Fundamentals of Radiation Protection Across Industries

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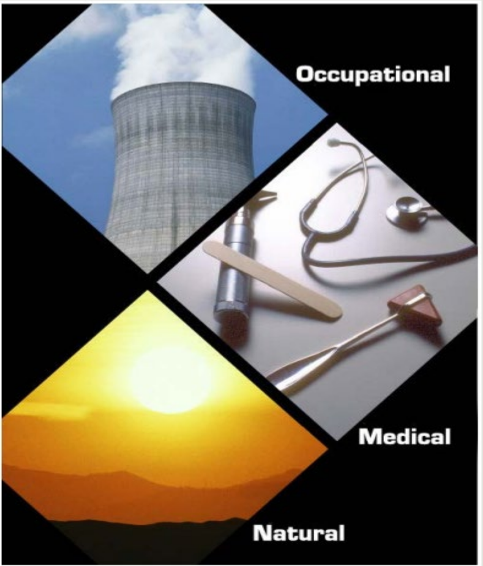

California Hospital Association

Presenter

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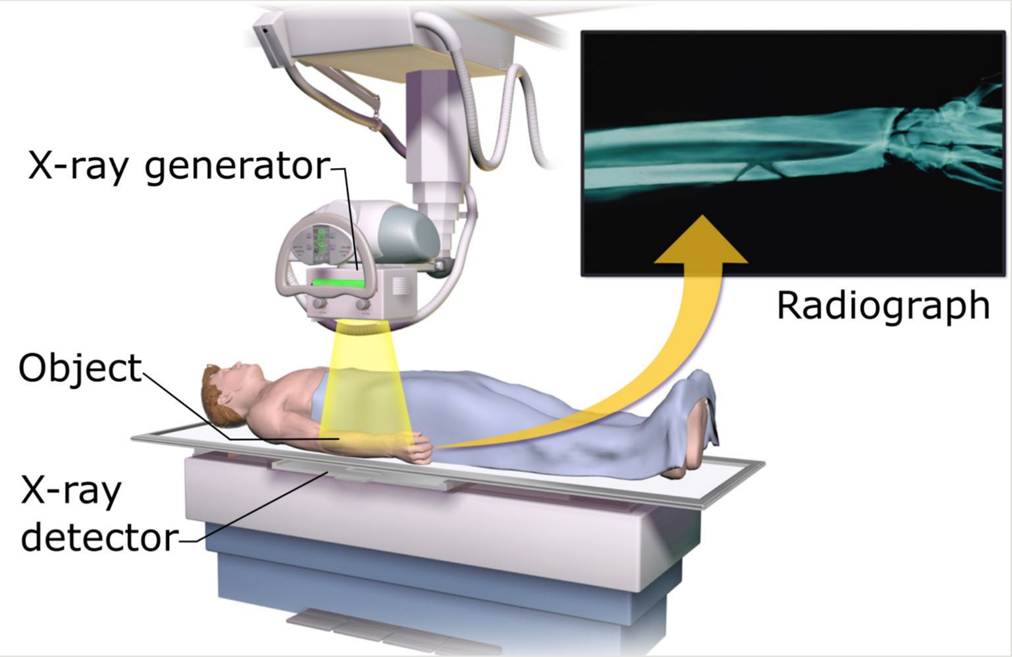
Dr. Raj Puri is the Corporate Medical Director for PBF Energy. He specializes in Occupational Medicine and Clinical Informatics and oversees the company's medical clinics as well as the health and well-being of employees across the company nationwide. Dr. Puri is a physician with expertise in exposure-related incidents and works at the intersection of medicine, public health, and technology involving workplace safety.

California Hospital Association

Disclosure of Relevant Financial Relationships

Raj Puri, MD, MPH reports no relevant financial relationships or relationships he has with ineligible companies of any amount during the past 24 months.



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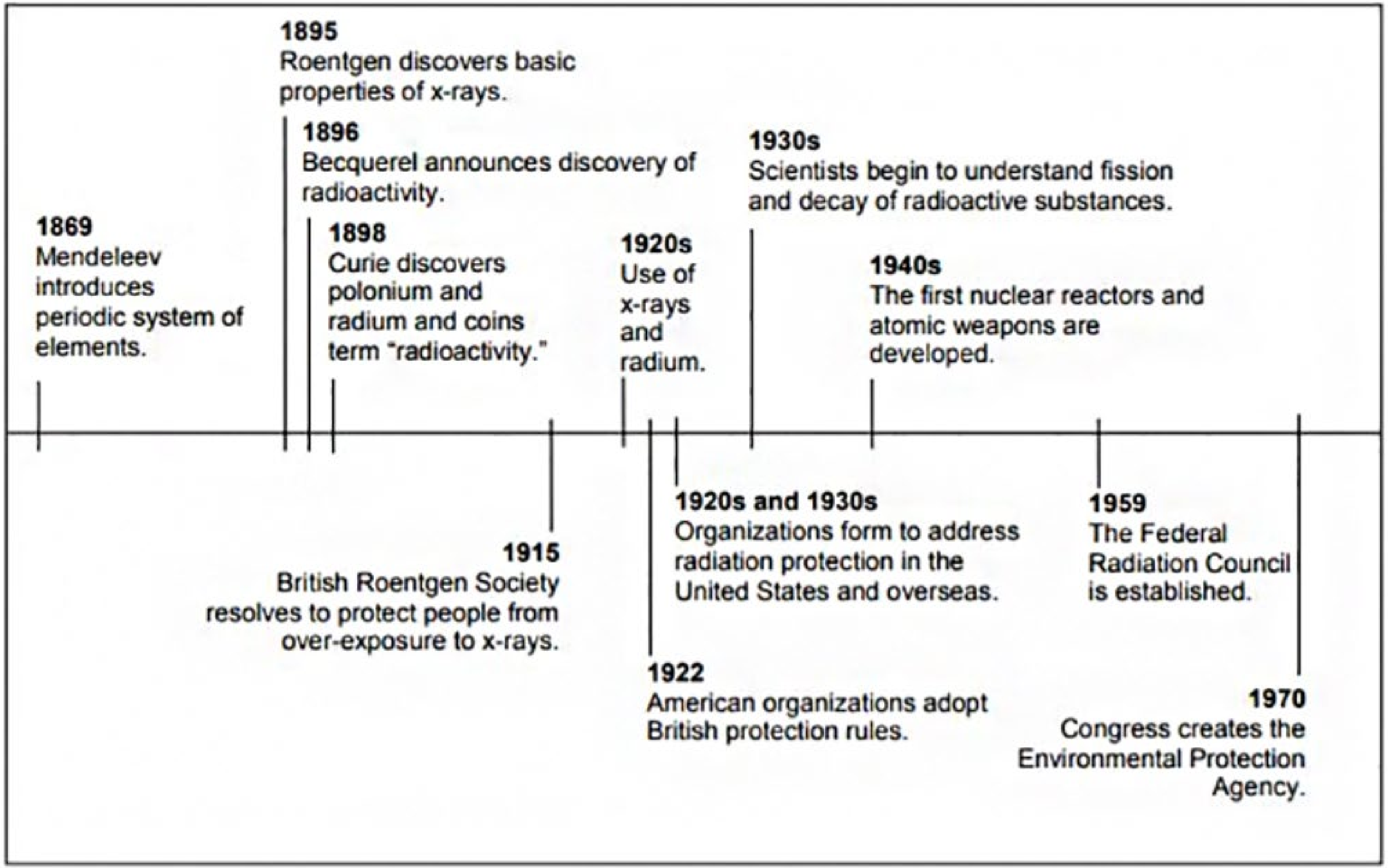
Outline

- Introduction – overview, not exhaustive discussion
- Brief overview of radiation basics
- Regulatory Framework and Standards
- Principles of Radiation Protection: ALARA
- Clinical/occupational examples – interspersed in between
- Emergency Response + Resources
- Summary

Historical Milestones for Radiation Protection



From Discovery to Modern Safety Standards for Radiation Protection

- **Late 19th Century:** Discovery of X-rays by Wilhelm Conrad Roentgen in 1895 revolutionized diagnostic medicine
- **Early 20th Century:** Rapid adoption of X-ray technology in medicine, with minimal understanding of radiation hazards
  - Early radiologists and patients suffered from **radiation burns** and other health issues due to **unregulated exposure**
- **Mid-20th Century:** Development of **nuclear medicine and radiation therapy**, employing radionuclides and linear accelerators to diagnose and treat diseases, notably cancer
  - This period also marked the emergence of significant radiation safety measures and the **establishment of regulatory bodies**

- **Regulatory Milestones:**
  - **1928:** The **International Commission on Radiological Protection (ICRP)** was established, focusing on radiation protection guidance
  - **1940s-1950s:** Increased awareness of radiation risks led to the development of **dose limits** and protective measures for occupational exposure
  - **1970s:** The establishment of the **Nuclear Regulatory Commission (NRC)** in the United States and similar bodies worldwide to regulate the use of nuclear energy and materials, including in health care

Radiation Basics

Units of **radiation dose**, we use either:

- International unit for dose: **Sievert (Sv) or the Gray (Gy)**
- United States unit for dose: **rem or the rad**

It is common to see variations of these units such as:

- millisievert (mSv)
- millirem (mrem)

Converting between international units and U.S. units:

- 1 Sv = 100 rem
- 1rem = 10 mSv
- 1 Gy = 100 rad
- 1 rad = 10 mGy

- **Inverse Square Law:** Intensity of the radiation dose decreases inversely with the square of the distance (1/R2); further is better

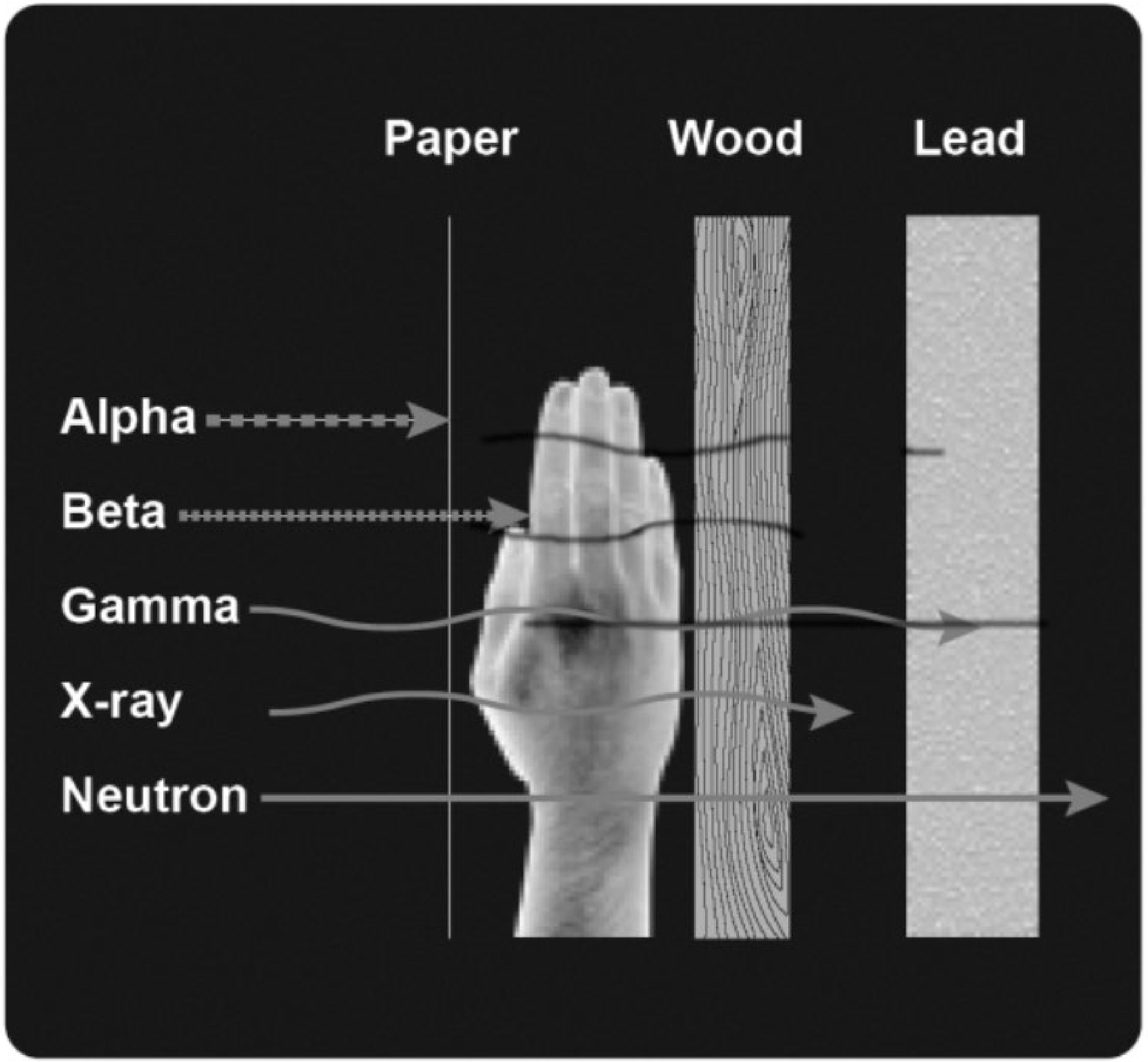
- **ALARA:** As low as Reasonably Achieved

- **TDS:** Time, Distance, Shielding

Ionizing vs. Non-Ionizing Radiation

- **Ionizing** radiation – enough energy to remove tightly bound electrons from atoms, creating ions e.g. diagnostic imaging (fluoroscopes, CT scanners) and cancer cell destruction (RF)
- **Non-ionizing** radiation – lacking energy to ionize atoms, includes MRI, ultrasound, and lasers

Ionizing Radiation



Sealed Sources in Industry and Medicine:

- Commonly contain iridium-192, cesium-137, and cobalt-60
- Utilized for their beta and gamma emissions

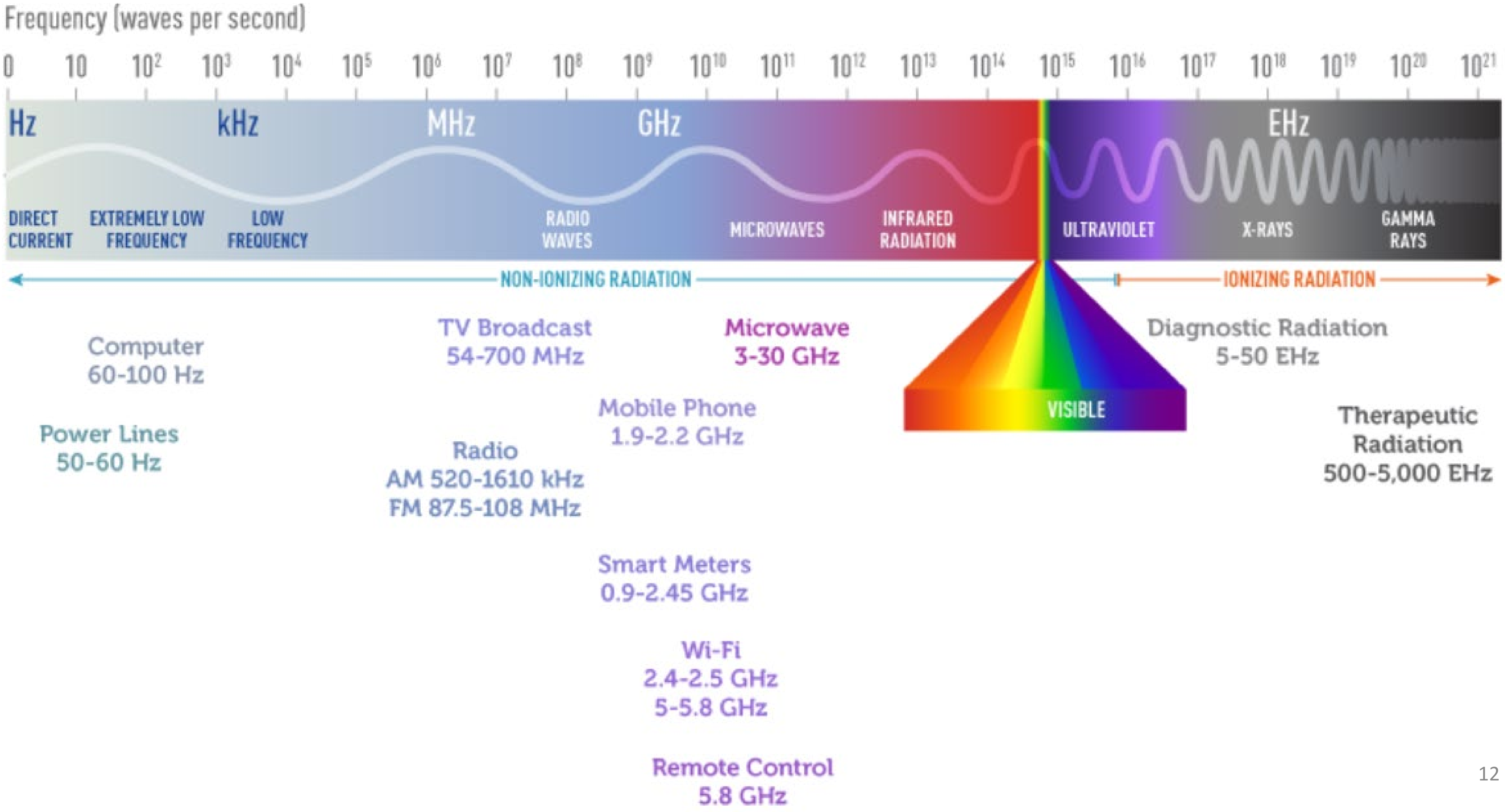
Exposure Types:

- Beta and gamma emitters lead to isolated exposure without contamination

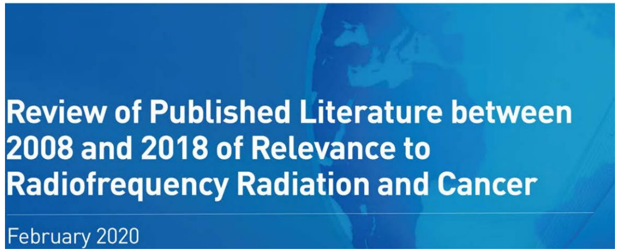
Emission Sources:

- Alpha and neutron emissions typically result from nuclear reactions
- Common in scenarios like nuclear detonations and power plant accidents

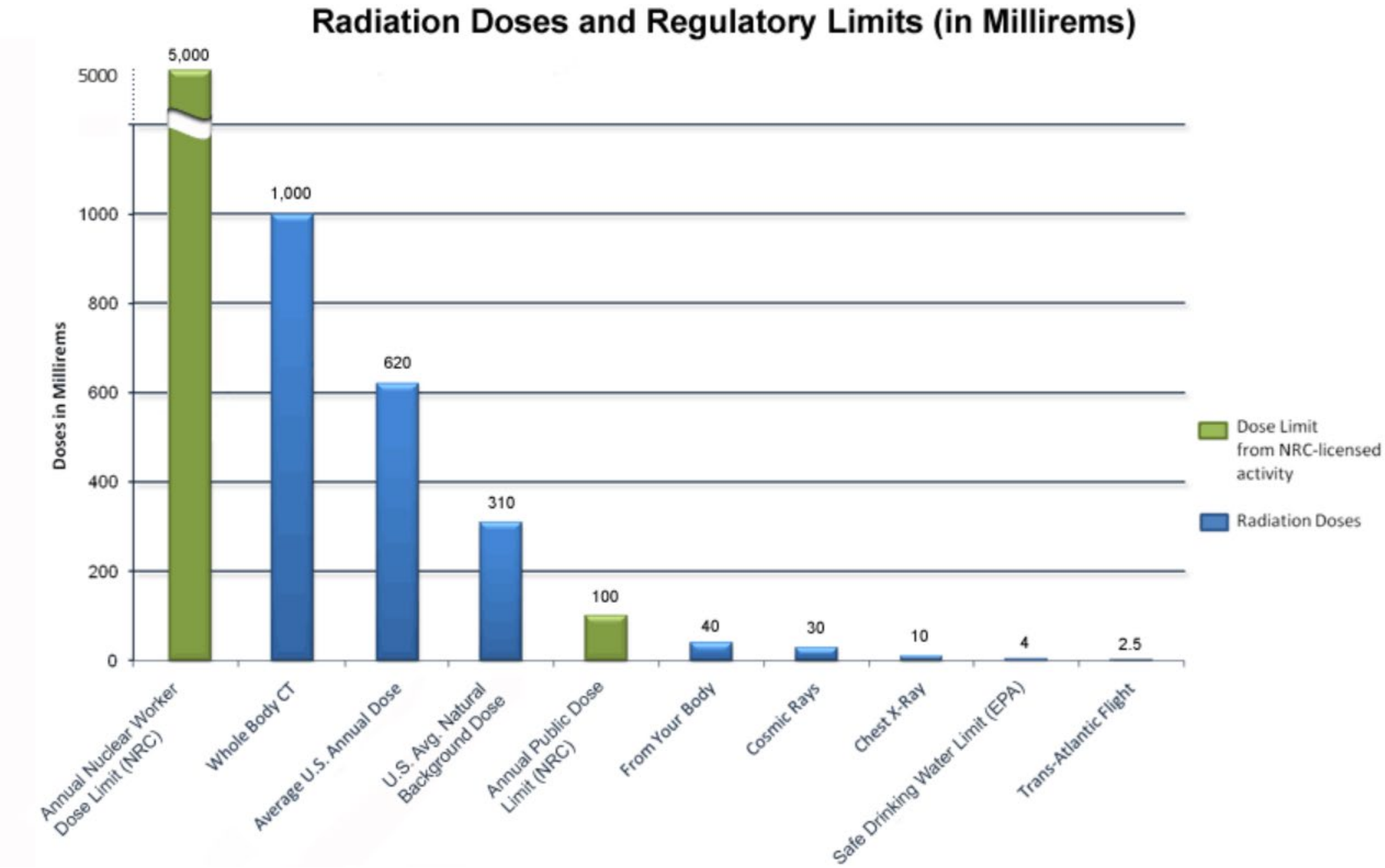
ELECTROMAGNETIC SPECTRUM



U.S. FOOD & DRUG ADMINISTRATION
CENTER FOR DEVICES & RADIOLOGICAL HEALTH



- Data Period: January 1, 2008, to May 8, 2018
- Key Findings:
  - **No quantifiable causal link** between RFR exposure and tumor formation (from cell phones)
  - Suggests **focus on individuals predisposed** to tumorigenesis, potentially more affected by intense RF-EMF exposure
- Study Limitations:
  - Studies generally rely on the participants to **track and self-report (recall bias)**
  - Actual RFR exposure remains an **estimate at best**
- Current Epidemiological Evidence:
  - Cell phone use **not an independent etiological factor** for intracranial or other tumors
  - Any potential risk is **extremely low** vs. natural incidence and known risks



- Americans receive an average annual radiation dose of about 0.62 rem (620 millirem)
- Half of this dose (0.31 rem or 310 mrem) is from natural background radiation, primarily radon in the air, with lesser contributions from cosmic rays and the Earth
- The other half (0.31 rem or 310 mrem) originates from man-made sources, such as medical, commercial, and industrial sources
- A yearly dose of 620 mrem from all radiation sources is generally not harmful to humans

OSHA Ionizing Radiation Standard

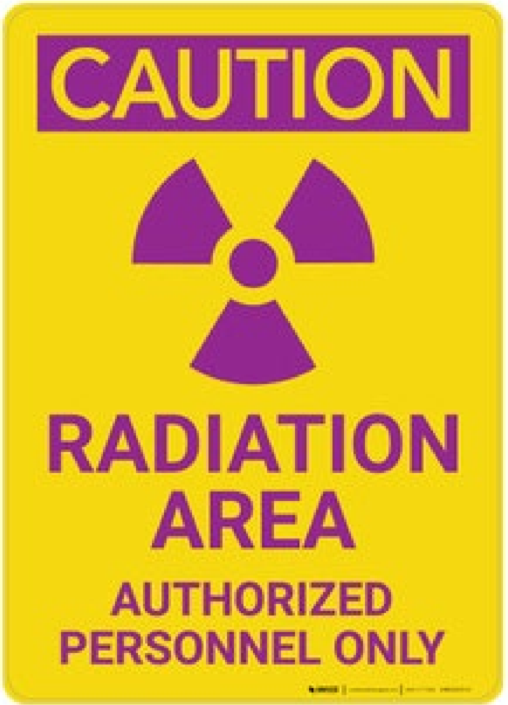
- Whole body: head and trunk; active blood-forming organs; lens of eyes; or gonads: **1.25 rem per quarter**
- Hands and forearms; feet and ankles: **18.75 rem per quarter**
- Skin of whole body: **7.5 rem per quarter**
- Employers must provide appropriate personal monitoring equipment (e.g., film badges, pocket chambers, dosimeters, film rings)
  - Required use of equipment for employees entering restricted areas
  - Applies when employees may receive **doses exceeding 25% of the occupational limit in any calendar quarter**

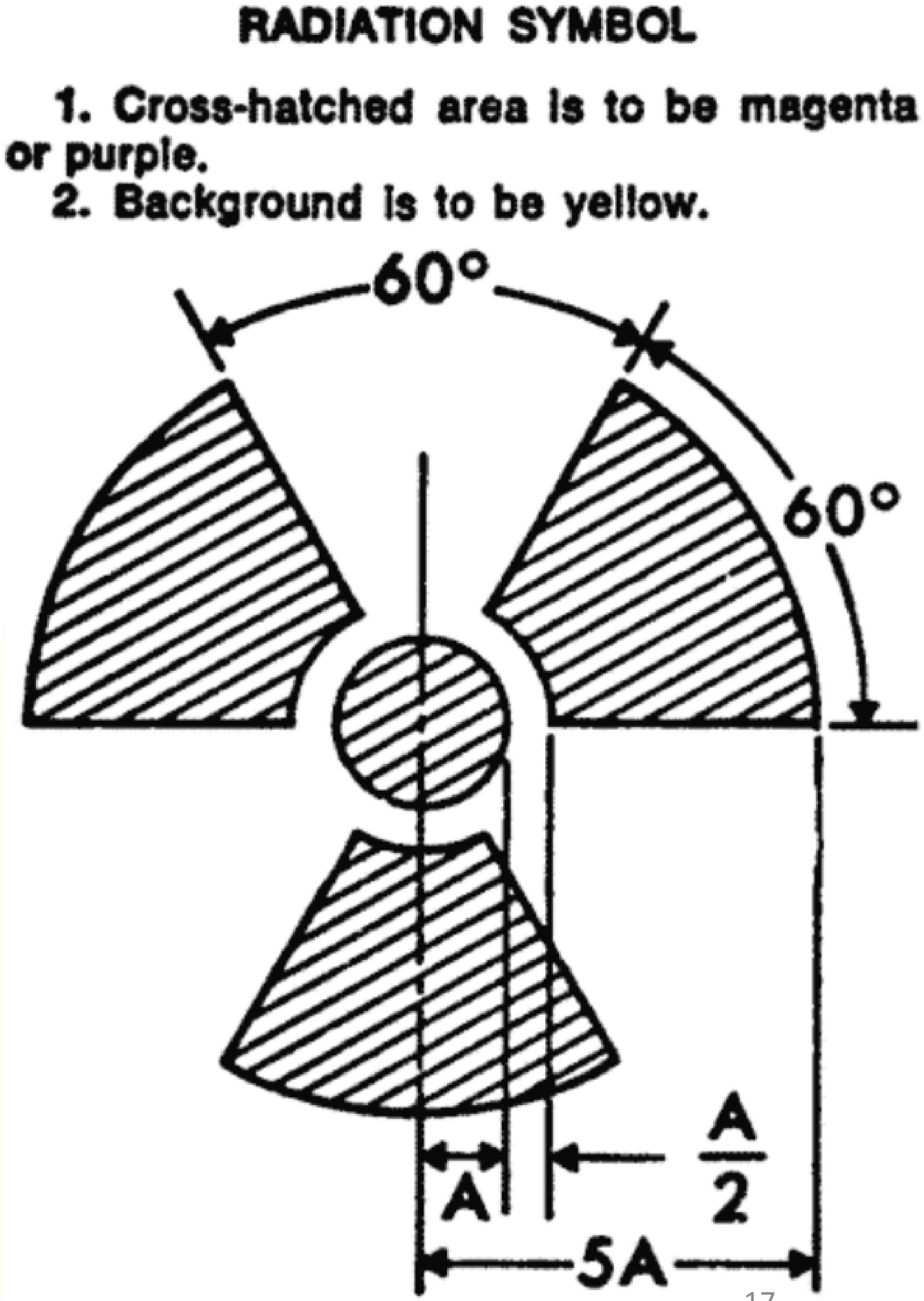
- **Annual Occupational Exposure Limit:**
  - 5 rem (0.05 Sv) across all occupations
  - Emphasis on minimizing dose through reasonably achievable actions
- **Infrastructure Protection (Lower-Hazard Areas):**
  - Limit: 10 rem (0.10 Sv) for public welfare tasks in Light Damage/fallout areas, excluding Dangerous Fallout zones
- **Life-Saving & Medical Response (Medium-Hazard Areas):**
  - Limit: 25 rem (0.25 Sv) for operations in Moderate Damage zones, excluding Dangerous Fallout zones
- **High-Hazard Zones Missions:**
  - Greater than 25 rem (>0.25 Sv) for direct population protection in Dangerous Fallout zones; up to 50 rem (0.5 Sv)

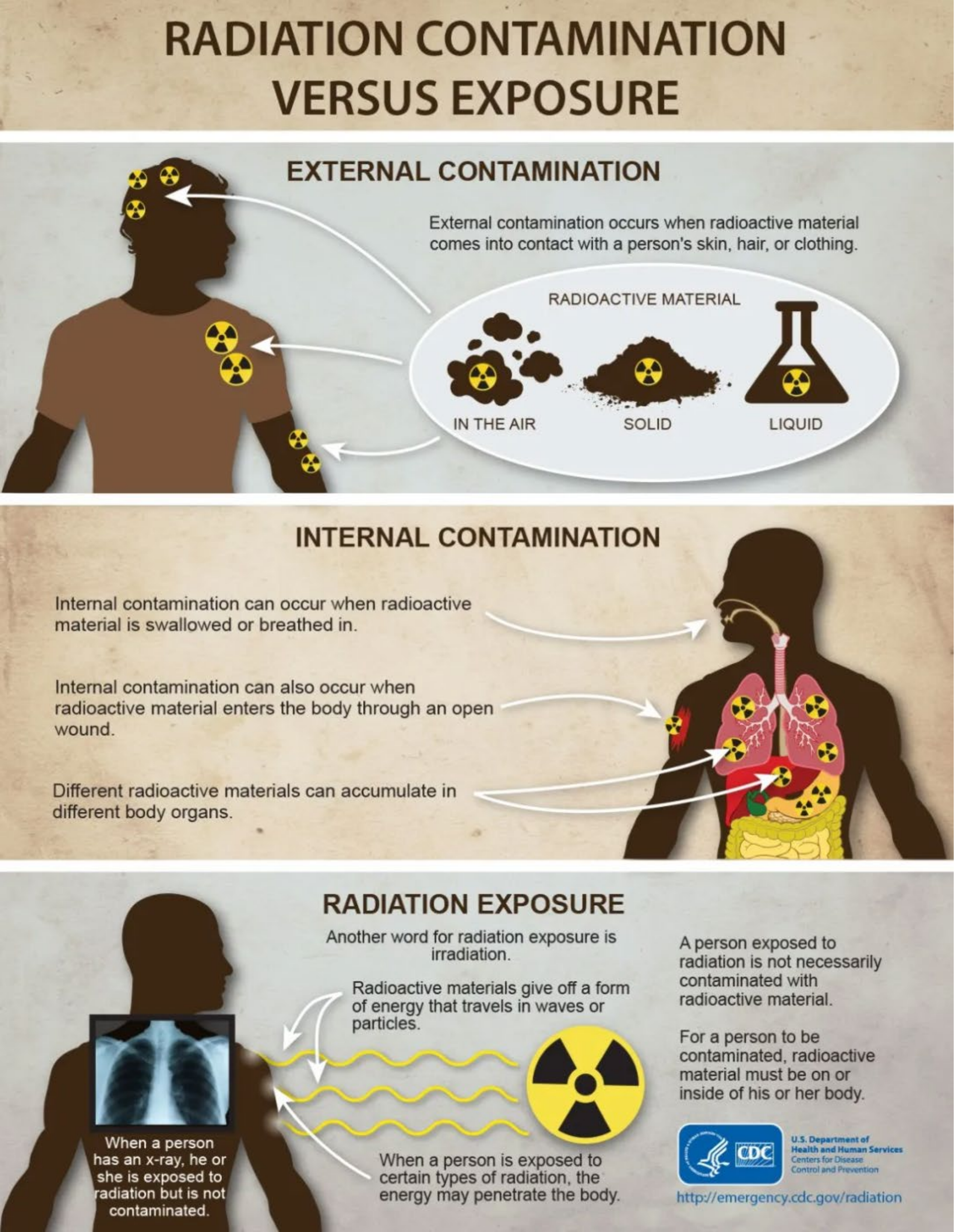
Adapted from "Health and Safety Planning Guide for Planners, Safety Officers and Supervisors for Protecting Responders Following a Nuclear Detonation" (2016)

Most Common Citations, OSHA Ionizing Radiation Standard

- Surveys of radiation levels 29 CFR 1910.1096(d)(1)
- Personal monitoring 29 CFR 1910.1096(d)(2)
- Posting of radiation areas 29 CFR 1910.1096(e)(2)
- Instruction of personnel 29 CFR 1910.1096(i)(2)
- Posting of operating procedures 29 CFR 1910.1096(i)(3)



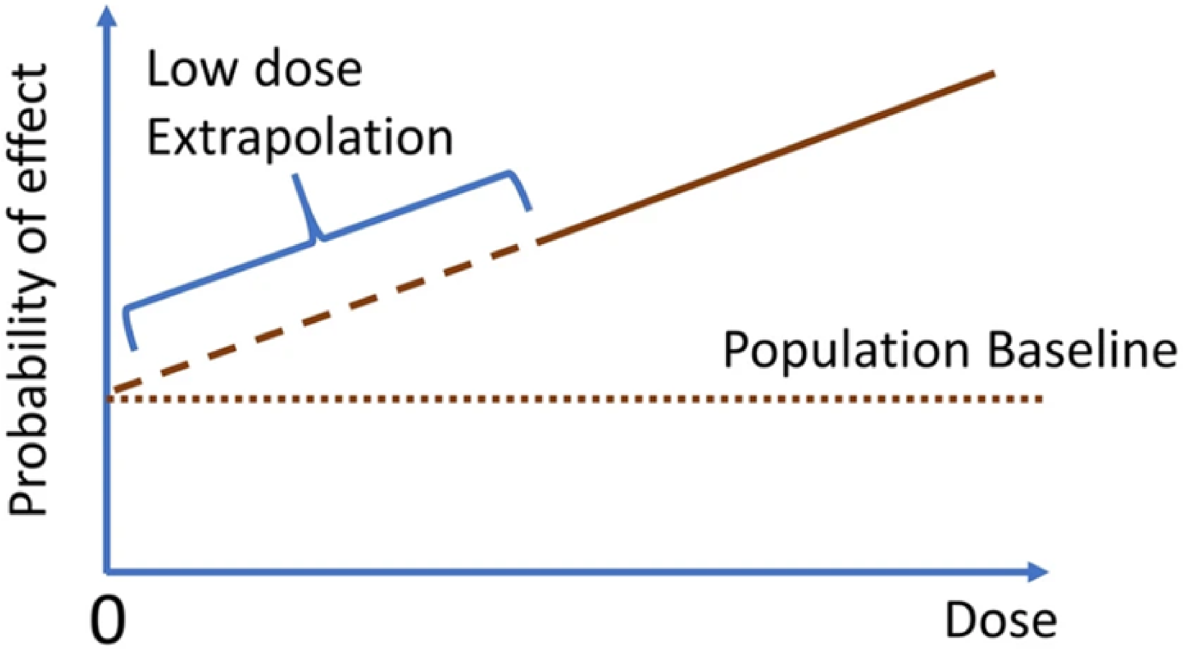




- **Nuclear Power Plant Accidents:** Release of radioactive materials into the environment (e.g., Fukushima Daiichi disaster)
- **Laboratory or Medical Settings:** Leakage or mishandling of radioactive sources contaminating surfaces and personnel
- **Radioactive Fallout:** After nuclear explosions, radioactive dust contaminates air, water, soil, and living beings

Stochastic Effects

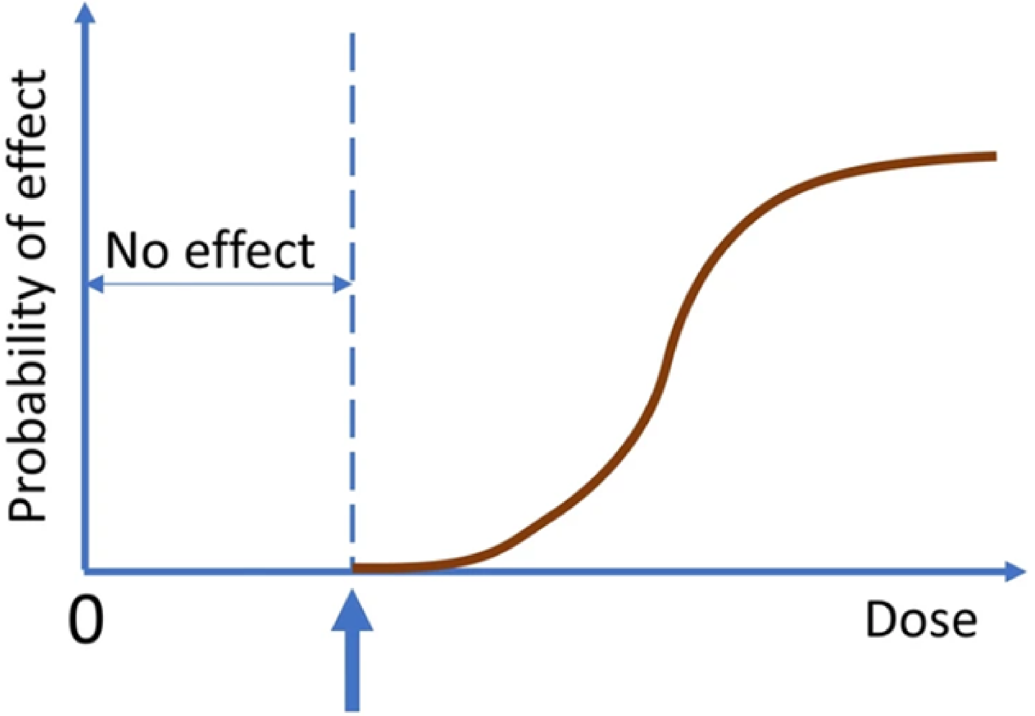
Includes cancer, leukemia, hereditary effects
Effect of radiation exposure below certain dose are unclear, but assumed to have some effect as well



No threshold Dose

Deterministic Effects
Tissue Reactions

Threshold dose is where 1% of those exposed at a given dose will be affected by certain symptoms. Probability and severity increase with dose



Threshold Dose

Conceptual dose response curves for stochastic effects (left) and tissue reactions (right)

Understanding Ionizing Radiation Exposure

- Natural vs. Manmade Sources
  - **Natural Sources:** emit low levels
    - Cosmic and solar radiation from space
    - Terrestrial radiation from the earth
    - Radon gas from underground: **2nd leading cause of lung cancer**
    - Radiation from building materials
  - **Manmade Sources:** main danger to humans
    - Smoke detectors, medical instrument sterilization
    - Diagnostic medical exams (X-rays, CT scans, PET scans, Fluoroscopy, Nuclear medicine)

Main Points:

- Exposure varies by location, altitude, and building materials
- Main manmade exposure is through **medical diagnostics**
- Radon is a significant natural source with health risks

Regulatory Overview of Radiation Safety

Ionizing Radiation

- Regulating Bodies: IAEA, ICRP, EPA, NRC, **OSHA**
- **Focus:** Minimize DNA damage, cancer risk, and radiation sickness
- Key Regulations: Safety standards for nuclear energy, radiological protection guidelines, workplace exposure limits
- Applications: Nuclear medicine, industrial radiography, environmental monitoring

Non-Ionizing Radiation

- Regulating Bodies: ICNIRP, WHO, FCC, FDA, **OSHA**
- **Focus:** Avoid thermal injury and photochemical effects on health
- Key Regulations: Exposure limits for electromagnetic fields, **guidelines for laser** and UV safety, mobile and broadcasting antenna standards
- Applications: Telecommunications, medical lasers, consumer electronics

Exposure examples

Chest X-Ray

- Exposure: 0.1 mSv
- Equivalent to natural background radiation **over 10 days**

Mammogram

- Exposure: 0.4 mSv
- Equivalent to natural background radiation **over 7 weeks**

Lower GI Series

- Exposure: 8 mSv
- Equivalent to natural background radiation **over 3 years**

CT Scan (Abdomen and Pelvis)

- Exposure: 10 mSv; **4 years** of background radiation

PET/CT Scan

- Exposure: 25 mSv
- Equivalent to **8 years** of average background radiation

American Cancer Society. Understanding Radiation Risk from Imaging Tests.

Medical Procedure Doses	
Procedure	**Dose (mrem)**
X-Rays-single exposure	
Pelvis	70
Abdomen	60
Chest	10
Dental	1.5
Hand/Foot	0.5
Mammogram (2 views)	72
Nuclear Medicine	400
CT	
Full body	1,000
Chest	700
Head	200

- Medical procedures are the source of nearly all (96%) human exposure to man-made radiation
- A chest x-ray delivers approximately 0.01 rem (10 millirem), while a full-body CT scan provides 1 rem (1,000 mrem)
- X-rays, mammography, and CT scans, which utilize radiation or similar functions but **do not contain radioactive material, fall outside U.S. Nuclear Regulatory Commission (NRC) regulation**
- Regulation of these procedures is primarily the responsibility of state health agencies
- The NRC and Agreement states specifically license and regulate only the use of radioactive materials in nuclear medicine

- All organic matter, including plants and animals, contains trace amounts of radiation from isotopes like potassium-40 (40K) and radium-226 (226Ra)
- Earth's water has small amounts of dissolved uranium and thorium
- Consequently, the average person receives an internal radiation dose of approximately 30 millirem per year from consuming food and water

Natural Radioactivity in Food		
Food	^{40}K (pCi/kg)	^{226}Ra (pCi/kg)
Bananas	3,520	1
Carrots	3,400	0.6 – 2
White Potatoes	3,400	1 – 2.5
Lima Beans (raw)	4,640	2 – 5
Red Meat	3,000	0.5
Brazil Nuts	5,600	1,000 – 7,000
Beer	390	---
Drinking Water	---	0 – 0.17

Exposure Examples

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AIRCREW SAFETY & HEALTH – Cosmic Ionizing Radiation

How much cosmic radiation (external) are crew members exposed to?

- National Council on Radiation Protection and Measurements reports that **aircrew have the largest average annual effective dose (3.07 mSv) of all US radiation-exposed workers**
  - ~50 % of exposure is from neutrons
  - Melanoma, breast cancer seen

National Council on Radiation Protection and Measurements. *Ionizing radiation exposure of the population of the United States. Report No. 160. Recommendations of the National Council on Radiation Protection and Measurements (NCRP).* Bethesda, MD: National Council on Radiation Protection and Measurements, 2009.

- Cosmic Ionizing Radiation Overview:
  - A form of ionizing radiation originating from outer space
  - Only minimal amount reaches the Earth's surface
  - Exposure levels increase at flight altitudes for passengers and crew
- Sources of Cosmic Radiation on Aircraft:
  - Galactic cosmic radiation: Constant presence
  - Solar particle events: Occasionally occur, also known as "solar flares"
    - significant release of particles from the sun, including protons, electrons, and heavy ions

UNDER SECRETARY OF DEFENSE
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WASHINGTON, D.C. 20301-4000

PERSONNEL AND READINESS

FEB - 8 2023

The Honorable Mike D. Rogers
Chairman
Committee on Armed Services
U.S. House of Representatives
Washington, DC 20515

Dear Mr. Chairman:

The Department's response to section 750 of the William M. (Mac) Thornberry National Defense Authorization Action Act (NDAA) for Fiscal Year (FY) 2021 (Public Law 116–283), "Study on the Incidence of Cancer Diagnosis and Mortality Among Military Aviators and Aviation Support Personnel," is enclosed. Section 750(a)(2)(B) requests a report on the results of Phase 1 of the study, which determines if there is a higher incidence of cancers occurring for these military aviators and aviation support personnel as compared to similar age groups in the general population through the use of the database of the Surveillance, Epidemiology, and End Results program of the National Cancer Institute.

This study found that compared to the U.S. population after adjusting for age, sex, and race, aircrew had an 87 percent higher rate of melanoma, 39 percent higher rate of thyroid cancer, 16 percent higher rate of prostate cancer, and a 24 percent higher rate of cancer for all sites. Ground crew members had higher incidence of cancers of brain and nervous system (by 19 percent), thyroid (by 15 percent), melanoma (by 9 percent), kidney and renal pelvis (by 9 percent), and of all sites (by 3 percent). However, aircrew and ground crew both had lower or similar cancer mortality rates for all cancer types when compared to the U.S. population. This concludes the Phase 1 epidemiologic study and triggers a Phase 2 study to identify risk factors for the cancer diagnoses identified in the Phase 1 study. Elements to be included in the Phase 2 study are outlined in section 750(a)(3)(c) of the NDAA for FY 2021.

Air & Space Forces Magazine. (2024). Study: Aviator Cancer Rates Concern Lawmakers, DoD.

Aircrew Cancer Risks:

- Melanoma: 87% higher risk
- Thyroid Cancer: 39% higher risk
- Prostate Cancer: 16% higher risk

Ground Crew Cancer Risks:

- Brain & Nervous System: 19% increased risk
- Thyroid Cancer: 15% higher risk
- Melanoma: 9% higher risk
- Kidney & Renal Pelvis Cancers: 9% higher risk

Research Limitations:

- Actual rates likely higher; VA and civilian registry data excluded
- Studies focused on rates, not causes

Potential Risk Factors:

- Galactic cosmic radiation, Ultraviolet radiation, Radar radiation
- Exposure to jet fuel and fumes
- Non-ionizing radiation from radars and jamming equipment

Friedberg W, Copeland K, Duke FE, O'Brien K 3rd, Darden EB Jr. Radiation exposure during air travel: Guidance provided by the FAA for air carrier crews. Health Phys 79(5):591–595; 2000.

- **Seattle to Portland:** 0.03 mSv per 100 block hours
- **New York to Chicago:** 0.39 mSv per 100 block hours
- **Los Angeles to Honolulu:** 0.26 mSv per 100 block hours
- **London to New York:** 0.51 mSv per 100 block hours
- **Athens to New York:** 0.63 mSv per 100 block hours
- **Tokyo to New York:** 0.55 mSv per 100 block hours

FEDERAL AVIATION ADMINISTRATION
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These forms require a javascript enabled browser.

Left Click on HELP
For Instructions
HELP

Galactic Radiation Received In Flight

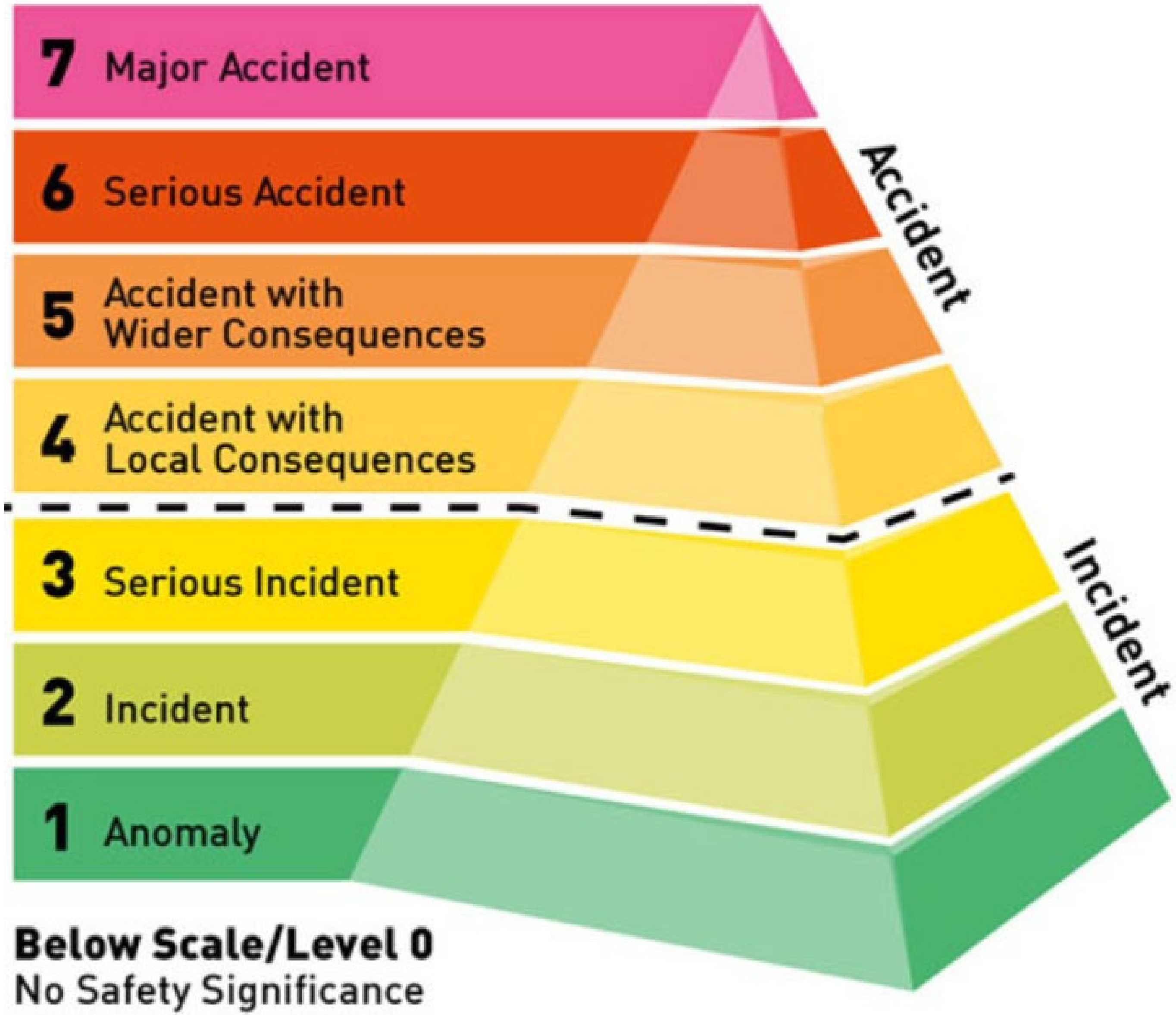
Enter Flight Data		
Date of Flight	**01/2024**	
Origin Code	**KSFO**	SAN FRANCISCO, CA
Destination Code	**KHOU**	HOUSTON, TX
Number of en route altitudes	**1**	
Minutes to 1st en route altitude	**60**	
En route altitude(s) and time(s)	**Altitude (in feet)** 60000 maximum 1)	**Minutes at altitude*** 1)
	Whole numbers only, no commas	
Minutes descending to touchdown		Whole number only
	Continue Please Be Patient Intensive processor calculations	

How much is too much?

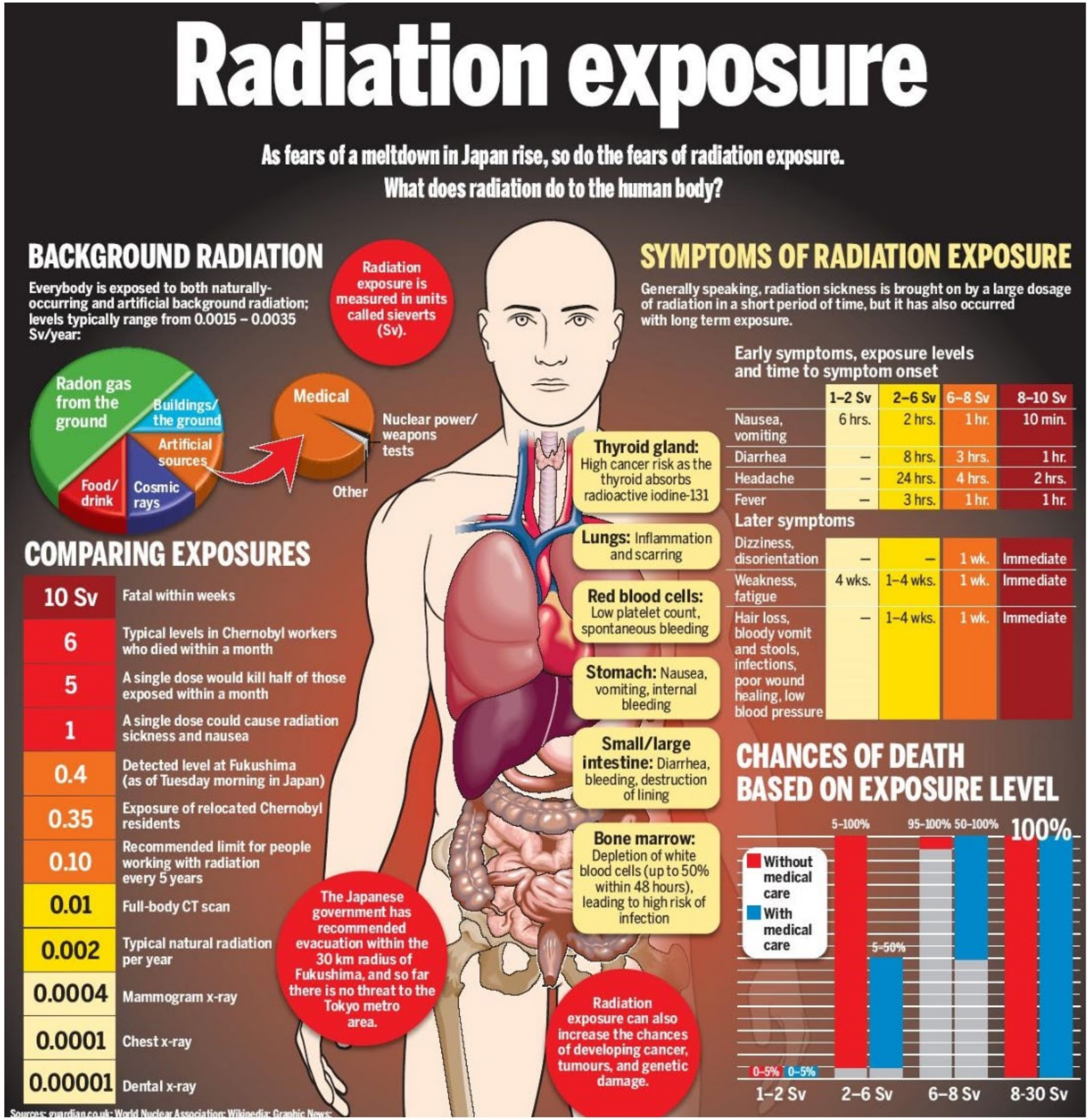
- **U.S. Regulations on Aircrew Cosmic Radiation:**
  - No official dose limits in the United States
  - Follows national and international guidelines
- **International Commission on Radiological Protection (ICRP) Recommendations:**
  - Aircrew considered as occupational exposure group
  - Recommend 20 mSv/year averaged over 5 years (100 mSv in 5 years) for radiation workers
  - Public exposure limit recommended at 1 mSv/year
  - For pregnant radiation workers, limit set at 1 mSv throughout pregnancy

- **European Union Standards:**
  - Member states assess aircrew exposure likely to exceed 1 mSv/year
  - Work schedules adjusted to keep individual exposure below 6 mSv/year

International Nuclear and Radiological Event Scale (emergency preparedness-NRC.gov)



- NRC Event Classifications:
  - Notification of Unusual Event: Potential safety degradation; no public health impact
  - Alert: Reduced safety margins; no radioactive material release requiring offsite response
  - Site Area Emergency: Actual/imminent core damage; potential public health response
  - General Emergency: Substantial core damage; radioactive releases needing offsite protection


Radiation exposure
As fears of a meltdown in Japan rise, so do the fears of radiation exposure.
What does radiation do to the human body?
BACKGROUND RADIATION
Everybody is exposed to both naturally-occurring and artificial background radiation; levels typically range from 0.0015 – 0.0035 Sv/year:
Radon gas from the ground
Buildings/ the ground
Artificial sources
Food/ drink
Cosmic rays
Medical
Nuclear power/ weapons tests
Other
Radiation exposure is measured in units called sieverts (Sv).
COMPARING EXPOSURES
10 Sv Fatal within weeks
6 Typical levels in Chernobyl workers who died within a month
5 A single dose would kill half of those exposed within a month
1 A single dose could cause radiation sickness and nausea
0.4 Detected level at Fukushima (as of Tuesday morning in Japan)
0.35 Exposure of relocated Chernobyl residents
0.10 Recommended limit for people working with radiation every 5 years
0.01 Full-body CT scan
0.002 Typical natural radiation per year
0.0004 Mammogram x-ray
0.0001 Chest x-ray
0.00001 Dental x-ray
The Japanese government has recommended evacuation within the 30 km radius of Fukushima, and so far there is no threat to the Tokyo metro area.
Thyroid gland: High cancer risk as the thyroid absorbs radioactive iodine-131
Lungs: Inflammation and scarring
Red blood cells: Low platelet count, spontaneous bleeding
Stomach: Nausea, vomiting, internal bleeding
Small/large intestine: Diarrhea, bleeding, destruction of lining
Bone marrow: Depletion of white blood cells (up to 50% within 48 hours), leading to high risk of infection
Radiation exposure can also increase the chances of developing cancer, tumours, and genetic damage.
SYMPTOMS OF RADIATION EXPOSURE
Generally speaking, radiation sickness is brought on by a large dosage of radiation in a short period of time, but it has also occurred with long term exposure.
Early symptoms, exposure levels and time to symptom onset
1–2 Sv 2–6 Sv 6–8 Sv 8–10 Sv
Nausea, vomiting 6 hrs. 2 hrs. 1 hr. 10 min.
Diarrhea – 8 hrs. 3 hrs. 1 hr.
Headache – 24 hrs. 4 hrs. 2 hrs.
Fever – 3 hrs. 1 hr. 1 hr.
Later symptoms
Dizziness, disorientation – – 1 wk. Immediate
Weakness, fatigue 4 wks. 1–4 wks. 1 wk. Immediate
Hair loss, bloody vomit and stools, infections, poor wound healing, low blood pressure – 1–4 wks. 1 wk. Immediate
CHANCES OF DEATH BASED ON EXPOSURE LEVEL
Without medical care
With medical care
0-5% 0-5%
5-100% 5-50%
95-100% 50-100%
100%
1–2 Sv 2–6 Sv 6–8 Sv 8-30 Sv
Sources: guardian.co.uk; World Nuclear Association; Wikipedia; Graphic News

Level 7 Events – Fukushima vs Chernobyl

- **Fukushima (3/11/2011)**
  - Cause: Magnitude 9.0 earthquake and subsequent tsunami
  - Reactor Type: Boiling Water Reactors (BWR) with active safety features
  - Impact: Meltdowns at three reactors; significant release of radioactive materials, but containment structures largely held
  - Evacuation: ~150,000 people evacuated as a precaution
  - Health Effects: No immediate deaths due to radiation exposure; long-term health effects being studied- thyroid, etc
  - Environmental: Contaminated water leakage; ongoing cleanup and decommissioning efforts

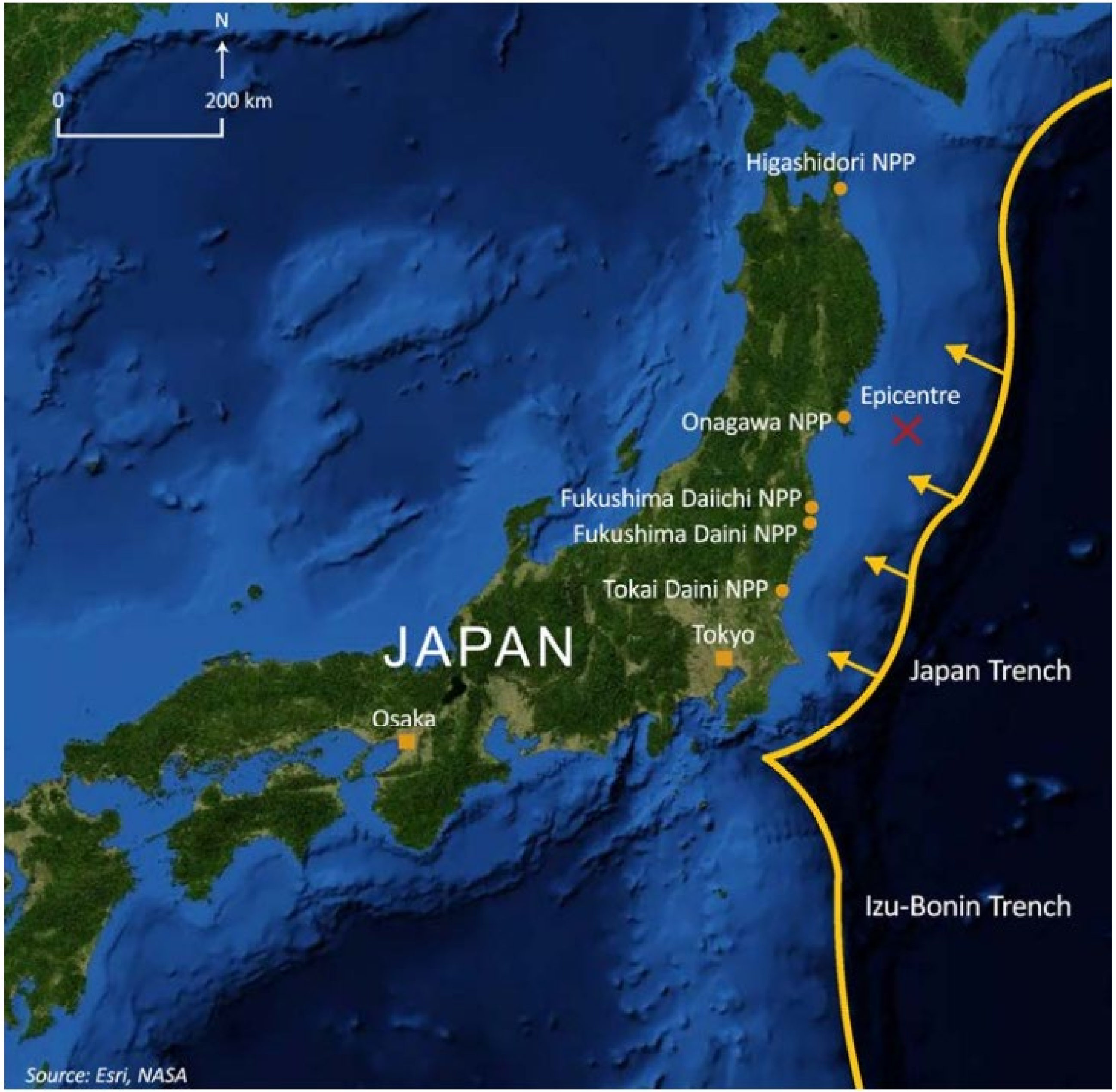


FIG. 1.1–1. The Great East Japan Earthquake and the NPPs nearby.

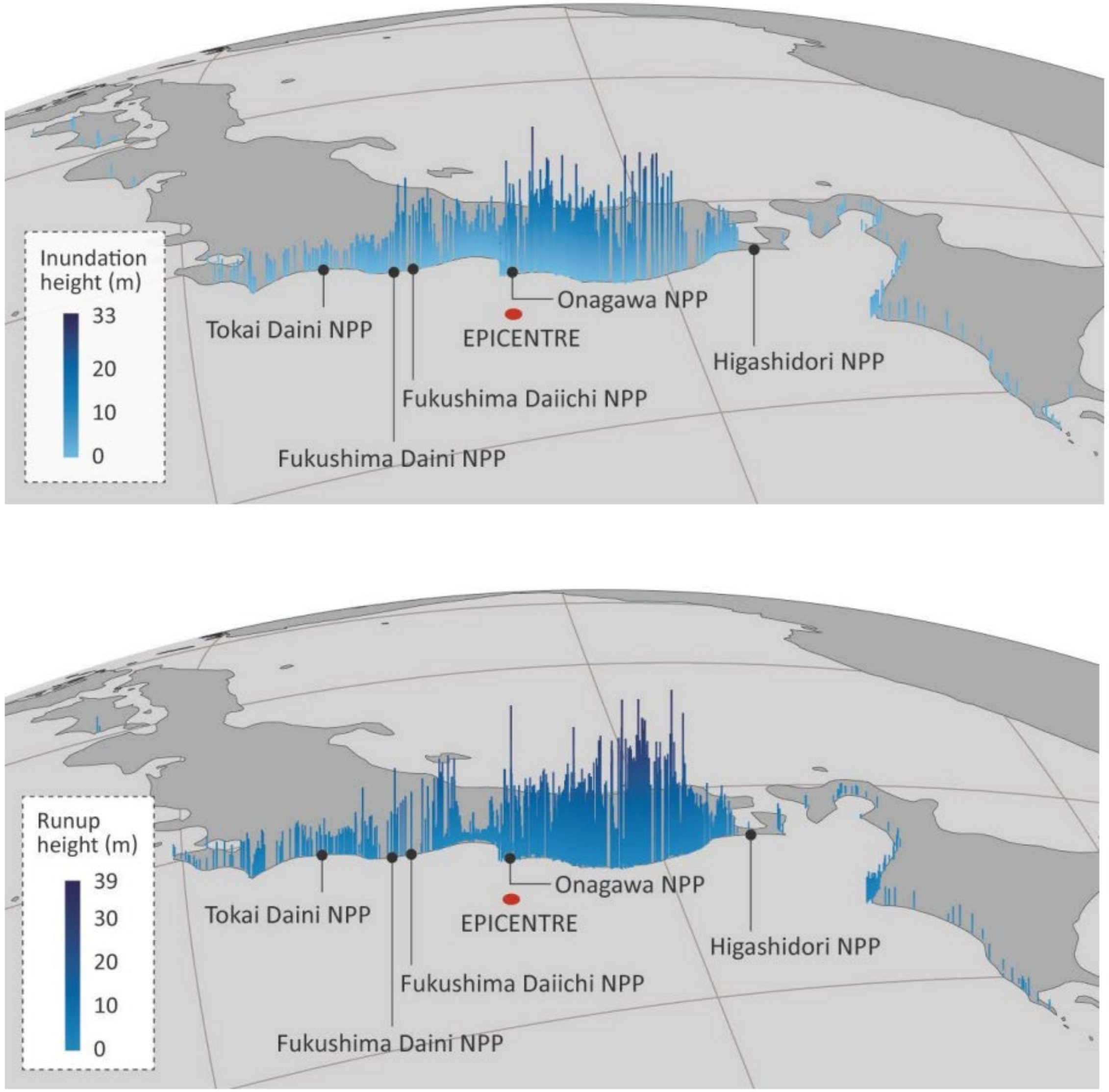


FIG. 1.1–5. The variation of tsunami wave impact, inundation (top) and runup (bottom), based on the coastal geography and topography [13].[12]

International Atomic Energy Agency. The Fukushima Daiichi Accident(2024).

- Tsunami waves reached Fukushima Daiichi NPP about 40 minutes post-earthquake, at 15:27
- First wave (4-5 m runup height) was initially stopped by seawalls designed for a 5.5 m tsunami
- Second, larger wave (14-15 m runup height) hit the plant between 15:36 and 15:37
- This wave overcame the seawalls, inundating the site
- Engulfed seafront structures/equipment and main buildings at higher elevations, including the reactor, turbines

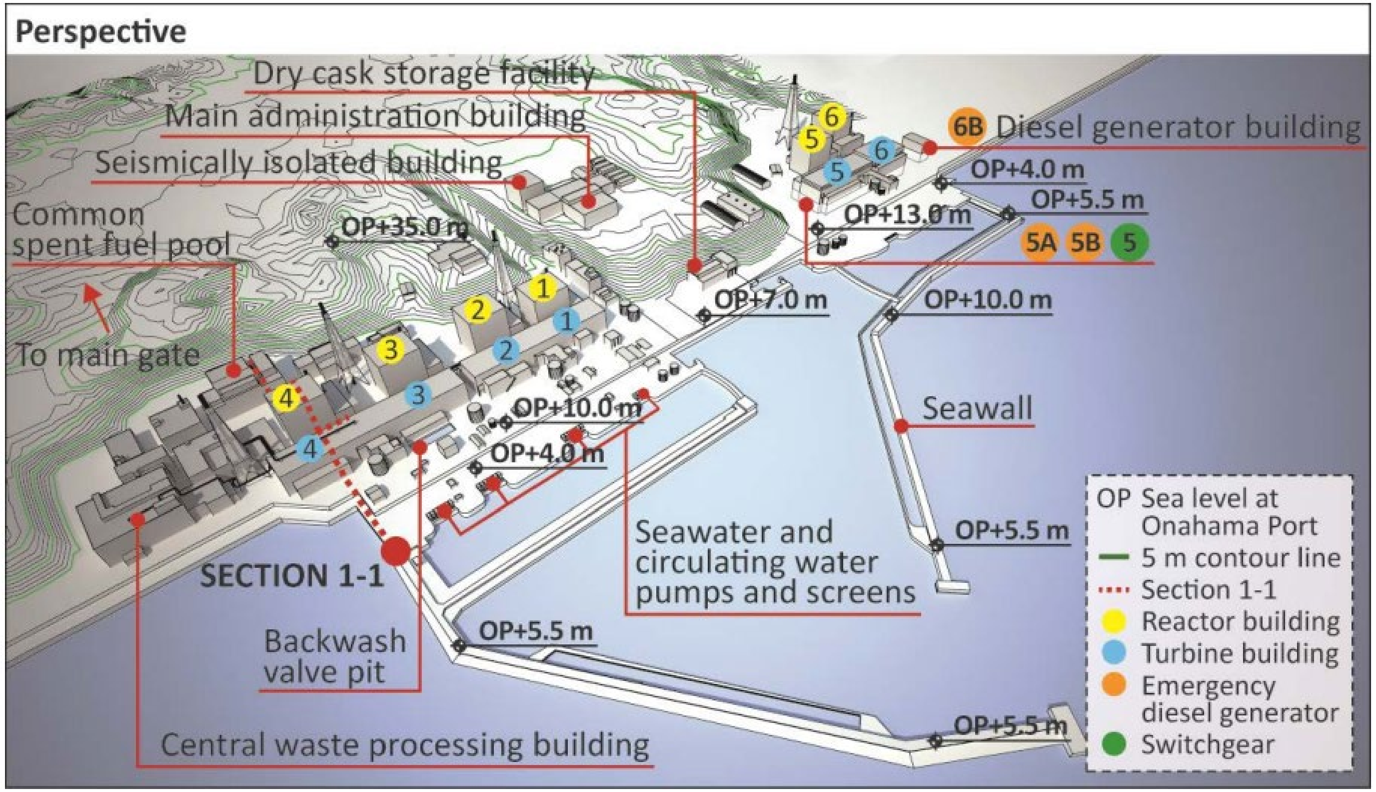


FIG. 1.1–6. The elevations and locations of structures and components at the Fukushima Daiichi NPP [16].

International Atomic Energy Agency. (2024).

- **Chernobyl (April, 1986)**
  - Cause: Explosion during a safety test due to flawed reactor design and operator errors
  - Reactor Type: RBMK, graphite-moderated reactor without a robust containment structure
  - Impact: Direct exposure to the reactor core; fire spread radioactive materials over a wide area
  - Evacuation: Immediate vicinity evacuated; long-term exclusion zone established
  - Health Effects: 28 immediate deaths from acute radiation syndrome; thousands more affected by long-term health issues, including cancer
  - Environmental: Large exclusion zone remains; significant long-term ecological impact

Key Differences:

- Causes: Natural disaster vs. human error and design flaws
- Reactor Safety: BWR with containment vs. RBMK without robust containment
- Health and Environmental Impact: Immediate vs. long-term significant impacts

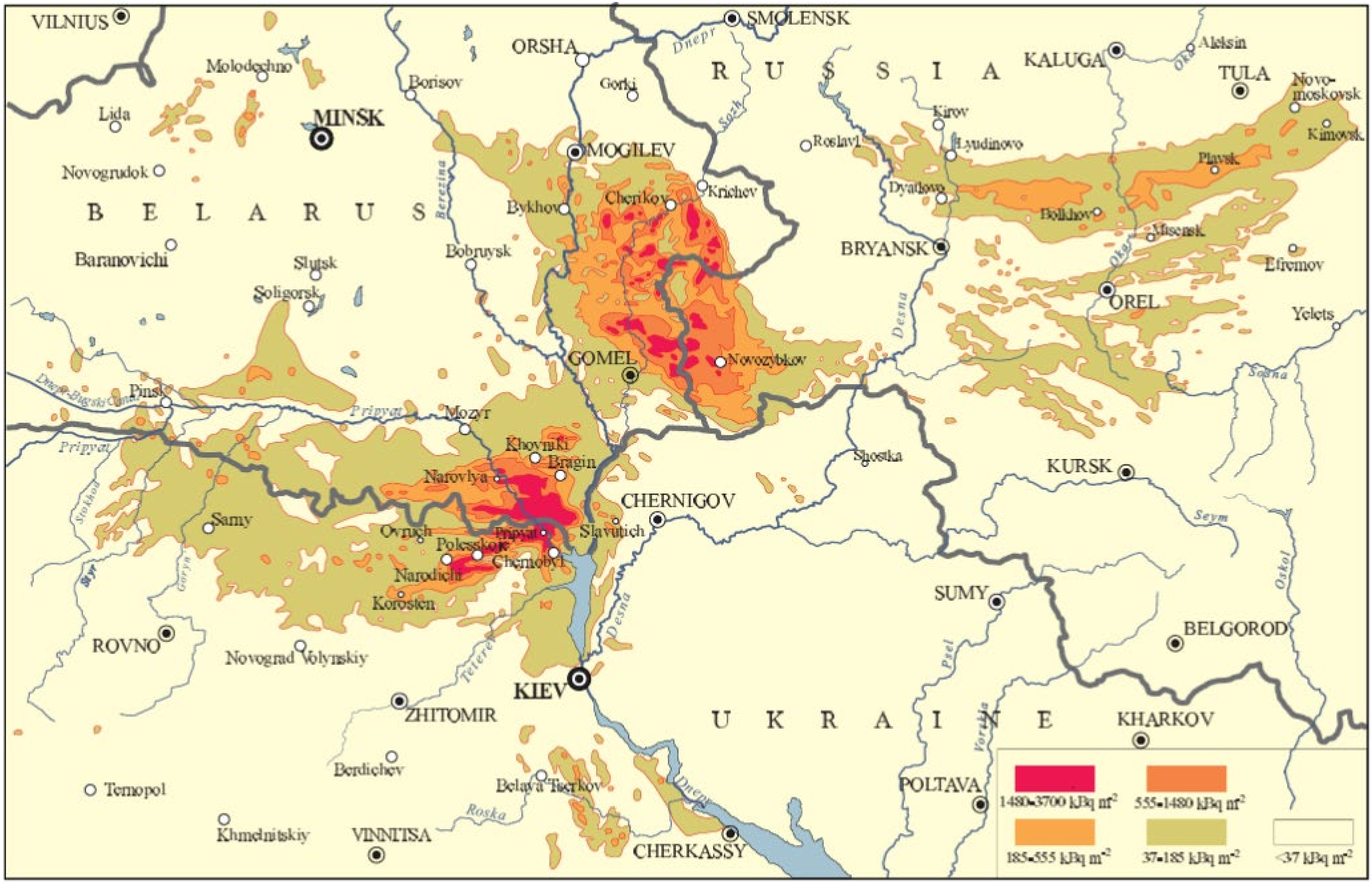
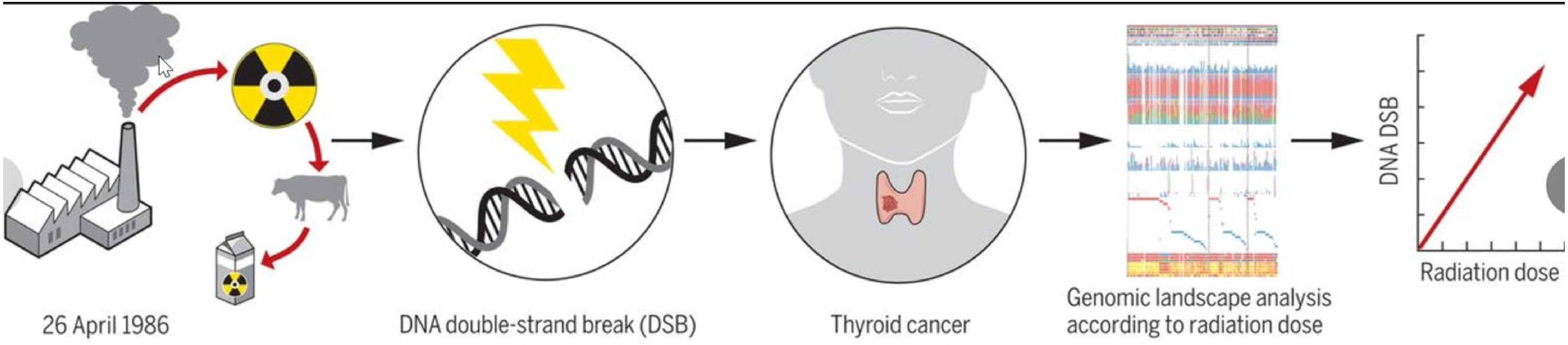


Figure VI. Surface ground deposition of caesium-137 released in the Chernobyl accident [I1, I3].



- Epidemiological and clinical research shows increased papillary thyroid carcinoma (PTC) risk with higher exposure to radioactive iodine (131I) from fallout, **consumed via milk and leafy greens** during early childhood
- Data from various populations exposed to different radiations confirm that PTC risk escalates after childhood exposure to ionizing radiation, a known carcinogen

Radiation-related genomic profile of papillary thyroid carcinoma after the Chernobyl accident, Volume: 372, Issue: 6543, DOI: (10.1126/science.abg2538)

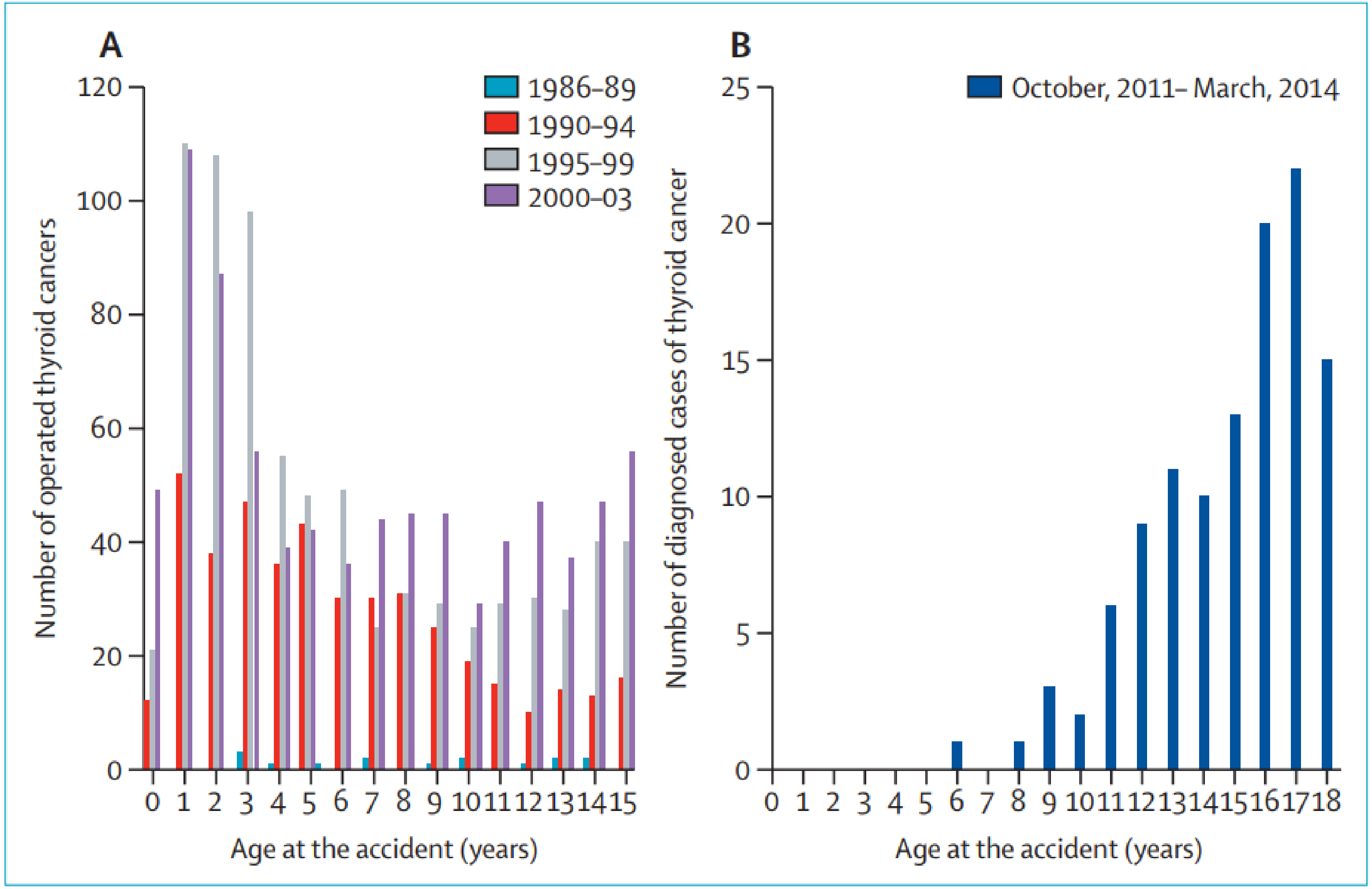
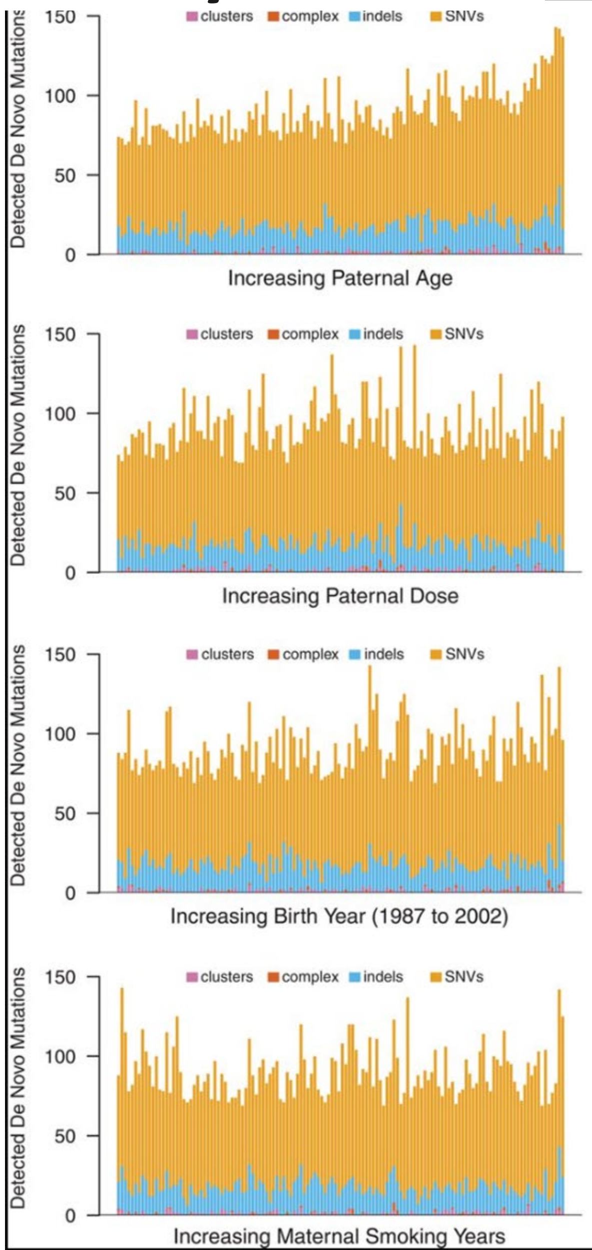


***Figure*: Numbers of operated thyroid cancers in patients aged 0–15 years at the accident in Belarus (A) and diagnosed cases of thyroid cancer in patients aged 0–18 years at the accident in Fukushima (B)**

On the balance of available evidence, the large increase ... in the number of thyroid cancers detected among exposed children (Fuk.) is not the result of radiation exposure," per UNSCEAR. "Rather, they are the **result of ultrasensitive screening** procedures that have revealed the prevalence of thyroid abnormalities in the population not previously detected."

Lack of transgenerational effects of ionizing radiation exposure from Chernobyl accident



Yeager, M., Machiela, M. J., Kothiyal, P., Dean, M., Bodelon, C., Suman, S., ... & Chanock, S. J. (2021). Lack of transgenerational effects of ionizing radiation exposure from the Chernobyl accident. Science, 372(6543), 725-729. https://doi.org/10.1126/science.abg2365

Fig. 1 Detected DNMs per genome based on distributions of individual characteristics

Analyses are presented by increasing paternal and maternal age at conception, paternal and maternal radiation dose, birth year of child, and paternal and maternal smoking behavior at conception

Pregnancy & Radiation

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Table 2 Tissue effects by gestational age and radiation threshold dose needed to observe the effect.

From: Effects of ionizing radiation exposure during pregnancy

Stage	Key development	Time (weeks)[a]	Radiation tissue effect	Threshold
Germinal		0–2	All (death) or none	50–100 mGy
	Implantation in uterus	1	Some likelihood of implant failure High likelihood of implant failure	100–500 mGy > 500 mGy
Embryonic	Formation of neural tube	4	Pregnancy loss likelihood increased	> 500 mGy
	Arms and legs	5	Congenital anomalies (skeleton, eyes, genitals)	200 mGy
	Organogenesis	3–8		
Fetal	Further neural development	9–12	Stunted growth Deformities	100–500 mGy
			Mental retardation (low risk)	60–310 mGy
	Fingers, toes		Severe mental retardation (high risk)	610 mGy
	Sex organs		Intellectual deficit	> 100 mGy (0.25–0.29 IQ point loss/10 mGy)
	Fully formed fetus		Microcephaly	200 mGy
Fetal (second and third trimesters)		18–25	Mental retardation	250–280 mGy
			Intellectual deficit	> 100 mGy (0.13–0.25 IQ point loss/10 mGy)
			Effects other than cancer only at doses high enough to cause acute illness in mother	
		> 26	Similar to postnatal, little chance of birth defects	

Mainprize, J.G., Yaffe, M.J., Chawla, T. *et al.* Effects of ionizing radiation exposure during pregnancy. *Abdom Radiol* **48**, 1564–1578 (2023).

Mainprize, J.G., Yaffe, M.J., Chawla, T. *et al.* Effects of ionizing radiation exposure during pregnancy. *Abdom Radiol* **48**, 1564–1578 (2023).

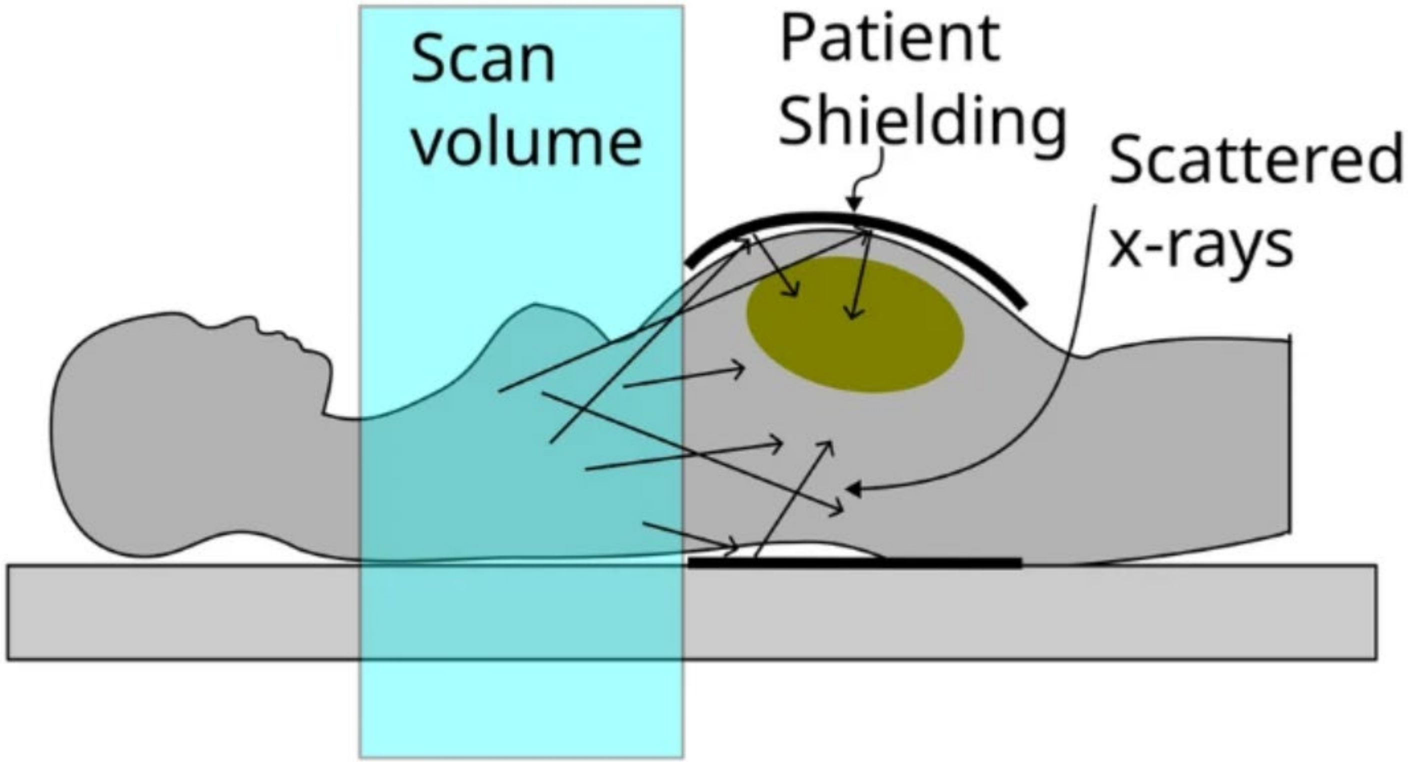
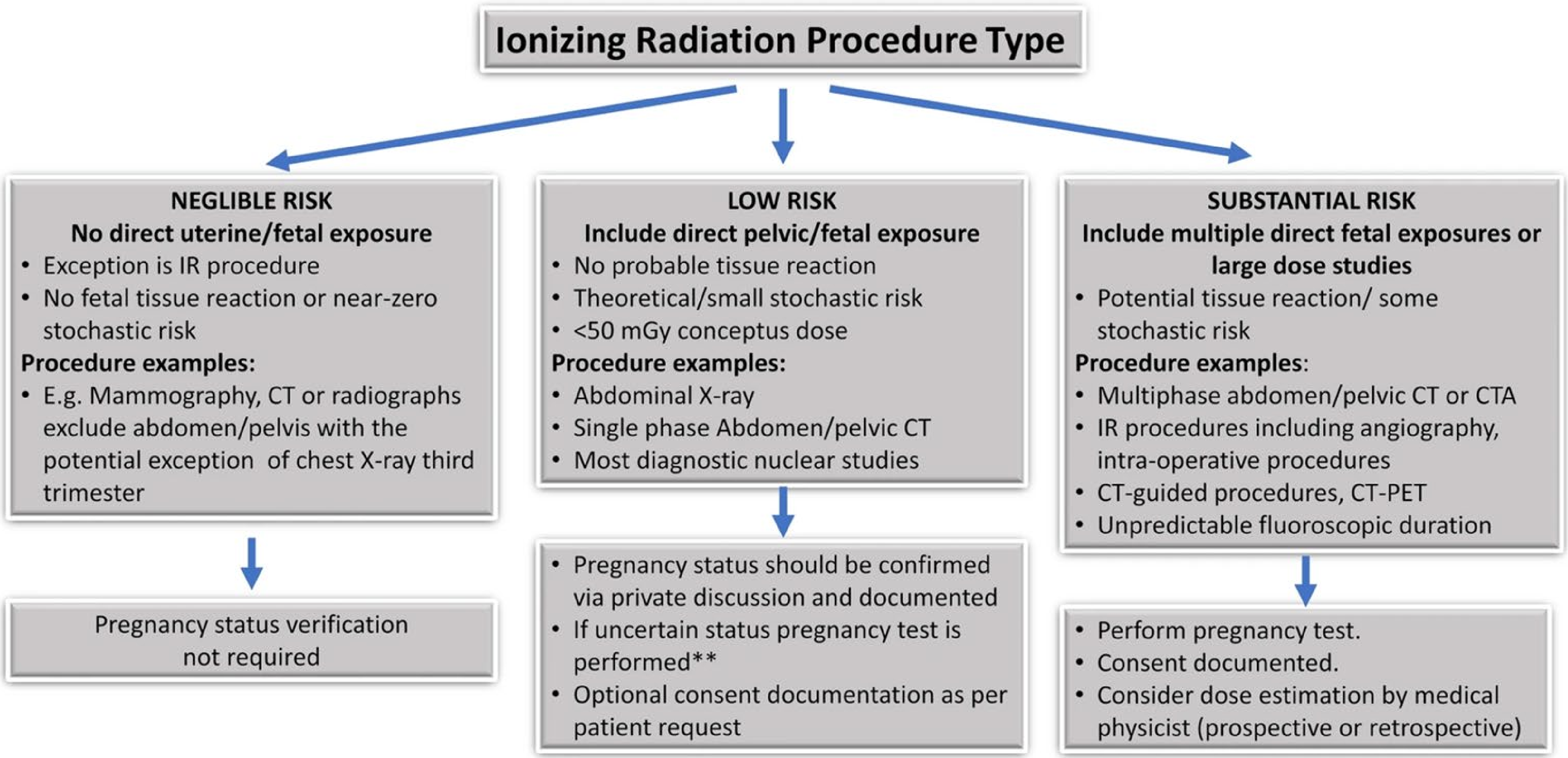


Illustration of internal scattered radiation which is not reduced by external patient shielding, and may cause backscatter from the material that would have otherwise escaped

- Evidence suggests negligible risk of harm to gonads/fetus in typical diagnostic imaging; shielding doesn't prevent internal scatter
- Improper shielding placement can obscure anatomy or introduce artifacts
- Only 26% of pediatric hip/pelvis exams had properly placed gonadal shielding
- Misplaced shielding may necessitate repeat examinations, compromising diagnostic quality
- Position statements from ACR, NCRP, ABR, SPR, and Image Gently **advise against the use of gonadal/fetal shielding in imaging**



Adapted from ACR [6], algorithm for determining procedure risk, need verification pregnancy status and formal consent process for ionizing radiation examinations. Pregnancy verification (lab test) can be performed via urine or blood sample, as per local practice. **Pregnancy verification required for long half-life nuclear medicine studies when conceptus dose > 0.5 mGy, *e.g.*, Iodine-131 whole body imaging/thyroid imaging

Refinery/Industrial Radiation

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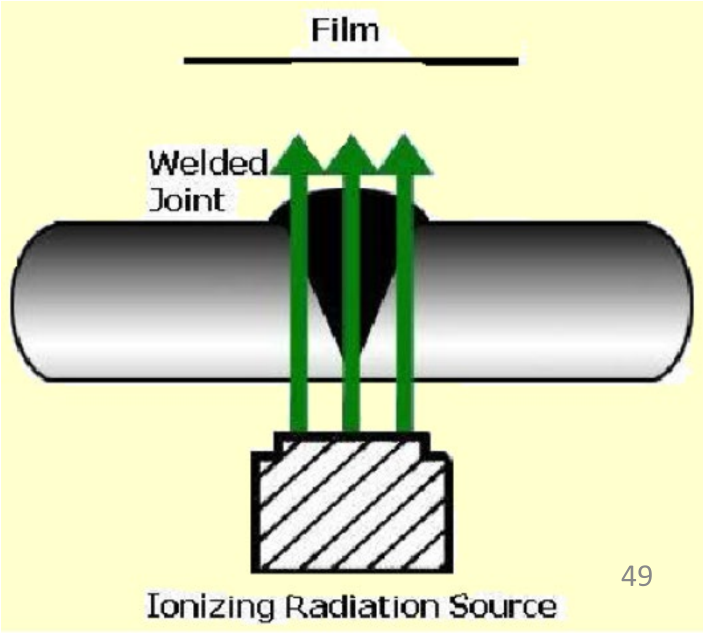
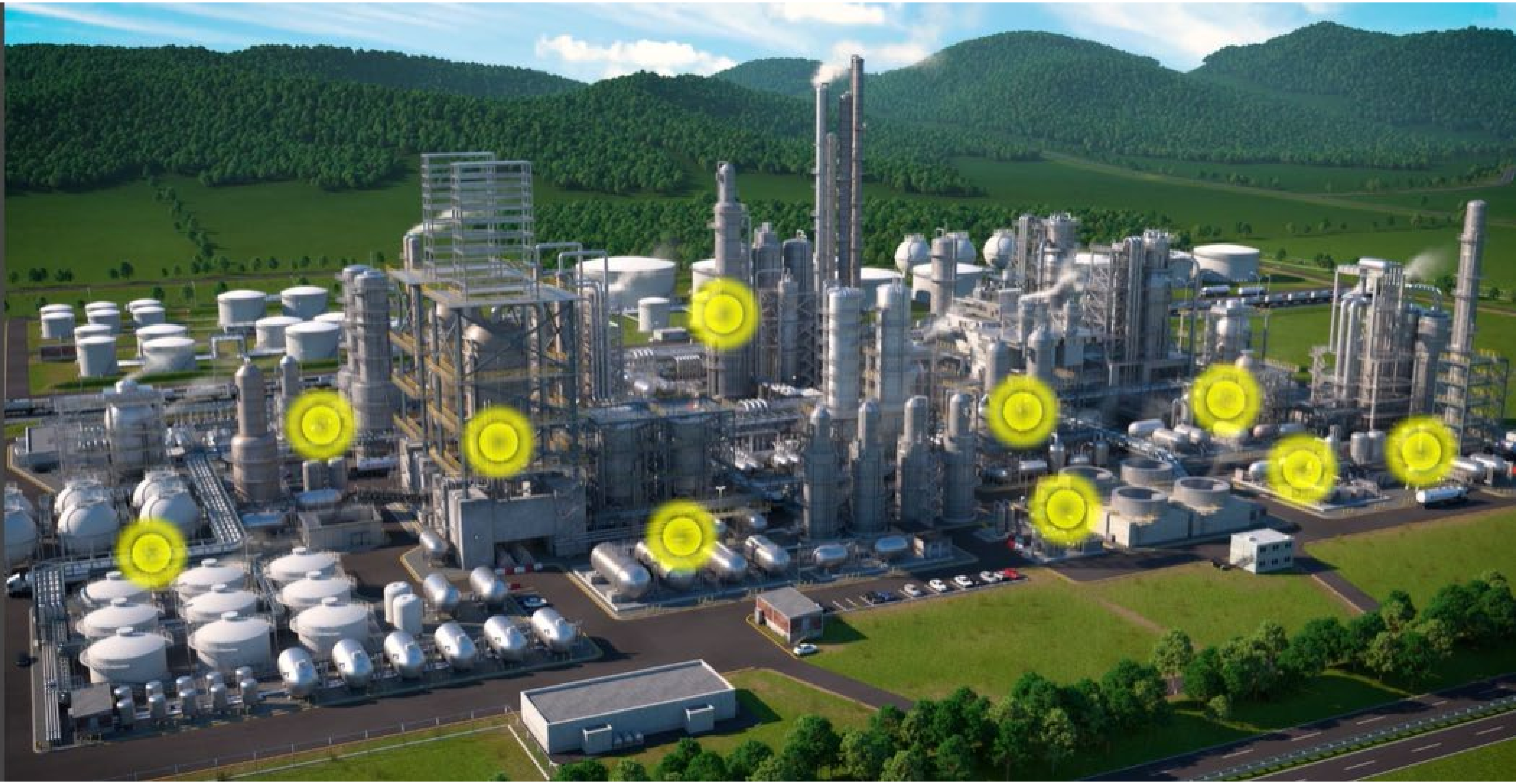
Potential Refinery Radiation Sources

- Radiography
  - Used the same way as X-ray machines are used for humans
  - Technique used to locate defects/corrosion in metal casings/welds, and to determine microscopic thickness of the metal that makes up piping, towers and tanks
- Measuring instruments of tanks/vessels
  - Potential for leaks
  - Quarterly checks
- Other sources, but minimal



Refining and petrochemical

VEGA offers a wide range of sensors for the typical applications in the petrochemical industry: from the delivery of crude oil via pipeline or ship to the storage of finished products. Measuring instruments from VEGA deliver reliable data on the volume, level and pressure of all types of media.

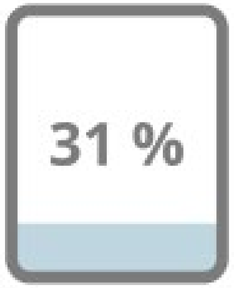


Rotary Shutter Source Holders

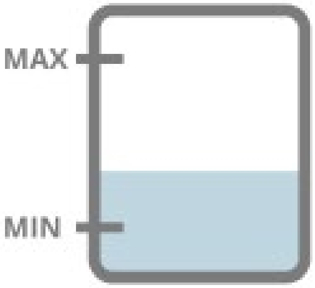
Source Spec

Radiometric sensor for continuous level and interface measurement

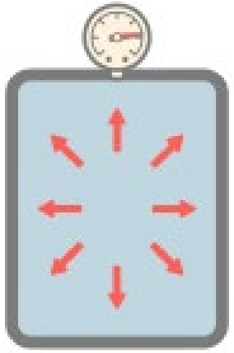
Level

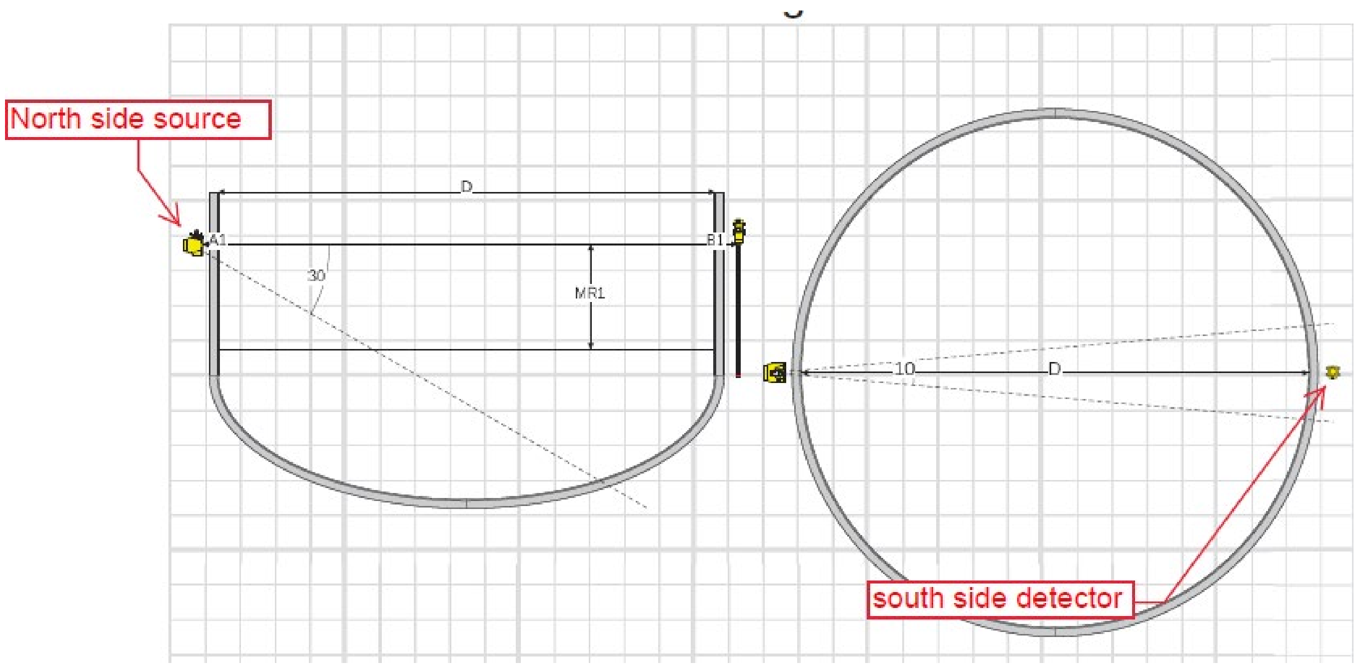


Point Level



Pressure



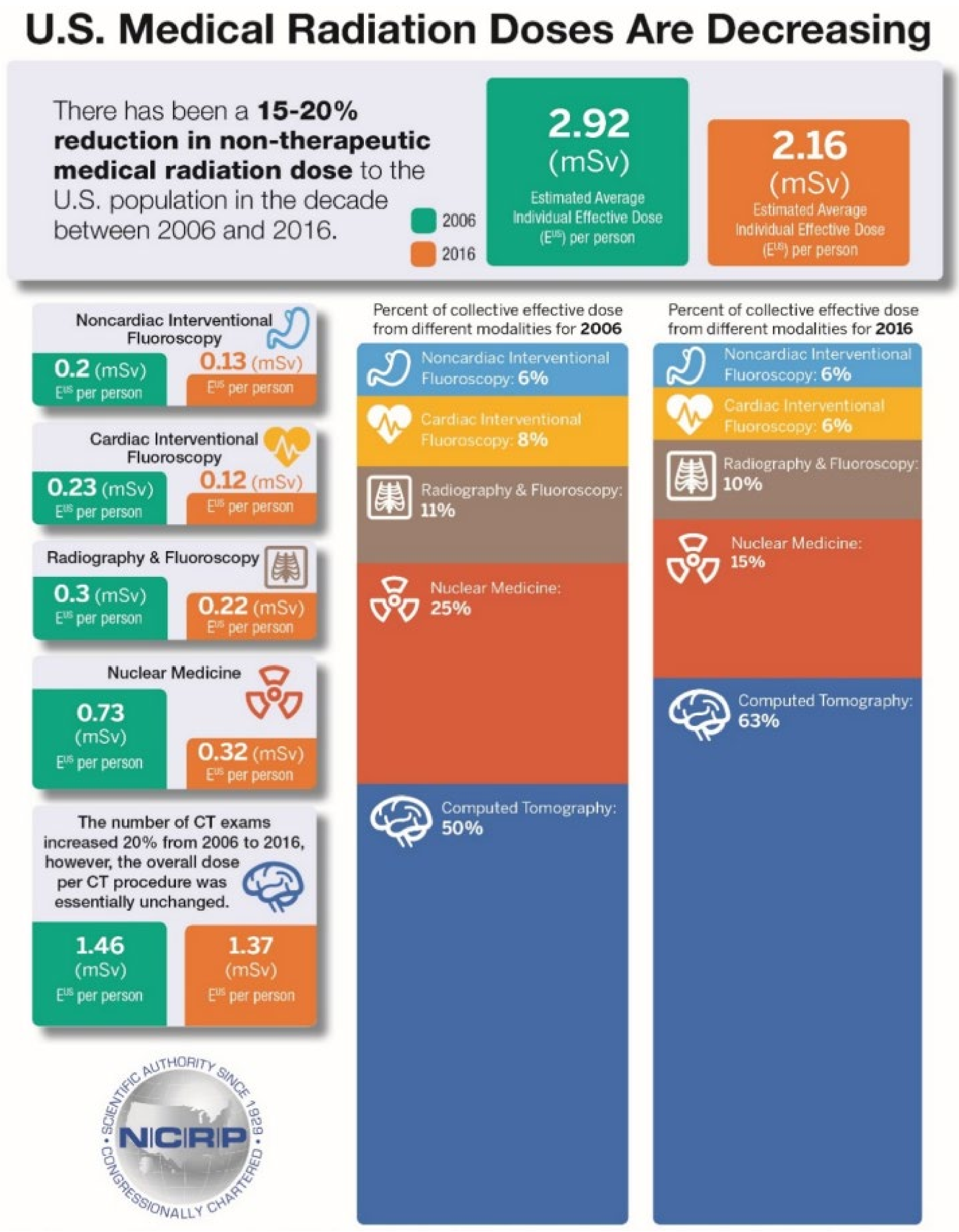

North side source
D
A1
B1
30
MR1
10
D
south side detector


South Side
SOURCE
mounting location


North Side
Detector Mounting
Location

How Are We Doing Overall with Radiation Exposure?

California Hospital Association



NCRP Report No. 184:

MEDICAL RADIATION EXPOSURE OF PATIENTS IN THE UNITED STATES

- NCRP Report No. 184 is an update to Report No. 160 (pub. in 2019), focusing on medical radiation exposure in the U.S. from 2006 to 2016
- The 2009 report indicated a significant rise in medical radiation exposure, accounting for about 50% of U.S. population's total radiation exposure, mainly from increased CT scans and cardiac nuclear medicine
- Over the decade since Report No. 160's publication, advancements in technology, dose reduction campaigns, changes in examination indications, and reimbursement policies

News Release

Contact: Laura Atwell
NCRP
301.657.2652
atwell@ncrponline.org

FOR IMMEDIATE RELEASE

AFTER A DRAMATIC RISE, THE AVERAGE U.S. MEDICAL RADIATION DOSES NOW ARE DECREASING

New NCRP Report shows a 15 to 20 % reduction in dose to the U.S. population from 2006 to 2016

WASHINGTON, D.C. (November 18, 2019) – The National Council on Radiation Protection and Measurements (NCRP) today issued a new Report showing a 15 to 20 % reduction in diagnostic and interventional medical radiation doses to the U.S. population from 2006 to 2016. Except for computed tomography (CT) scans, most medical imaging doses are stable or decreasing. This finding is a contrast to the dramatic rise documented in a 2009 NCRP report, which showed a six-fold increase from the early 1980s to 2006.

NCRP Report No. 184, entitled "Medical Radiation Exposure of Patients in the United States," is a 10-year update to an NCRP report published in 2009. The current Report updates medical radiation exposure information with data collected between 2006 and 2016.

"Our Report demonstrates that medical radiation doses in the United States are on the decline, which is a positive shift from a decade ago when doses were increasing significantly," said Dr. Fred Mettler, chair of the NCRP Report and Professor Emeritus and Clinical Professor at the Department of Radiology and Nuclear Medicine at the University of New Mexico School of Medicine. "In the Report, we pay particular attention to medical procedures that contribute the largest share of dose and provide information on average doses that patients may experience from a specific examination."

NCRP Report No. 184 shows that CT scans made up 63 % of collective dose from medical imaging procedures in 2016, compared to 50 % in 2006. While the number of CT scans increased by 20 % over that decade, the overall dose per person for CT procedures was essentially unchanged.

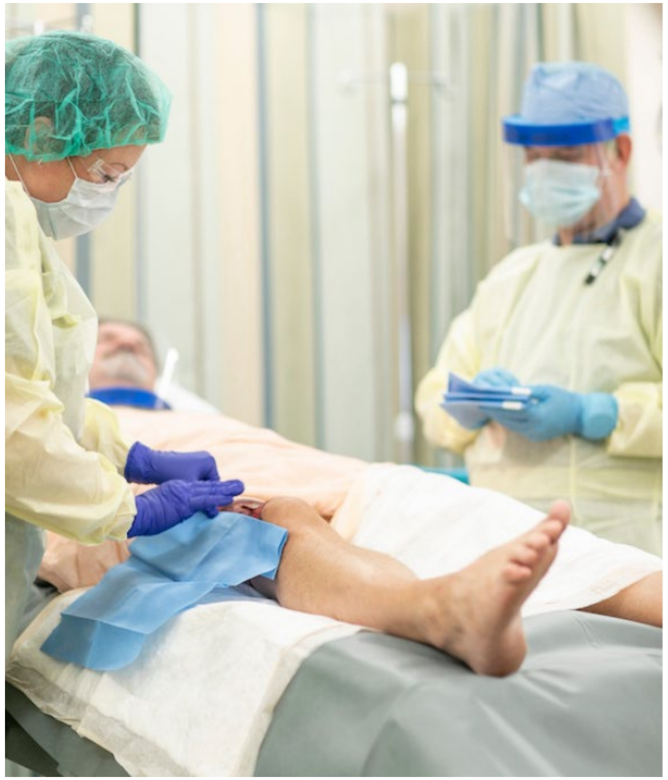
For a number of other modalities, the Report shows the average radiation dose per person has decreased. The Report discusses technological advances that have yielded hardware improvements and protocols, leading to higher quality images at lower doses. In addition, radiography has moved away from standard film and increased use of digital receptors, leading to lower radiation doses for some procedures. Further, efforts by organizations such as the American College of Radiology (ACR), the U.S. Food and Drug Administration (FDA), and the Image Gently®/Image Wisely® Programs have increased awareness and understanding of medical radiation doses and dose optimization and reduction.

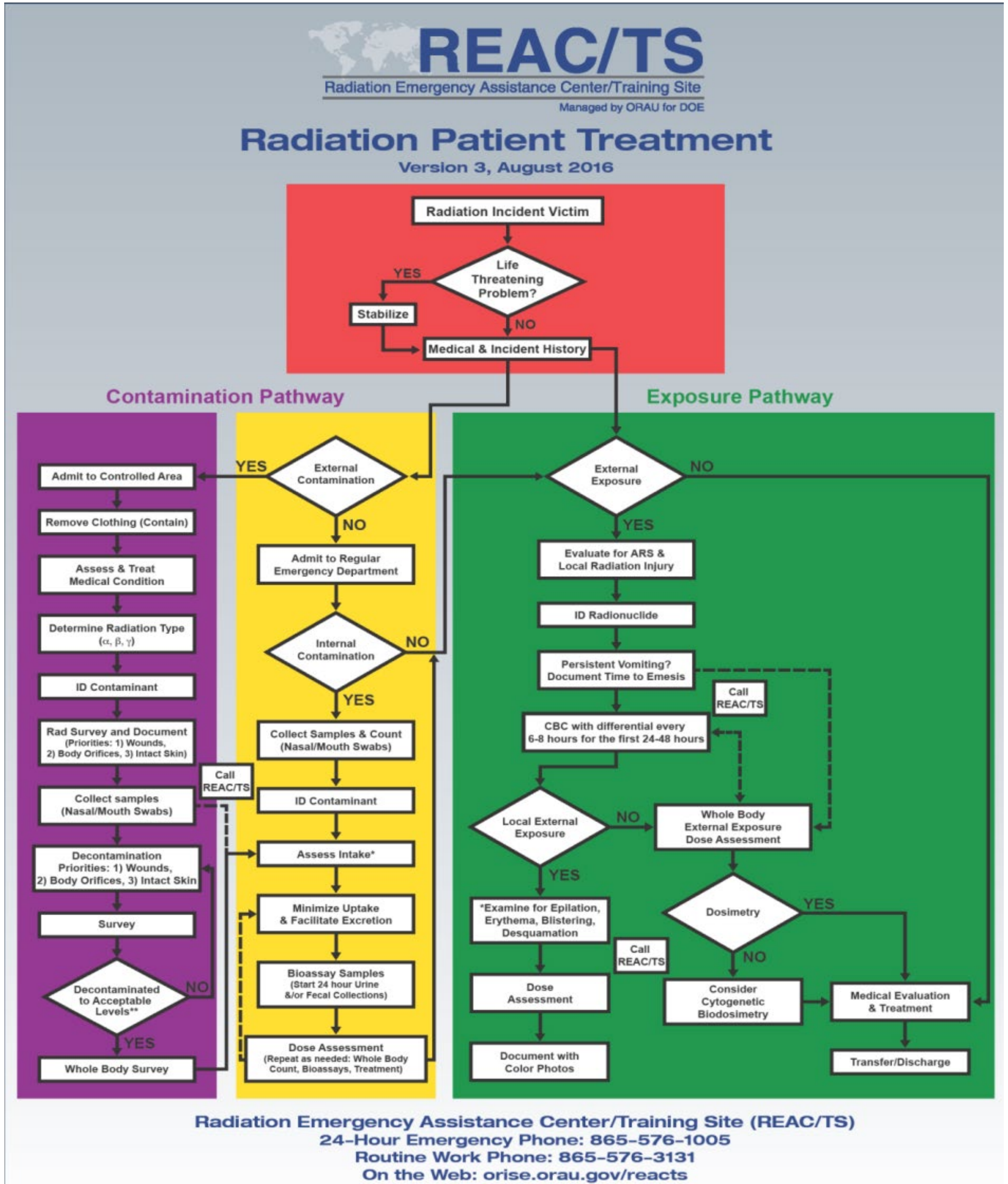
NCRP Report No. 184 highlights:

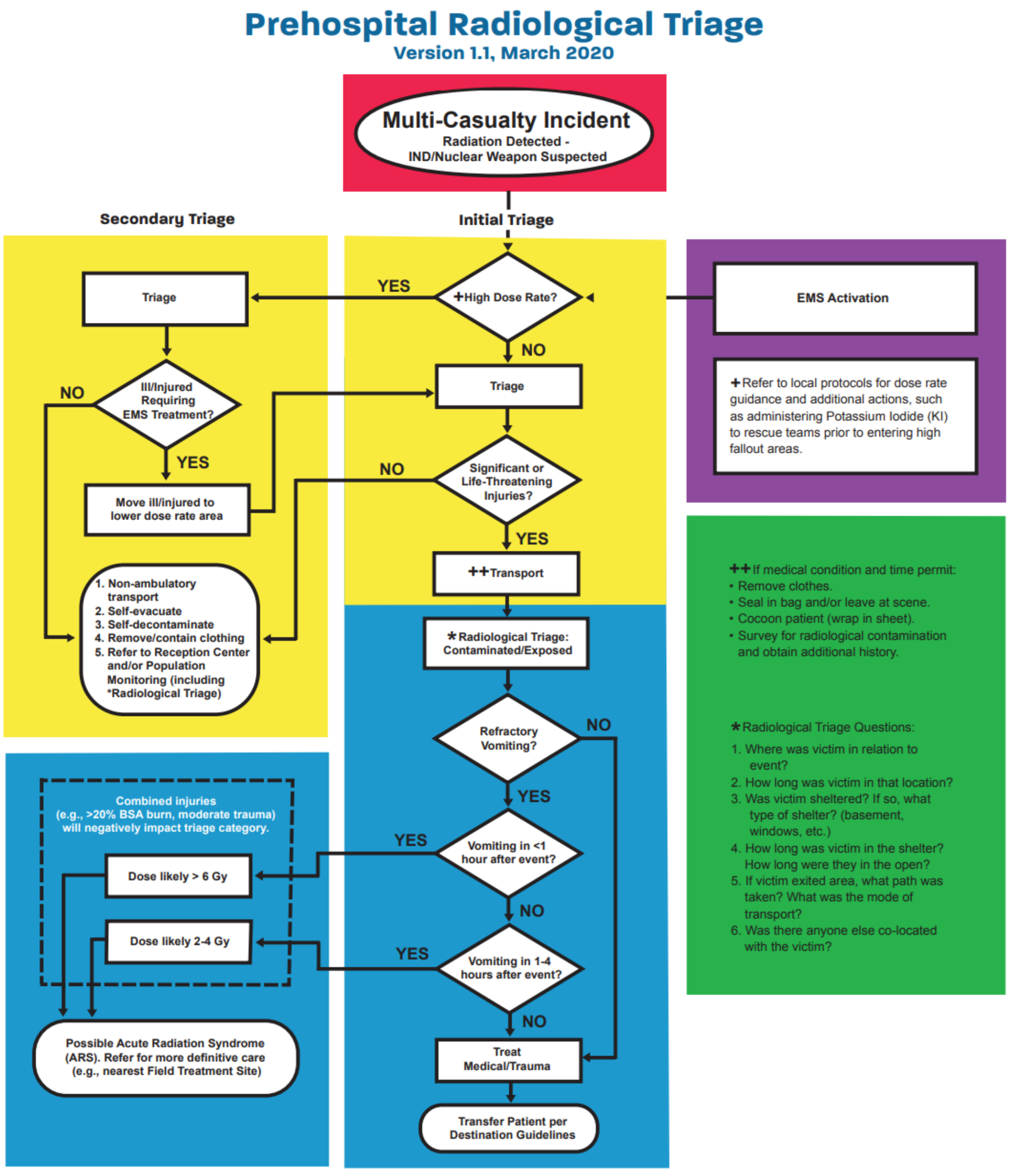
- CT scans constituted 63% of the collective dose from medical imaging in 2016, up from 50% in 2006
- Number of CT scans rose by 20% over the decade
- Overall dose per person for CT procedures remained essentially unchanged despite the increase in scan numbers

Emergency Response Resources

Who to contact and what should I do in acute events?

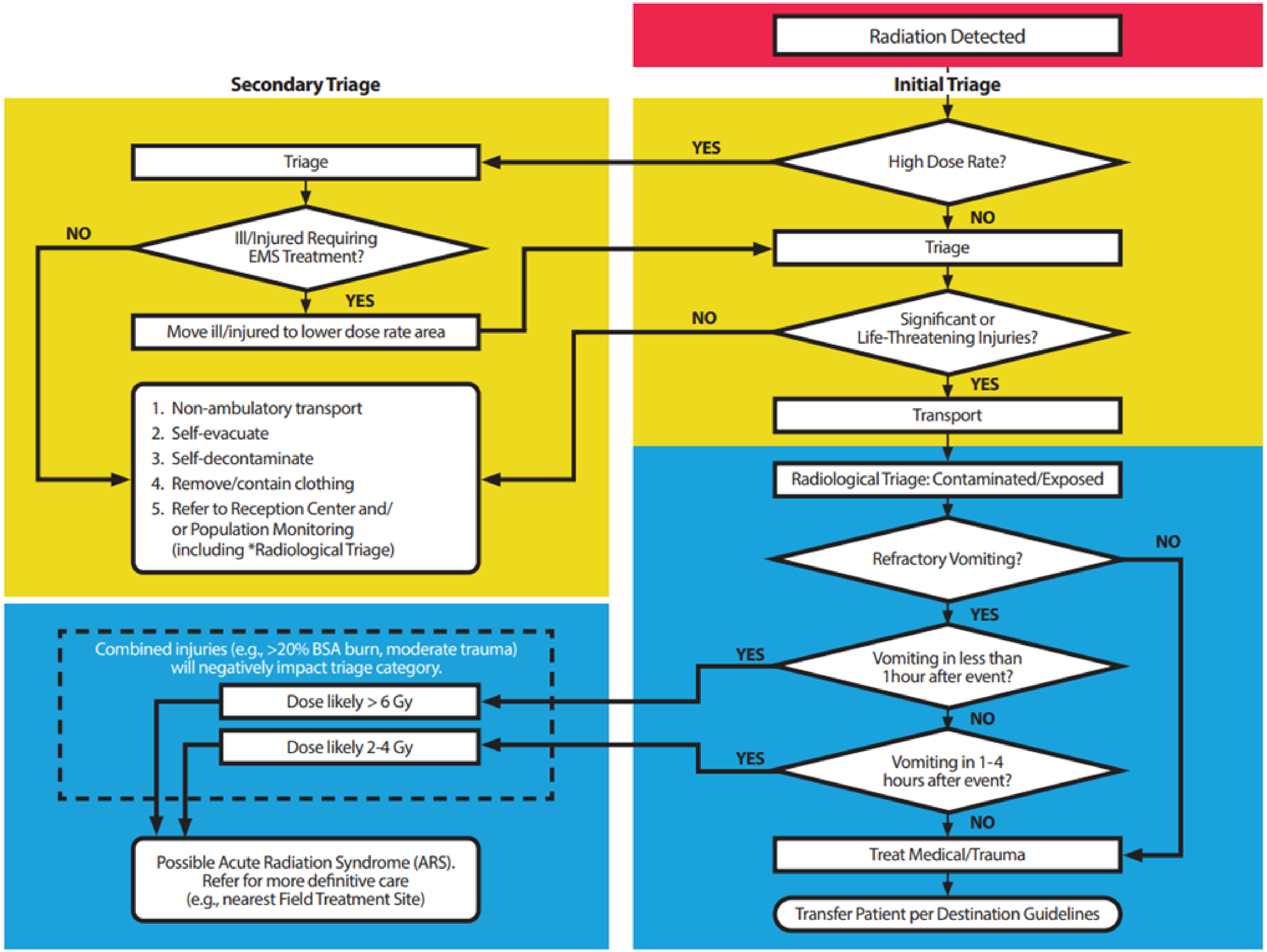






Radiation Emergency Assistance Center/Training Site (REAC/TS)
After Hours Emergency Assistance
US Department of Energy Oak Ridge Operations Center: 865.576.1005

Oak Ridge Institute for Science and Education
Shaping the Future of Science



Radiological Triage

Contamination v. Exposure?

Exposure occurs when someone is close enough to a radioactive source to absorb some of the energy emitted. Exposure-only patients are not radioactive and don't pose a radiological risk to others.

Contamination occurs when someone physically comes in contact with radioactive materials. That material may be transferred to healthcare providers or surfaces.

Radiation type:

- Alpha: May be stopped with a few inches of air or a piece of paper
- Beta: May be stopped by a piece of plastic
- Gamma: May be stopped by several inches of heavy metal, such as lead

If contaminated, how much is present?

Is actual isotope involved known?

Radiological Triage Questions:

Where was victim in relation to event?

How long was victim in that location?

Was victim sheltered? If so, what type of shelter? (basement, windows, etc.) How long were they there?

Summary

- **Radiation Across Settings:**
  - Industrial: Testing in manufacturing, safety checks in refineries
  - Medical/Hospital: Diagnostic imaging (X-rays, CT scans)
  - Airline Flights: Increased exposure to cosmic radiation at high altitudes
  - Nuclear Reactors: Acute/post disaster effects

- **Impacts and Awareness:**
  - Positive Uses: medical diagnostics, treatment, and ensuring safety in industrial applications
  - Challenges: Historical incidents (Fukushima, Chernobyl) highlight the risks of nuclear power
  - Safety Concerns: Occupational exposures, environmental impacts, and health risks from improper use

Questions?

California Hospital Association

Thank you

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California Hospital Association