Personnel Monitoring and Upper-Bound Dose Calculations Operation TOMODACHI Registry

Brief for: Veterans' Advisory Board on Dose Reconstruction
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- Dr. Daniel Blumenthal, National Nuclear Security Administration, who shared DOE's radiological monitoring results,
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- My co-authors: Dr. Falo, Dr. Rademacher, LTJG Alleman, USN, LTC Rosser, USA, Mr. Dunavant, Dr. Case, & Dr. Blake.

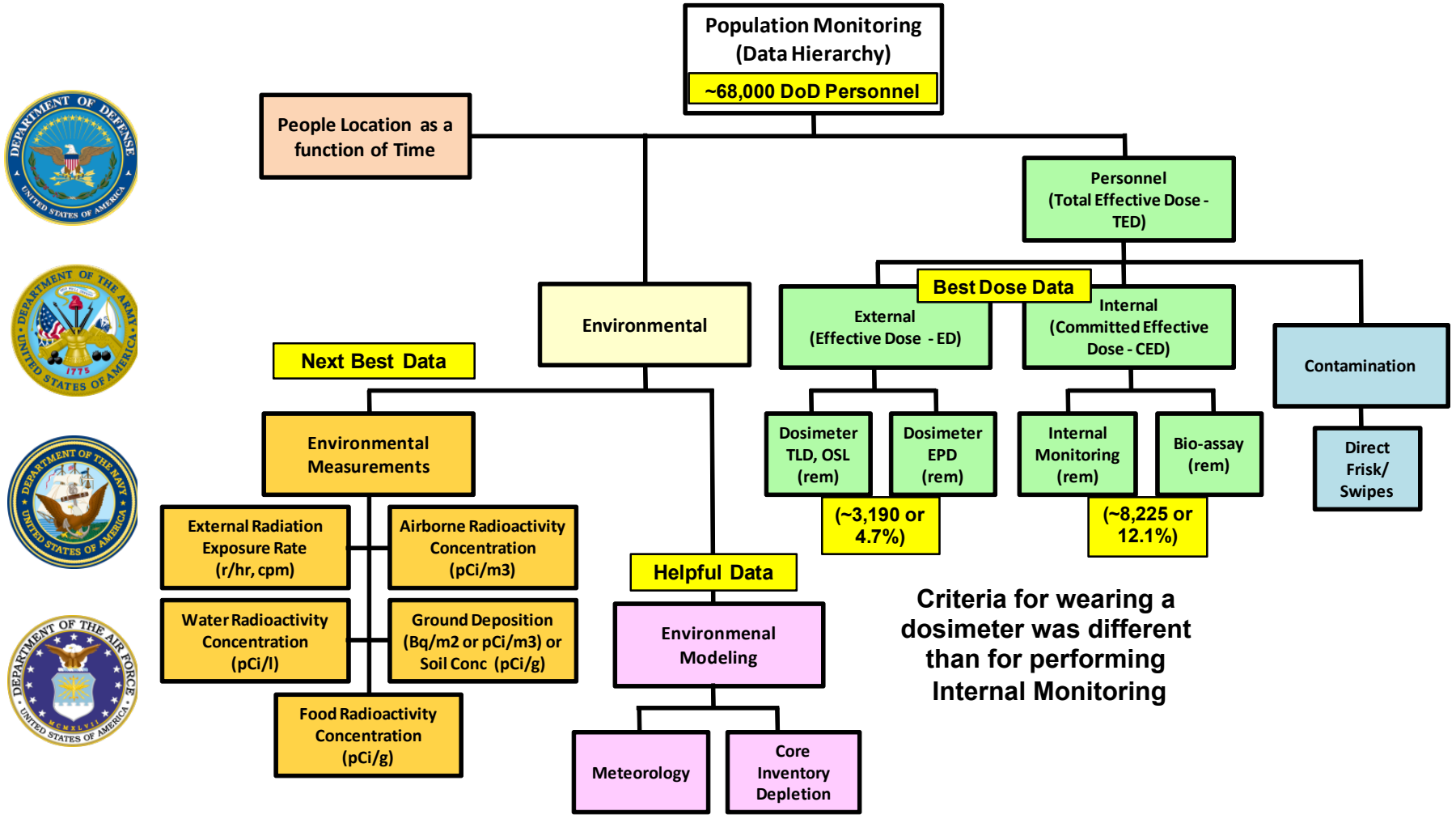
Outline

- Internal Monitoring (IM) of Personnel
- External Personnel Monitoring
- Calculation of Operation TOMODACHI (OT) Registry Period
- Preliminary Upper Bound Calculations for Shore Populations

TOMODACHI is friend in Japanese

Map of Major U. S. Military Bases (red stars) and Fukushima Daiichi Nuclear Power Station (FDNPS) (yellow trefoil)

Review of Data Types

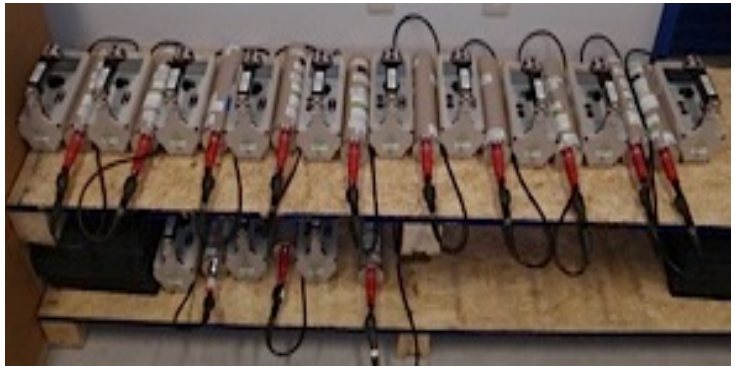


Internal Monitoring (IM) for OT

- **Initial Goal:**
  - Provide IM to DoD personnel that are at higher potential for internally deposited radionuclides as a result of relief operations.
- **Challenges:**
  - No existing Fixed IM equipment in Japan, only limited units available in DoD system.
  - Potentially thousands of persons would be identified for candidates for IM.
  - Measurements time sensitive because of radioactive decay and biological elimination.
- **Plan:**
  - Use portable instruments as **screening devices** (widely available and measurements can be taken at remote locations (ships)).
  - Use limited fixed systems to **confirm positive cases** where operationally possible.

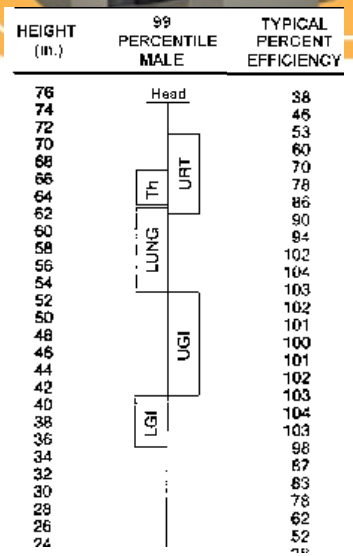
IM for OT – Portable Scanners

- **E600/SPA3 Survey Meter/Probe- 25 Units**
- ***E600 rate meter/ scaler/ integrator.***
- ***SPA-3 is a 2”dia x 2”thick NaI(Tl) smart probe system used in open window mode-no spectrums, with 60 keV to 2.0 MeV, 14 µs dead time.***
- **Use of certified clean human phantoms for background counts.**
- **Instruments attached to stands and not moved after background count.**
- **Background highly dependent on location.**
- **Unshielded, 100% cross-talk between thyroid and chest measurements for Cs-134, 136, and 137.**
- **Low Level clothing contamination a real issue resulting in the need for tighter rad controls and change into Tyvek coveralls.**

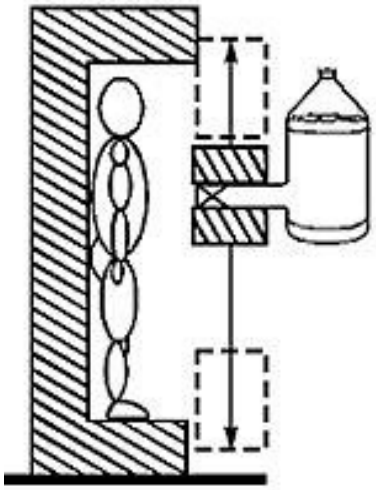


IM for OT Fixed Scanners

- **Fastscan-2 Units**:
- **Whole body and Thyroid Counter.**
- **300 keV to 1.8 MeV.**
- **Two (3”x5”x16”) fixed NaI(Tl) detectors.**
- **Shielded by 4” steel.**
- **6 min counts.**
- **full spectroscopy.**
- **Located at Yokosuka NB and Okinawa.**



- **Accuscan-1 Unit**:
- **Whole body and Thyroid Counter.**
- **300 keV to 1.8 MeV.**
- **Two Germanium moveable detectors.**
- **Shielded by 4” for person and 2” for detector.**
- **10 min counts.**
- **Full spectroscopy.**
- **Located at Atsugi AB.**



Identification of Personnel IM

1. Initially Higher Risk Groups Internally Monitored.
   - Active Duty personnel operating within the Sendai area
   - Aviators (i.e. helicopter pilots and aircrews) that have flown through known plumes
   - Personnel supporting aviation operations and aircraft/ship decontamination teams
   - Supporting ship crew (including nuclear trained personnel)
   - Supporting shore activity personnel
   - Naval Nuclear Propulsion Personnel
   - 10% random from other groups
2. Additionally, each service component was asked to provide lists of personnel who had a higher operational potential for internal exposure who were then internally monitored.
3. Open Availability Phase (26 July – 31 August 2011)
   - Voluntary for Military, Civilian Employees, Contractors, Beneficiaries, including infants and children

Preliminary IM Results
(8225 Persons Monitored Over 169 Days)

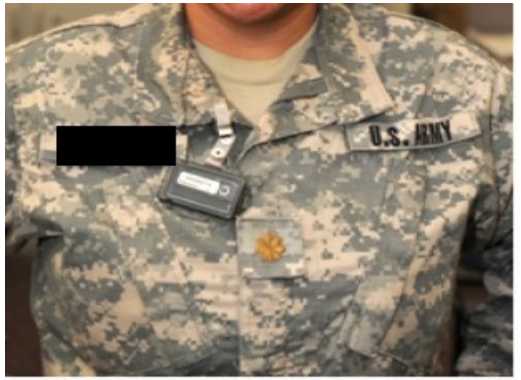
- **Higher Priority Service Members and DoD Civilian Workers:**
  - Performed in CONUS: 16 Mar- 19 May **(65 Days, 855 People)**
  - Performed in Japan: 14 Apr-31 Aug **(140 Days, 7215 People)**
    - **Preliminary results** (undergoing independent review).
    - **98%** with less than Minimum Detectable Activity (MDA).
    - For the 2% above MDA **Committed Effective Doses ranged from 1 to 25 mrem** with an **average of 4 mrem** (Committed Equivalent Doses to thyroid about 10 to 20x's larger)
    - For the 2% above MDA, about **half were measured in first 30 days** in CONUS with **detectable I-131**, very few with Cs-134 or Cs-137.
- **Expanded IM (Open Availability):**
  - Performed in Japan from 26 July thru 31 Aug **(37 days, 155 People)**
  - **51 Children**, 46 Dependent Adults; 38 DoD Civilian Employees/ Contractors; 20 Active Duty.
  - All results less than MDA. However, **IM of limited value the further the measurement is taken from the assumed intake date** due to decay and biological elimination. It's really measuring intake in the previous 30 to 60 days.

External Personnel Monitoring - Types of Personnel Dosimeters Used

Force, Army, and Navy all have large nationally accredited dosimetry centers in CONUS

- Active: Electronic Personal Dosimeter (EPD) (real time measurements) Supplied by Air Force and Navy

- Passive: Thermo/Optical Luminescence (TLD/OSL) (only read once per longer period, i.e., 6-7 weeks) Supplied by Air Force, Army, and Navy



External Personnel Monitoring - Groups Who Were Issued Dosimeters

- Persons entering warm and hot zones.
  - Warm Zone: 40 to 80 km from Fukushima Daiichi or 0.1 to 10 mrem/ hr.
  - Hot Zone: 0 to 40 km from Fukushima Daiichi or > 10 mrem/ hr.
- Persons involved with equipment decontamination.
- Persons who were part of an aircrew who flew thru identified plume.
- Persons who could potentially exceed the 300 mrem Total Effective Dose control level.
- Occupational workers who are normally issued dosimeters as part of their job (i.e., nuclear trained in Shipyard or on carriers and for some medical personnel)

Ref: HQ USPACOM JOC message DTG: 16 1643Z Mar 11
Ref: USFJ Command Center message DTG: 20 0704Z Mar 11
Ref: Joint Support Forces Japan DTG 15 1005Z Apr 11

External Personnel Monitoring – Concept of Operations – Preliminary Results

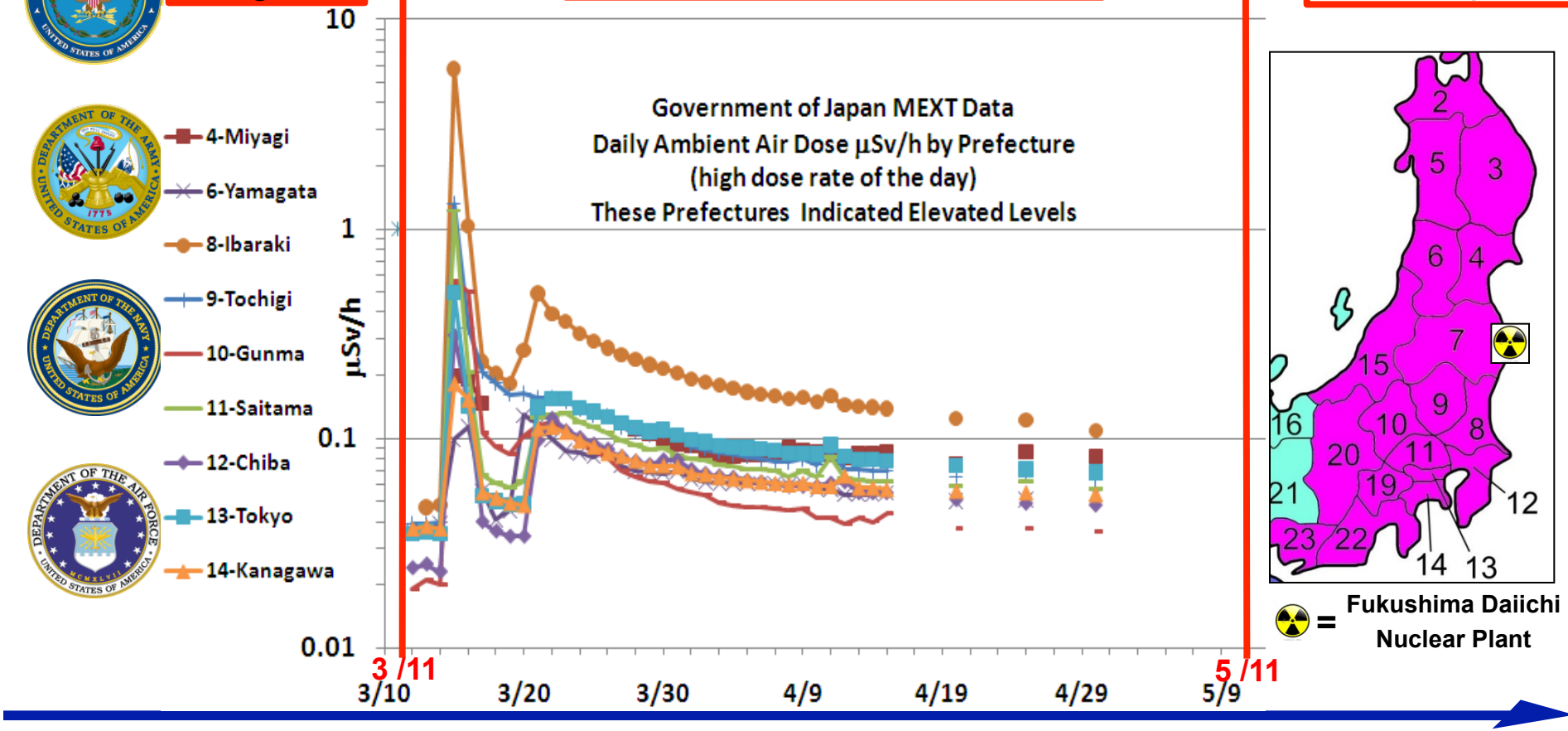
- **Each component service developed it's own** procedures for local issue, use, and collection of personnel dosimeters.
- Generally, **large numbers of dosimeters were sent** into Japan for local distribution and tracking.
- **Persons were not suppose to receive more than one dosimeter**. Those normally badged were not suppose to receive another.

Service	Number of Dosimeters Sent	Number of Dosimeters Used	Number of Dosimeters per Dose Range					
			0 mrem	1-25 mrem	26-50 mrem	51-100 mrem	101-500 mrem	>501 mrem
US Army (OSL)	2,000	326 (16.3%)	77	247	0	1	1	0
US Navy (TLD)	14000	1669 (11.9%)	1349	310	7	3	0	0
US Navy (EPD)	685	126 (18.4%)	16	110	0	0	0	0
US Air Force (EPD)	1,400	711 (50.8%)	90	620	1	0	0	0
US Air Force (TLD)	6,500	364 (5.6%)	361	3	0	0	0	0
Grand Total	24,585	3190 (13%)	1997	1180	8	4	1	0
Percent of Total Used		100%	62.6%	37.0%	0.3%	0.1%	0.0%	0.0%

Calculation of OT Registry Period

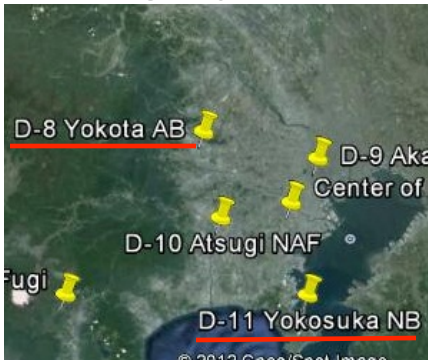
Conceptually: Determine the earliest date when the effects of the transient reached new steady state

Pre-Incident Background | **0 Days** | **Transient Additional Exposure (only from *external* exposure data)** | **60 Days** | **Post Transient or New Background**



Determination of OT Registry Period

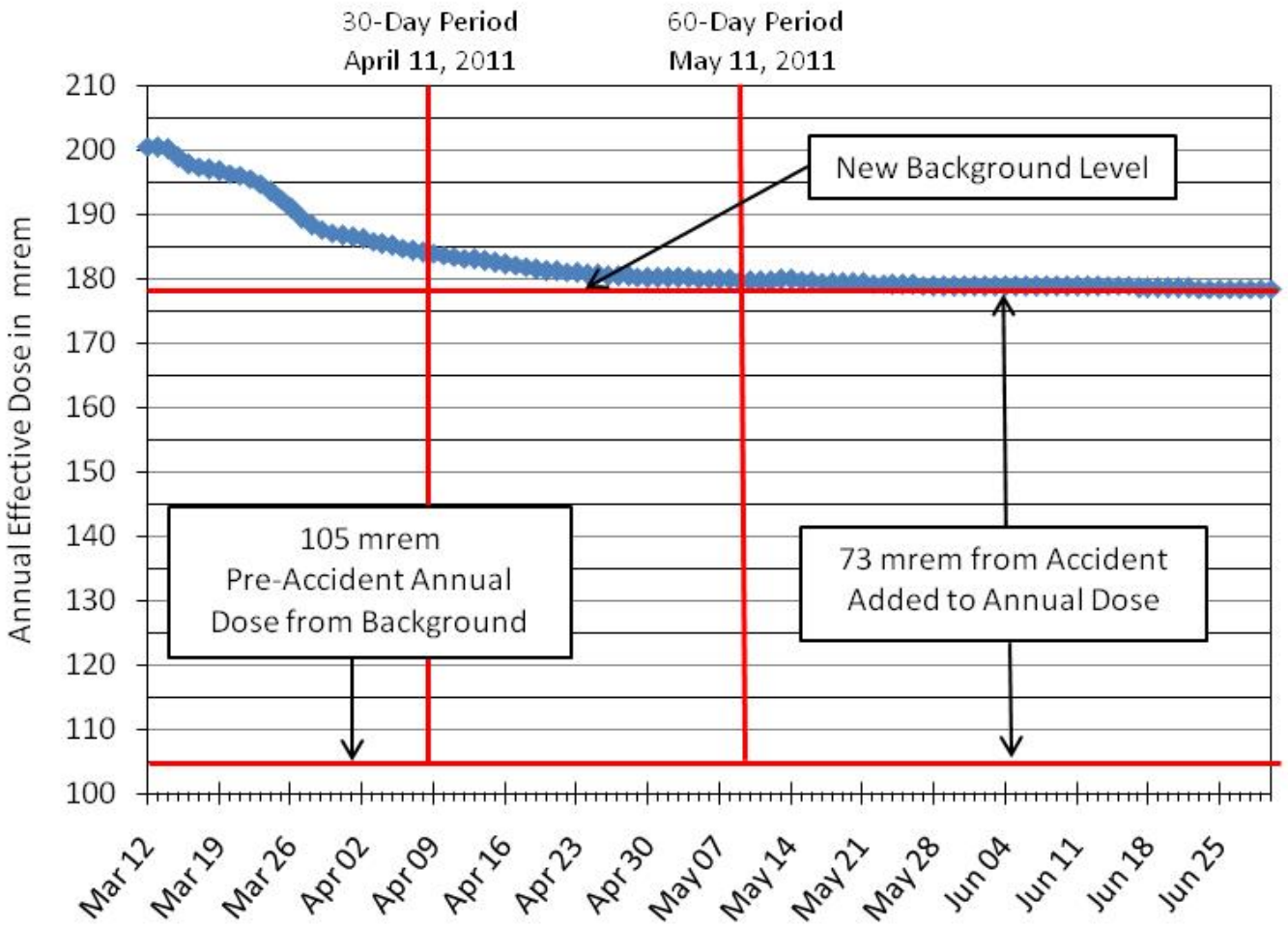
Technical Criteria: For DoD installations, choose the earliest possible date for which a calculated projected annual Total Effective Dose from that date would not change by more than ~ 0.01 mSv (1 mrem) from that date forward.



Scheme for Calculation of Projected Annual Total Effective Dose (TED)

Calculations performed for D-8 Yokota AB and D-11 Yokosuka NB

Projected Annual Effective Dose As a Function of Calculation Start Date For Yokota Air Force Base



Calculation Start Date in 2011 for Each Projected Annual Effective Dose Calculated

Upper Bound Dose Calculations (UBDC) Over OT Registry Period of 60-Days

- Registry to include an estimated **68,000 DOD Affiliated Personnel** (uniform military, civilian federal workers, contractors, and dependents)
- Initial dose calculations have been done for shore populations to be followed by shipboard personnel.
- Placed shore personnel into **861 cohorts** [Potentially Exposed Populations (PEPs)] based on **age**, **physical activity level**, **time spent indoors**, and **location**.

Adult Shore Based PEPS	Child PEPS
1 Age (>17 y)	5 Ages Categories (3 m, 1y, 5 y, 10 y, 15 y)
4 Physical Activity Levels for Breathing and Ingestion Rates	4 Physical Activity Levels for Breathing and Ingestion Rates
4 Time Indoor Categories	4 Time Indoor Categories
1 Additional Humanitarian Category with Higher Rates	
13 Locations	8 Locations
# PEP Categories = 1*4*4+1=17	# PEP Categories = 5*4*4=80
# PEPs = (17 Categories)*13 Locations = 221	# PEPs = (80 Categories)*8 Locations = 640

- Calculations automated with macro-scripts in EXCEL spreadsheets.

Upper Bound Dose Calculations (UBDC)

- Calculations performed with environmental data to include **external radiation exposure** and internal deposition from **air inhalation**, **water ingestion**, and **soil/dust ingestion**.

$$\text{Whole Body Total Effective Dose (TED) (rem)} = \sum_{1=1}^{\text{All hours over 60 Days}} \dot{\text{TED}}_i \left(\frac{\text{rem}}{\text{h}}\right)$$

$$\dot{\text{TED}}\left(\frac{\text{rem}}{\text{h}}\right) = \dot{\text{E}}_{\text{External Radiation}} + \dot{\text{E}}(\tau)_{\text{Air Inhalation}} + \dot{\text{E}}(\tau)_{\text{Water Ingestion}} + \dot{\text{E}}(\tau)_{\text{Soil Ingestion}}$$

$$\text{Thyroid Equivalent Dose (rem)} = \sum_{1=1}^{\text{All hours over 60 Days}} \dot{\text{Thyroid Equivalent Dose}}_i \left(\frac{\text{rem}}{\text{h}}\right)$$

$$\dot{\text{Thyroid Equivalent Dose}}\left(\frac{\text{rem}}{\text{h}}\right) = \dot{\text{H}}_{\text{T External Radiation}} + \dot{\text{H}}_{\text{T},\tau\ \text{Air Inhalation}} + \dot{\text{H}}_{\text{T},\tau\ \text{Water Ingestion}} + \dot{\text{H}}_{\text{T},\tau\ \text{Soil Ingestion}}$$

- Each term is broken down into its components slides that follow.

Upper Bound Dose Calculations (UBDC)

Numbers of Measured Values used in Radiation Dose Calculations

DARWG No.	DARWG Location	External (hourly values)			Air DOD*	Water GOJ*	Soil DOD*
		DOD	DOE	GOJ			
D-1	Misawa AB	107	0	1333	52	60	0
D-2	Sendai Airport	269	219	612	16	0	7
D-3	City of Ishinomaki	66	84	950	19	0	0
D-4	City of Yamagata	2	489	949	0	60	0
D-5	J-Village	N/A	N/A	N/A	0	0	0
D-6	Hyakuri AB	0	3	1437	0	60	0
D-7	City of Oyama	0	4	1436	0	60	0
D-8	Yokota AB	225	4	1211	60	60	4
D-9	Akasaka Press Center	89	225	1126	45	60	2
D-10	Atsugi NAF	486	5	949	45	60	4
D-11	Yokosuka NB	0	15	1425	17	60	6
D-12	Camp Fuji	0	20	1420	0	60	0
D-13	Iwakuni MCAS	0	398	1042	0	60	0
D-14	Sasebo NB	0	0	1440	0	60	0

* Composite Daily Values, Note: GOJ=Government of Japan Data

Dose Ratios of "Air, Water, Soil" to "External" Used for Data Gaps

UBDC: Whole Body Effective Dose Rate from External Exposure

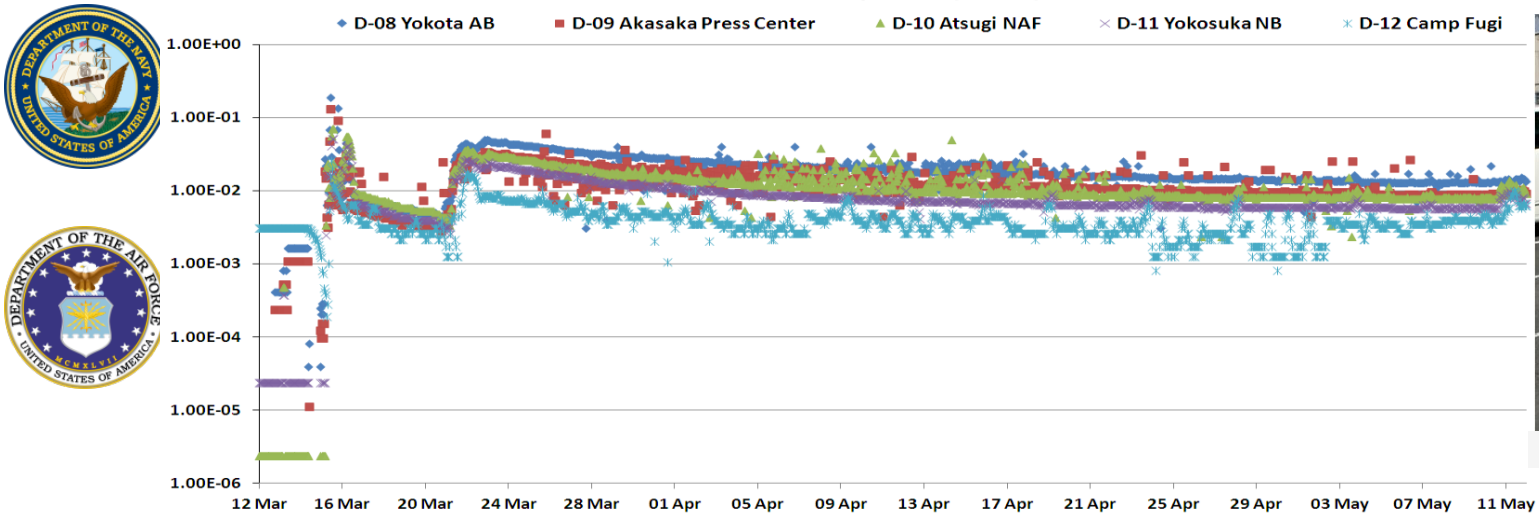
$$\dot{TED}\left(\frac{rem}{h}\right) = \dot{E}_{External\ Radiation} + \dot{E}(\tau)_{Air\ Inhalation} + \dot{E}(\tau)_{Water\ Ingestion} + \dot{E}(\tau)_{Soil\ Ingestion}$$

$$\dot{E}\left(\frac{rem}{h}\right) = External\ Radiation\ Exposure\ Rate\ Measurement\left(\frac{R}{h}\right) x$$

$$Dose\ per\ Exposure\left(\frac{rem}{R}\right) x$$

$$Indoor\ Dose\ Protection\ Factor\ for\ External\ Radiation\ (No\ Units)$$

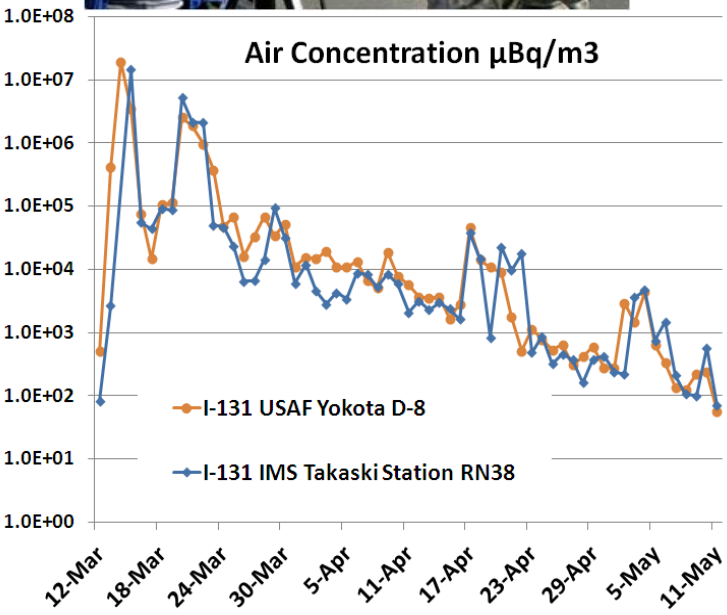
Tokyo Prefecture (roof 18 m high)
GOJ MEXT Station



Field Monitoring with AN/VDR-2

UBDC: Committed Effective Dose Rate from Air Inhalation

$$\dot{TED}\left(\frac{rem}{h}\right) = \dot{E}_{External\ Radiation} + \dot{E}(\tau)_{Air\ Inhalation} + \dot{E}(\tau)_{Water\ Ingestion} + \dot{E}(\tau)_{Soil\ Ingestion}$$



$$\dot{E}(\tau)_{Air\ Inhalation}\left(\frac{rem}{h}\right) = \text{Volume Air Breathed per Day}/24\left(\frac{m^3}{h}\right) \times$$

$$\text{Sample Time Decay Correction Factor (No Units)} \times$$

$$\text{Unit Conversion}\left(\frac{Bq}{\mu Bq} \times \frac{rem}{Sv}\right) \times$$

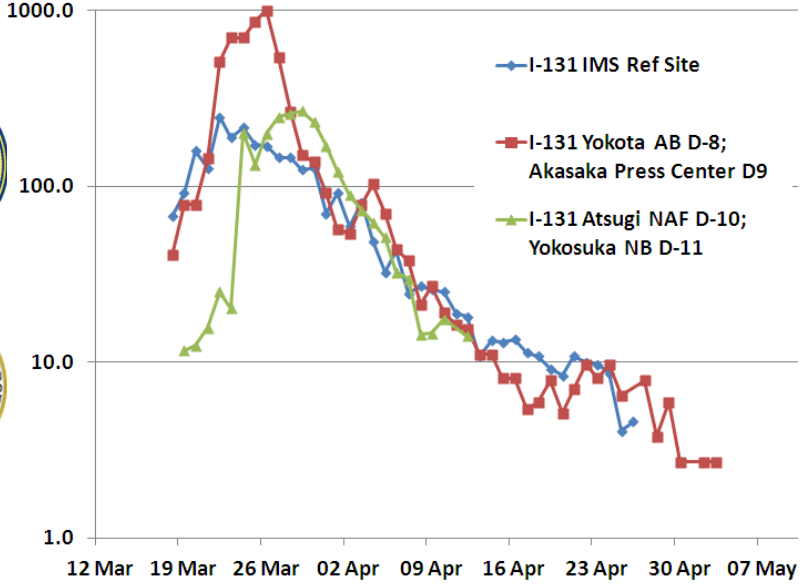
$$\sum_{Species\ i}^{Species\ 22}\left(\text{Measured Activity per Air Volume}_{Species\ i}\left(\frac{\mu Bq}{m^3}\right) \times\right.$$

$$\text{Dose per Activity Intake Inhalation}_{Species\ i}\left(\frac{Sv}{Bq}\right) \times$$

$$\left.\text{Indoor Dose Protection Factor for inhalation (No Units)}_{Species\ i}\right)$$

UBDC: Committed Effective Dose Rate from Water Ingestion

$$\dot{TED}\left(\frac{rem}{h}\right) = \dot{E}_{External\ Radiation} + \dot{E}(\tau)_{Air\ Inhalation} + \dot{E}(\tau)_{Water\ Ingestion} + \dot{E}(\tau)_{Soil\ Ingestion}$$



$$\dot{E}(\tau)_{Water\ Ingestion}\left(\frac{rem}{h}\right) =$$

$$\text{Volume Water Ingested per Day}/24\left(\frac{L}{h}\right) \times$$

$$\sum_{Species\ 1}^{Species\ 3}\left(\text{Measured Activity per Water Volume}_{\ Species\ i}\left(\frac{pCi}{L}\right) \times \right.$$

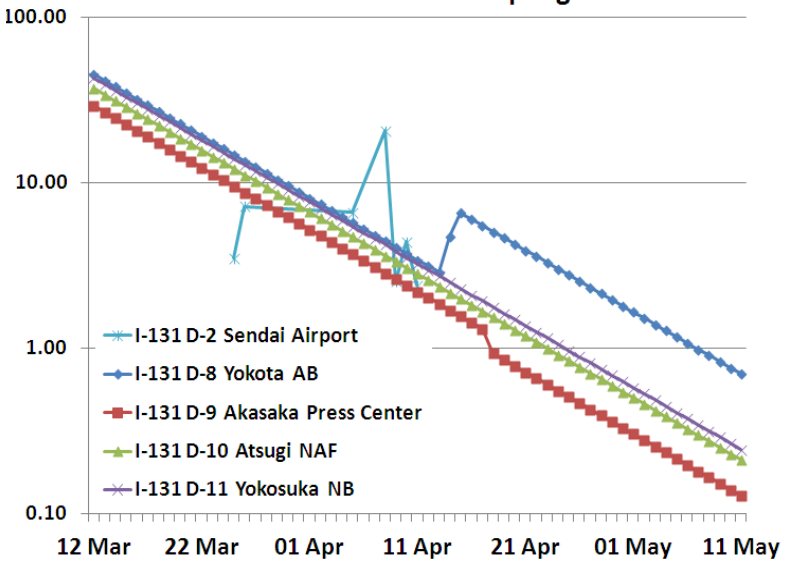
$$\left.\text{Dose per Activity Intake Water Ingested}_{\ Species\ i}\left(\frac{Sv}{Bq}\right)\right)$$

$$\times\ \text{Unit Conversion}\left(\frac{Bq}{pCi}\cdot\frac{rem}{Sv}\right)$$

UBDC: Committed Effective Dose Rate from Soil/Dust Ingestion

$$\dot{TED}\left(\frac{rem}{h}\right) = \dot{E}_{External\ Radiation} + \dot{E}(\tau)_{Air\ Inhalation} + \dot{E}(\tau)_{Water\ Ingestion} + \dot{E}(\tau)_{Soil\ Ingestion}$$

Soil Concentration pCi g^{-1}



$$\dot{E}(\tau)_{Soil\ Ingestion}\ (rem/h) =$$

$$\text{Mass Soil Ingested per day}/24\left(\frac{g}{h}\right) \times$$

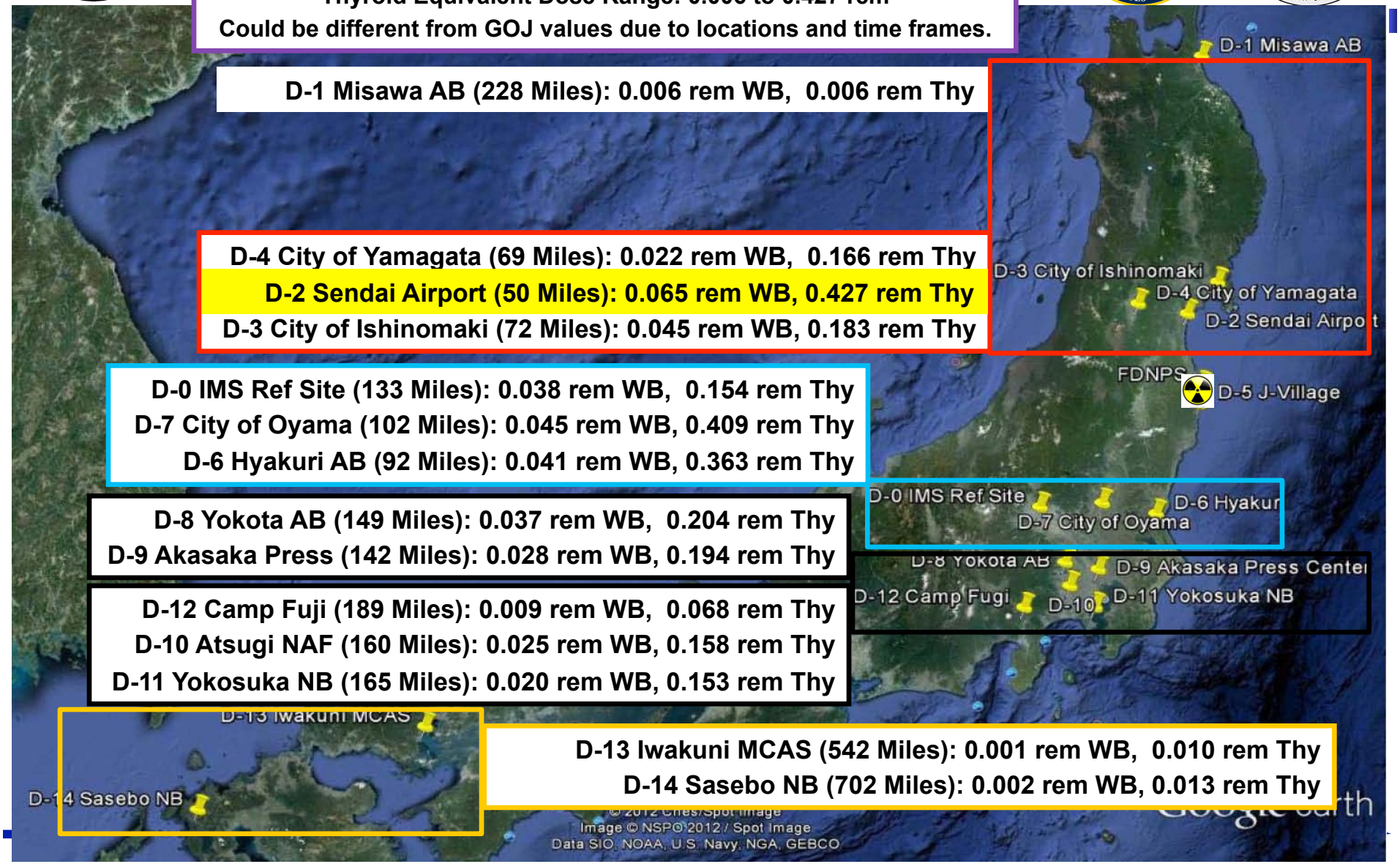
$$\sum_{Species\ 1}^{Species\ 5}\left(\text{Measured Activity per Soil Mass}_{Species\ i}\left(\frac{pCi}{g}\right) \times \right.$$

$$\left.\text{Dose per Activity Intake Soil Ingested}_{Species\ i}\left(\frac{Sv}{Bq}\right)\right)$$

$$\times \quad \text{Unit Conversion}\left(\frac{Bq}{pCi}\cdot\frac{rem}{Sv}\right)$$

Preliminary Adult Upper-Bound Doses

Whole Body Effective Dose Range: 0.001 to 0.065 rem
Thyroid Equivalent Dose Range: 0.006 to 0.427 rem
Could be different from GOJ values due to locations and time frames.



D-1 Misawa AB (228 Miles): 0.006 rem WB, 0.006 rem Thy

D-4 City of Yamagata (69 Miles): 0.022 rem WB, 0.166 rem Thy
D-2 Sendai Airport (50 Miles): 0.065 rem WB, 0.427 rem Thy
D-3 City of Ishinomaki (72 Miles): 0.045 rem WB, 0.183 rem Thy

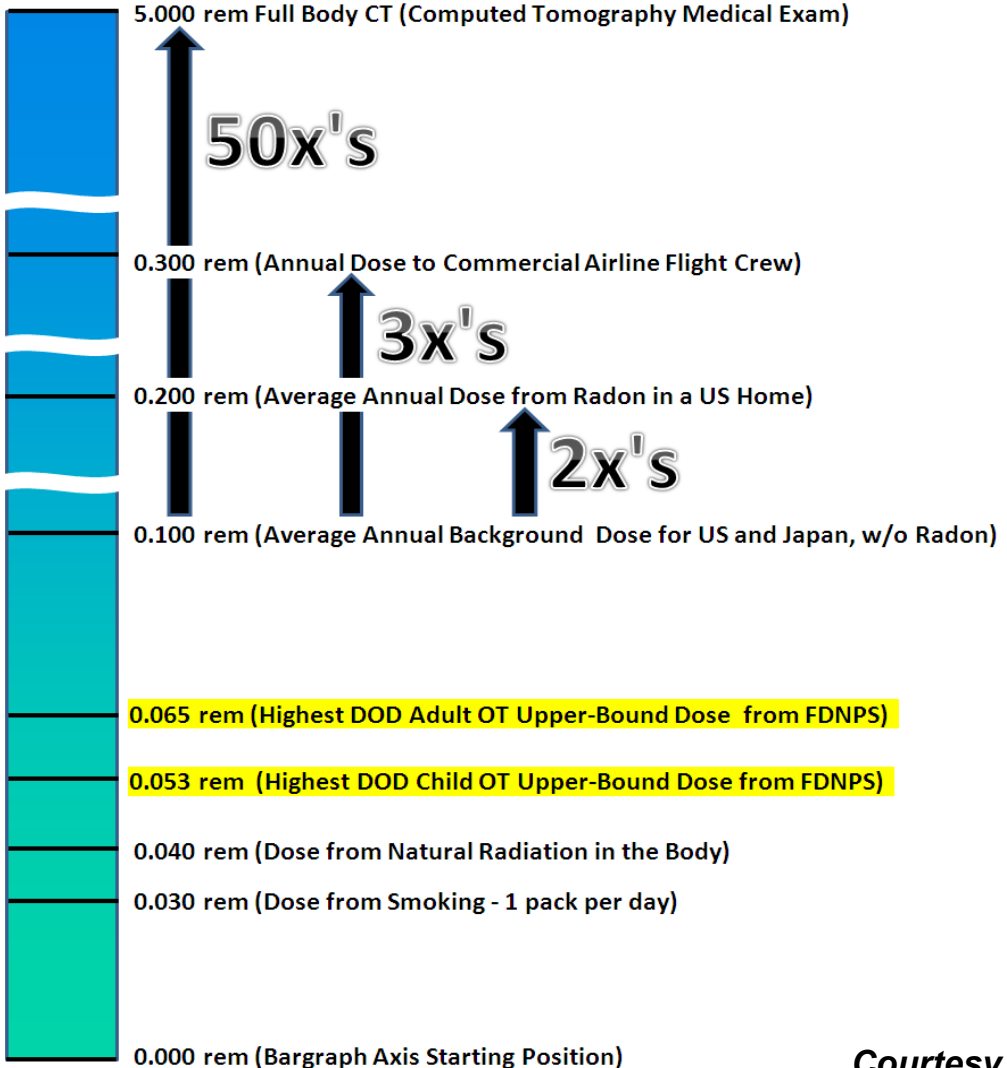
D-0 IMS Ref Site (133 Miles): 0.038 rem WB, 0.154 rem Thy
D-7 City of Oyama (102 Miles): 0.045 rem WB, 0.409 rem Thy
D-6 Hyakuri AB (92 Miles): 0.041 rem WB, 0.363 rem Thy

D-8 Yokota AB (149 Miles): 0.037 rem WB, 0.204 rem Thy
D-9 Akasaka Press (142 Miles): 0.028 rem WB, 0.194 rem Thy

D-12 Camp Fuji (189 Miles): 0.009 rem WB, 0.068 rem Thy
D-10 Atsugi NAF (160 Miles): 0.025 rem WB, 0.158 rem Thy
D-11 Yokosuka NB (165 Miles): 0.020 rem WB, 0.153 rem Thy

D-13 Iwakuni MCAS (542 Miles): 0.001 rem WB, 0.010 rem Thy
D-14 Sasebo NB (702 Miles): 0.002 rem WB, 0.013 rem Thy

Dose Perspective – Whole Body Effective Dose



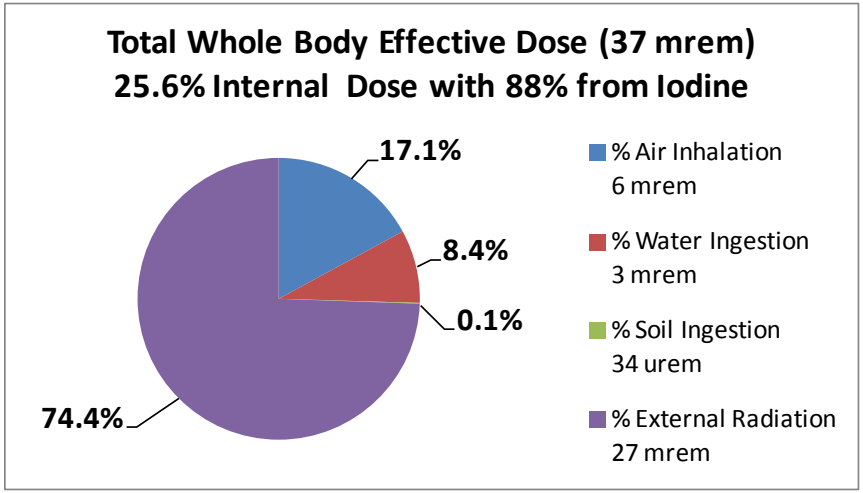
Courtesy of Dr. Jerry Falo

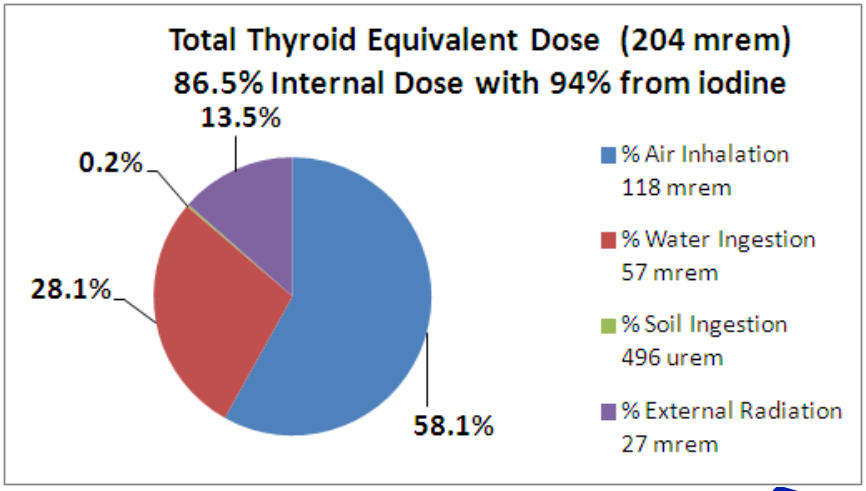
UBDC: Organ and Whole Body Dose Comparison

Committed equivalent dose to organs from inhalation and ingestion calculations (internal doses) for adults performing humanitaritian work (rem)				
Organ	D-8 Yokota AB	D-9 Akasaka Press Center	D-10 Atsugi NAF	D-11 Yokosuka NB
Adrenals	0.001	0.003	0.007	0.001
Bladder Wall	0.002	0.004	0.012	0.003
Bone Surface	0.001	0.004	0.009	0.003
Brain	0.001	0.002	0.006	0.001
Breast	0.000	0.002	0.005	0.001
Oesophagus	0.001	0.003	0.007	0.001
St Wall	0.001	0.003	0.007	0.001
SI Wall	0.001	0.003	0.008	0.001
ULI Wall	0.001	0.004	0.008	0.002
LLI Wall	0.002	0.005	0.009	0.003
Colon	0.001	0.004	0.008	0.002
Kidneys	0.001	0.003	0.007	0.002
Liver	0.001	0.004	0.007	0.001
Muscle	0.001	0.003	0.006	0.001
Ovaries	0.001	0.003	0.008	0.001
Pancreas	0.001	0.003	0.008	0.001
Red Marrow	0.001	0.003	0.007	0.002
ET Airways	0.004	0.010	0.018	0.006
Lungs	0.001	0.003	0.007	0.001
Skin	0.000	0.002	0.005	0.001
Spleen	0.001	0.003	0.007	0.001
Testes	0.001	0.003	0.006	0.001
Thymus	0.001	0.003	0.007	0.001
Thyroid	0.176	0.358	0.531	0.294
Uterus	0.001	0.003	0.008	0.001
Remainder	0.001	0.005	0.010	0.002
Effective dose	0.009	0.021	0.034	0.016

Results validate that the thyroid is the only organ of concern.

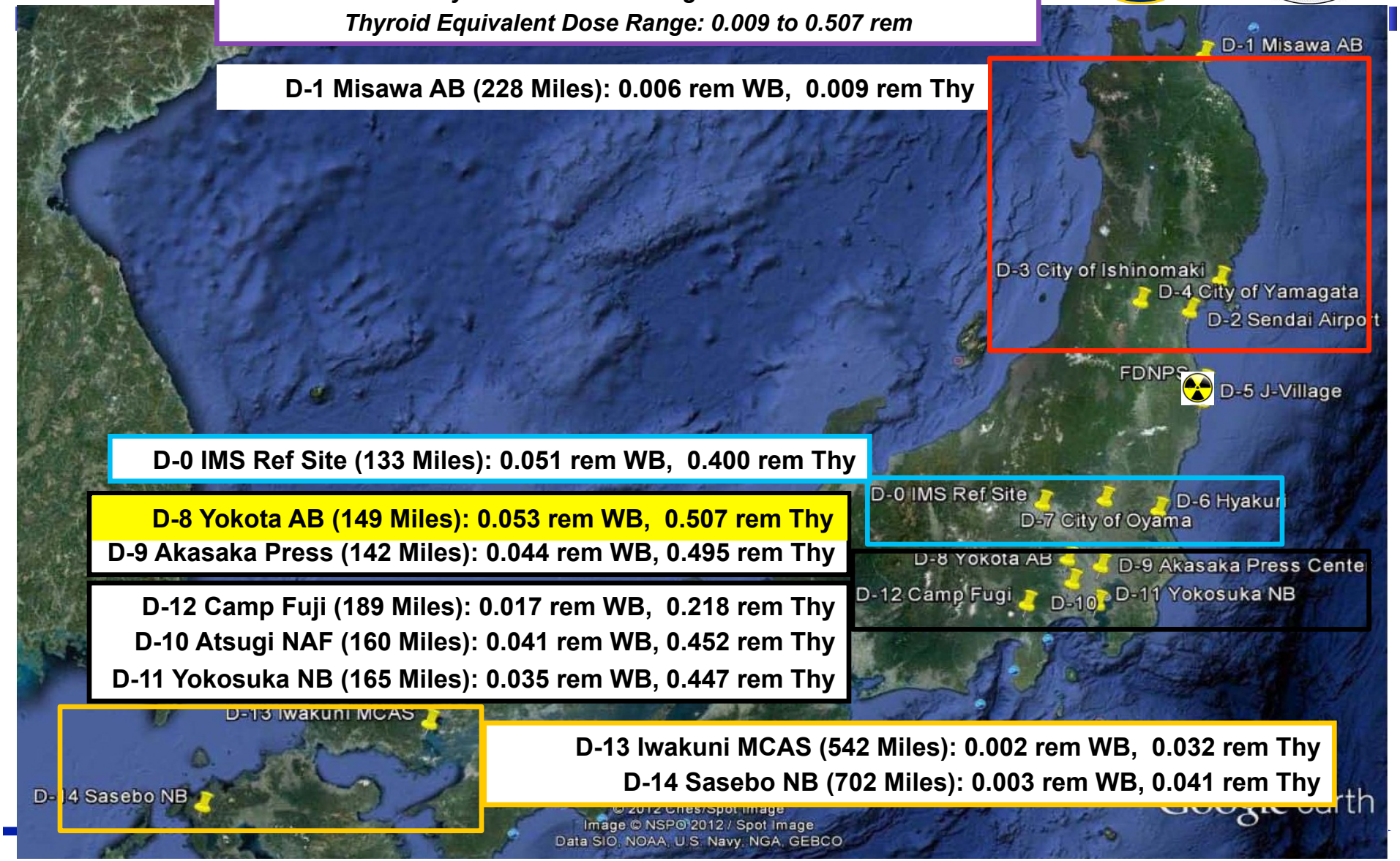
D-8 Yokota Air Base Doses (Iodine dominates)





Preliminary Children (1 to 2 Years) UB Doses

Whole Body Effective Dose Range: 0.002 to 0.053 rem
Thyroid Equivalent Dose Range: 0.009 to 0.507 rem



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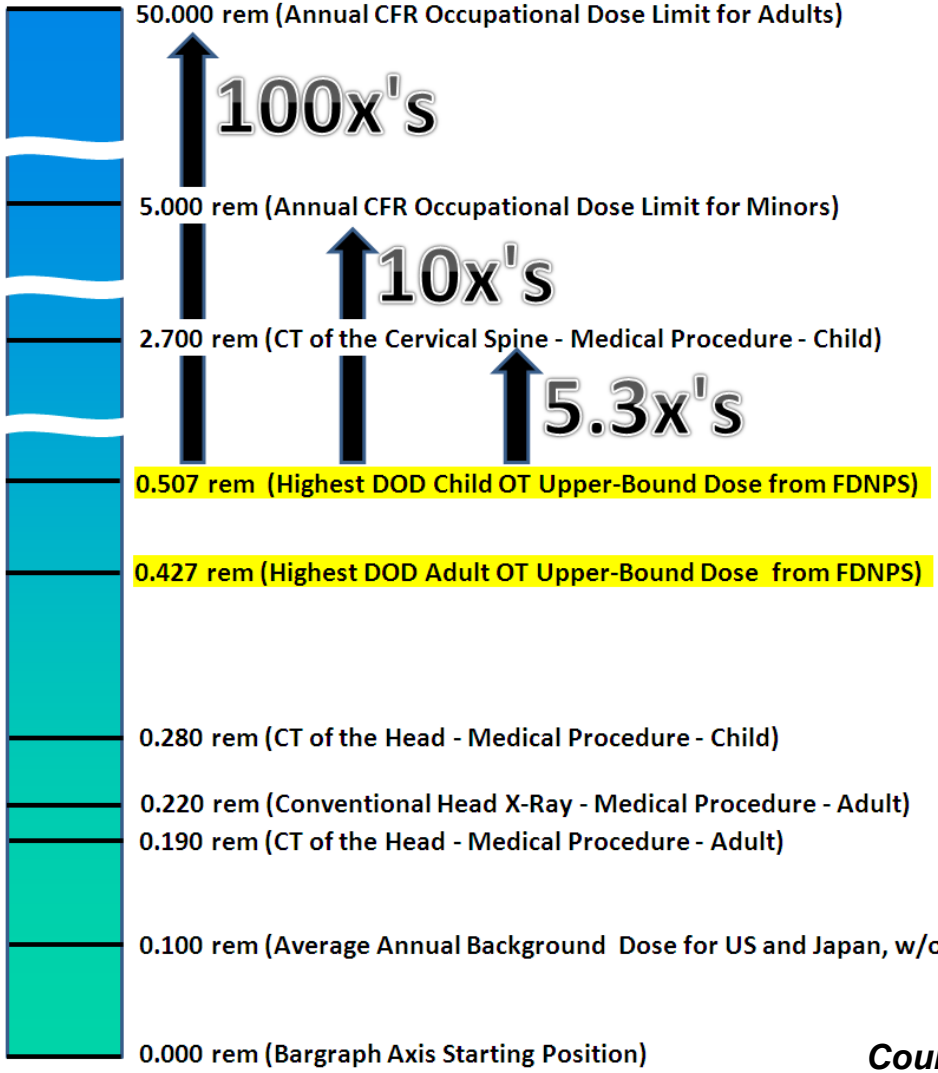
D-12 Camp Fuji (189 Miles): 0.017 rem WB, 0.218 rem Thy
D-10 Atsugi NAF (160 Miles): 0.041 rem WB, 0.452 rem Thy
D-11 Yokosuka NB (165 Miles): 0.035 rem WB, 0.447 rem Thy

D-13 Iwakuni MCAS (542 Miles): 0.002 rem WB, 0.032 rem Thy
D-14 Sasebo NB (702 Miles): 0.003 rem WB, 0.041 rem Thy

Dose Perspective – Thyroid Equivalent Dose



Courtesy of Dr. Jerry Falo

Questions?

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