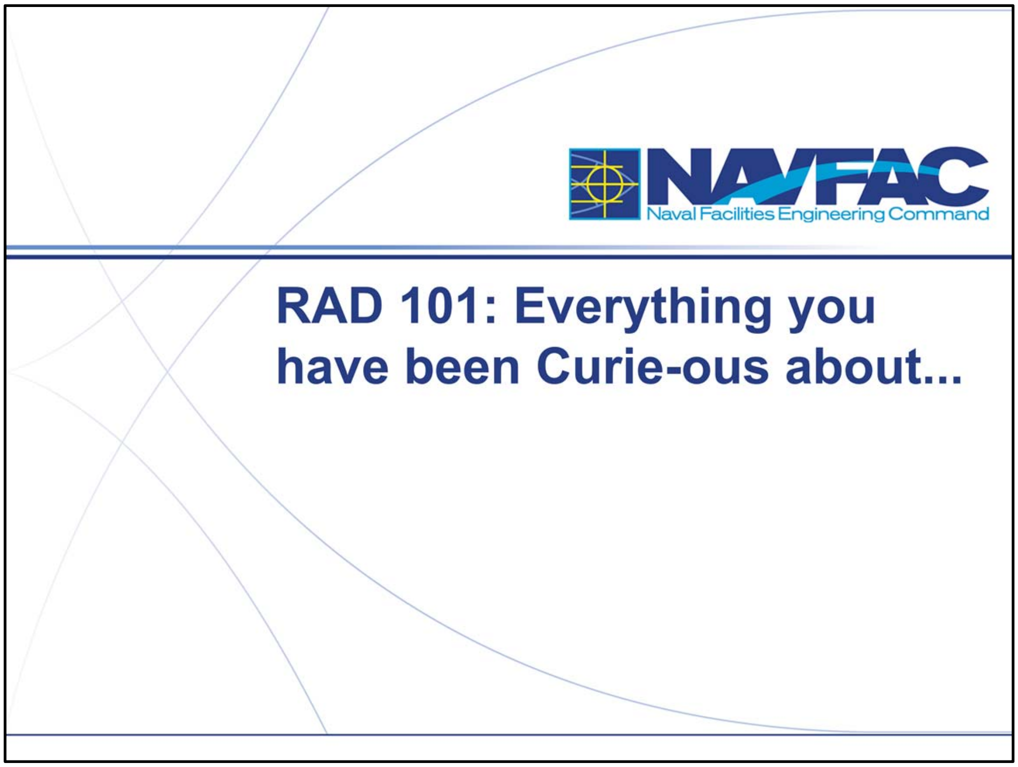
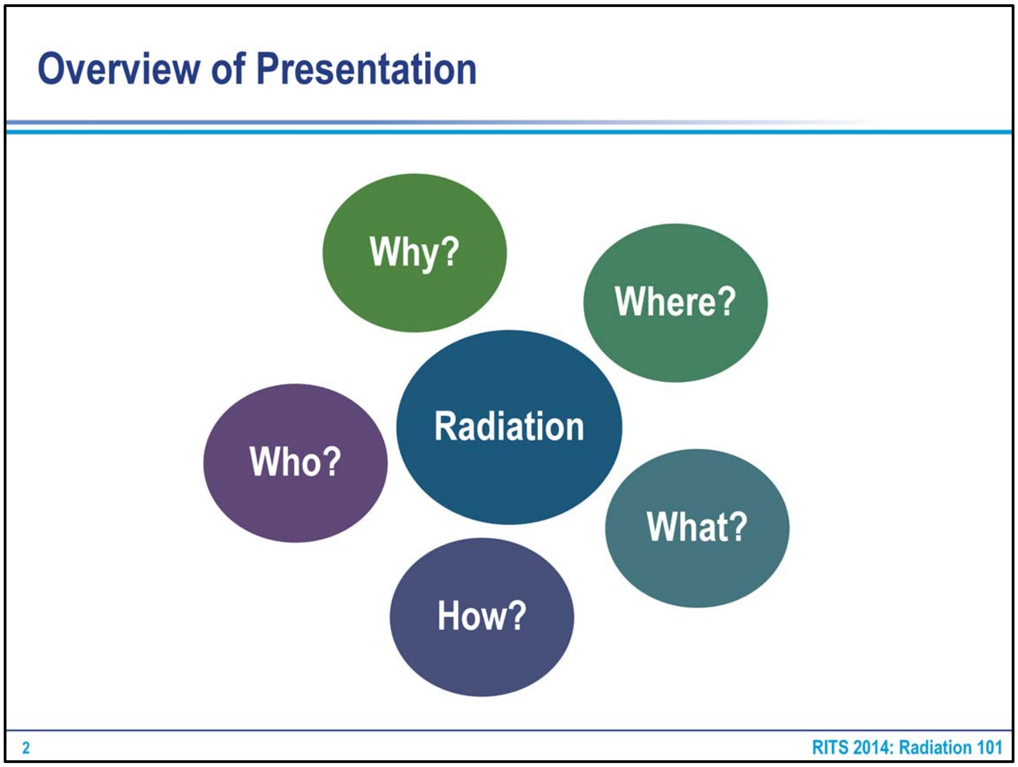
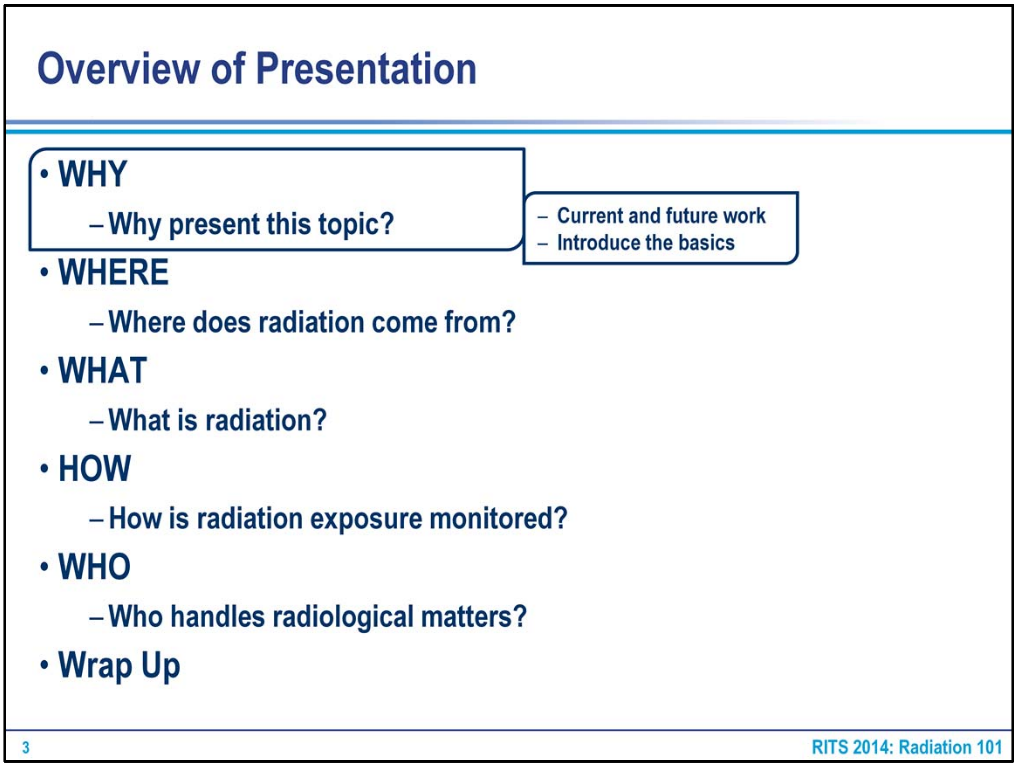


For today's RAD 101 or fundamentals of radiation presentation, I'm hoping to bring both an environmental restoration and nuclear engineering perspective to the topic of radiation/radiation protection and touch on some matters that you might be curie-ous about… CLICK



While there a lot of questions that could be discussed regarding the subject of radiation & radiation protection, this presentation was developed to answer five questions :

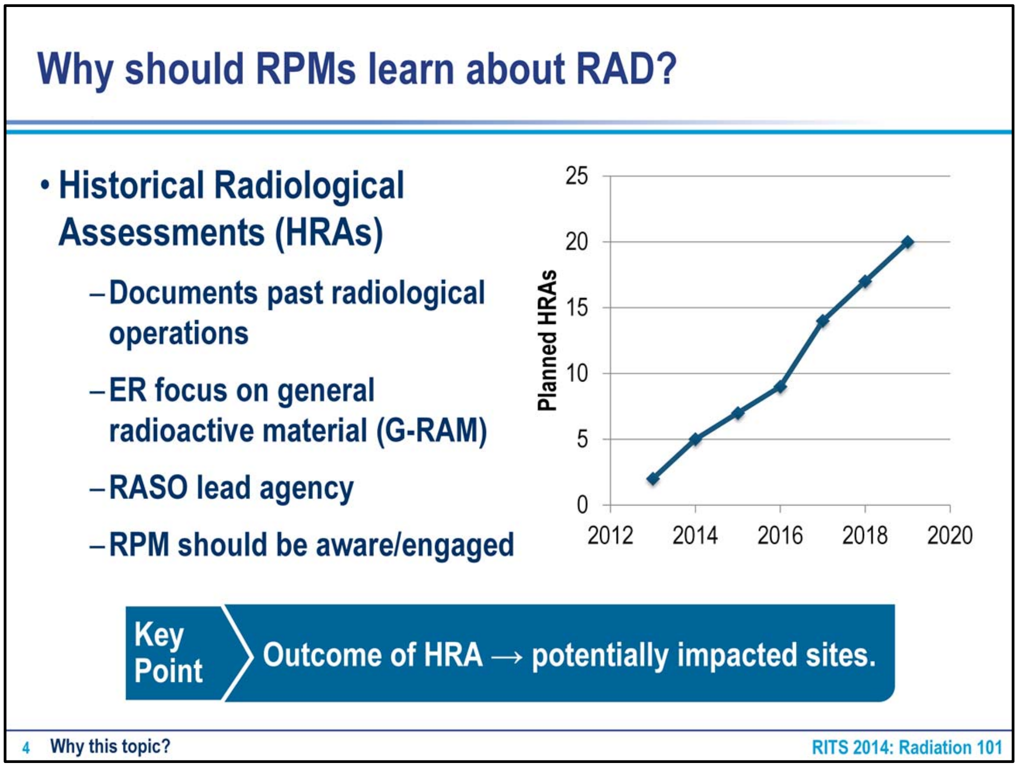
- First off, Why is this presentation being given?
    - Without looking at the next slide, can anyone offer a reason why RPMs might want to learn about radiation & radiation protection? (Current and Future Work)
- Then, we'll discuss "Where does radiation come from?"
    - Types of radioactive material
    - Potential sources at Naval Installations
- Move into the meat of the presentation: "What is Radiation?"
    - Physics refresher
    - Types of radiation
- Once the types of radiation are discussed, then we'll discuss "How is radiation exposure monitored?"
    - Dosimetry
    - Detection
- Finally, we'll review Who handles radiological matters?
    - Roles
    - Responsibilities
    - HRA Case Study



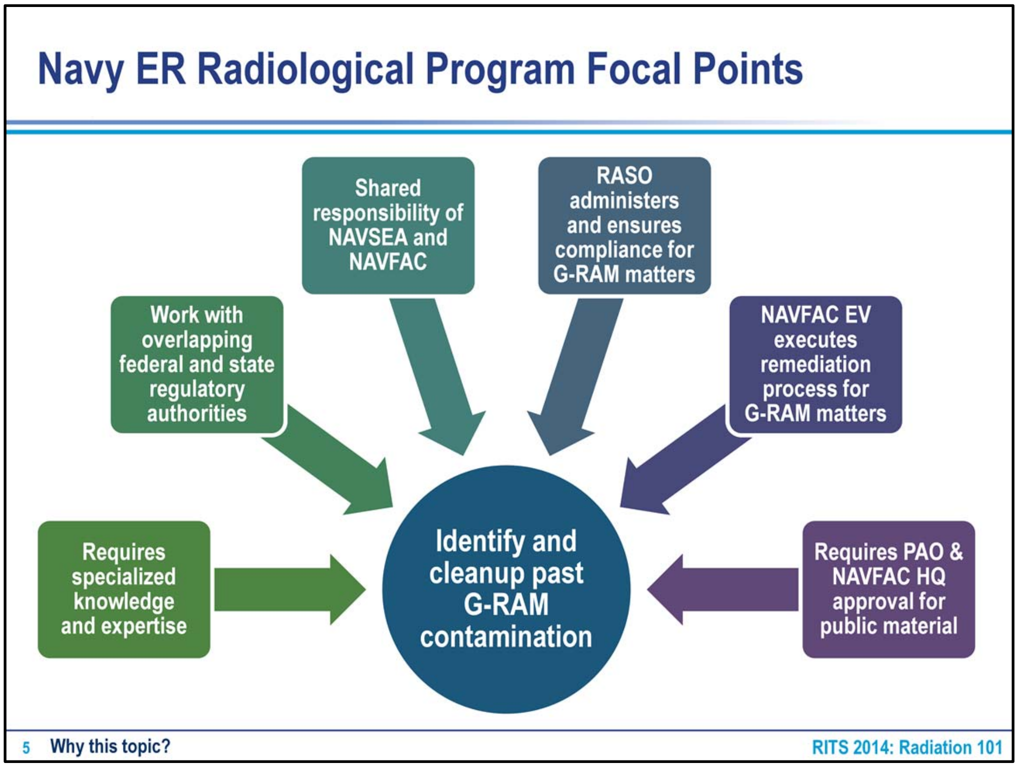
To start of start off today's talk, let answer Why – Why present this topic?

Although we have already had a sneak peak discussion on this question, some of the main reasons for discussing RAD 101 at a RITS forum are due to

- Current and future work for RPMs
- Many RPMs are already working at ER/IR sites w/radiological issues



- Delving more into the future work aspect, many RPMS already know about Historical Radiological Assessments or HRAs. On average, 3 new HRAs are planned to start each year and typically take 2 years to complete.
- As environmental restoration folks, the CERCLA parallel for HRA is the PA. The work will document past radiological operation at the Installation. Specifically, G-RAM or general radioactive material which encompasses practically everything EXCEPT radioactive material associated with the Navy's Nuclear Propulsion Program, Medical, and Weapons.
- RASO will be overseeing HRAs, and RPMs will be involved and should maintain awareness.
    - You can coordinate radiological work with the Navy's technical experts, NAVSEA RASO, to accomplish ER Program goals
- At the end of the day, the results from these RASO-led HRAs may "make" new ER sites.
    - You may be required to manage an IR site with radiological G-RAM contamination.

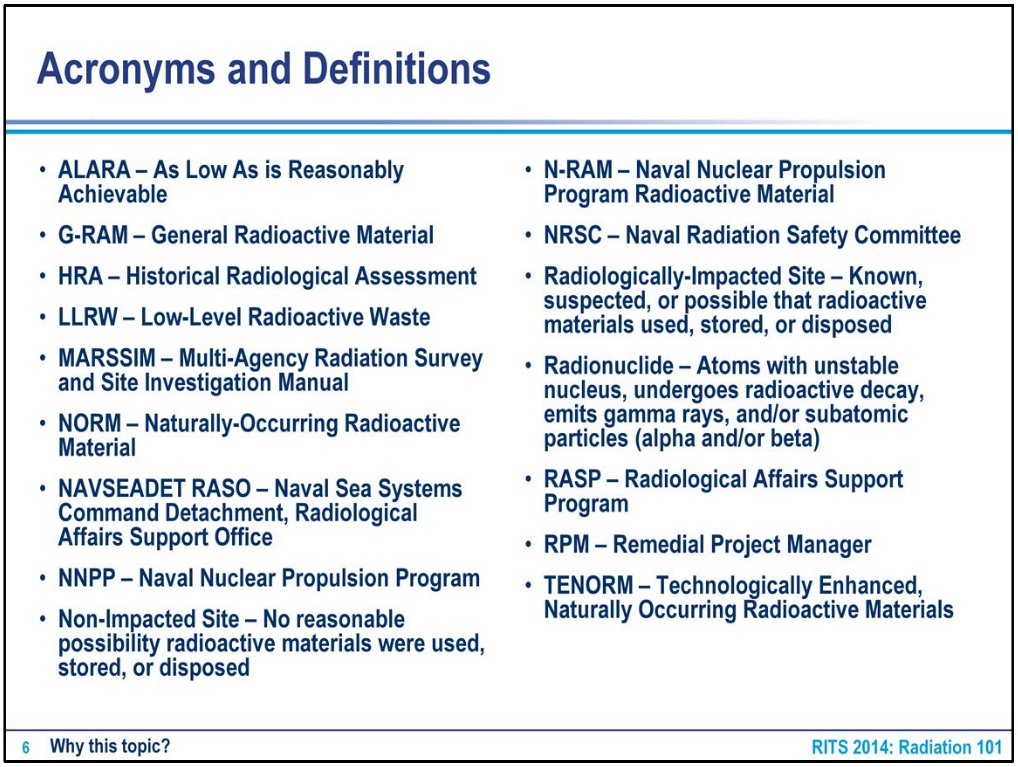


So, what is the role of an RPM with regards to RAD?

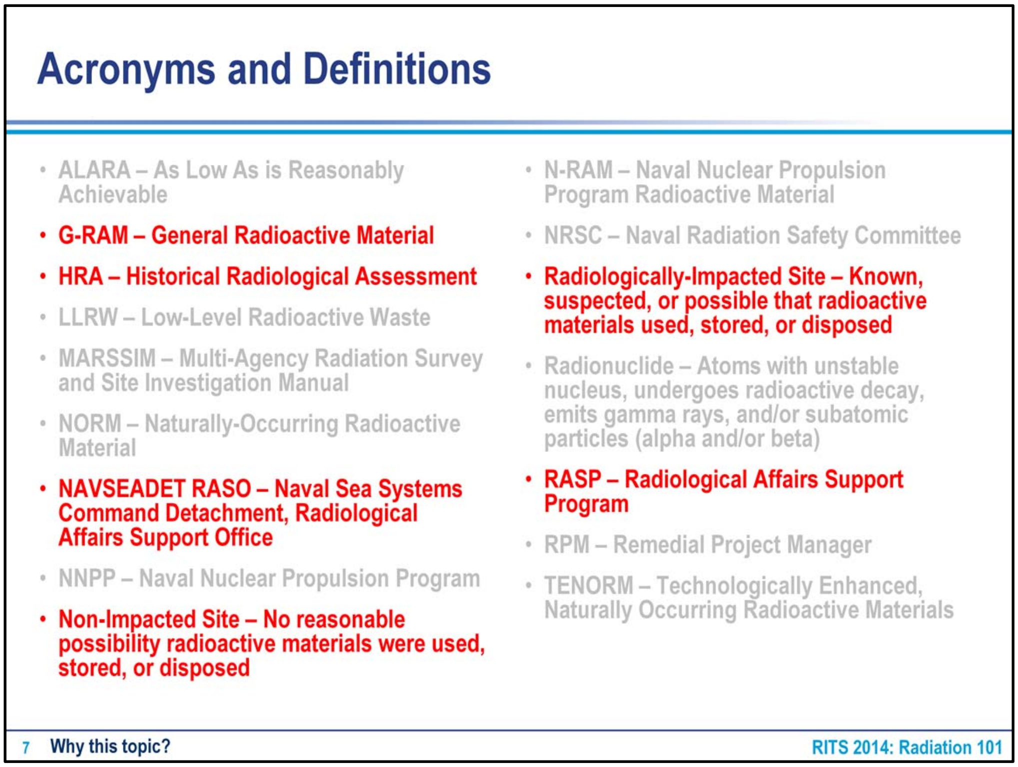
- Identify and cleanup past contamination from the use of G-RAM in order to protect human health and safety, and the environment at both Navy and Marine Corps installations. ***While sites are found as part of an HRA, there may already be sites on a short list (like a radium dial painting facility) – be proactive!***
  - Investigation & cleanup of G-RAM is similar, but different enough from normal restoration work, to require specialized knowledge and expertise
  - Special complexities with G-RAM management entails overlapping federal and state regulatory authority, including the DON itself
  - Identification & cleanup of G-RAM at DON is a shared responsibility of NAVSEA under RASP and NAVFAC under ER/BRAC programs
  - NAVSEA 04N/RASO is responsible for ***administering and ensuring compliance*** with NRSC/NAVSEA requirements with regards to G-RAM within the remediation process of the ER / BRAC programs
  - NAVFAC EV is responsible for execution of G-RAM matters within the remediation process of the ER program
  - G-RAM involves specific PAO procedures requiring NAVFAC HQ approval for ALL public communications

Unlike the ER program where the RPM is the lead from the Navy perspective for ***all*** actions, for G-RAM matters, RASO is part of the team and must be in agreement/consulted on actions/statements. Another reason for this presentation is so that you (RPM) can have a better understanding for the scope of a radiological response action, for determining the necessary resources to accomplish the project, and for choosing the best cleanup option(s)

Remember: States don't have authority over the RASP program. Navy works with them as part of the ALARA process.

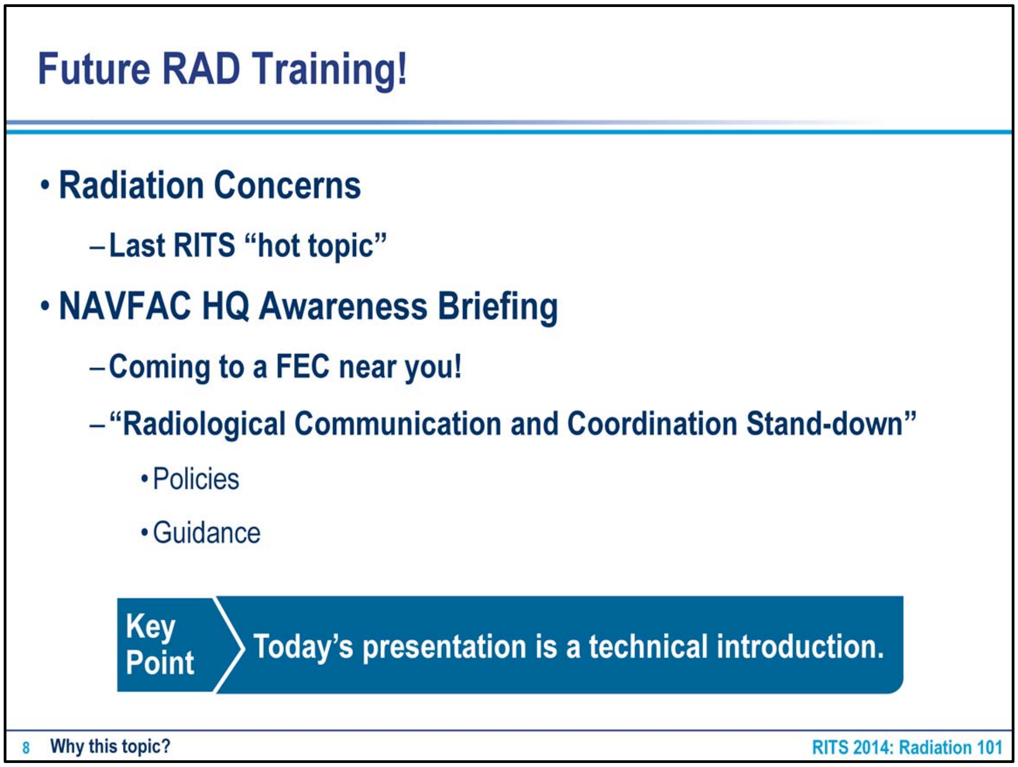


As with any technical topic, vocab is critical

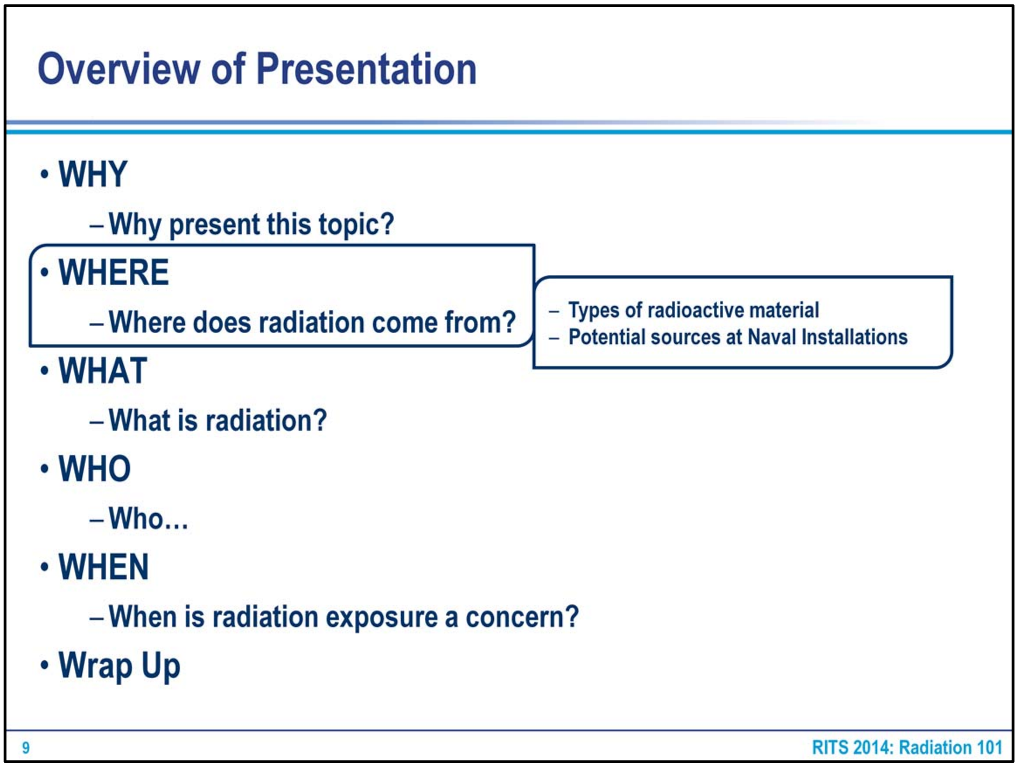


New acronyms already covered within the first 5 slides!

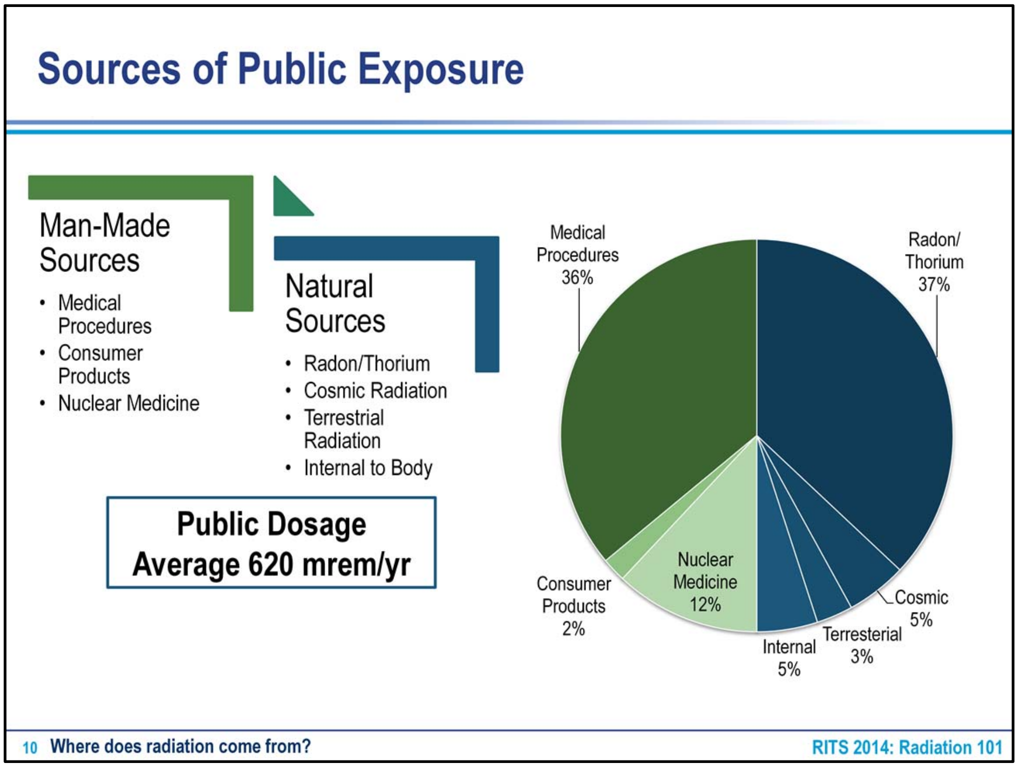
Highlighted acronyms have already been used in this presentation



- This means future work for RPMs. Future work in an area few ER folks are familiar with – hence the need for training on RAD/RAD protection.
- This training effort has already begun within NAVFAC. For example at the 2013 RITS, Radiation Concerns were part of the RITS intro "hot topics". Additionally, NAVFAC HQ may have presented at the FECs in regards to awareness surrounding "Radiological Communication and Coordination". In that presentation, NAVFAC policies and guidance were/will be reviewed.
- With those previous effort in mind, the purpose of today's presentation is to introduce technical basics
    - What is Radiation exactly?
    - And how is radiation measured and reported?
- The information in this presentation will help you as the RPM work better with the folks who deal with RAD on a daily basis. It should help you feel more comfortable with the vocabulary when reading reports. Hence the title Rad 101 – this presentation isn't even RAD 110!

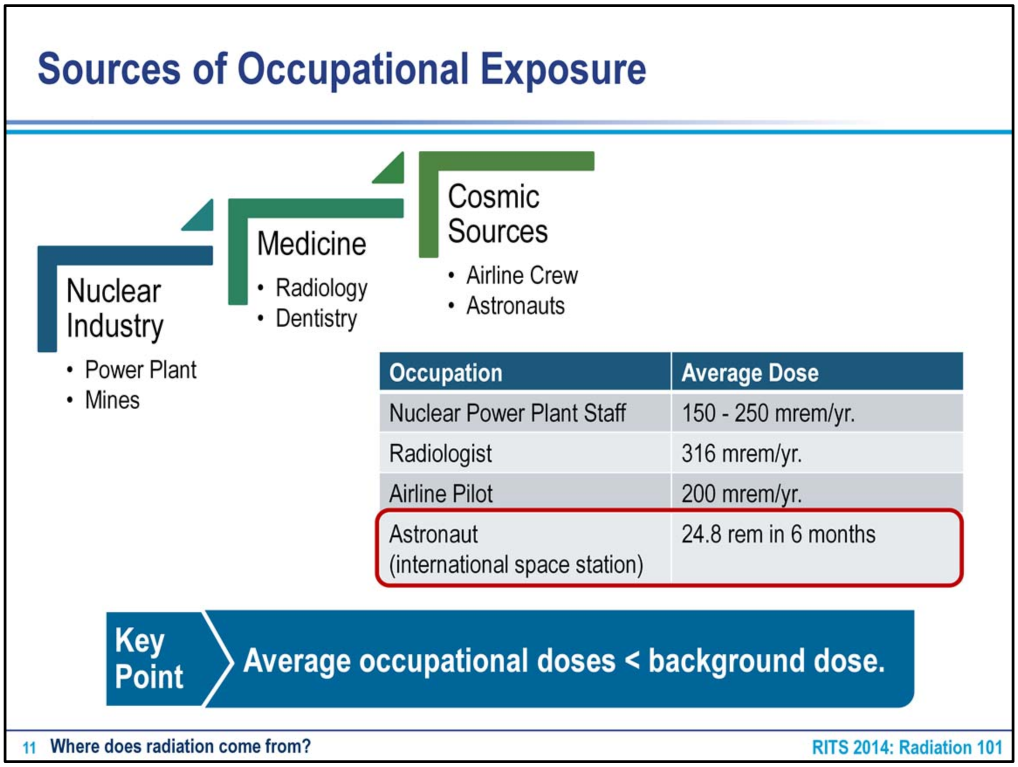


Before getting into the nitty-gritty physics, let's answer: Where – Where does radiation come from?

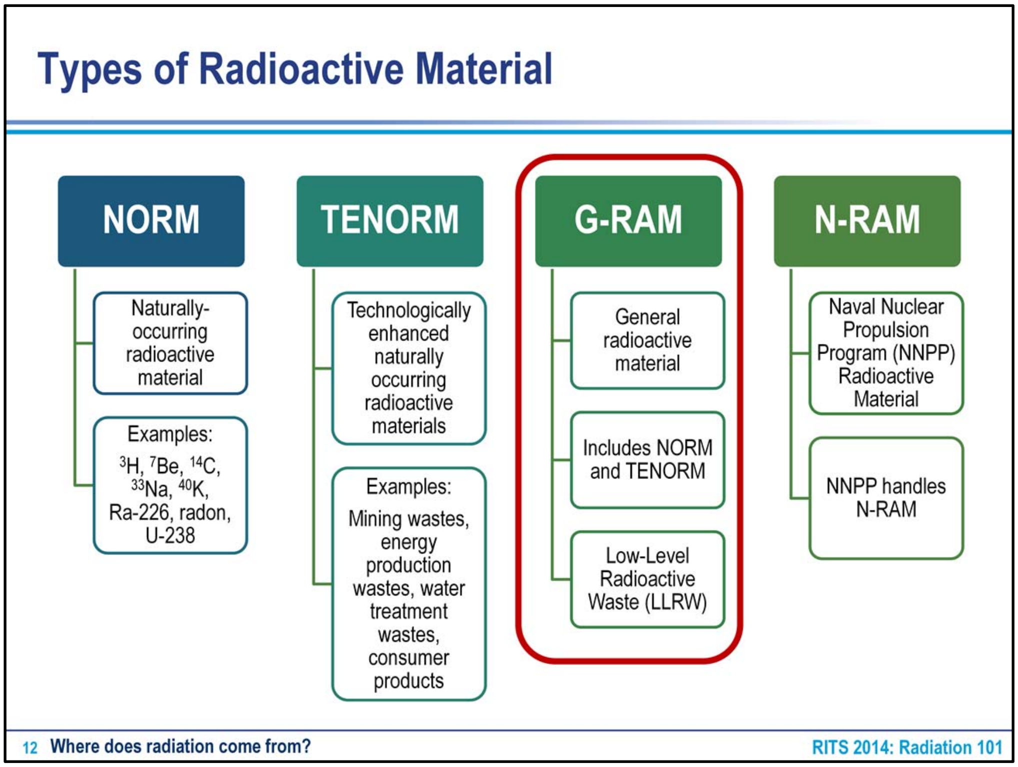


Radiation is everywhere. Everyone is exposed to varying levels of background radiation on a daily basis including both natural and artificial sources.

- Natural Sources = 310 mrem
    - Radon/thorn accounts 66% of natural exposure (207 mrem)
- Man-made sources = 310 mrem
    - CT scans = 150 mrem
    - Consumer products (tobacco, fertilizer, exit signs, smoke detectors) = 10 mrem

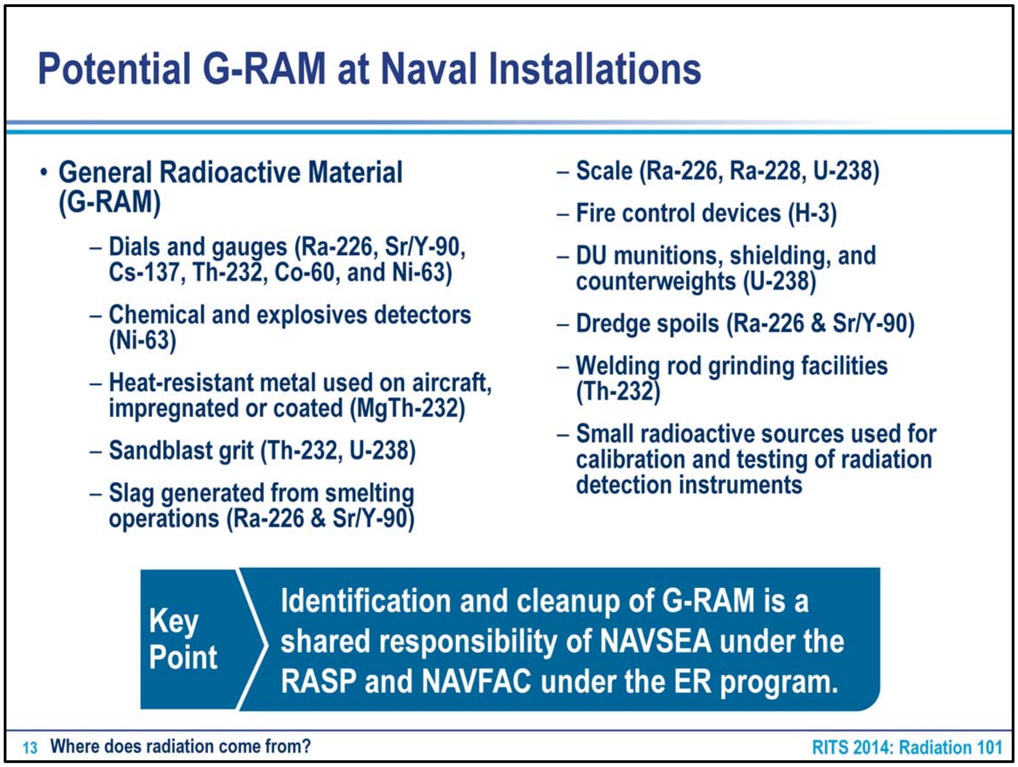


Contrast background radiation to occupational exposures.



So far this presentation has discussed mostly “G-RAM”. Let’s break the types of radiation down a little bit more.

- NORM: Cosmic and terrestrial sources
- TENORM: enriched material
- G-RAM: Note that NORM and TE-NORM are included in G-RAM
- N-RAM: Handled by the NNPP folks
- Highlight G-RAM – this type is the focus of this discussion



When discussing the HRAs, the term G-RAM was mentioned. Now, let's look a deeper look into the potential types of radioactive materials that might be encountered at a Navy installation. G-RAM may include:

- The legacy of luminous dial paint and gauges
- Commodity items
- Sources
- Fission by products

Remember finding and clean up of G-RAM is a shared responsibility of RASO (NAVSEA) and NAVFAC

Radioluminescent devices: Most common G-RAM

- **Radium** paint facilities (1940s-1960s)
- Disposed on ground and down storm and sanitary drains

- **Strontium** personnel locators
- Often 'Disposed by Burial'
- Used in electric, optical, and instrument repair shops

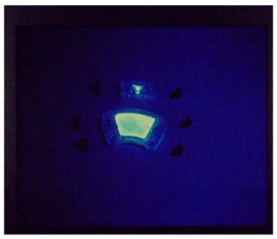
Photos courtesy U.S. Navy

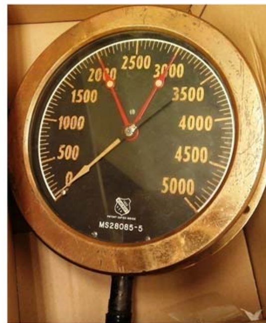
14 Where does radiation come from? RITS 2014: Radiation 101

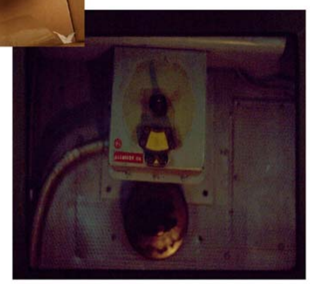
A compass was found recently. This was the first time they saw one intact. Most of the time, just chucky bits.

Radioactive Commodities Examples

- Radioluminescent devices







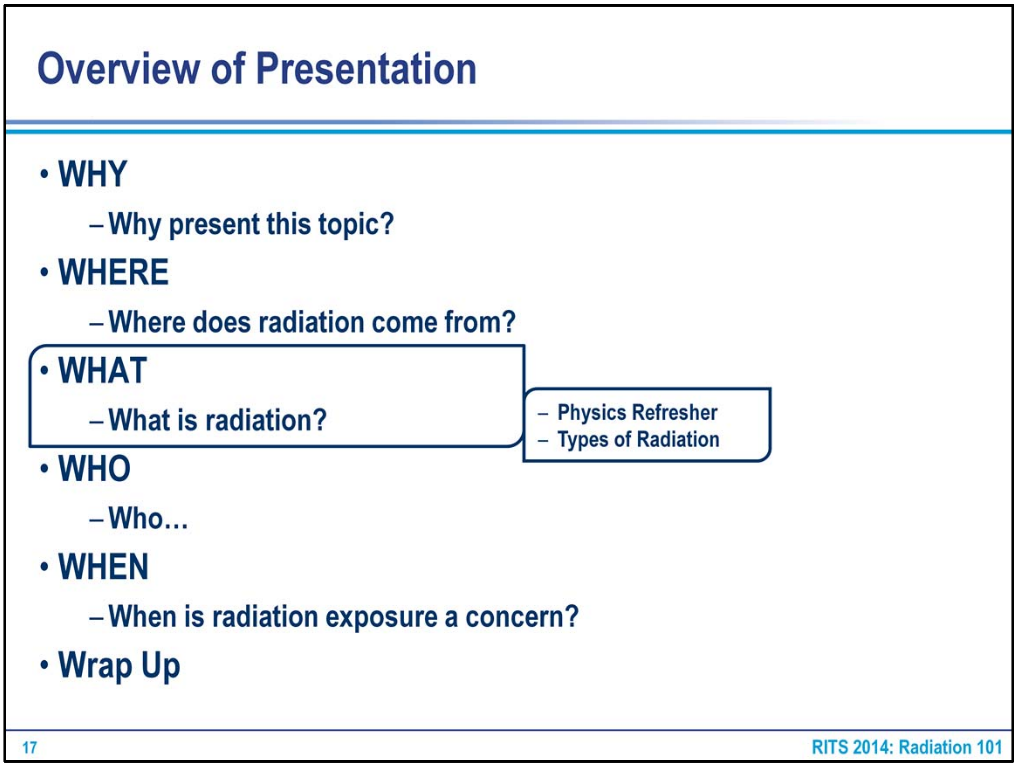
Photos courtesy U.S. Navy

Radioactive Commodities

- Sand-blast grit containing **Thorium**

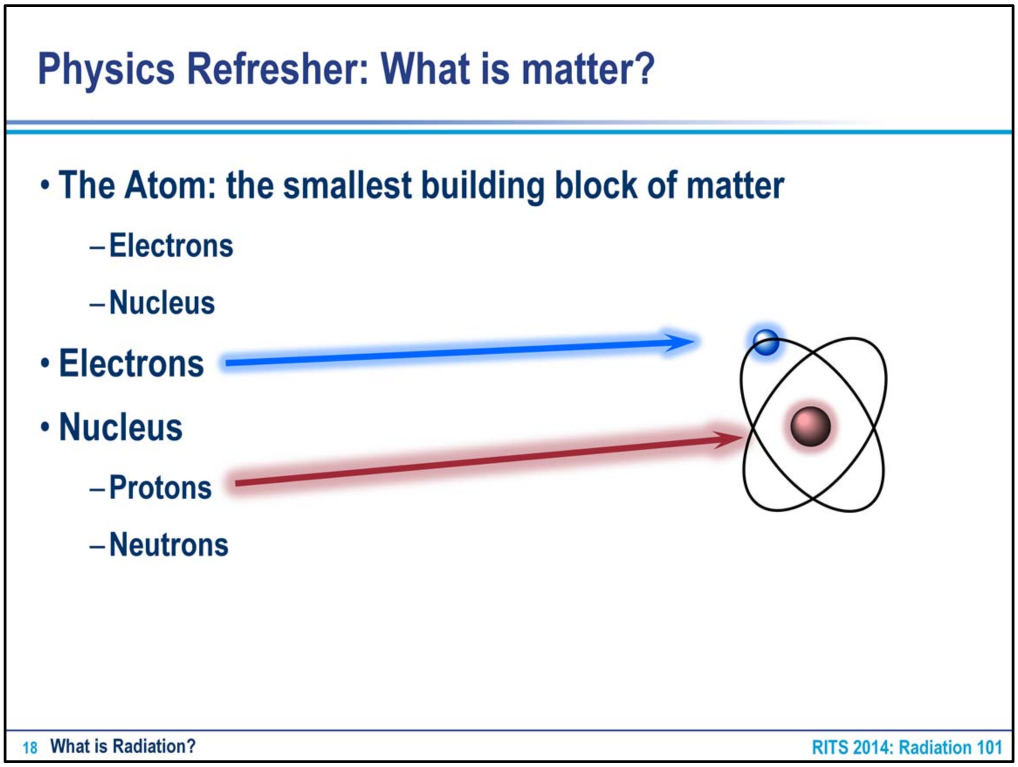
Photo courtesy U.S. Navy

16 Where does radiation come from? RITS 2014: Radiation 101

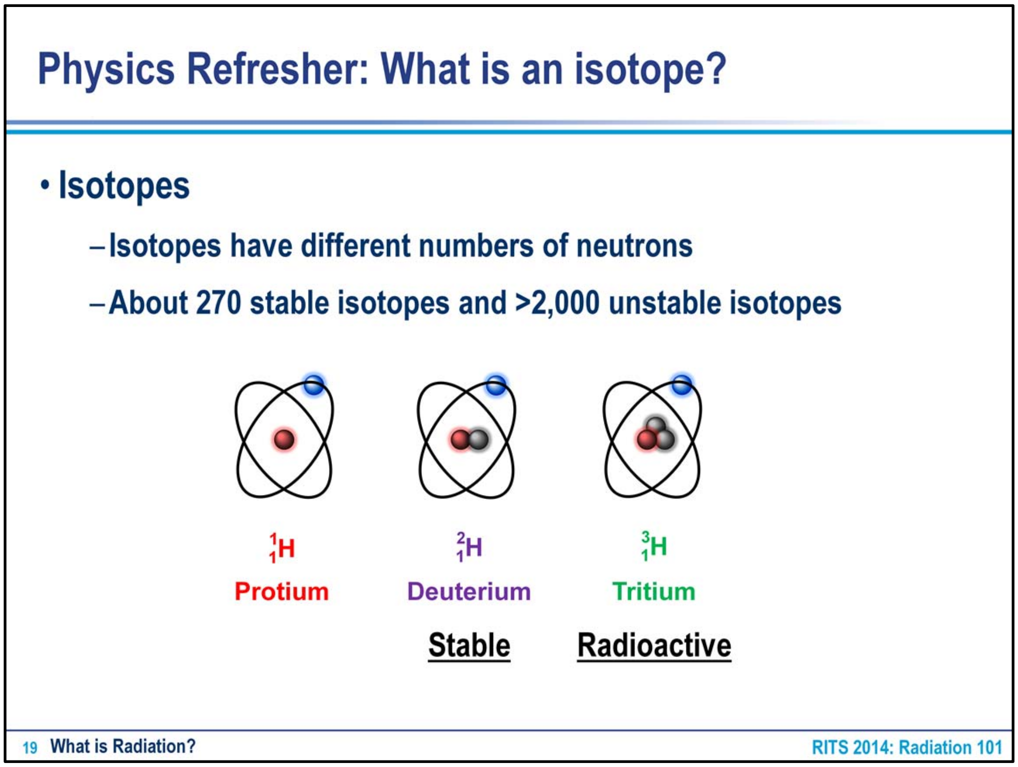


Next, let's discuss what is radiation.

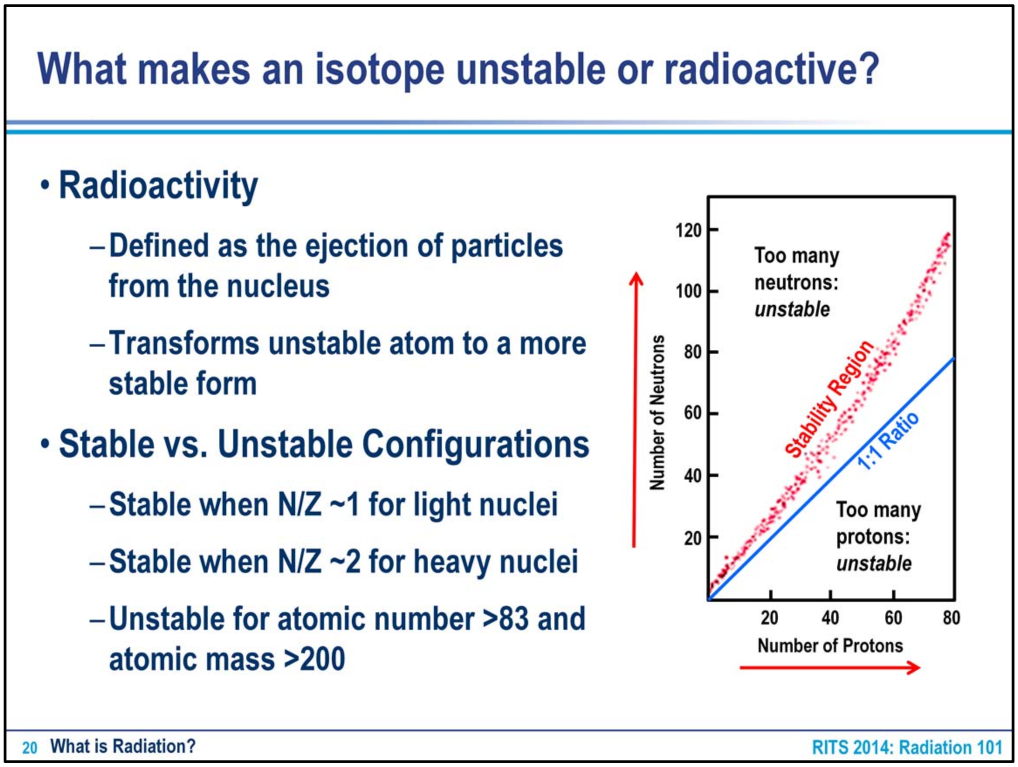
What is radiation?
- Physics refresher
- Types of radiation (and shielding)



I remember my third grade teacher introducing the subject of matter with the question of….”What is matter?” He noted the difference between what ***is*** matter and what is ***the*** matter… What a huge difference a definite article can make?!



- As you probably already know, isotopes differ by the # of neutrons.
- Some configurations of protons and neutrons in the nucleus are stable, while others are unstable or radioactive.
- But this begs the question of why is Tritium radioactive and Deuterium isn't?



Before we get into the reason that some isotopes are radioactive, let's define radioactivity first

- Spontaneous ejection of particles from the nucleus
- This emission helps move the unstable nucleus towards a more stable form

OK, then what makes a nucleus stable or unstable?

- Basically, too many proton or neutron isn't a good thing
- The general rules of thumb are
    - For light nuclei, the N/Z (neutron to proton ratio) should be about 1
    - For heavy nuclei, the N/Z ratio should be higher – 1.5 – 2
- Think about it as more position protons are added to the nucleus is takes more binding force from neutrons to hold the system together
- That being said, elements with more than 83 protons are inherently unstable

Physics Refresher: The Discovery of Radioactivity

- Henri Becquerel
- Marie and Pierre Curie

Key Point — Shared the 1903 Nobel Prize in Physics

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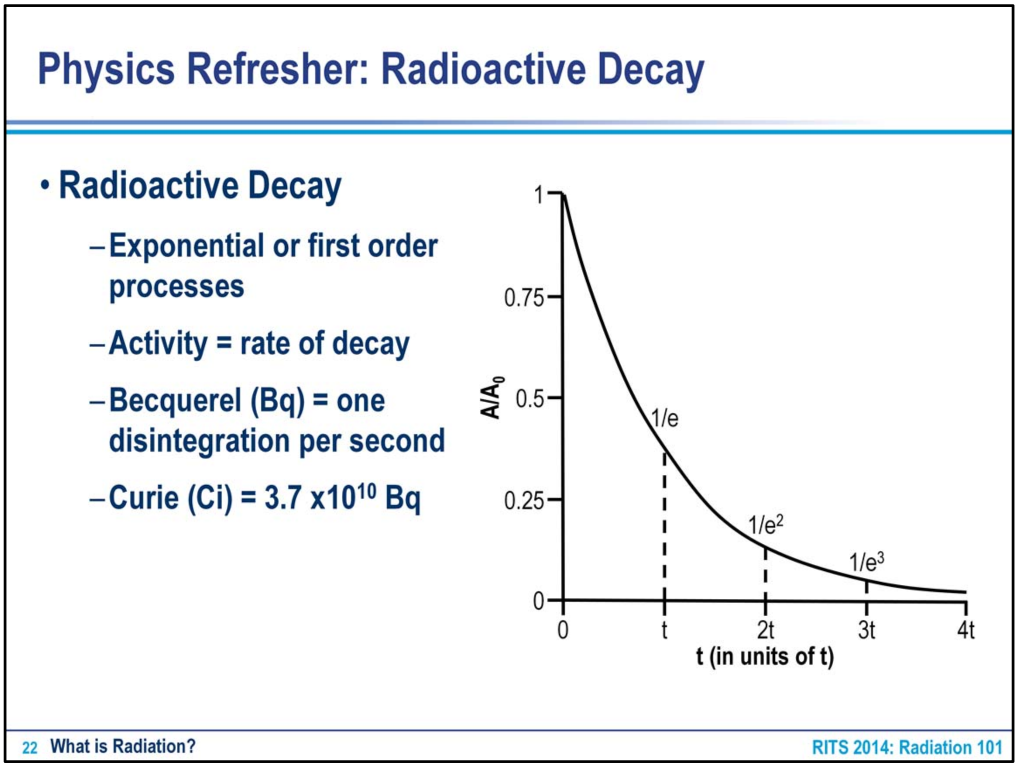
Now that we've gone over atomic structure, let's take breather and talk a little about history. The discovery of radioactivity to be specific. Before the turn of the last century, there was a lot of work being done in the fields of chemistry and physics.

- Becquerel
    - In 1896, mistakenly thought that minerals, made phosphorescent by visible light, could generate x rays.
        - Phosphorescence is when a substance releases the energy absorbed from visible light over a period of time – like glow in the dark toys.
    - When his experiment with uranium showed that uranium did not need light (through serendipity – sun didn't shine) to expose a photographic plate, he concluded the exposure came from the uranium itself.
- Curies
    - He recommended this new phenomenon to Marie Curie for her doctoral research.
    - Her work showed that the amount of radioactivity (a term she coined) was directly proportional to the amount of uranium (and thorium)
    - Then, she and her husband went on to isolate polonium and radium from pitchblende (uranium ore)
- For this work, all three shared the 1903 Nobel Prize in physics.



Now back to technical aspects,

- Radioactivity as discussed before, is the release of energy and matter that results from changes in the nucleus of an atom.
- Radioactive decay is the process by which the energy and matter are released. It is a stochastic or random process and first order decay. Just like when ER folks discuss biodegradation rate and half lives of organic contaminants.
- The rate of decay is expressed in units of
    - Becquerel = one disintegration per
    - Curie (Ci) = originally was the activity of 1 g of Ra-226, now defined as 3.7×10^{10} Bq
- Please NOTE that each occurrence of a nucleus emitting particles or energy is a disintegration. This is NOT EQUAL to source strength in terms of # of particles/sec
    - Cs-137 can emit 2 particles - this leads into the next slide…

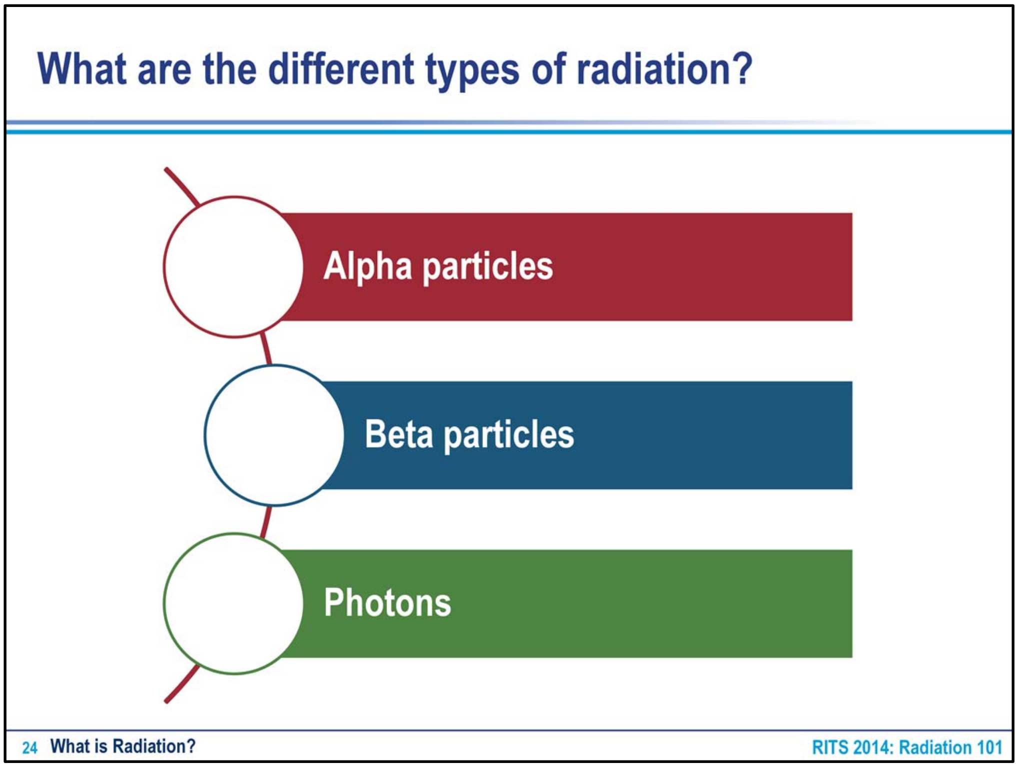
Physics Refresher: Half Lives

Atomic Number	Nuclide	Half-Life	Nature of Radiation
1	H-3	12.3 yr	β
6	C-14	5,730 yr	β
38	**Sr-90**	**28.1 yr**	β
55	**Cs-137**	**30.2 yr**	β, γ
88	**Ra-226**	**1,620 yr**	α, γ
92	U-238	4.5×10^9 yr	α

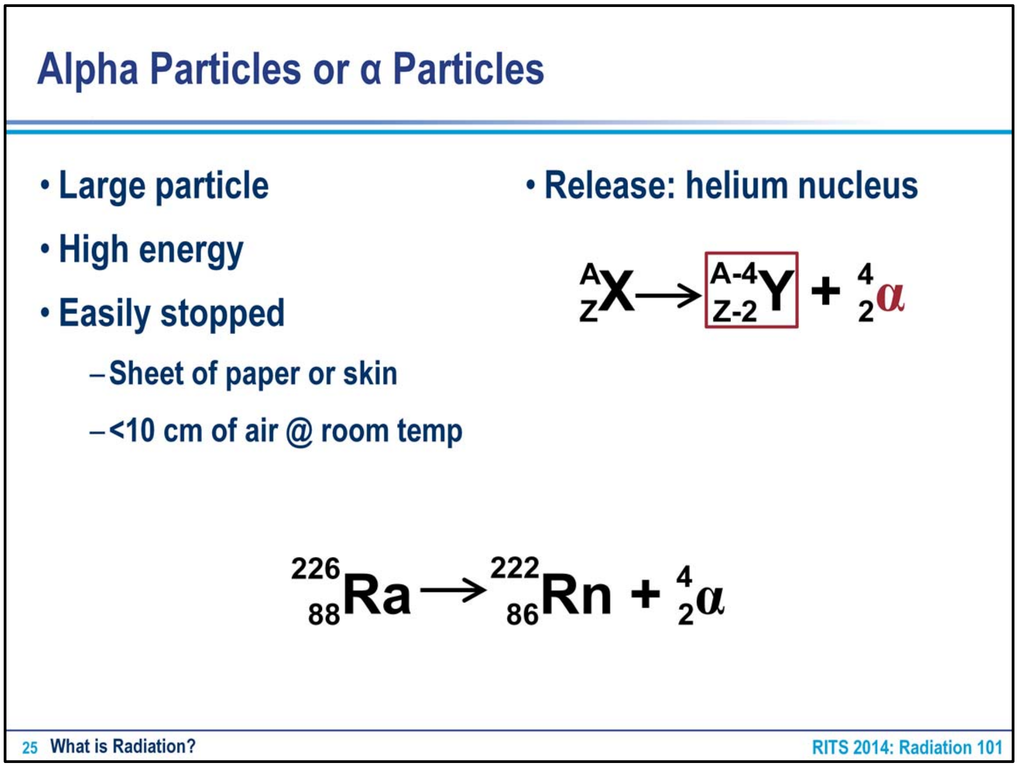
Potential COCs on Navy RAD Sites

When discussing half-lives, here are some representative examples.

- NOTE: the lighter isotopes seem to decay through beta decay, whereas the heavy isotopes decay through alpha decay.
  - Reasons for this trend will be evident shortly (next set of slides)
- For Sr-90 and Cs-137, half of the activity will be gone in generation, whereas radium-226 has a considerably longer half-life. Translating this to Navy sites, the activity of the radium dials really hasn't decreased much since the instruments were made.

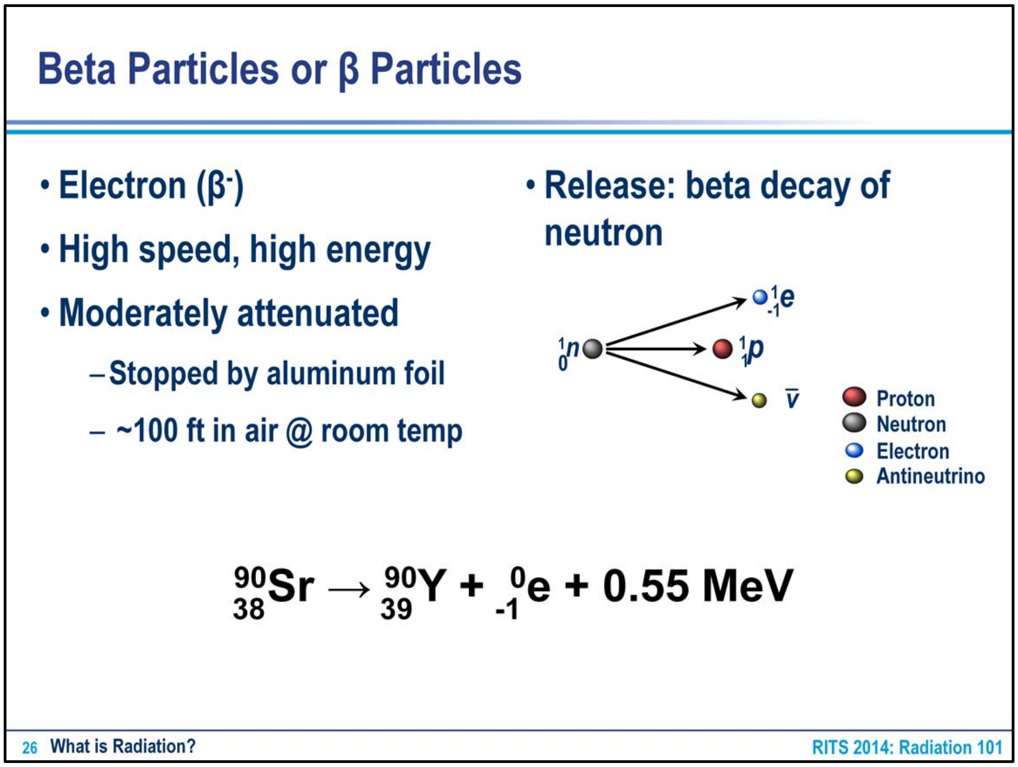


Now that the basics associated with the broader picture of ration have been presented, it’s time to discuss the different types/different particles of radiation.



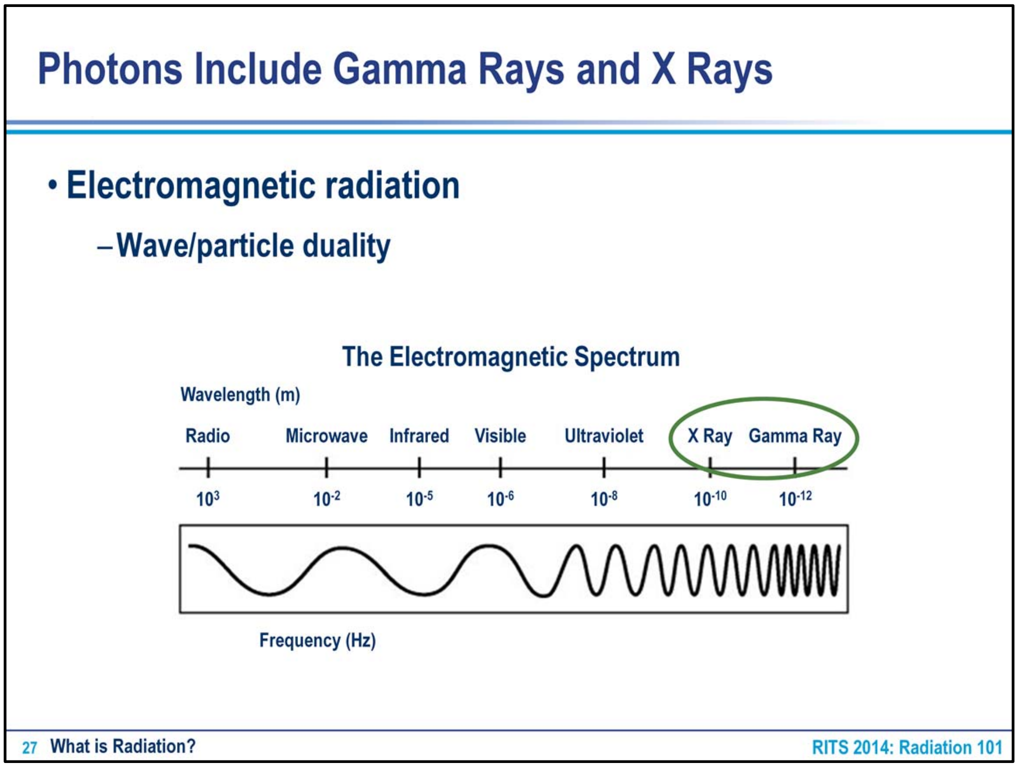
First up are alpha particles, which are basically charged ions of helium and one type of ionizing radiation.

- As you can see, Ra-226 decays with the nucleus releasing a particle with 2 protons and 2 neutrons, which is a pretty good move towards a more stable nucleus – unloading both protons and neutrons.
    - When an element emits an alpha particle, the mass number decreases by 4 and the atomic number by 2. This results in a product with the properties of an element two places to the left on the periodic table.
- Also, these alpha particles are emitted with high energy, but due to their size, they are easily attenuated;
    - Attenuated, another ER word! Think monitored natural attenuation.
    - They can be stopped by a sheet of paper or skin or within 10 cm in air



Next up are beta particles,

- Beta particles are released from an unstable nucleus when a neutron is transformed into a proton; When a beta particle is released, the product has the properties of an element one place to the right on the periodic table.
- See Sr decay equation
- In terms of energy, these particles are emitted over a spectrum because of the nature of the decay into 3 particles (all of which receive some of the energy)
- Beta particles are emitted at a higher speed than alpha particles and are also ionizing radiation
    - Ionizing radiation = sufficient energy to remove an electron
- Attenuated by a few mm of aluminum foil or 100 ft in air @ room temp

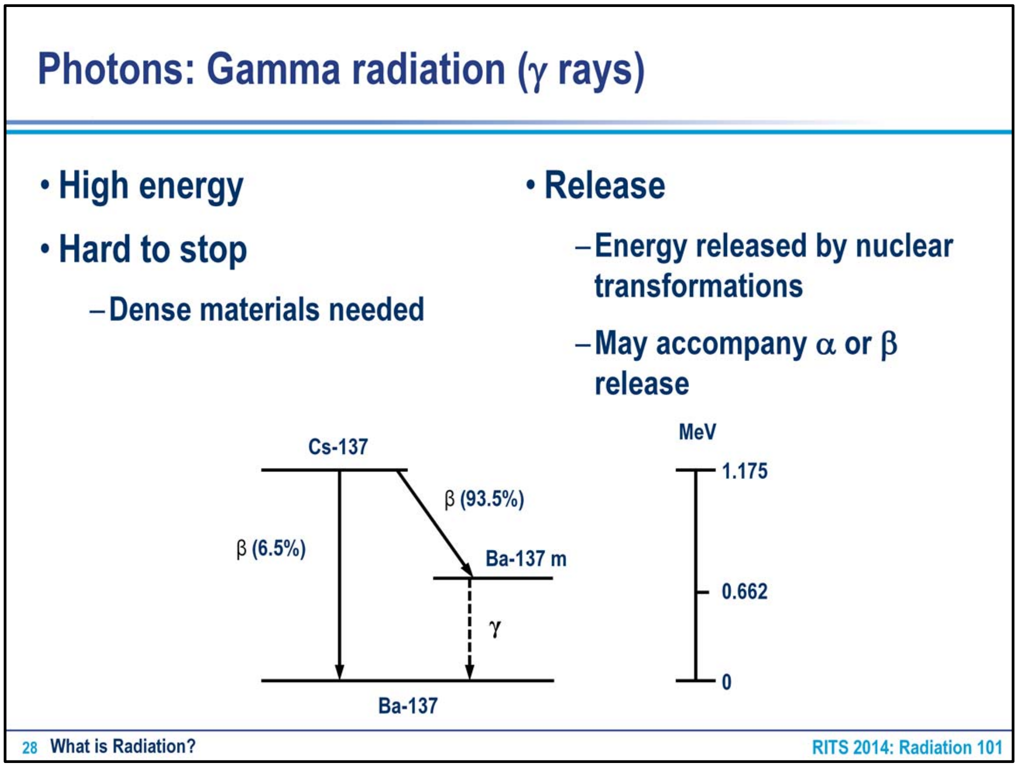


With the traditional, elementary particle having already been discussed, it's time for a joke!

- When checking into a hotel, a photon is asked by a bell hop if the photon needs help with his luggage. The photon replied – No , thanks, I'm traveling light!
- The point being gamma rays and x rays are photons and have the whole wave/particle duality going on with them.

In the figure, you can see that in general x rays have longer wavelengths than gamma rays.

- Another distinction made between the two is
  - Gamma rays are emitted from the nucleus
  - X rays are emitted by electrons (de-excitation)



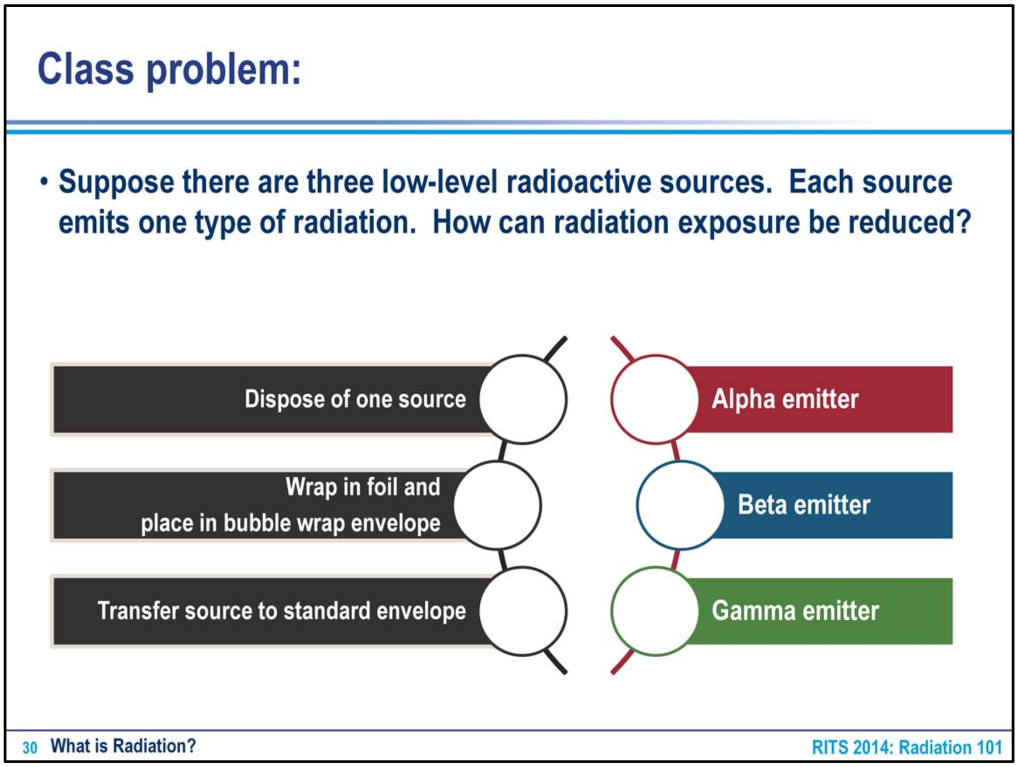
Gamma radiation is true electromagnetic radiation that travels at the speed of light.

- Similar to x rays but shorter wavelength and therefore greater penetrating power.
- Requires several cm of lead or concrete to attenuate.
- Frequently, gamma radiation may accompany the release of alpha or beta particles.
    - It is the result of energy released by nuclear transformations

- Electromagnetic radiation emitted when a charged particle (such as an electron, beta particles) passes through a dielectric medium (water) at a speed greater than the phase velocity of light in that medium

29 What is Radiation? RITS 2014: Radiation 101

Electromagnetic radiation emitted when a charged particle (such as an electron, beta particles) passes through a dielectric medium (water) at a speed greater than the phase velocity of light in that medium



Equating information on the different emitters to potential shielding available on a job site

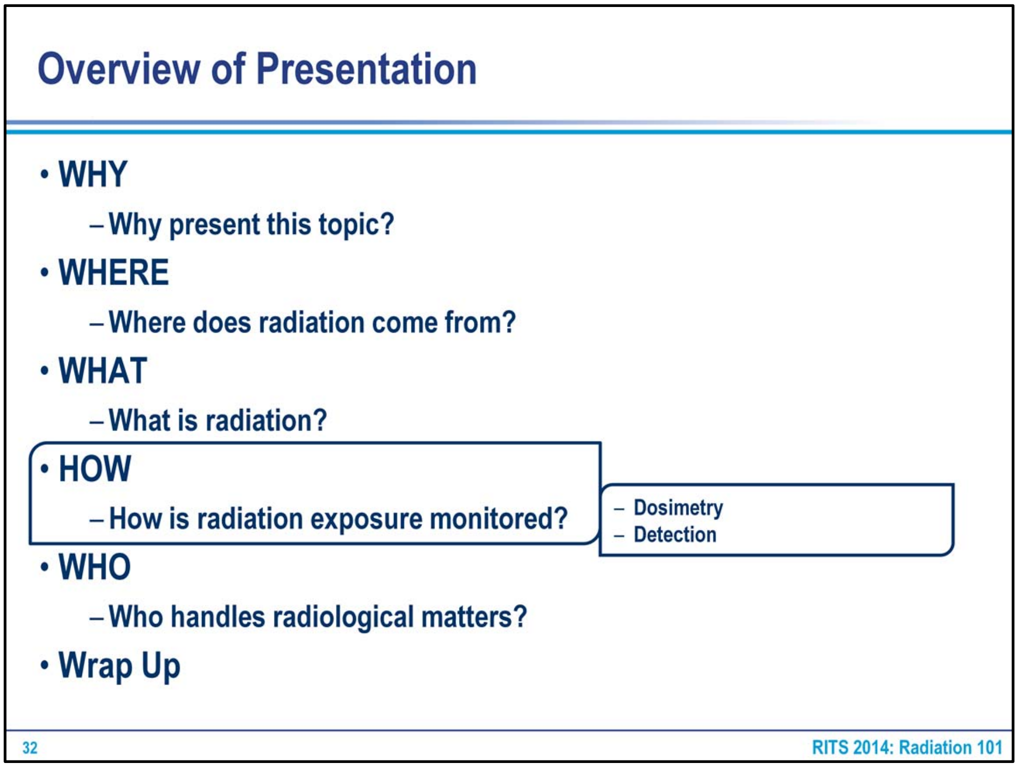
Class problem: Answer

- Suppose there are three low-level, radioactive sources. Each source emits one type of radiation. How can radiation exposure be reduced?

Alpha emitter – place in envelope because thin paper stops particle

Beta emitter – wrap in foil and place in padded envelope because a double layer is best

Gamma emitter – dispose of it because external hazard



Overview of Presentation
• WHY
– Why present this topic?
• WHERE
– Where does radiation come from?
• WHAT
– What is radiation?
• HOW
– How is radiation exposure monitored?
– Dosimetry
– Detection
• WHO
– Who handles radiological matters?
• Wrap Up
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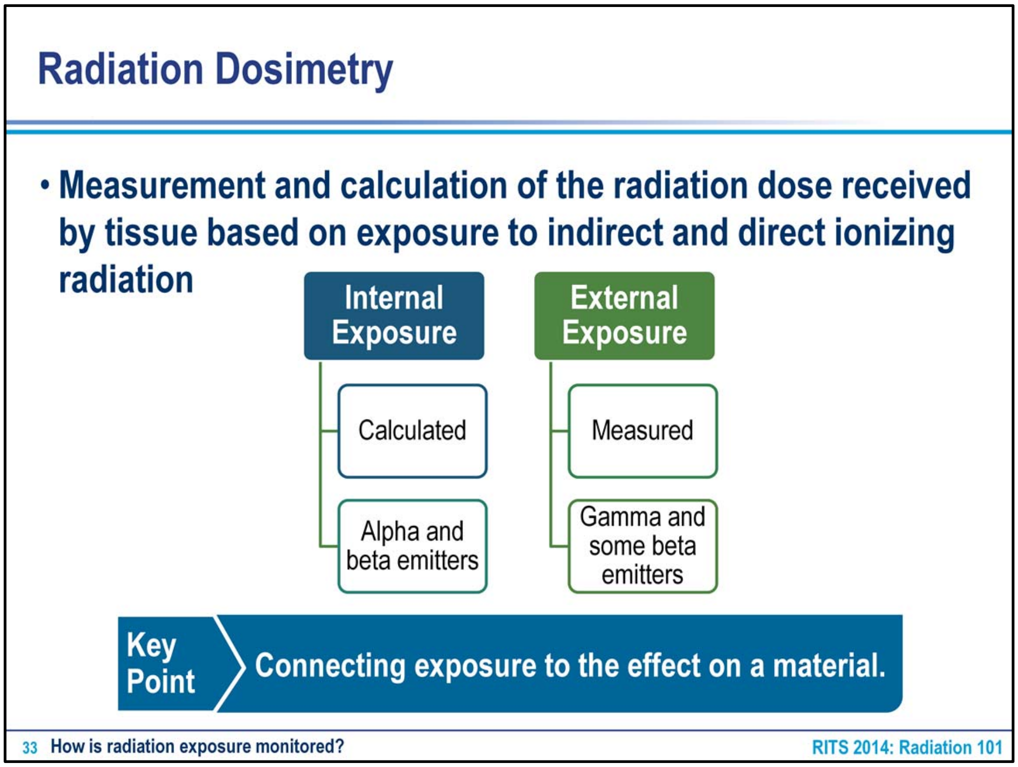
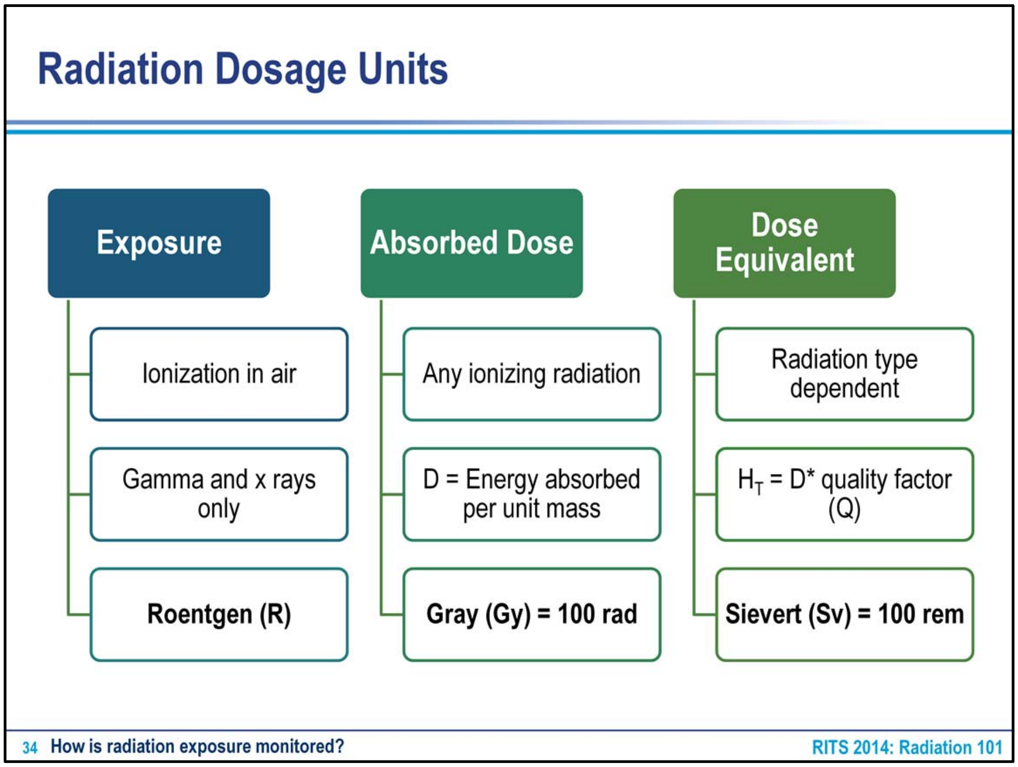
RITS 2014: Radiation 101



Knowing potential exposure routes is good for the CSM

- But as RPMs and consultants, we need to be able to translate the exposure to impact.
- Or the biological damage caused to tissue
    - For internal exposure, dose can be calculated with physiological techniques
    - For external exposure, dose can be measured by RAD detectors



But, there are several types of dosage units

- Roentgen (R) is the just the energy for ionization in air
    - This only applied to photons
- Radiation absorbed dose (rad) is the amount of ionizing energy deposited in material through which the radiation passes
    - Note SI and Traditional units
- Dose equivalent takes the concept one step further and brings how different types of radiation can impact or damage tissue differently
    - Dose times the quality factor
        - Now called the radiation weighting factor
        - Helps take the type of radiation and energy of the radiation into account
    - Rem = Roentgen-equivalent-man

Quality Factors Depend on Linear Energy Transfer (LET) of Radiation Type

Type of radiation	Quality factor (Q)
X, gamma, or beta radiation	1
Alpha particles	20
Neutrons of unknown energy	10
High-energy protons	10

Key Point LET is expressed as energy per distance of travel.

35 How is radiation exposure monitored? RITS 2014: Radiation 101

A little more on Quality factors or radiation weighting factors

- These weighting factors depend on the linear energy transfer of the radiation
- Or, how much energy is deposited per distance of travel
- For example, alpha particles are more biologically damaging than other type of radiation, so alpha particles receive a higher weighting factor

Care should be taken when using "Dose"…

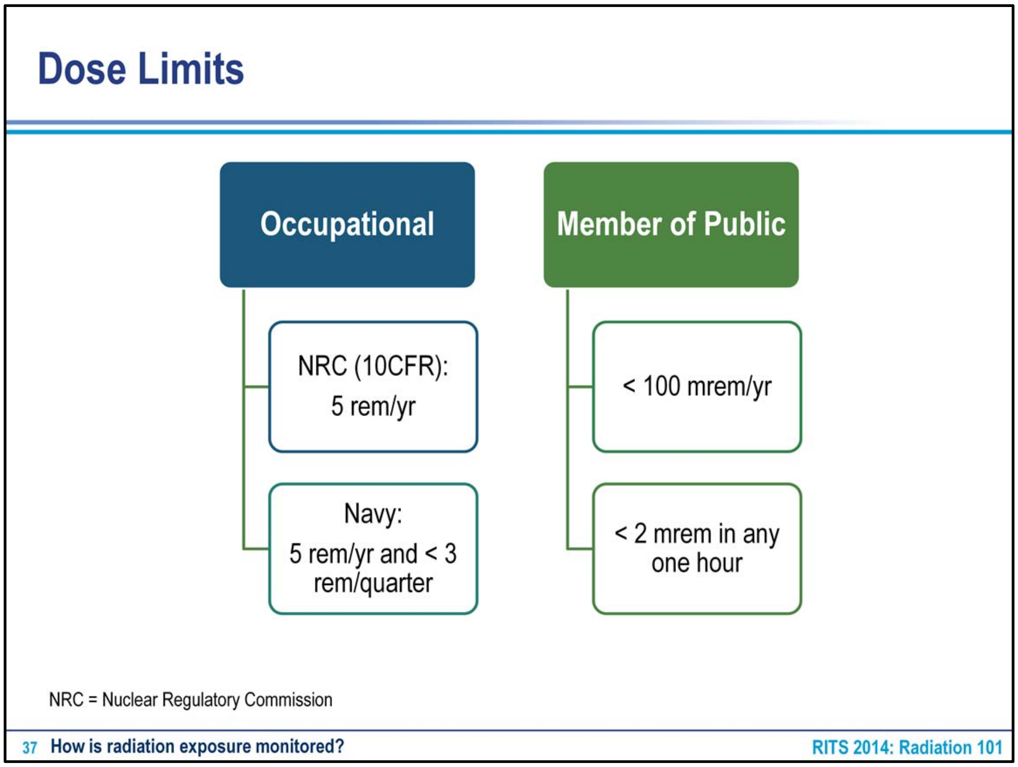
Dose is a generic term that can mean:	
Dose equivalent (H_T)	Measure of biological damage to living tissue
Effective dose equivalent (EDE)	$\sum(H_T * [organ\ weight\ factor])$
Committed dose equivalent (CED)	Dose to specific tissue over 50 yr
Committed effective dose equivalent (CEDE)	$\sum CEDs$
Total effective dose equivalent (TEDE)	$\sum(\boldsymbol{deep\ H_T + CEDE})$

36 How is radiation exposure monitored? RITS 2014: Radiation 101

To make the matters of units even more confusing, there are different types of "dose"

- Dose equivalent was discussed on the previous slides (measure of biological damage to living tissue)
- EDE: is the sum of the dose equivalents (H_T) times weighting factors for those organs = H_E. **These are external exposures.**
- CDE: is the dose to a specific organ or tissue that will be received over 50 years **after intake**…
- CEDE: sum of all the CDEs…
- TEDE: sum of deep dose equivalent and CEDE

So, at the end of the day, it's important to remember that doses aren't all the same and when reading reports, double check what type of dose is being discussed!



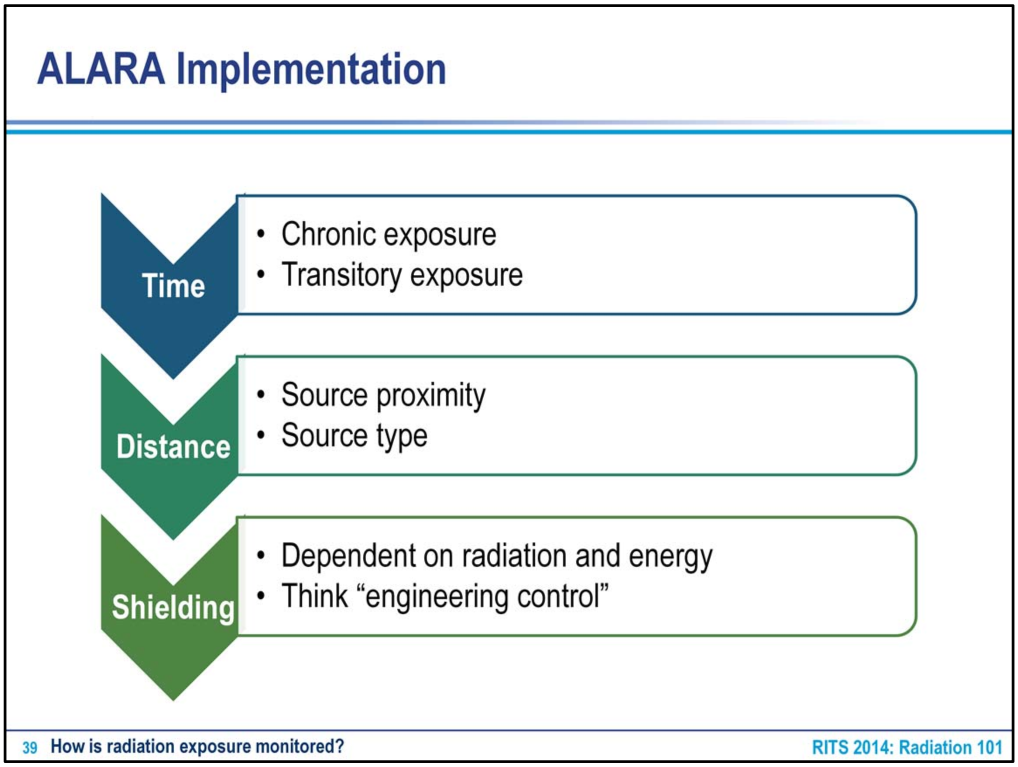
Exposure Limit References:

- 10 CFR 20.1201 limits for occupational workers
- 10 CFR 20.1301 limits for members of the public
- NAVMED P-5055, Radiation Health Protection Manual
- NAVSEA S0420-AA-RAD-010

Exposure Best Practice

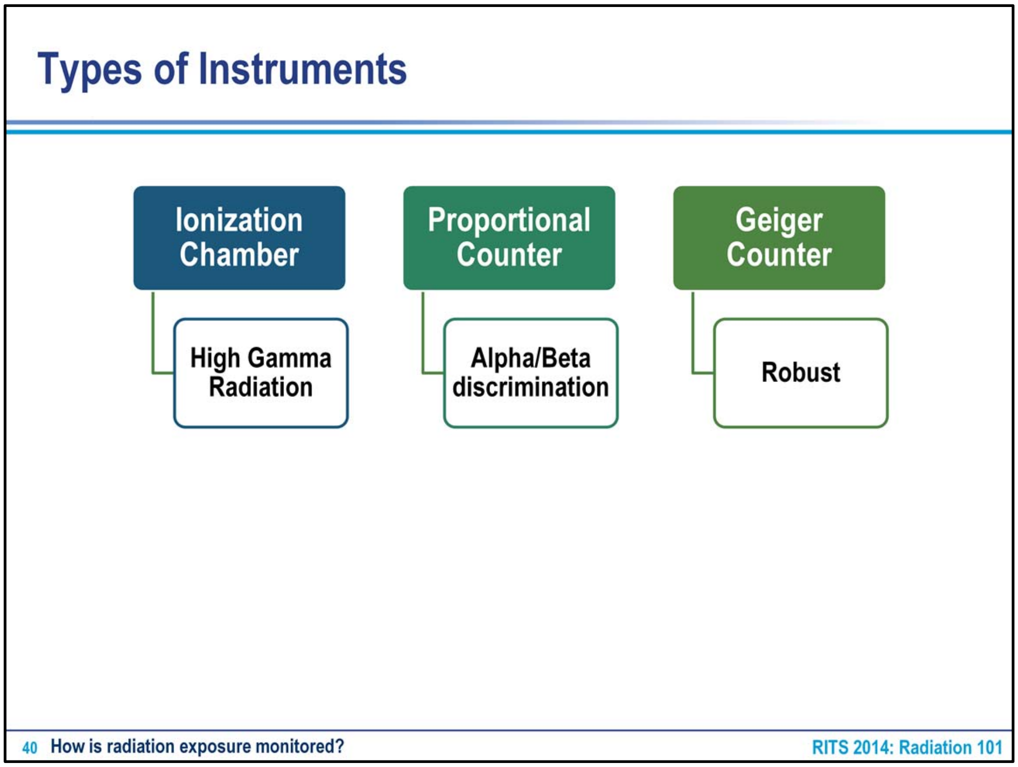
- **As Low As Reasonably Achievable (ALARA)**
  - **For all exposures to radiation**
  - **Requires:**
    - Management, commitment, and support
    - Careful design of facilities and equipment
    - Good radiation protection practices by qualified, well trained personnel

38 How is radiation exposure monitored? RITS 2014: Radiation 101



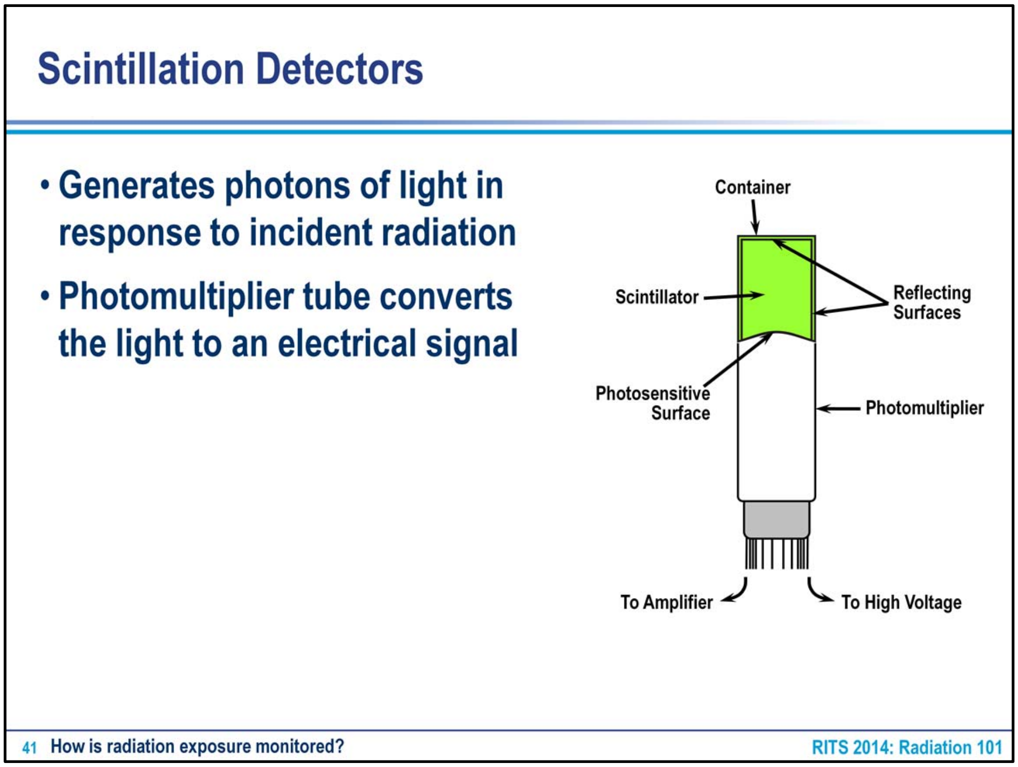
These three basics are still and will always be the main triad in radiation protection

- What's the exposure time? Chronic from natural radiation? Or transitory from a specific event – like getting an x ray taken.
- How close is the source? Is the source a point source (again, think x-ray machine)? Or is the contamination airborne or in water?
- Is shielding needed? What shield is available (or needed)?



How is radiation measured?

- There are lots of instruments to detect radiation.
- Here are three gas-filled types, able to detect ionizing radiation
    - Ionization chamber provides a uniform response over a wide range of radiation energy
    - Proportional counters can measure the energy of the incident radiation
    - Geiger-Mueller tubes can detect all types of radiations and are quite robust
        - Everyone's heard of Geiger counter, right?



There are other types of RAD detectors and this presentation won't go into them all. However, scintillation detectors are often used in the field

- They couple scintillators with photomultiplier tubes, photodiodes or the like
- Scintillators are materials that luminesce with exposure to ionizing radiation
    - Can be crystals like NaI activated with thallium
    - Energy of the incident radiation is directly proportional to the light produced
- Photomultiplier tubes then convert the light into a signal

Types of Instruments: Hand Held

- **When to use**
  - Field monitoring and sampling to identify areas requiring additional remediation
  - Frisking of personnel and examining equipment leaving a radiologically-controlled area
- **MARSSIIM recommendations**
  - Scintillators that read in
    - µR/h or µSv/h (based on 137-Cs)
    - Tissue equivalent “dose”

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MARSSIIM recommendations
- Ludlum Model-19
  - NaI scintillator
  - µR/h or µSv/h (for 137-Cs)
- Bicron MicroREM
  - Scintillator
  - Tissue equivalent “dose”

Types of Instruments: Swipes

- **When to use**
  - Control of radiologically-impacted areas and work sites
  - Examining equipment leaving a radiologically-controlled area

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Swipes

Ludlum Model-2929 scaler with a Model 43-10-1 ZnS(Ag) scintillation probe (or equivalent)

Overview of Presentation

- WHY
  - Why present this topic?
- WHERE
  - Where does radiation come from?
- WHAT
  - What is radiation?
- HOW
  - How is radiation exposure monitored?
- WHO
  - Who handles radiological matters?
- Wrap Up

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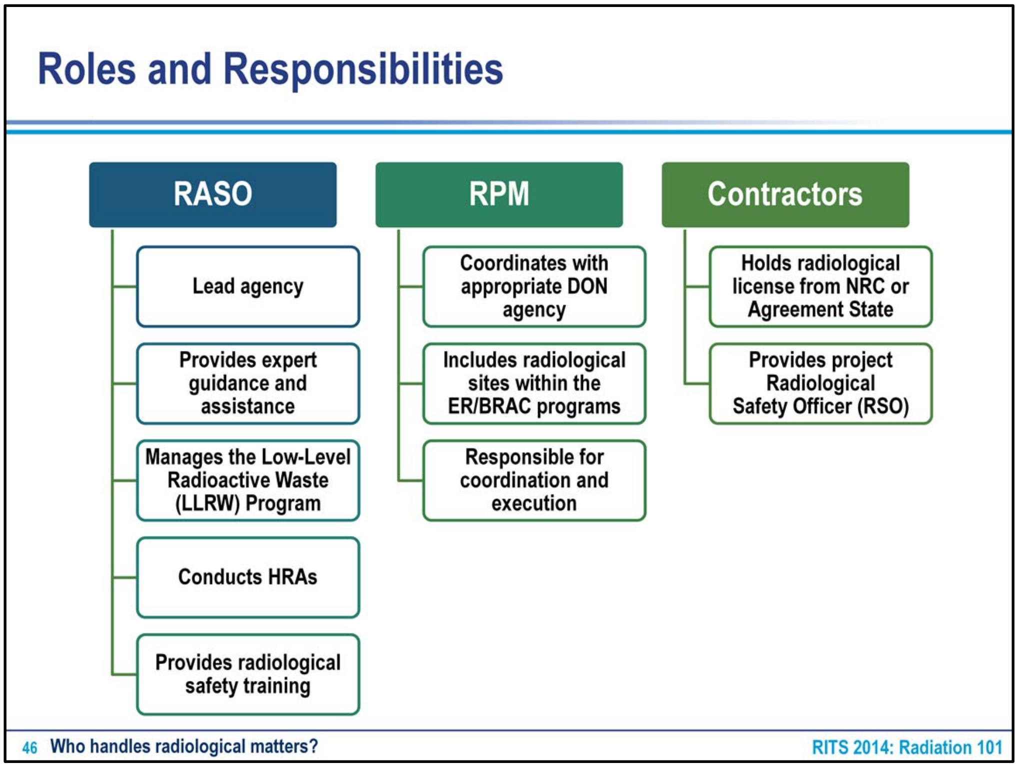
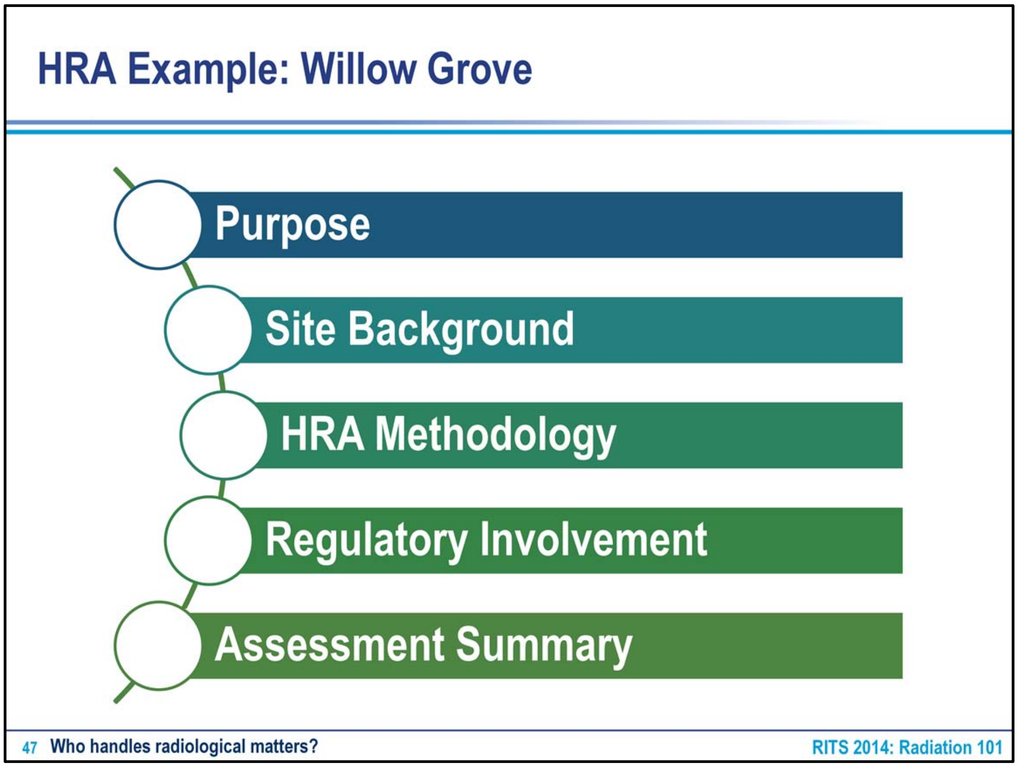


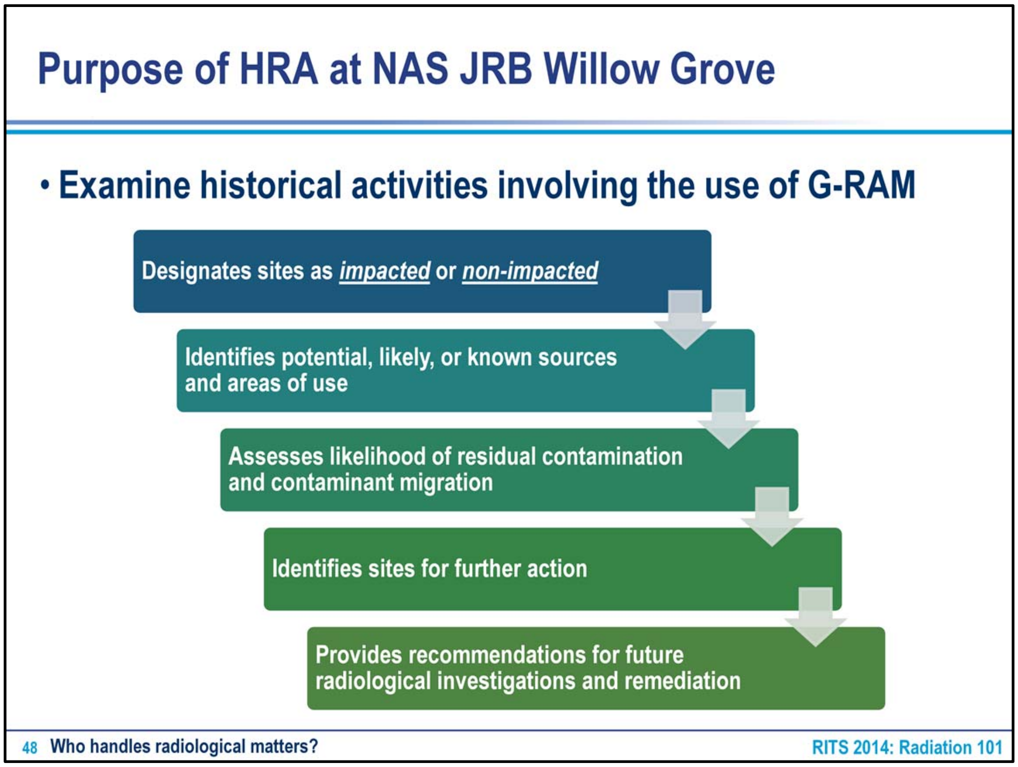
RASO

- Echelon 2 (SYSCOM) – NAVSEA headquarters detachment in Yorktown, VA
- Technical Support Center
    - NAVSEASYSCOM
    - OPNAV N45 (NRSC)
- Delegated technical authority with cognizance for administering and enforcing the NRSC/NAVSEA G-RAM policies and requirements
- Providing expert guidance and assistance
- Managing the Low-Level Radioactive Waste (LLRW) Program - All G-RAM waste
- Conducting Historical Radiological Assessments (HRAs)

RASO is the component that RPMs will have the most interaction with. As noted, RASO is the designated command charged with accountability and serves as the Navy's experts and technical authority for all things G-RAM. Consider them analogous to NOSSA for munitions response, but with more emphasis on ER activities at the site level.

Key point, NAVFAC is responsible for execution, RASO is the technical authority, administrator and enforcer of G-RAM requirements. Actions at G-RAM sites are a partnership between RASO and ER/BRAC


HRA Example: Willow Grove
Purpose
Site Background
HRA Methodology
Regulatory Involvement
Assessment Summary
47 Who handles radiological matters?
RITS 2014: Radiation 101

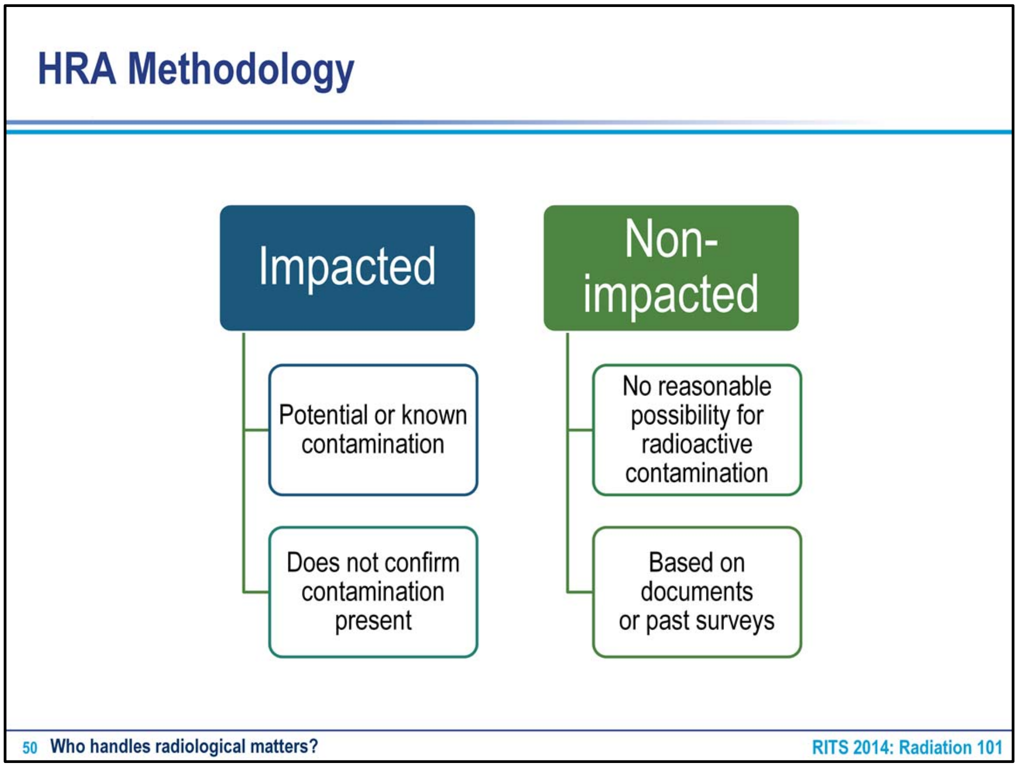


Examined historical activities involving the use of G-RAM at NAS JRB Willow Grove

- designates sites as impacted or non-impacted by the use or disposal of G-RAM;
- identifies potential, likely, or known sources of radioactive materials, contamination, and areas of use;
- assesses the likelihood of residual contamination and contaminant migration;
- identifies sites that need further action
- provides recommendations for future radiological investigations and remediation processes to remove threats to human health and the environment

Site Background

- Focus on Navy operations
- Historical G-RAM operations at NAS JRB Willow Grove included:
  - Repair, use, and disposal of radioluminescent commodity items
  - Handling, storage, repair, and disposal of aircraft counterweights containing depleted uranium (DU)
  - Storage and handling of commodity items containing radioactive materials
  - On-site disposal of radioactive materials
  - Handling and disposal of radioactive materials by shipment to off-site vendors or waste disposal sites



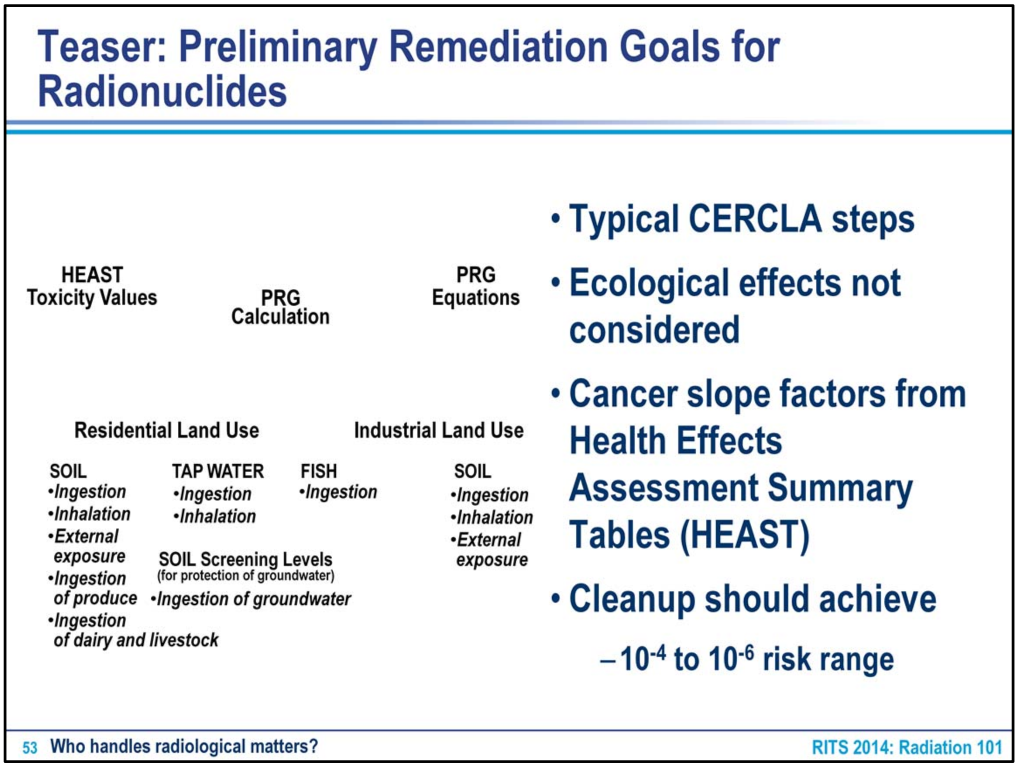
Both impacted and non-impacted sites are mainly based on historical document reviews. Although the HRA does not usually confirm the presence of a contaminated site by survey/sampling, it can determine a site is contaminated by research.

Regulatory Involvement

- Review of NRC licenses
  - Willow Grove did not hold any specific licenses
  - DON held general licenses
- Review of Master Material License to the DON which allowed the DON to issue Naval Radioactive Materials Permits (NRMPs)
  - No NRMP permits were issued to Willow Grove

Assessment Summary

- There is a low to moderate potential for residual radioactive contamination at 18 impacted sites
- Scoping surveys are recommended for all 18 sites
- No historical information indicates a level of concern that would require any emergency action
- High-level radiological contamination is not considered a possibility in this HRA
- No impacted sites require restricted access due to known presence of radioactive material



For soil, residential and industrial land use scenarios are considered.

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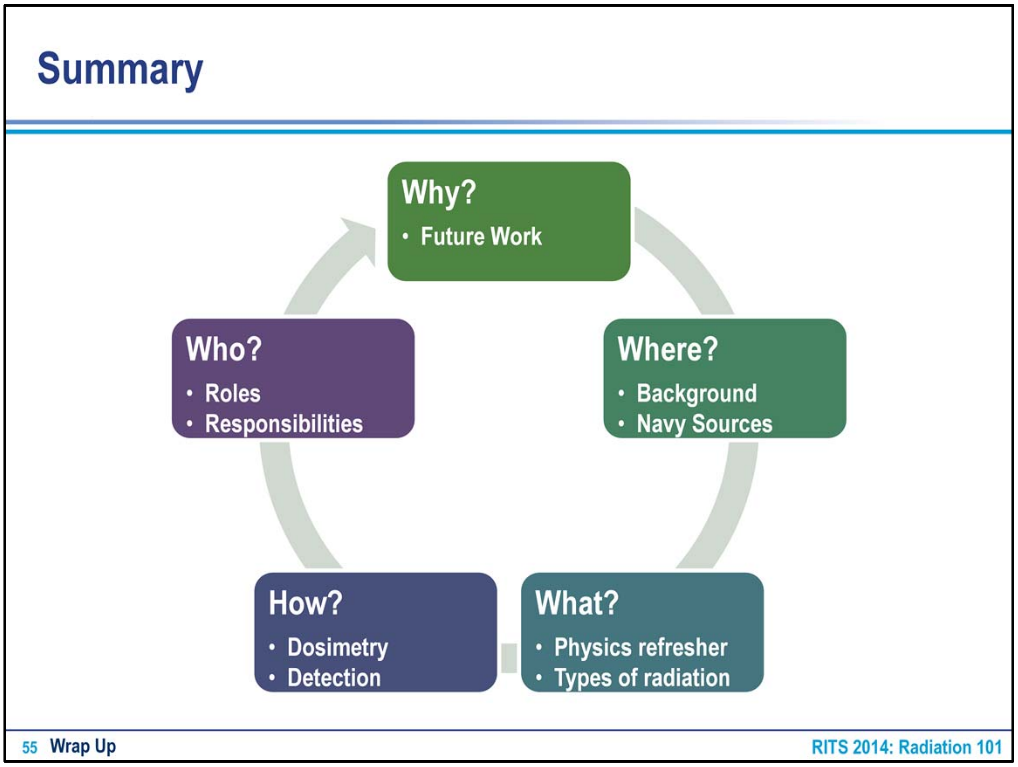


Why (is this presentation being given)?

- Future Work

Where is radiation found?

- Types of radioactive material
- Potential sources at Naval Installations

What is Radiation?

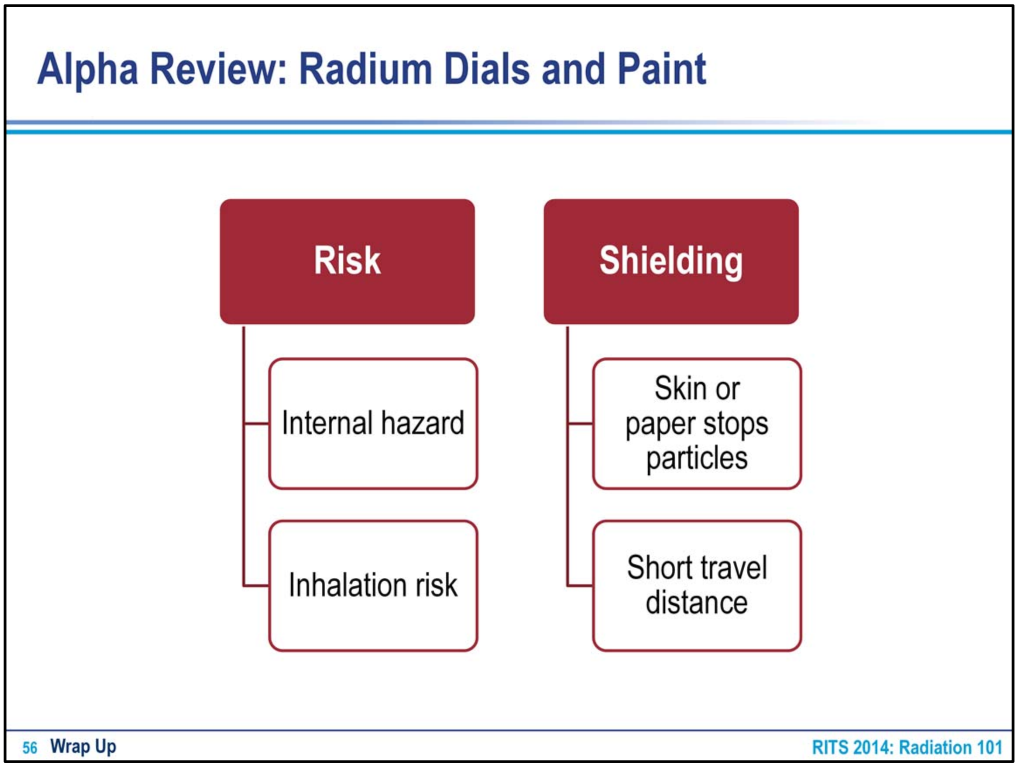
- Physics refresher
- Types of radiation

How is radiation exposure monitored?

- Dosimetry
- Detection

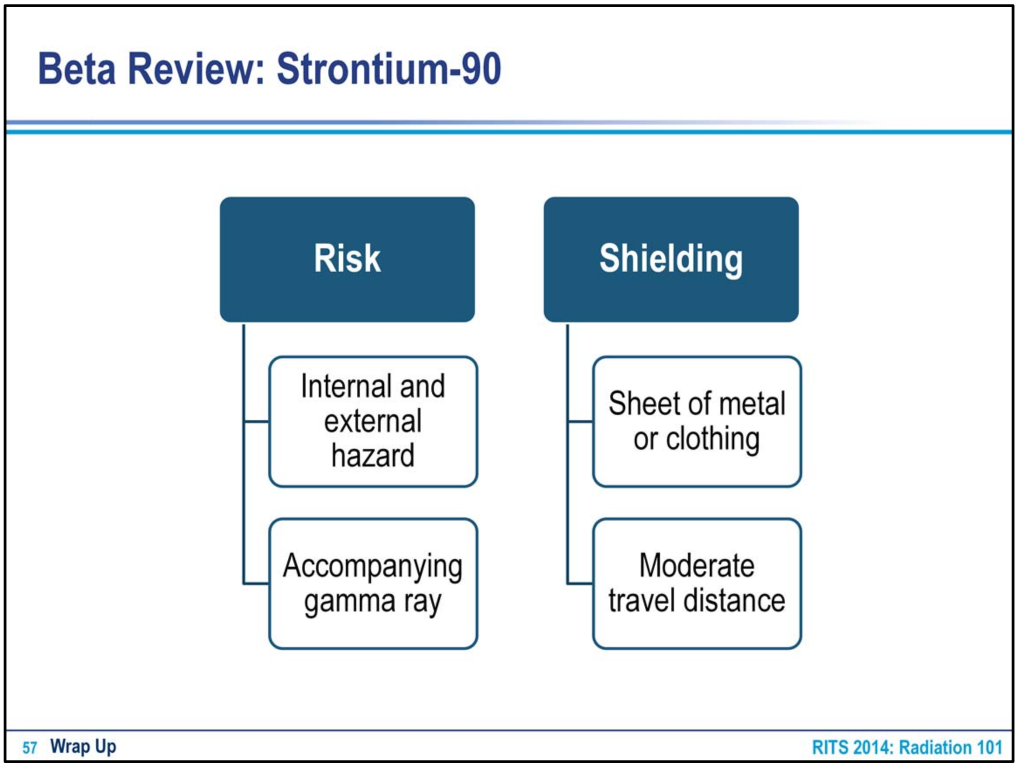
Who handles radiological matters?

- Roles
- Responsibilities
- HRA Case Study



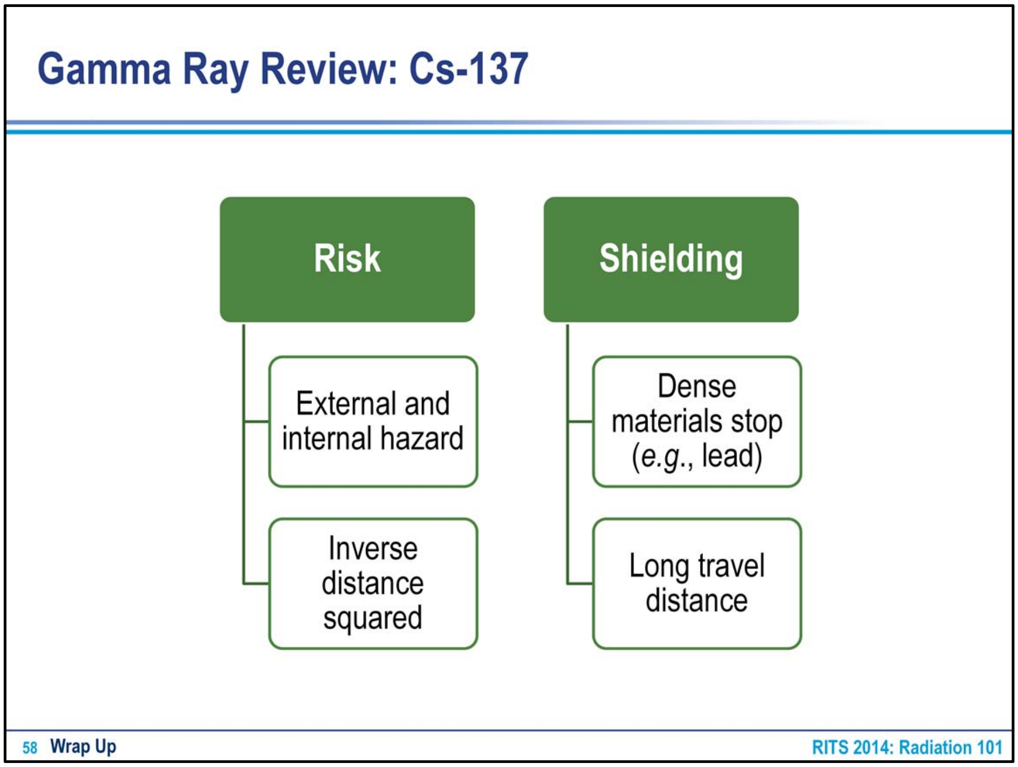
Knowing about alpha particles, let's translate this into risk

- Pose little external exposure as paper or skin stops particles
- But, alpha particles due pose an internal risk
  - ingestion or inhalation
  - Think dust contaminated with radium paint… both could be inhaled and alpha particles would be released in the lungs



Overall, beta particles are seen more as an internal hazard:

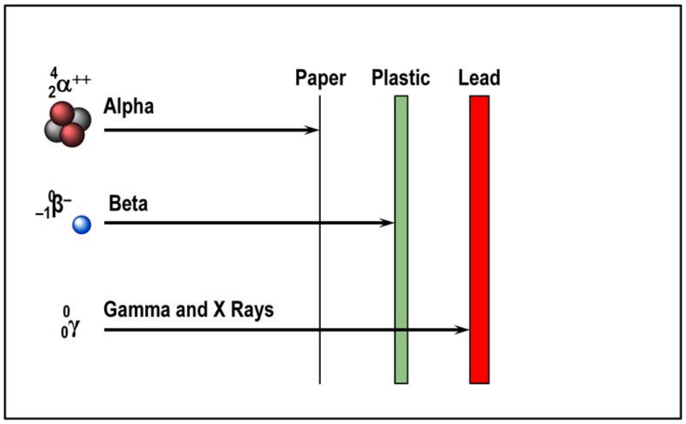
- Similar to alpha particles, due to weak penetrating ability



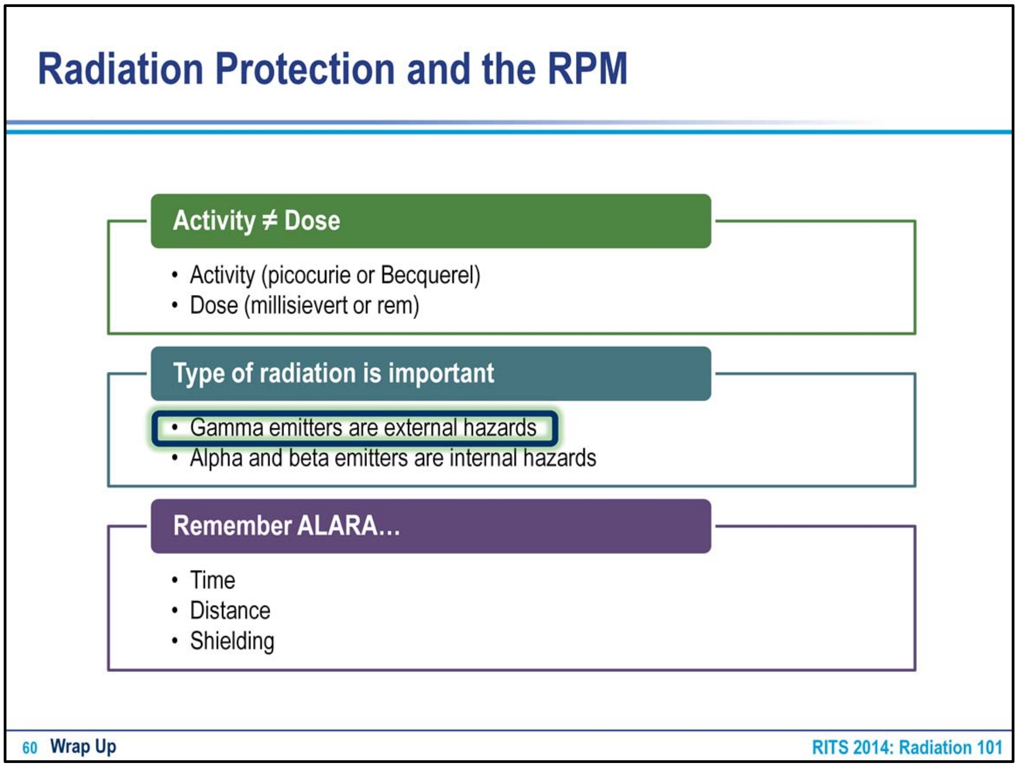
Pulling all the information together on photons,

- The higher energy, greater penetrating ability make photons internal and external hazards
- Shielding, like the lead aprons, are good for gamma rays as well.
    - With the thickness increased in relationship to the energy of the gamma decay
- One important aspect to remember
    - Just like light, exposure decreases with distance – squared.

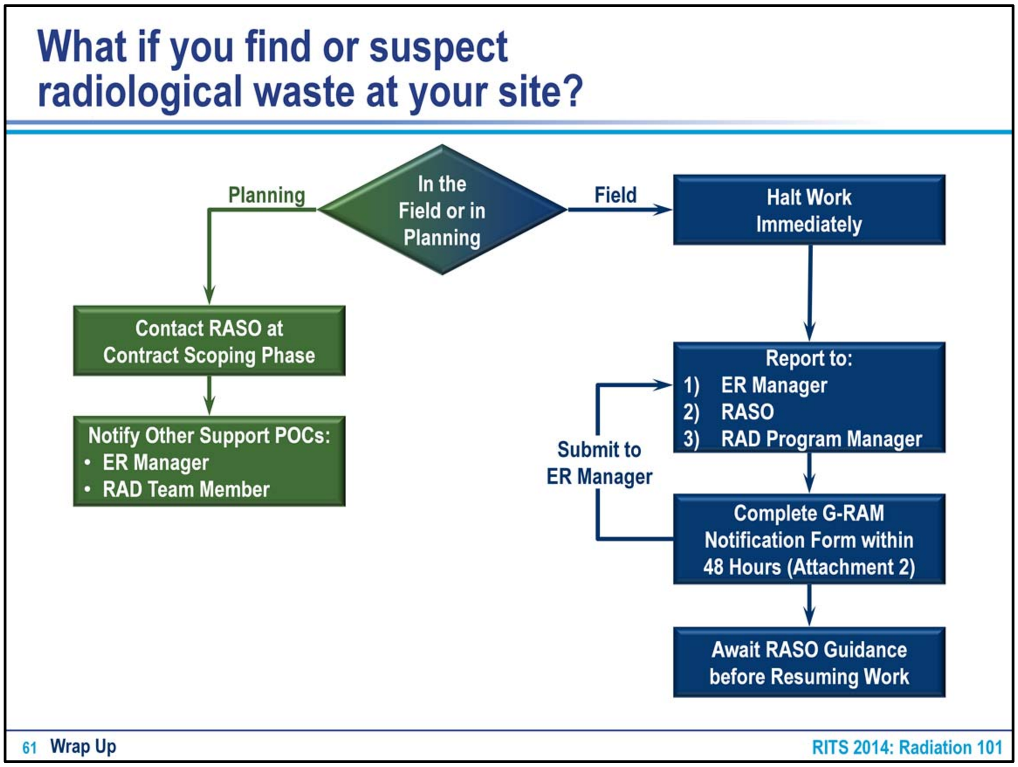
Shielding for Radiation



59 Wrap Up RITS 2014: Radiation 101



The Navy’s primary radiological contaminants are gamma emitters.



If you find a suspect (or actual) radiological item stop work immediately, consult with RASO for appropriate worker protection and screening steps.

- If working on a suspected radiological site, it is appropriate (and required) to bring RASO in at the RFP planning stage, in order to insure that the contract/contractor has the appropriate qualifications/abilities to pursue the work.
- Working with RASO is not an option, they are the delegated technical authority having cognizance for administering and enforcing the Naval Radiation Safety Committee (NRSC) G-RAM policies and requirements.
- The forthcoming safety stand down will have additional materials and details.

Resources

- BMS 9.6.1 – Radiological Contamination
- OPNAV – DON Policy on Activities Involving General Radioactive Material (G-RAM) at Environmental Restoration Program Sites, Ser N453/10U158072 of 10 FEB 2010
- Department of the Navy Environmental Restoration Program Manual, Section 13.12 – Radiological Issues (Currently Under Revision)
- DOD 4715.6 – Low Level Radioactive Waste Disposal Program
- NAVSEAINST 5100.18B – Radiological Affairs Support Program (RASP)
- NAVFACINST 5104.1 – Radiological Contractor Oversight, Management and Safety