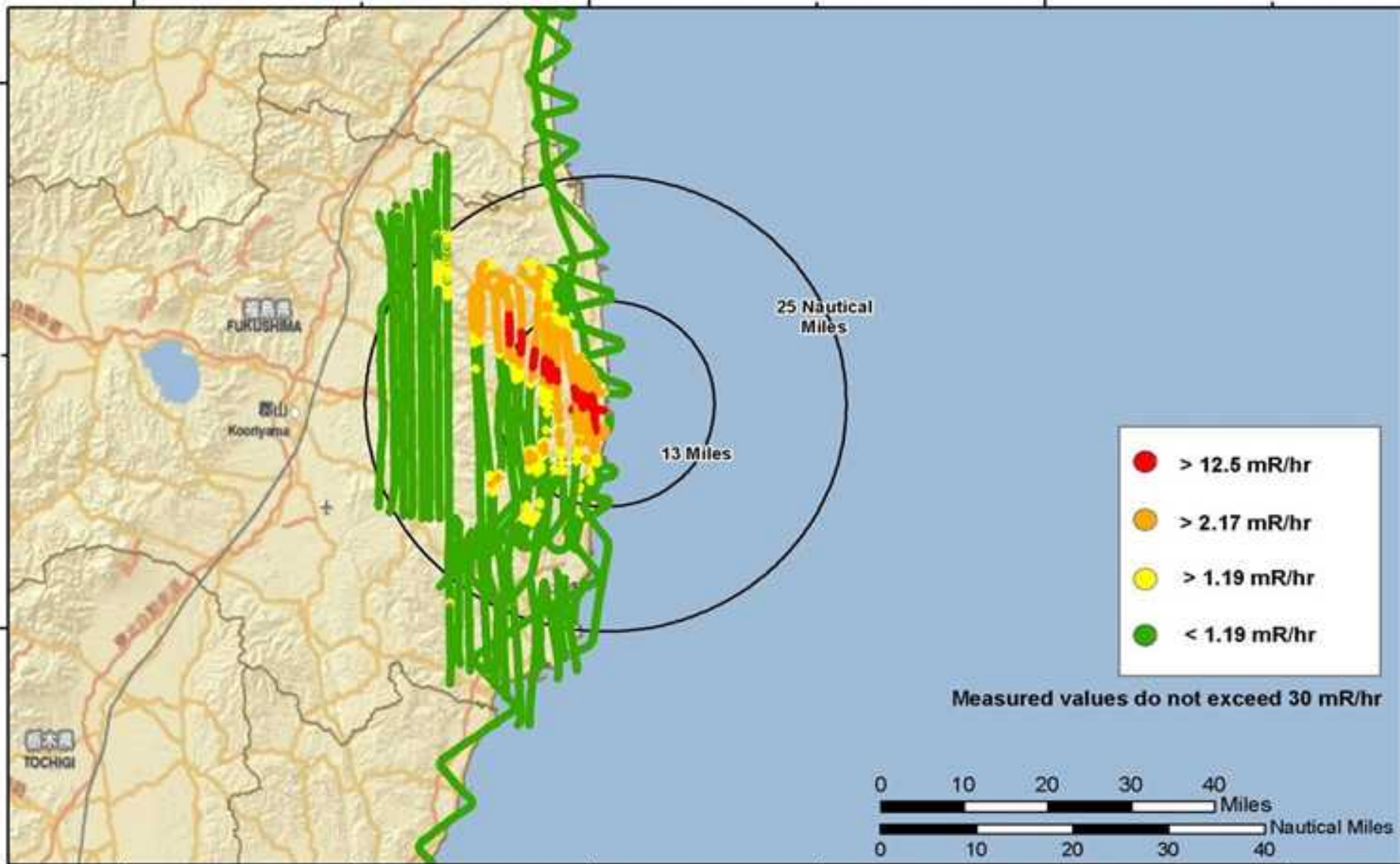
20 km radius of the plant and other designated areas

→ to evacuate

20 to 30 km radius of the plant

→ to shelter indoors





Map created on 03232011 0210 JST

Nuclear Incident Team DOE NIT

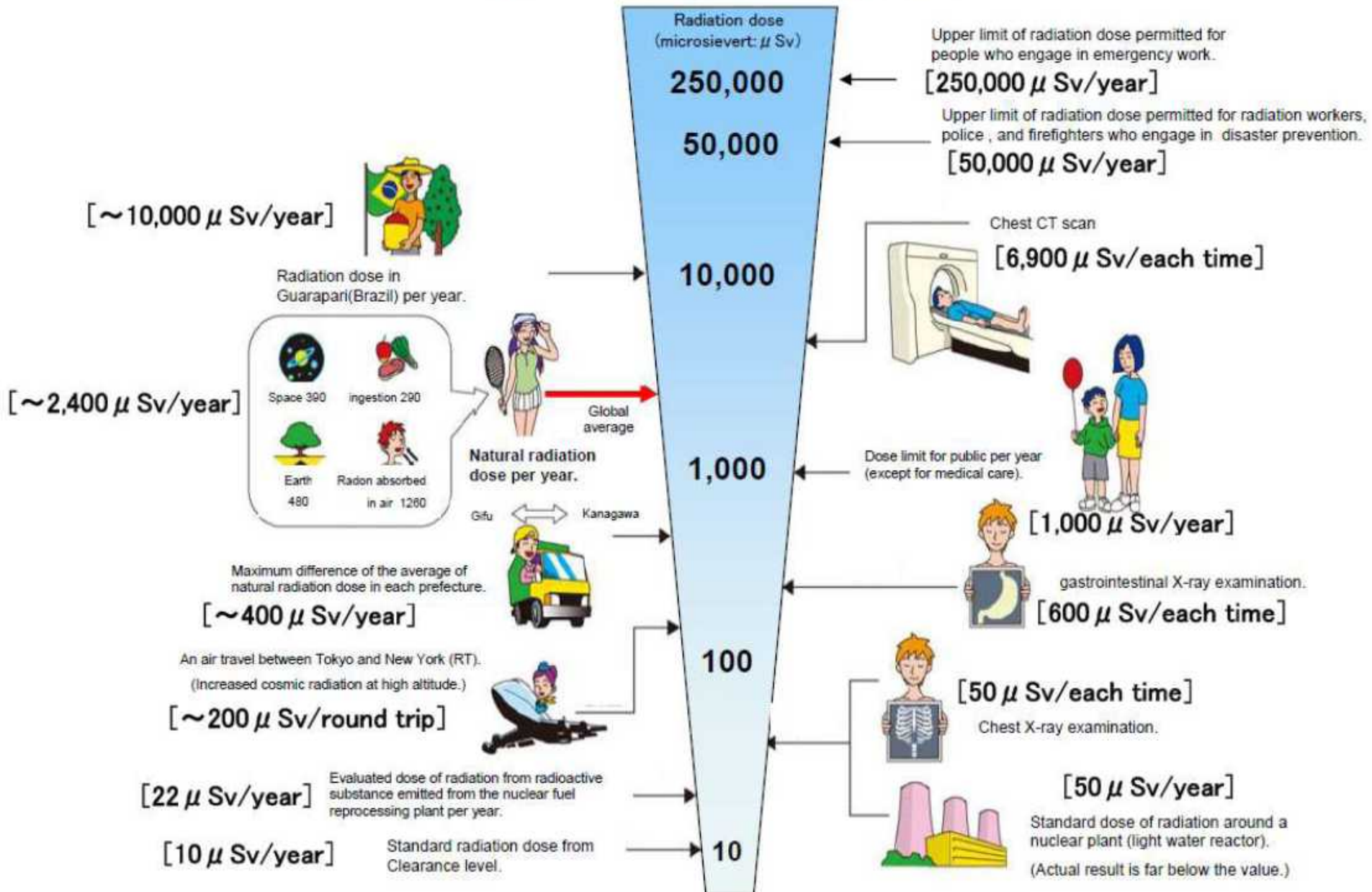
2. Contain the Spread of Radioactive Substances (sea, soil and atmosphere)

Experts are making the utmost efforts to prevent dispersing radioactive substances contained in dust, debris and vapor.

**Spraying synthetic materials on the surface of the ground
and debris to prevent radioactive substances dispersion**



Radiation in Daily-life



※ Sv [Sievert] = Constant of organism effect by kind of radiation (※) × Gy [gray]

※ It is 1 in case of X ray and γ ray.

Cooperation with the IAEA

1. Information Sharing

- (1) Japan has been providing facility-related and other relevant information to the IAEA.
- (2) Nuclear Industry Safety Agency (NISA) provided updates on situations of the Fukushima Dai-ichi Nuclear Power Station at the IAEA Technical Briefing (21st March) and at the side event of the Fifth Review Meeting of the Contract Parties to the Convention on Nuclear Safety (4th April).

2. IAEA Expert Missions

- (1) The IAEA has extended to Japan upon the request of the Government of Japan, in connection with the incidents involving the nuclear power plants in Japan by dispatching a series of the IAEA experts to Japan mainly in the field of radiation monitoring. Such dispatch of experts includes :
 - (a) Radiation Monitoring Teams, totaling up to 16 members who have been taking measurements mainly in Fukushima since 19 March;
 - (b) one marine expert from the IAEA's laboratory in Monaco, who boarded Research Vessel "MIRAI" during 2 -4 April to observe and provide advice for Japanese experts on their method of collection and analysis of seawater samples; and
 - (c) A Joint FAO/IAEA Food Safety Assessment Team, who met with local government officials, farmers etc. in Fukushima, Ibaraki, Tochigi and Gunma prefecture.
- (2) In addition, IAEA experts in BWR technology met with Japanese officials and operators including NISA and the Tokyo Electric Power Company (TEPCO) and visited the Fukushima Dai-ichi Nuclear Power Plant on 6 April.

➤ The Government took measures such as taking shelters or evacuation as follows based on the reports from Fukushima Daiichi & Daini

Fri, 11 March

- 14:46 The earthquake occurred
- 19:03 Emergency Declaration by the Gov't (Daiichi)
- 21:23 3 km radius evacuation (Daiichi)
10 km radius taking shelter (Daiichi)

Sat, 12 March

- 5:44 10 km radius evacuation (Daiichi)
- 7:45 3 km radius evacuation (Daini)
10 km radius taking shelter (Daini)
- 17:39 10 km radius evacuation directed by the PM (Daini)
- 18:25 20 km radius evacuation directed by the PM (Daiichi)

Tue, 15 March

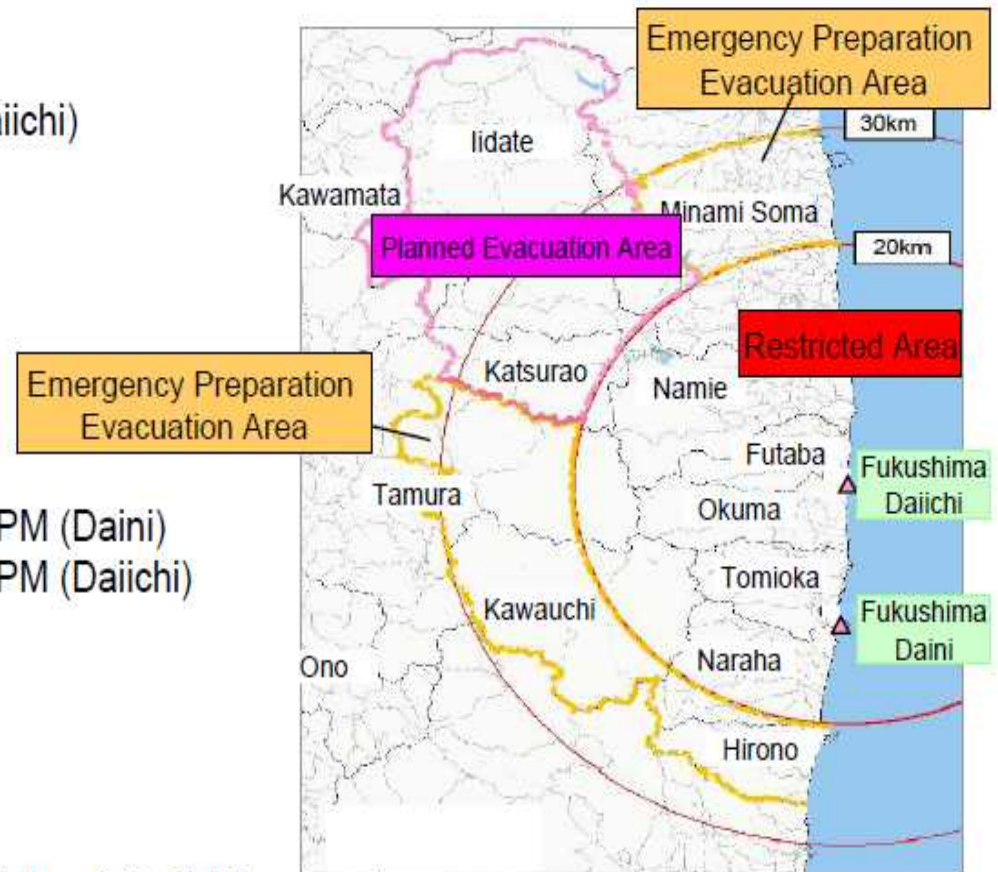
- 11:00 20-30 km radius taking shelter (Daiichi)

Thu, 21 April

- 11:00 20 km radius is designated as "Restricted Area" (Daiichi)

Fri, 22 April

- 9:44 20-30 km radius taking shelter has been lifted (Daiichi)
Establishment of "Planned Evacuation Area" and "Emergency Preparation Area"



Source: NISA website

Roadmap Towards Restoration

- By bringing the reactors and spent fuel pools to a stable cooling condition and mitigating the release of radioactive materials, we will make every effort to enable evacuees to return to their homes and for all citizens to be able to secure a sound life.

< Roadmap for Immediate Actions (Issues / Targets / Major Countermeasures) >

		Current Status	STEP1 (around 3 months) "Radiation dose is in steady decline"	STEP2 (around 3 to 6 months after achieving Step 1) "Release of radioactive materials is under control and radiation dose is being significantly held down"	Mid-term Issues
I. Cooling	(一) Reactors	Injecting fresh water	Nitrogen gas injection (Unit1-3) Flooding up to top of active fuel Examination and implementation of heat exchange function (Unit 2) Sealing the damaged location	Stable cooling Flooding up to top of active fuel Cold shutdown confirmed	Prevention of breakage of structural materials, etc.
	(二) Spent Fuel Pools	Injecting fresh water	Enhance reliability of water injection Restore coolant circulation system (Unit 4) Install supporting structure	Stable cooling Remote control of water injection Examination and implementation of heat exchange function	Removal of fuels
II. Mitigation	(三) Accumulated Water	Transferring water with high radiation level Storing water with low radiation level	Installation of storage / processing facilities Installation of storage facilities / decontamination processing	Secure storage place Expansion of storage / processing facilities Decontamination / Desalt processing (reuse), etc	Decrease contaminated water Installation of full-fledged water treatment facilities
	(四) Atmosphere / Soil		Dispersion of inhibitor Removal of debris	Installing reactor building cover	Installation of reactor building cover (container with concrete) Solidification of contaminated soil, etc
III. Monitoring/Decontamination	(五) Monitoring, Radiation and Environment	Monitoring of radiation dose in and out of the power station	Expand/enhance monitoring and inform of results fast and accurately	Sufficiently reduce radiation dose in evacuation order / planned evacuation / emergency evacuation preparation areas	Continue monitoring and informing environmental safety

Survey Inside Reactor Buildings by Robot

- Measured a dose of radiation, etc by remote control robots “inside the double doors” in reactor buildings of Units 1-3 where were inhibited to enter due to high radiation dose assumed.
- Examining how to utilized the robots for field survey such as measuring radiation dose indoors or not.




Opening a double door (April 18)

<measurement results>

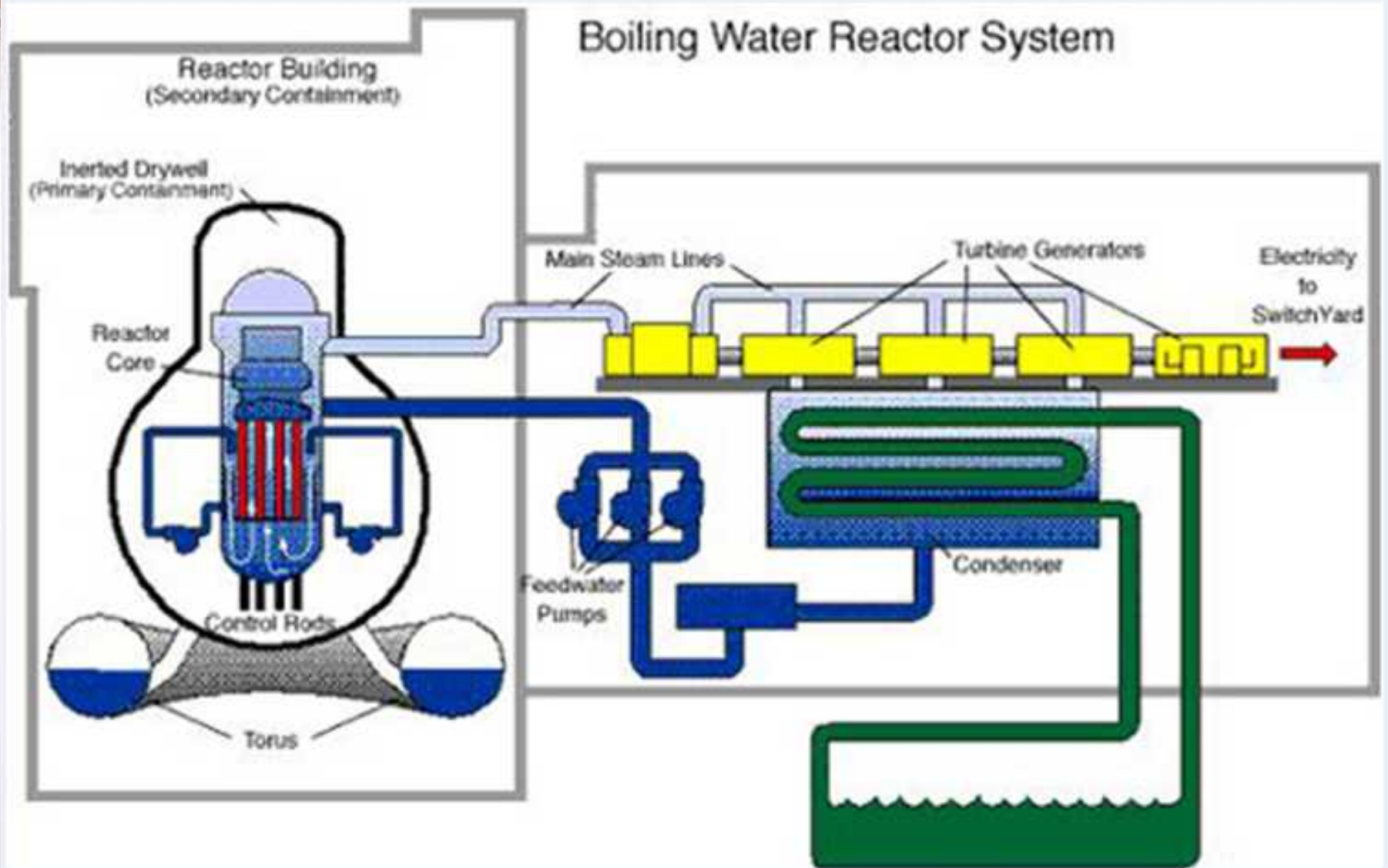
	Unit 1	Unit 3
Measurement area	Reactor building 1 st floor From northern double doors to elevator	Reactor building 1 st floor Around southern double doors
Radiation dose	49mSv/h(Maximum) 10mSv/h(Minimum)	57mSv/h(Maximum) 28mSv/h(Minimum)
Temperature	About 28~29°C	About 19~22°C
Humidity	About 49~56%	About 32~35%
oxygen density	About 21%	About 21%

(provisional figure)

<The list of provided robots>

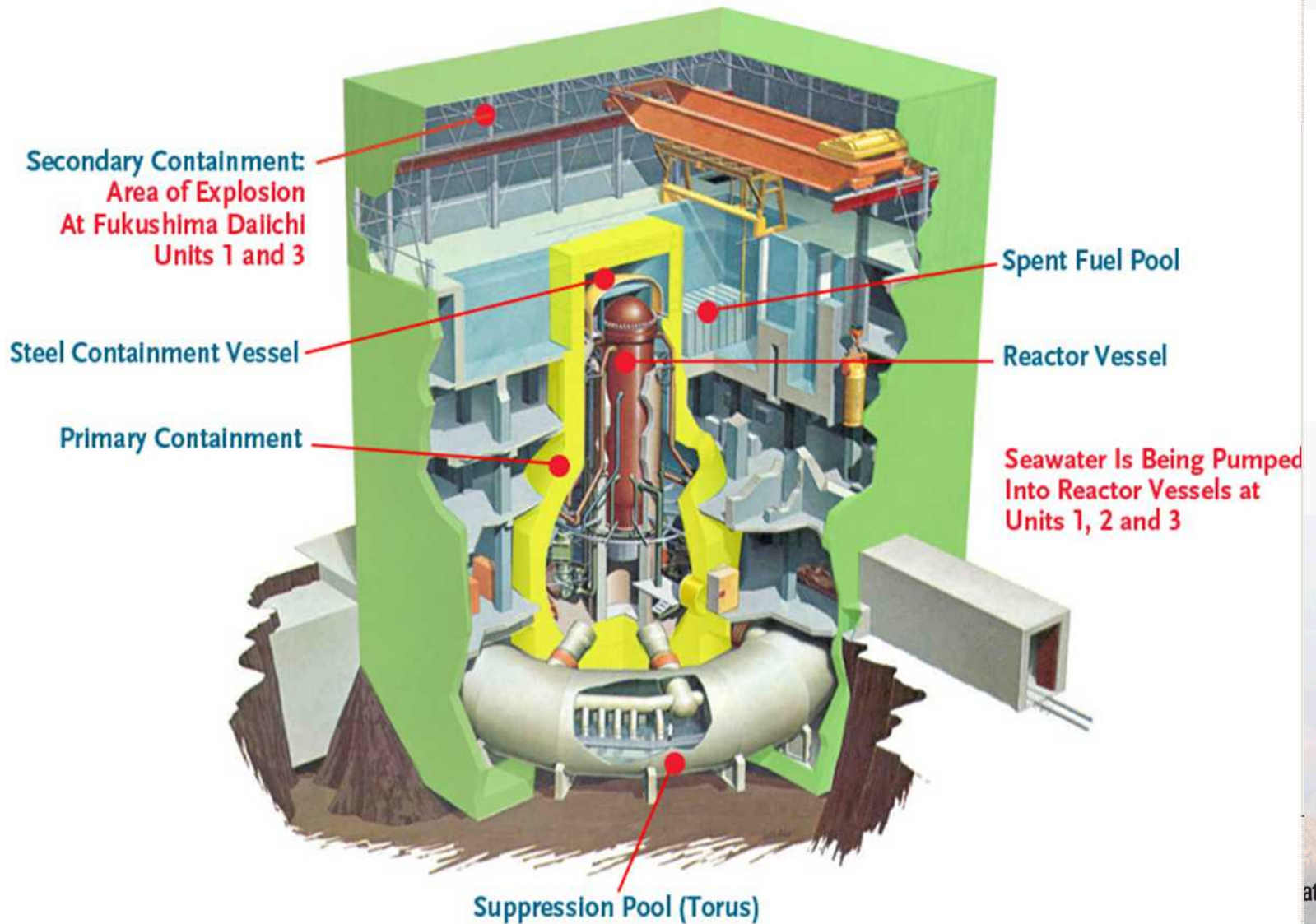
maker	Robots by iRobot		Robots by QinetiQ	
				
name	Packbot	Warrior	Talon	Dragon Runner
Monitoring function	image	Image only	image	Image only
	Radiation etc.	—	Radiation etc.	—
Arm keeping function	○	◎	○	○

Boiling Water Reactor System



A BWR reactor: The schematic above shows the torus at left, which is doughnut-shaped.

Fukushima BWR



How a Reactor Shuts Down and What Happens in a Meltdown

The operating reactors at Fukushima Daiichi power station automatically shut down during the earthquake. But after subsequent cooling failures, two of them went into partial meltdown.

1 2 3 4 5 6 7 NEXT ▶

Inside a nuclear reactor, fuel rods are tubes made of zirconium alloy containing uranium fuel pellets. These rods are immersed in water, and heat generated by the nuclear reaction inside the rods turns the water into steam, which drives turbines to make electricity.

WATER INLET

PLATES TO HOLD THE RODS

FUEL RODS

By MATTHEW ERICSON, XAGUÍN G.V., DYLAN McCLAIN, TOMOEH MURAKAMI-TSE, GRAHAM ROBERTS, ARCHIE TSE and JOE WARD | [Send Feedback](#)

Sources: Nuclear Energy Institute; Nuclear Regulatory Commission; Tokyo Electric Power; satellite image by Digital Globe via Google Earth

RECOMMEND

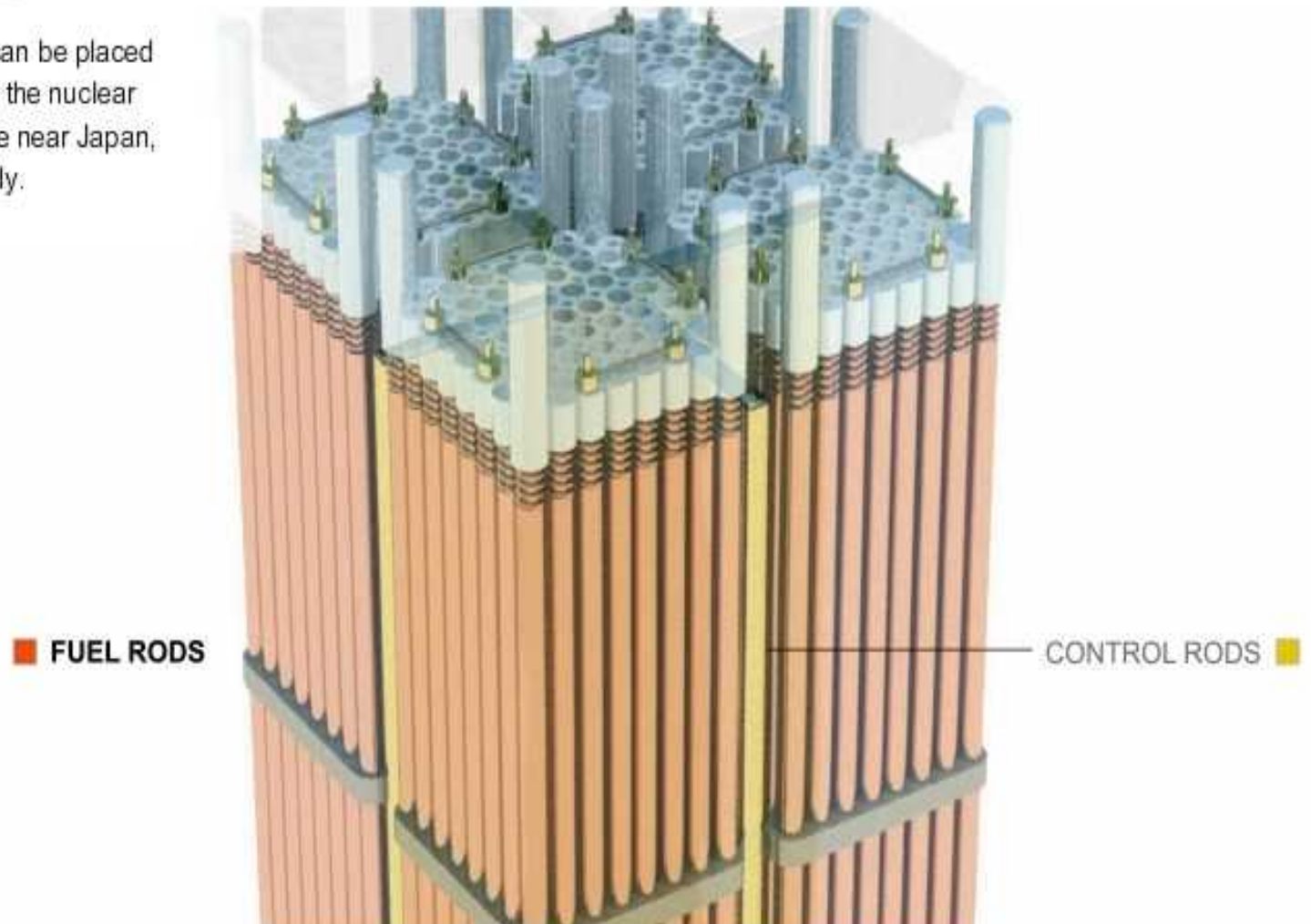
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1 2 3 4 5 6 7 NEXT ▶

In a shutdown, control rods can be placed between the fuel rods to stop the nuclear reaction. After the earthquake near Japan, control rods deployed correctly.



By MATTHEW ERICSON, XAGUÍN G.V., DYLAN McCLAIN, TOMOEI MURAKAMI-TSE, GRAHAM ROBERTS, ARCHIE TSE and JOE WARD | [Send Feedback](#)

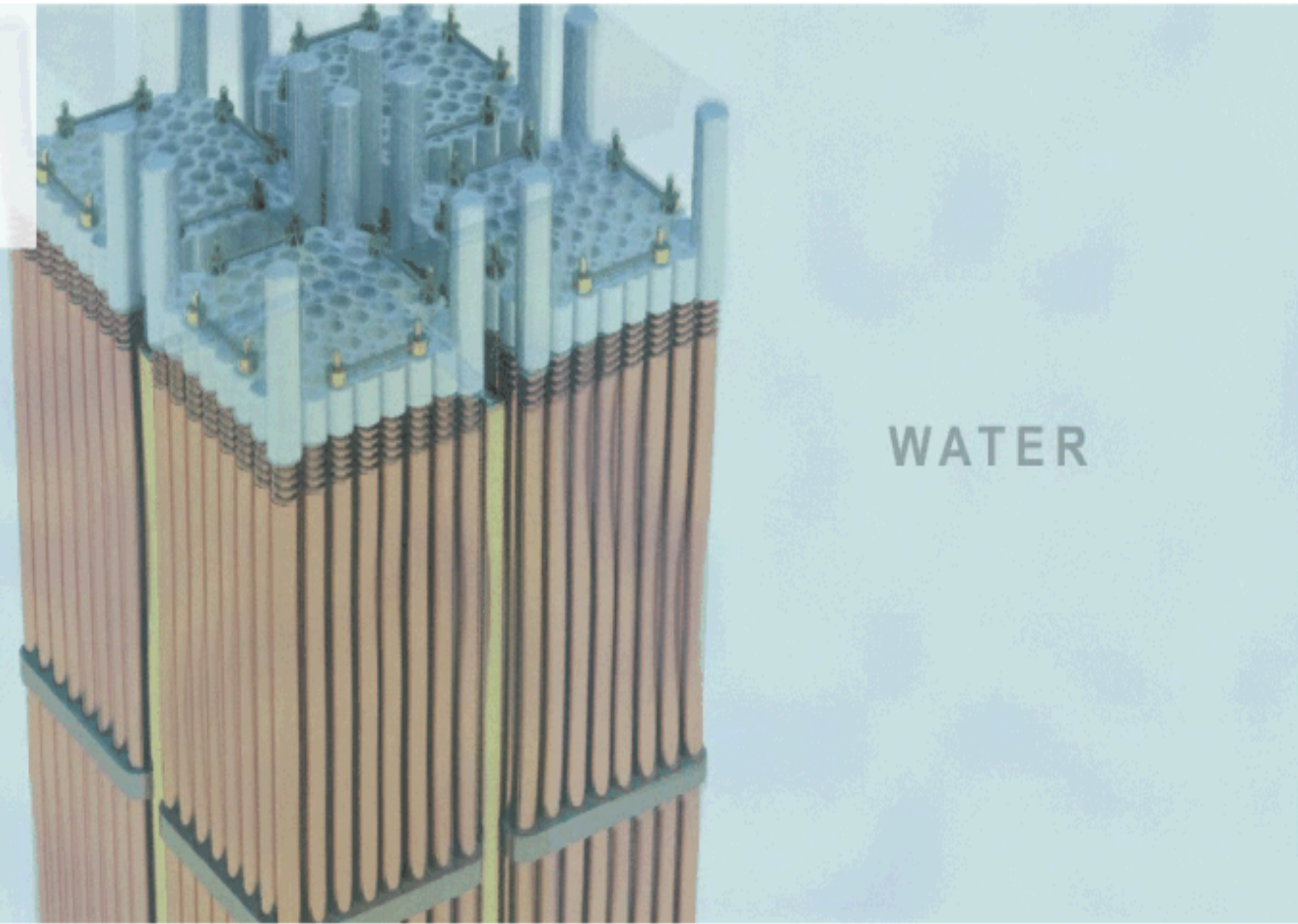
Sources: Nuclear Energy Institute; Nuclear Regulatory Commission; Tokyo Electric Power; satellite image by Digital Globe via Google Earth

How a Reactor Shuts Down and What Happens in a Meltdown

The operating reactors at Fukushima Daiichi power station automatically shut down during the earthquake. But after subsequent cooling failures, two of them went into partial meltdown.

- 1
- 2
- 3
- 4
- 5
- 6
- 7
- NEXT ▶

Though the reaction stops, fuel rods continue to give off enormous amounts of heat. To keep the rods from getting too hot, they must be kept submerged in water.



By MATTHEW ERICSON, XAGUÍN G.V., DYLAN McCLAIN, TOMOE MURAKAMI-TSE, GRAHAM ROBERTS, ARCHIE TSE and JOE WARD | [Send Feedback](#)

Sources: Nuclear Energy Institute; Nuclear Regulatory Commission; Tokyo Electric Power; satellite image by Digital Globe via Google Earth

RECOMMEND

TWITTER

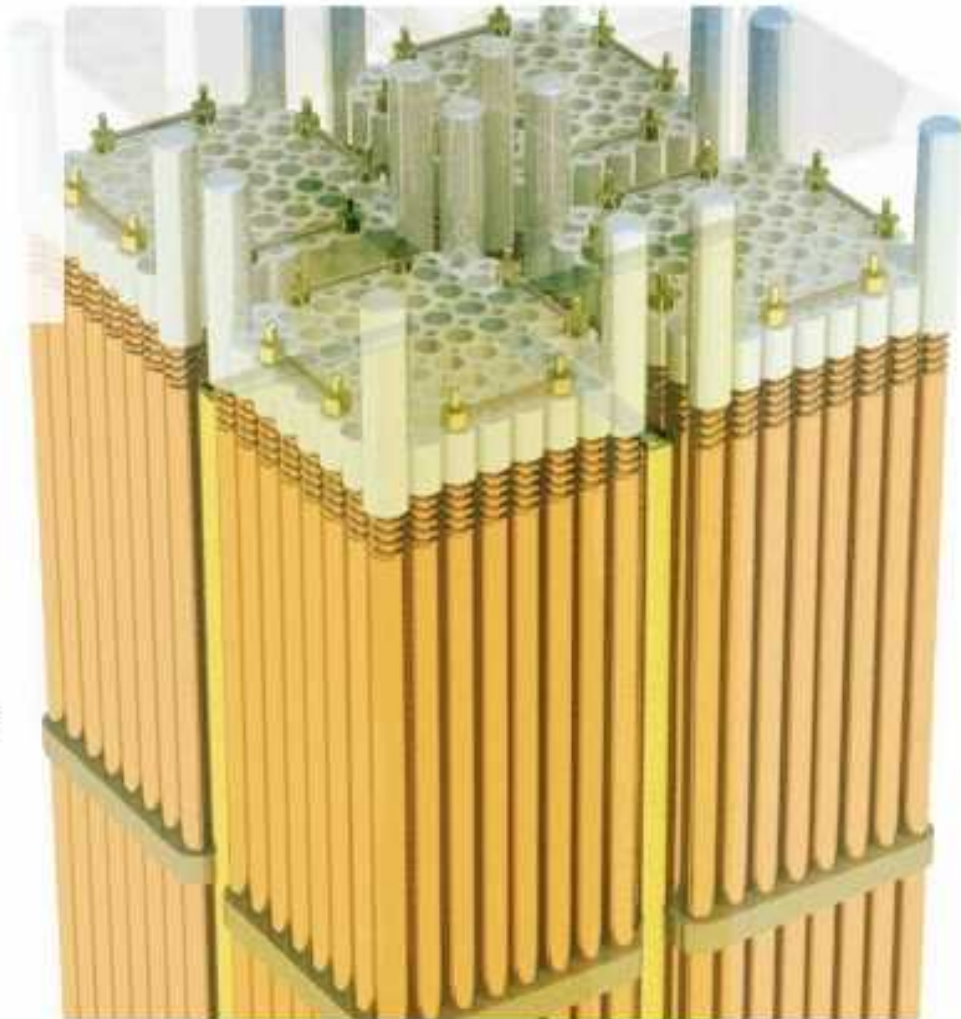
How a Reactor Shuts Down and What Happens in a Meltdown

The operating reactors at Fukushima Daiichi power station automatically shut down during the earthquake. But after subsequent cooling failures, two of them went into partial meltdown.

1 2 3 4 5 6 7 NEXT ▶

In Japan, there was no electricity to run the cooling system. Operators added water, intending to vent the steam and replace the water as it evaporated. But the water began boiling away faster than they could replace it.

FUEL RODS



By MATTHEW ERICSON, XAQUÍN G.V., DYLAN McCLAIN, TOMOE MURAKAMI-TSE, GRAHAM ROBERTS, ARCHIE TSE and JOE WARD | [Send Feedback](#)

Sources: Nuclear Energy Institute; Nuclear Regulatory Commission; Tokyo Electric Power; satellite image by Digital Globe via Google Earth

Fuel Rod Schematic

Fuel rod

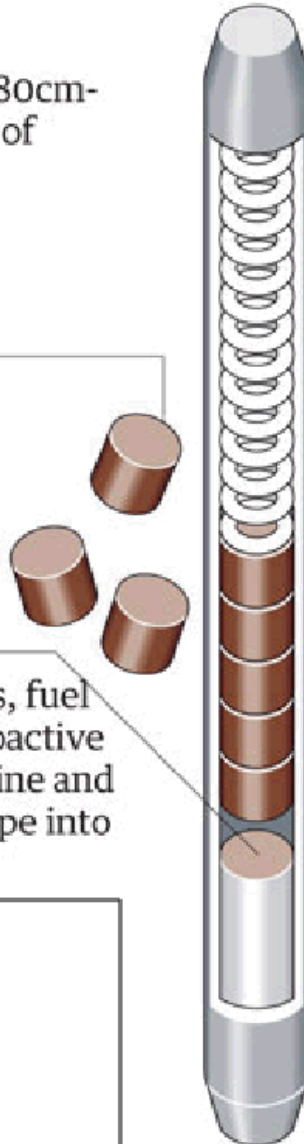
Thousands of thin, 180cm-long fuel rods, made of zirconium alloy

Fuel pellets

Uranium dioxide or mixed oxide (MOX fuel) - blend of plutonium and uranium

Washout

If rod cladding cracks, fuel pellets fall out. Radioactive isotopes in fuel - iodine and caesium - could escape into the atmosphere

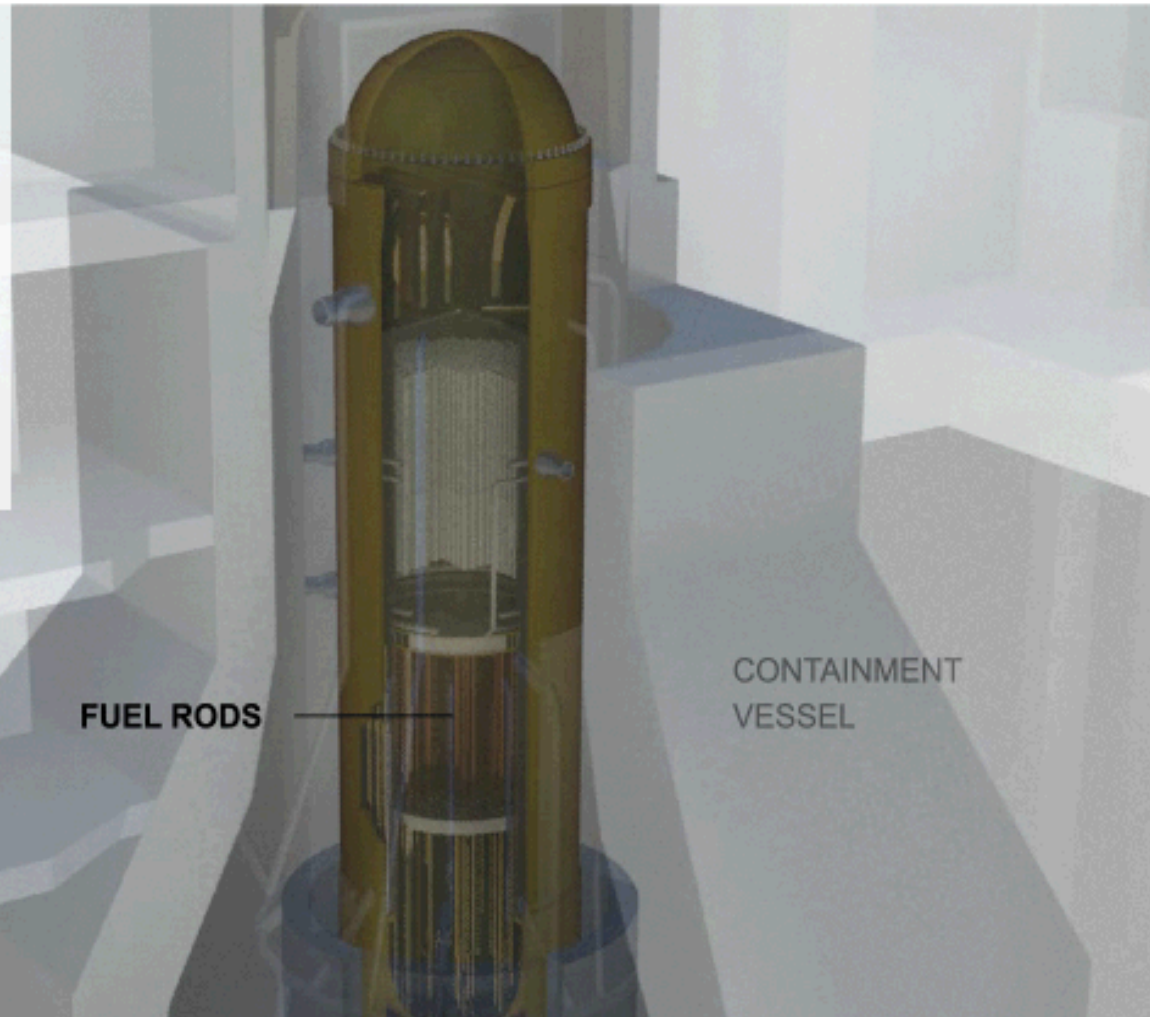


How a Reactor Shuts Down and What Happens in a Meltdown

The operating reactors at Fukushima Daiichi power station automatically shut down during the earthquake. But after subsequent cooling failures, two of them went into partial meltdown.

1 2 3 4 5 6 7 NEXT ▶

In a full meltdown, fuel pellets would drop to the bottom of the reactor vessel; they might burn through it. An outer containment vessel with steel and concrete walls may or may not hold the melted fuel and prevent it from escaping the reactor building. Worst case: Molten fuel breaches all structures and releases enormous amounts of radioactive material, but physicists question whether this is possible.



By MATTHEW ERICSON, XAQUÍN G.V., DYLAN McCLAIN, TOMOEHI MURAKAMI-TSE, GRAHAM ROBERTS, ARCHIE TSE and JOE WARD | [Send Feedback](#)

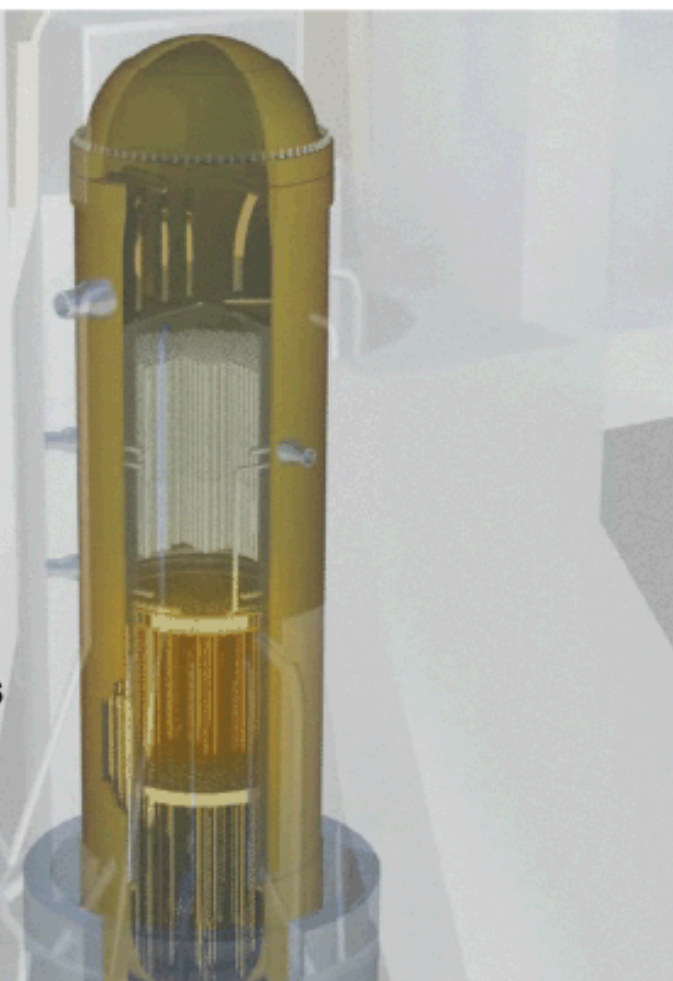
Sources: Nuclear Energy Institute; Nuclear Regulatory Commission; Tokyo Electric Power; satellite image by Digital Globe via Google Earth

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1 2 3 4 5 6 7 NEXT ▶

The rods were exposed to air, heating up quickly. As temperatures spiked, the zirconium casings cracked, releasing radioactive gases and hydrogen — probably the cause of Saturday's explosion. It is not known if any of the uranium fuel has melted.



FUEL RODS

By MATTHEW ERICSON, XAGUÍN G.V., DYLAN McCLAIN, TOMOEH MURAKAMI-TSE, GRAHAM ROBERTS, ARCHIE TSE and JOE WARD

Sources: Nuclear Energy Institute; Nuclear Regulatory Commission; Tokyo Electric Power; satellite image by Digital Globe via Google Earth

Fukushima Unit Specifications

Unit	Type ^[9]	First criticality	Electric power	Reactor supplier	Architecture	Construction
Fukushima I – 1	BWR-3	October 1970 ^[8]	460 MW	General Electric	Ebasco	Kajima
Fukushima I – 2	BWR-4	July 18, 1974	784 MW	General Electric	Ebasco	Kajima
Fukushima I – 3	BWR-4	March 27, 1976	784 MW	Toshiba	Toshiba	Kajima
Fukushima I – 4	BWR-4	October 12, 1978	784 MW	Hitachi	Hitachi	Kajima
Fukushima I – 5	BWR-4	April 18, 1978	784 MW	Toshiba	Toshiba	Kajima
Fukushima I – 6	BWR-5	October 24, 1979	1,100 MW	General Electric	Ebasco	Kajima
Fukushima I – 7 (planned)	ABWR	October 2016 ^[10]	1,380 MW			
Fukushima I – 8 (planned)	ABWR	October 2017 ^[10]	1,380 MW			

Health Effects of Radiation from Japanese Reactor Leaks

By Blaine N. Howard, Radiological Physicist

There are two types of health effects of radiation -- short term and long term.

The **short term** effects include **radiation sickness and death**.

The **long term** effects include **cancer**.

The Japanese emergency workers are the only people who receive significant amounts of radiation. For this emergency, the exposure limit has been raised from 100 mSv to 250 mSv which still prevents them from the danger of short term radiation effects. See Figure 1.

Thus, there should be no **short term** radiation health effects in Japan.

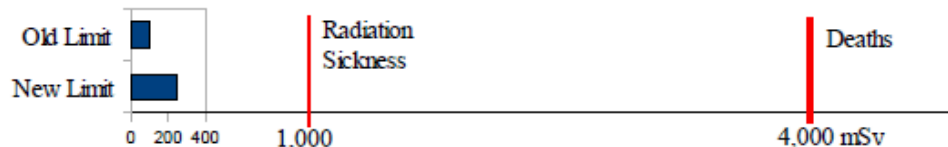


Figure 1. Emergency Worker Limits and Short Term Effects

Some claim that all radiation increases the risk of getting cancer. This is not in agreement with good radiological science. The General Accounting Office states it this way.

*"According to a consensus of scientists, there is a **lack of conclusive evidence of low level radiation effects below total exposures of about 5,000 to 10,000 millirem.**" [50 to 100 mSv]*

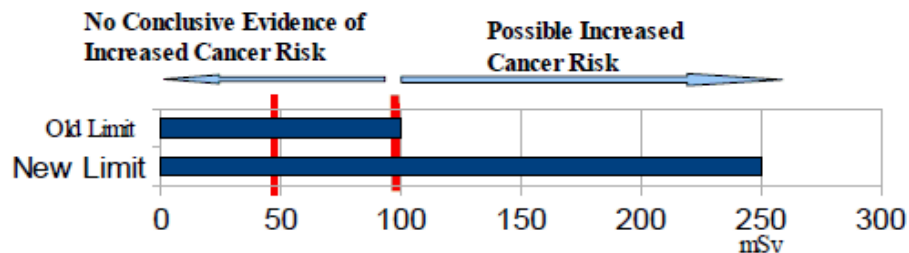


Figure 2. Emergency Worker Limits and Long Term Radiation Effects.

The emergency workers are likely to be at an increased risk of dying from cancer. See Figure 2. The Linear No Threshold (LNT) model may be used to calculate an upper limit of the expected risk. This calculation for a worker exposed to 250 mSv gives a 0.5% increase risk of dying from cancer. Since cancer deaths normally account for about 25% of all deaths and vary each year, an additional 0.5% would probably not be observable.

At the current levels of radiation, it is unlikely for persons outside the exclusion area to receive 50 mSv even if the levels persist for a year. This includes external radiation and internal radiation from ingestion or inhalation of radioisotopes. Japanese officials are monitoring these levels. About April 12, they expanded the evacuation zone to include areas where there is a risk of more than 20 mSv annual dosage.

Thus, **no significant increase in cancer risk** among the public is expected.

The danger of low dose radiation is very much exaggerated.

If the Japanese should not worry, why should we?

Regional Training Workshops

- Bahrain 2007 and 2008
- Qatar 2008
- Jordan 2007 and 2008



Radiation Measurements Standards in the Middle East

- Radiation Measurements Cross Calibration (RMCC) Project
 - Develop a network of scientists and labs that can devise indigenous solutions to issues such as proliferation monitoring, environmental assessments, emergency response, and radioactive materials smuggling
 - Partnered with the IAEA, DOE/MAPEP



First RMCC Workshop, Kuwait, October 2004



Fifth RMCC Workshop, Doha, Qatar, May, 2010

The NAVRUZ Experiment: Cooperative Monitoring for Radionuclides Central Asia Transboundary Rivers



Negotiations during project workshop in Tashkent

Training on sample collection, Chirchik River, Uzbekistan





Final Thoughts

- **Strengthen Interagency Coordination and Cooperation**
- **Develop a Strategy for International Engagement**
 - Why? Who? How?
- **Phases of Engagement**
 - Introductory
 - Intermediate
 - Advanced

U.S. Response Timeline

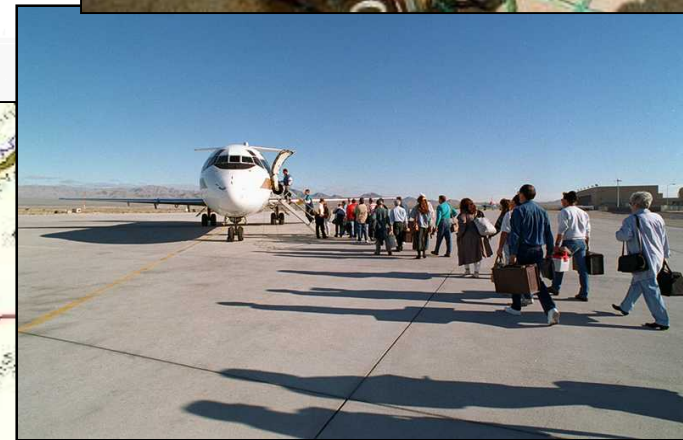
T = 0 to 1 Hour

- Local Authority and/or Nuclear Facility will implement its Emergency Response Plans
- State and Local Officials will be notified.
 - Local First Responders will be first to arrive on the scene.
 - First Responders will begin responding to the emergency and evacuation of local area based upon Emergency Response Plans.

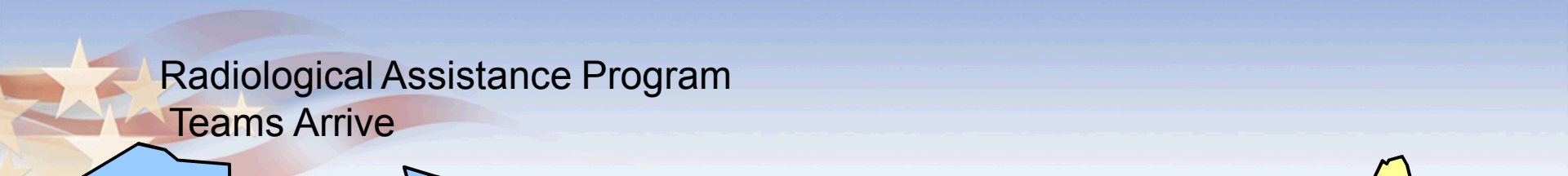


CM Resource Response *Timeline T = 1 to 6 Hours*

- NNSA's Radiological Assistance Program Teams (RAP Teams) begin to arrive.
- Department Of Energy activates National Consequence Management Assets upon request of state.
 - CM Home Team Activated and providing assessment within 2 hours of activation.
 - CM Response Team assets in route within 4-hours of activation.
- NNSA's Plume Dispersion Modeling underway.



100 and 500 uSv Dose Contours



Radiological Assistance Program Teams Arrive

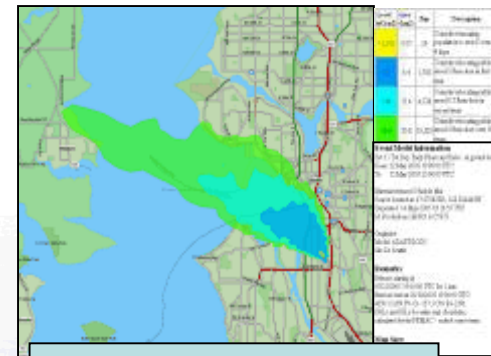
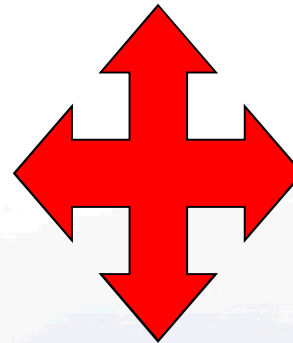


CM Home Team Is Activated

Field Team



Assmt Experts



Plume modeling



Emergency Operations Center

- Objectives:

- Provide Technical Assessment and Plume Map support before CM response team assets arrive at the event site
- Provide a resource for local authorities early in an event

- Resources

- National Lab personnel
- Assessment tools
- Plume modeling

CM Response

Timeline T = 24 to 36 Hours

- CM Response Teams arrive (approximately 150 - 400 additional personnel in 3 teams).
- Provides experts to support the operations:
 - Sampling Experts
 - Lab Analysis Experts
 - Health and Safety Experts
 - Assessment Experts
 - Radiological Technicians
- All of these individuals take on specific roles as defined in pre-event planning/training.





Consequence Reports

- **Standardized report integrating effects predictions with Geographical Information System (GIS) provides consequence information in a format more directly useful to decision makers**
- **Reports are customized for different Weapons of Mass Destruction (WMD) scenarios or accident situations**
- **Different levels of detail can be selected**
 - summary, full report, full report including background and reference information

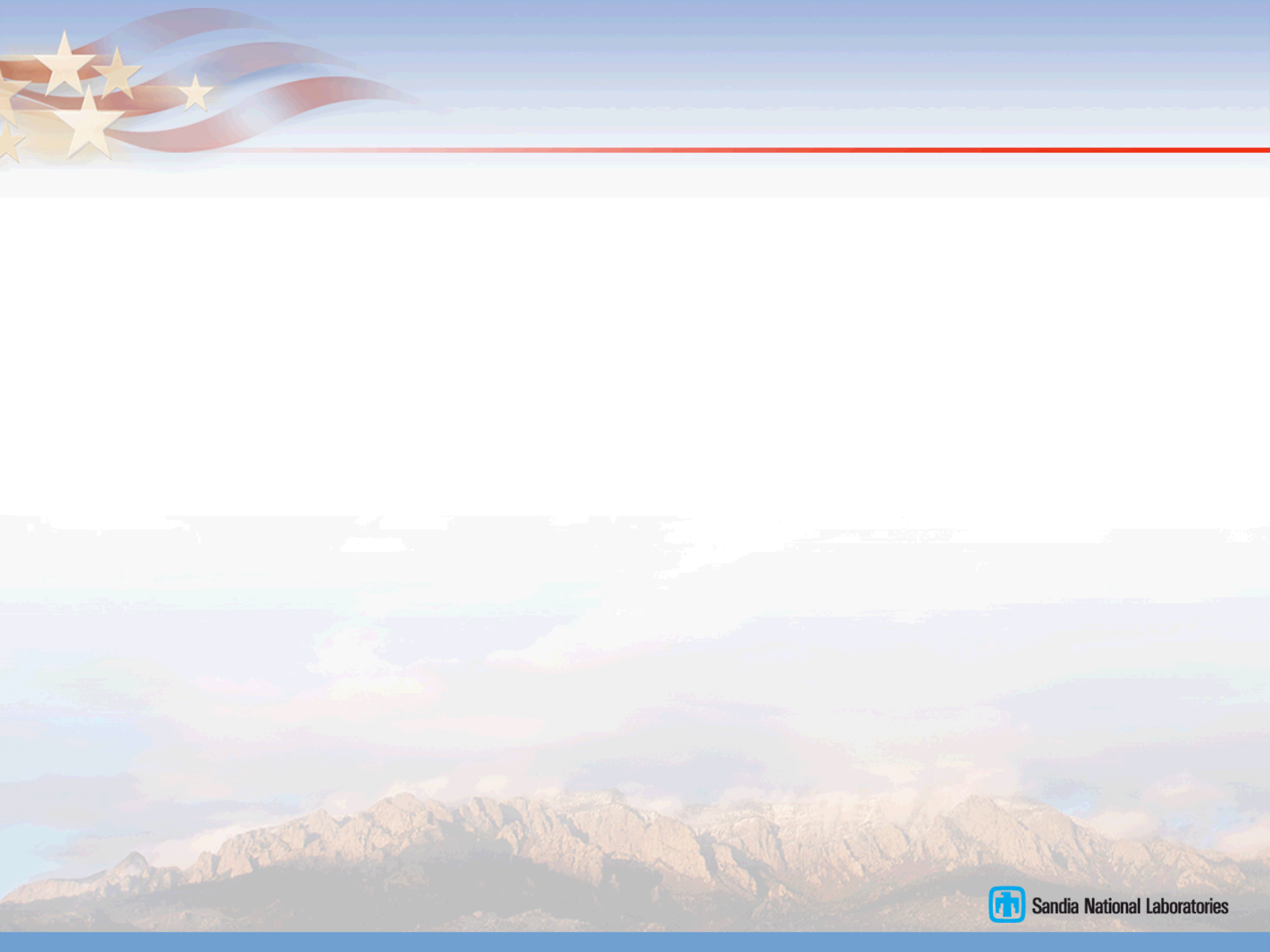


Thank You!



EXTRA SLIDES







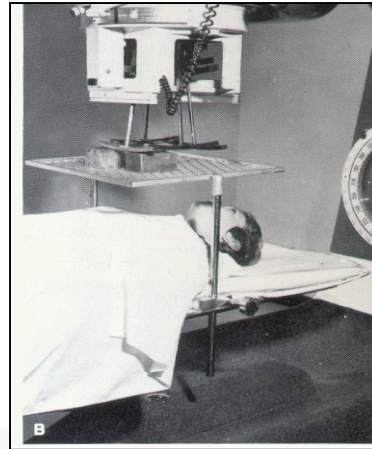
DOE/NNSA Consequence Management (CM) Program Overview

**Prepared by:
Thomas Laiche, CHP**

**Nuclear Incident Response Programs
Sandia National Laboratories
Albuquerque, NM**

Large Quantities of Radioactive Material can be Found Throughout the World

- **Nuclear Reactors**
- **Nuclear Weapons**
- **Medical/Industrial Applications**
 - **Therapy Equipment**
 - **Sterilization Equipment**
 - **Density Gauges**
 - **Well Logging**
 - **Radiography**
 - **Thickness and Level Gauges**
 - **Power Generation**
 - **Radioisotopic Thermal Generators (RTG)**

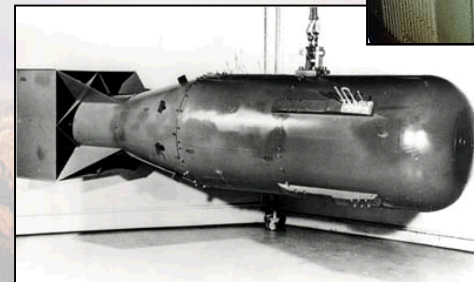


Radiotherapy Unit



Nuclear Power Plants

Nuclear Weapons



RTG

History

- **March 28, 1979: Three Mile Island**
- **Event highlighted inadequacies in planning for a large-scale Nuclear Emergency**
 - **Evacuation Plans for the nearby cities inadequate**
 - **Significant confusion about protective actions**
- **An Executive Order was issued mandating federal preparations for radiological emergencies**
- **Preparations focused on nuclear power and weapon accidents**



**Three Mile Island
Nuclear Power Plant**



New CM Program Focus

- The events of September 11, 2001 resulted in a philosophical change:
 - Terrorists may strike with no warning
 - First knowledge of nuclear terrorism attack may be the explosion/dispersion
- DOE/NNSA CM Program transitioned focus to preparations for intentional terrorist attack(s)



Mission

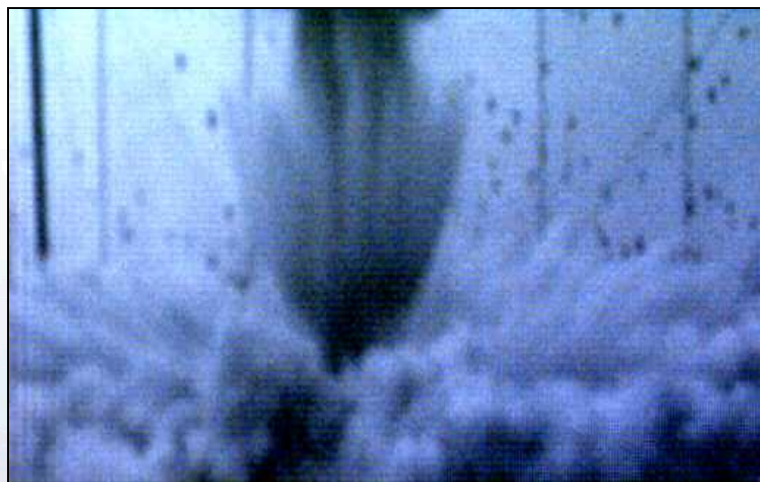
Develop and maintain rapidly-deployable equipment and technical expertise for world-wide response to nuclear and radiological terrorism events as well as nuclear/radiological accidents or emergencies





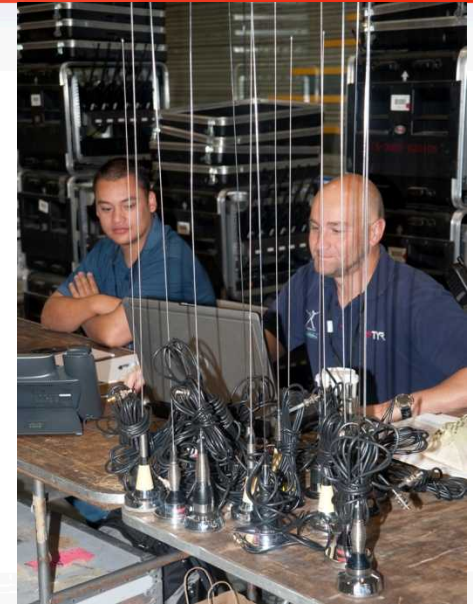
DOE/NNSA CM Expertise

Research – Explosive Dispersion of
Radioactive Materials



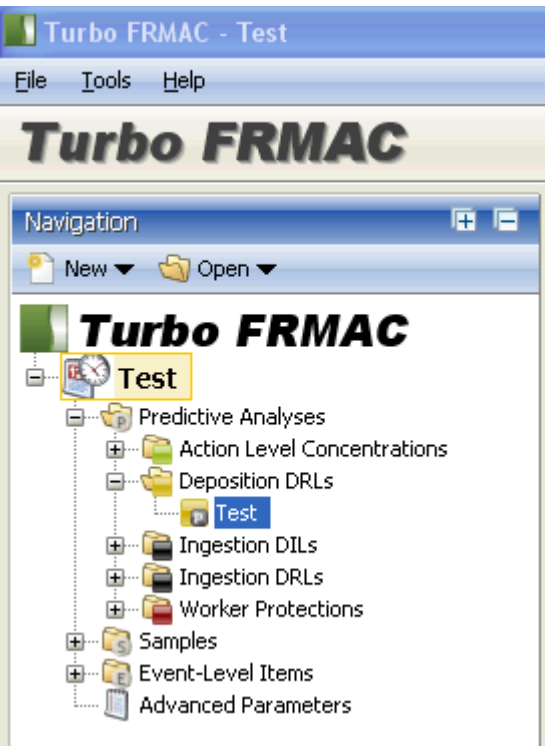
DOE/NNSA CM Expertise

Equipment – Fixed Wing and Rotary Aircraft,
Radiological Monitoring Equipment,
Communications, Mobile Laboratories



DOE/NNSA CM Expertise

Models and Software – Develop and Use the most up-to-date Software, Databases, and Effect Models



Turbo FRMAC - Test

File Tools Help

Turbo FRMAC

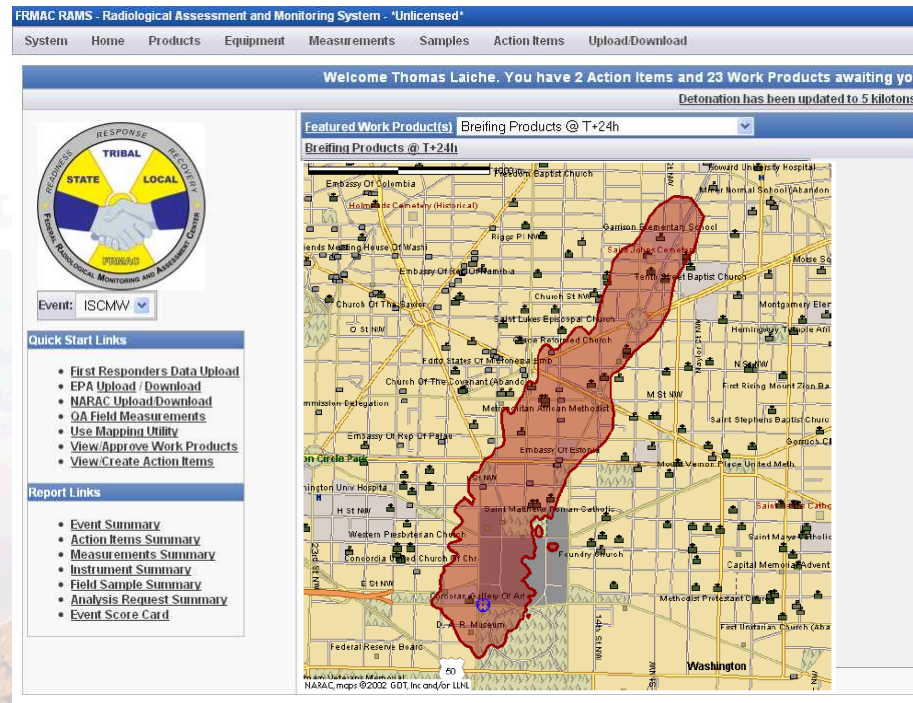
Navigation

- New
- Open

Turbo FRMAC

Test

- Predictive Analyses
 - Action Level Concentrations
 - Deposition DRLs
 - Test
- Ingestion DILs
- Ingestion DRLs
- Worker Protections
- Samples
- Event-Level Items
- Advanced Parameters



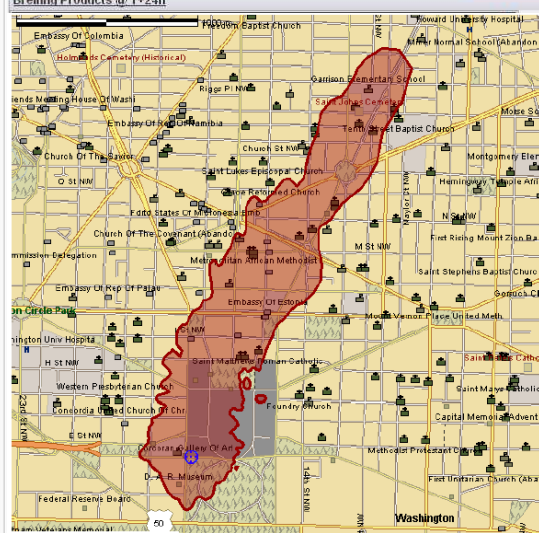
FRMAC RAMS - Radiological Assessment and Monitoring System - "Unlicensed"

System Home Products Equipment Measurements Samples Action Items UploadDownload

Welcome Thomas Laiche. You have 2 Action Items and 23 Work Products awaiting your attention. Detonation has been updated to 5 kilotons.

Featured Work Product(s) Briefing Products @ T+24h

Briefing Products @ T+24h



Quick Start Links

- First Responders Data Upload
- EPA Upload / Download
- NARAC Upload/Download
- QA Field Measurements
- Use Mapping Utility
- View/Approve Work Products
- View/Create Action Items

Report Links

- Event Summary
- Action Items Summary
- Measurements Summary
- Instrument Summary
- Field Sample Summary
- Analysis Request Summary
- Event Score Card



DOE/NNSA CM Expertise

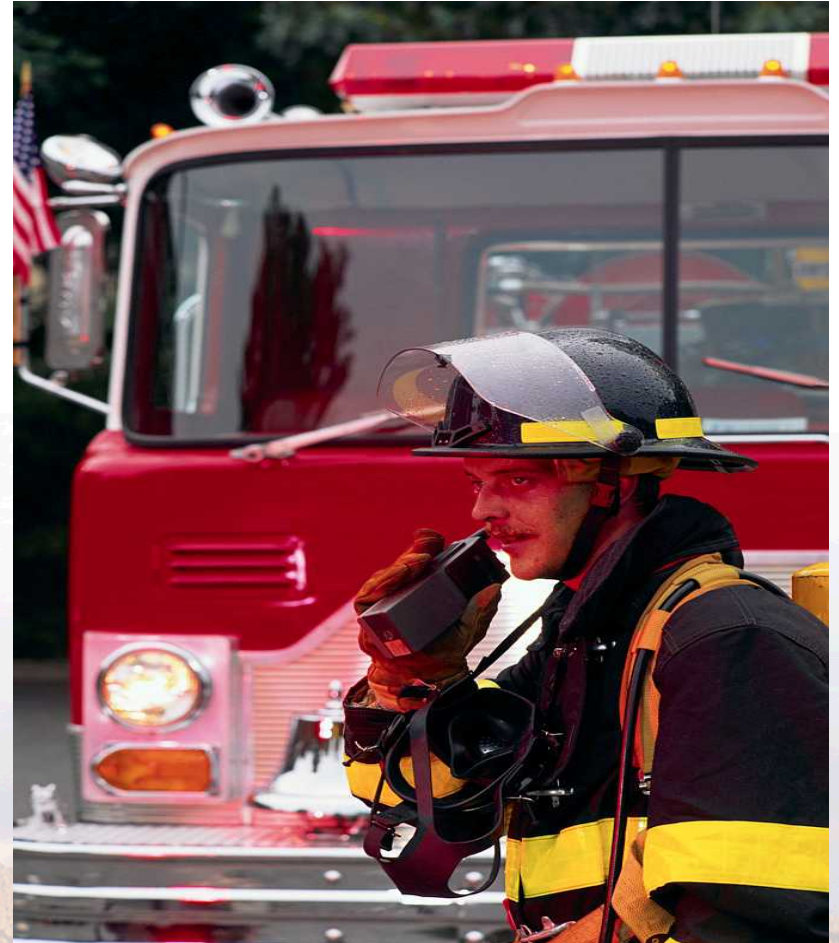


Personnel – Staffed with Personnel with Various Technical Expertise



What is FRMAC?

Federal Radiological Monitoring and Assessment Center (FRMAC) is a federal asset available upon request to respond to nuclear/radiological incidents as described in the [National Response Framework \(NRF\)](#) and the Nuclear/Radiological Incident Annex



What is the Purpose of FRMAC?

- Assist the state, local and tribal governments in their mission to **PROTECT THE HEALTH AND WELL BEING OF THEIR CITIZENS**
- Integrate multiple Federal agencies into one center where the Federal government can act and speak with **one voice**



CM Program/FRMAC Help Provide Coordinated Radiological Emergency Response

CMHT, RAP, CMRT I
CMRT II, FRMAC
Augmentation

Gather facts

*Use Protective Action
Guidelines and facts
to make projections*

**Coordinating Agency
and Advisory Team**

**State, Local
Tribal
Governments**

**Shelter-in-Place
Evacuate
Return
Recovery**

***Make protective action
recommendations***

Who Makes Up FRMAC?

- **Department of Energy**
- **Environmental Protection Agency**
- **Department of Homeland Security**
- **Department of Health and Human Services**
 - Center for Disease Control
- **Department of Agriculture**
 - Food and Drug Administration
- **Nuclear Regulatory Commission**
- **And at least 10+ other Federal Departments and Agencies**
- **State, Local and Tribal Representation**



FRMAC within ICS

LEGEND

FRMAC

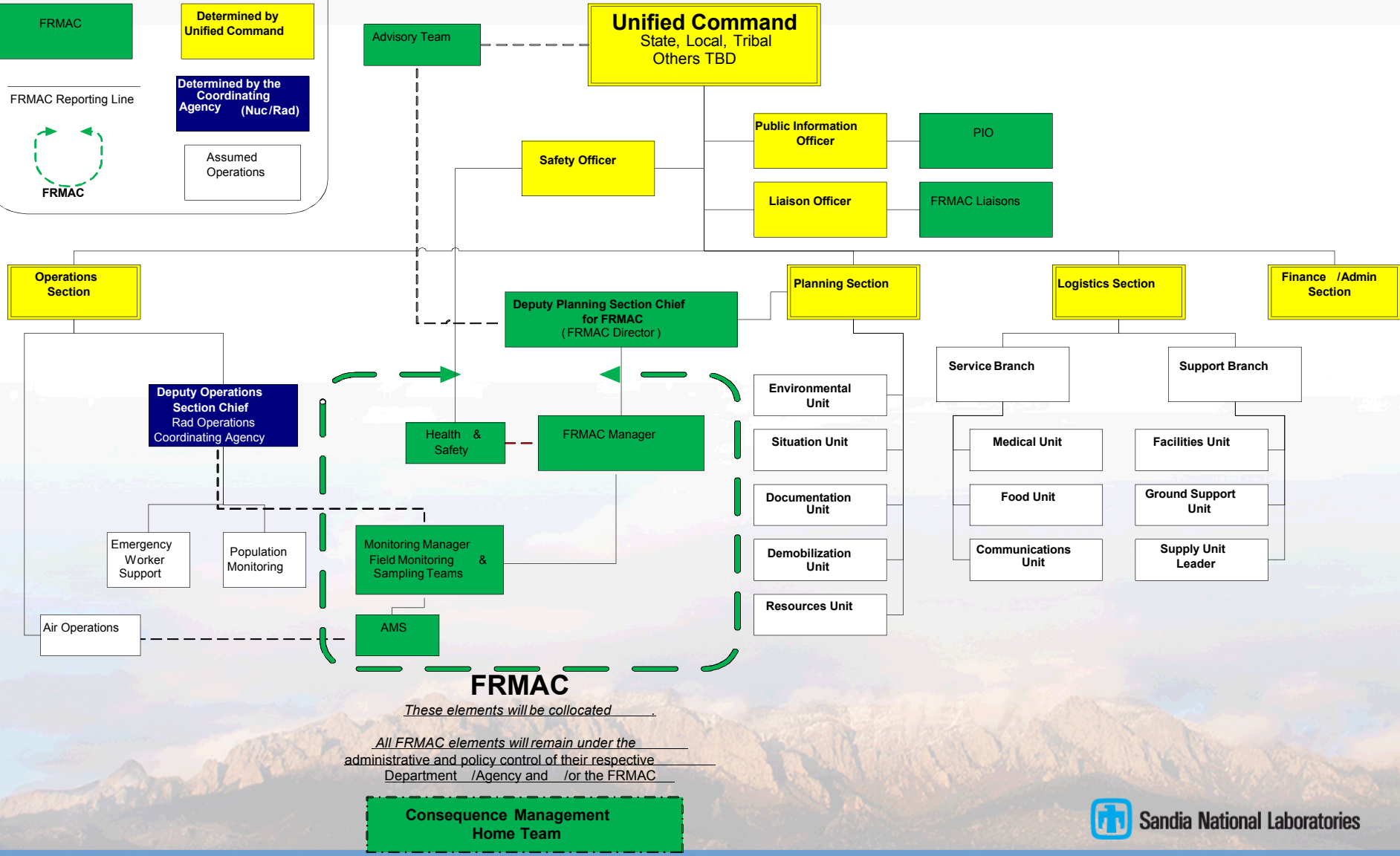
Determined by Unified Command

FRMAC Reporting Line

Determined by the Coordinating Agency (Nuc/Rad)

Assumed Operations

FRMAC



FRMAC

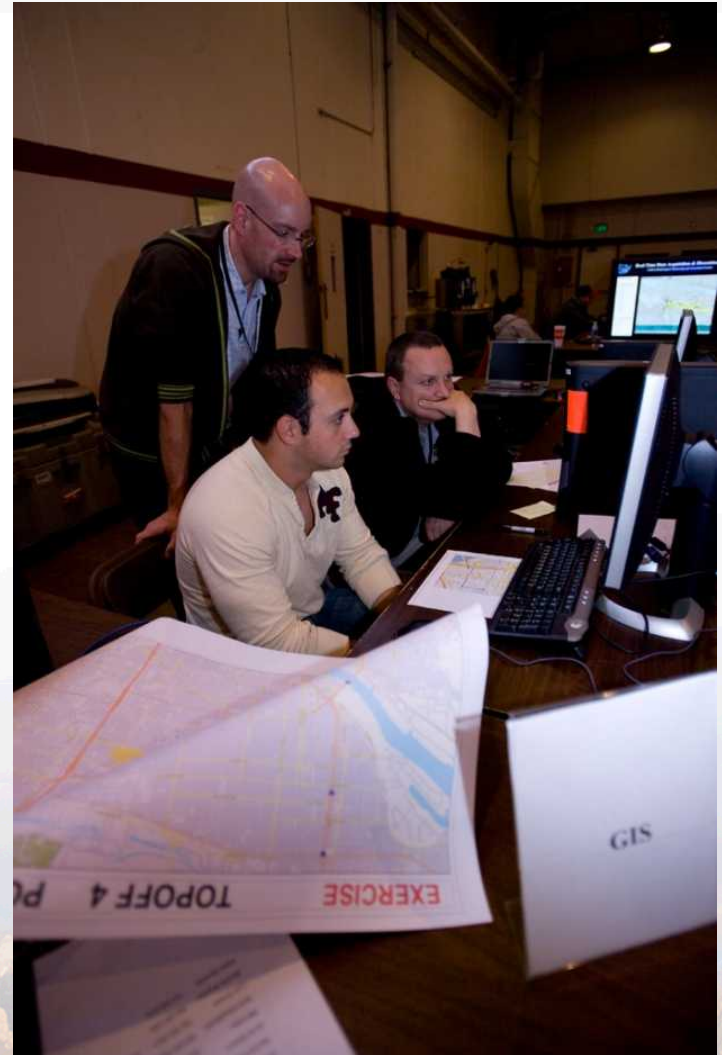
These elements will be collocated

All FRMAC elements will remain under the administrative and policy control of their respective Department /Agency and /or the FRMAC

Consequence Management Home Team

Elements of FRMAC

- **CM Home Team**
- **Assessment**
- **Health and Safety**
- **Monitoring and Sampling**
 - AMS
- **Laboratory Analysis**
- **A Team**
- **GIS**
- **Document Control**
- **NARAC**



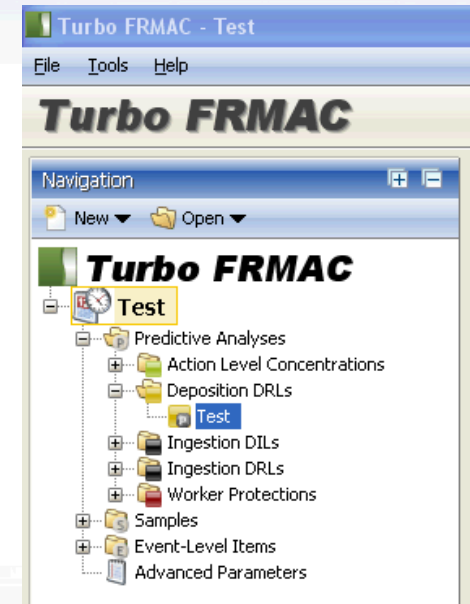
Elements of FRMAC



- **CM Home Team** - Provides technical support to event response while CMRT is enroute
 - Used as a reach-back resource
 - Used for expertise that may not be available in the field

Elements of FRMAC

- **Assessment** - Provides decision makers with radiological information that can be used to issue Protective Actions



- Interprets radiological information in terms of EPA, FDA, or State/Local/Tribal Protective Action Guides (PAGs)
- Uses FRMAC-approved methodology to calculate potential dose consequence

Elements of FRMAC

- **Health & Safety** - Responsible for the H & S of all FRMAC personnel involved in operations
 - Determines appropriate Emergency Worker Protective Action Guides
 - Determines Stay Times
 - Determines if Respiratory Protection is needed



Elements of FRMAC

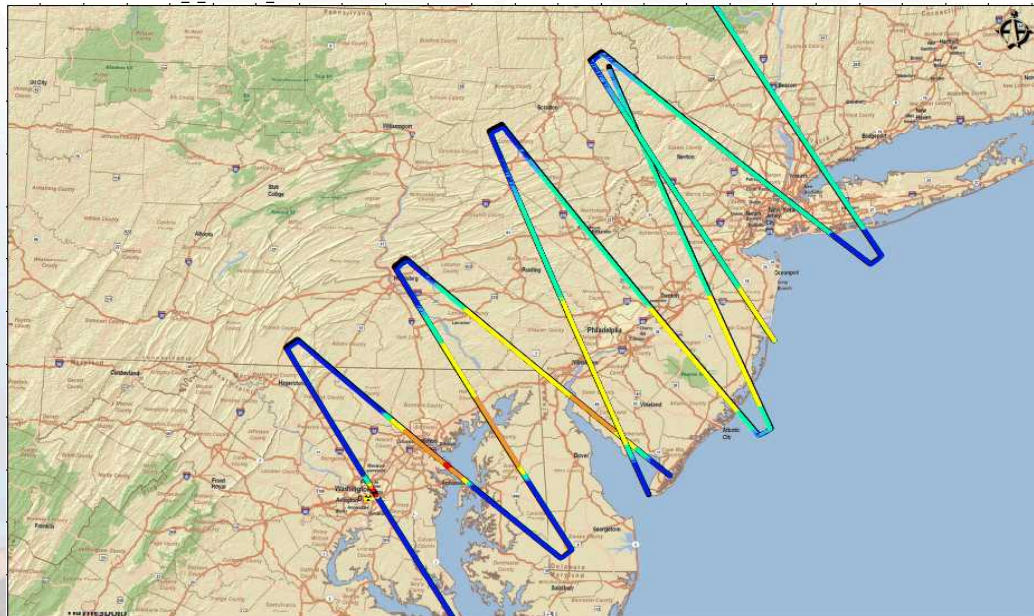
- **Monitoring & Sampling** - Coordinates efforts to provide scientifically defensible data of acceptable quality

- Develops sampling plans that include:
 - Monitoring point locations
 - Sample volume and types



Elements of FRMAC

- **Aerial Monitoring System (AMS)** - DOE's aerial-based radiation detection platform used to verify initial plume



Elements of FRMAC

- **Laboratory**
Analysis - Provides in-the-field radioanalysis of samples
 - Maintains ability to ship samples off-site to contract laboratories



Elements of FRMAC

- **Advisory Team**
(A Team) - Federal Agency entity that makes recommendations to State, Local, or Tribal Decision Makers
 - Provides approval to deviate from standard assessment calculations



Elements of FRMAC

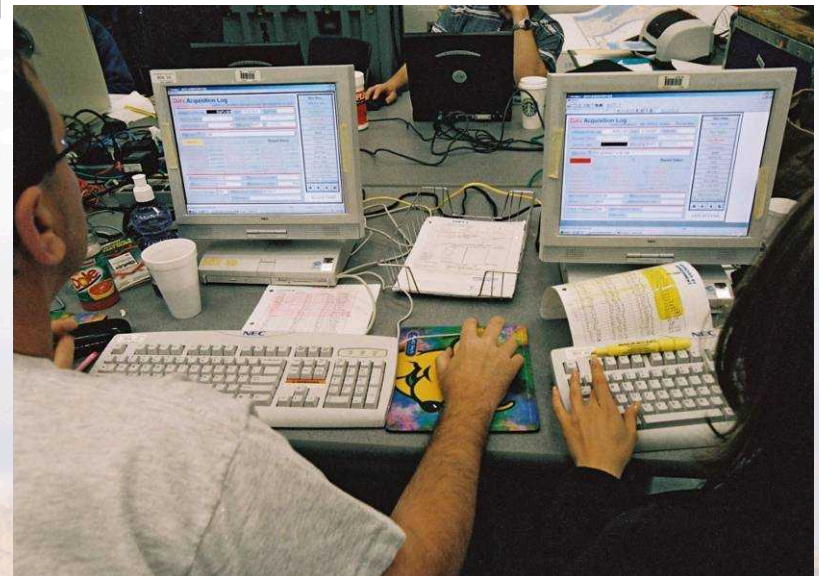
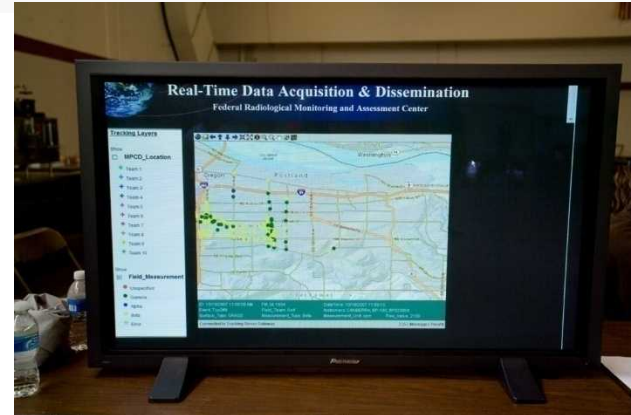
- **Geographic Information System (GIS)** – A Computerized Database Management System that provides for the capture, storage, retrieval, analysis and display of spatial data
 - Assists in the development of the Data Products
 - Most visible of FRMAC assets
 - Interacts closely with NARAC for Data Product development



Elements of FRMAC

- **Document Control** - Every off-site environmental radiological data point stored for long-term retention in FRMAC Data Center

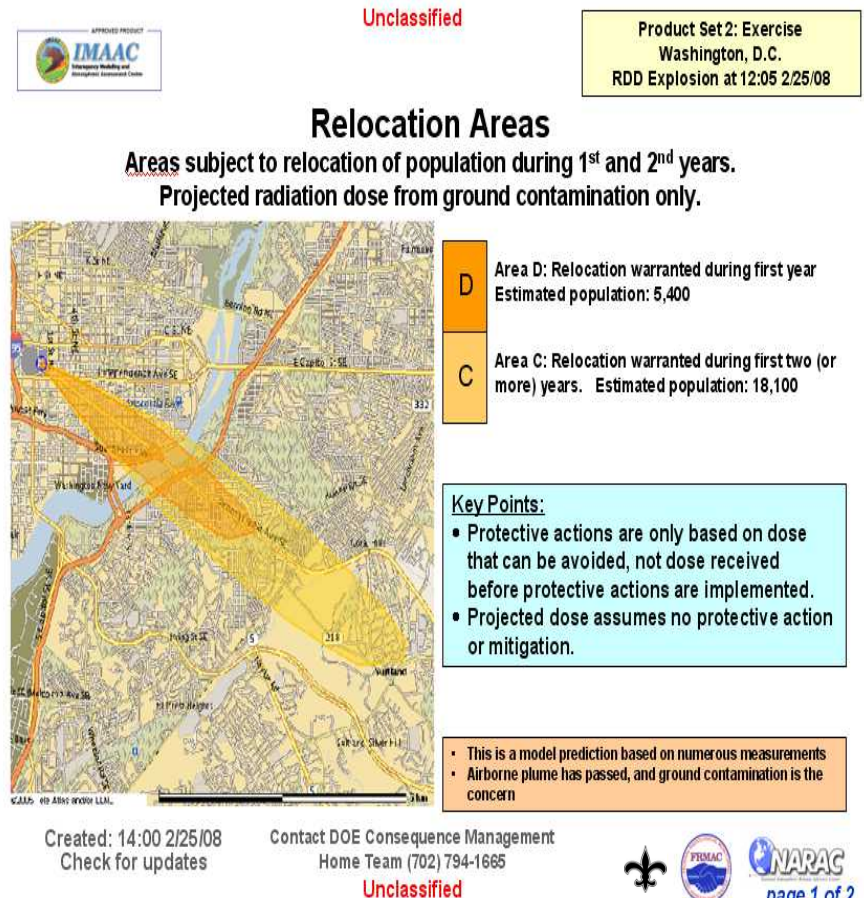
- Uses RAMS Database to electronically collect and store Field Data, Laboratory Analyses, etc.



Elements of FRMAC

National Atmospheric Release Advisory Center (NARAC) - Provides models, tools and services that plot the probable spread of radioactive materials laid over a map of the affected area

- Uses the plots as part of both the Briefing Products and Data Products
- These Products are used by Decision Makers to determine appropriate Protective Actions as well as disseminate information



DOE/NNSA CM Program Overview Conclusion

- **Legislated Federal Program to prepare for and respond to nuclear and radiological terrorism events as well as nuclear/radiological accidents or emergencies**
- **Rapid, World-Wide Deployable Equipment and Personnel**
- **FRMAC established to provide the resources to State, Local and Tribal governments to assist with emergency response**



DOE/NNSA CM Program Overview

Conclusion

- FRMAC comprised of multiple Federal Agencies working together to speak with one voice
- Resources include personnel, communications, data analysis, models, monitoring, laboratories





Questions