Everyday Radiation

David D. Dixon
HDT Rally – Hutchinson, KS
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Overview

- Nuclear Energy Industry Outlook
- Types of radiation and radiation damage
- Sources of radiation
  - Naturally Occurring
  - Medical
  - Energy Industry
  - Other Man-Made Sources
- Consequences of Radiation Exposure
- Epidemiology and Hormesis

Nuclear Energy Industry Outlook

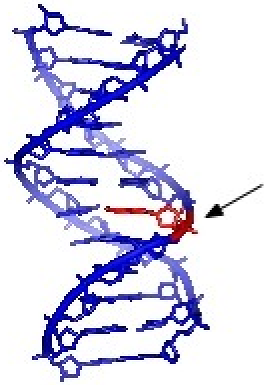
- Shale oil/gas boom has significantly cut the investment required to add generating capacity
- New nuclear construction (5 reactors in US under construction currently) has experienced cost overruns and delays
  - Most have been relatively minor
- The US nuclear fleet is aging
  - Most US reactors are approaching the end of their initial 40-year licenses, or have received 20-year extensions
  - Costs to operate older plants are significantly higher than new plants
- For the first time in the last several decades, there are fewer than 100 operating nuclear plans in the US
  - 99 currently, down from 104. All 5 were shut down prior to expiration of their licenses
- As many as 20 nuclear plants may be shuttered prior to license expiration if energy prices remain at current levels.

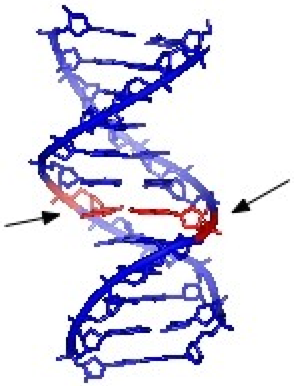
Types of Radiation

- Non-ionizing radiation
  - Sound waves, radio waves, microwaves, infrared and visible light
  - Not enough energy to strip an atom of electrons or to break chemical bonds
- Ionizing radiation
  - Has enough energy to strip electrons from an atom
  - Can damage chemical bonds in DNA
  - Alphas, betas, gammas
  - Radioactive decay, man-made sources (e.g. PET)
    - Indirect ionization from neutrons, photons (X-rays and gamma rays)

What does ionizing radiation actually do?

- Fundamentally, ionizing radiation causes damage to DNA.
  - If a single strand is broken, several repair mechanisms exist using the unbroken half as a “template” for the repair
  - A double strand break leaves the cell without a template for repair. Roll the dice!
- Both types of DNA damage are frequent, with or without radiation exposure!
  - 20,000 DNA damage events per cell per day





What does ionizing radiation actually do?

- Acute, deterministic effects
  - Cell death. Enough damage is caused at the cellular level that the cell ceases to function.
  - Symptoms: Radiation burns, nausea. Fatal if the damage is severe/widespread.
- Stochastic effects
  - Increased risk of cancer and heritable effects
  - Generally years/decades later

Naturally Occurring Radiation

- Radon, thorium, potassium
- Radon is a noble gas, heavier than air, and is typically inhaled after it is attached to another molecule (e.g. dust)
  - While radon is an alpha-emitter, once inside the lungs its effect is much more significant
- Thorium is present in trace amounts (along with many other radioactive isotopes) in most ores.
- 0.01% of potassium is potassium-40, which is radioactive. Potassium is a necessary nutrient, found in many common foods (e.g. bananas, potatoes)

Medical Procedures

- Diagnostics
  - X-rays, CT scans, mammography, imaging procedures using radioactive tracers (e.g. PET)
- Treatments
  - Conventional external beam
  - Proton therapy
  - Brachytherapy (internal radiation therapy)

Energy Industry

- A coal plant sends more uranium up the stacks than a nuclear plant uses for fuel.
- Radiation doses (and other occupational hazards) in the mining industry are proportional to the amount of ore being mined
  - Nuclear plants require far less ore!

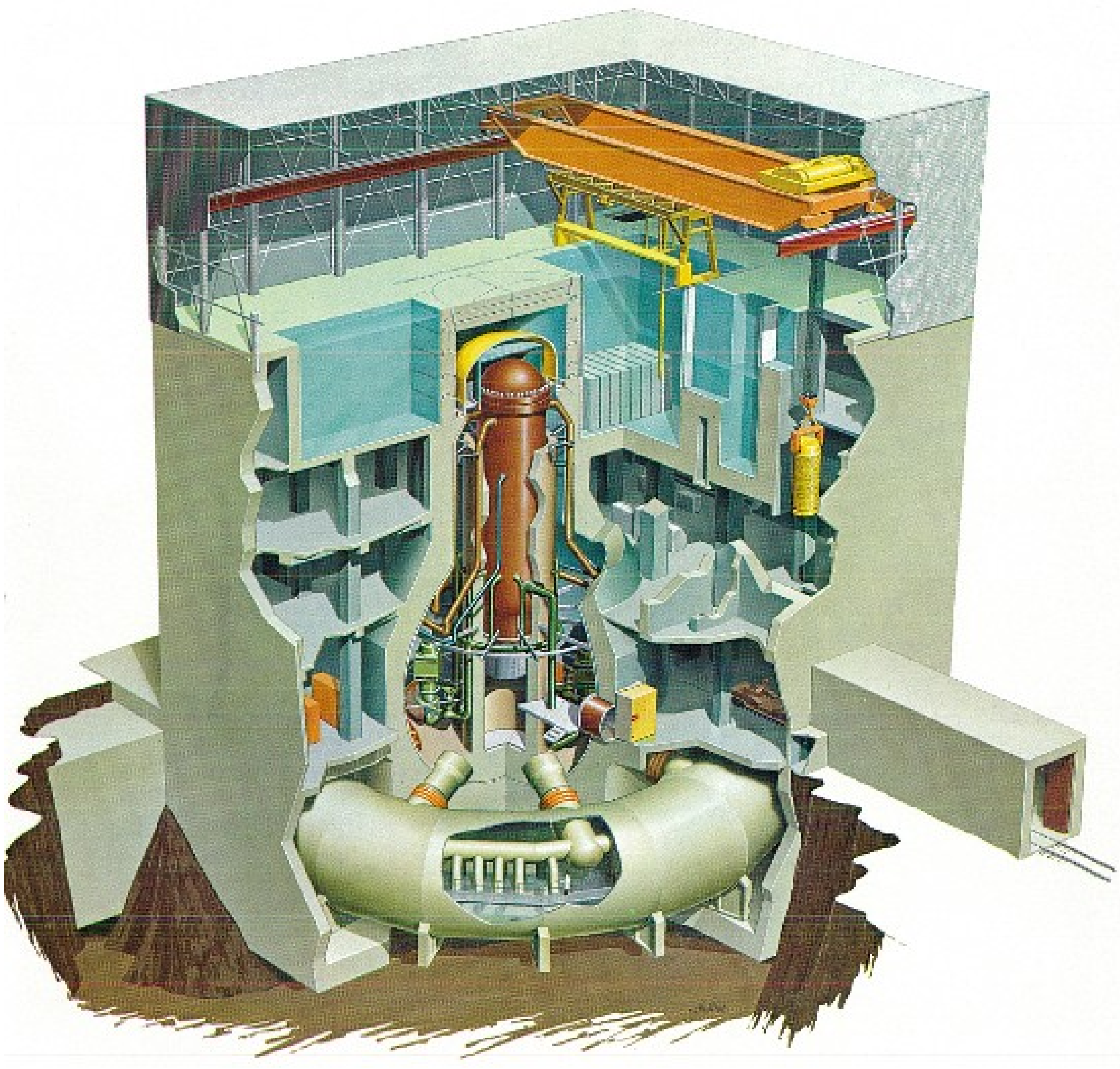
Energy Industry

Energy Source	Mortality Rate (deaths/trillionkWhr)
Coal – global average	170,000 (50% global electricity)
Coal – China	280,000 (75% China's electricity)
Coal – U.S.	15,000 (44% U.S. electricity)
Oil	36,000 (36% of energy, 8% of electricity)
Natural Gas	4,000 (20% global electricity)
Biofuel/Biomass	24,000 (21% global energy)
Solar (rooftop)	440 (< 1% global electricity)
Wind	150 (~ 1% global electricity)
Hydro – global average	1,400 (15% global electricity)
Nuclear – global average	90 (17% global electricity w/Chernobyl & Fukushima)

http://www.forbes.com/sites/jamesconca/2012/06/10/energys-deathprint-a-price-always-paid/

Fukushima Daiichi Nuclear Power Plant

BWR-3 with Mark I Containment



http://www.world-nuclear-news.org/newsarticle.aspx?id=30084

48-foot Wave Impact

http://www.cnn.com/2011/WORLD/asiapcf/04/09/japan.nuclear.reactors/index.html

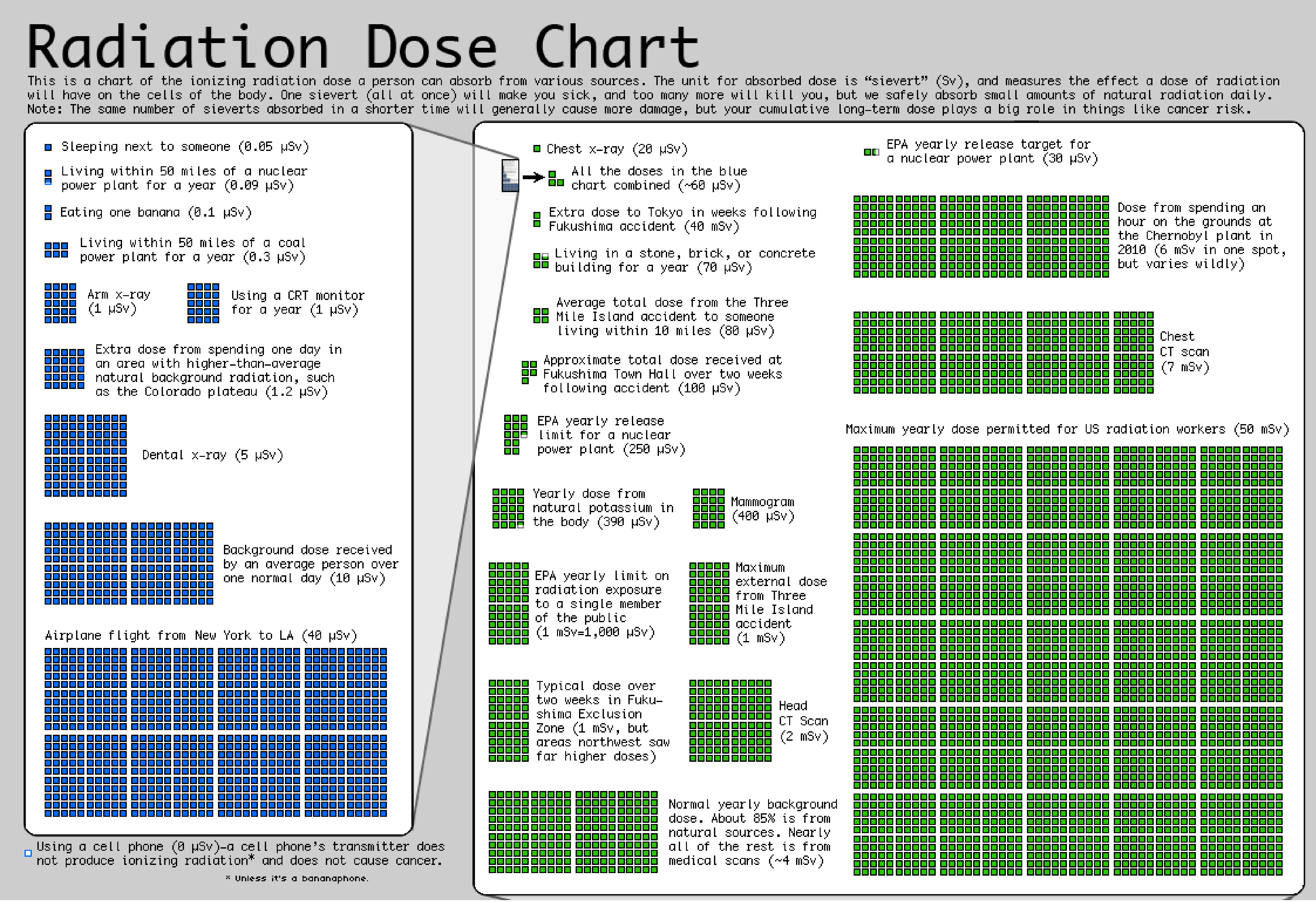
Evacuations

- Initially 10-km radius, later expanded
- Initially thought that plant site was evacuated for a period of hours; investigation shows key personnel remained
- 1600 deaths directly caused by evacuation process
  - Mostly hospital patients, elderly
- Many evacuees moved northwest, to areas with higher dose rates
  - Took about a year for this to be refined, with some towns reopening April 2012

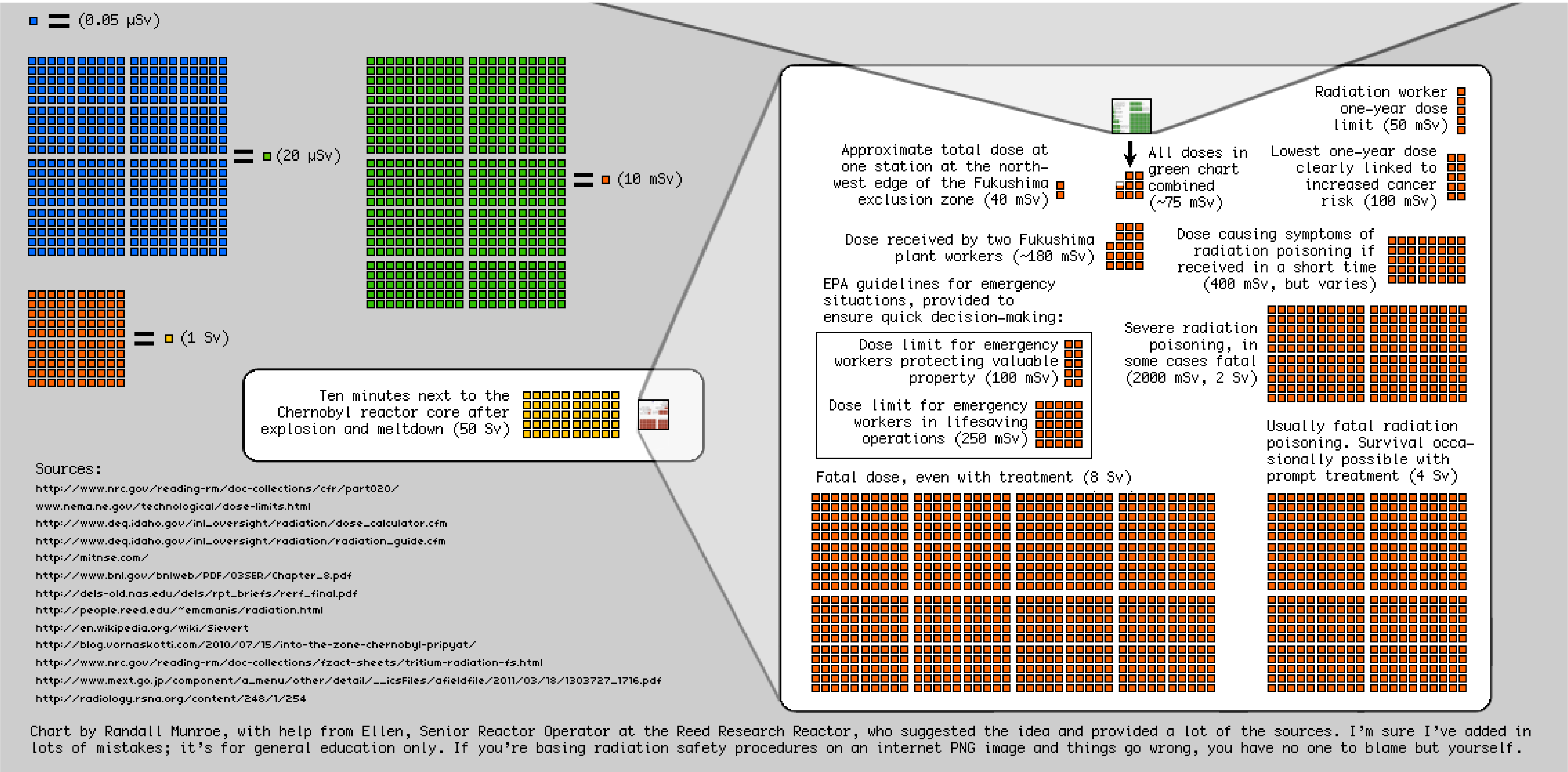
Police in protective suits in Minamisoma in April last year. Photograph: Athit Perawongmetha/Getty Images

Linear No-Threshold Hypothesis

- Straight-line connection between high dose, high dose rate data and zero effect at zero dose
- If dose X causes certain death, ½X dose causes half to die
  - LNT makes this assumption whether dose is immediate or spread over time
- Hypothesis has little scientific basis, first published in 1928.
- Leukemia data from atomic bombs dropped over Hiroshima and Nagasaki largely disproves LNT
- Leads to severe overprediction of radiation induced cancers from small exposures to large populations
  - At most, 245 deaths in Fukushima using this theory if no evacuations had taken place
  - In hindsight, evacuations should not have been ordered, as they resulted in at least 355 additional fatalities. More accurate model would suggest almost all fatalities associated with evacuation could have been avoided.



Radiation Dose Chart
This is a chart of the ionizing radiation dose a person can absorb from various sources. The unit for absorbed dose is "sievert" (Sv), and measures the effect a dose of radiation will have on the cells of the body. One sievert (all at once) will make you sick, and too many more will kill you, but we safely absorb small amounts of natural radiation daily.
Note: The same number of sieverts absorbed in a shorter time will generally cause more damage, but your cumulative long-term dose plays a big role in things like cancer risk.
Sleeping next to someone (0.05 µSv)
Living within 50 miles of a nuclear power plant for a year (0.09 µSv)
Eating one banana (0.1 µSv)
Living within 50 miles of a coal power plant for a year (0.3 µSv)
Arm x-ray (1 µSv)
Using a CRT monitor for a year (1 µSv)
Extra dose from spending one day in an area with higher-than-average natural background radiation, such as the Colorado plateau (1.2 µSv)
Dental x-ray (5 µSv)
Background dose received by an average person over one normal day (10 µSv)
Airplane flight from New York to LA (40 µSv)
Using a cell phone (0 µSv)—a cell phone's transmitter does not produce ionizing radiation* and does not cause cancer.
* Unless it's a bananaphone.
Chest x-ray (20 µSv)
All the doses in the blue chart combined (~60 µSv)
Extra dose to Tokyo in weeks following Fukushima accident (40 mSv)
Living in a stone, brick, or concrete building for a year (70 µSv)
Average total dose from the Three Mile Island accident to someone living within 10 miles (80 µSv)
Approximate total dose received at Fukushima Town Hall over two weeks following accident (100 µSv)
EPA yearly release limit for a nuclear power plant (250 µSv)
Yearly dose from natural potassium in the body (390 µSv)
Mammogram (400 µSv)
EPA yearly limit on radiation exposure to a single member of the public (1 mSv=1,000 µSv)
Maximum external dose from Three Mile Island accident (1 mSv)
Typical dose over two weeks in Fukushima Exclusion Zone (1 mSv, but areas northwest saw far higher doses)
Head CT Scan (2 mSv)
Normal yearly background dose. About 85% is from natural sources. Nearly all of the rest is from medical scans (~4 mSv)
EPA yearly release target for a nuclear power plant (30 µSv)
Dose from spending an hour on the grounds at the Chernobyl plant in 2010 (6 mSv in one spot, but varies wildly)
Chest CT scan (7 mSv)
Maximum yearly dose permitted for US radiation workers (50 mSv)

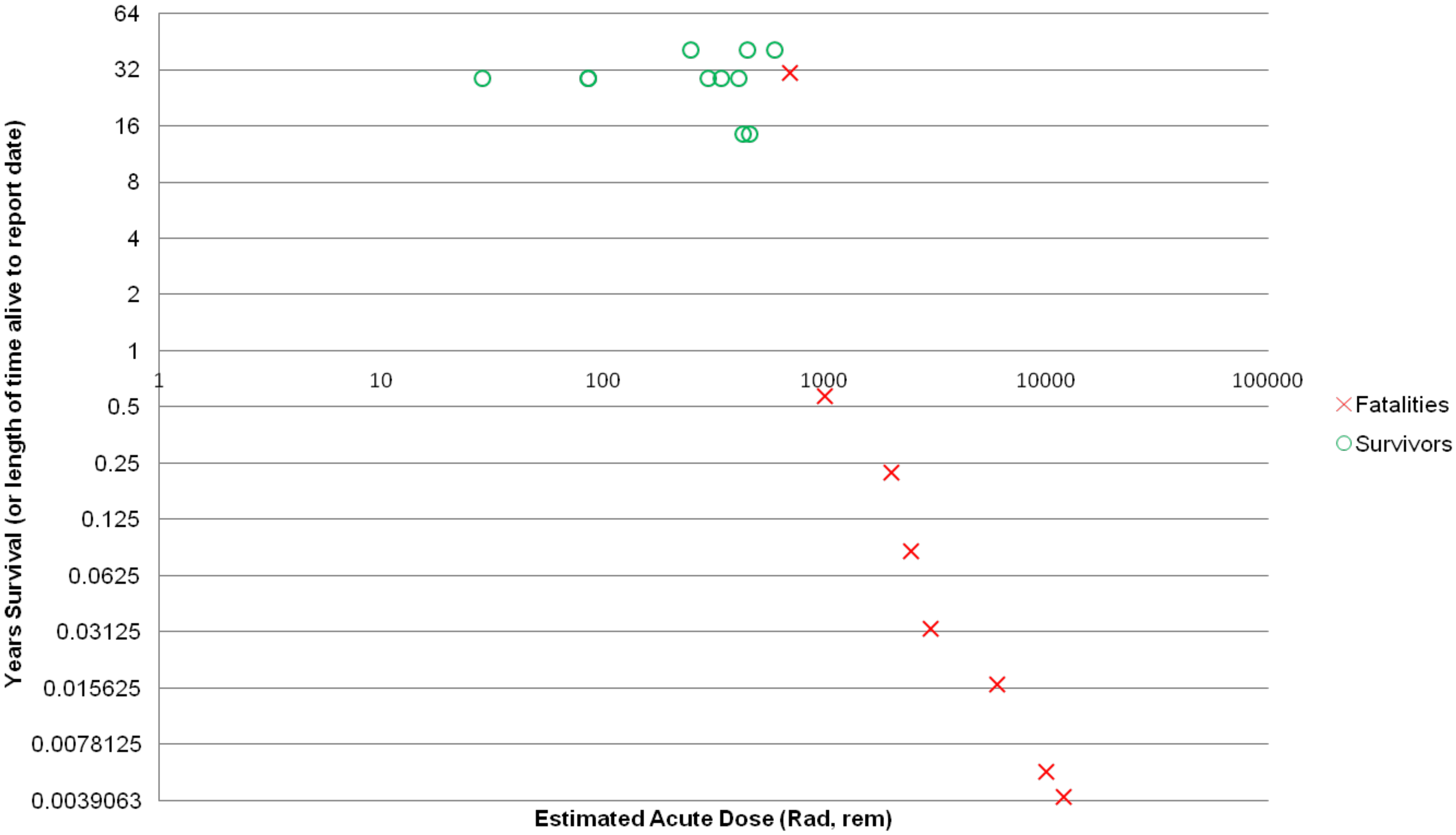


http://xkcd.com/radiation/

1958 Oak Ridge Criticality Accident

- Process accident involving nuclear material in solution
- Eight people received significant radiation doses (461, 428, 413, 341, 298, 86.5, 86.5, and 28.8 rem).
- One person survived 14.5 years, one 17.5 years, the status of one is unknown, and five were alive 29 years after the accident
    - LA-13638, *A Review of Criticality Accidents*
- One of the fatalities was the result of a motorcycle accident, not radiation!

Dose vs. Survival Time for Criticality Accidents



LA-13638: A Review of Criticality Accidents

Linear No-Threshold Hypothesis

- Despite minimal basis for, and significant evidence against the LNT model, it remains the standard model for regulatory purposes.
- Efforts to challenge the model have been suppressed on numerous occasions, prompting ANS to publish a special volume on low level radiation effects (http://ansnuclearcafe.org/category/hormesis/)
- Numerous studies (hundreds of thousands of people involved) have also shown health benefits from long-term low-level radiation exposure, consistent with :
  - Naval Reactors Radiological Data: 1954-present
  - Nuclear Shipyard Worker Study
  - Taiwan Cobalt-60 Apartment Exposure
  - Large number of French laboratory studies
  - 2012 National Institutes of Health report
- "No DNA damage seen in long-exposure study" that exposed "mice to radiation hundreds of times greater than background"

What should I do if a nuclear accident occurs?

- Don't panic! Even if we're talking about a nuclear weapon going off in a major city, it won't do any good to panic.
- Stay indoors
  - If you've survived the initial event, your biggest health risk is from airborne radioactive particles
  - Once the airborne risk is diminished, then—if appropriate—you might evacuate
- Don't do anything more dangerous trying to get away from it

What should I do if a doctor prescribes radiation?

- Don't worry, but understand what the procedure is attempting to do
- Ask what the estimated dose will be, whole body or to a particular organ.
  - Insist on real numbers, not a generic answer like “not much”
- Compare that dose to radiation received under normal circumstances (300-600 mrem or 3-6 mSv per year)
- Look at the risks associated with not doing the procedure
  - If you might have cancer, or are diagnosing a significant medical ailment, you should probably be more concerned with the problem affecting you now, over the chance of a problem in the future
  - If you're treating cancer, the risk of latent cancer from radiation isn't really relevant anymore
- Only you can decide if the benefits outweigh the possible consequences!