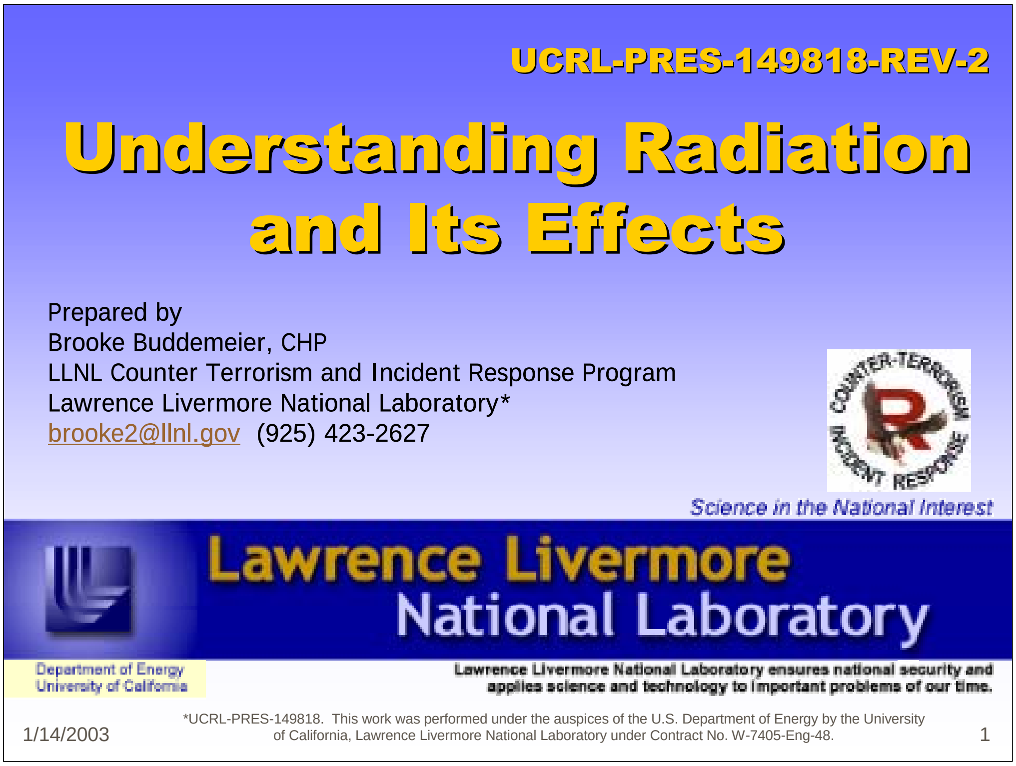

{Note, the Speakers notes of this presentation will often contain a suggested narrative and additional information for the presenter}

This presentation is meant to be a “primer” on radiation issues for emergency responders.

Explain what a health physicist is

Brooke Buddemeier, CHP
Lawrence Livermore National Laboratory
Nuclear Counterterrorism Program

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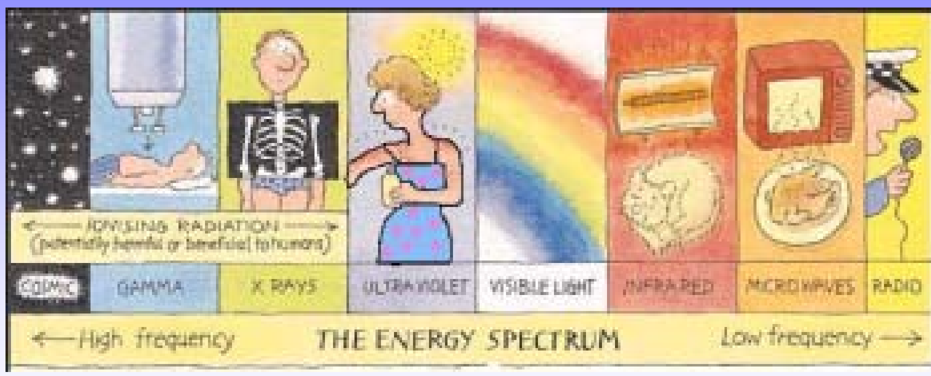
Radiation is Energy

- **The energy is given off by unstable (radioactive) atoms and some machines.**



- **For this talk, we will be focusing on <u>ionizing radiation</u> and its health effects.**

1/14/2003

UCRL-PRES-149818. Understanding Radiation and it's Effects.

<u>Narrative</u>

"Radiation energy come is several forms that can best be described as waves (light, microwaves, x-rays, gamma-rays, etc.) and particles (alpha particles, beta particles, etc.)"

For this talk we will be focusing on "ionizing Radiation" which is the high frequency radiation that haws enough energy to liberate electrons from atoms that it hits.

In other words, it creates ions.

=================== Additional Info And Notes ================

Graphic taken from **Radiation and Life** web page of the **Uranium Information Centre**

Melbourne, Australia. (sundress added by my niece)

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Radiation and Radioactive Material are a Natural Part of Our Lives

- We are constantly exposed to low levels of radiation from outer space, earth, and the healing arts.
- Low levels of naturally occurring radioactive material are in our environment, the food we eat, and in many consumer products.
- Some consumer products also contain small amounts of man-made radioactive material.

Narrative

The top picture is the a view of Aurora Borealis from outer space which is just of cosmic radiation interacting with or ionosphere

The Orange Glaze used in Fiestaware was made using natural uranium

For decades, Lantern Mantels have contained natural Thorium. Thorium is natural radioactive material with a half live of 14 billion years

Smoke detectors have man-made Am-241, which is used to detect the presence of smoke.

Emphasize: there is <u>no difference</u> between the type of radiation emitted by natural or man-made sources.

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Unstable Atoms Decay

- The number of "decays" that occur per unit time in the radioactive material tell us how radioactive it is.
  - Units include Curies (Ci), decays per minute (dpm), and Becquerels (decays per second).
- When an unstable atom decays, it ***transforms*** into another atom and releases its excess energy in the form of radiation.
- Sometimes the new atom is also unstable, creating a "decay chain"

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Narrative

"Atoms are the building blocks of our world, we are made from atoms, as is the air we breath and the world we live in. If you recall your high school "Table of Elements," there are a little over 100 different elements, or "flavors" of atoms.

Everything above Element number 89 (Bismuth) is unstable. This includes the uranium and thorium we dig out of the ground as well as man-made elements such as plutonium and Americium.

Even the "stable" elements have unstable "brothers and sisters" that ***chemically*** behave identically to their stable sibling, but are radioactive. Again, these unstable brethren, or isotopes, include naturally occurring isotopes like Carbon-14 and Tritium (a radioactive form of Hydrogen) and man-made isotopes like Cesium-137 and Iodine-131.

UNSTABLE ATOMS DECAY

I often relate this to the hyperactive brother, who just has too much energy. The unstable atoms eventually get rid of this energy by "**Decaying,**" or more accurately "**Transforming,**" to different element. During this process, they get rid of excess energy by giving off radiation.

We define **how radioactive** something is by how many decays occur in a given amount of material over a given time. In fact, one of our oldest units was defined by Madam Curie as the number of decays in **1 gram of radium**. This unit, named after her as "The curie" turned out to be 37 billion decays per second. Which, explains why Marie died of Leukemia and had lesions on her hip from carrying her precious Radium in her lab coat pocket.

When atoms decay, they release much of their excess energy in the form of radiation. There are two main types of radiation; **Gamma rays** are electromagnetic radiation, like light and radio-waves… except that these photons have enough energy to strip off the outer electron, or "ionize," any atoms that they hit.

During the Decay Process, particles are also ejected from the nucleus. The most common of these, ***alpha, beta, and Neutron particles***, are ejected with enough energy to also **ionize** other atom that they hit.

Often, unstable atoms transform into another unstable atom! This can lead to a series of transformations, or "decay chain." As you can see by the graphic, the most common Uranuim isotope actually goes through 14 different decays before reaching a stable lead isotope.

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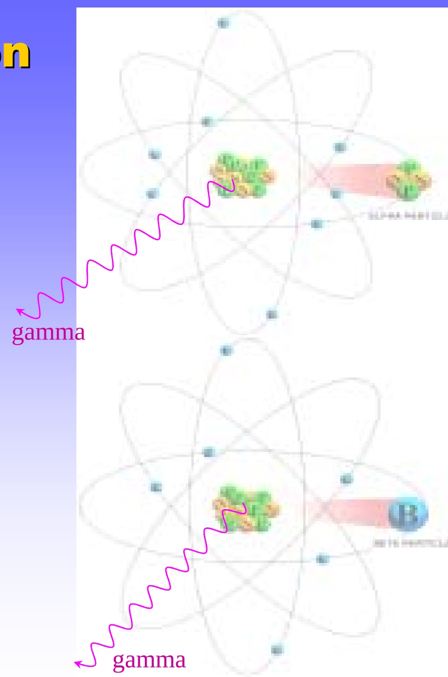
Forms of Radiation

- When unstable atoms transform, they often eject particles from their nucleus. The most common of these are:
  - Alpha Radiation
    High energy, but short range (travels an inch in air, not an external hazard)
  - Beta Radiation
    Longer range (10 – 20 feet in air) and can be a skin and eye hazard for high activity beta sources.
- Gamma Rays (electromagnetic radiation)
  Often accompany particle radiation. This "penetrating" radiation is an external hazard and can travel 100s of feet in air.



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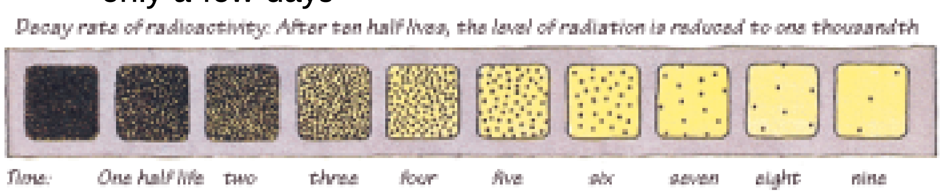
How Unstable Is It?

- The "Half-Life" describes how quickly Radioactive Material decays away with time.

  It is the time required for **half** of the unstable atoms to decay.

- Some Examples:
  - Some natural isotopes (like uranium and thorium) have half-lives that are billions of years,
  - Most medical isotopes (like Technicium-99m) last only a few days



Narrative

How Unstable an atom is will drive the speed at which it decays. Some unstable atoms last for billions of years and are older than the Earth itself, others have a hard time staying around a microsecond after it was created.

Since this is a random process, we don't know exactly when any specific unstable atom will decay…. But, on average, we know how long it takes <u>for half of a group of unstable atoms to decay</u>.

This measurement of time is called the half-Life. After each "half-life," half of the remaining unstable atoms would transform.

<u>The Picture</u> can help visualize this. Each dot represents an unstable atom. The first picture is almost black because of them. After one half life, half are gone. After another half-life, half of the remaining atoms are gone. Statistically, even after 10 half lifes, there could still be a few unstable atoms hanging around… but their number will be one thousandth of the starting number of atoms.

<u>============================= Additional Info ==============</u>

<u>For non technical Overview, Change SLIDE to</u>

•The number of "decays" that occur per unit time in the radioactive material tell us how radioactive it is.

•Radioactive Material "decays away" with time, though different isotopes decay away at different rates. For Example:

- •Some natural isotopes (like uranium and thorium) have half-lives that are billions of years.
- •Most medical isotopes (like I-131) last only a few weeks.

Some Isotopes & Their Half Lives

ISOTOPE	HALF-LIFE	APPLICATIONS
Uranium	**billions of years**	Natural uranium is comprised of several different isotopes. When enriched in the isotope of U-235, it's used to power nuclear reactor or nuclear weapons.
Carbon-14	**5730 y**	Found in nature from cosmic interactions, used to "carbon date" items and as radiolabel for detection of tumors.
Cesium-137	**30.2 y**	Blood irradiators, tumor treatment through external exposure. Also used for industrial radiography.
Hydrogen-3	**12.3 y**	Labeling biological tracers.
Irridium-192	**74 d**	Implants or "seeds" for treatment of cancer. Also used for industrial radiography.
Molybdenum-99	**66 h**	Parent for Tc-99m generator.
Technicium-99m	**6 h**	Brain, heart, liver (gastoenterology), lungs, bones, thyroid, and kidney imaging, regional cerebral blood flow, etc.

Narrative

Here are some examples of radioactive isotopes commonly used in industry.

{Read slide it time permits}

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note: this slide can be removed for an overview

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The Amount of Radioactivity is NOT Necessarily Related to Size

- Specific activity is the amount of radioactivity found in a gram of material.
- Radioactive material with <u>long half-lives</u> have <u>low specific activity</u>.

<u>1 gram</u> of Cobalt-60
has the same activity as
<u>1800 tons</u> of natural Uranium

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<u>Narrative</u>
You can't judge how much radiation is being produced based on the physical size of the source.

Radioactive material with <u>long half-lives,</u> **meaning it decays away slowly,** will not give off a lot of radiation **per unit mass. This is referred to as the isotope's <u>Specific</u> <u>Activity</u>.**

For isotopes like Cobalt-60, which only has a half life of a few years, a gram of Co-60 has the same activity (number of decays per minute) are almost **two thousand tons** of uranium.

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What is a “Dose” of Radiation?

- When radiation’s energy is deposited into our body’s tissues, that is a dose of radiation.
- The more energy deposited into the body, the higher the dose.
- **Rem** is a unit of measure for radiation dose.
- Small doses expressed in **mrem = 1/1000 rem**.
- **Rad** & **R** (Roentgens) are similar units that are often equated to the Rem.

Lecture: Read slide

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Remove This Slide for an Overview presentation

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Typical Doses

Average Dose to US Public from All sources	360 mrem/year
Average Dose to US Public From Natural Sources	300 mrem/year
Average Dose to US Public From Medical Uses	53 mrem/year
Coal Burning Power Plant	0.2 mrem/year
Average dose to US Public from Weapons Fallout	< 1 mrem/year
Average Dose to US Public From Nuclear Power	< 0.1 mrem/year
Occupational Dose Limit for Radiation Workers	5,000 mrem/yr

Coast to coast Airplane roundtrip	5 mrem
Chest X ray	8 mrem
Dental X ray	10 mrem
Head/neck X ray	20 mrem
Shoe Fitting Fluoroscope (not in use now)	170 mrem
CT (head and body)	1,100 mrem
Therapeutic thyroid treatment (dose to the whole body)	7,000 mrem

Narrative:

Here are some examples of typical doses received by people. On Average, people in the US get about 360 mrem per year. Most of this, 300 mrem, is from “natural” sources such as the uranium in the ground and cosmic radiation from outer space.

The second biggest contributor to our annual dose is medical use of radiation.

If you can read this slide, you may notice that a Coal Burning power plant gives more dose to the public than nuclear power. This isn’t a type-O; Coal, oil, and natural gas all come from the ground and have trace quantities of uranium in them. When we burn this material in our powerplants and homes, the radioactive material exposes us when it is released in the exhaust, in addition to the greenhouse gasses and ash.

Although Nuclear Power generates a lot more radioactive material, when everything goes as planned, it is contained in the spent fuel. No greenhouse gasses either.

Highlighted in yellow is the annual occupational exposure limit of 5,000 mrem.

I’ve also listed the doses you might get from a few events, such as flying across the country, which leads to a 5 mrem cosmic radiation dose, and some common medical procedures.

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<u>Narrative</u>

<u>Emphasize:</u> A person exposed to radiation does not become radioactive. When you get an X-ray at the doctor's office, it does not make you radioactive.

Getting a radiation exp[osure is just like going to the beach and being exposed to sunshine. The light rays may deposit enough energy into you body to cause an effect, like a sun burn, but when you turn off the lights that night you will not be glowing.

Contamination is Radioactive Material spilled someplace you don't want it. For example it can be the spilt vial of the radioactive liquid of radiopharmaceutical pictured above, or it can be dust of even chunks of radioactive material wherever it is not wanted.

Even when spread around the radioactive material in the **Contamination still emits radiation.**

•Contamination can get on you.

•If you walk through it, touch it, or breath airborne contamination; it may get on, or inside of you.

•The contamination may be too small to be visible.

Our Bodies Are Resilient

- **DNA damage is most important and can lead to cell malfunction or death.**
- **Our body has ~ 60 trillion cells**
  - **<u>Each cell</u> takes "a hit" about every 10 seconds, resulting in <u>tens of millions</u> of DNA breaks <u>per cell</u> each year.**
  - **BACKGROUND RADIATION causes only a very small fraction of these breaks (~ 5 DNA breaks <u>per cell</u> each year).**
- **Our bodies have a highly efficient DNA repair mechanisms**

<u>Narrative</u>

The Cells in our body live in a continuing barrage of damaging events. About every 10 seconds, **each** cell in our body "takes a hit." Sitting through this lecture, you will have been assaulted trillions of times! Call the police, Crime in {insert lecture location} is on the rise ;-)

The VAST majority of these assaults is NOT from radiation, but from inescapable byproducts of the chemical processes in our bodies that enable us to live. Behind that is the natural or man-made toxins which we take into our body.

Way below those effects are the 5 or so DNA breaks per cell each year that happen because of background radiation. (out of the 10s of millions total)

Of course, if our bodies didn't have extremely efficient DNA repair mechanisms, our breakfast would probably have already done us in.

===================== Notes =============

Most of this reference comes from:

Smithsonian, V26, #9. December 1995, RISK, Part 2: Safeguarding our cells by James Trefil.

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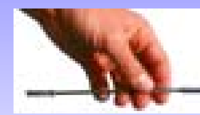
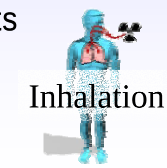
Types of Exposure & Health Effects

- **Acute Dose**
  - Large radiation dose in a short period of time
  - Large doses may result in observable health effects
    - Early: Nausea & vomiting
    - Hair loss, fatigue, & medical complications
    - Burns and wounds heal slowly
  - Examples: medical exposures and accidental exposure to sealed sources



- **Chronic Dose**
  - Radiation dose received over a long period of time
  - Body more easily repairs damage from chronic doses
  - Does not usually result in observable effects
  - Examples: Background Radiation and Internal Deposition



Suggested narrative:

The types of radiation exposures that hurt us the most are **Large Doses** delivered **over a short period of time**. These types of exposures overwhelm our body's repair mechanisms. These are referred to a **ACUTE** exposures or doses

Pictured in that person's hand is a dummy industrial radiography source. At least I hope it's a dummy source, otherwise holding a source like that for a minute or two can cause painful burns and wounds that refuse to heal.

In contrast, a CHRONIC exposure is one that is received over a long period, allowing the body to more effectively manage the effects**.**

==========Notes=======================

Consider a (small) 30 Ci ^{192}Ir radiography source.

Surface dose = 36,000 rad/min
at 1 cm - dose rate=2400 rad/min
at 2 cm - dose rate = 600 rad/min
at 3 cm - dose rate=267 rad/min
at 4 cm - dose rate=150 rad/min
at 5 cm - dose rate=96 rad/min

Early: Nausea & vomiting => Usually happens within a few hours of large (> 100 rad) exposures. The higher the dose, the sooner and more severe the symptom.

Burns and wounds heal slowly => For localized exposures, burns and tissue necrosis.

Hair loss, Fatigue, & medical complications =>

Dose (rads)	**Effects**
25-50 (drop in white blood cell count)	First sign of physical effects
100 (within a few hours of exposure)	Threshold for vomiting
320 - 360 (with minimal supportive care)	~ 50% die within 60 days
480 - 540 (with supportive medical care)	~50 % die within 60 days
1,000	~ 100% die within 30 days

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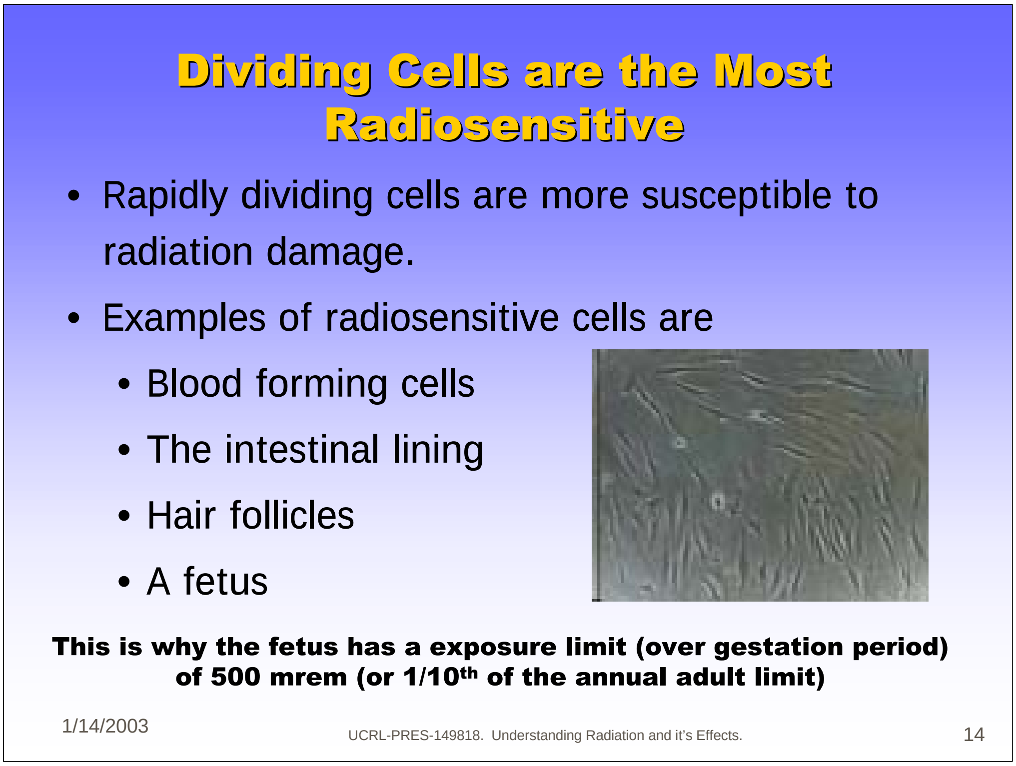

Suggested narrative:

When cells are dividing (or undergoing mitosis) they are more susceptible to radiation damage because the cells don't have their full suite of repair mechanisms. Because of this, cells that are often dividing like

The cells that create our blood or line our intestine, also

Hair follicles, and, of course, fetal cells

are more susceptible to radiation damage.

This is why the fetus has a exposure limit (over gestation period) of 500 mrem (or 1/10th of the annual adult limit)

Specialized or slowly dividing cells, like brain cells are radio-insensitive.

Credit: The vedio (and voiceover) was Excerpted from DOE's **Transportation Emergency Preparedness Program (TEPP)**

http://www.em.doe.gov/otem/program.html

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At HIGH Doses, We KNOW Radiation Causes Harm

- High Dose effects seen in:
  - Radium dial painters
  - Early radiologists
  - Atomic bomb survivors
  - Populations near Chernobyl
  - Medical treatments
  - Criticality Accidents
- In addition to radiation sickness, increased cancer rates were also evident from high level exposures.

<u>Narrative</u>

The Picture of woman using ***fluoroscope***. Just off the picture to the right is the business end on an X-ray machine beaming toward her face.

The beam hits the ***phosphors*** on the back of the "telescope" and she can she her hand as an X-ray and watch it move…. She also gets a whopping dose to the face!

Throughout this century, people have been exposed to radiation. Some through accident or ignorance; others, like the atomic bomb survivors or medical patients, where exposed intentionally.

Extensive data has been collected on these exposures in an attempt to understand more about it's effects.

At high doses of radiation, we know there are physical effects such as burns, radiation sickness and even death.

Another observed effect of high doses of radiation is a detectable increase in certain cancer rates. Not a sure thing, but rather a slight increase over the natural incidence of cancer for large exposures.

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Effects of ACUTE Exposures

Dose (Rads*)	Effects
25-50	First sign of physical effects (drop in white blood cell count)
100	Threshold for vomiting (within a few hours of exposure)
320 - 360	~ 50% die within 60 days (with minimal supportive care)
480 - 540	~50 % die within 60 days (with supportive medical care)
1,000	~ 100% die within 30 days

*** For common external exposures 1 Rad ~ 1Rem = 1,000 mrem**

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<u>Narrative</u>

<u>As we start talking about large doses, please note that I've changed the units on you. I'm now using RADs instead of mrem. It takes 1000 mrem to equal 1 rem which is about the same as a rad.</u>

For example, using the mrem units we talked about before, it would take 25,000 to 50,000 mrem to see any kind of physical effects in humans. Effects that we would not even feel, but a blood test could reveal due to the lower white blood cell count.

<u>================ notes ============</u>

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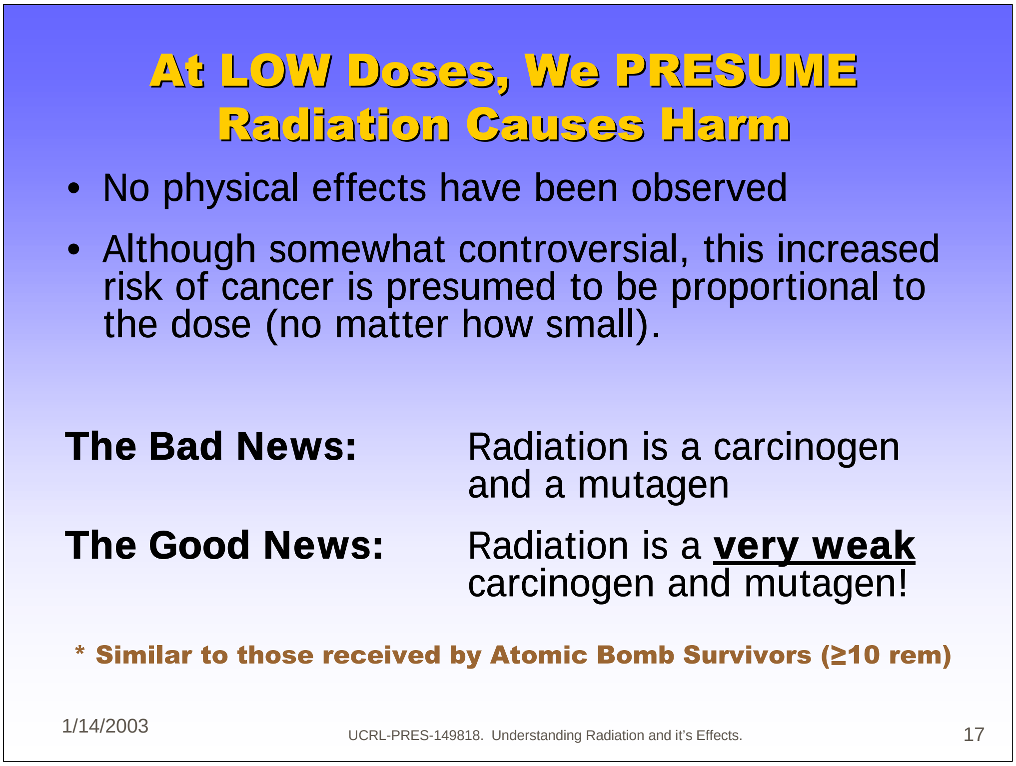
A Good source of information on Acute Effects of Radiation can be found on:

http://radefx.bcm.tmc.edu/ionizing/subject/risk/acute.htm



Narrative: Read the slide

Verbally mention that the LNT theory is done for conservatism

============ Additional Info ------------

Rule of thumb: Every 1 rem of dose increase risk by 0.08%

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Long-term Effects of Radiation

- **Radiation is assumed to increase one's risk of cancer**
  - The "normal" chance of dying of cancer is ~ 23% (~460 out of 2,000).
  - Each rem is assumed to increase that risk by 0.05% (~1 chance in 2,000).

The occupational radiation dose limit to the whole body is 5 rem/yr

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[Source: Table V-25, B.E.I.R. V Linear Risk Model]

Suggested Narrative:

Unexposed, our "normal" chance of being done in by cancer is about 20%. If we receive an ACUTE 1 rem exposure (**3 times our annual background dose**), you might increase your chances by 1 in 2000, or about 0.05%.

As you can see, this kind of math looses its meaning on the individual level. It is most commonly used to describe increased number of cancer deaths in large, exposed populations. For example, if you exposed 10,000 people to that same 1 rem, you could predict an additional 5 cancer deaths over the normal 2,300 cancer deaths.

Keep in mind that these estimates are based on high exposures because no statistically significant data can be generated at low exposures when you consider the low number of occurrences and the cancer's latency period.

Depending on the audience. It might be worthwhile to go into comparative risk factors….

Common activities that cause 1 in a million chances of dying

10 mrem of radiation (cancer)
smoking 1.4 cigarettes (lung cancer)
eating 40 tablespoons of peanut butter
spending 2 days in NYC (air pollution)
driving 40 miles in a car (accident)
flying 2500 miles in a jet (accident)
canoeing for 6 minutes

OR

Life Expectancy Lost

Health Risk Est. life expectancy lost
Smoking 20 cigs a day 6 years
Overweight (15%) 2 years
Alcohol (US Ave) 1 year
All Accidents 207 days
All Natural Hazards 7 days
Occupational dose (300 mrem/yr) 15 days
Occupational dose (1 rem/yr) 51 days

You can also use the same approach to looking at risks on the job:

Industry Est. life expectancy lost
Agriculture 320 days
Construction 227 days
Mining and quarrying 167 days
Manufacturing 40 days
Occupational dose (300 mrem/yr) 15 days
Occupational dose (1 rem/yr) 51 days

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Conclusion (1 of 2):
Understanding Radiation and it's Effects

- Radiation is energy given off by unstable atoms and some machines.
- Radioactive Material contains unstable atoms that give off radiation when they "decay."
- Contamination is Radioactive Material spread someplace where you don't want it.

Narrative: Read the slide

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Conclusion (2 of 2):

Understanding Radiation and it's Effects

- Radiation damages our cell's DNA, fortunately our body has very efficient repair mechanisms.
- Large acute doses of radiation can cause sickness or even death. The severity of the effects are proportional to the dose.
- All exposures to presumed to increase the risk of cancer. The amount of "increased risk" is proportional to exposure.

Very Small DOSE = Very Small RISK

Narrative: Read the slide

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References

Risk, DNA, & Dose Effects:

RadEFX(sm) Ionizing Radiation Health Effects Forum

http://radefx.bcm.tmc.edu/ionizing/subject/risk/acute.htm

Which cites several references, including:

NCRP Report 98 "Guidance on Radiation Received in Space Activities," NCRP, Bethesda (MD) (1989).

Health Effects Model for Nuclear Power Plant Accidence Consequence Analysis. Part 2, Scientific Basis for Health Effects Models. U.S. Nuclear Regulatory Commission, Report NUREG CR-4214, Rev. 1. Part II. Washington, D.C. NRC: 1989

Smithsonian, V26 No.9. December 1995; "RISK, Part 2: Safeguarding our cells" by James Trefil.

Other Graphics and Info from:

Uranium Information Centre

Melbourne, Australia

http://www.uic.com.au/index.htm

DOE; Transportation Emergency Preparedness Program (TEPP)

http://www.em.doe.gov/otem/program.html