SAND2012-10738C

National Nuclear Security Administration

Office of Nonproliferation and International Security (NIS)

www.nnsa.doe.gov

Planning for Emergency Field Environmental Radiological Monitoring

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SAND No. 2011-3172C

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Safeguard nuclear material to prevent its diversion for illicit use.

Control the spread of WMD-related material, equipment, technology and expertise.

Verify nuclear reductions and compliance with international nonproliferation treaties and agreements.

Develop and implement nonproliferation and arms control policy.

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. 52, *Cs-137 from the Environment to Man: Metabolism and Dose*
- NCRP Report No. 109, *Effects of Ionizing Radiation on Aquatic Organisms*
- 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. 159, *Risk to the Thyroid from Ionizing Radiation*
- NCRP Report No. 161, *Management of Persons Contaminated*

Useful Reference Documents (cont'd)

- *Commentary No. 10, Advising the Public about Radiation Emergencies*
- Commentary No. 19, *Key Elements of Preparing Emergency Responders for Nuclear and Radiological Terrorism*
- *Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion, EPA-520/1-88-20, FGR No. 11.*
- *Health Risk from Low-Level Environmental Exposure to Radionuclides, EPA 402-R-97-014, FGR No. 13.*
- *External Dose-Rate Conversion Factors for Calculation of dose to the Public, DOE/EH-0070.*
- *Derived Concentration Technical Standard.* DOE-STD-1196-2011, April 2011

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.)

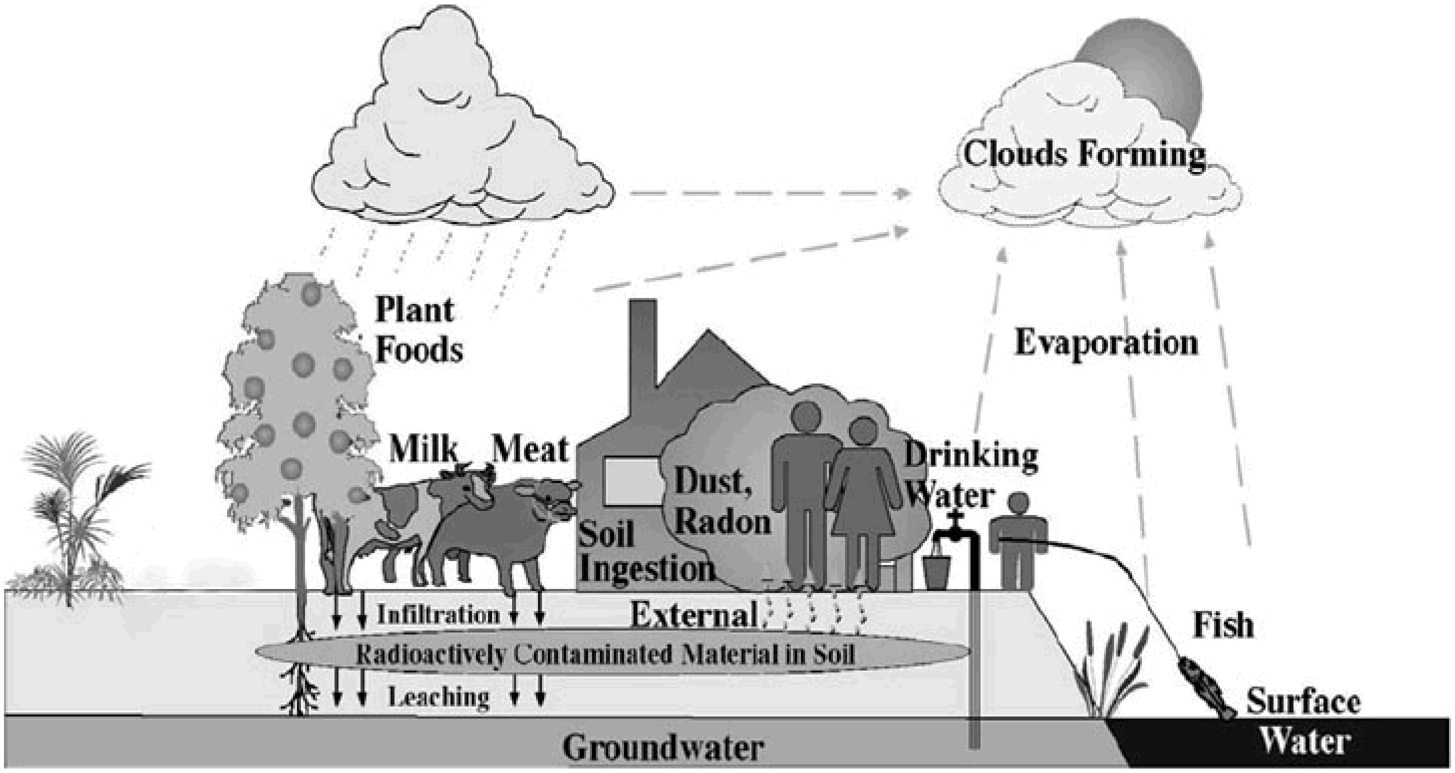


FIGURE 1.1 Exposure Pathways Considered in RESRAD

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

Office of Nonproliferation and International Security (NIS)

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

- H^3 – Liquid Scintillation Counting (LSC) – activation product
- Zn^{65} – Gamma Spec – fission product
- Co^{60} – Gamma Spec – activation product
- Sr^{90} – Radiochemistry – fission product
- Cs^{137} – Gamma Spec – fission product

Radionuclides of Concern Assay Techniques (cont'd)

- Ra^{226} – Gamma Spec - NORM
- U^{235} - ICP-MS – fuel component
- U^{238} - ICP-MS – fuel component
- Pu^{239} – Alpha Spec or ICP-MS – fuel component / activation product

❖ Other radionuclides may be identified via gamma spec or LSC software during assay

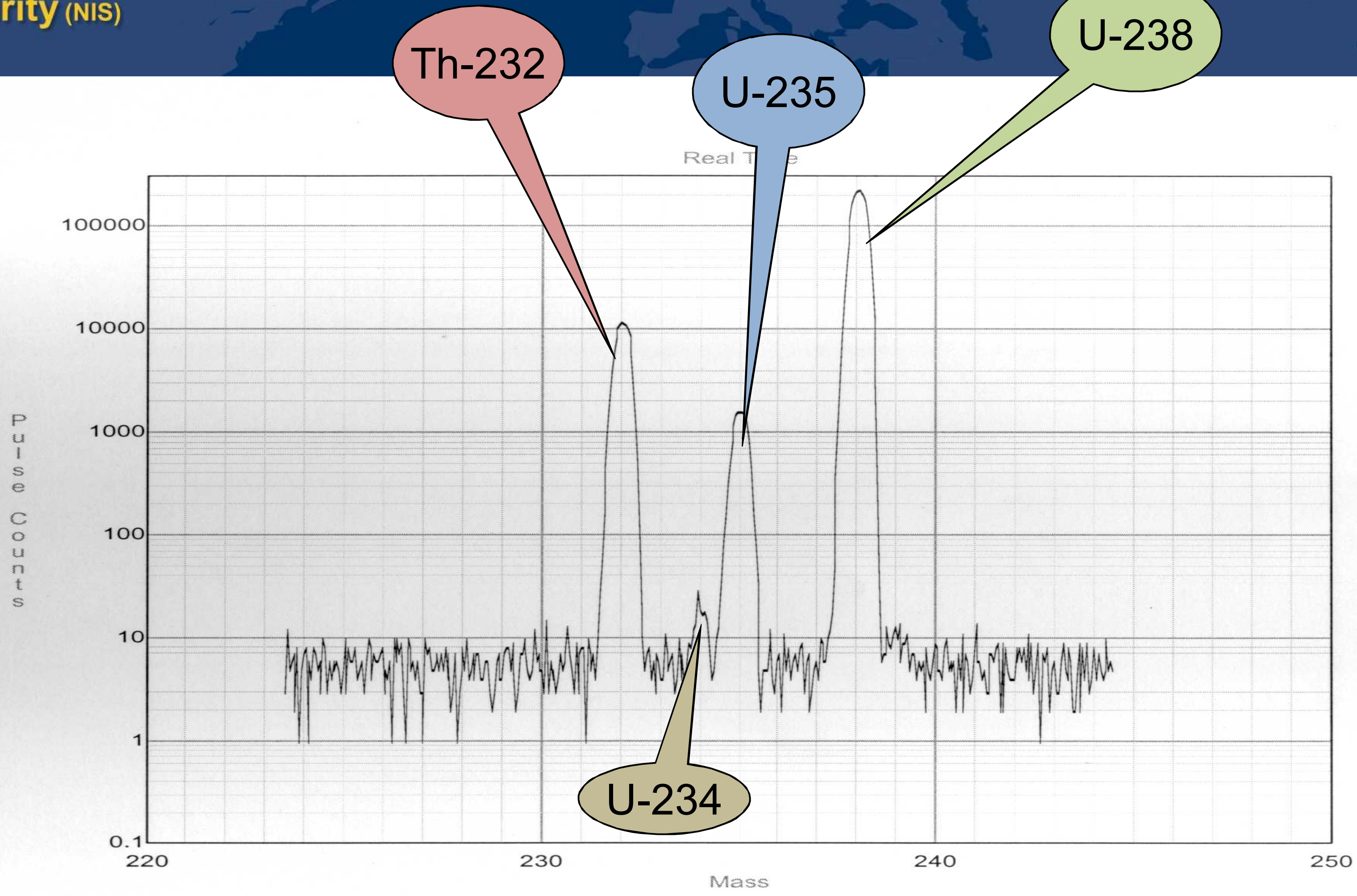
❖ Additional (or fewer) target radionuclides in successive sampling

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

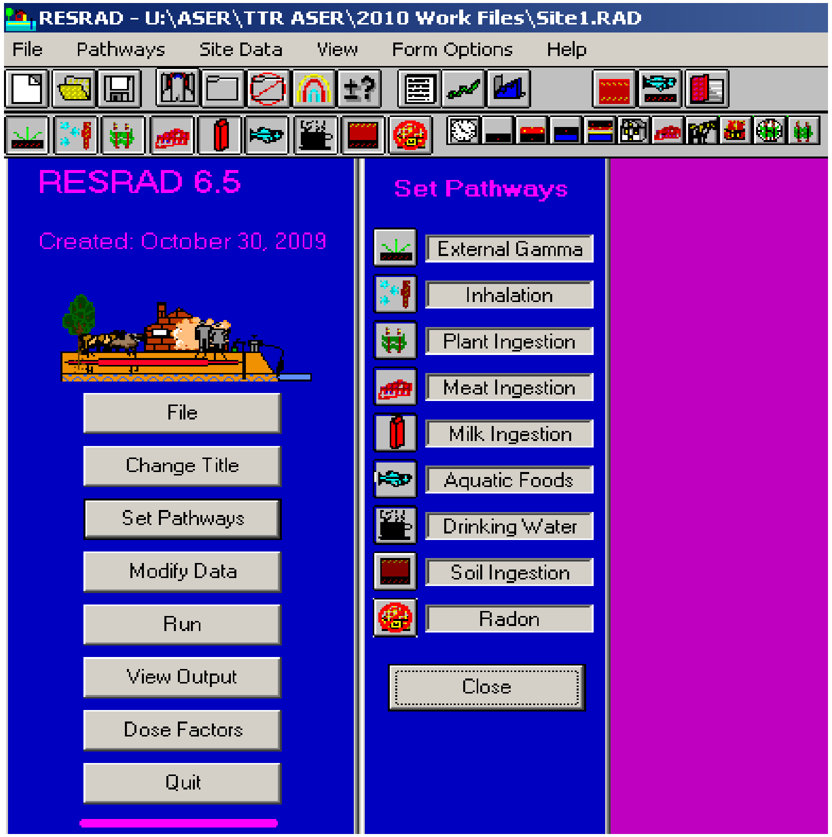
Office of Nonproliferation and International Security (NIS)

ICP-MS Spectrum for U / Th / Pu



Related Input Parameters Needed

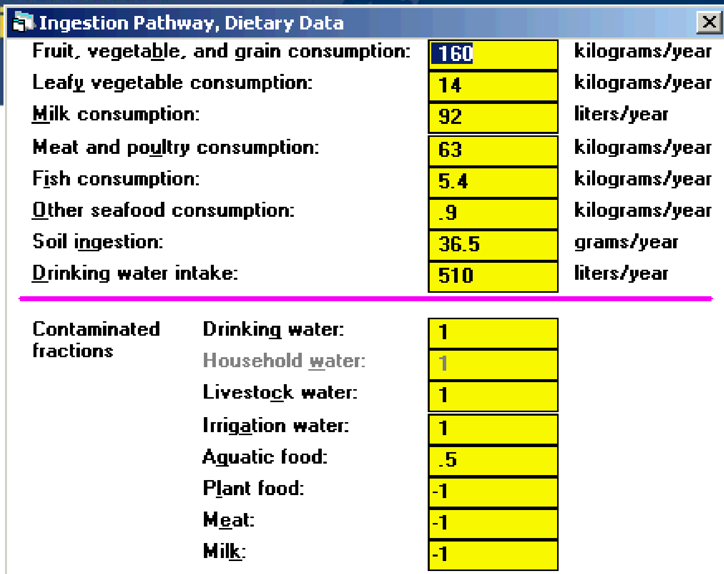
- Seafood Consumption Rates
- Meat / Dairy / Vegetable Consumption



- **Many Others (RESRAD provides default values than can be over-ridden by user.)**
- **http://web.ead.anl.gov/resrad/home2/**

Office of Nonproliferation and International Securi

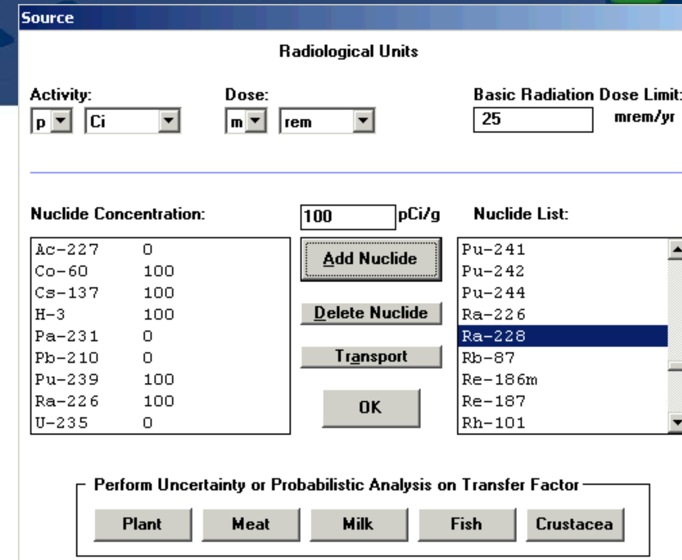
Example of RESRAD Parameters



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: p Ci   Dose: m rem   Basic Radiation Dose Limit: 25 mrem/yr

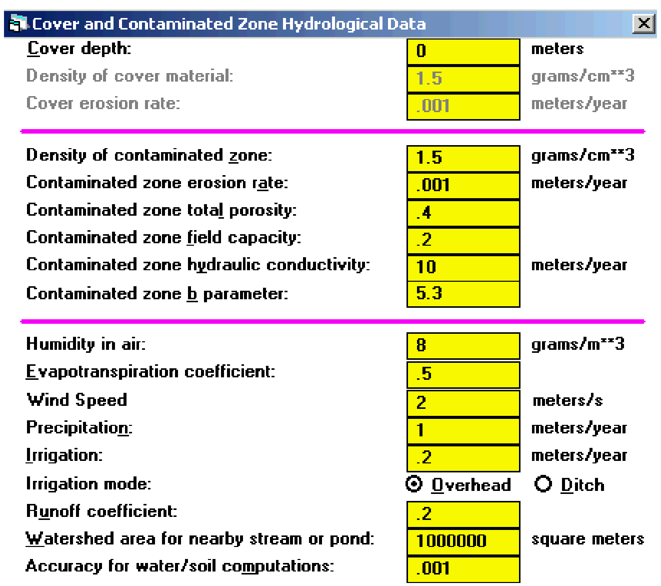
Nuclide Concentration: 100 pCi/g

Ac-227	0
Co-60	100
Cs-137	100
H-3	100
Pa-231	0
Pb-210	0
Pu-239	100
Ra-226	100
U-235	0

Add Nuclide | Delete Nuclide | Transport | OK

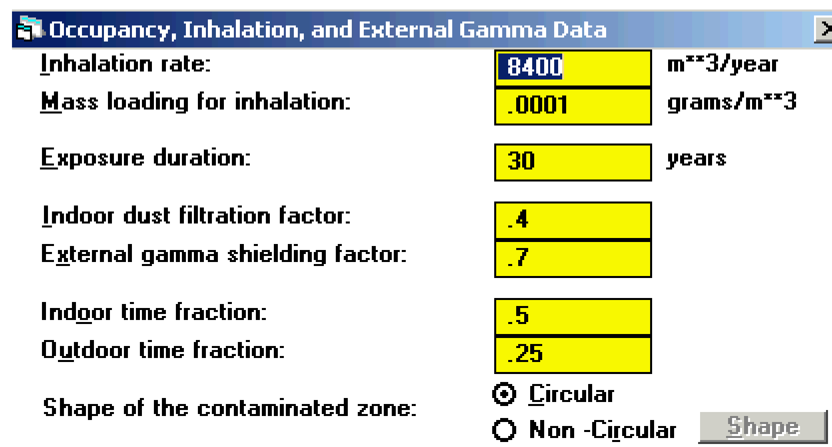
Nuclide List: Pu-241, Pu-242, Pu-244, Ra-226, Ra-228, Rb-87, Re-186m, Re-187, Rh-101

Perform Uncertainty or Probabilistic Analysis on Transfer Factor: Plant | Meat | Milk | Fish | Crustacea



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:	(•) Overhead	( ) 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:	(•) Circular	( ) Non -Circular 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.

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	MDA Solid pCi/g	MDA Air Filter pCi/sample	MDA Urine pCi/L	MDA 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 (Lc) 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)

Office of Nonproliferation and International

Table III. Gas Proportional Counting Radionuclides and Required Critical Levels (Lc) 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	[illegible]	[illegible]	[illegible]

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

Radionuclide	L_c (Concentration Corrected) Water pCi/L	Solid/Soil pCi/g	Air Filter pCi/sample	Swipe pCi/100cm²
^{3}H	200*	200[1]* (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		

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

Data Quality Objectives

Office of Nonproliferation and International

NNSA National Nuclear Security Administration

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

1. 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.

Radionuclide	f_1 Value	Ingested Water DCG (μCi/mL)	Inhaled Air DCG (μCi/mL) D	W	Y
Co-56	3.E-01	1.E-05	-	-	-
Co-57	5.E-02	2.E-04	-	7.E-09	2.E-09
	3.E-01	1.E-04	-	-	-
Co-58m	5.E-02	2.E-03	-	2.E-07	2.E-07
	3.E-01	2.E-03	-	-	-
Co-58	5.E-02	5.E-05	-	3.E-09	2.E-09
	3.E-01	4.E-05	-	-	-
Co-60m3/	5.E-02	4.E-02	-	9.E-06	6.E-06
	3.E-01	4.E-02	-	-	-
Co-60	5.E-02	1.E-05	-	4.E-10	8.E-11
	3.E-01	5.E-06	-	-	-
Cs-137 3/	1.E+00	3.E-06	4.E-10	-	-

	2.E-03	5.E-06	-	-	9.E-14
U-235	5.E-02	6.E-07	5.E-12	2.E-12	-
	2.E-03	5.E-06	-	-	1.E-13
U-236	5.E-02	5.E-07	5.E-12	2.E-12	-
	2.E-03	6.E-06	-	-	1.E-13
U-237	5.E-02	5.E-05	6.E-09	4.E-09	-
	2.E-03	5.E-05	-	-	4.E-09
U-238	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"**

Office of
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and International
Sec

Chain of Custody

Sample Management and Custody
Administrative Operating Procedure

ATTACHMENT A
ANALYSIS REQUEST/CHAIN OF CUSTODY (ARCOC)

CONTRACT LABORATORY
ANALYSIS REQUEST AND CHAIN OF CUSTODY

Internal Lab

Page _1_ of __

Batch No. SMO Use AR/COC

Dept. No./Mail Stop:	Date Samples Shipped:	Project/Task No.:
Project/Task Manager:	Carrier/Waybill No.	SMO Authorization:
Project Name:	Lab Contact:	Contract #
Record Center Code:	Lab Destination:	
Logbook Ref. No.:	SMO Contact/Phone:	
Service Order No.:	Send Report to SMO:	

☐ Waste Characterization
Send Preliminary/Copy Report to:
☐ Validation Required
☐ Released by COC No.:
Bill To: Sandia National Labs (Accounts Payable)
P.O. Box 5800, MS-0154
Albuquerque, NM., 87185-0154

Location	Tech Area
Building	Room

Reference LOV(available at SMO)

Sample No.-Fraction	ER Sample ID or Sample Location Detail	Beginning Depth (ft)	ER Site No.	Date/Time(hr) Collected	Sample Matrix	Container Type	Container Volume	Preservative	Collection Method	Sample Type	Parameter & Method Requested	Lab Sample ID

RMMA	☐ Yes ☐ No	Ref. No.	Sample Tracking	SMO Use
Sample Disposal	☐ Return to Client	☐ Disposal by lab	Date Entered(mm/dd/yy)	
Turnaround Time	☐ 7 Day * ☐ 15 Day *	☐ 30 Day	Entered by:	
Return Samples By:		☐ Negotiated TAT	QC inits.	

Special Instructions/QC Requirements:
EDD ☐ Yes ☐ No
Level D Package ☐ Yes ☐ No
*Send/e-mail report to:

*Please list as separate report.

Abnormal Conditions on Receipt

Lab Use

Sample Team Members	Name	Signature	Init	Company/Organization/Phone/Cellular

1.Relinquished by	Org.	Date	Time	4.Relinquished by	Org.	Date	Time
1. Received by	Org.	Date	Time	4. Received by	Org.	Date	Time
2.Relinquished by	Org.	Date	Time	5.Relinquished by	Org.	Date	Time
2. Received by	Org.	Date	Time	5. Received by	Org.	Date	Time
3.Relinquished by	Org.	Date	Time	6.Relinquished by	Org.	Date	Time
3. Received by	Org.	Date	Time	6. Received by	Org.	Date	Time

Office of Nonproliferation and International Security (NIS)

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

A Real World Example

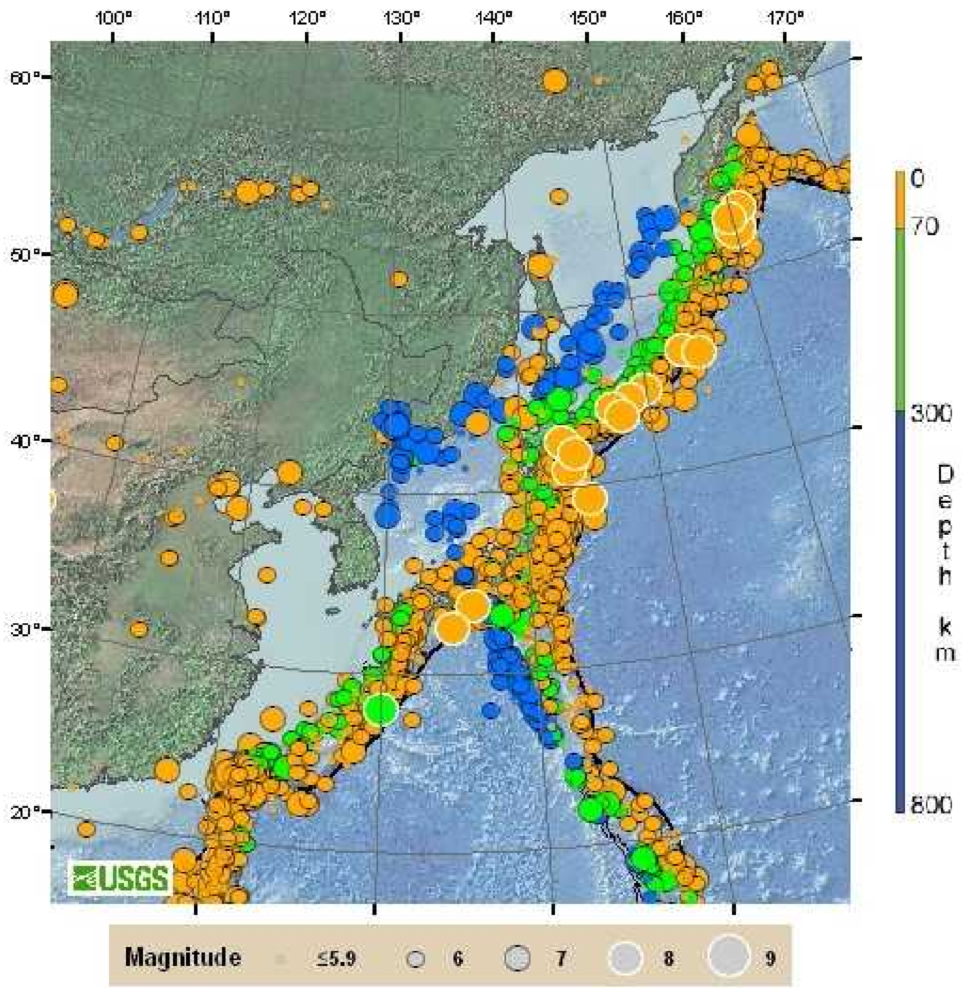
The M9.0 Tohoku Earthquake and Tsunami of 11 March 2011 Impact on the Fukushima Nuclear Power Station

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.

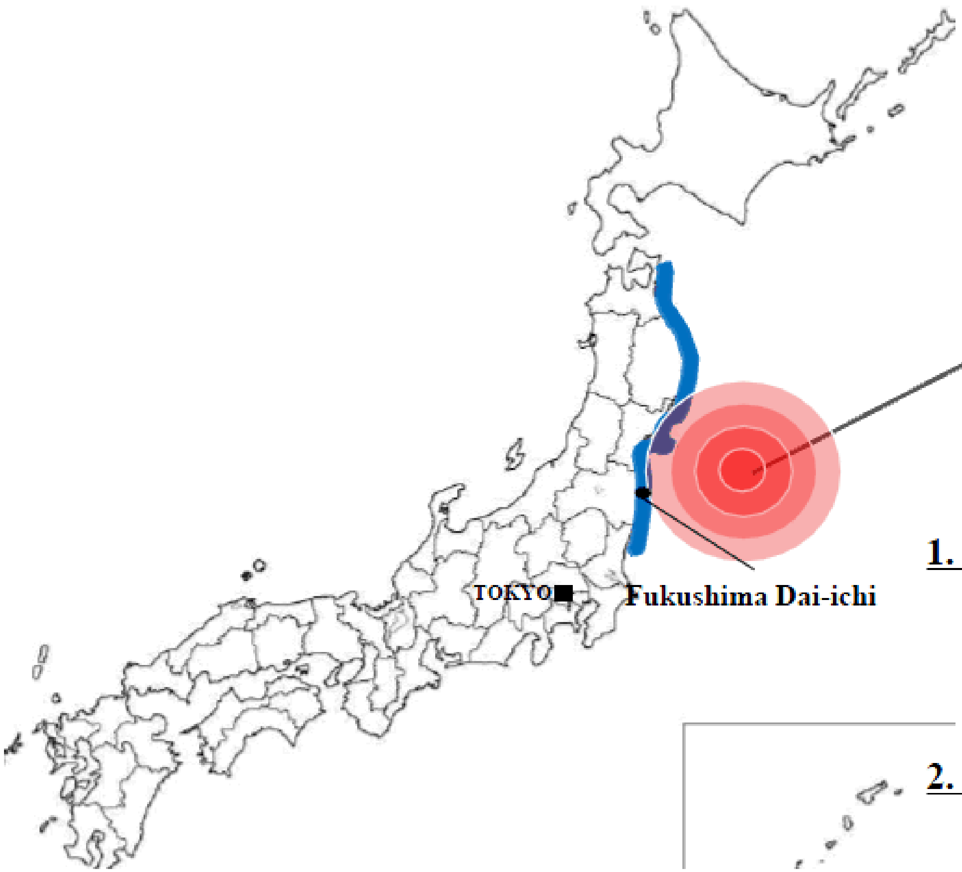
Historically, it was known that a great earthquake associated with a huge tsunami occurred in 869 and killed more than 1000 people.



USGS Slides from Dr. Lind Gee, Albuquerque USGS

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

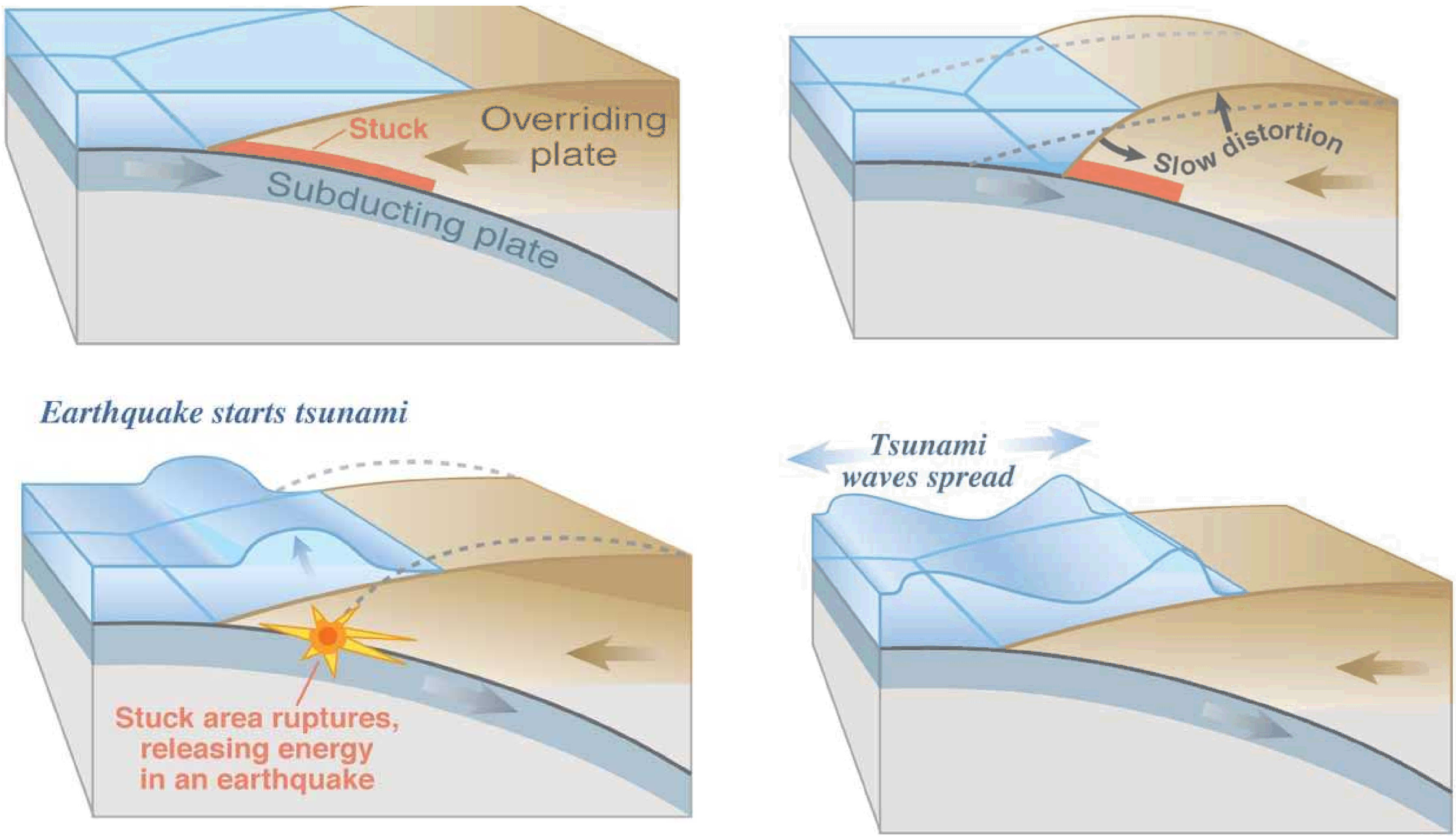
Dead	over 13,000
Missing	over 14,000

2. Evacuees : over 136,000

(As of April 17th)

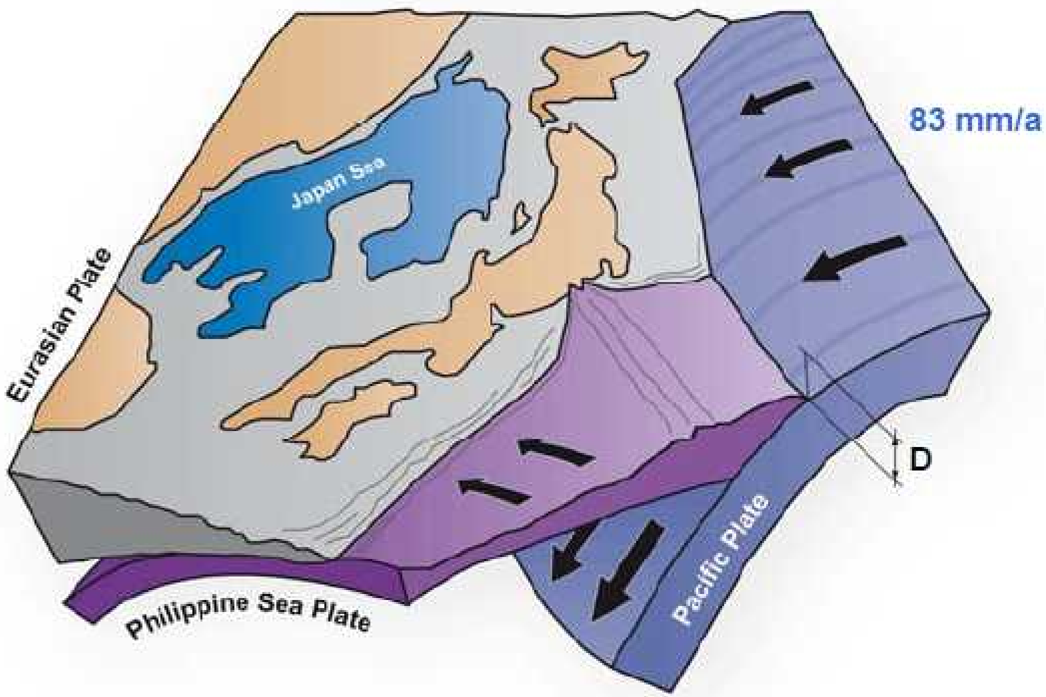
Tsunami Generation

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



Tohoku-Taiheiyou-Oki Earthquake

VGB POWERTECH



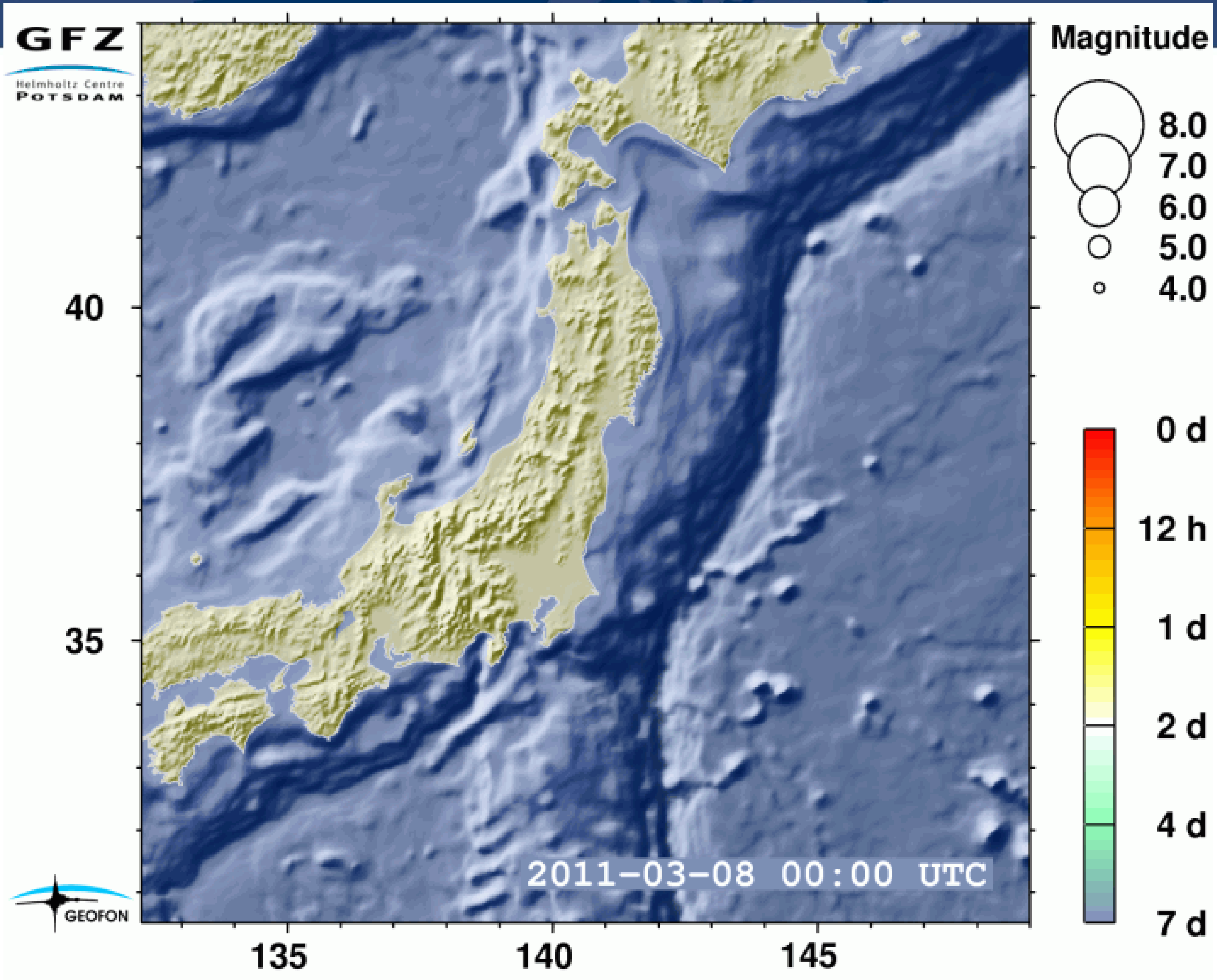
- **Vertical Displacement**
  $D \approx 7$ to 10 m
- **Peak Displacement**
  $D_{max} \approx 17$ to 25 m [1])
- **Rupture Zone**
  $A \approx 500$ km x 100 km
- **Hypo Center Depth**
  $Z_H \approx 20$ to 25 km
- **Crack Velocity**
  $v \approx 2$ km/s
- **Water Depth**
  $Z \approx 8$ km

- **Rough Estimate of Water Volume Involved**
  $V \approx A \cdot \frac{1}{4} D \approx 500 \text{ km} \cdot 100 \text{ km} \cdot 2{,}5 \text{ m} = 125 \text{ km}^3$
- **Consequence:** Sudden displacement of a huge water volume ► **Tsunami.**

Source: Dr. Hein Meidow, Cologne, 2011 JST: Japan Standard Time UTC: Coordinated Universal Time [1]) in deep underground

Office of Nonproliferation and International Security (NIS)

Seismicity Animation



Office of Nonproliferation and International Security (NIS)

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?

Office of Nonproliferation and International Security (NIS)

Regional Training Workshops

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

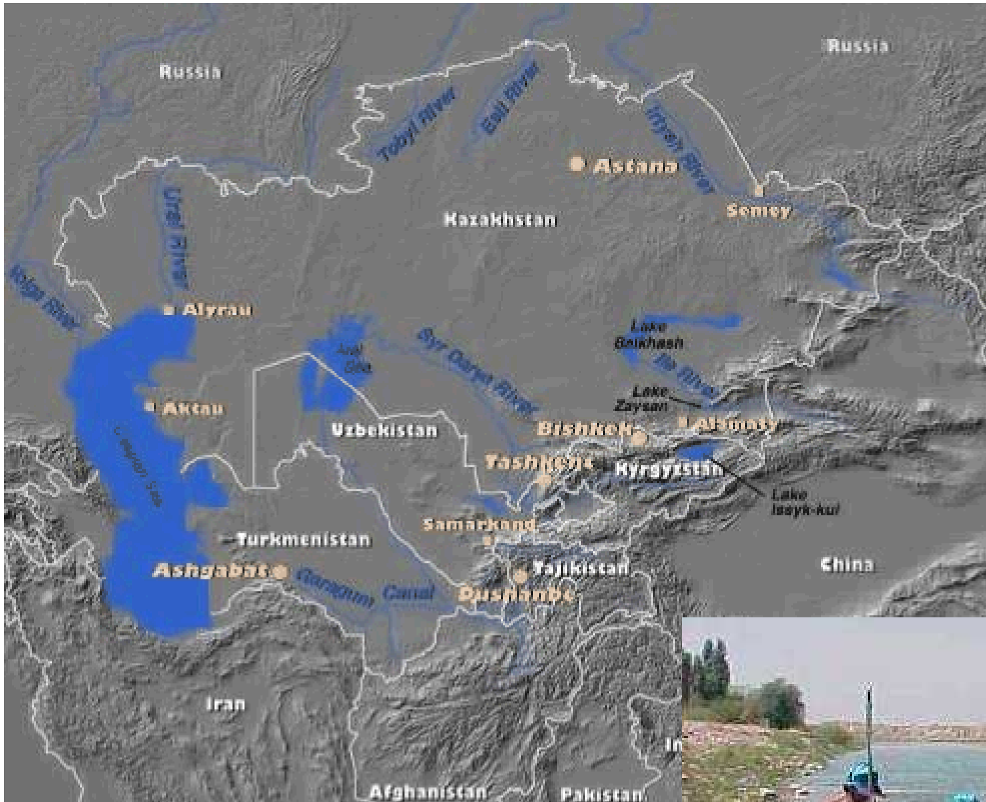
Radiation Measurements Standards in the Middle East

- 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

Thank You!

EXTRA SLIDES

Criteria for Use in Preparedness and Response for a Nuclear or Radiological Emergency, IAEA General Safety Guide, No. GSG-2, 2011.

IAEA Safety Standards

for protecting people and the environment

Criteria for Use in Preparedness and Response for a Nuclear or Radiological Emergency

Jointly sponsored by the
FAO, IAEA, ILO, PAHO, WHO

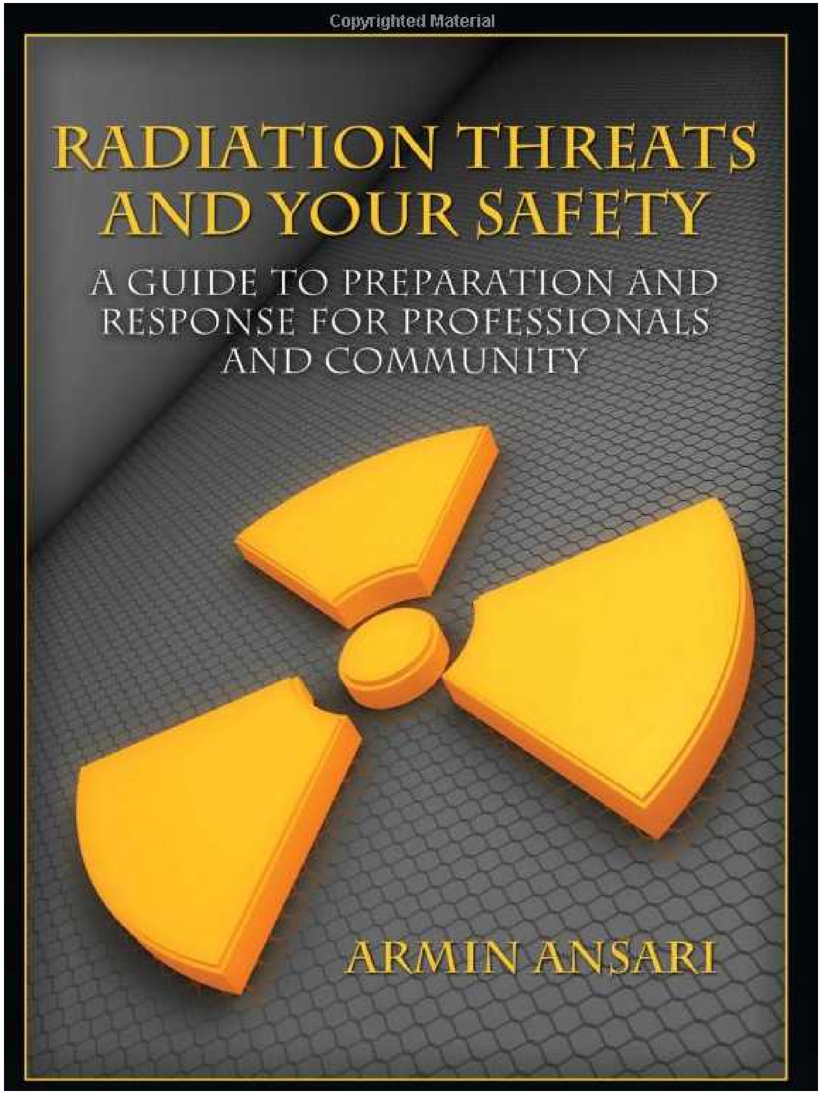
IAEA WHO

General Safety Guide

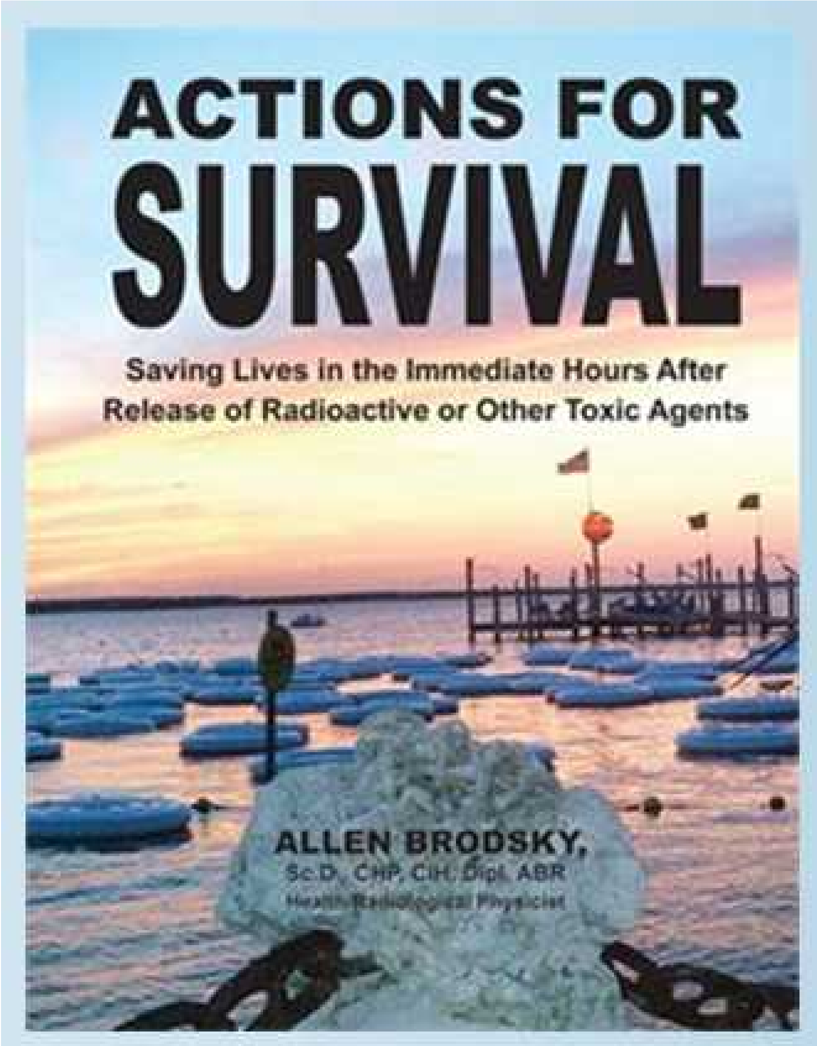
No. GSG-2

IAEA
International Atomic Energy Agency

Radiation Threats and Your Safety: A Guide to Preparation and Response for Professionals and Community , 2010, $75.



[Actions for Survival: *Saving Lives in the Immediate Hours after Release of Radioactive or Other Toxic Agents*]. by Allen Brodsky



Fukushima Event Evolution

"Before Earthquake" Photo


Incoming Tsunami


Tsunami Floodwater

All Emergency Shutdown Systems WORKED (Initially)

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

Post-quake Tsunami Hits Coast

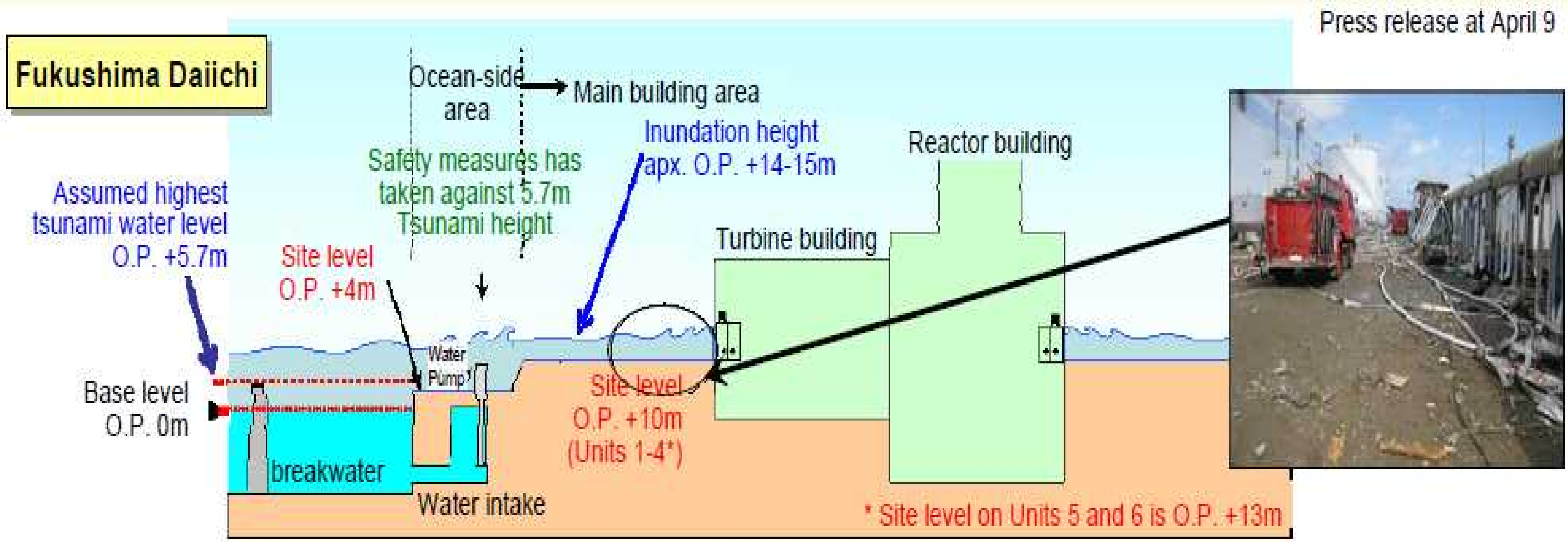
- **Massive Damage**
- **Destroys Electric Power Grid (which supplied power for "routine" plant operations)**
- **Emergency Diesel Generators Started, as Designed**
    - ➢ **HOWEVER, tsunami washed diesel fuel storage tanks away! Pumps ran ~ 8 hrs on battery backup.**

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



O.P.：Onahama bay construction base level

Office of Nonproliferation

View of explosion / Steam venting

Office of Nonproliferation and International Security (NIS)

Monday, March 14

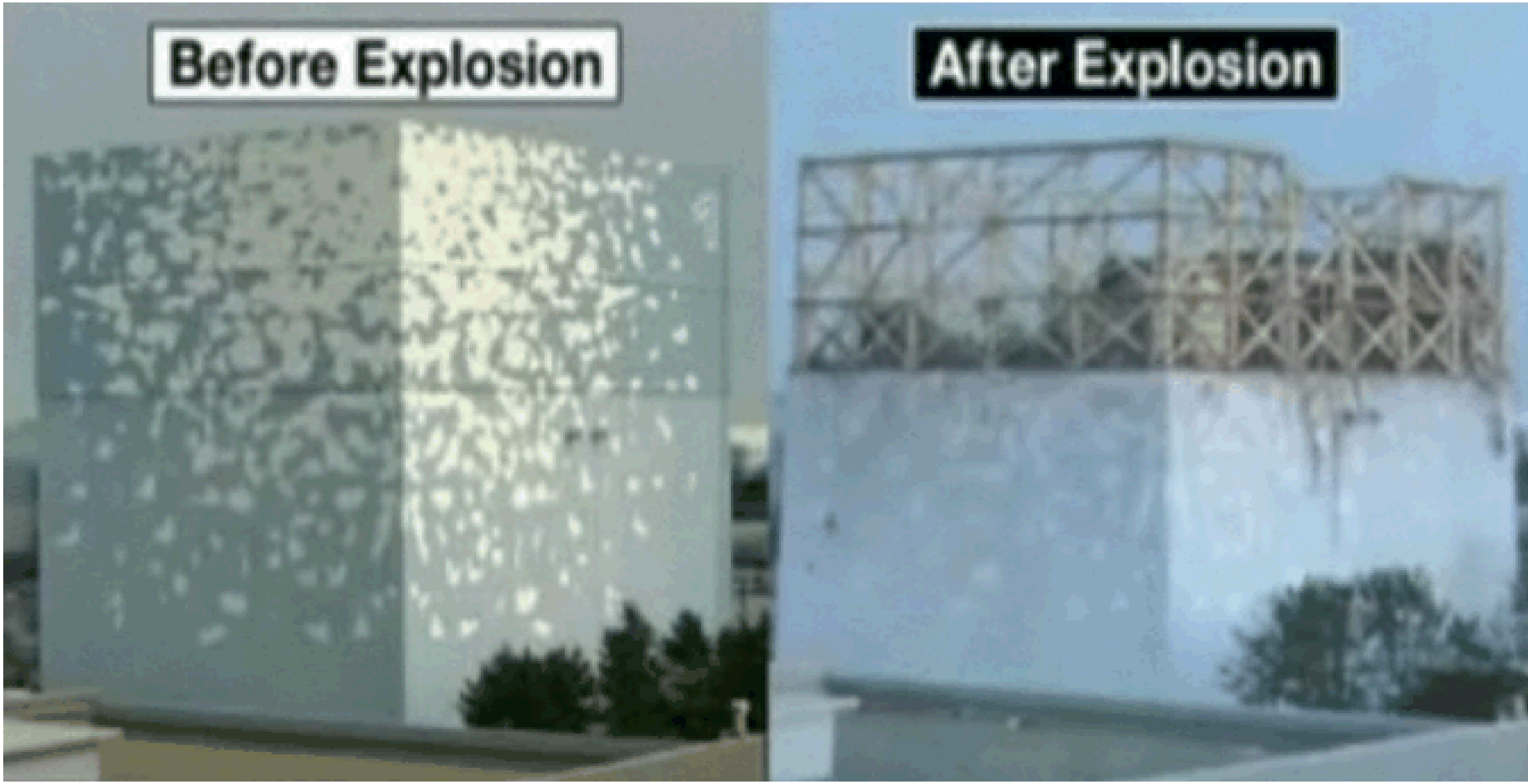
Monday's blast destroyed the containment building but the reactor is still intact. Japanese officials also said cooling systems have failed at a third reactor.

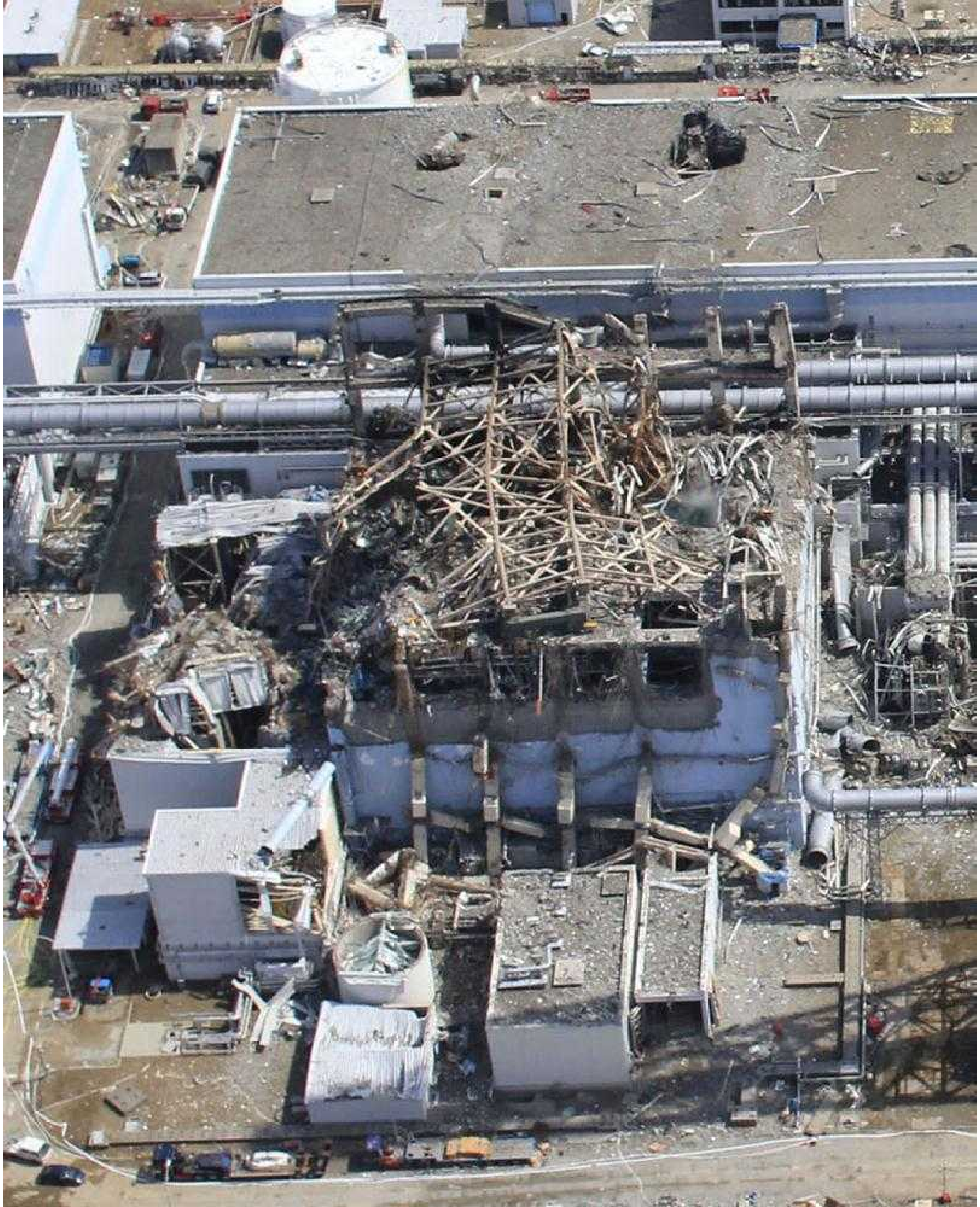
In this image made off NTV/NNN Japan television footage, smoke ascends from the Fukushima Dai-ichi nuclear plant's Unit 3 in Okumamachi, Fukushima Prefecture, northern Japan, March 14. The second hydrogen explosion in three days rocked Japan's stricken nuclear plant Monday, sending a massive column of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

NTV/NNN Japan/AP

Office of Nonproliferation and International Security (NIS)

View of explosion / Steam venting

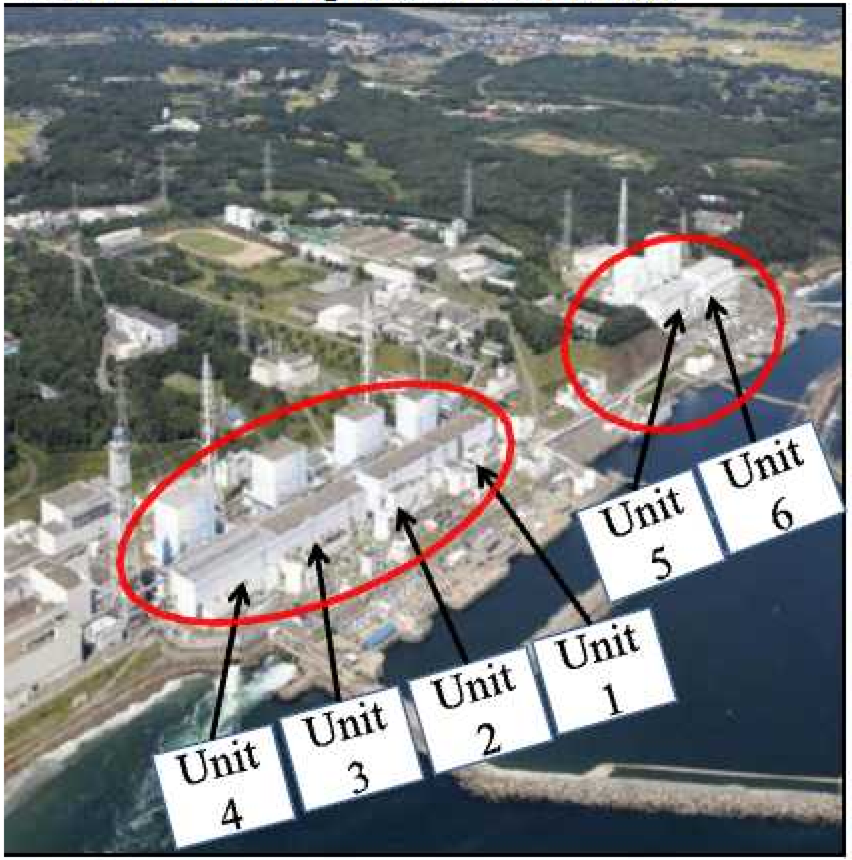

Before Explosion
After Explosion




Explosion
Damage

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

Fukushima Daiichi Nuclear Power Plant

Okuma, Japan

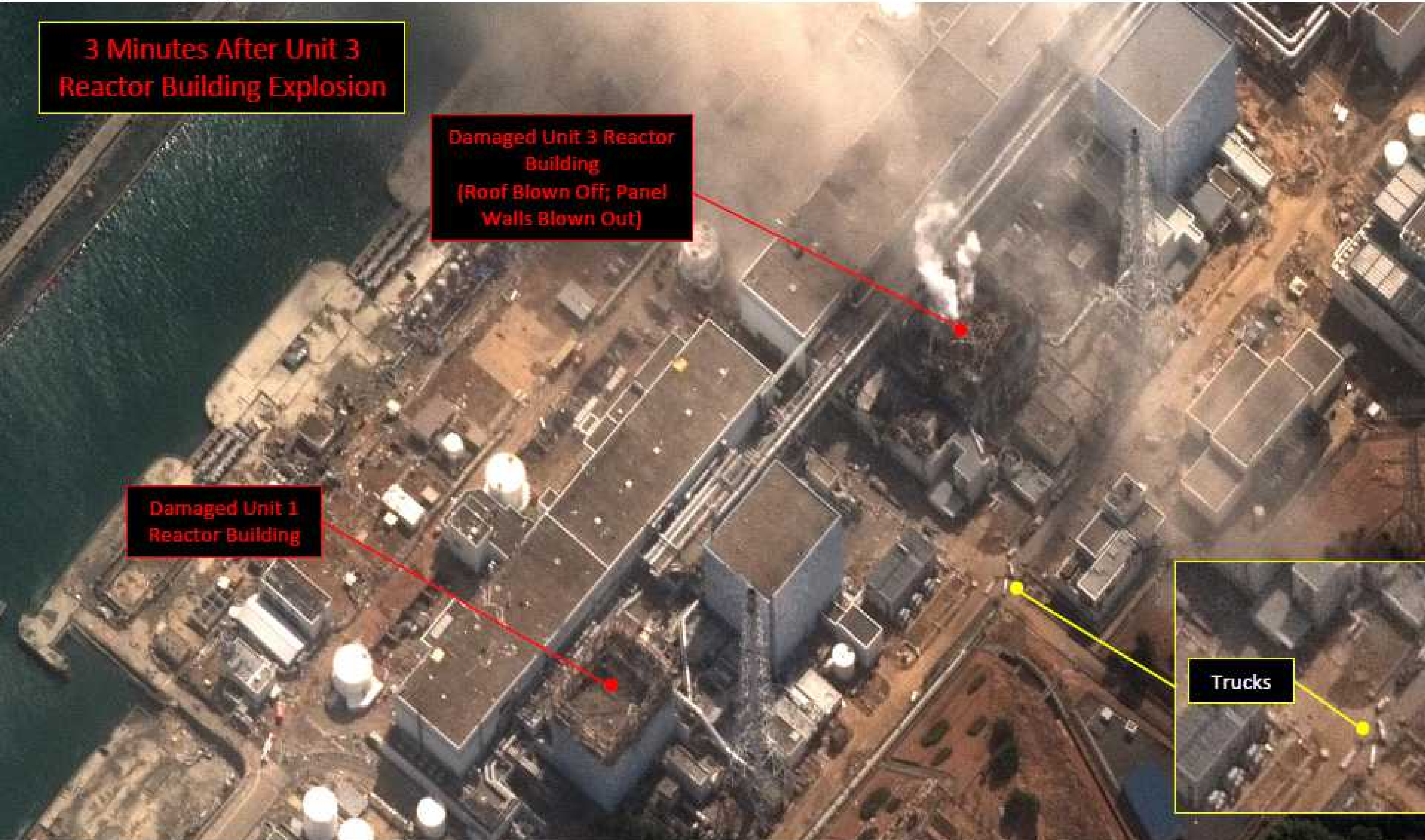
37 25 18N 141 01 56E

DigitalGlobe's Natural Color Satellite Image

Fukushima Daiichi Nuclear Power Plant

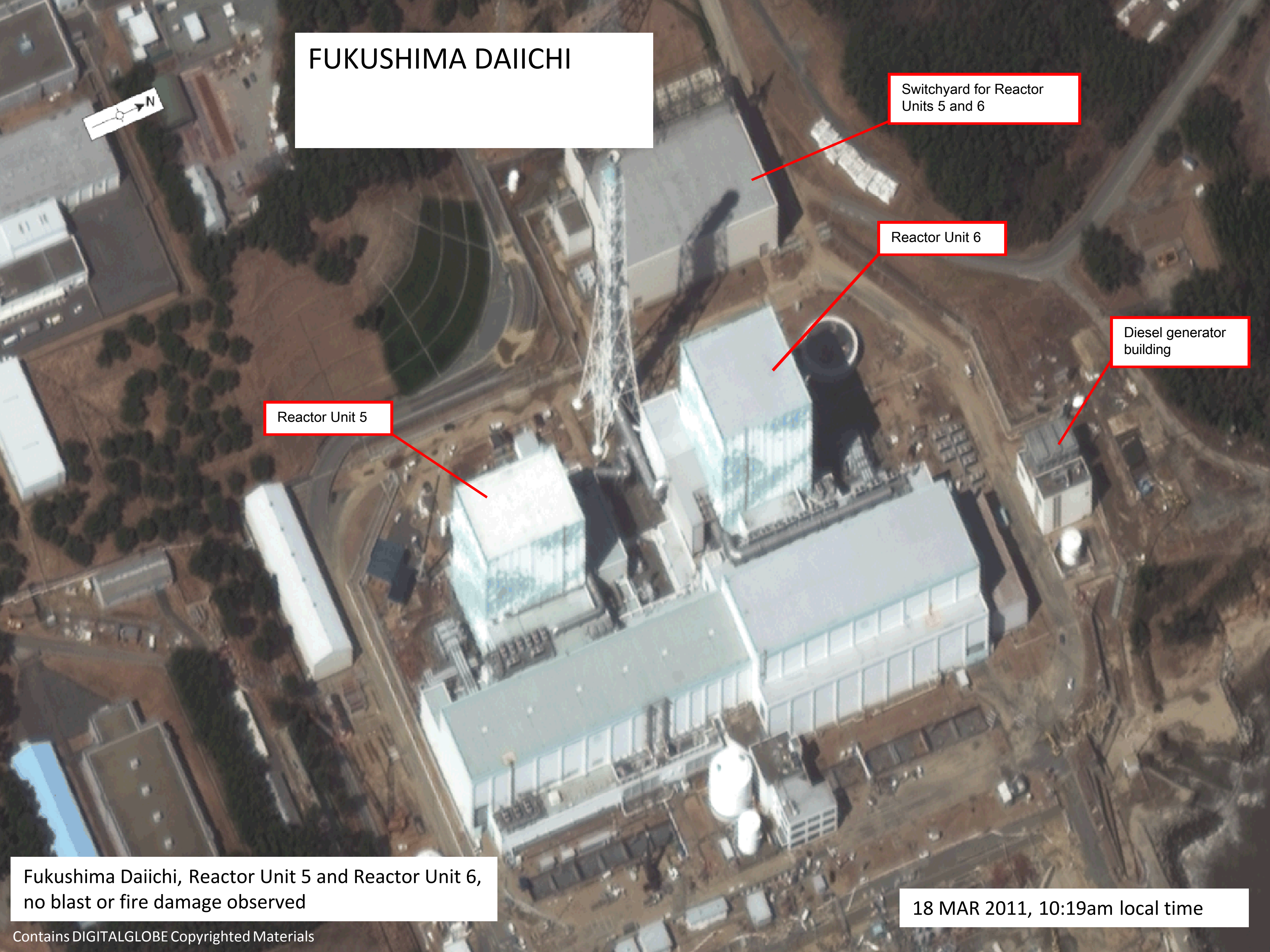
Okuma, Japan

37 25 18N 141 01 56E



DigitalGlobe's Natural Color Satellite Image

FUKUSHIMA DAIICHI

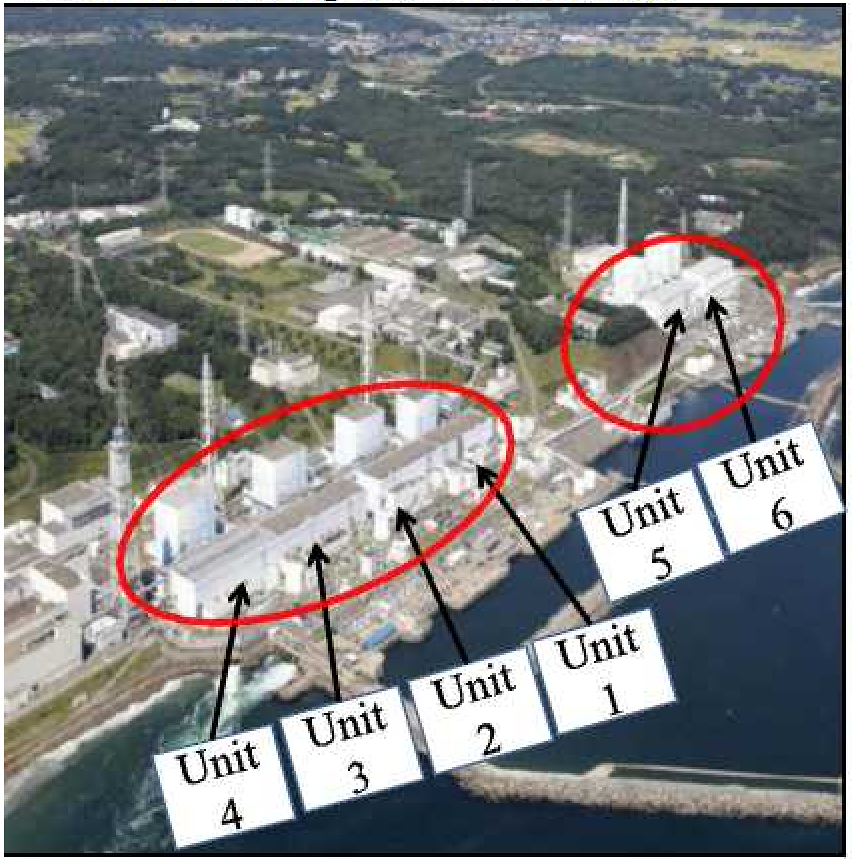


Fukushima Daiichi, Reactor Unit 5 and Reactor Unit 6, no blast or fire damage observed


Explosion Damage

3. Nuclear Power Stations
Fukushima Dai-ichi Nuclear Power Station

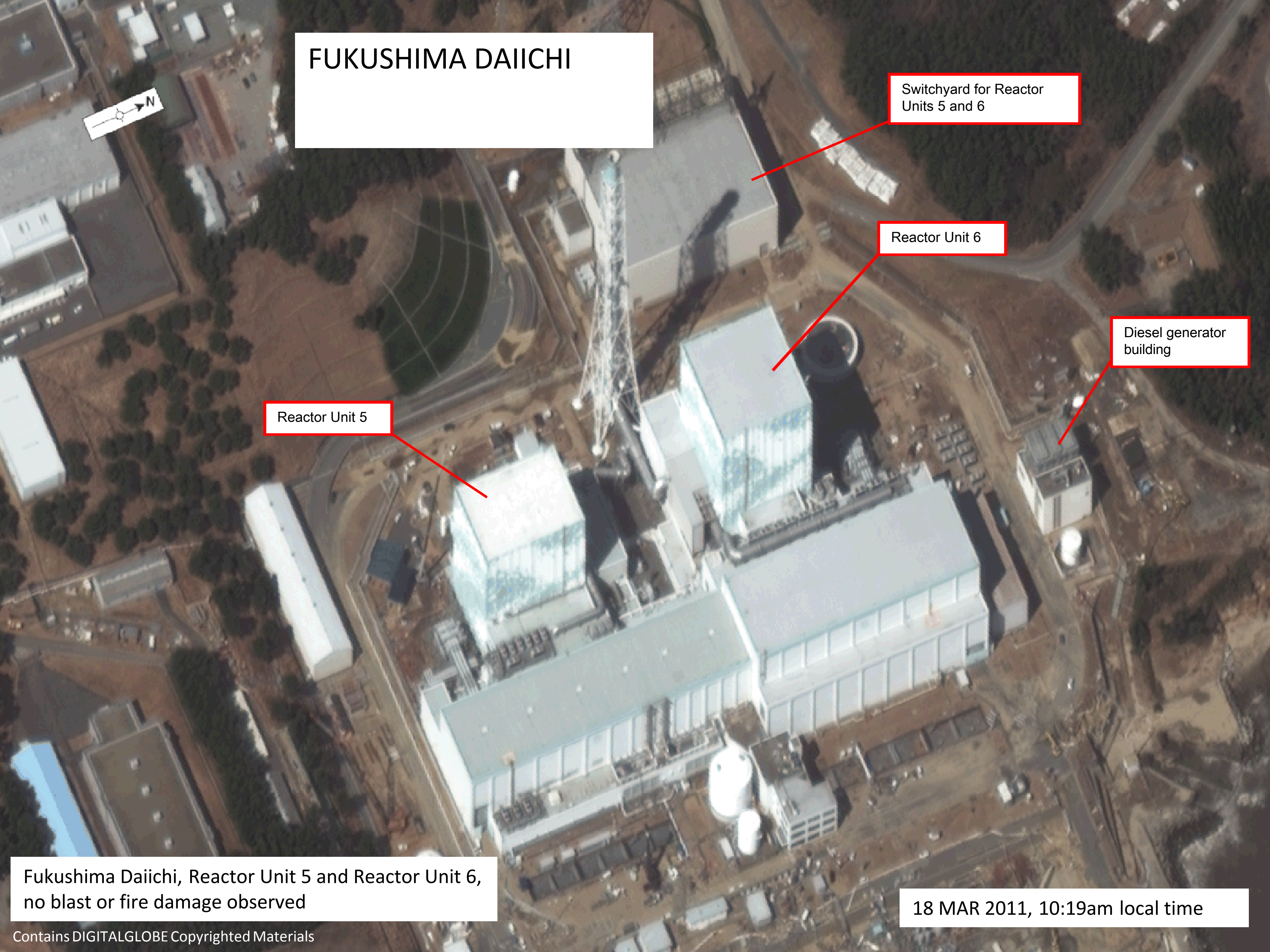
Before the Earthquake and Tsunamis



TEPCO

After the Earthquake and Tsunamis

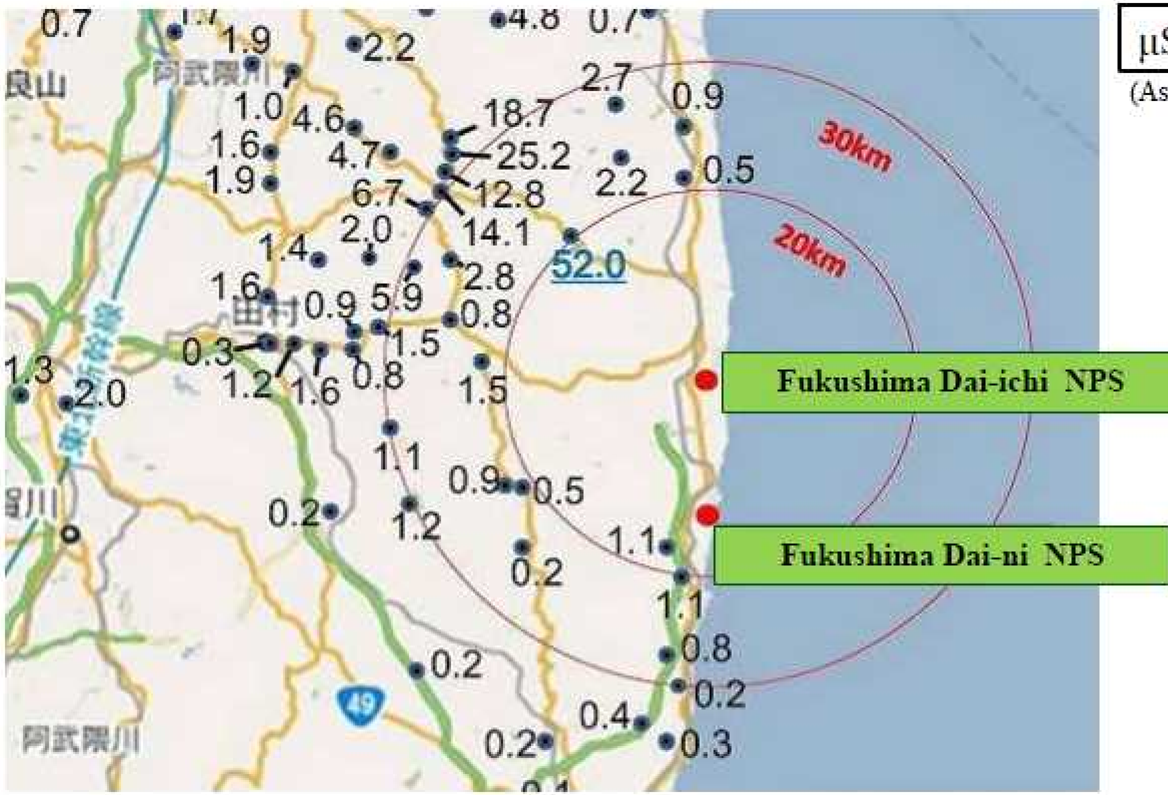
Air Photo Service Inc (Myoko, Niigata Japan)



FUKUSHIMA DAIICHI
N
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
Contains DIGITALGLOBE Copyrighted Materials

Fire Trucks

3. Nuclear Power Stations
Fukushima Dai-ichi Nuclear Power Station



μSv/hour

(As of Apr.10th)

20 km radius of the plant and other designated areas → to evacuate

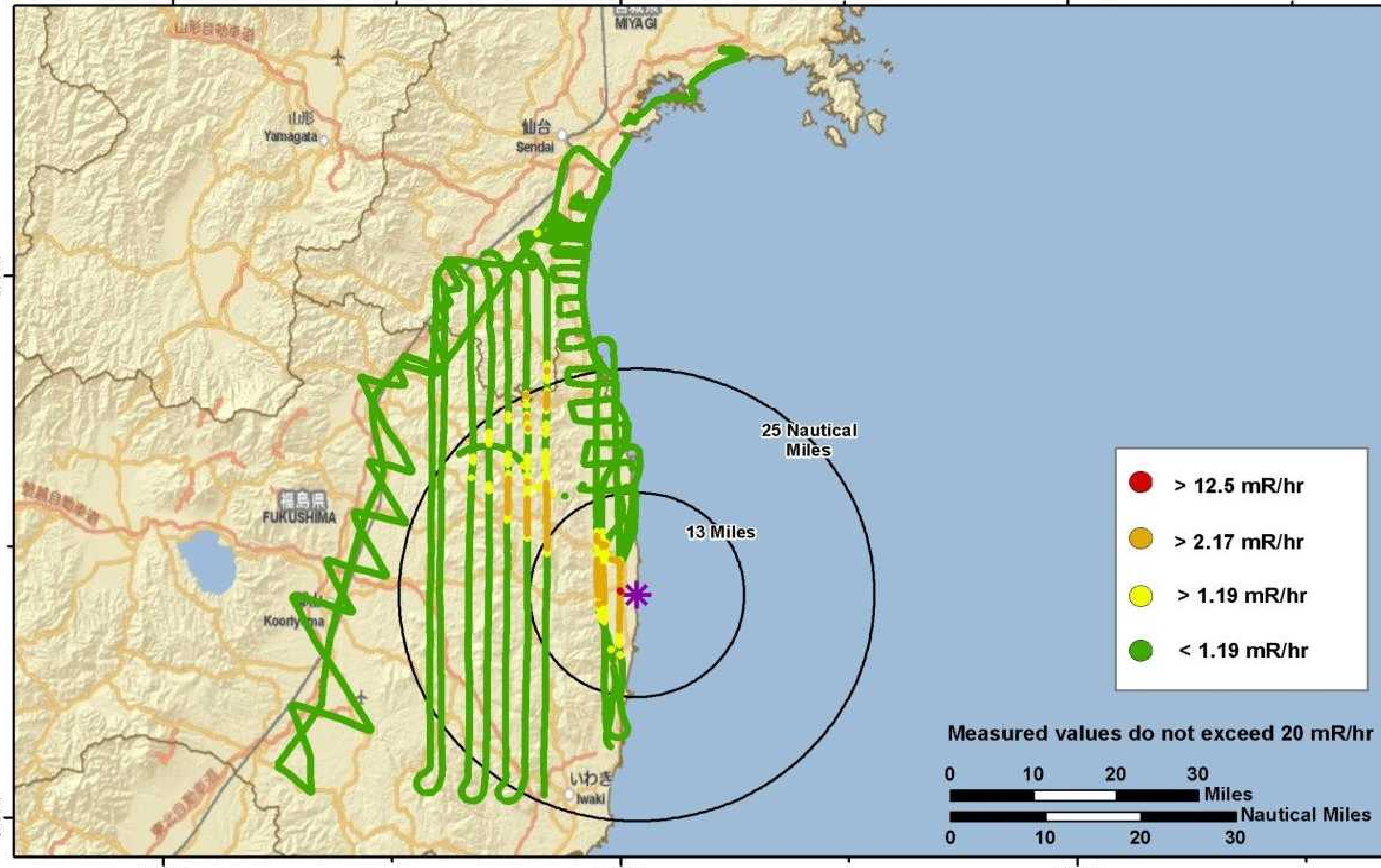
20 to 30 km radius of the plant → to shelter indoors

NNSA National Nuclear Security Administration

Aerial Monitoring Results

Combined UH-1 and C-12 Flights (March 24 & 26, 2011)

FUKUSHIMA DAIICHI
JAPAN



Map created on 03272011 0220 JST

Name: NIT Combined C12 and UH1 26Mar2011 Results

UNCLASSIFIED

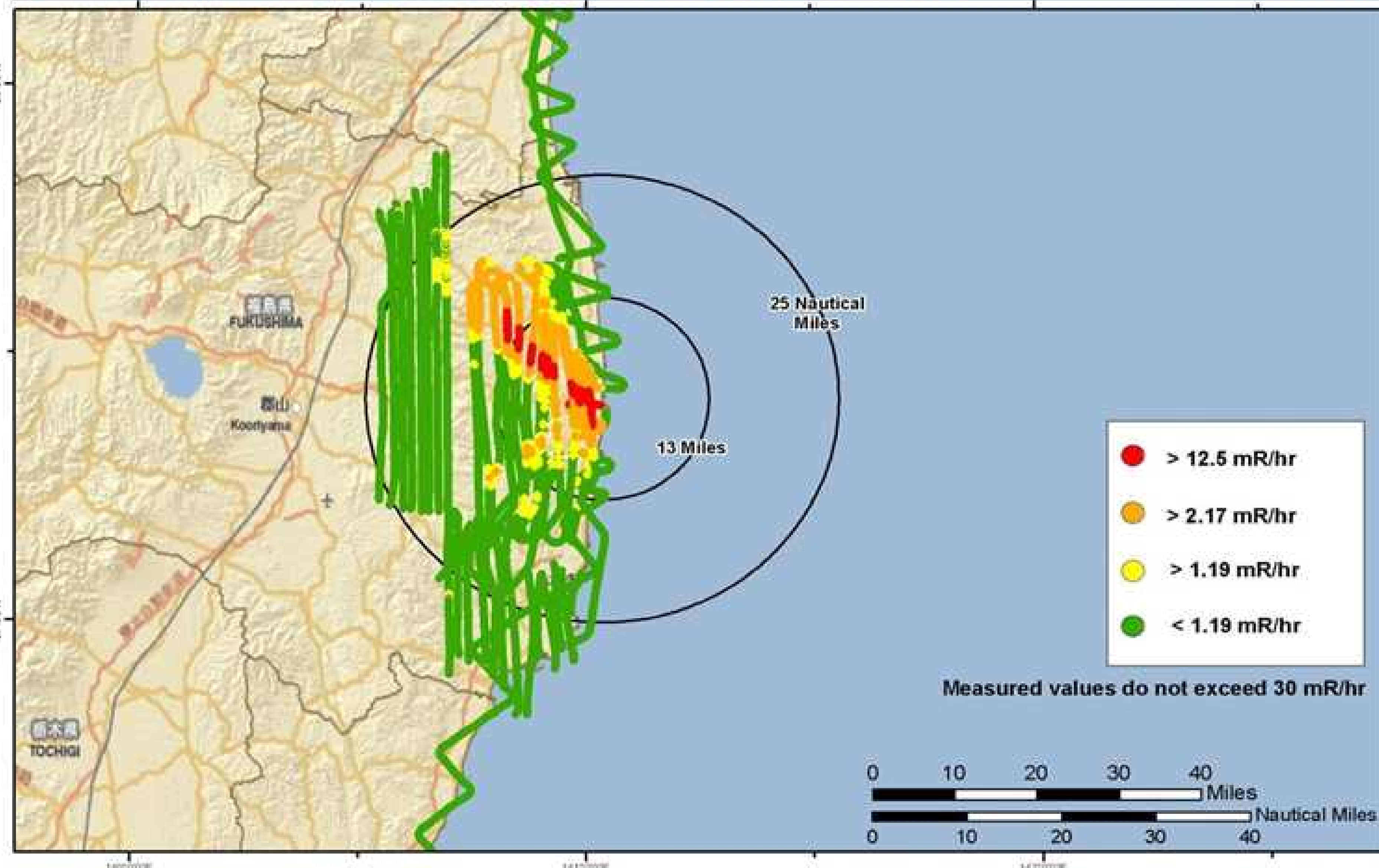
Nuclear Incident Team DOE NIT
Contact (202) 586 - 8100

Aerial Monitoring Results - C-12

Survey Date - 17, 18, 19 March 2011

FUKUSHIMA DAIICHI
JAPAN

NNSA National Nuclear Security Administration



Map created on 03232011 0210 JST

Name: NIT_C-12 23Mar2011 v4

Nuclear Incident Team DOE NIT

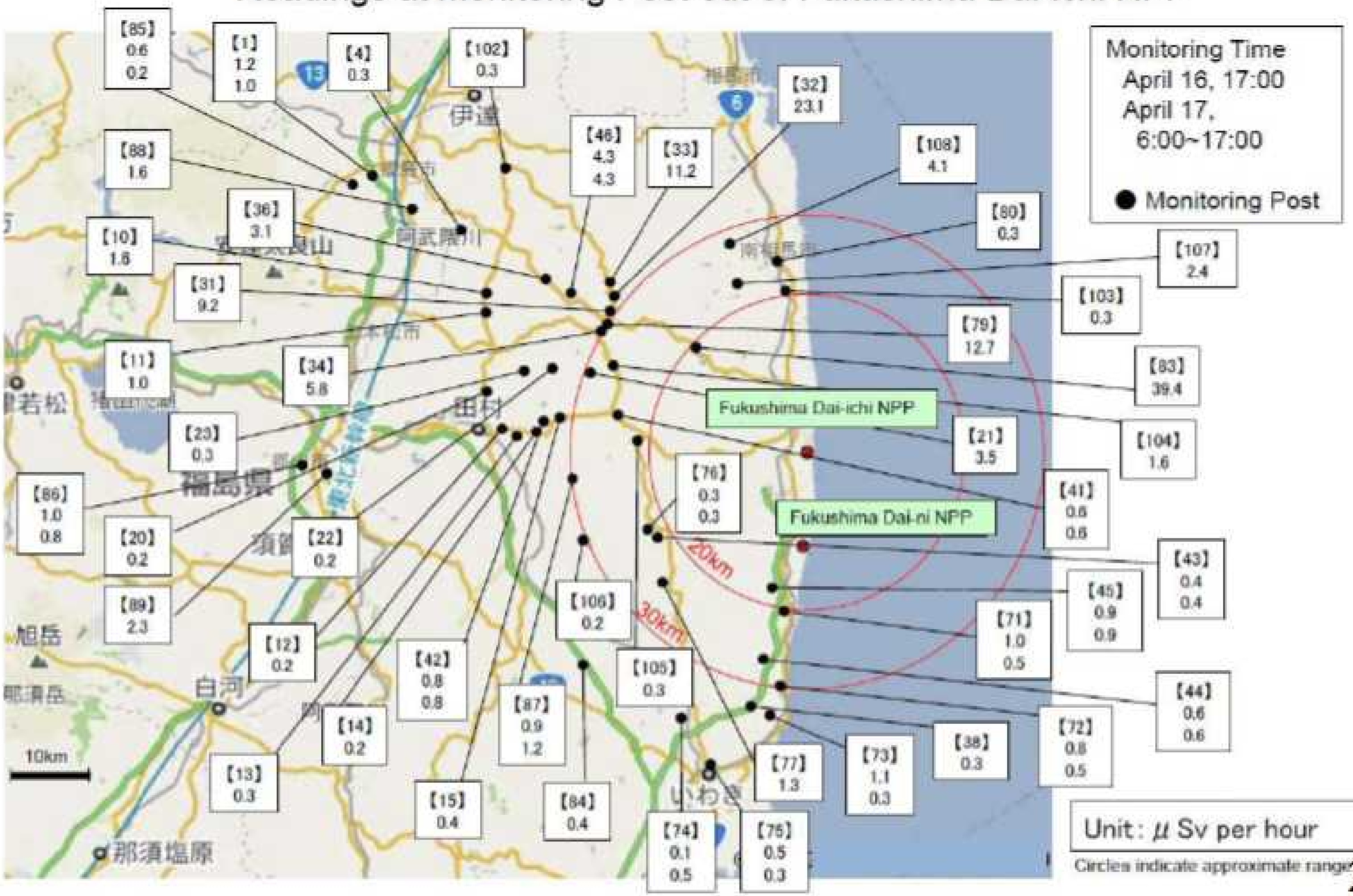
2. Contain the Spread of Radioactive Substances
(sea, soil and atmosphere)

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

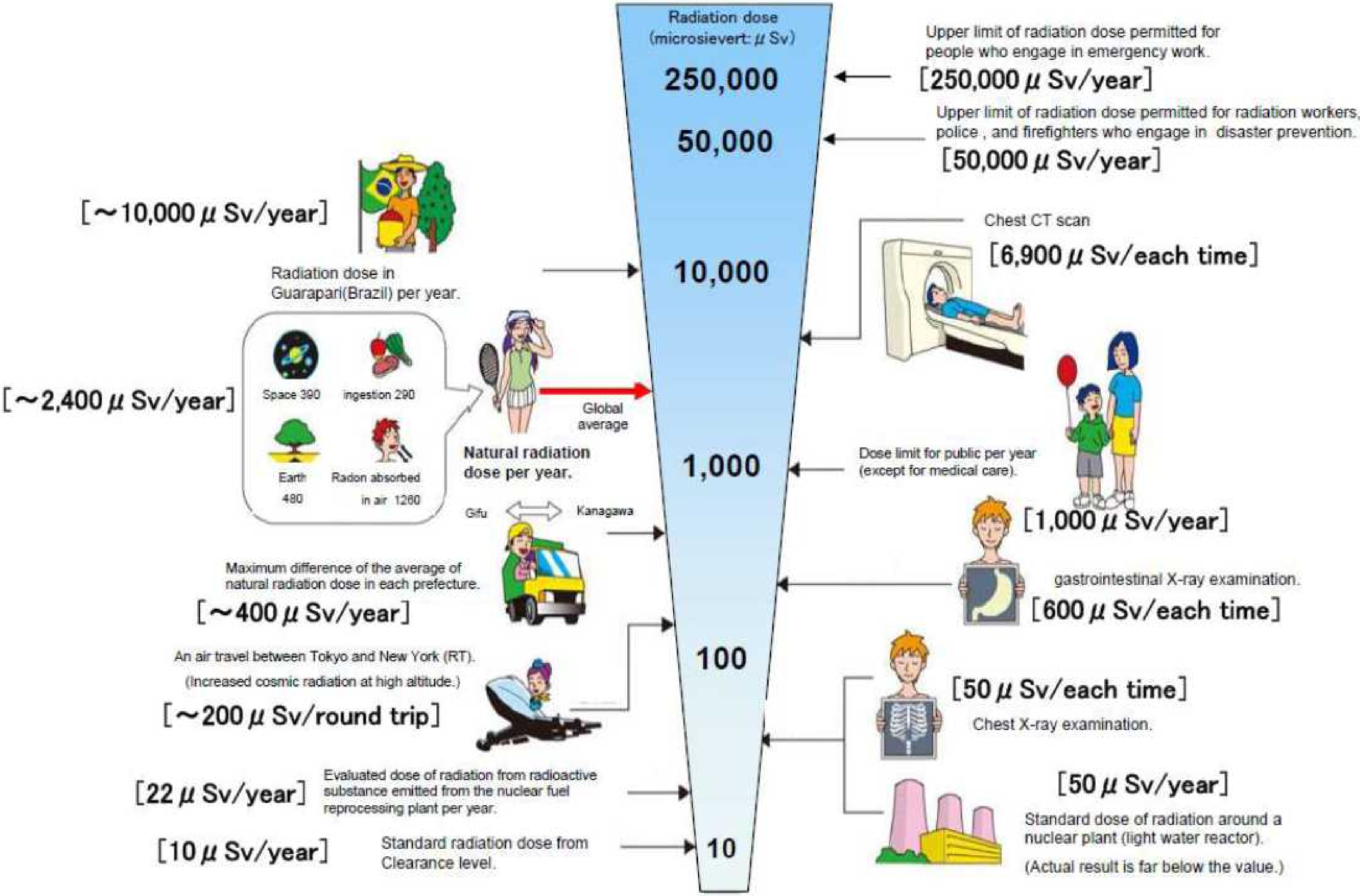
Spraying synthetic materials on the surface of the ground and debris to prevent radioactive substances dispersion

Readings at Monitoring Posts out of Fukushima Dai-ichi NPS

Readings at Monitoring Post out of Fukushima Dai-ichi NPP



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 occured
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

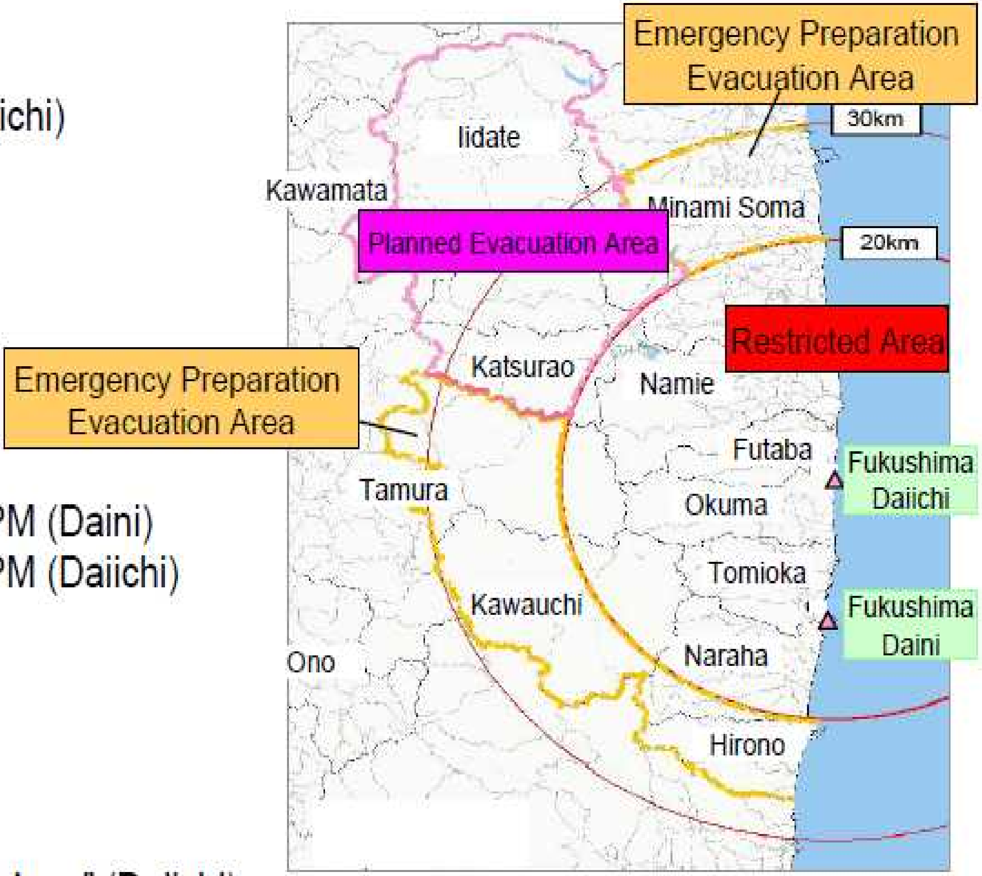
5:44 10 km radius evacuation (Daiichi)
7:45 3 km radius evacuation (Daini)
10 km radius taking shelter (Daini)
17:39 10 km radius evacuation directed by the PM (Daini)
18:25 20 km radius evacuation directed by the PM (Daiichi)

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)



Source: NISA website

Fri, 22 April

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

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 1st floor From northern double doors to elevator	Reactor building 1st floor Around southern double doors
Radiation dose	49mSv/h(Maximum) 10mSv/h(Minimam)	57mSv/h(Maximam) 28mSv/h(Minimam)
Temperature	About 28～29℃	About 19～22℃
Humidity	About 49～56%	About 32～35%
oxygen density	About 21%	About 21%

(provisional figure)

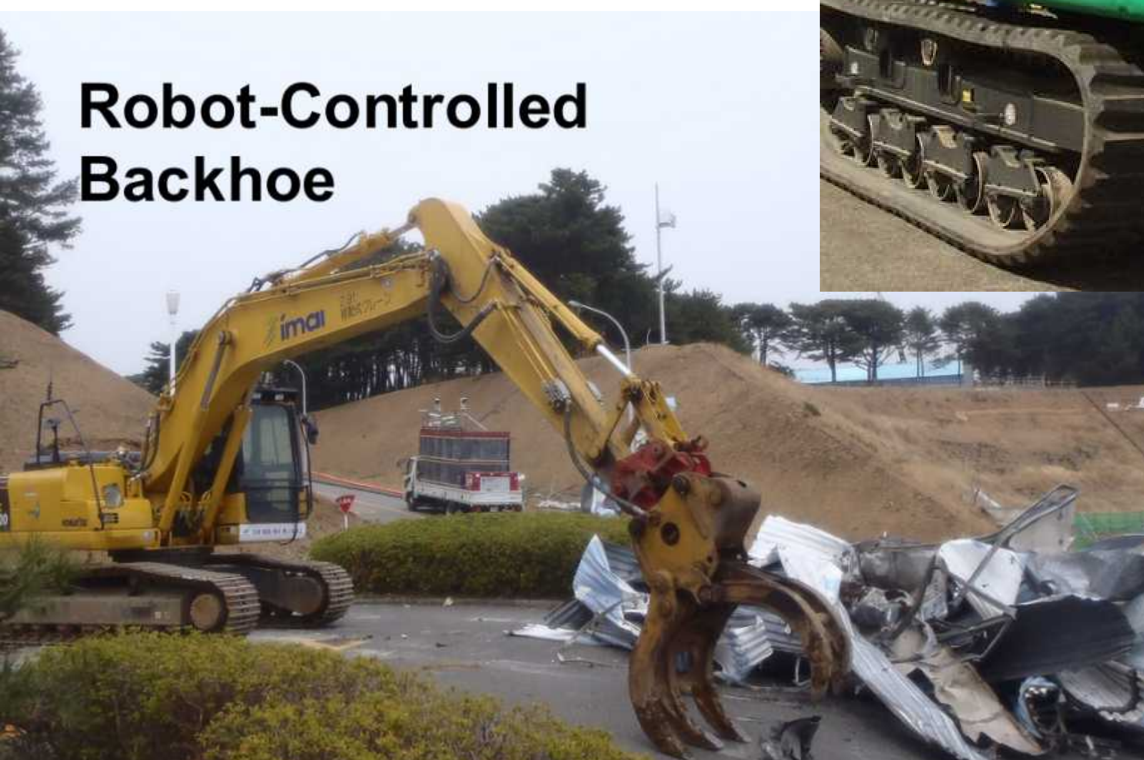
<The list of provided robots>

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	○	◎	○	○

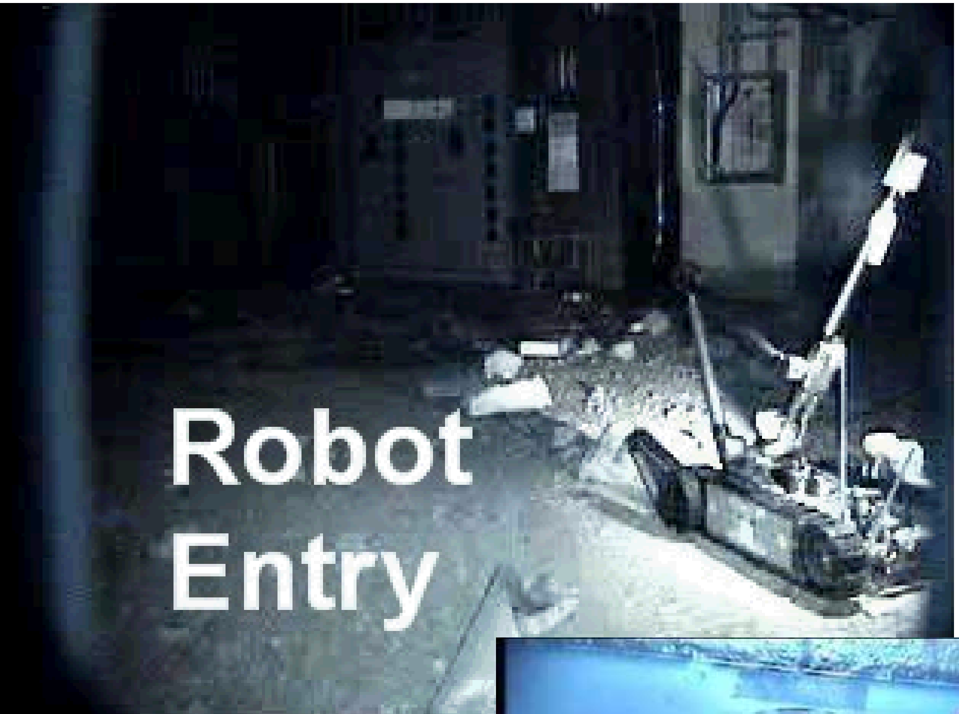

iRobot

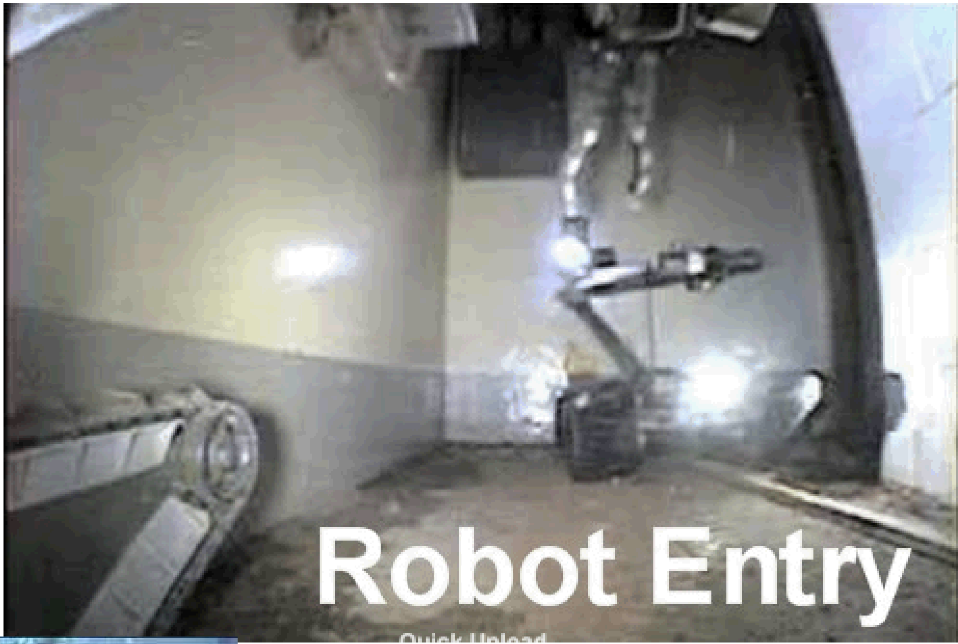

Robot on
Obstacle Course
photo : Wataru Umehara


Robotically Conrolled
Track Vehicle
かたつむり
1号機

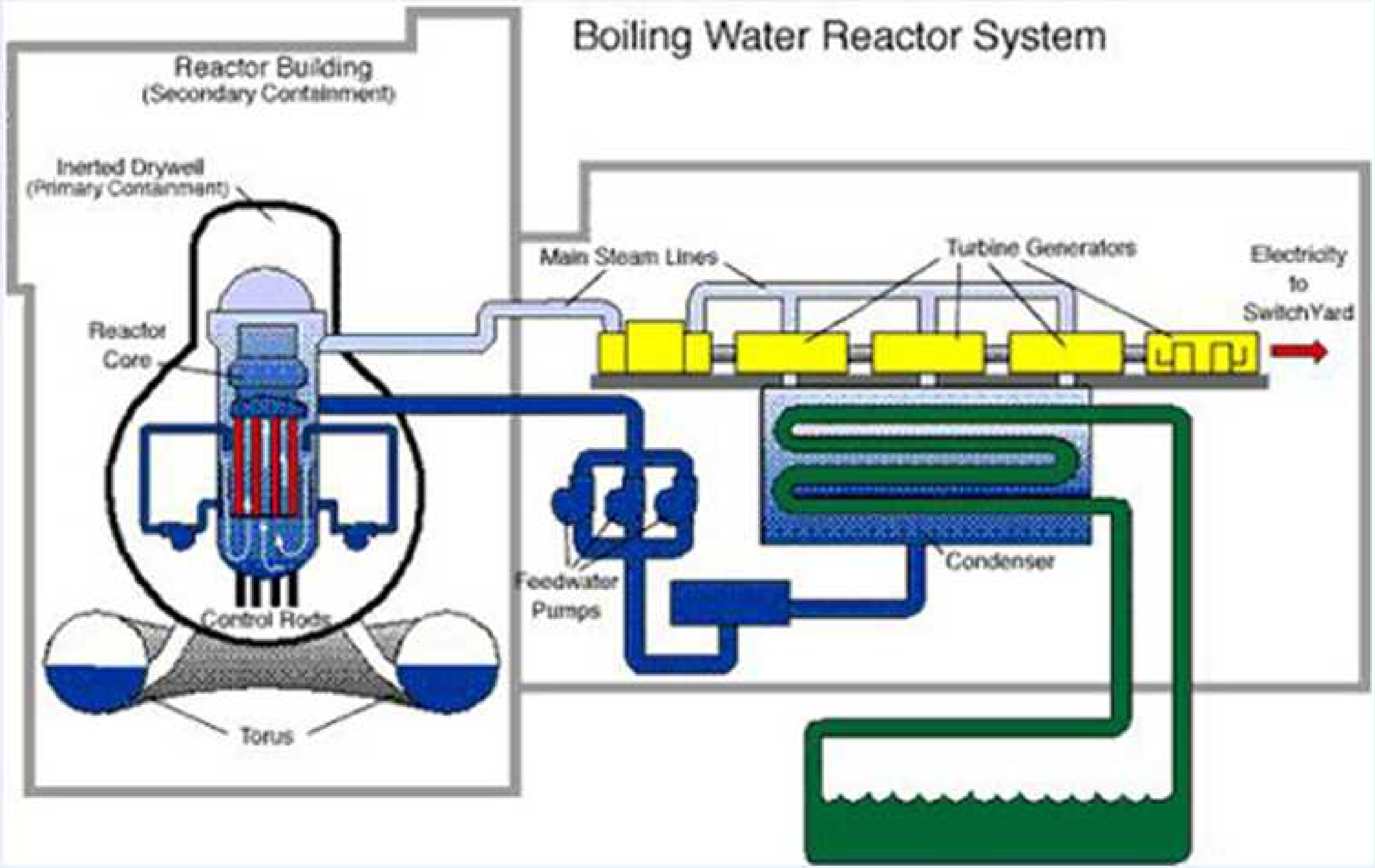

Robot-Controlled
Backhoe
imai


Robot Controller
Command Center
クローラダンプ CD110(1)


Robot
Entry

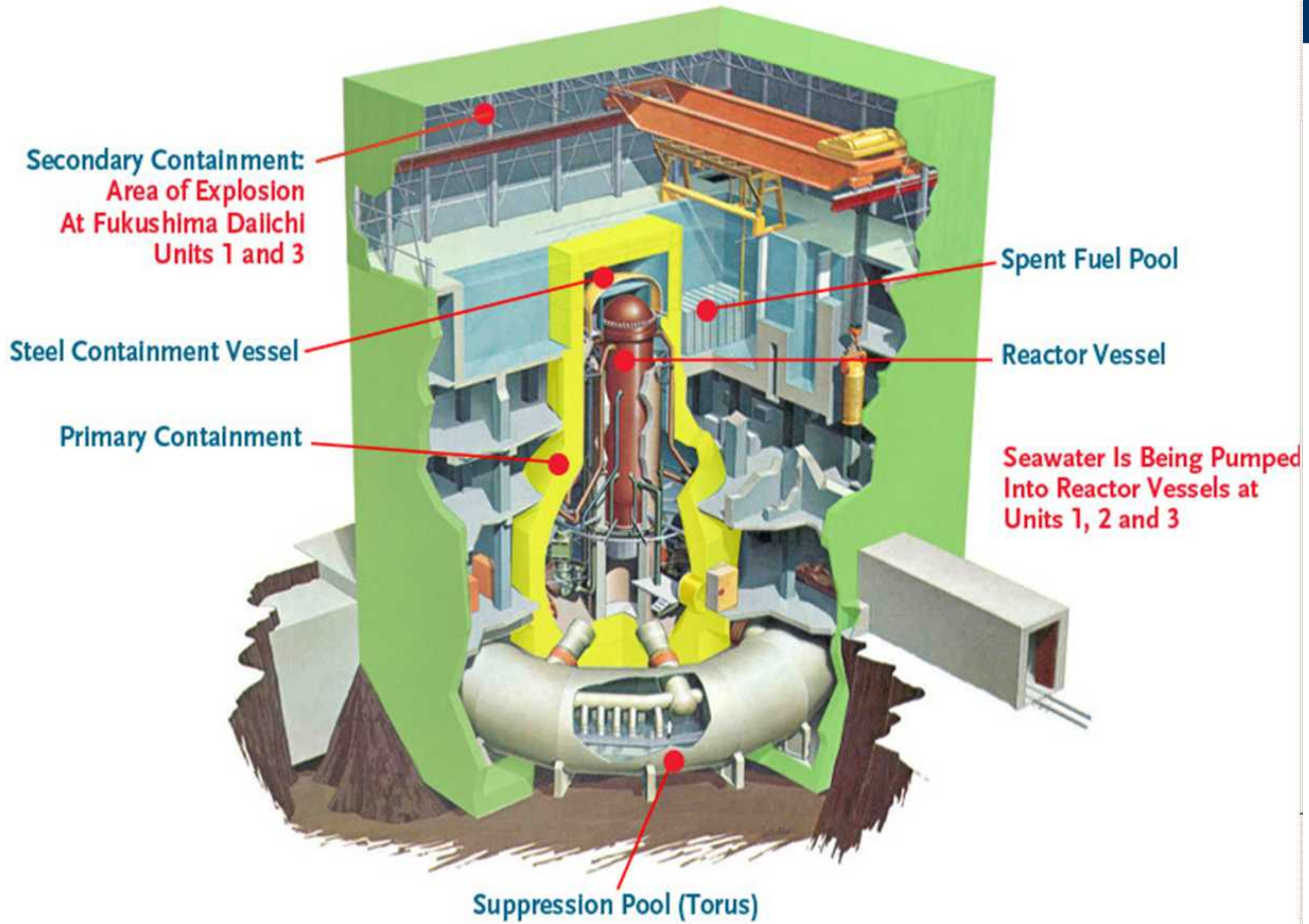

Robot Entry


0.1
0.2
0
0.3
-0.1
0.4
PI-1601-68
Robot Entry
Reading



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

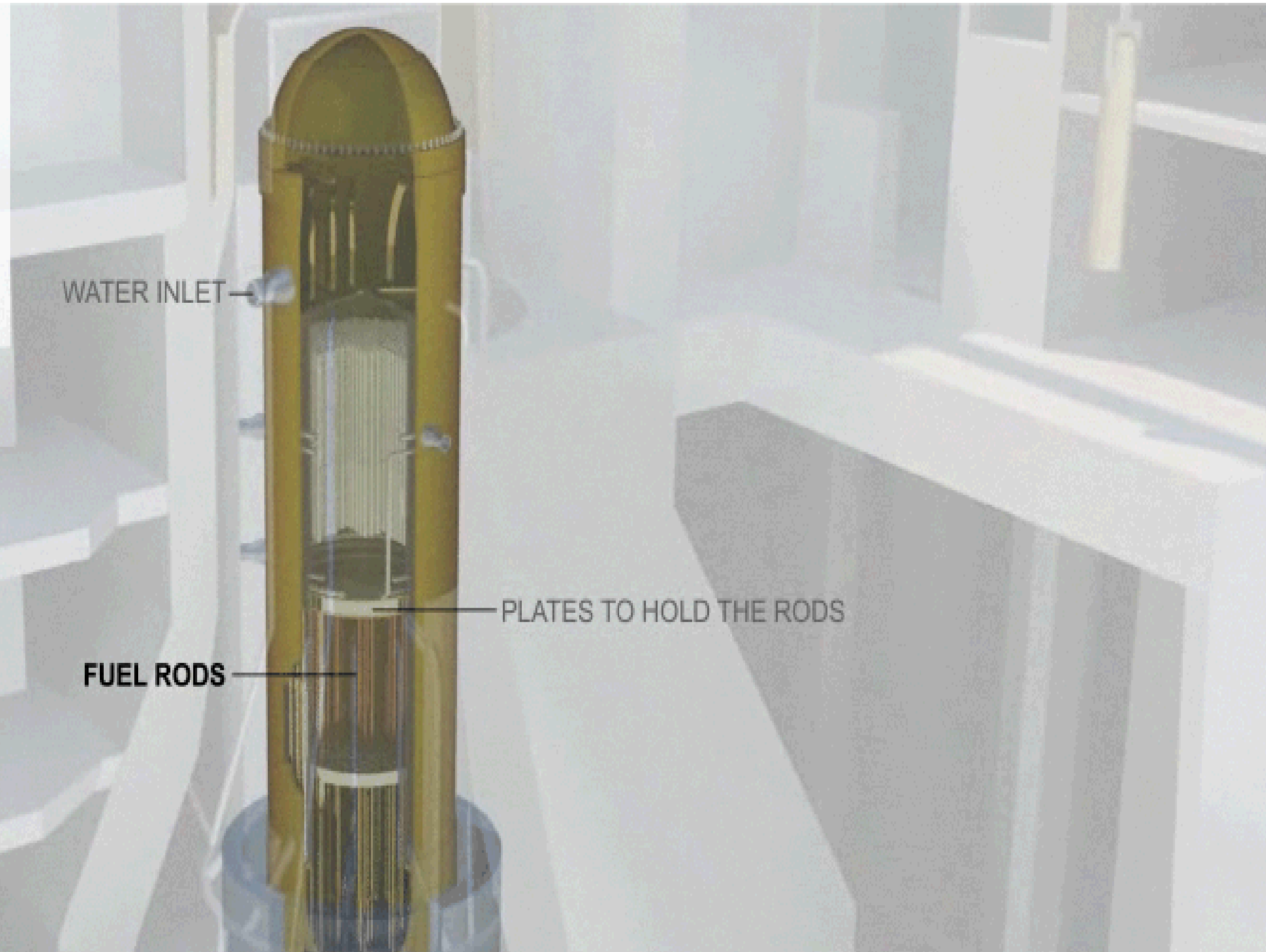
Fukushima BWR



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.

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.



By MATTHEW ERICSON, XAQUÍN G.V., DYLAN McCLAIN, TOMOEH MURAKAMI-TSE, GRAHAM ROBERTS, ARCHIE TSE and JOE WARD | Send Feedback

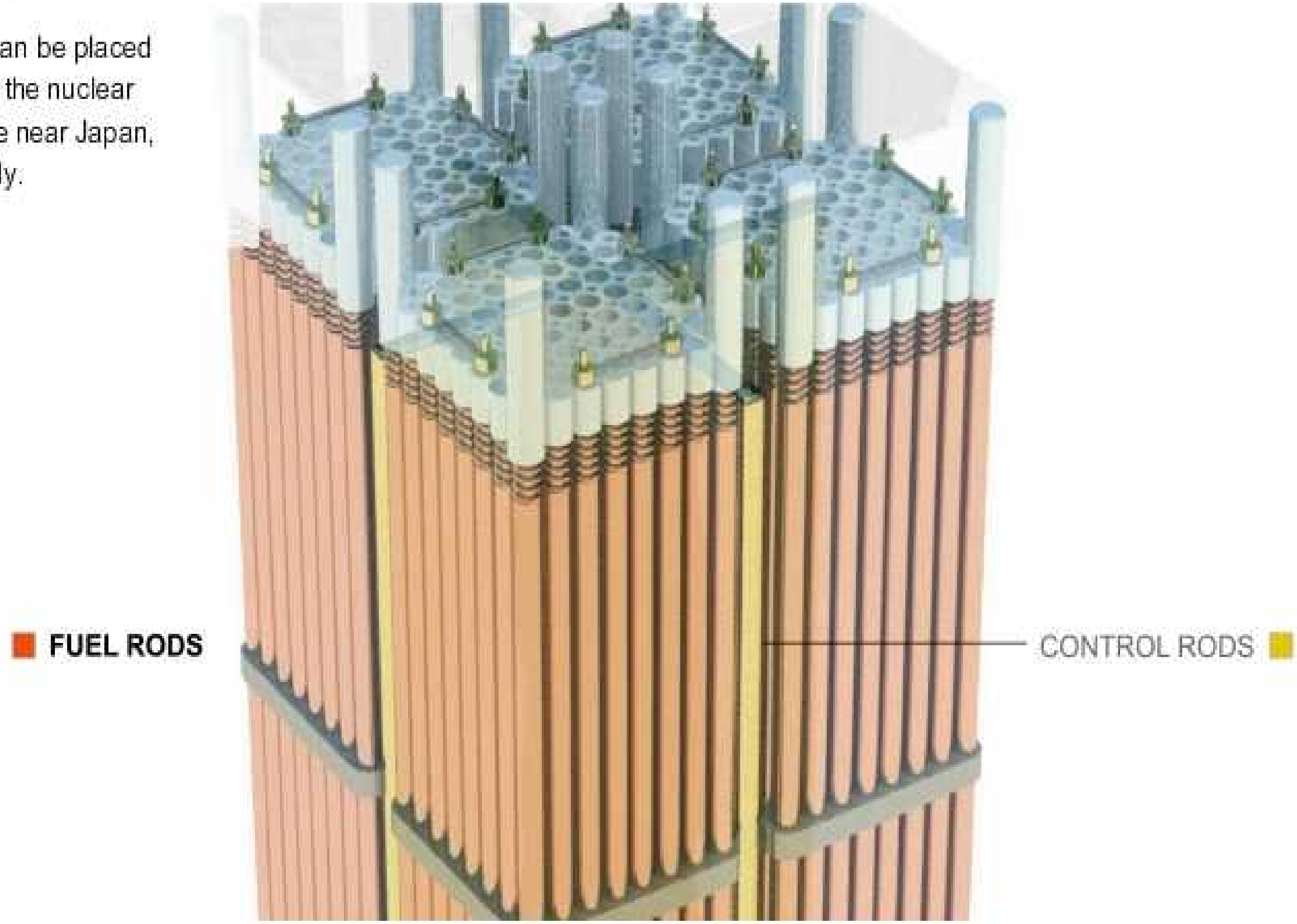
Sources: Nuclear Energy Institute; Nuclear Regulatory Commission; Tokyo Electric Power; satellite image by Digital Globe via Google Earth

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



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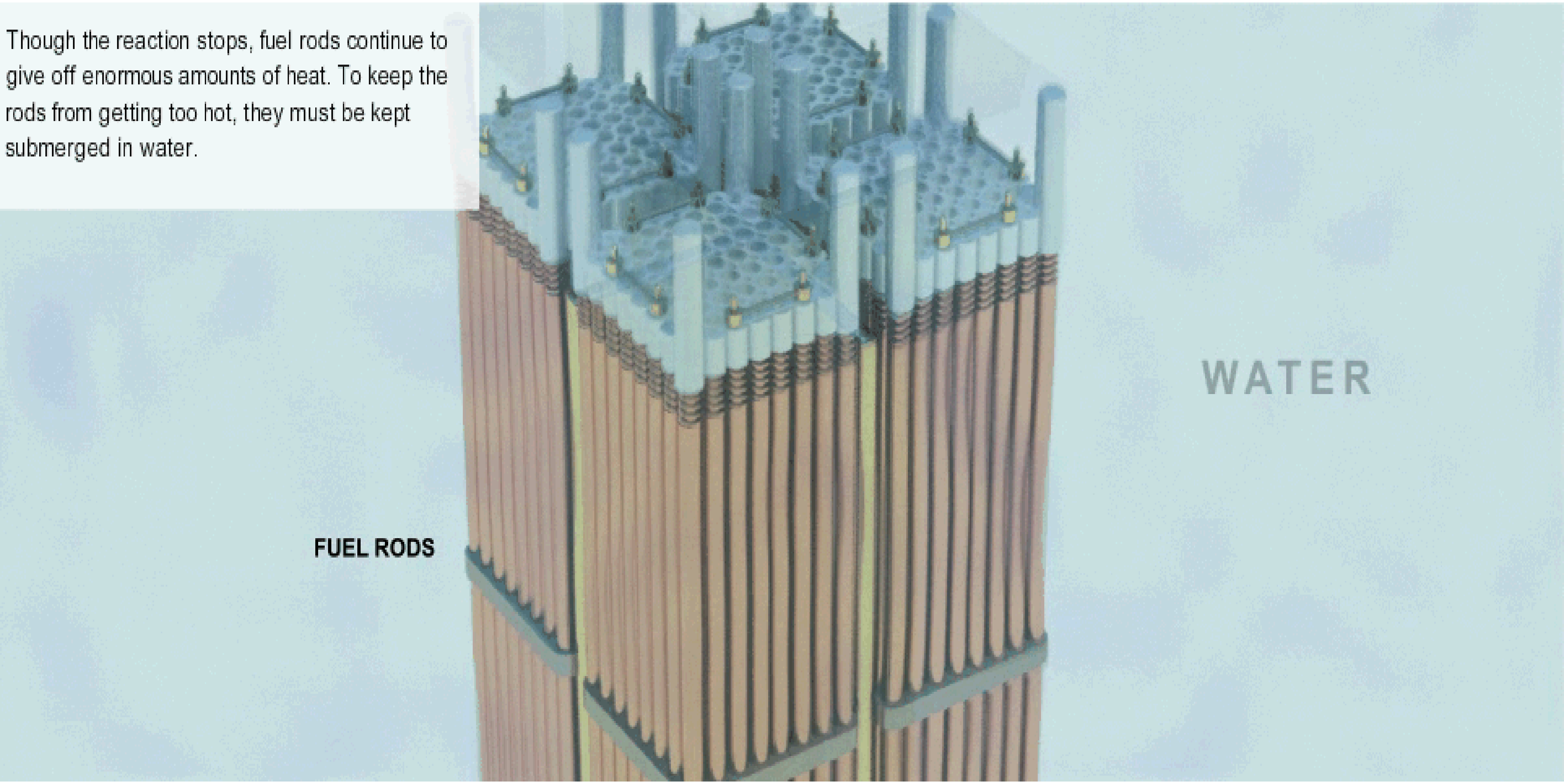
1 2 3 4 5 6 7 NEXT

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.



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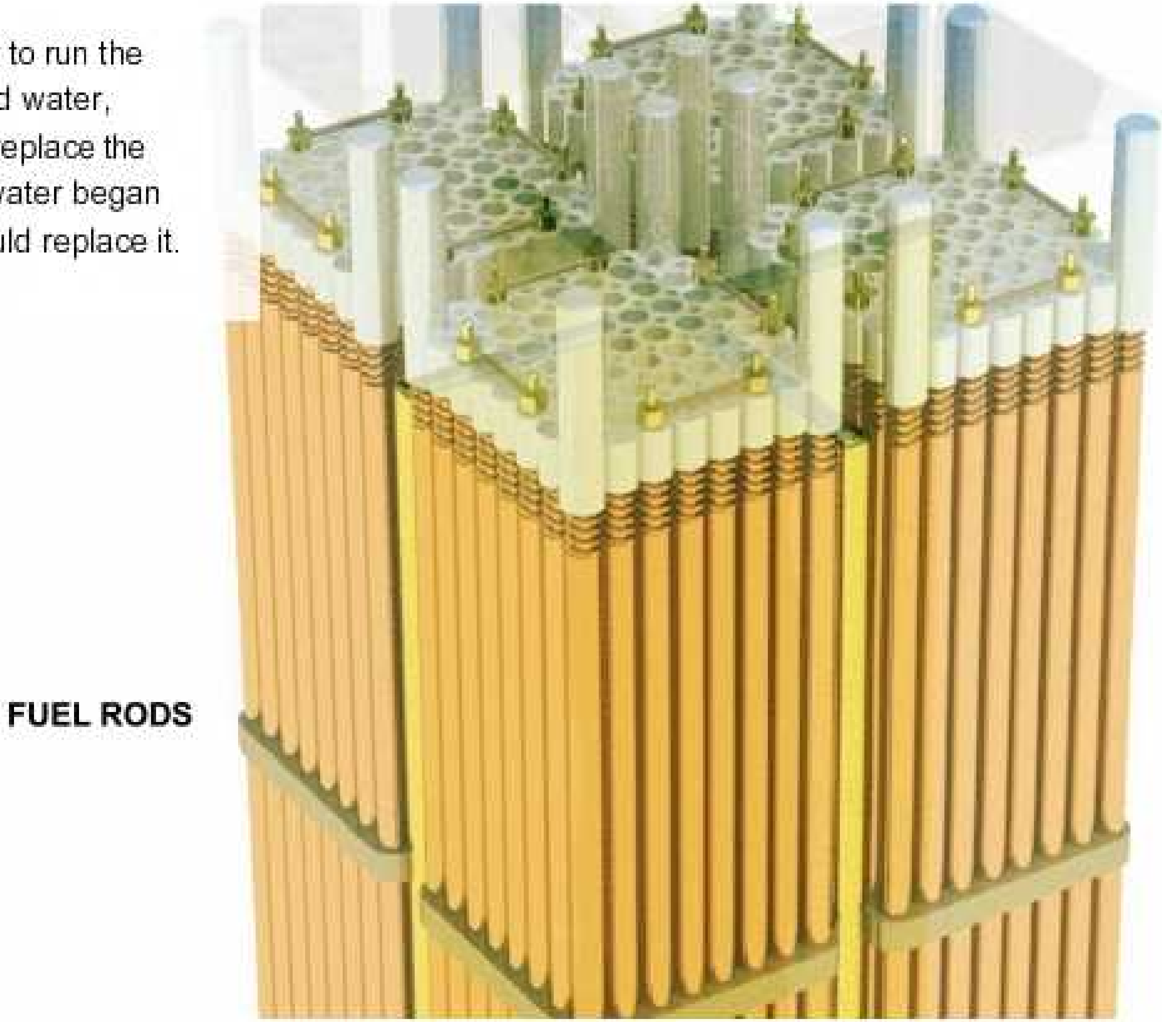
1 2 3 4 5 6 7 NEXT

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.



By MATTHEW ERICSON, XAQUÍN 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


Used Nuclear Fuel Shipping Cask

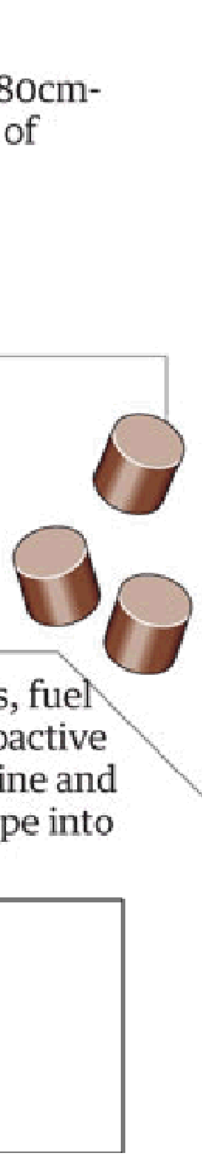
Fuel Rod Schematic

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

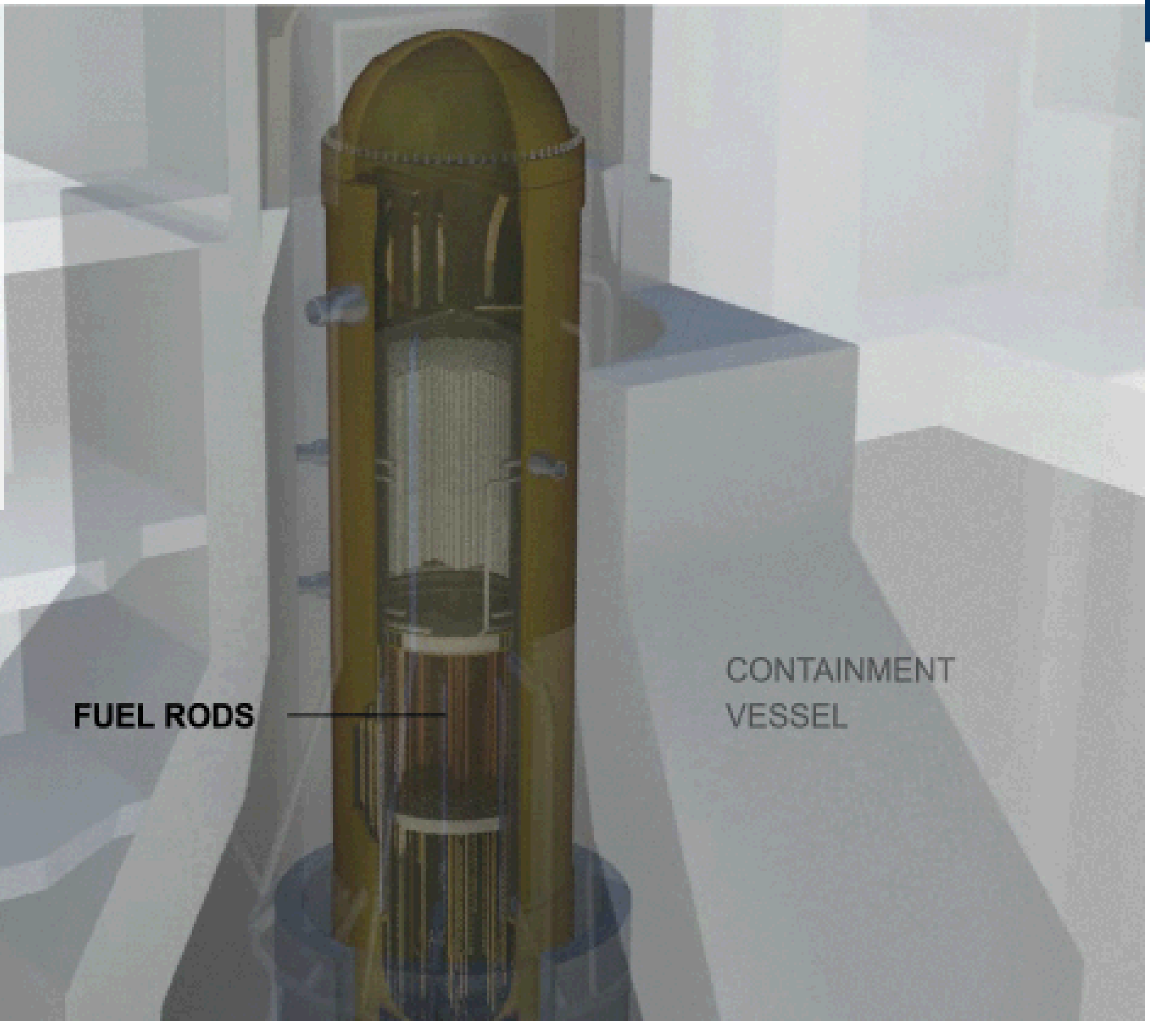
Washout
If rod cladding cracks, fuel pellets fall out. Radioactive isotopes in fuel - iodine and caesium - could escape into the atmosphere



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.

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.



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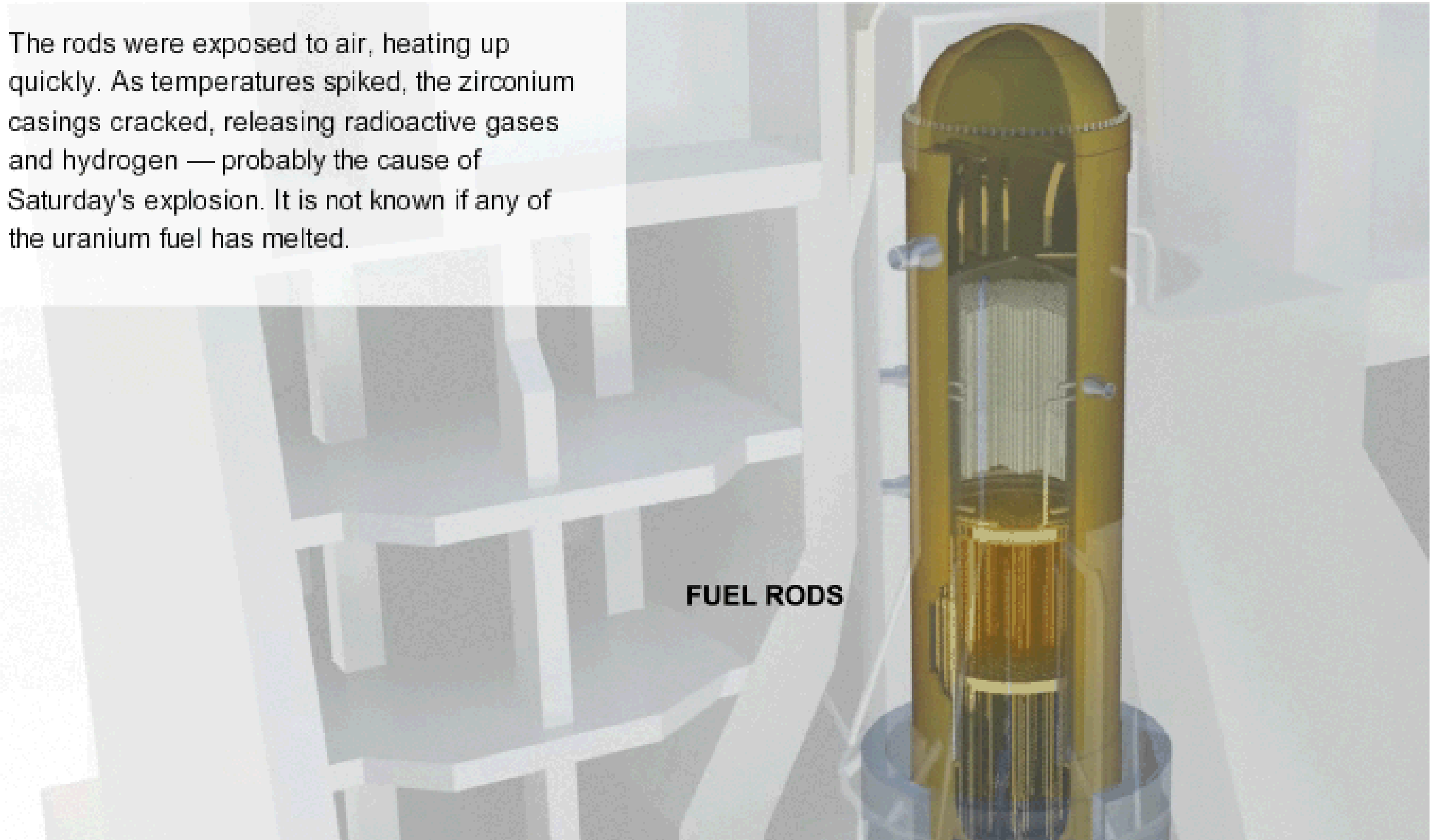
The operating reactors at Fukushima Daiichi power station automatically shut down during the earthquake. But after subsequent cooling failures, two of them went into partial meltdown.

1 2 3 4 5 6 7 NEXT

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.



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

Office of
Nonproliferatio
and Internationa
Security (NIS)

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 250 mSv which still prevents them from the danger of short term radiation effects. See Figure 1.

Thus, there should be no <u>short term</u> radiation health effects in Japan.

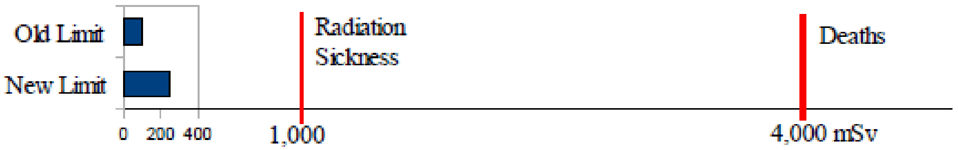


Figure 1. Emergency Worker Limits and Short Term Effects

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 <u>lack of conclusive evidence</u> of low level radiation effects below total exposures of about 5,000 to 10,000 millirem." [50 to 100 mSv]

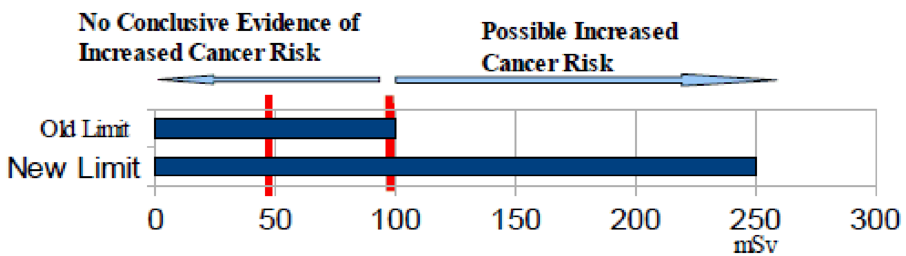


Figure 2. Emergency Worker Limits and Long Term Radiation Effects.

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, <u>no significant increase in cancer risk</u> among the public is expected.

The danger of low dose radiation is very much exaggerated.

If the Japanese should not worry, why should we?

DOE/NNSA Consequence Management (CM) Program Overview

Prepared by:

Thomas Laiche, CHP

Nuclear Incident Response Programs
Sandia National Laboratories
Albuquerque, NM

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

Office of Nonproliferation and International Security (NIS)

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.

Office of Nonproliferation and International Security (NIS)

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

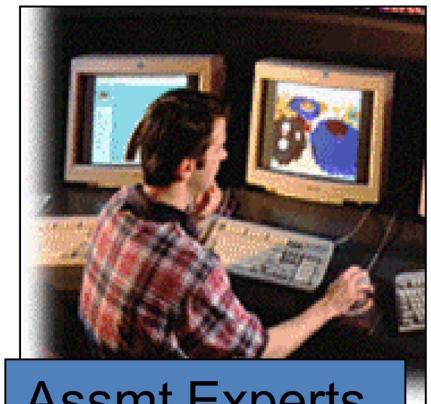
Radiological Assistance Program Teams Arrive

CM Home Team Is Activated

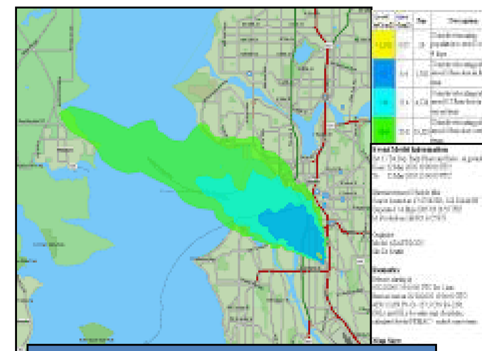
- Objectives:
  - Provide Technical Assessment and Plume Map support before CM response team assets arrive at the event site
  - Provide a resource for local authorities early in an event

- Resources
  - National Lab personnel
  - Assessment tools
  - Plume modeling

Field Team



Assmt Experts



Plume modeling

Emergency Operations Center

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 operatio

  – Sampling Experts
  – Lab Analysis Experts
  – Health and Safety Experts
  – Assessment Experts
  – Radiological Technicians

- All of these individuals take on specific ro as defined in pre-event planning/training.

Consequence Reports

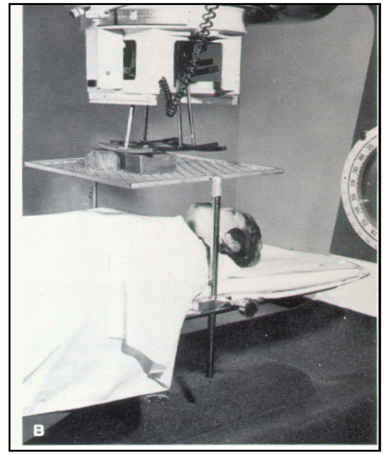
- Standardized report integrating effects predictions with Geographical Information System (GIS) provides consequence information in a format more directly useful to decision makers

- 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

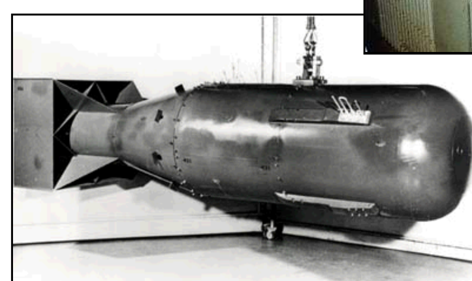
Large Quantities of Radioactive Material can be Found Throughout the World

- **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**

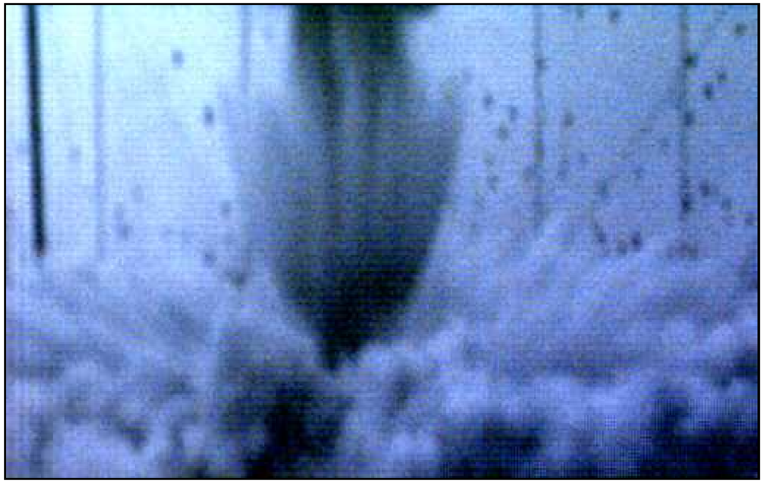
- **DOE/NNSA CM Program transitioned focus to preparations for intentional terrorist attack(s)**

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

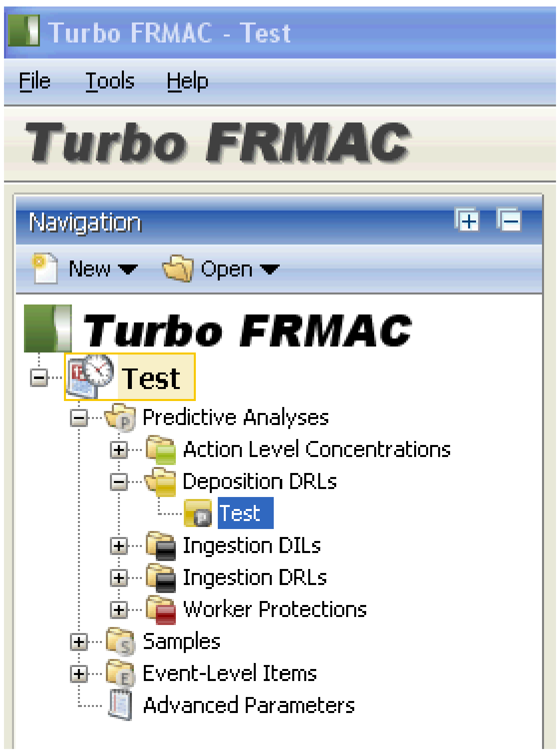


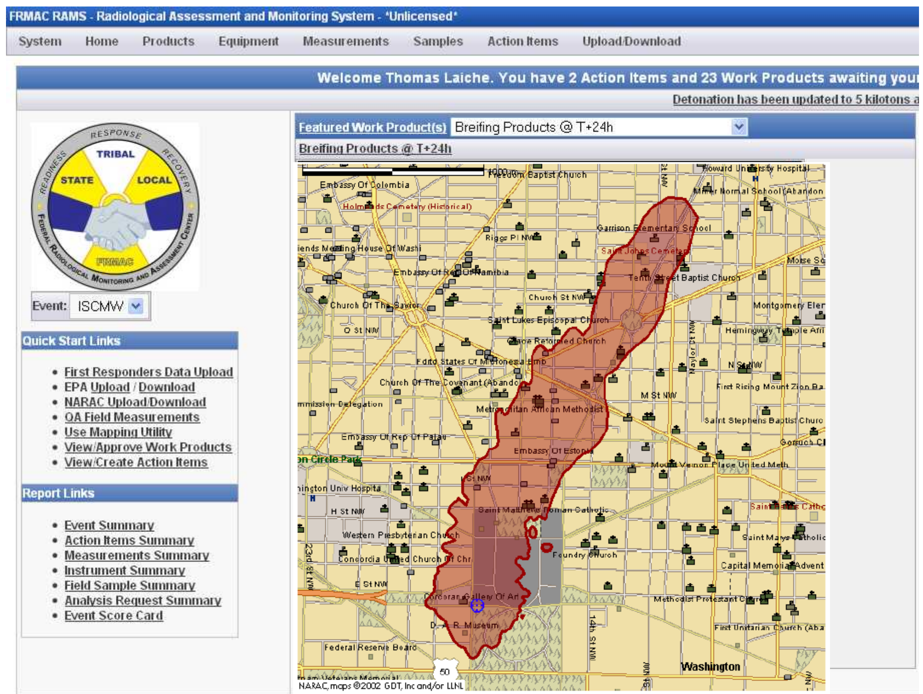
DOE/NNSA CM Expertise

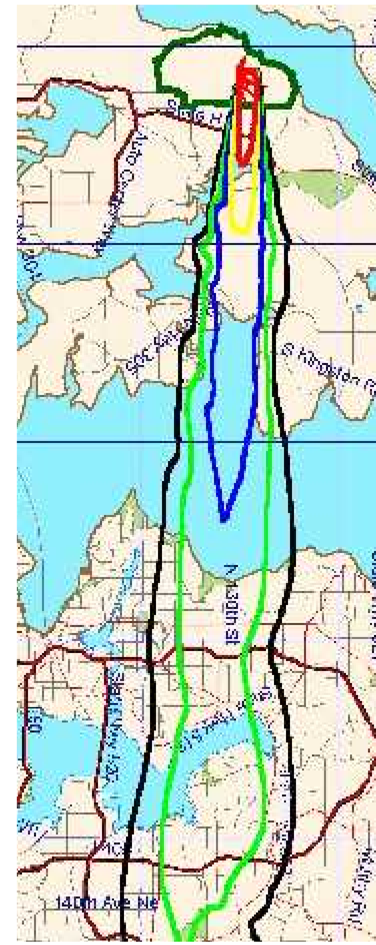
Equipment – Fixed Wing and Rotary Aircraft, Radiological Monitoring Equipment, Communications, Mobile Laboratories

DOE/NNSA CM Expertise

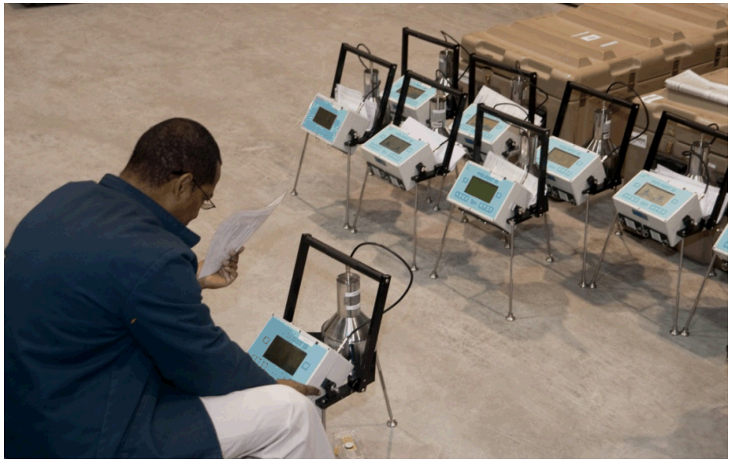
Models and Software – Develop and Use the most up-to-date Software, Databases, and Effect Models







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

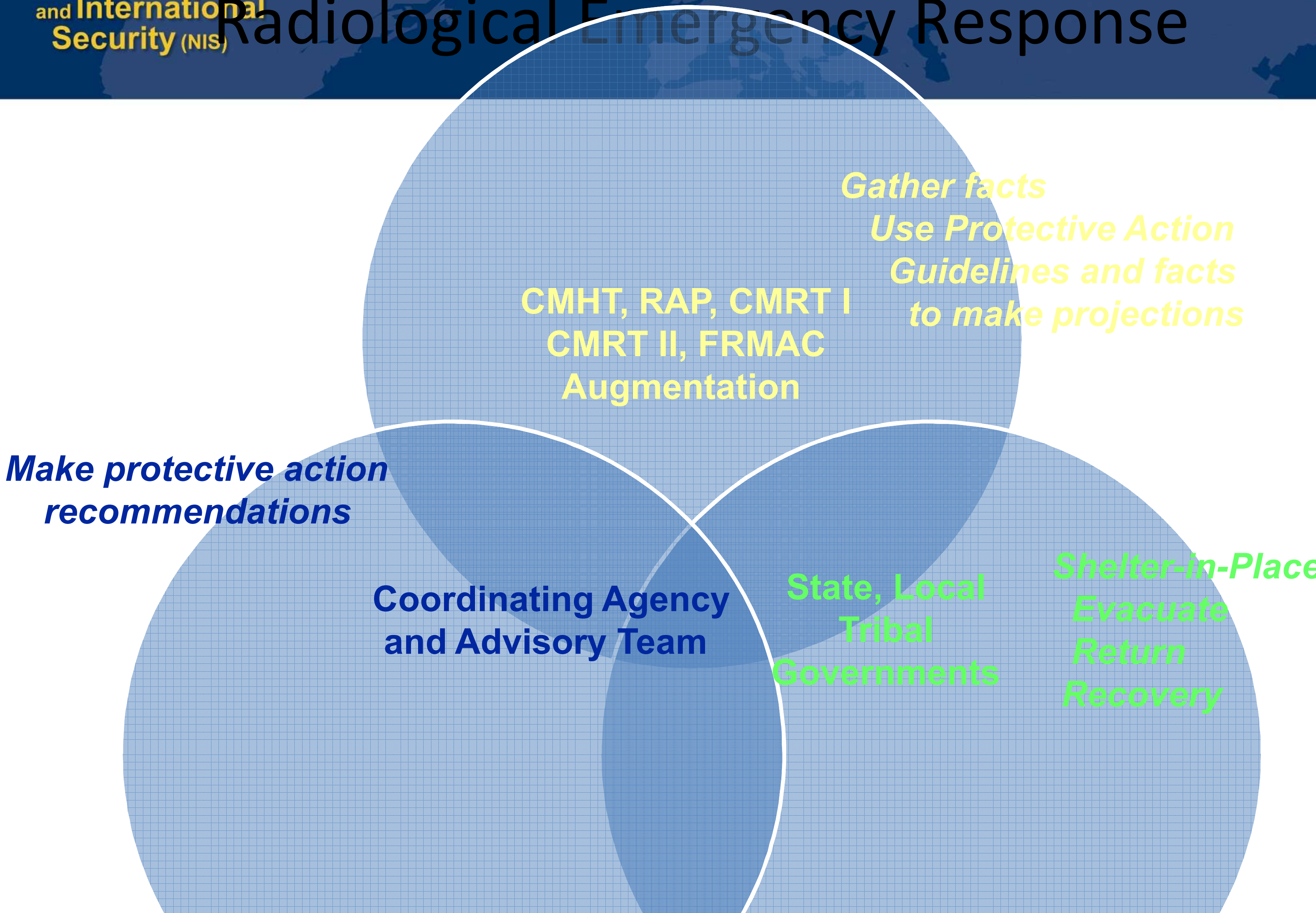
Office of Nonproliferation and International Security (NIS)

FRMAC/CM Assets

Federal Radiological Monitoring and Assessment Center (FRMAC) includes:

- Data Analysis/CM Home Team
- Field Monitoring Teams
- Mobile Laboratory
- Radiological Assessment
- Aerial Measurement System
- Effects Models

CM Program/FRMAC Help Provide Coordinated Radiological Emergency Response

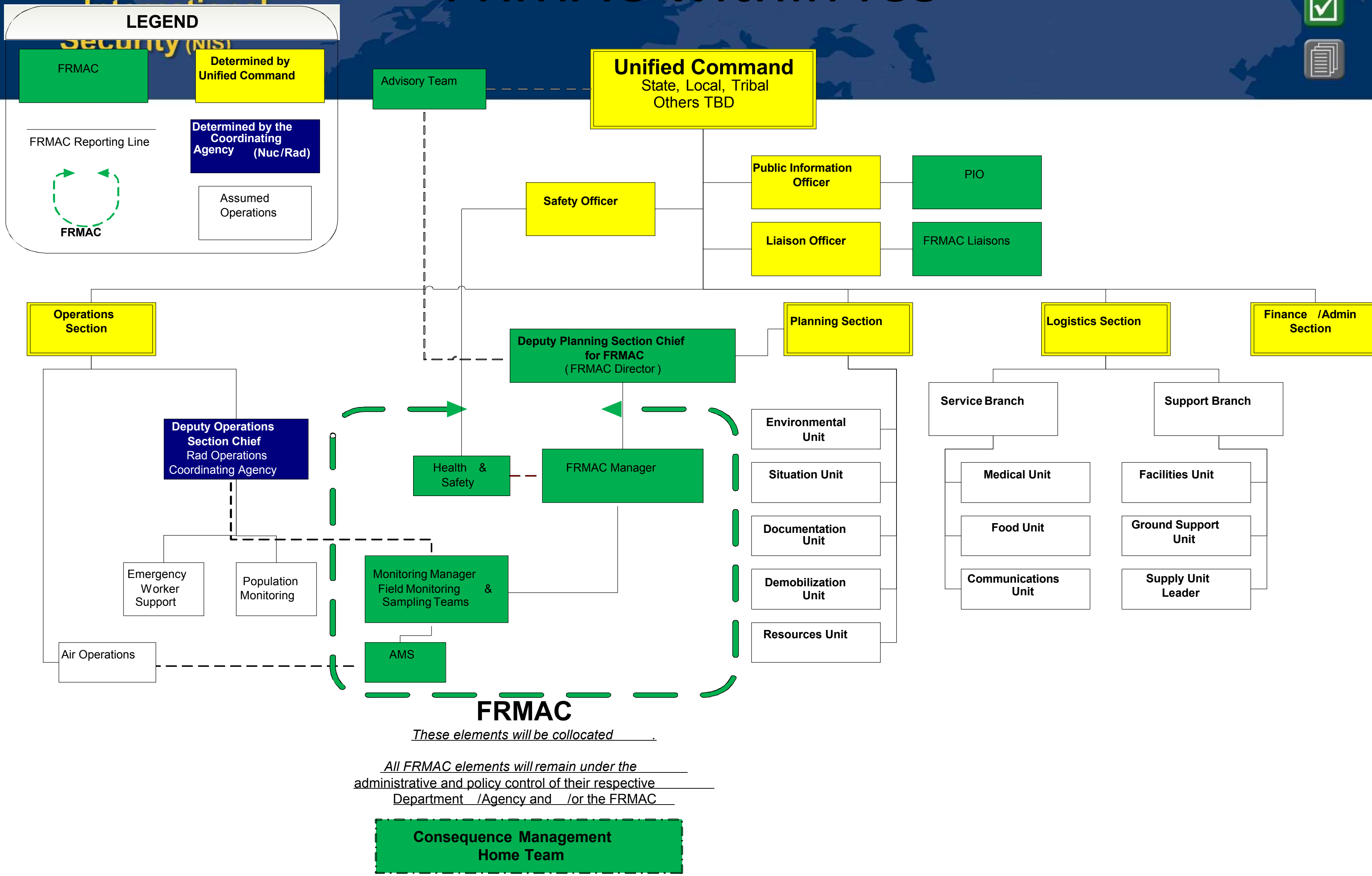


Office of Nonproliferation and International Security (NIS)

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



Elements of FRMAC

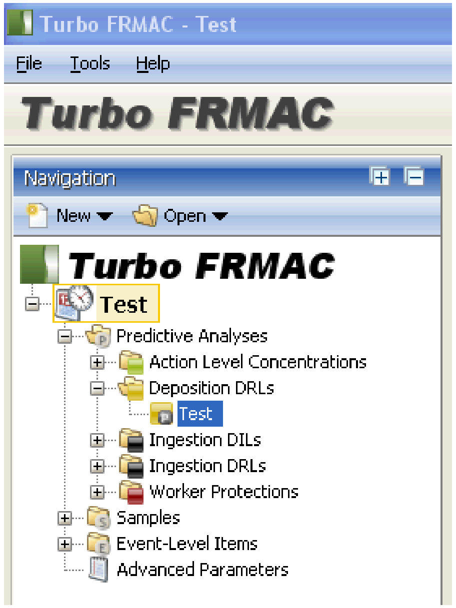
- CM Home Team
- Assessment
- Health and Safety
- Monitoring and Sampling
  - AMS
- Laboratory Analysis
- A Team
- GIS
- Document Control
- NARAC

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

- **<u>Assessment</u>** - 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

- <u>Health & Safety</u> - 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

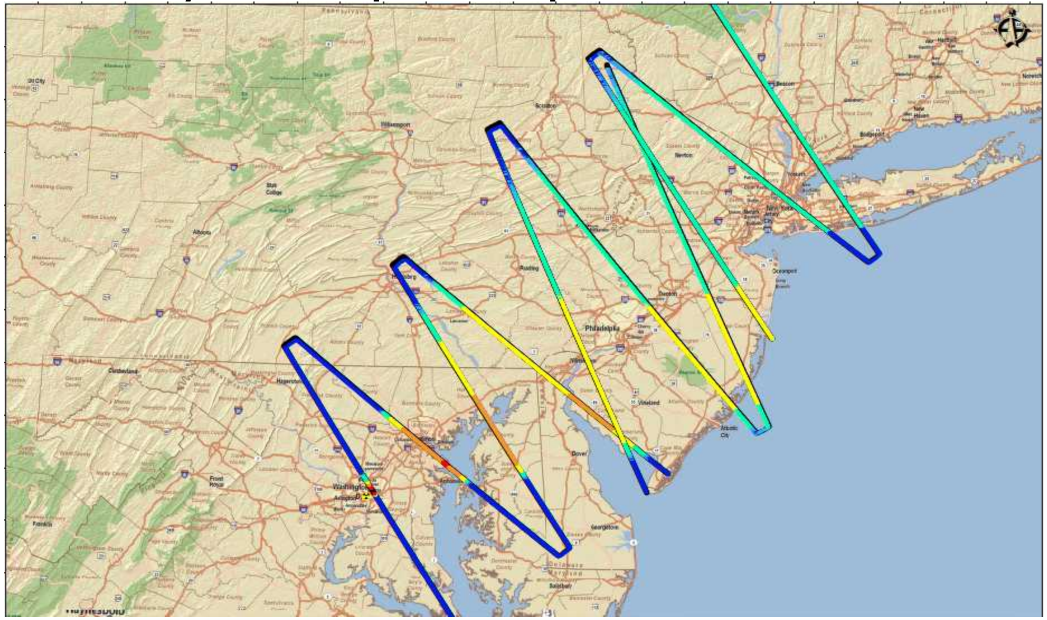
Elements of FRMAC

- <u>Monitoring & Sampling</u> - 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

- <u>Aerial Monitoring System (AMS)</u> - DOE's aerial-based radiation detection platform used to verify initial plume predictions



Elements of FRMAC

- <u>Laboratory Analysis</u> -_ Provides in-the-field radioanalysis of samples
  - Maintains ability to ship samples off-site to contract laboratories

Elements of FRMAC

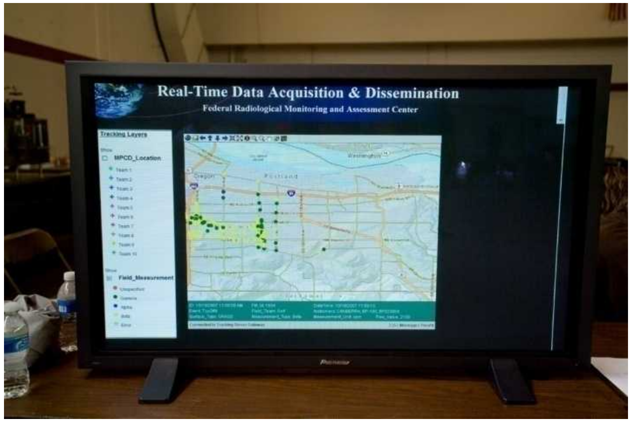
- <u>Advisory Team (A Team)</u> - Federal Agency entity that makes recommendations to State, Local, or Tribal Decision Makers
  - Provides approval to deviate from standard assessment calculations

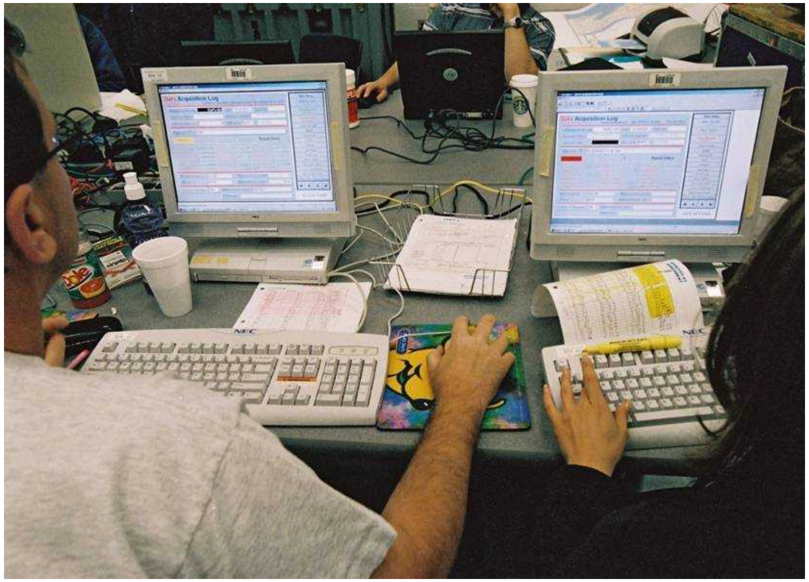
Elements of FRMAC

- 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

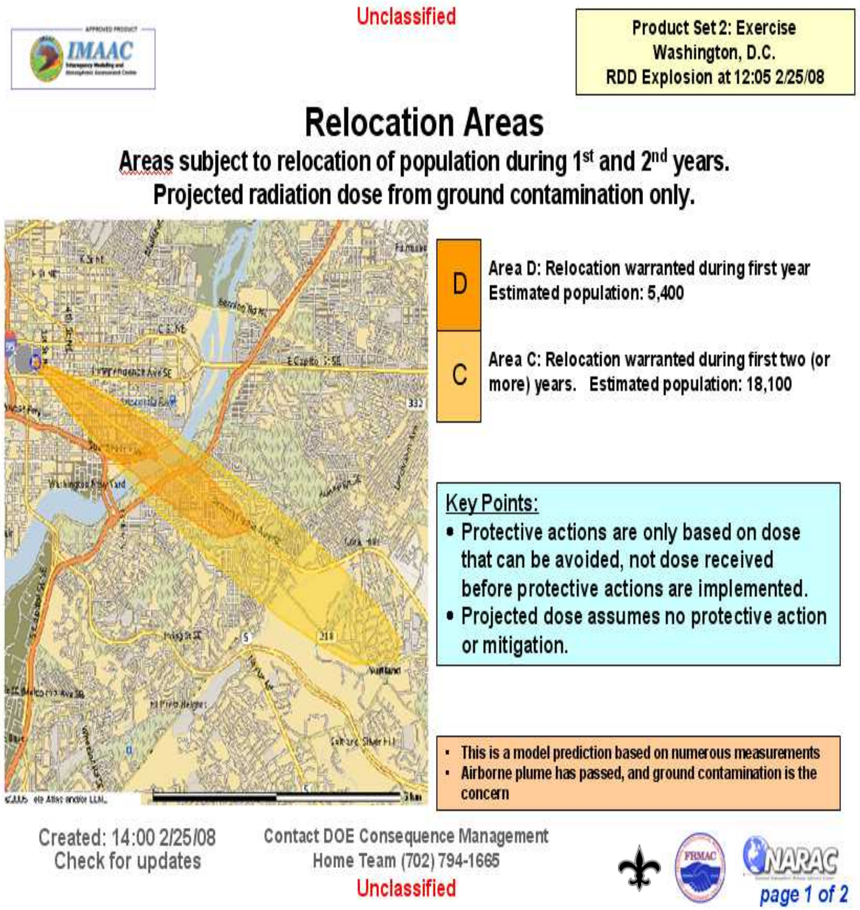
- **<u>Document Control</u>** - Every off-site environmental radiological data point stored for long-term retention in FRMAC Data Center
  - Uses RAMS Database to electronically collect and store Field Data, Laboratory Analyses, etc.





Elements of FRMAC

- <u>National Atmospheric Release Advisory Center (NARAC)</u> - 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 on voice**
- **Resources include personnel, communications, data analysis, models, monitoring, laboratories**

Questions