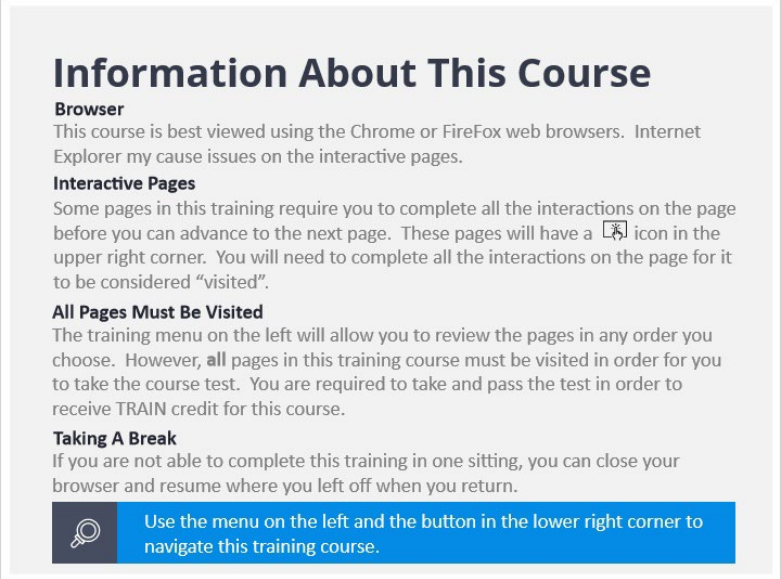
# Radiological Worker FN000470

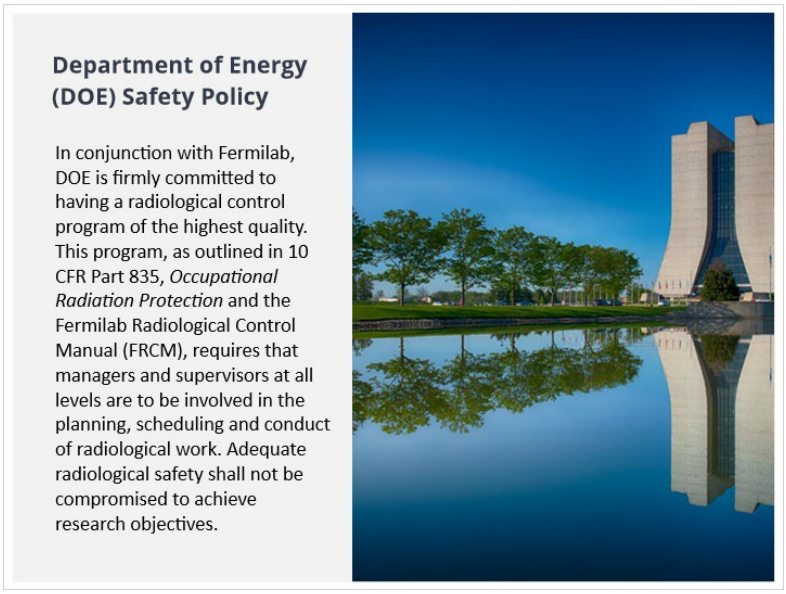
## Radiological Worker

### *1.1 Radiological Worker*

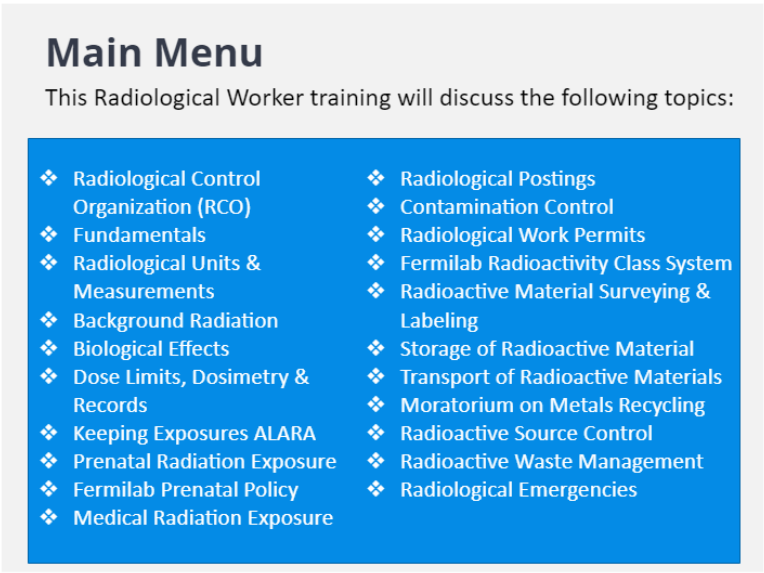

### *1.2 Information About This Course*



## *1.3 Department of Energy (DOE) Safety Policy*

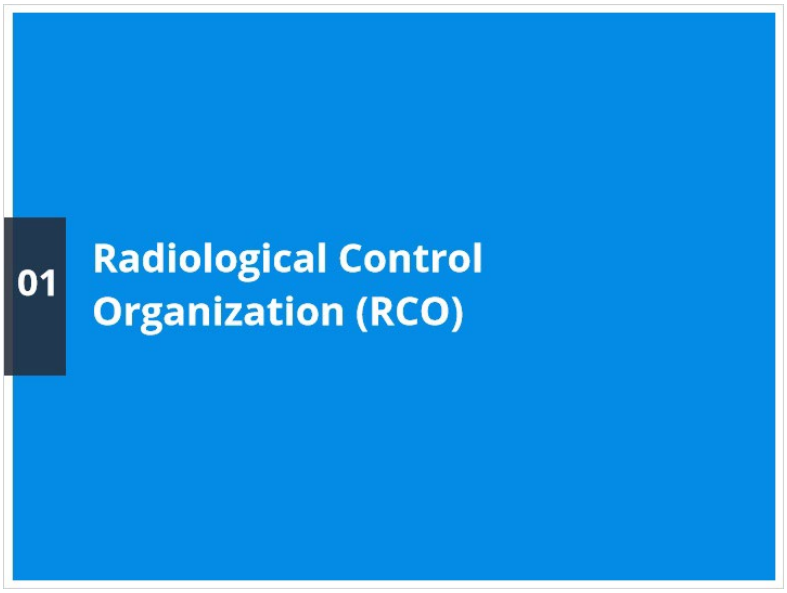



## *1.4 Main Menu*

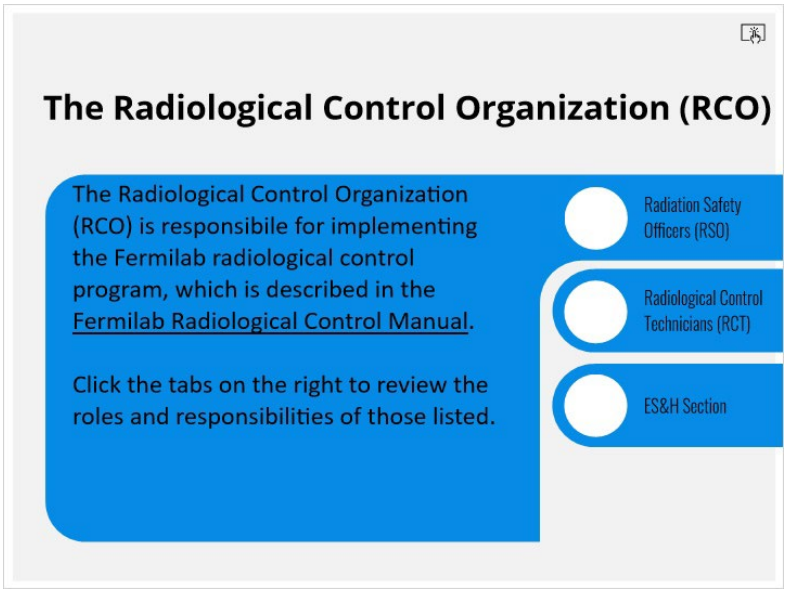


## 2. Radiological Control Organization

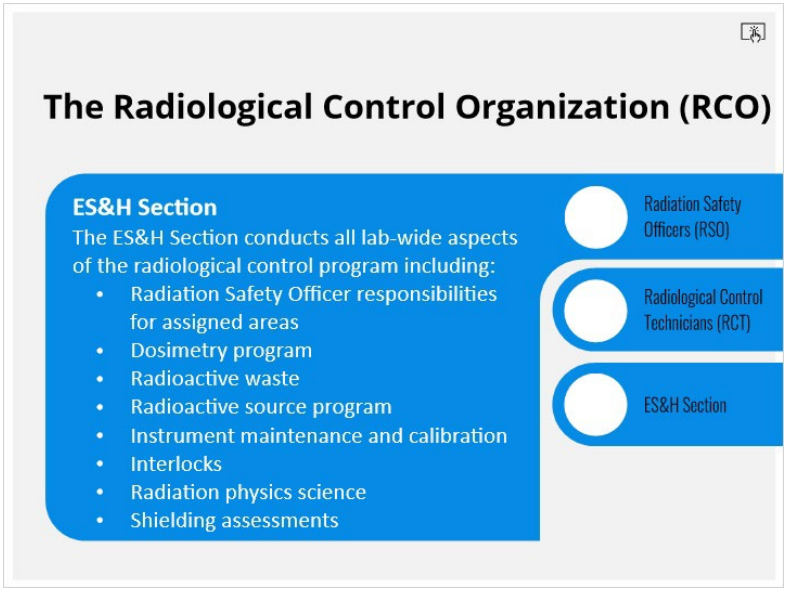
### *2.1 Radiological Control Organization*



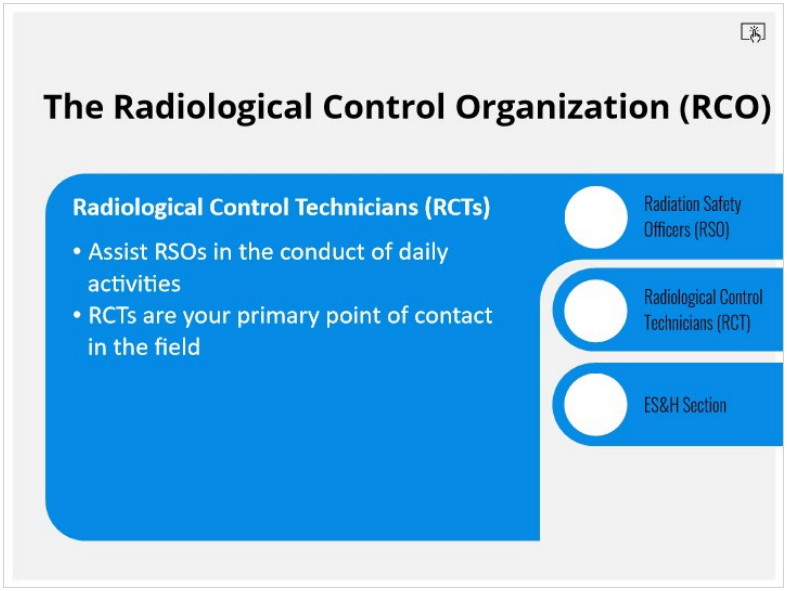

### *2.2 The Radiological Control Organization (RCO)*



## ESH&Q Section (Slide Layer)



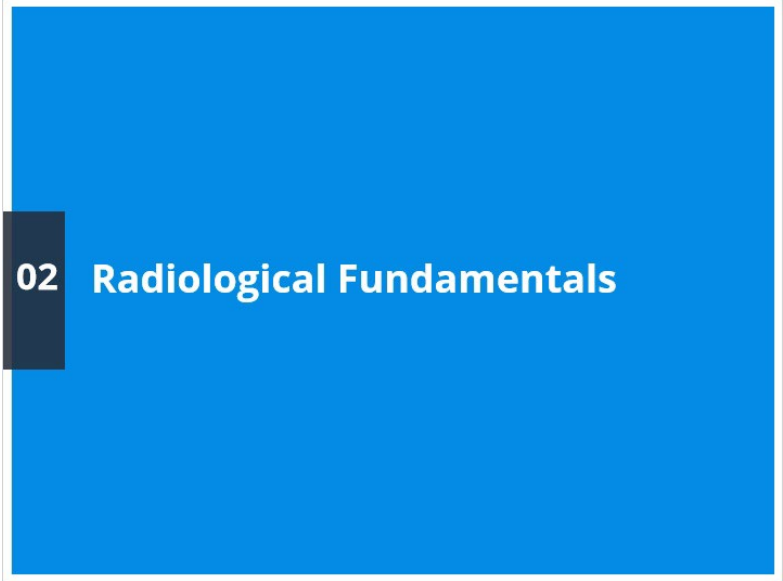

## RCT (Slide Layer)



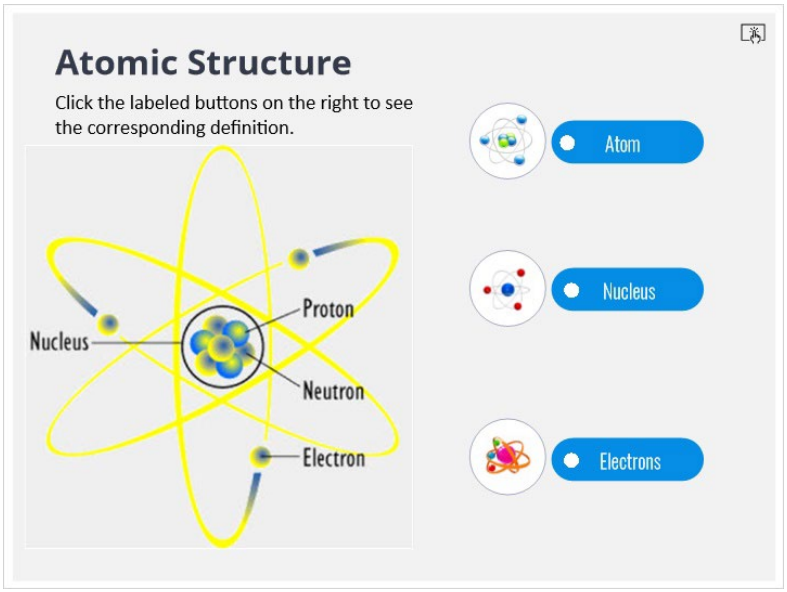
**RSO (Slide Layer)**


## 3. Radiological Fundamentals

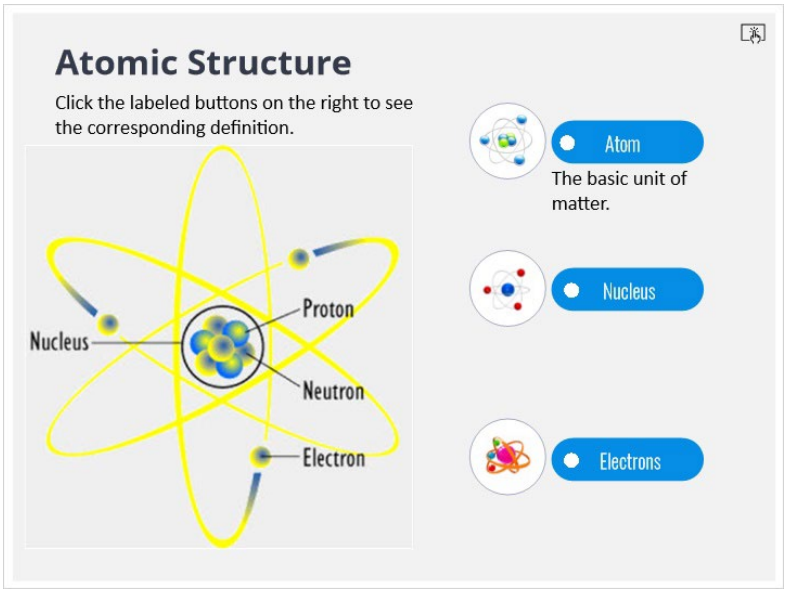
### *3.1 Radiological Fundamentals*



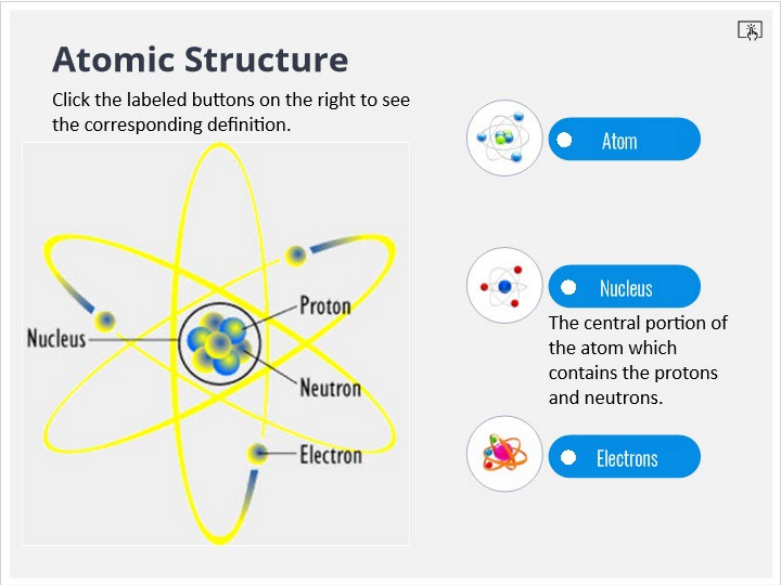
## *3.2 Atomic Structure*



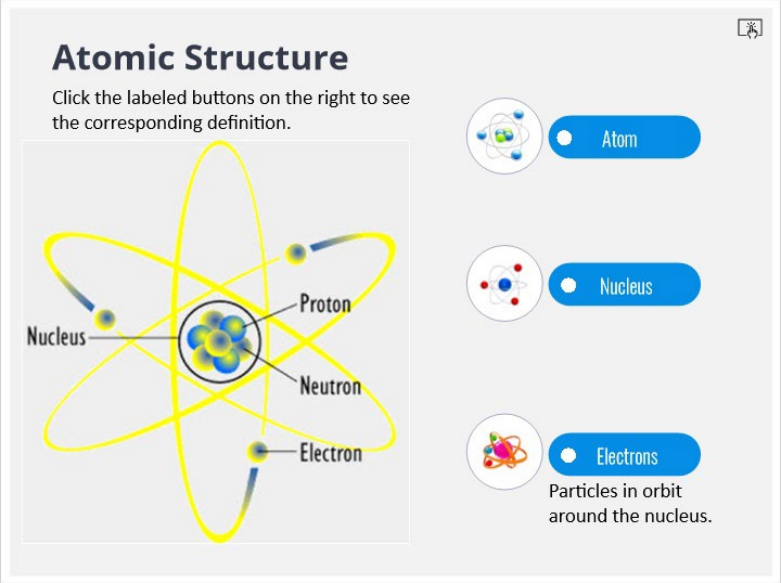

**Atom (Slide Layer)**



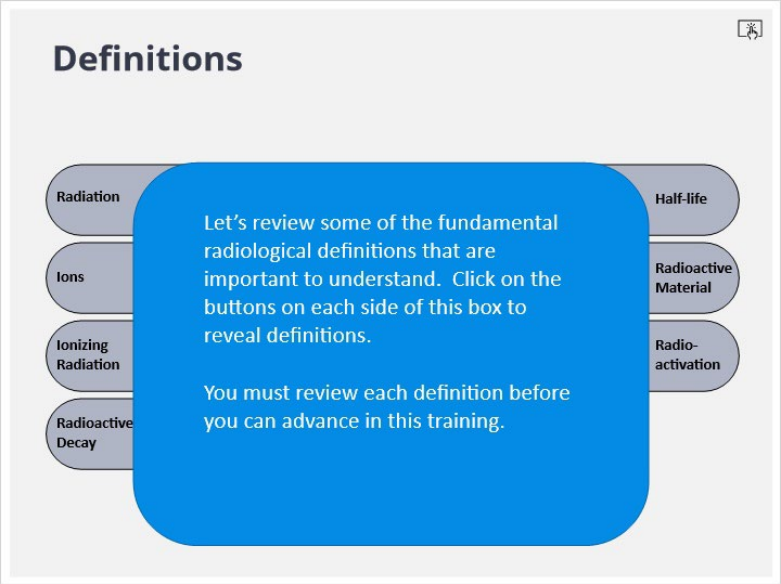
## Nucleus (Slide Layer)



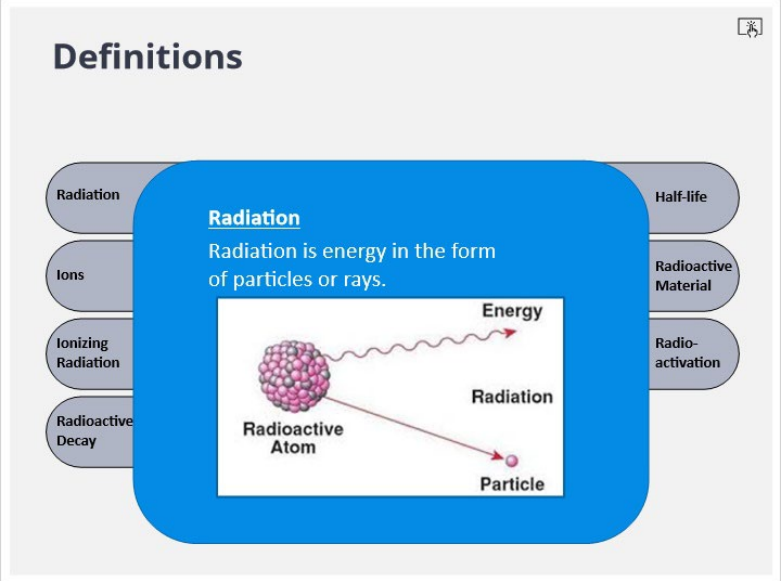

## Electrons (Slide Layer)



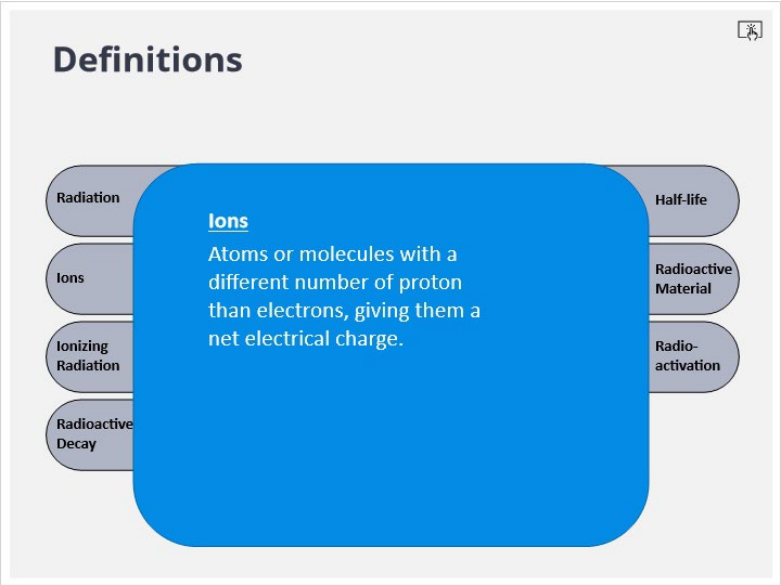
## *3.3 Definitions*



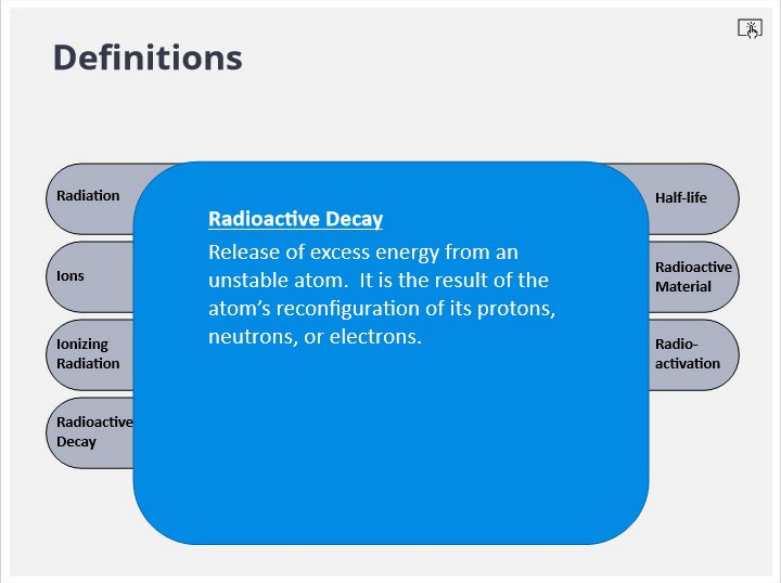

**Radiation (Slide Layer)**



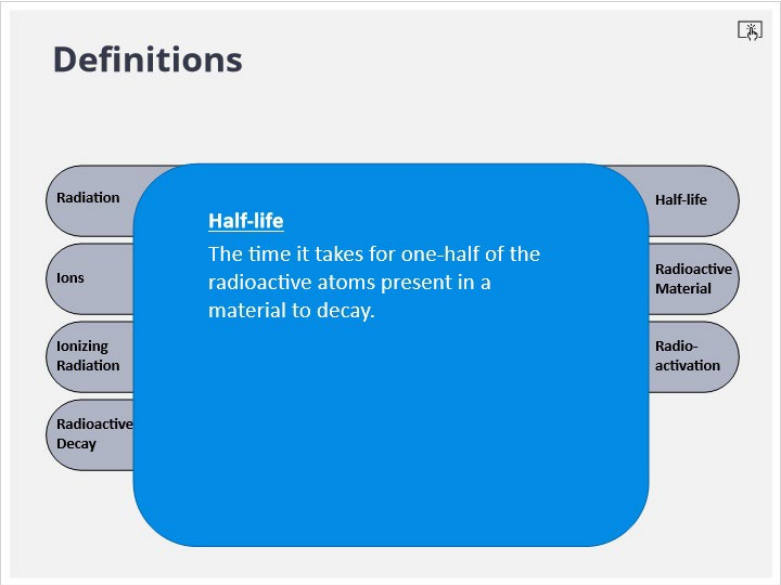
## Ion (Slide Layer)



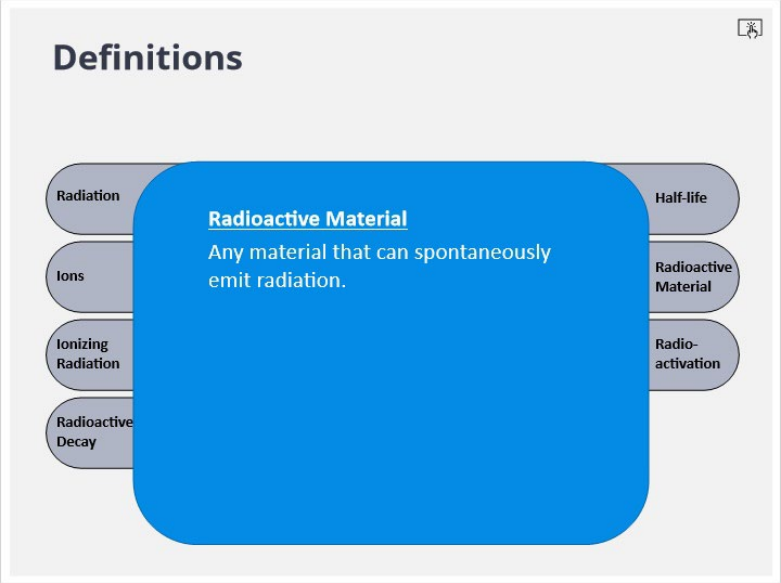

## Radioactive Decay (Slide Layer)



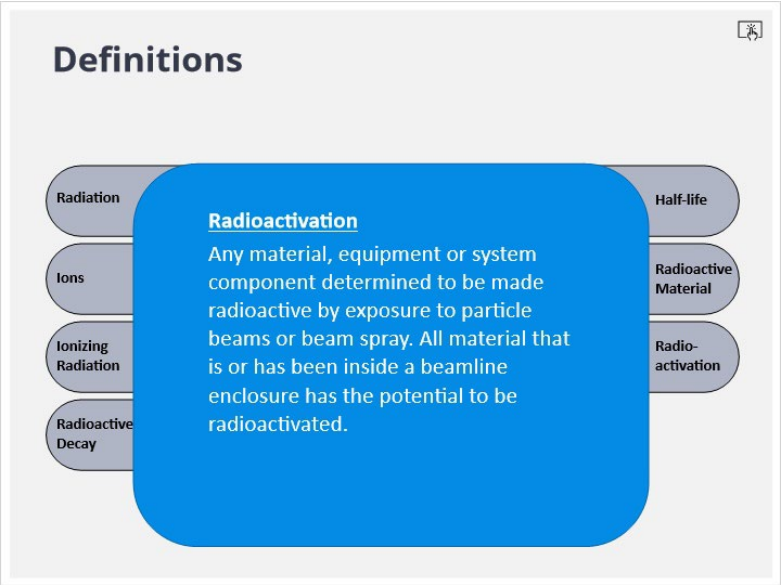
## Half-life (Slide Layer)



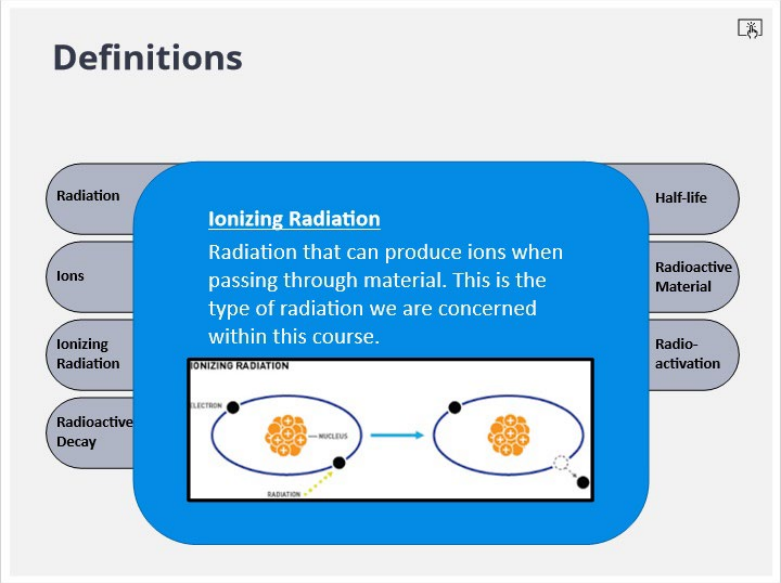

## Radioactive Material (Slide Layer)



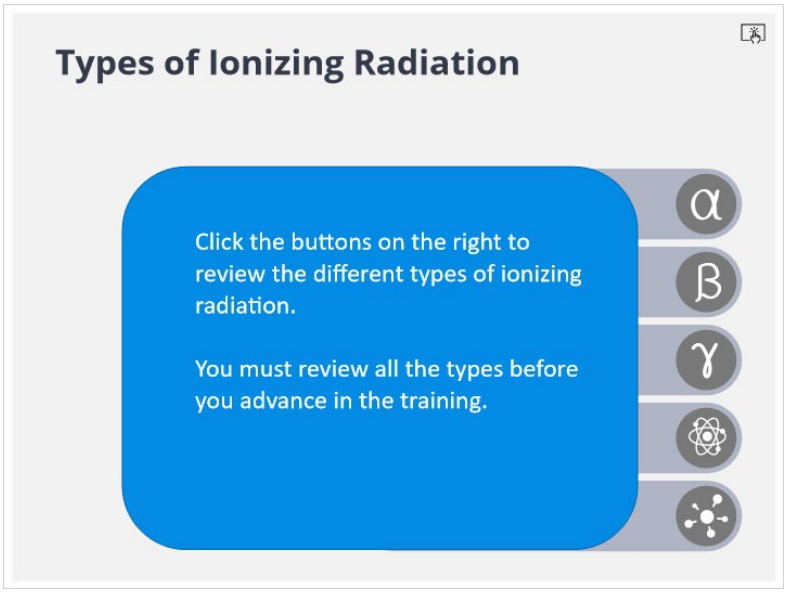
## Radioactivation (Slide Layer)



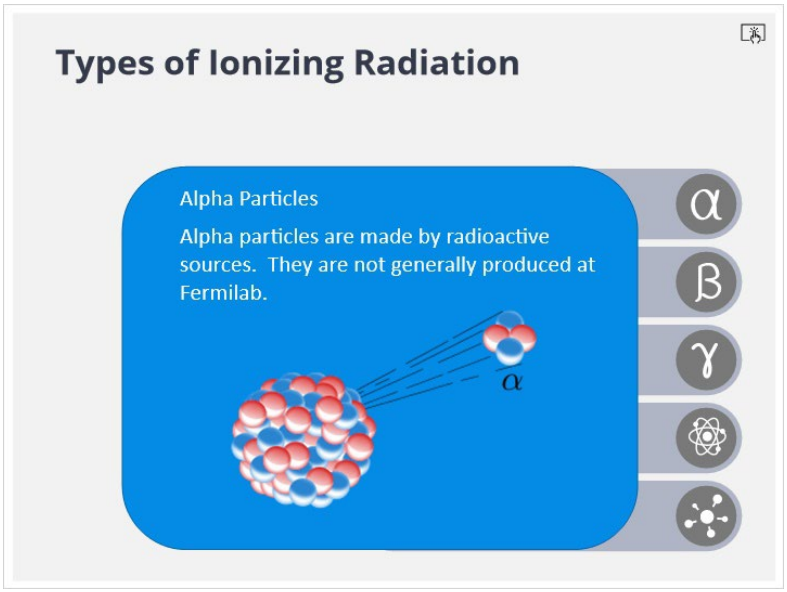

## Ionizing Radiation (Slide Layer)



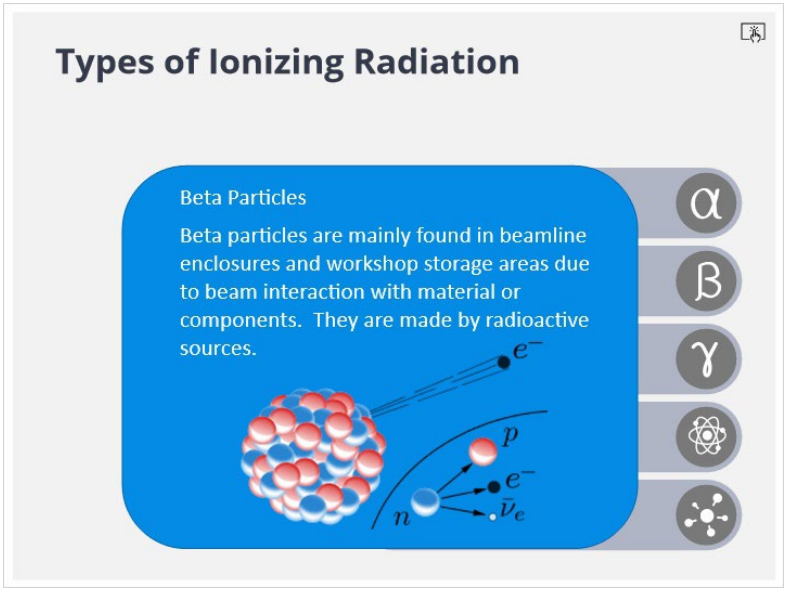
## *3.6 Types of Ionizing Radiation*



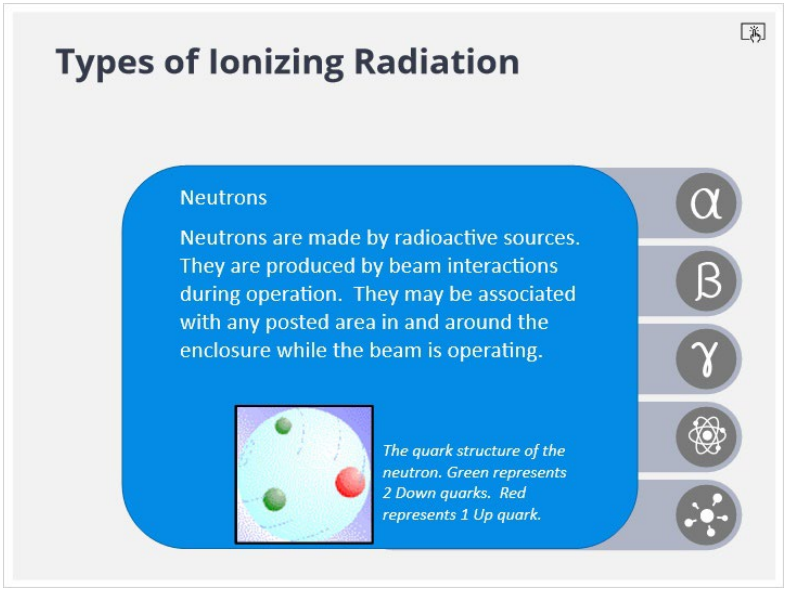

**Alpha Particles (Slide Layer)**



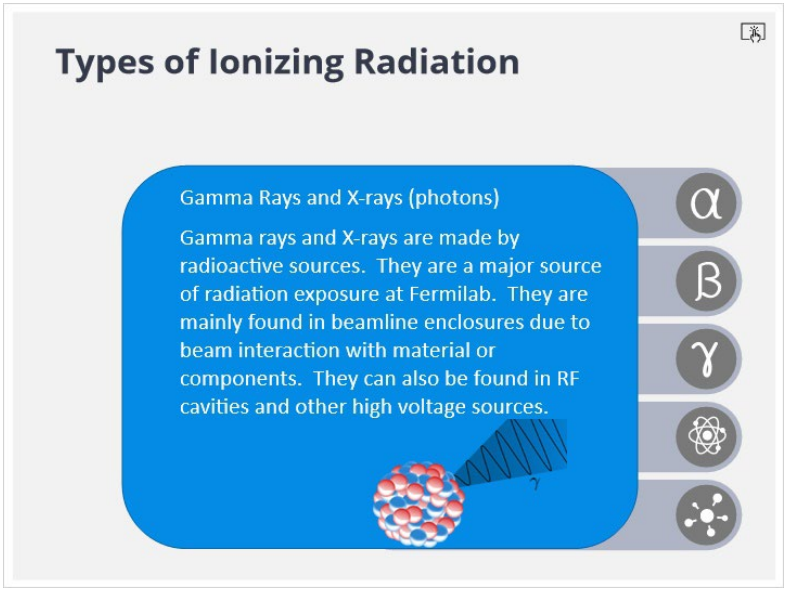
**Beta Particles (Slide Layer)**



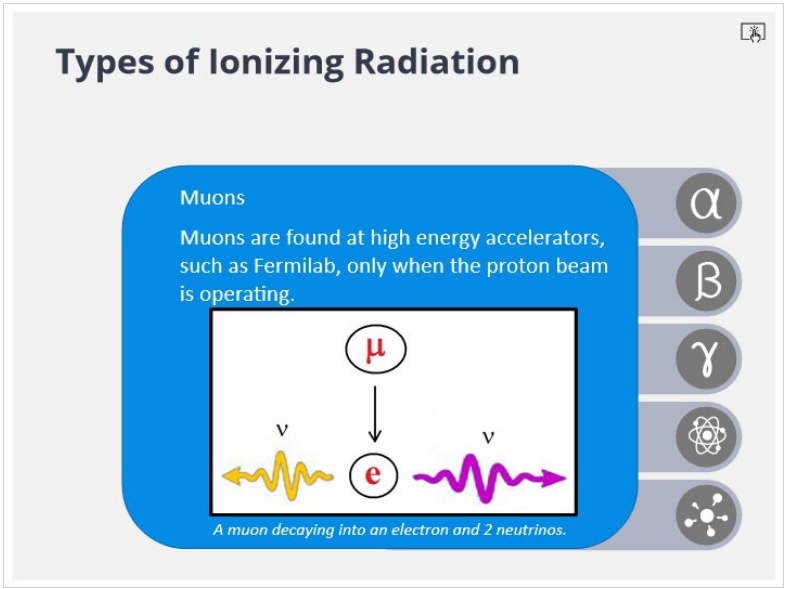

**Neutrons (Slide Layer)**



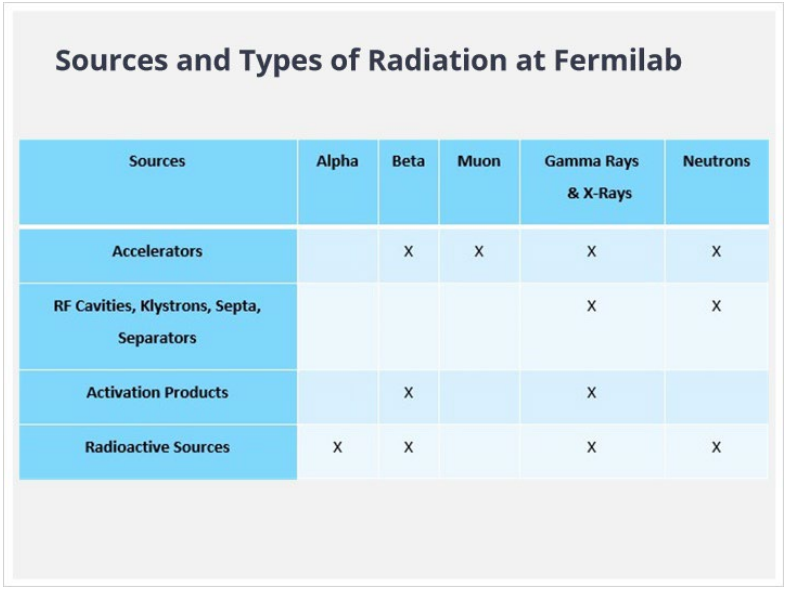
**Gammy ray and X-rays (Slide Layer)**




**Muons (Slide Layer)**

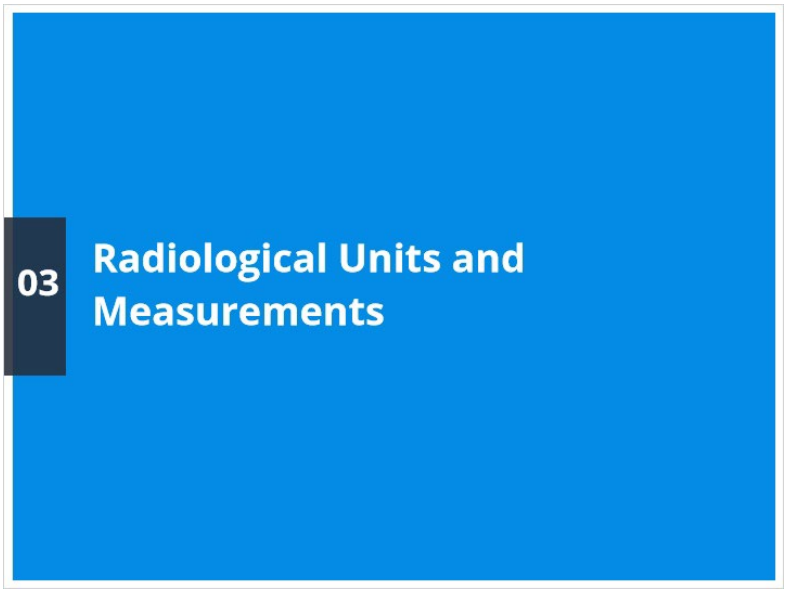


### *3.7 Sources and Types of Radiation at Fermilab*




## 4. Radiological Units and Measurement

### *4.1 Radiological Units & Measurements*



## *4.2 Radiological Units and Measurements*

### Radiological Units and Measurements

Conventional radiological units are required to be used in the U.S. This system differs from the International System of Units (SI) that are used in other countries. If you have questions about radiological units used at Fermilab please contact your assigned RSO.

**Conventional and SI Unit Conversions**

| | SI Units* | Common Units |
|---|---|---|
| **Radioactivity** | becquerel (Bq) | curie (Ci) |
| **Absorbed Dose** | gray (Gy) | rad |
| **Effective Dose** | sievert (Sv) | rem |
| **Exposure** | coulomb/kilogram (C/kg) | roentgen (R) |

* SI Units: International System of Units

Note: In the table above the common units and SI units in each row are not equivalent in value, i.e., 1 curie does not equal 1 becquerel, but they both measure the same parameter

## *4.3 Roentgen (R)*

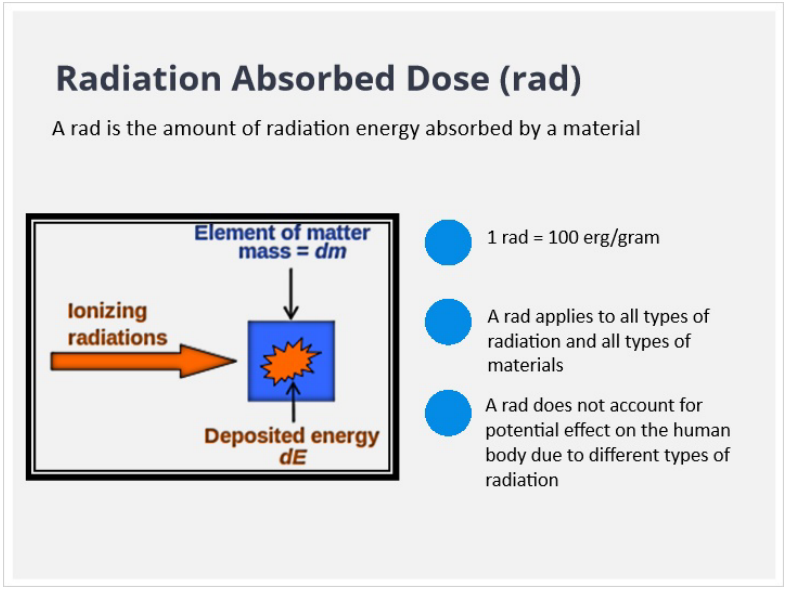
### Roentgen (R)

A Roentgen is a measure of radiation exposure in the air.

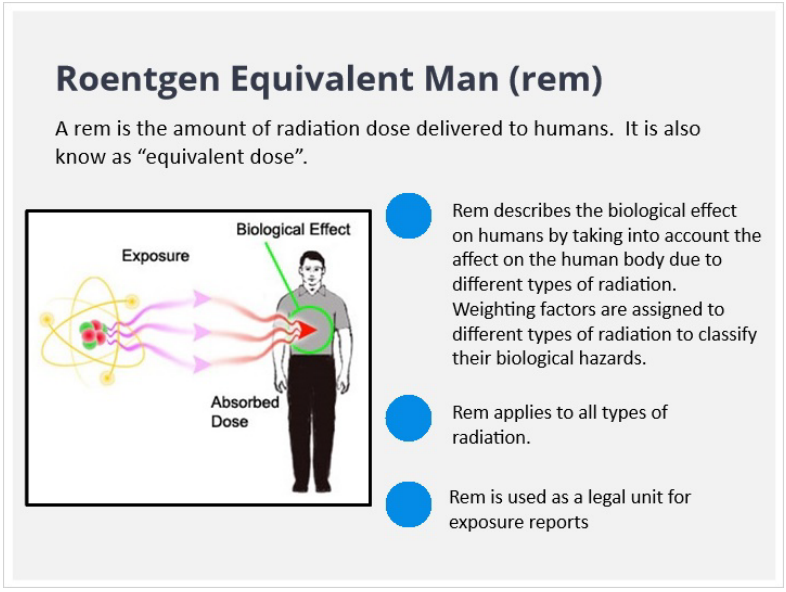
Wilhelm Conrad Roentgen

- Roentgens only apply to gamma and X-rays.
- A Roentgen does not describe biological effects of radiation to humans.
- Many instruments at Fermilab read out in Roentgen or milliRoentgen (mR) such as Log Survey Meters and Wallflowers.

## *4.4 Radiation Absorbed Dose (rad)*




## *4.5 Roentgen Equivalent Man (rem)*



## *4.6 Radiological Units and Measurements Cont.*

### Radiological Units and Measurements

The units of measurement we have discussed are all to large for daily use. Therefore, we refer to them in smaller units as seen here.

1000 milliRoentgen = 1 Roentgen

1000 millirad = 1 rad

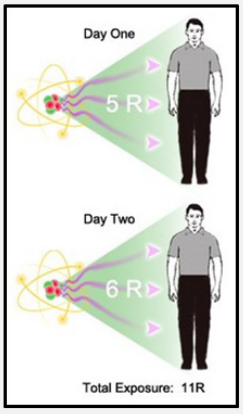
1000 millirem = 1 rem

## *4.7 Dose Rate and Exposure Rate*

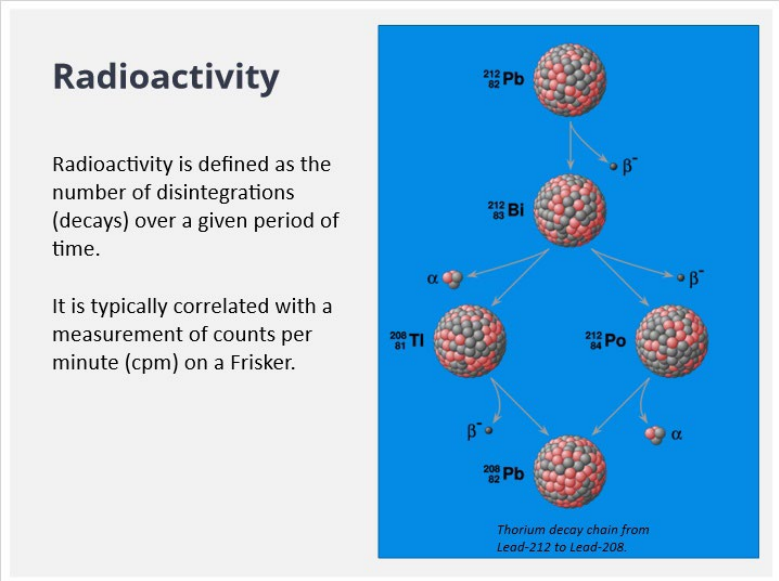
### Dose Rate and Exposure Rate

Dose rates and exposures rates are measured over a given period of time.

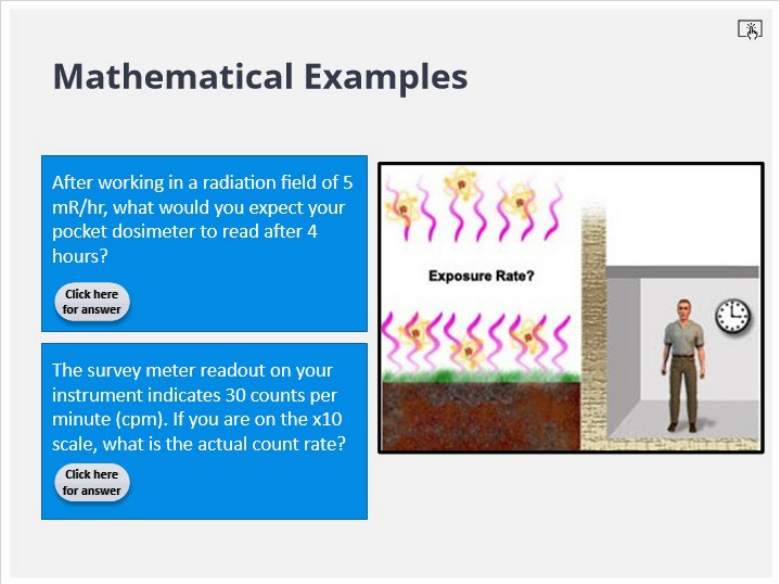
- Dose rate is typically measured in mrem/hr
- Exposure rate is measured in mR/hr
- Dose rate and exposure rate are common units for measuring gamma and X-rays emitted by radioactive materials at Fermilab



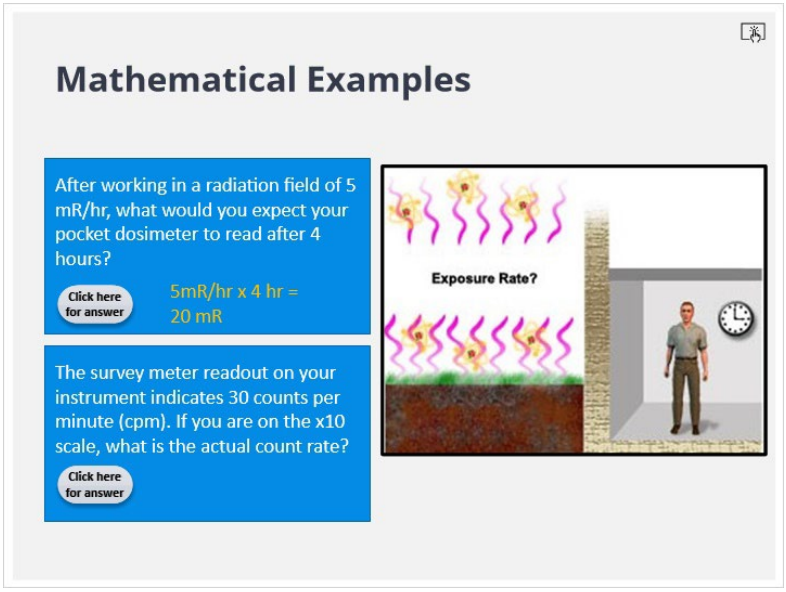
## *4.8 Radioactivity*



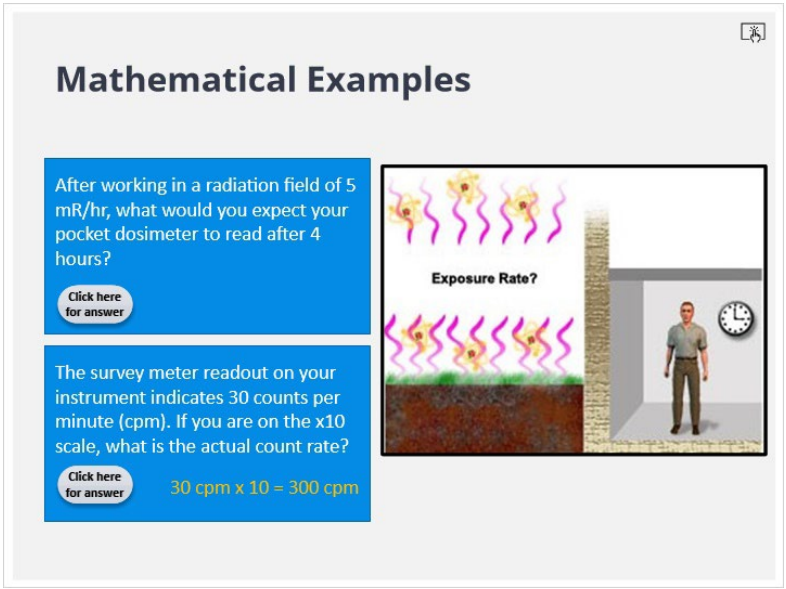

## *4.9 Mathematical Examples*



## Question 1 Answer (Slide Layer)

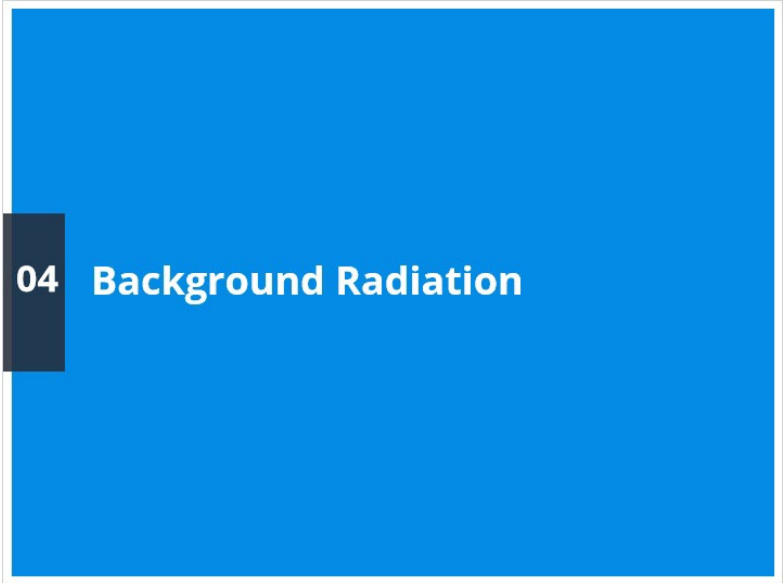



## Question 2 Answer (Slide Layer)

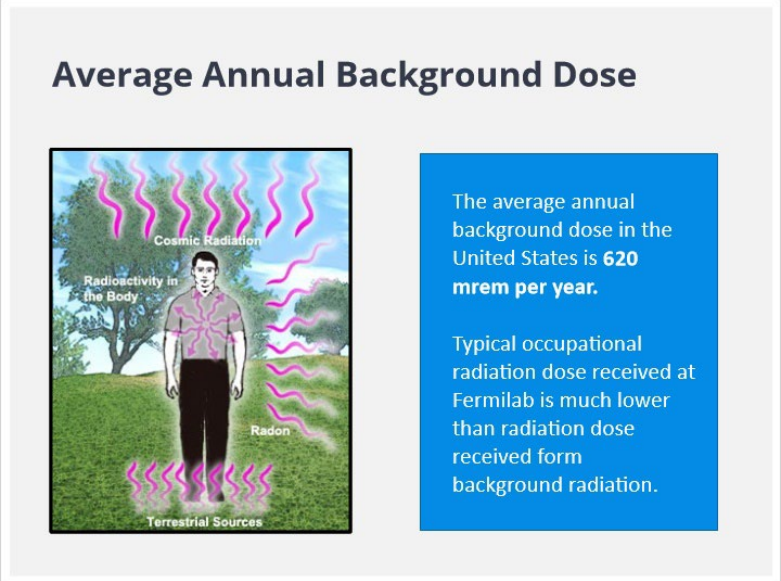


## 5. Background Radiation

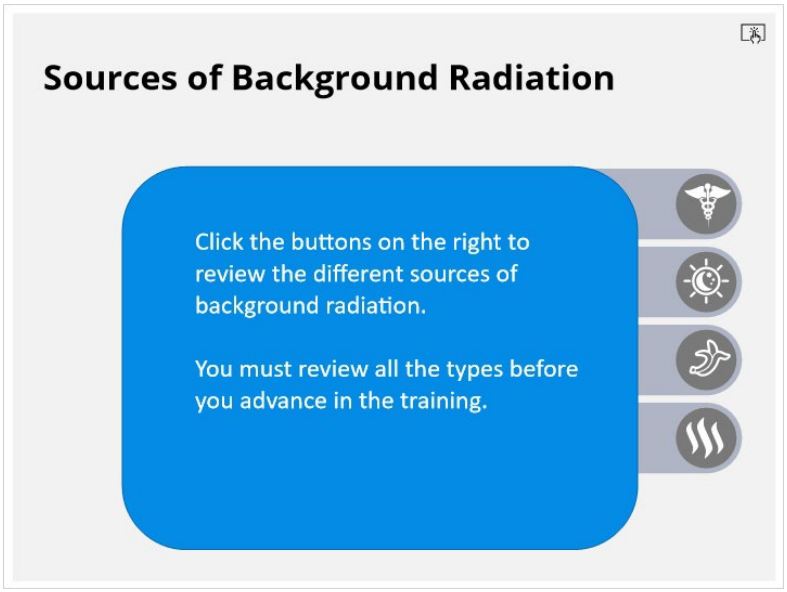
### *5.1 Background Radiation*



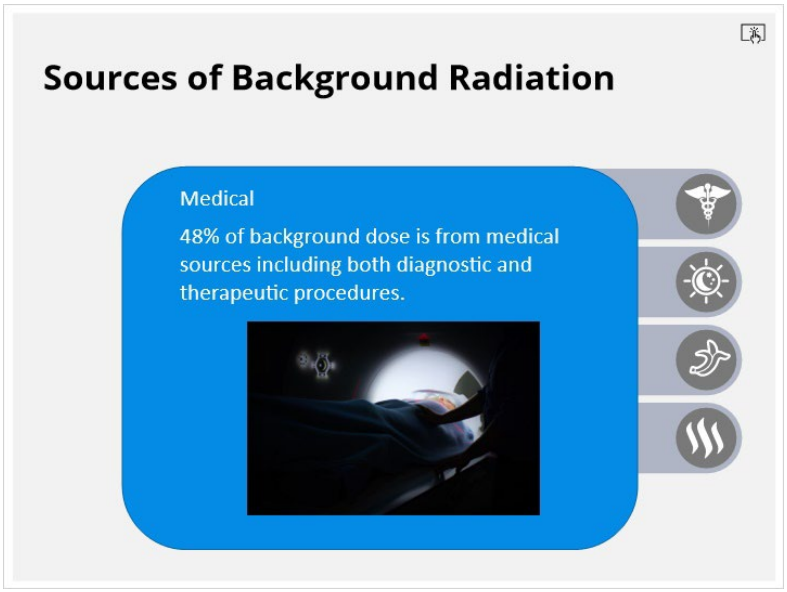

### *5.2 Average Annual Background Dose*



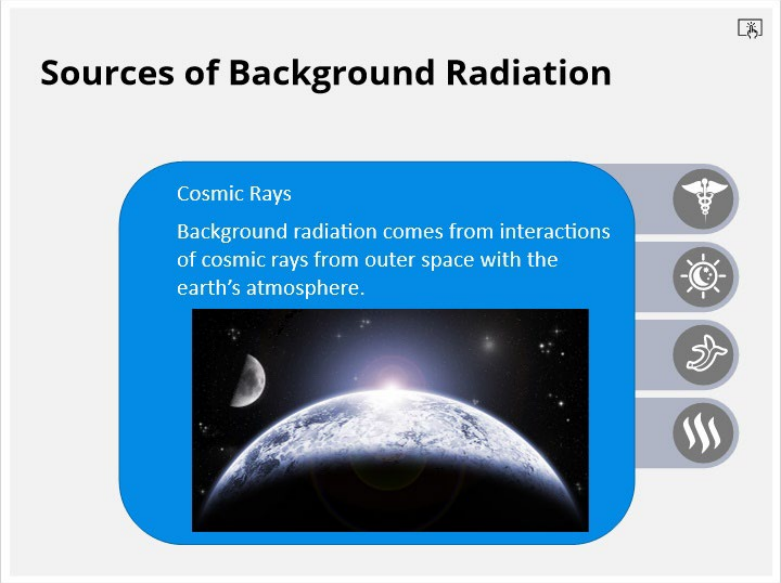
## *5.3 Sources of Background Radiation*



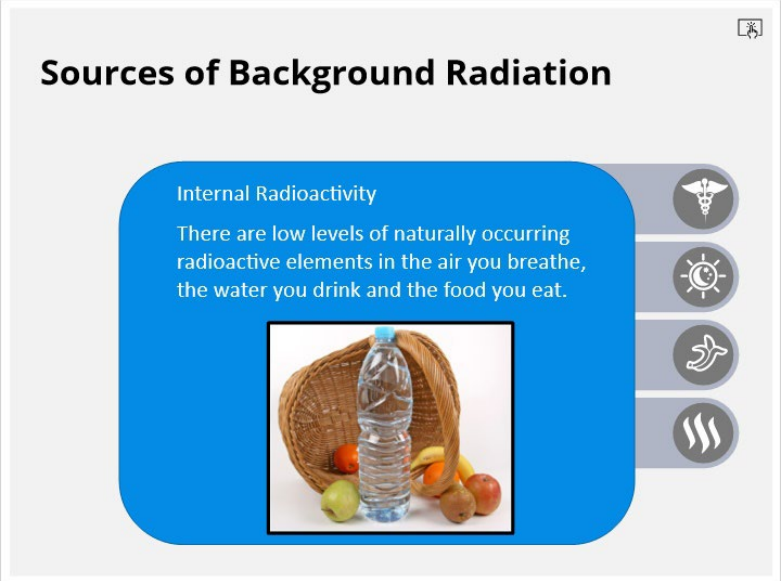

**Medical (Slide Layer)**



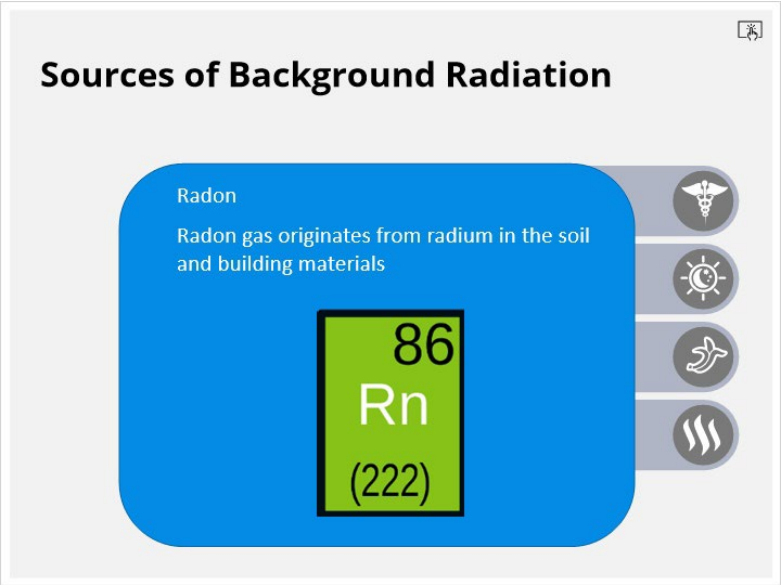
**Cosmic Rays (Slide Layer)**



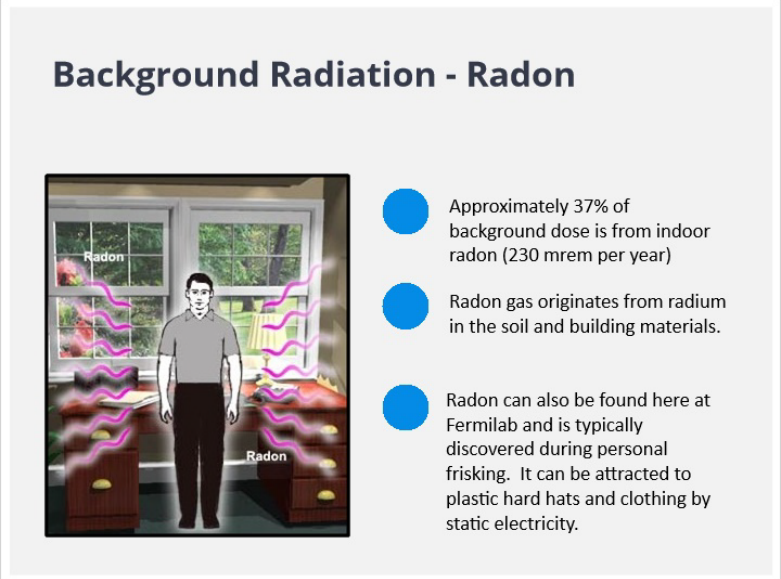

**Internal Radioactivity (Slide Layer)**



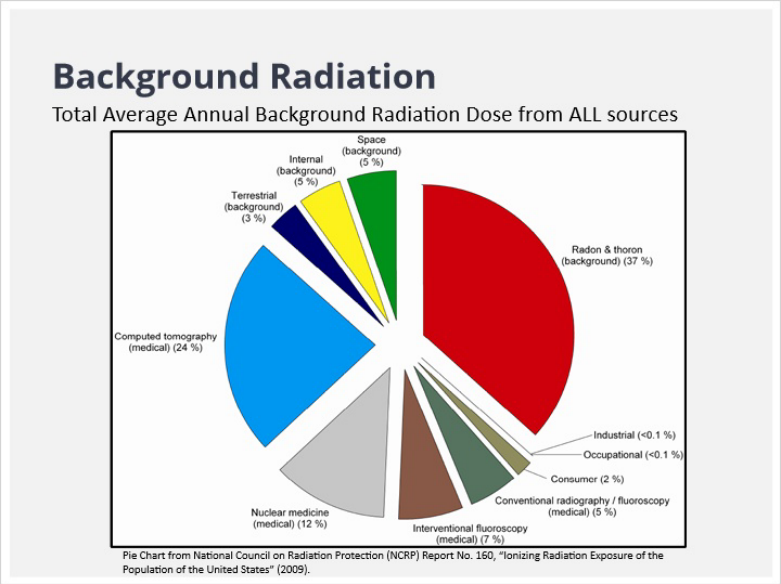
**Radon (Slide Layer)**



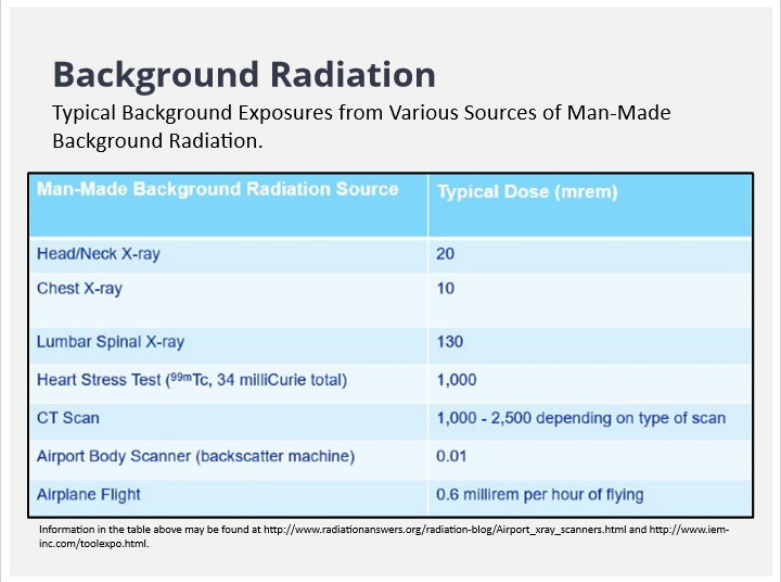

## *5.4 Background Radiation - Radon*



## *5.5 Background Radiation Chart*




## *5.6 Background Radiation*



**Background Radiation**

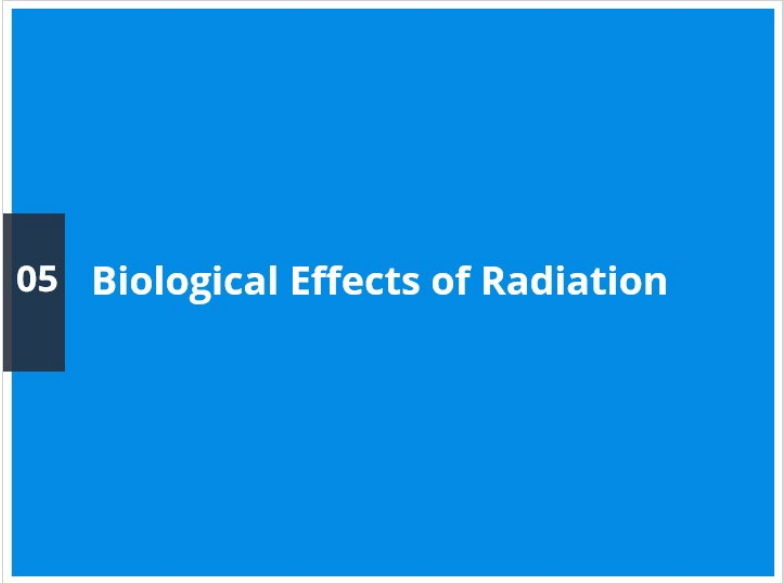
Typical Background Exposures from Various Sources of Man-Made Background Radiation.

| Man-Made Background Radiation Source | Typical Dose (mrem) |
|---|---|
| Head/Neck X-ray | 20 |
| Chest X-ray | 10 |
| Lumbar Spinal X-ray | 130 |
| Heart Stress Test ($^{99m}$Tc, 34 milliCurie total) | 1,000 |
| CT Scan | 1,000 - 2,500 depending on type of scan |
| Airport Body Scanner (backscatter machine) | 0.01 |
| Airplane Flight | 0.6 millirem per hour of flying |

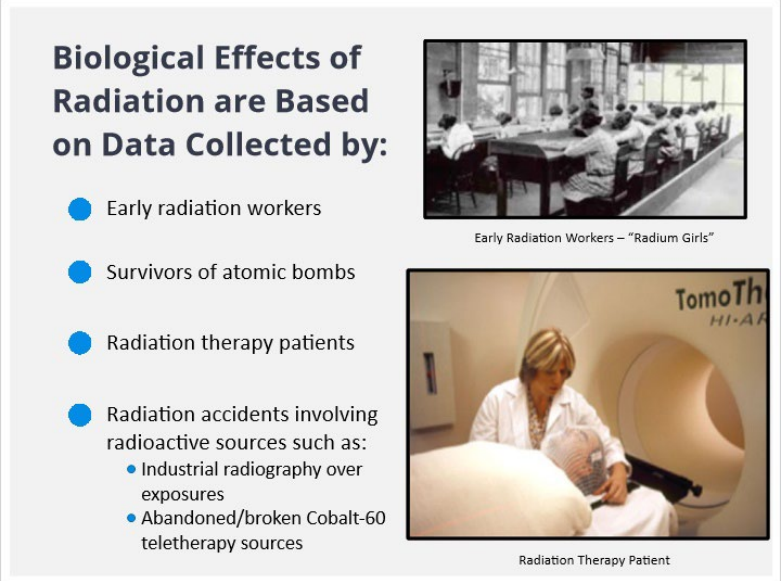
Information in the table above may be found at http://www.radiationanswers.org/radiation-blog/Airport_xray_scanners.html and http://www.iem-inc.com/toolexpo.html.

# 6. Biological Effects of Radiation

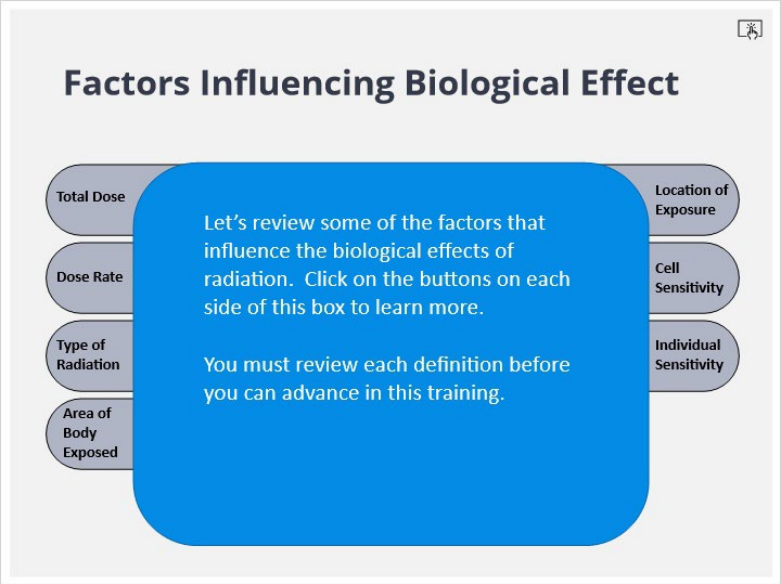
## *6.1 Biological Effects*



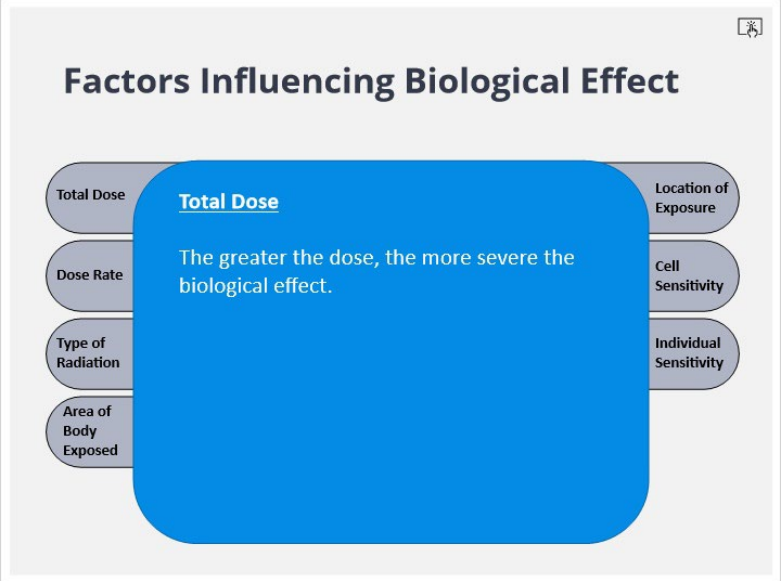

## *6.2 Biological Effects of Radiation are Based on Data Collected by:*



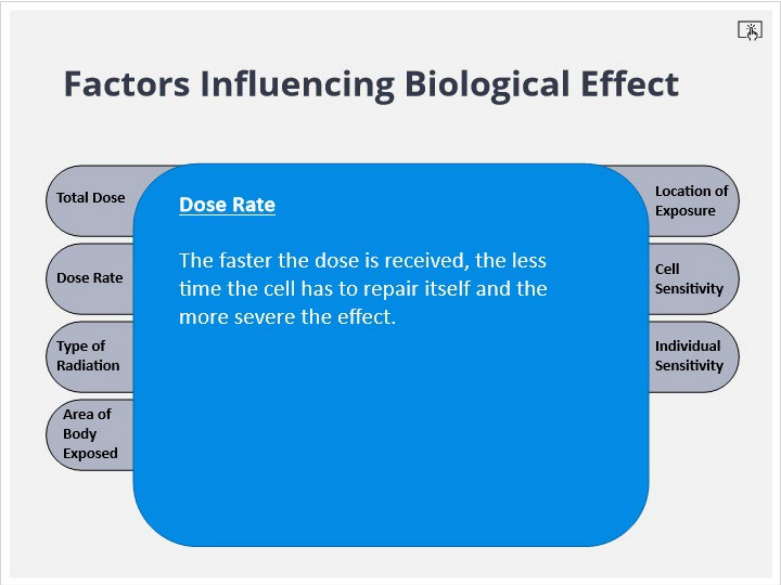
## *6.3 Factors Influencing Biological Effect*



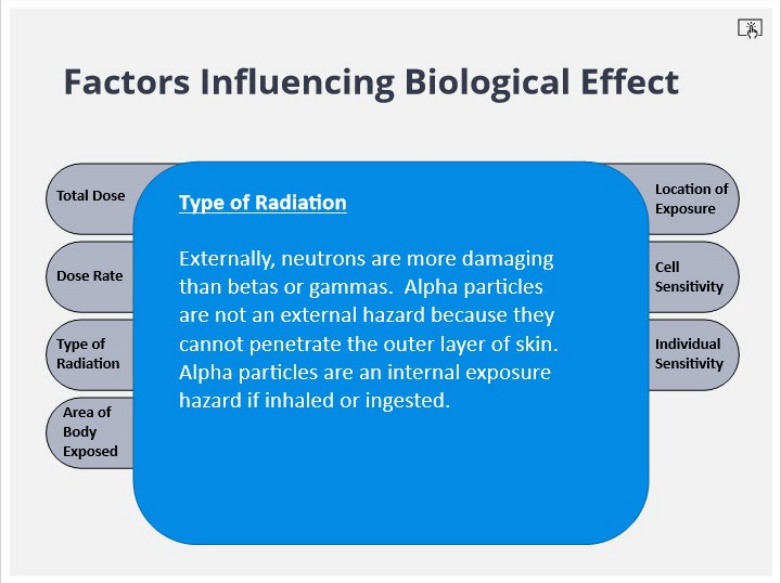

### Total Dose (Slide Layer)



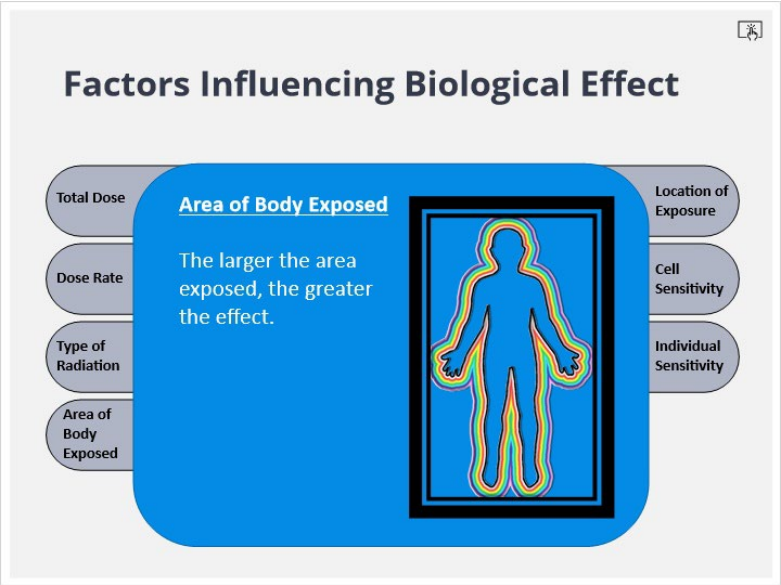
## Dose Rate (Slide Layer)



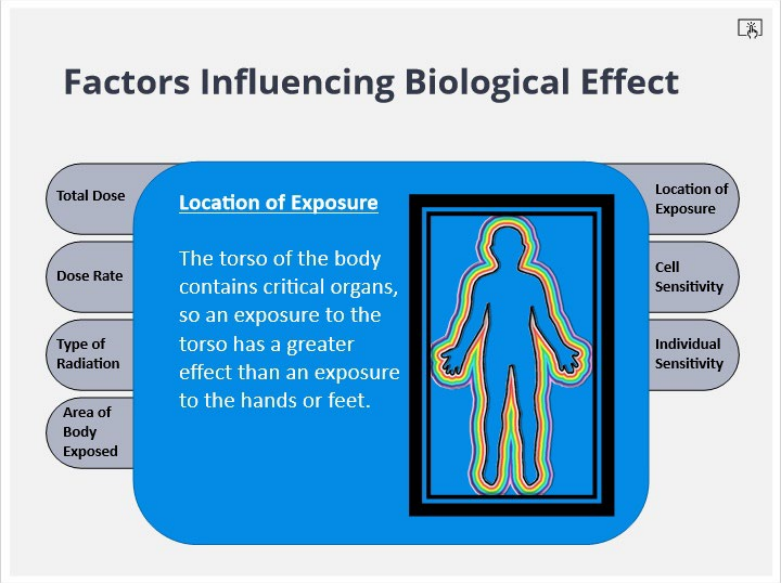

## Type of Radiation (Slide Layer)



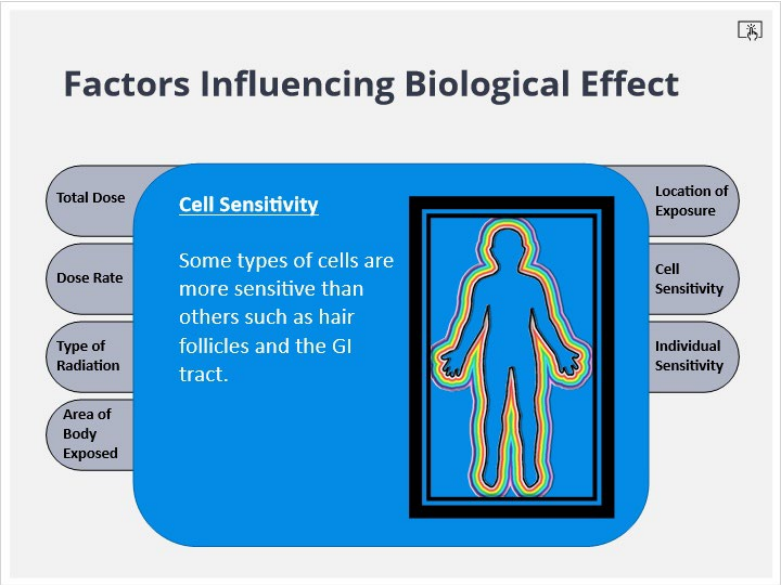
## Area Exposed (Slide Layer)



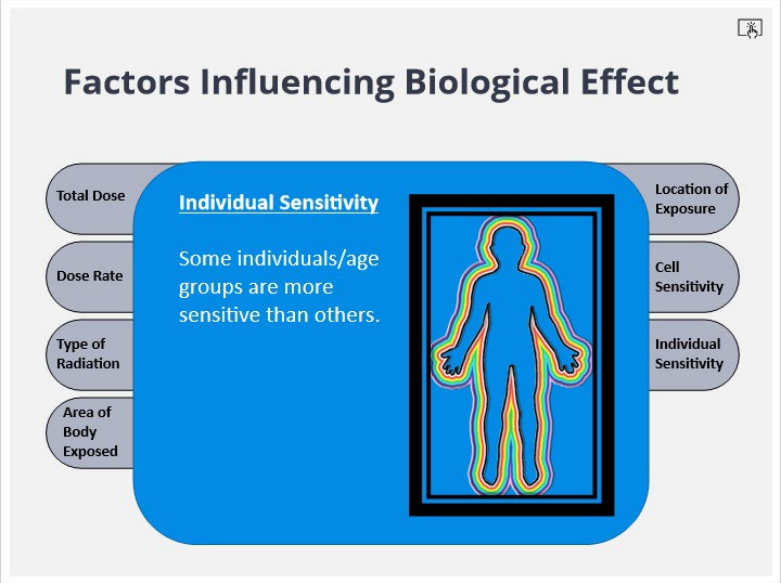

## Location of Exposure (Slide Layer)



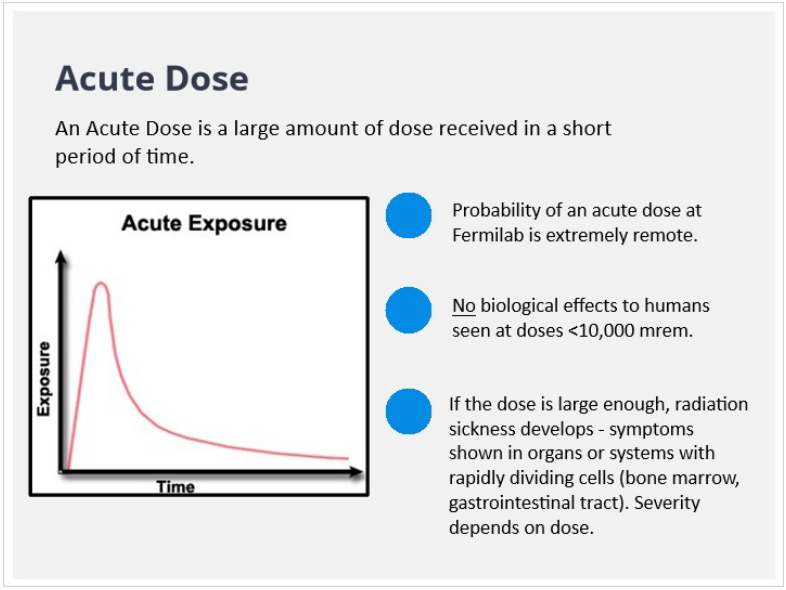
## Cell Sensitivity (Slide Layer)



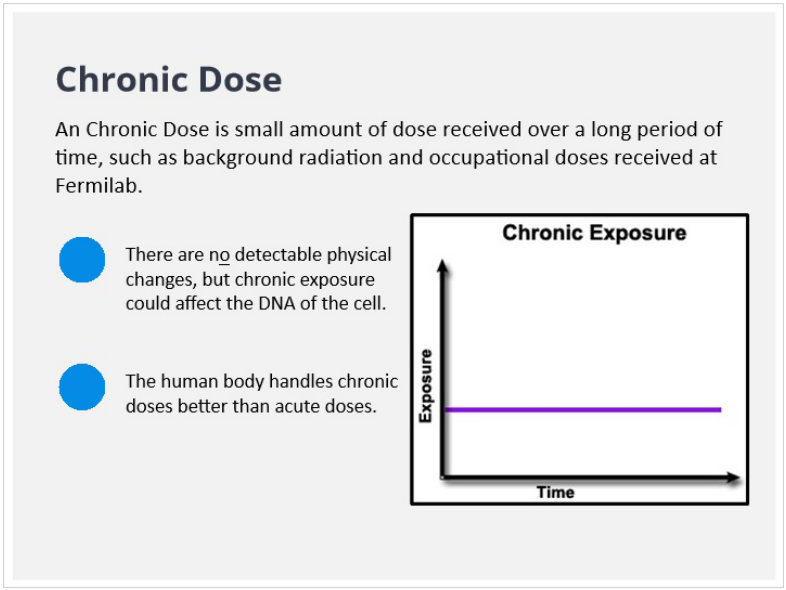

## Individual Sensitivity (Slide Layer)



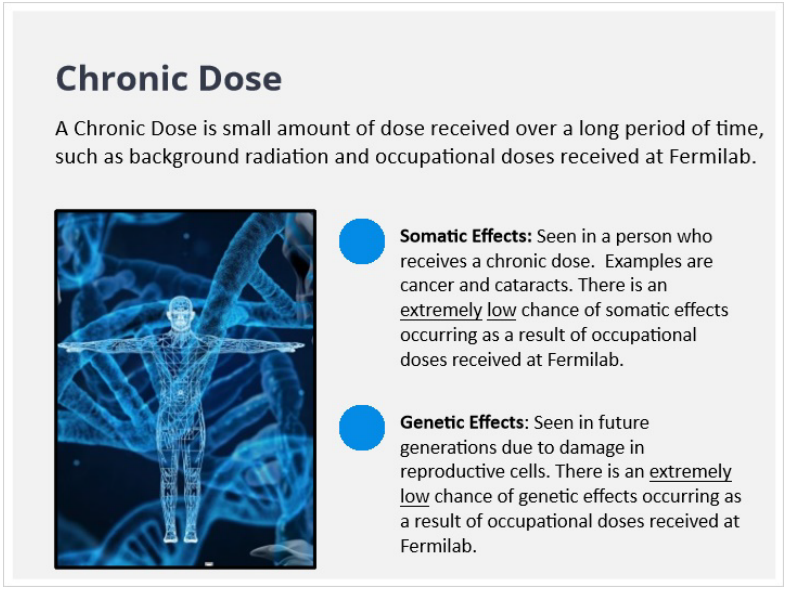
## *6.5 Acute Dose*




## *6.7 Chronic Dose*

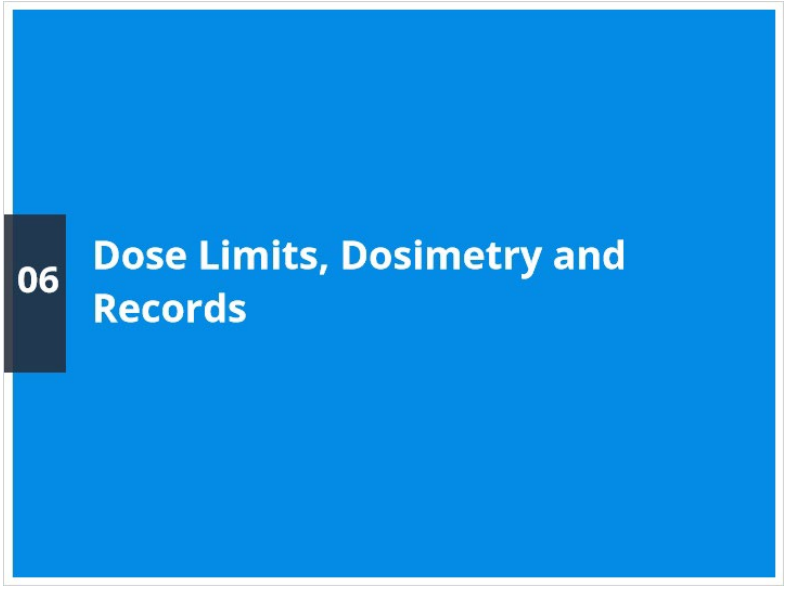


### *6.8 Chronic Dose Cont.*

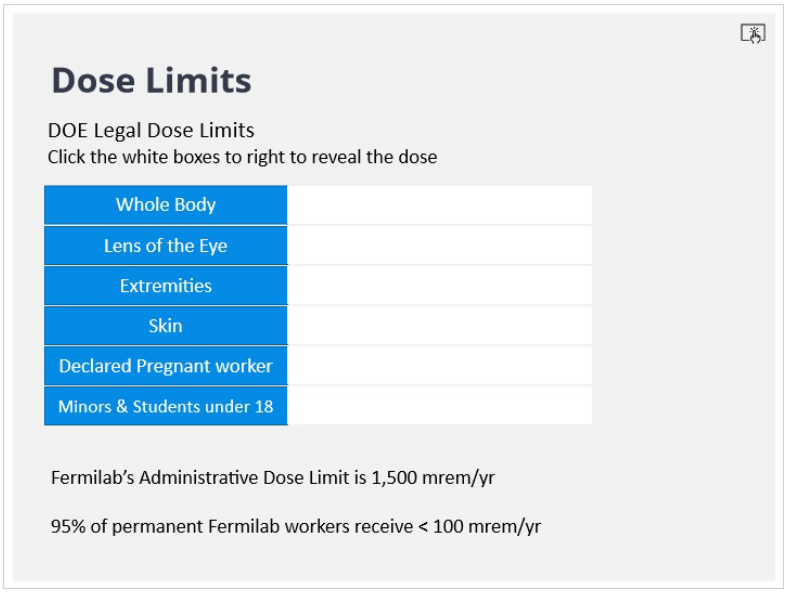



## 7. Dose Limits, Dosimetry and Records

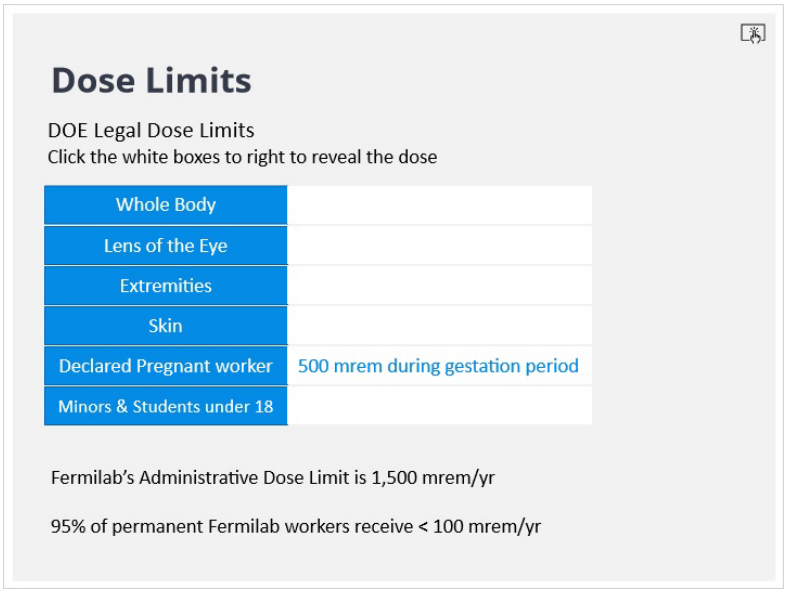
### *7.1 Dose Limits, Dosimetry and Records*



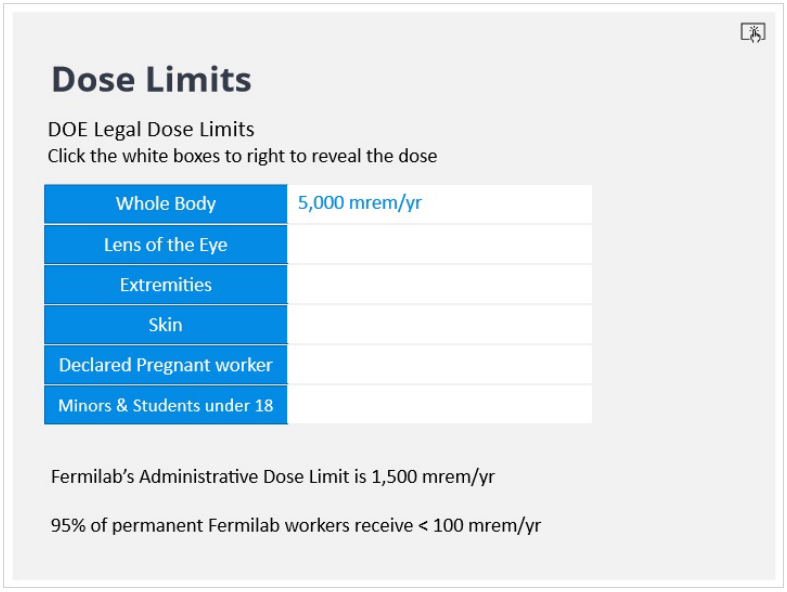
## *7.2 Dose Limits*



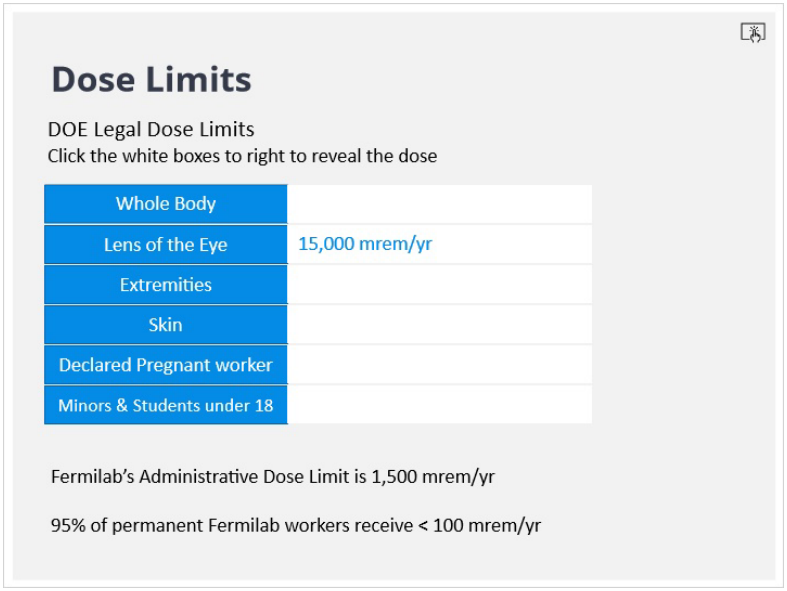

### Declared Pregnant Worker (Slide Layer)



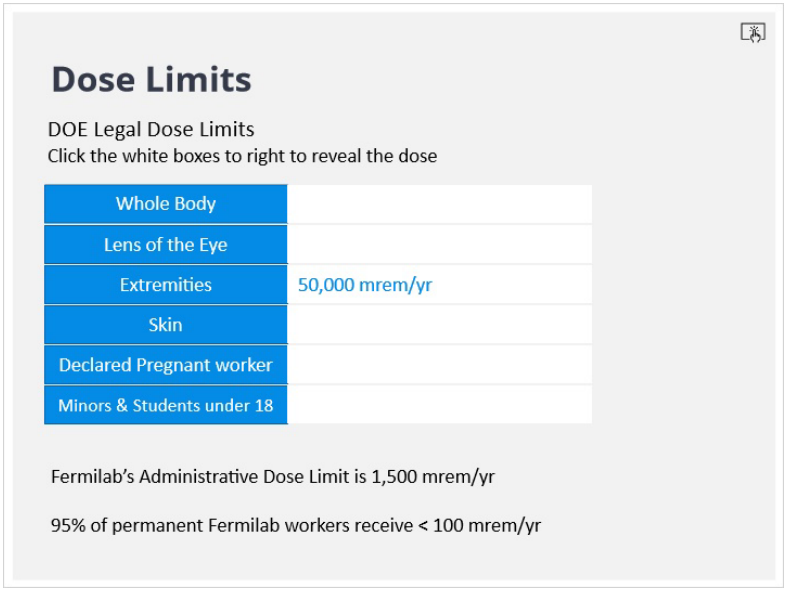
## Whole Body (Slide Layer)



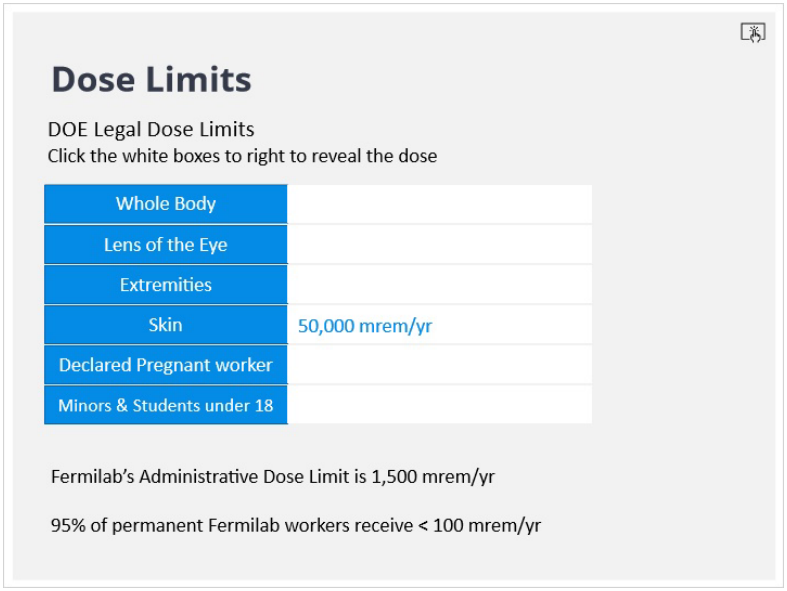

## Lens of the Eye (Slide Layer)



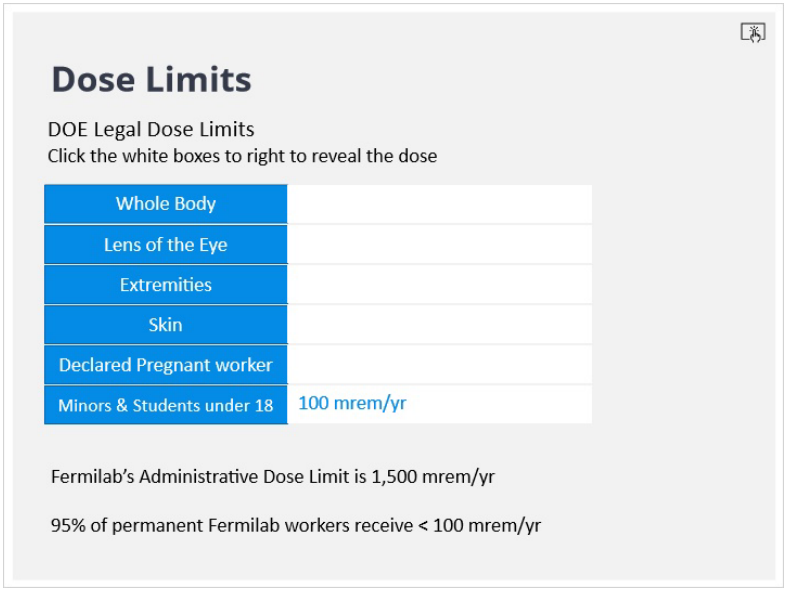
## Extremities (Slide Layer)



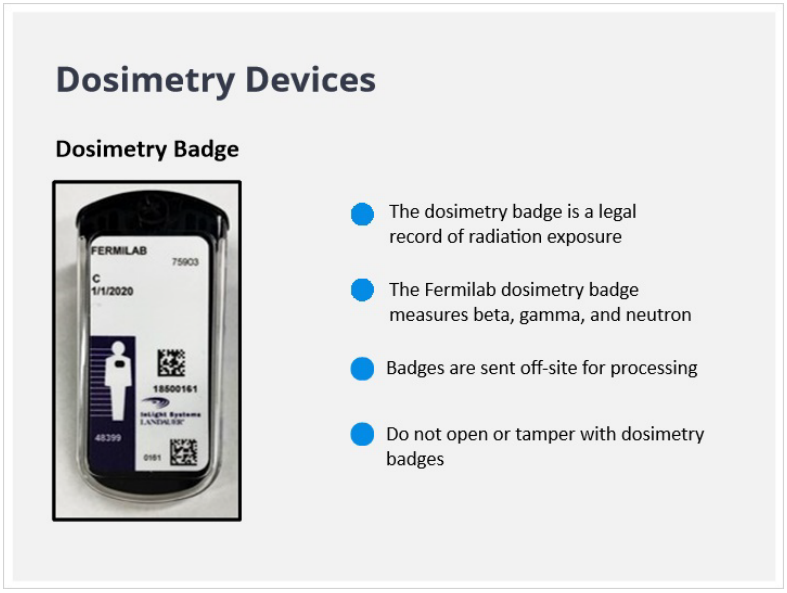

## Skin (Slide Layer)



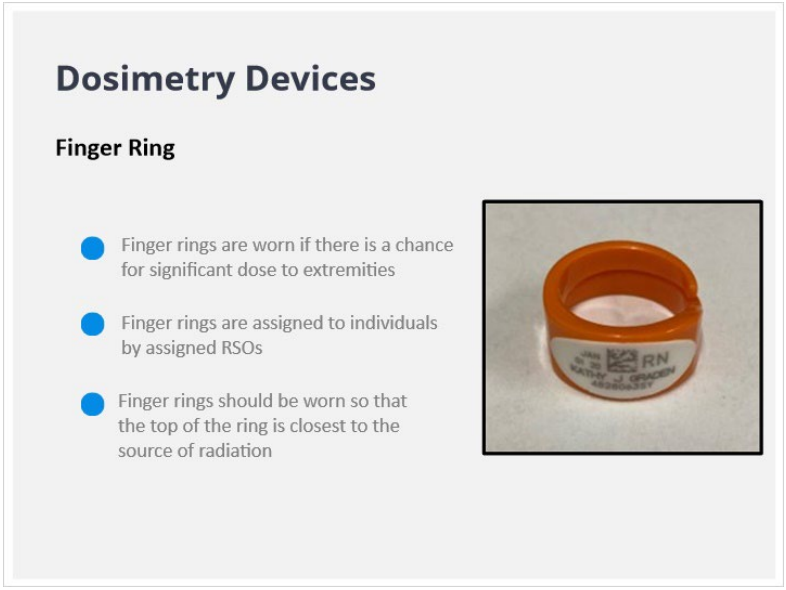
## Minors and students (Slide Layer)



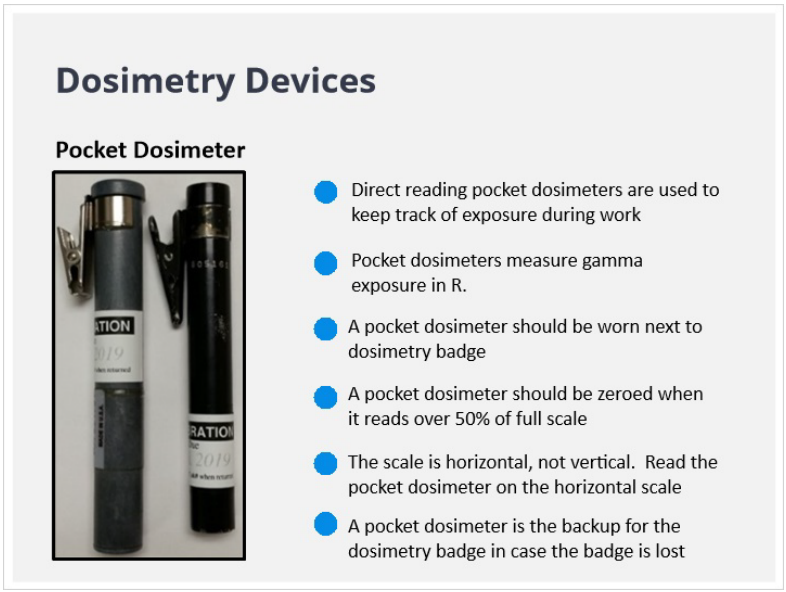

## *7.5 Dosimetry Devices - Badge*



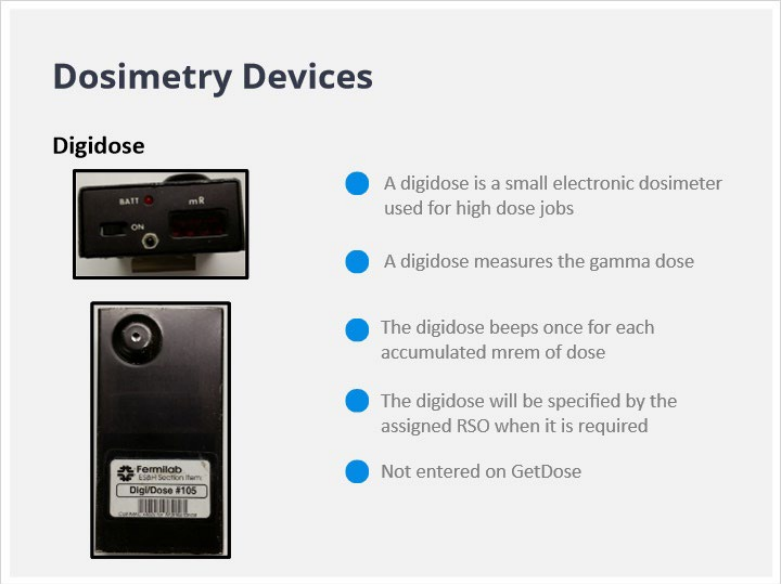
## *7.6 Dosimetry Devices - Finger Ring*



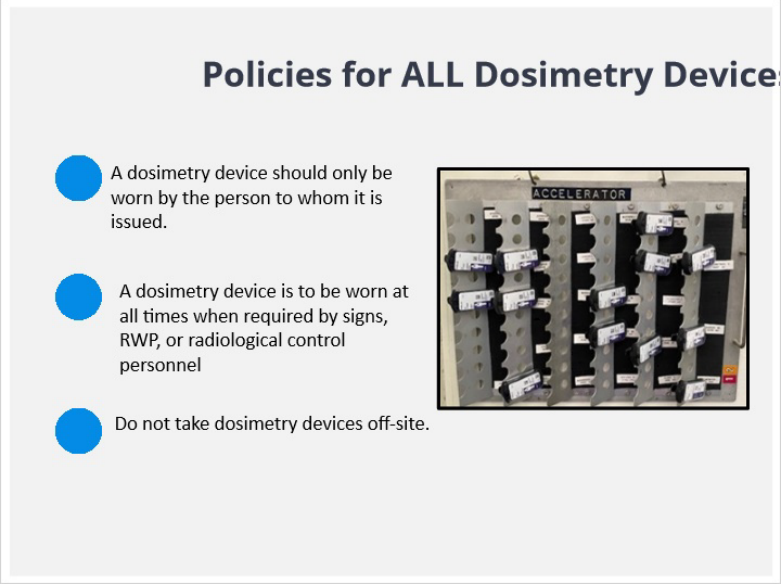

## *7.7 Dosimetry Devices*



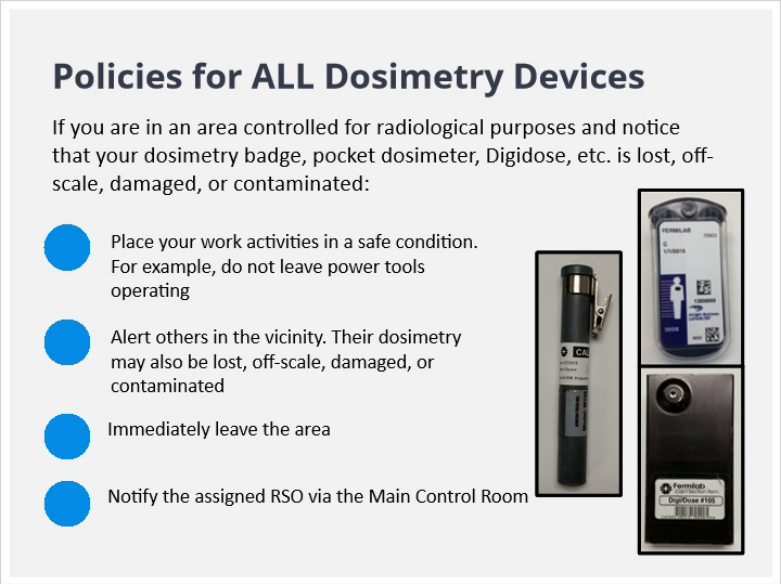
## *7.8 Dosimetry Devices - Digidose*



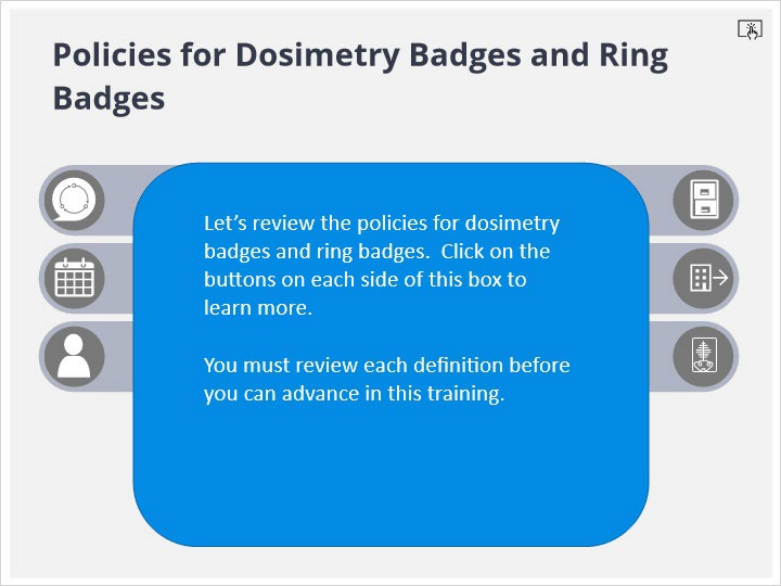

## *7.9 Policies for ALL Dosimetry Devices*



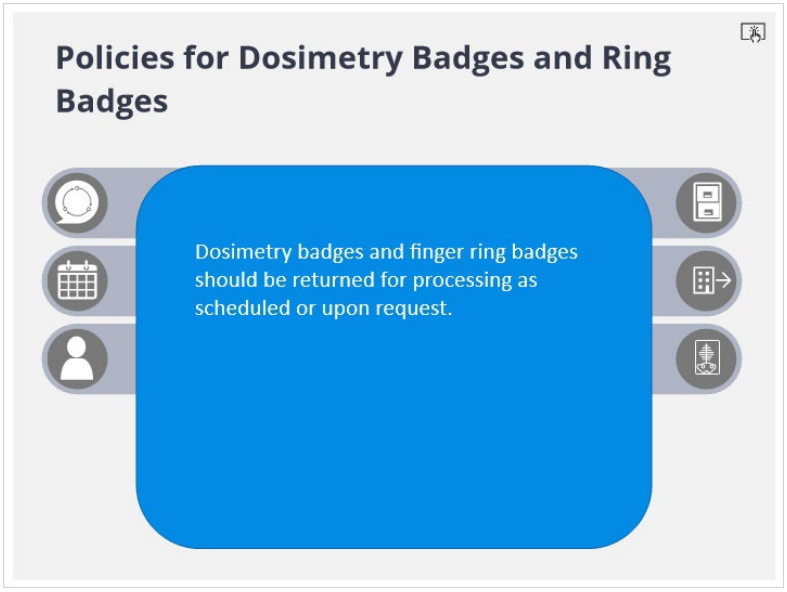
## *7.10 Policies for ALL Dosimetry Devices cont.*



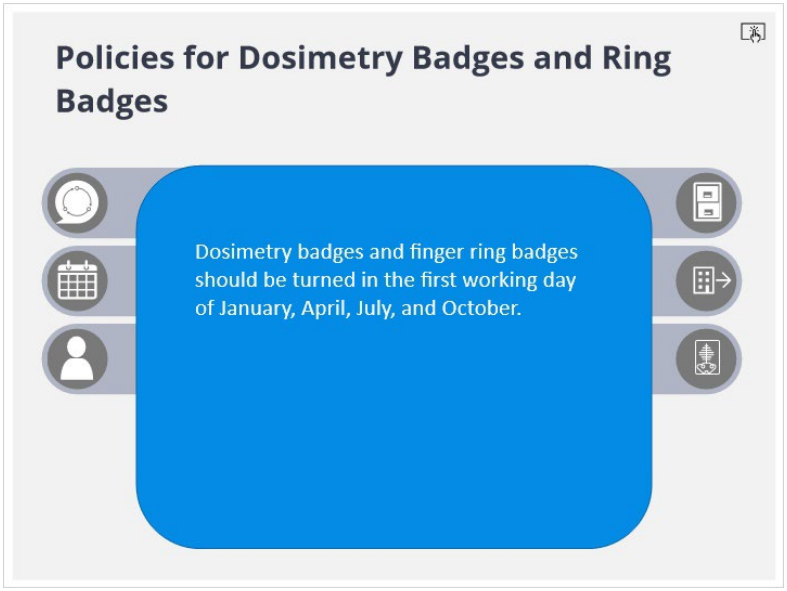

## *7.11 Policies for Dosimetry Badges and Ring Badges*



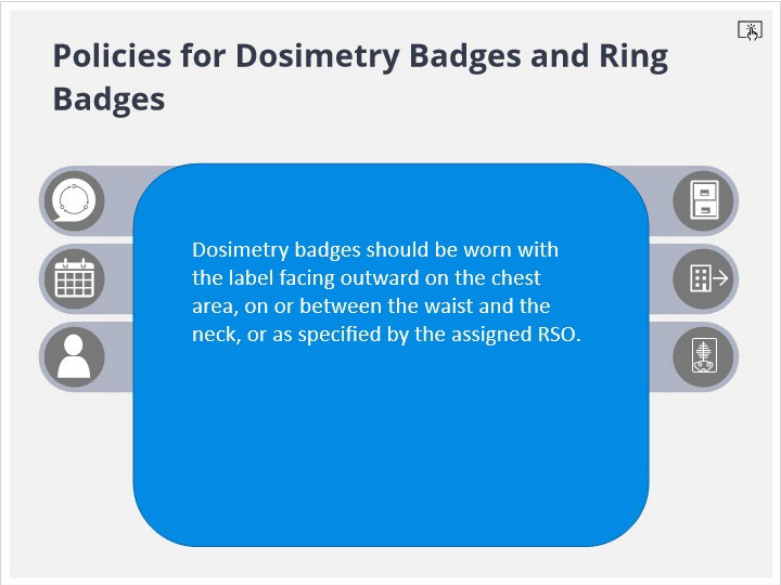
**Return for processing (Slide Layer)**



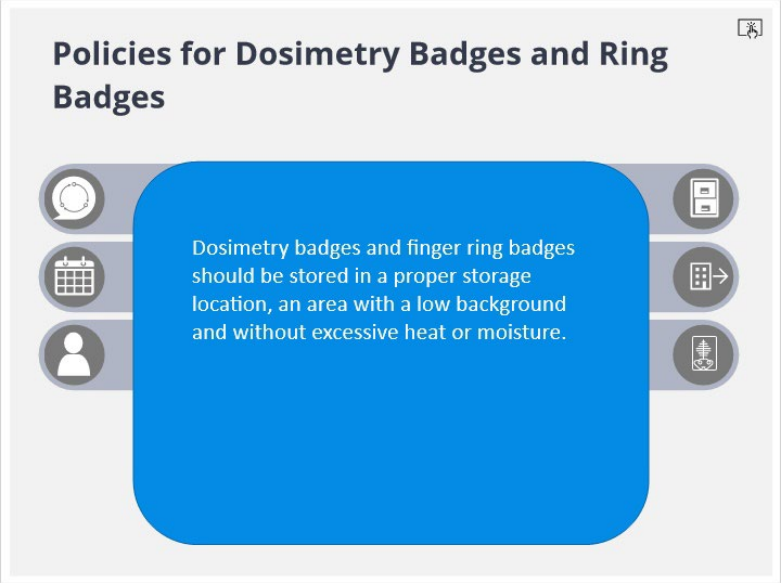

**Turn in (Slide Layer)**



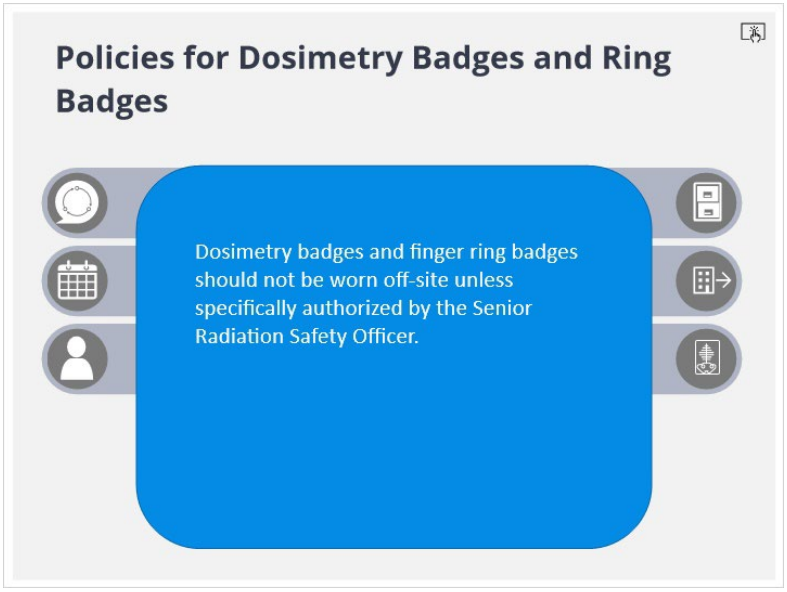
**Wear facing forward (Slide Layer)**



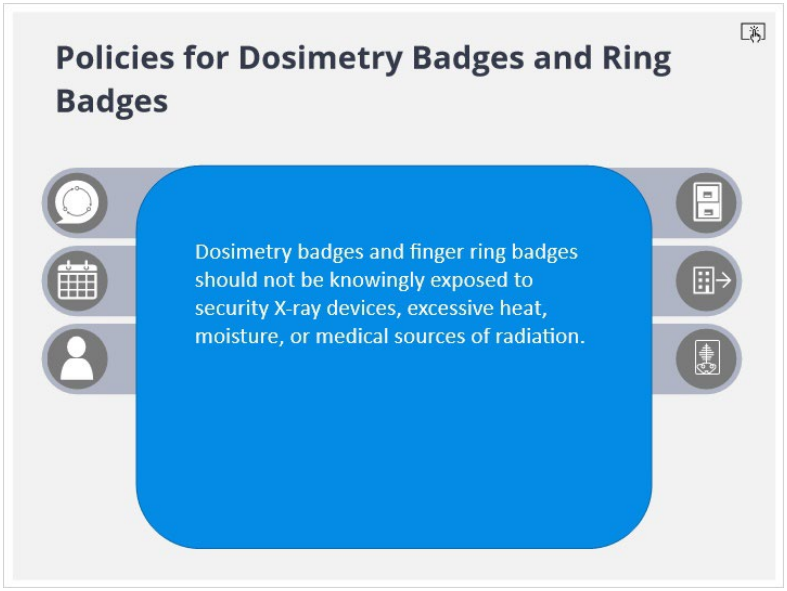

**Store in proper location (Slide Layer)**



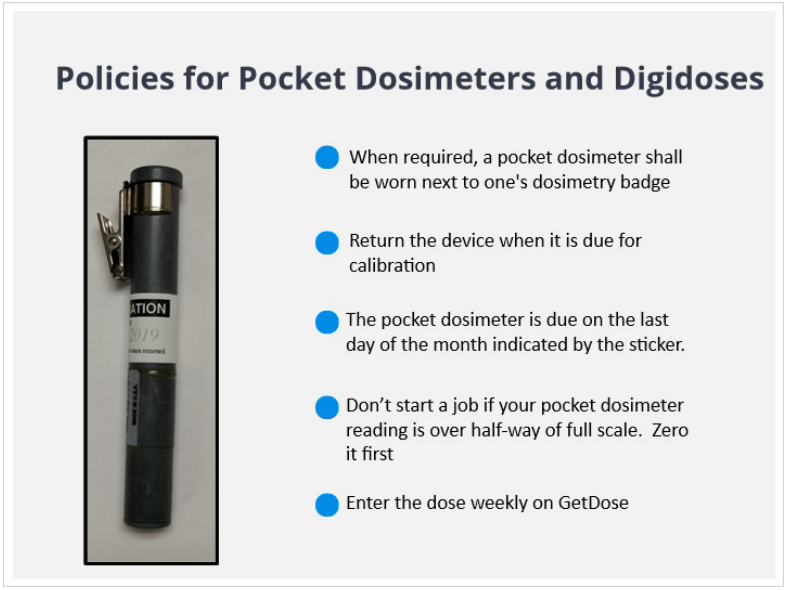
**Do not wear off-site (Slide Layer)**



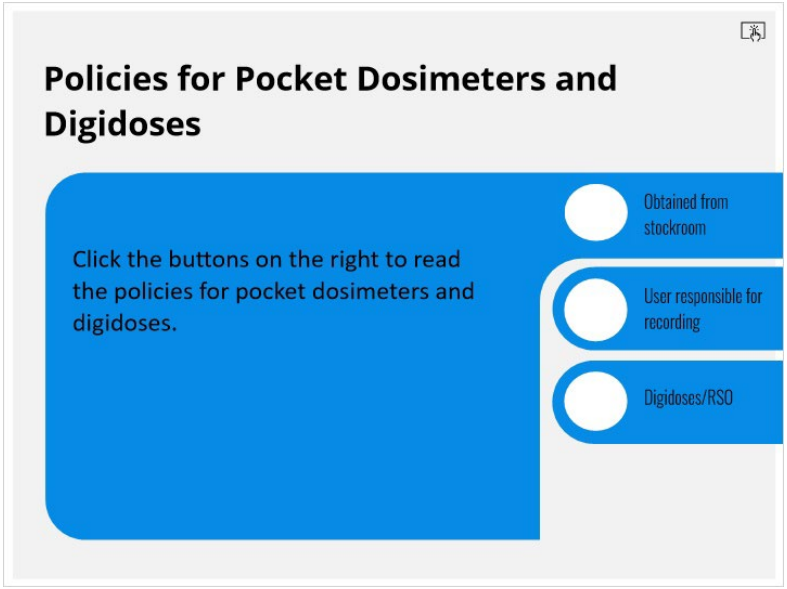

**Do not expose (Slide Layer)**



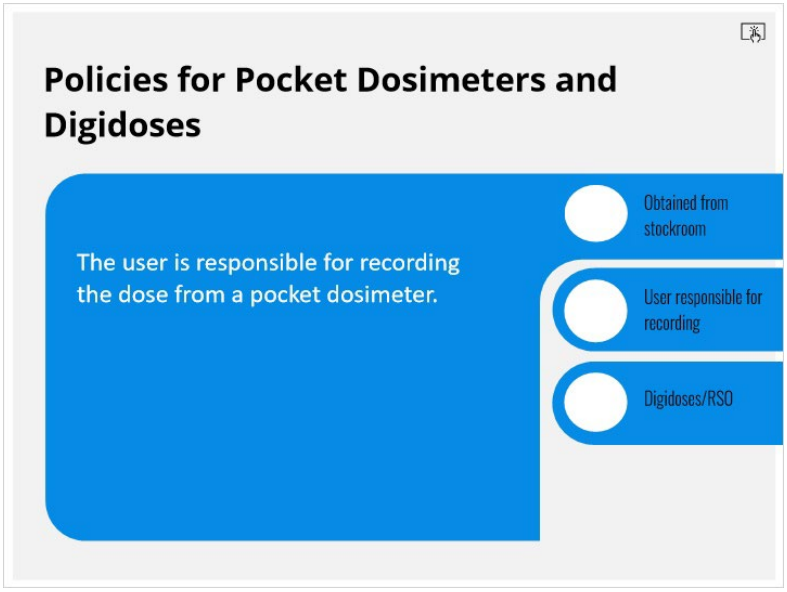
## *7.14 Policies for Pocket Dosimeters and Digidoses*



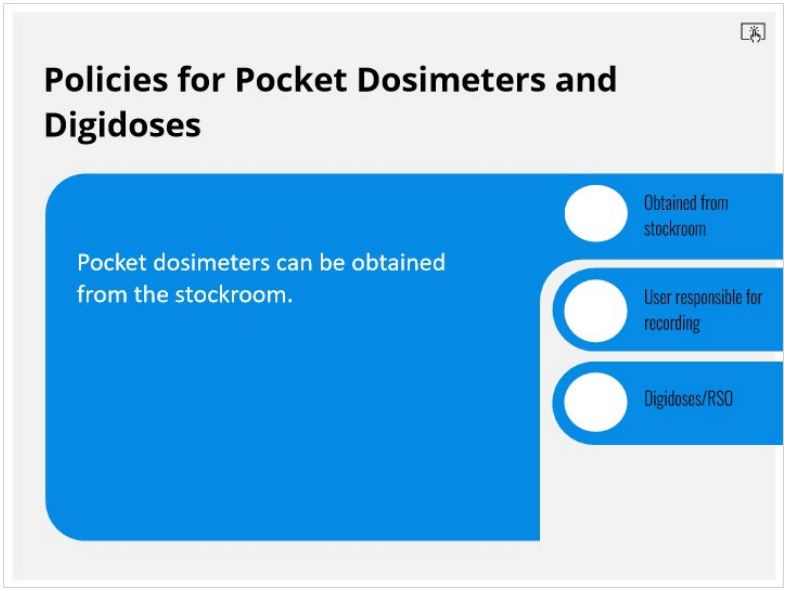

## *7.15 Policies for Pocket Dosimeters and Digidoses*



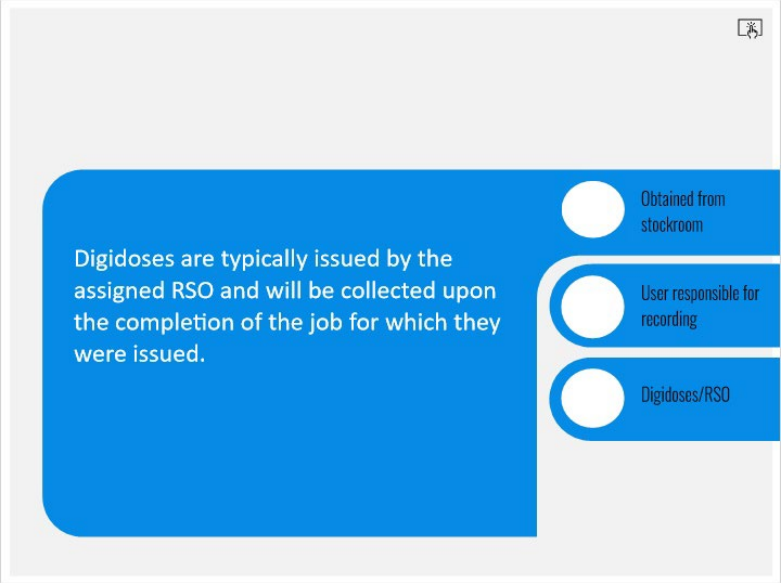
**User responsibility (Slide Layer)**



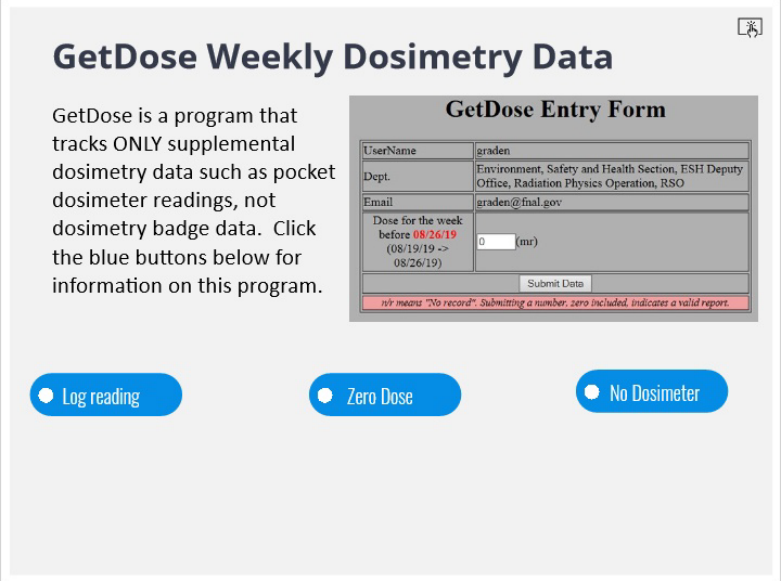

**stockroom (Slide Layer)**



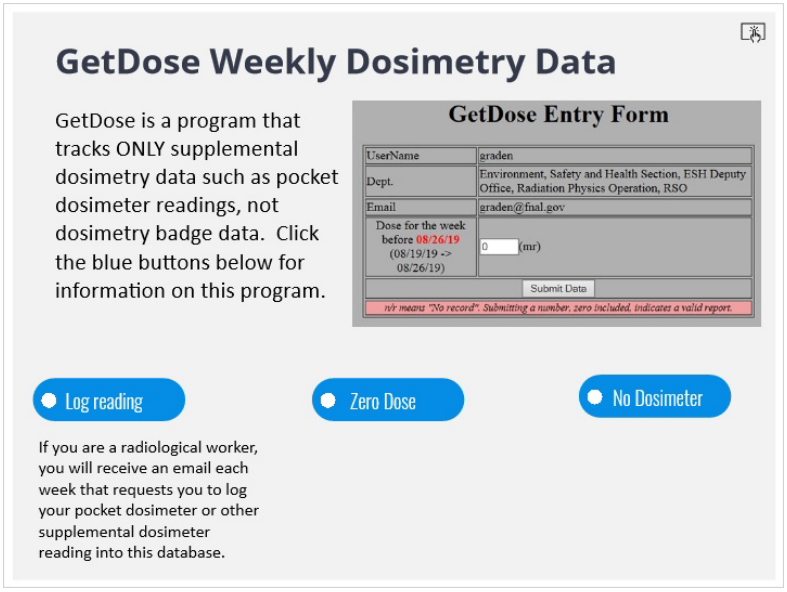
**RSO (Slide Layer)**



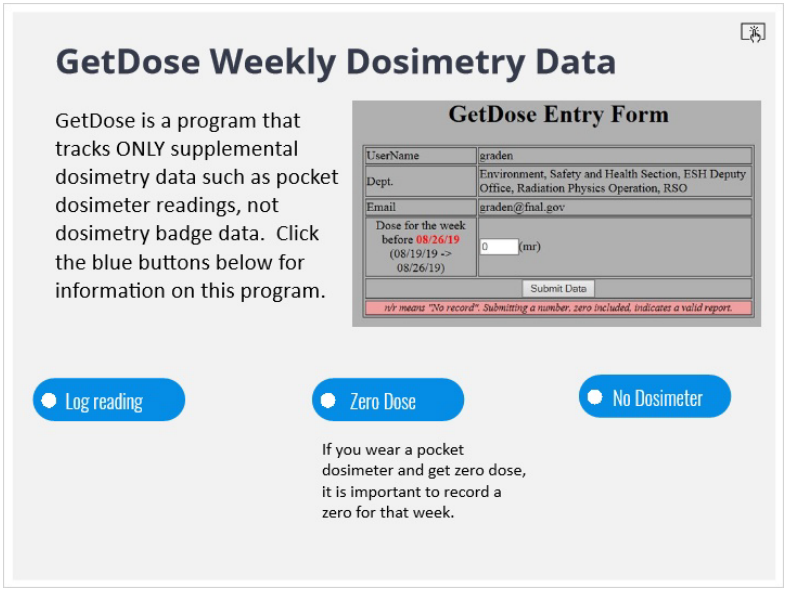

## *7.16 GetDose Weekly Dosimetry Data*



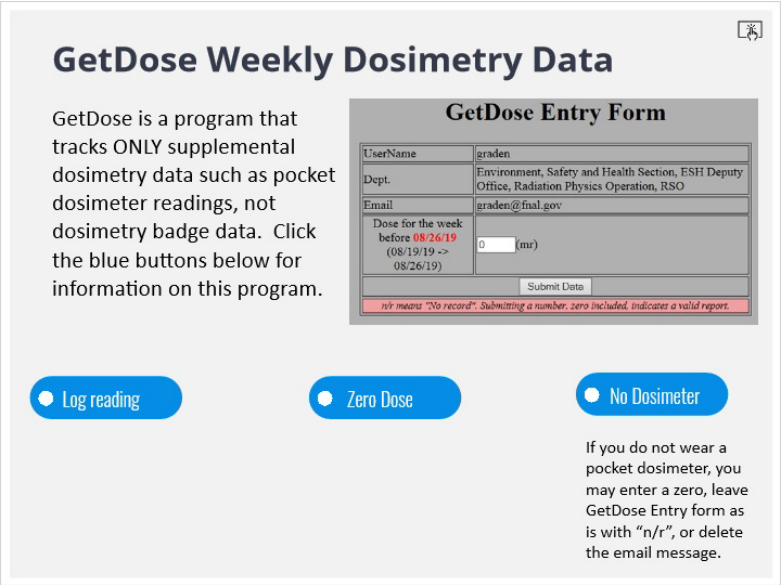
## Log reading (Slide Layer)



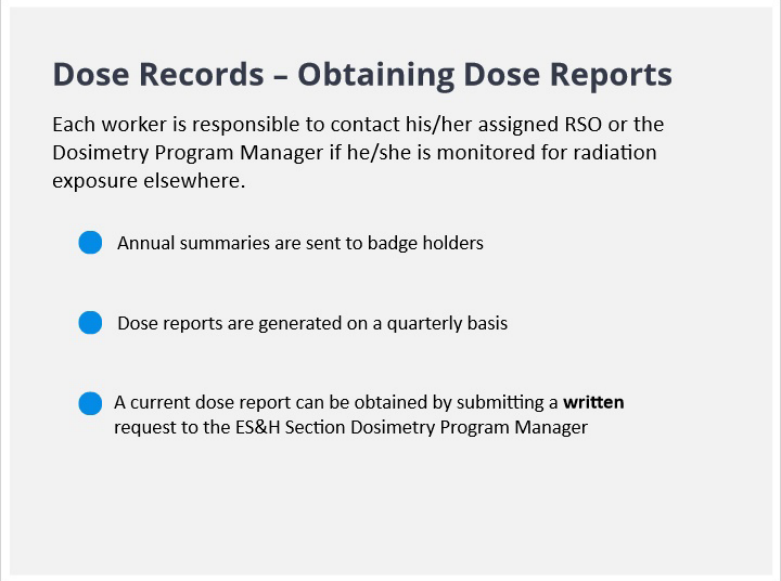

## Zero dose (Slide Layer)



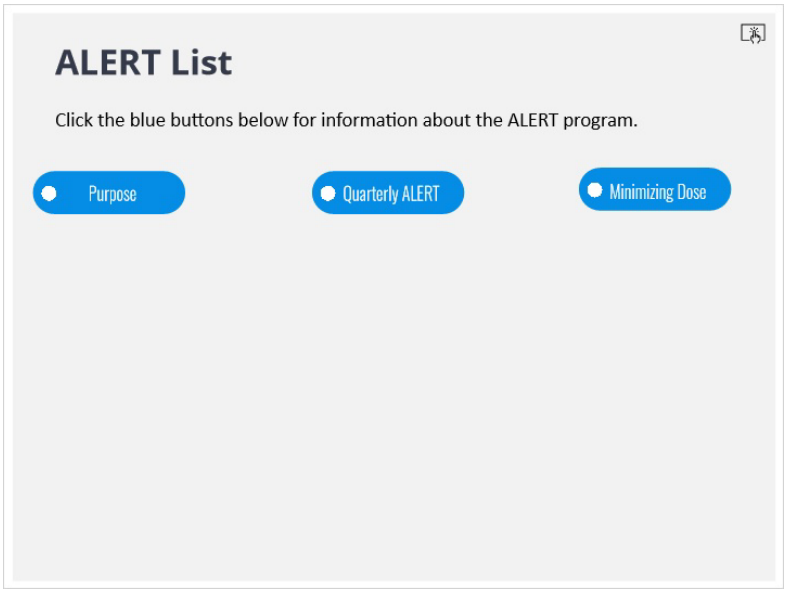
**no dosimeter (Slide Layer)**



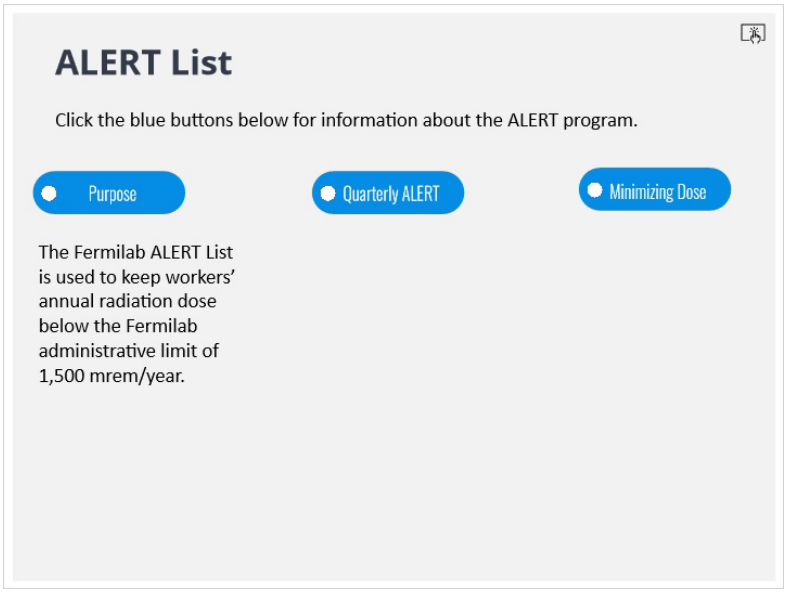

## *7.17 Dose Records – Obtaining Dose Reports*



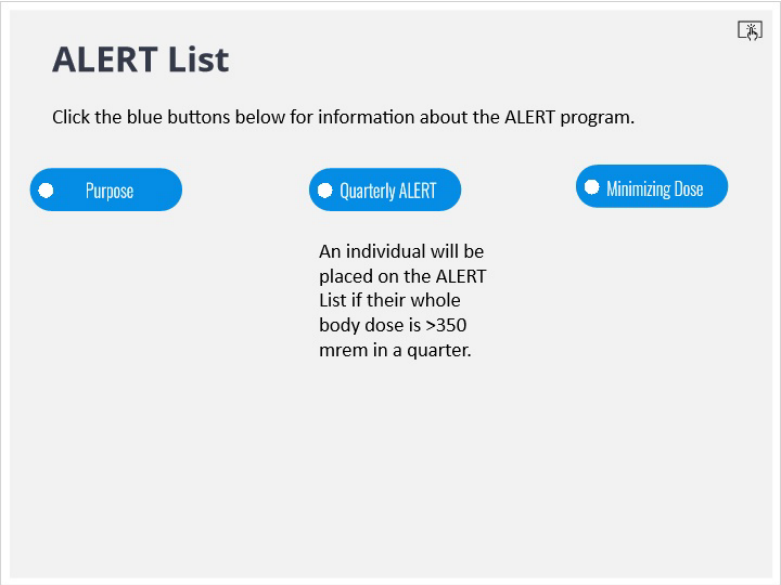
## *7.18 ALERT List*



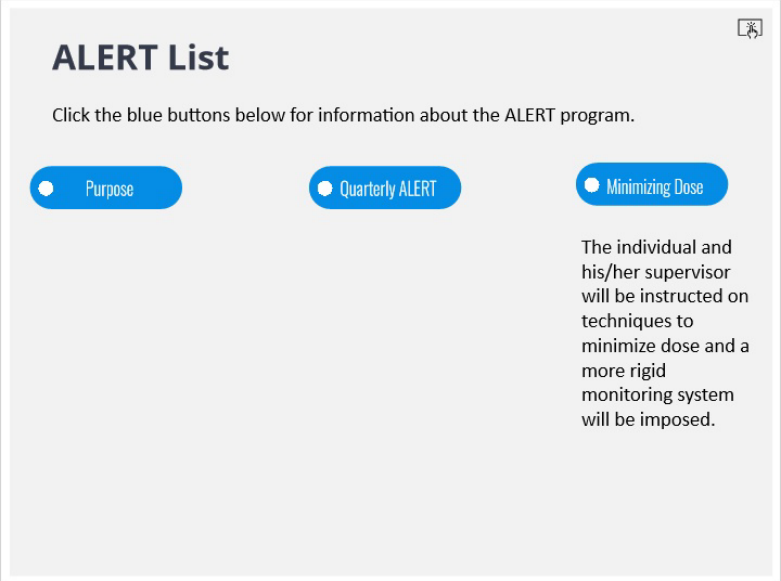

**Annual ALERT (Slide Layer)**



## Quarterly ALERT (Slide Layer)



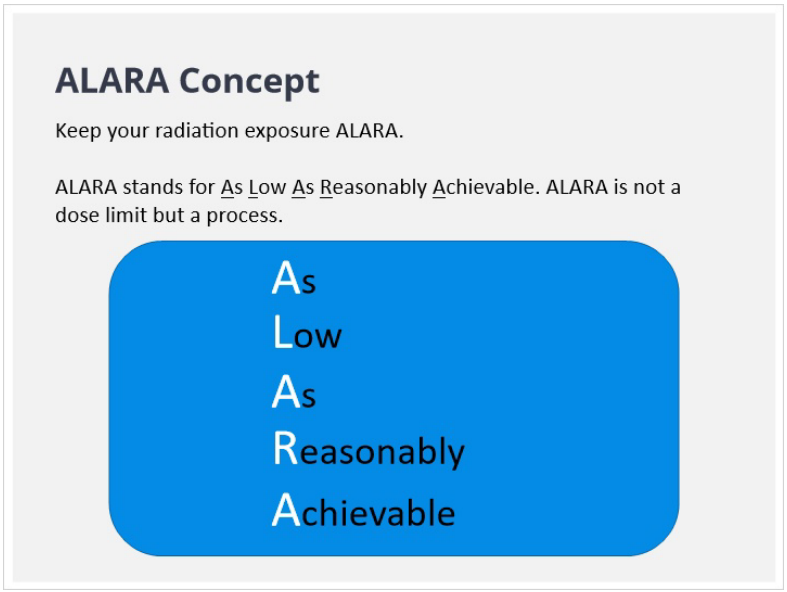

## Minimizing Dose (Slide Layer)



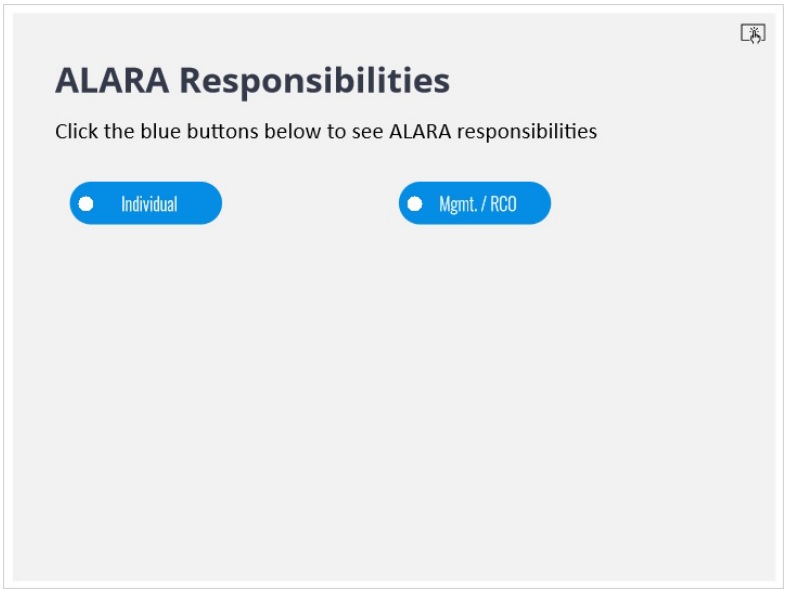
## 8. Keeping Exposures ALARA

### *8.1 Keeping Exposures ALARA*

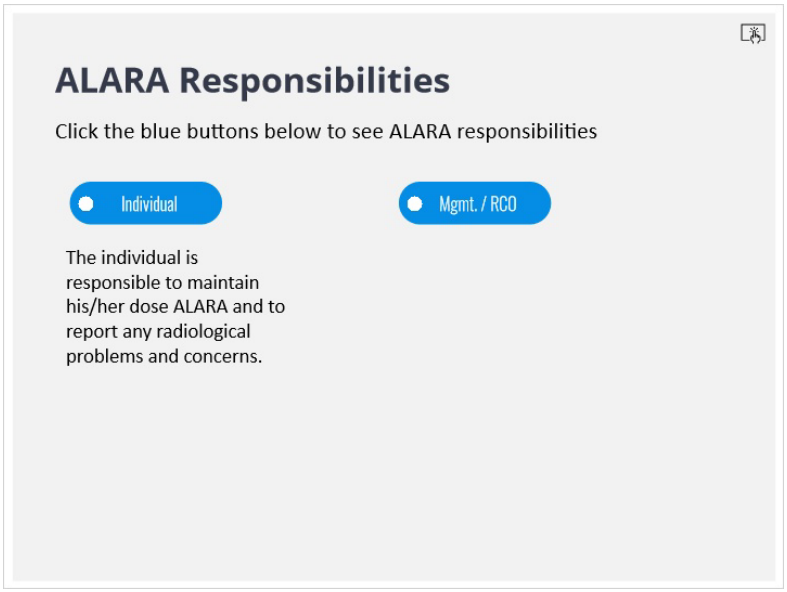

### *8.2 ALARA Concept*



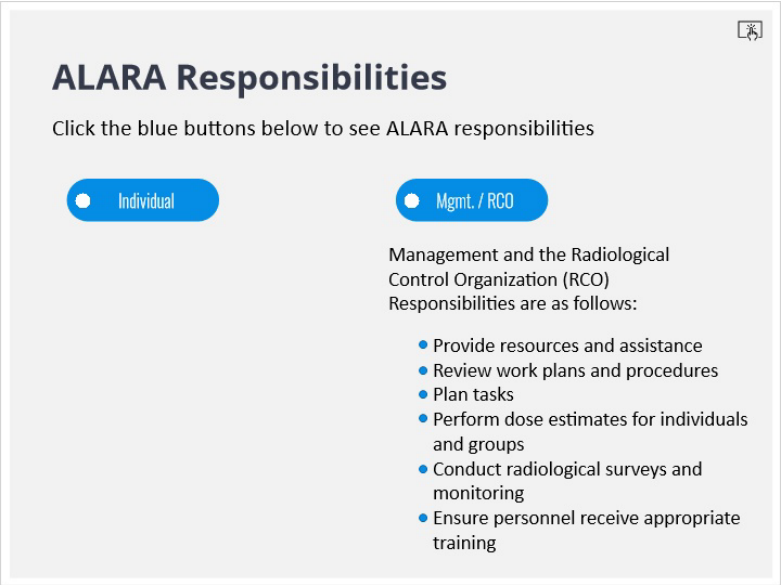
## *8.3 ALARA Responsibilities*



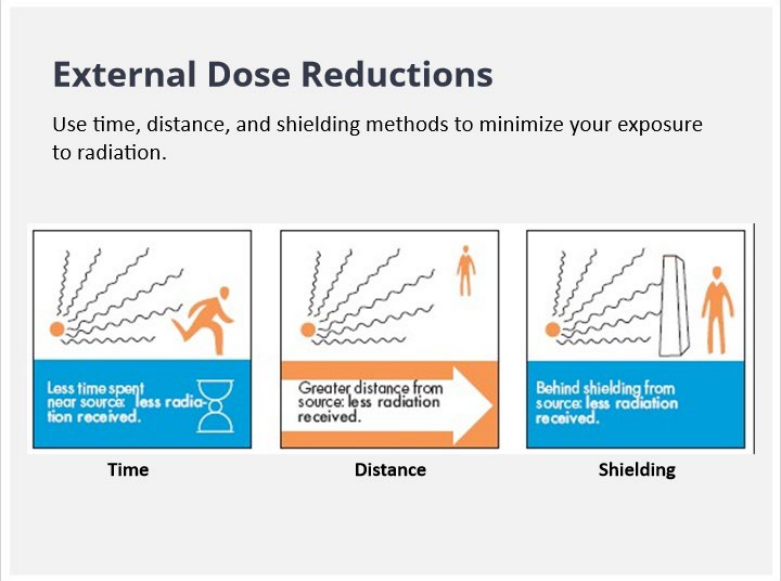

**Individual (Slide Layer)**



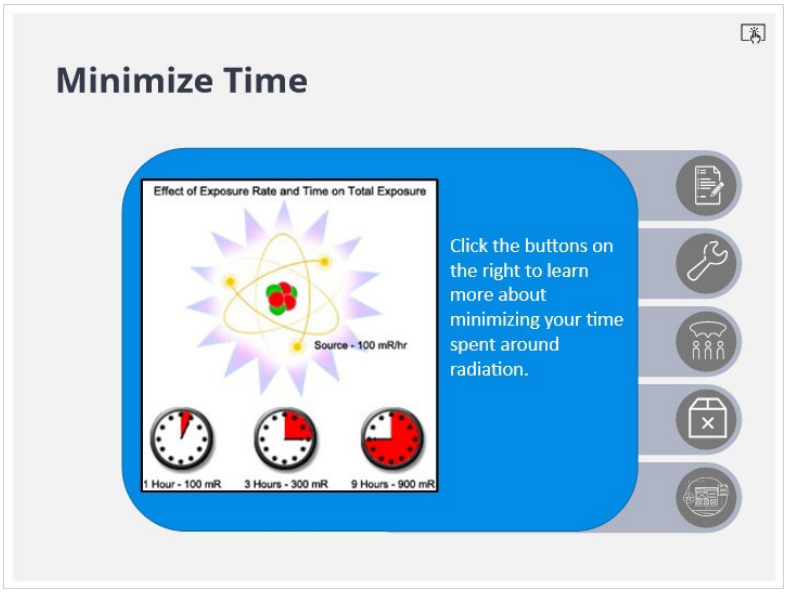
**Management/RCO (Slide Layer)**



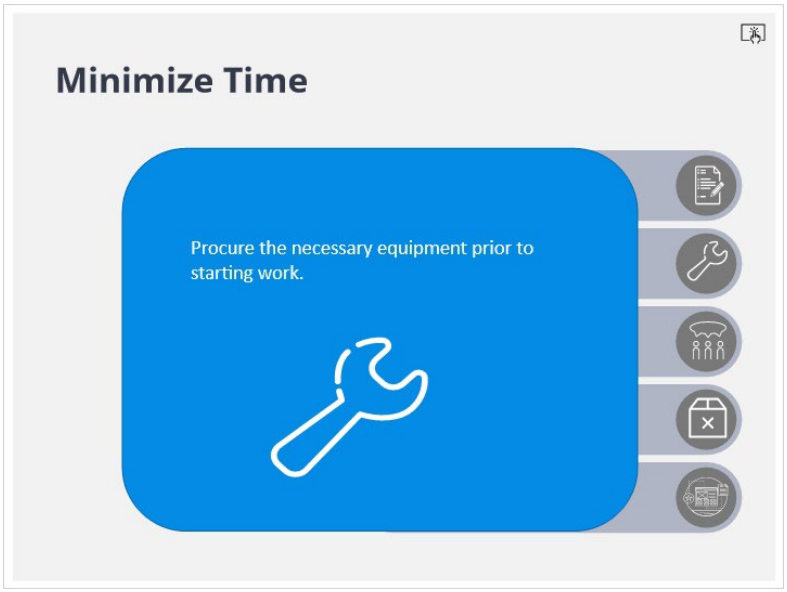

## *8.4 External Dose Reductions*



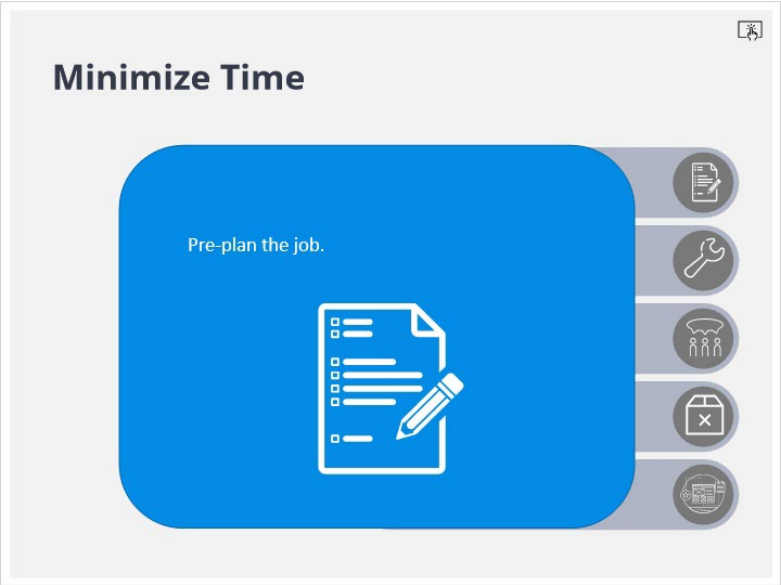
## *8.5 Minimize Time*



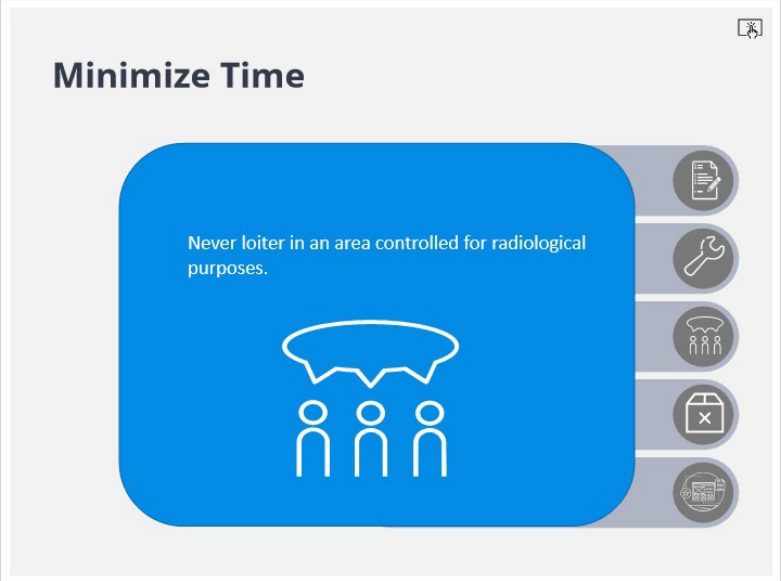

**Procure equipment (Slide Layer)**



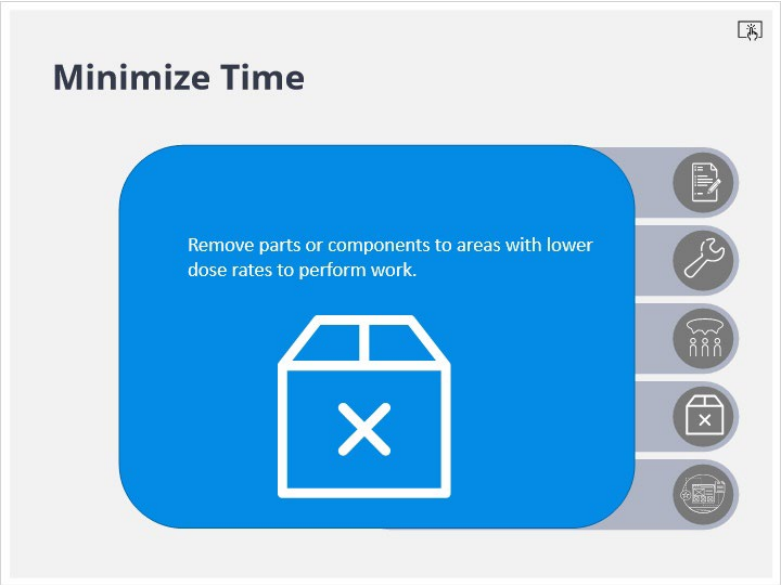
**Pre-plan (Slide Layer)**



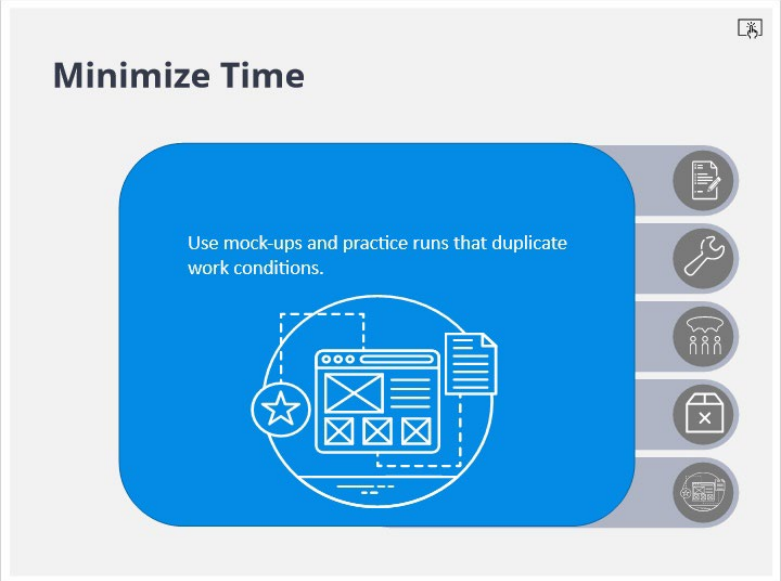

**Never Loiter (Slide Layer)**



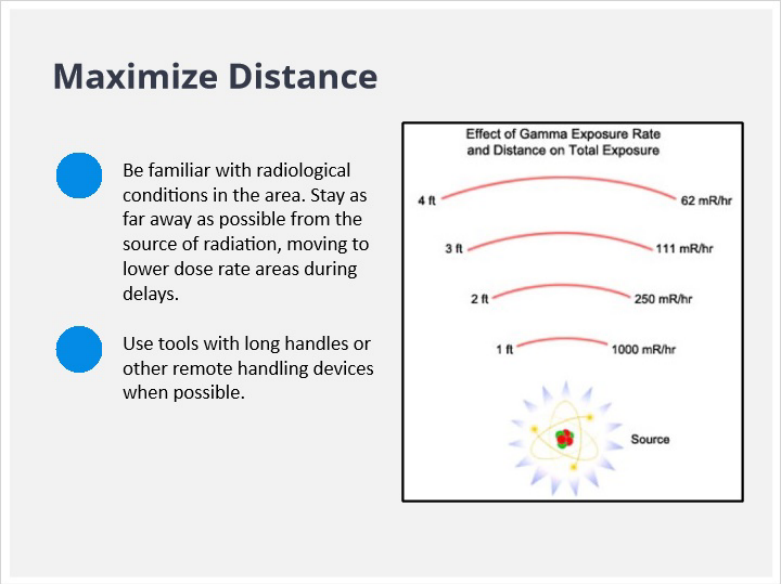
**Remove (Slide Layer)**



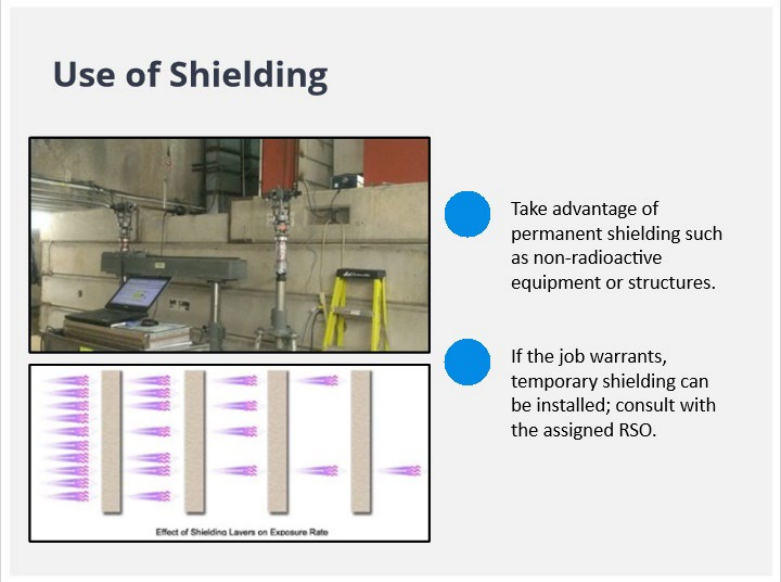

**Mock-ups (Slide Layer)**



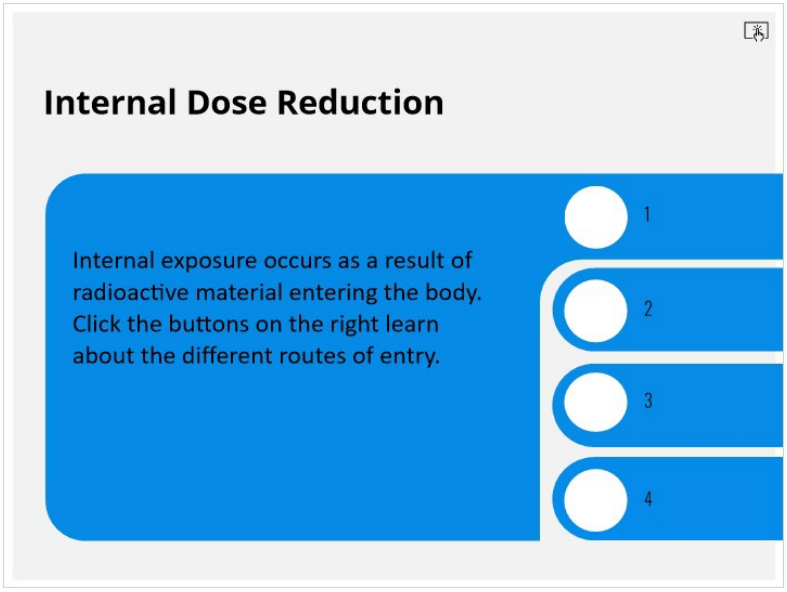
## *8.6 Maximize Distance*



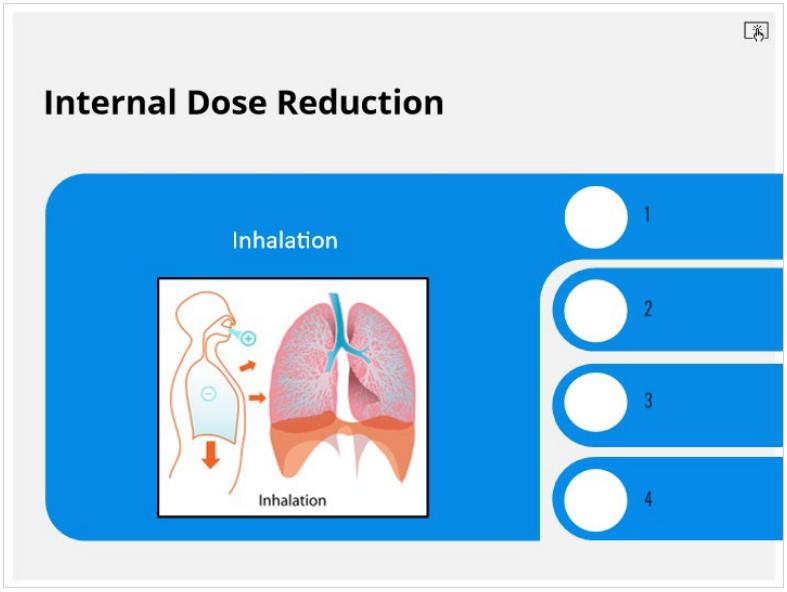

## *8.7 Use of Shielding*



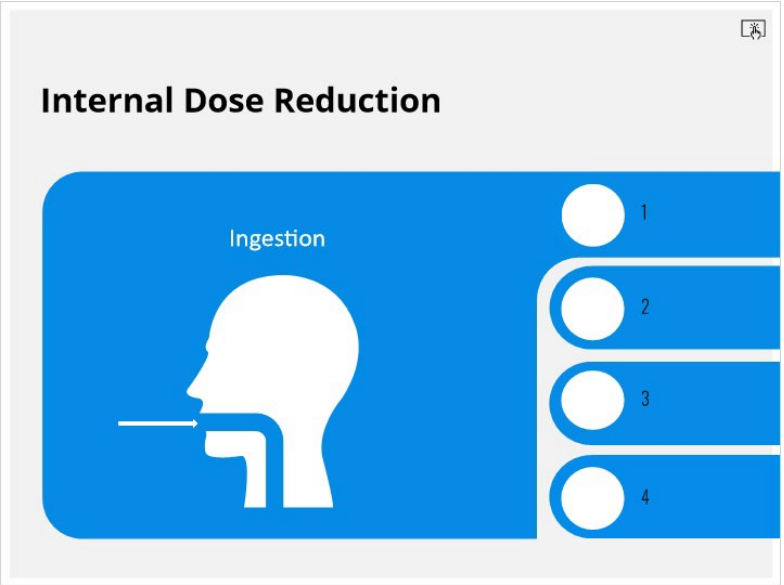
## *8.9 Internal Dose Reduction*




**Inhalation (Slide Layer)**

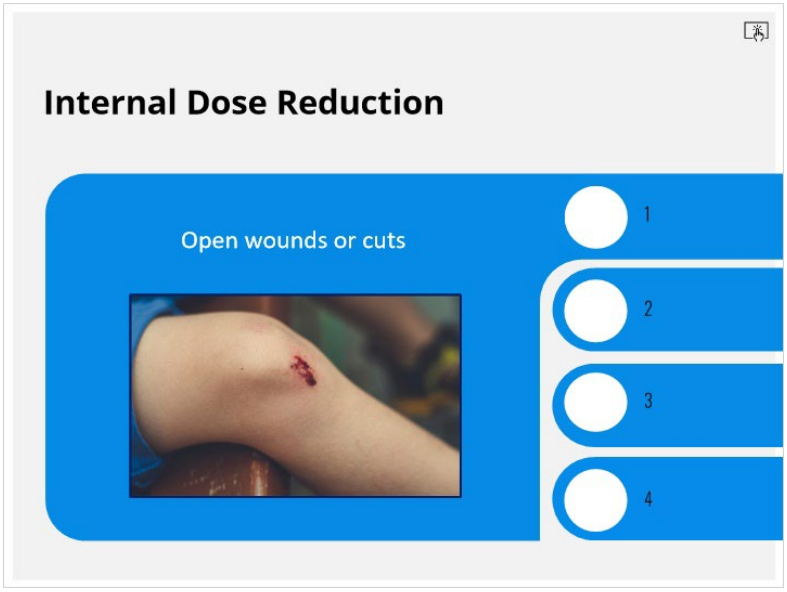


**Ingestion (Slide Layer)**

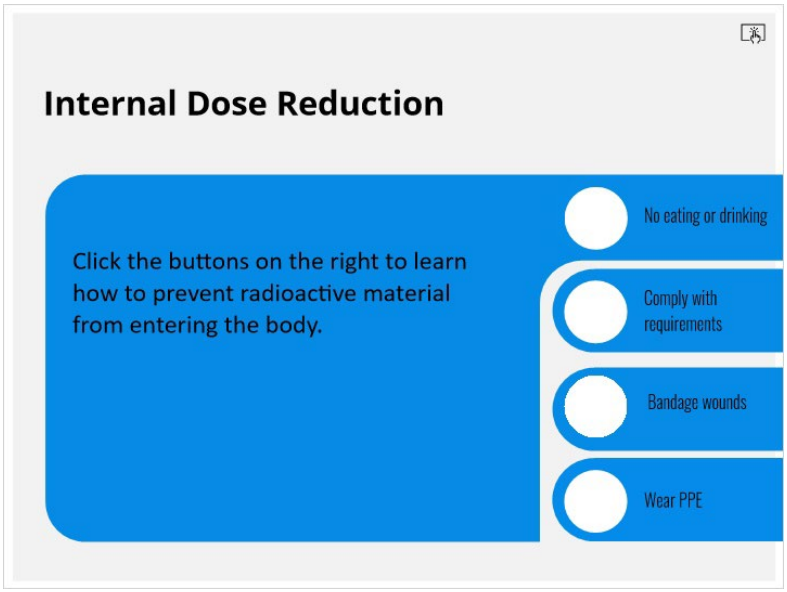



**Absorption (Slide Layer)**

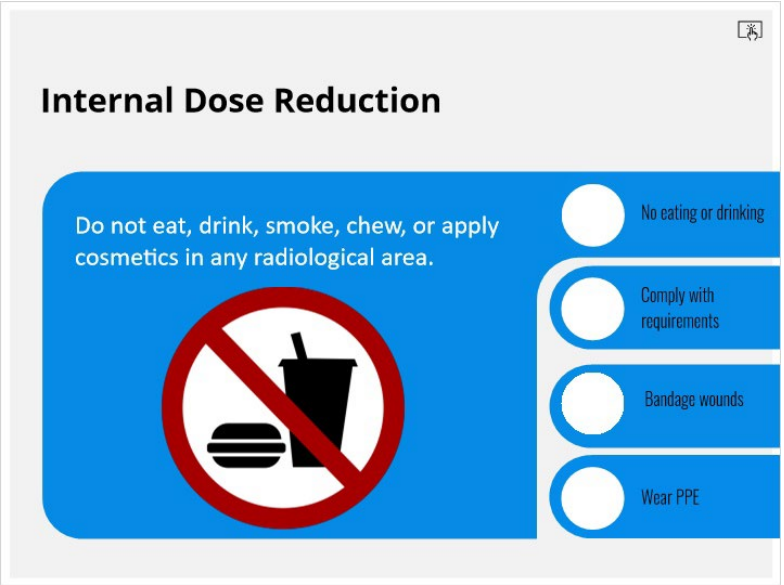
**Wounds (Slide Layer)**



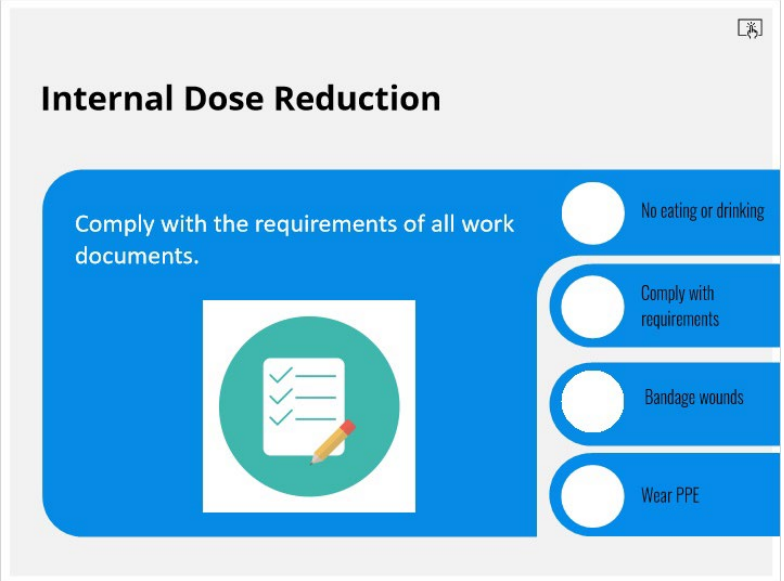

***8.10 Internal Dose Reduction Cont.***



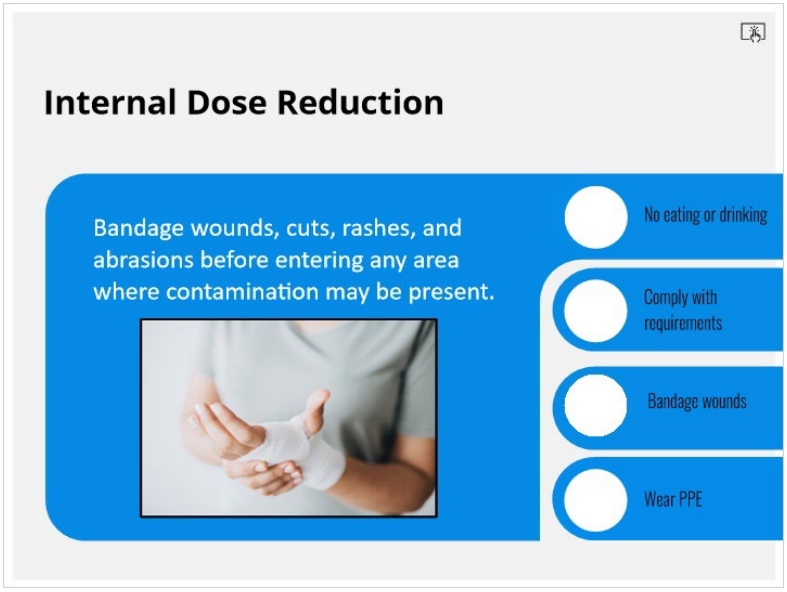
**No eating or drinking (Slide Layer)**



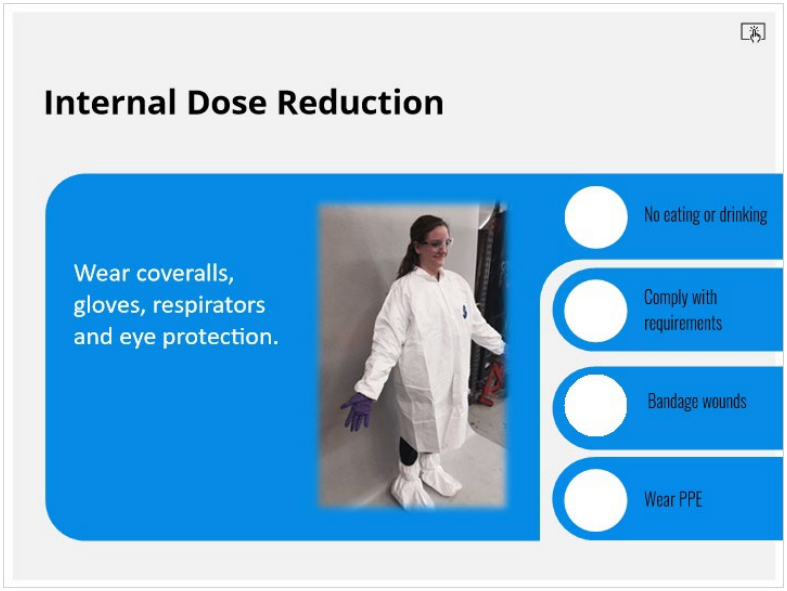

**Comply (Slide Layer)**



**Bandage wounds (Slide Layer)**

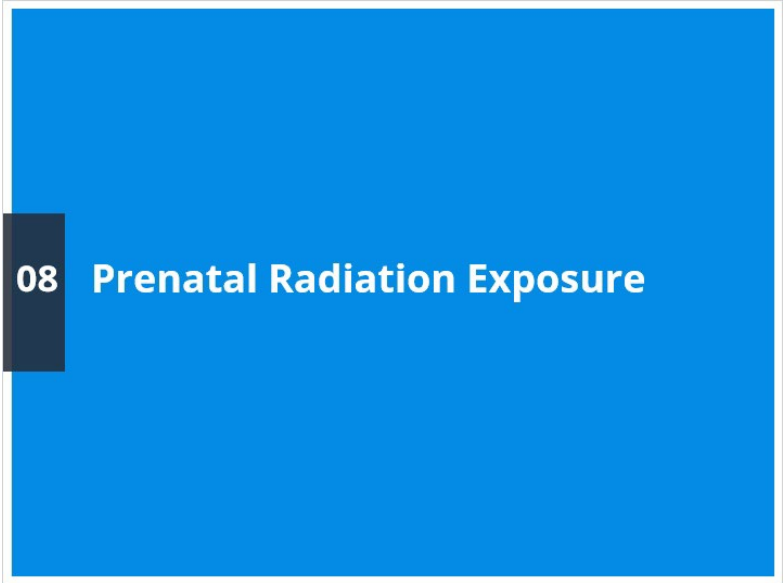



**PPE (Slide Layer)**

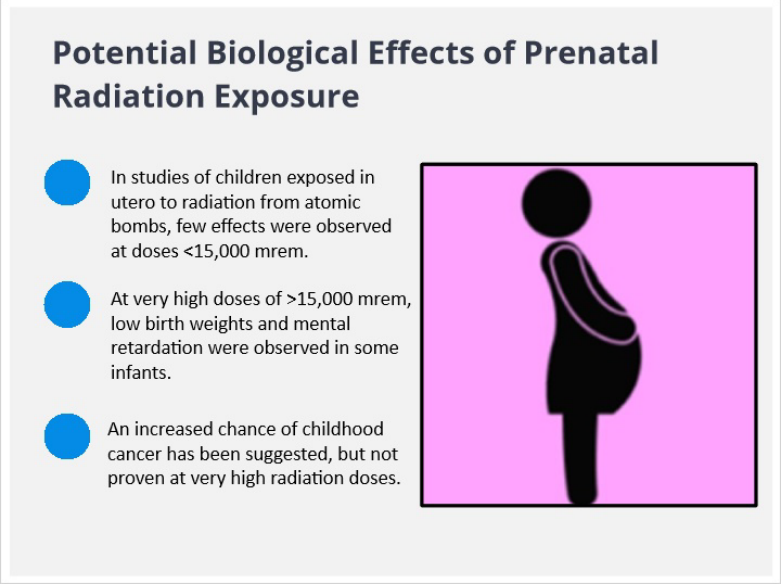


## 9. Prenatal Radiation Exposure

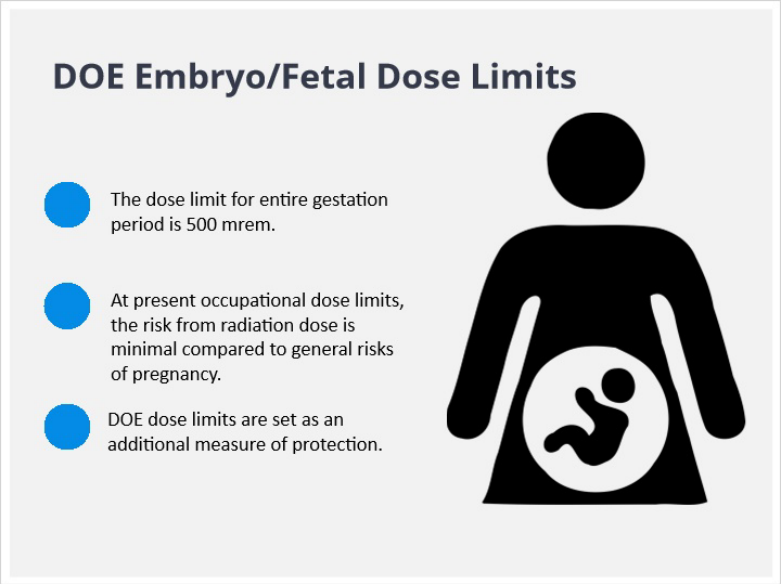
### *9.1 Prenatal Radiation Exposure*



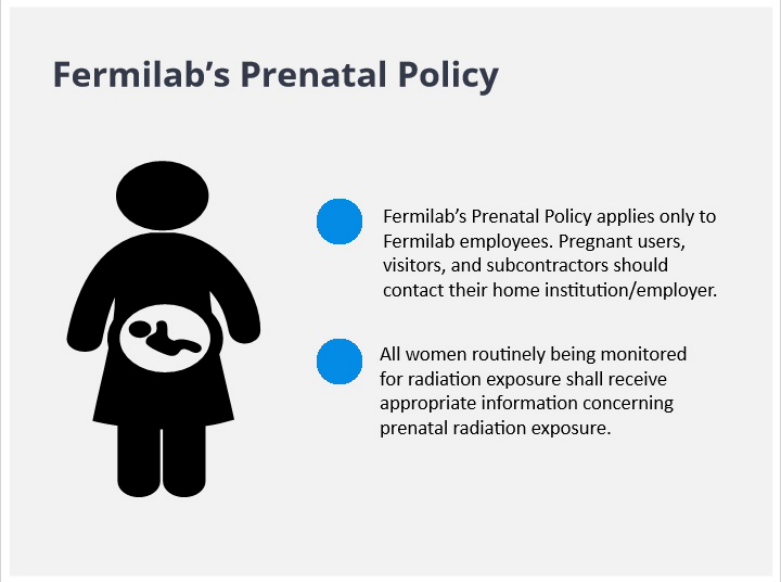

### *9.2 Potential Biological Effects of Prenatal Radiation Exposure*



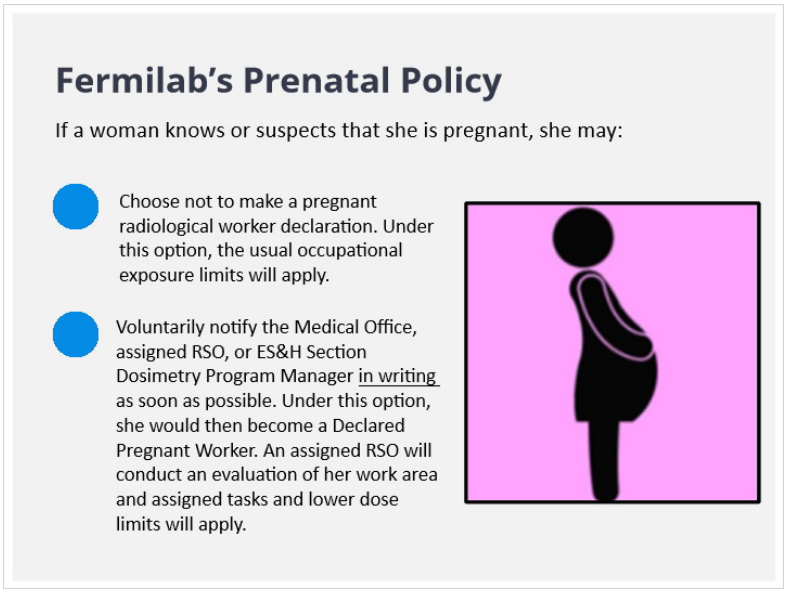
## *9.3 DOE Embryo/Fetal Dose Limits*



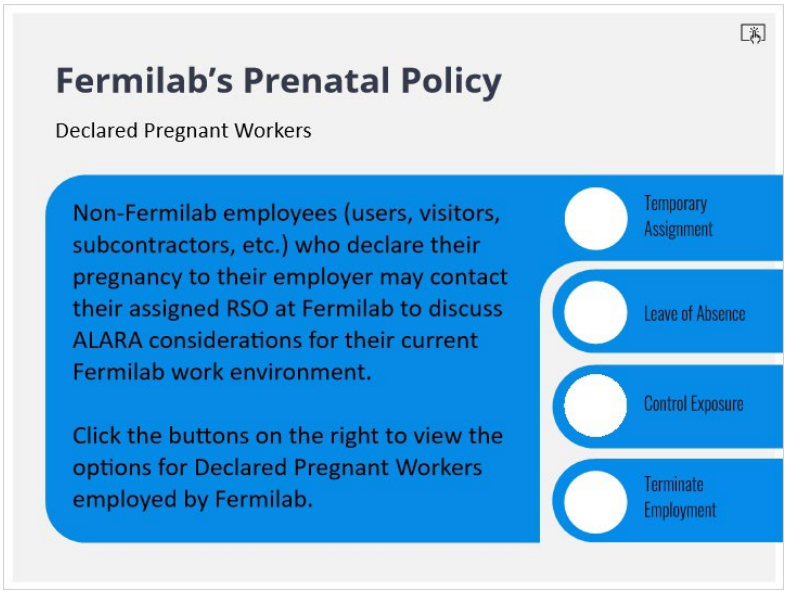

## *9.4 Fermilab's Prenatal Policy*



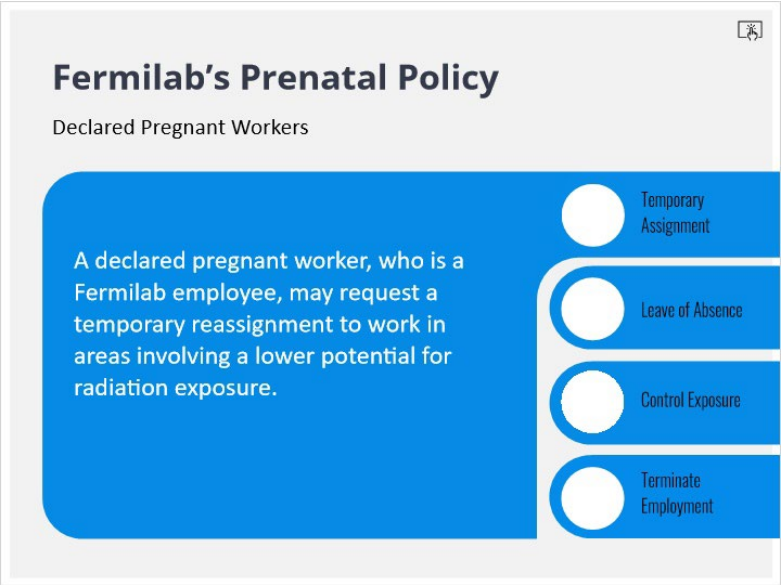
## *9.5 If A Women knows or Suspects She is Pregnant*



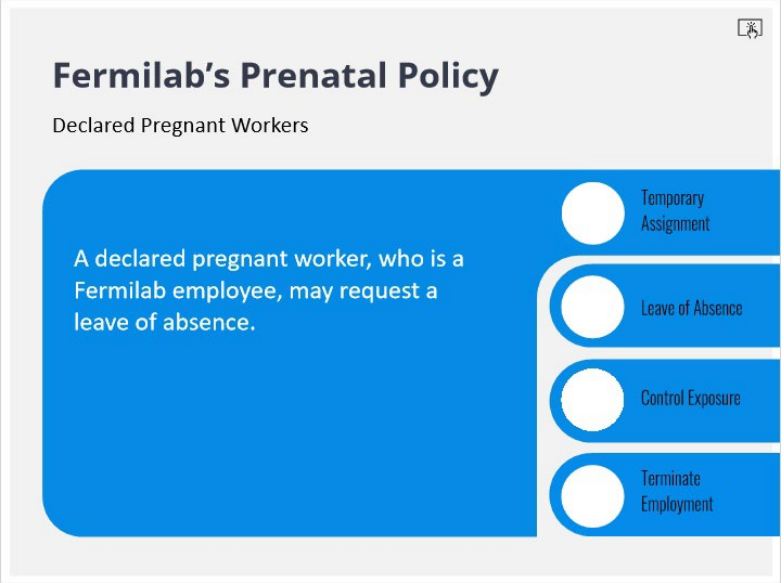

## *9.6 Fermilab's Prenatal Policy Cont.*



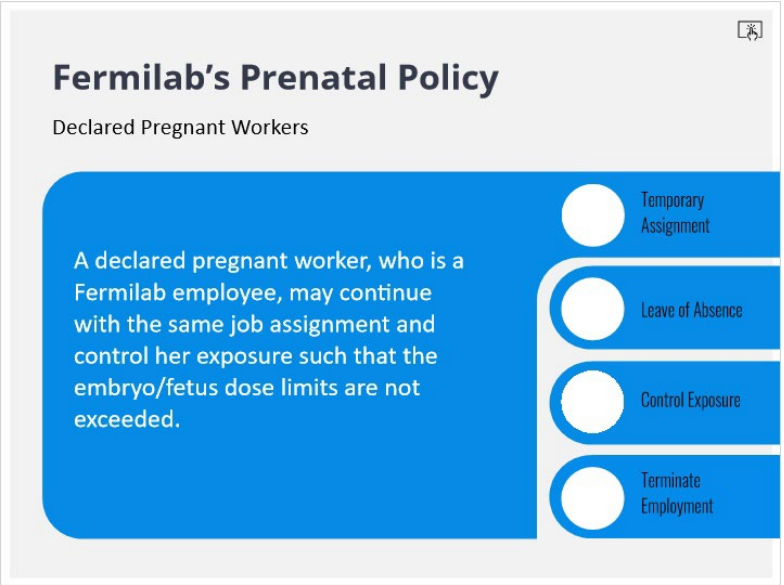
## Temporary Assignment (Slide Layer)



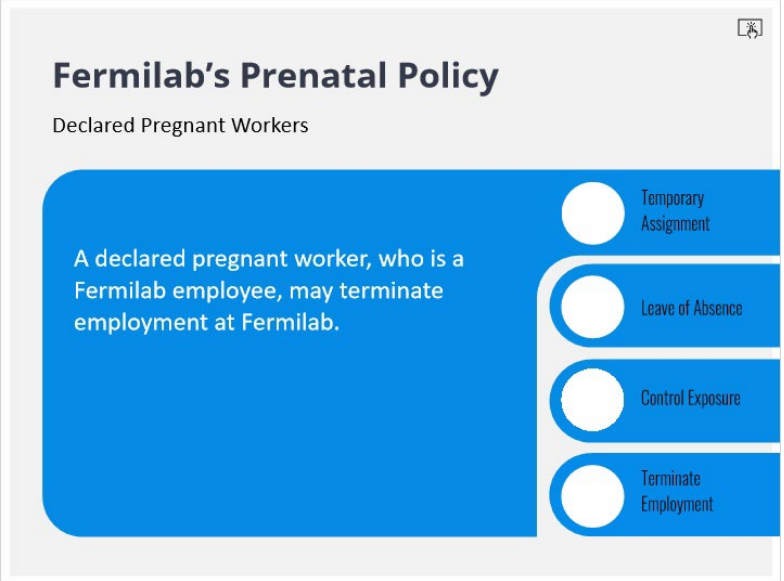

## Leave of Absence (Slide Layer)



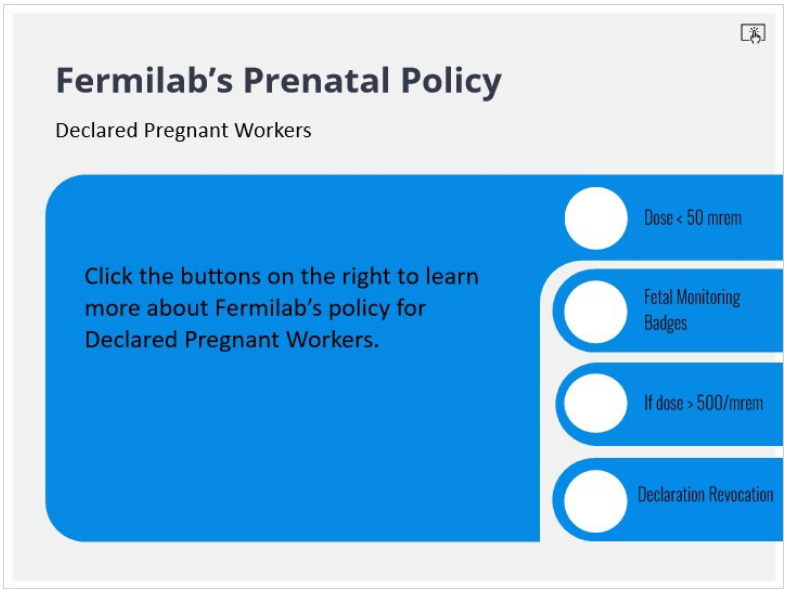
**Control Exposure (Slide Layer)**



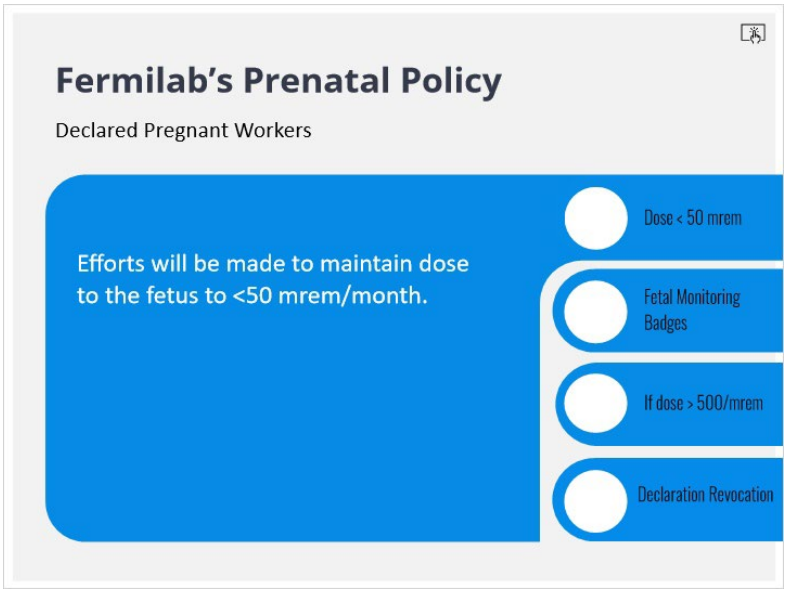

**Terminate employment (Slide Layer)**



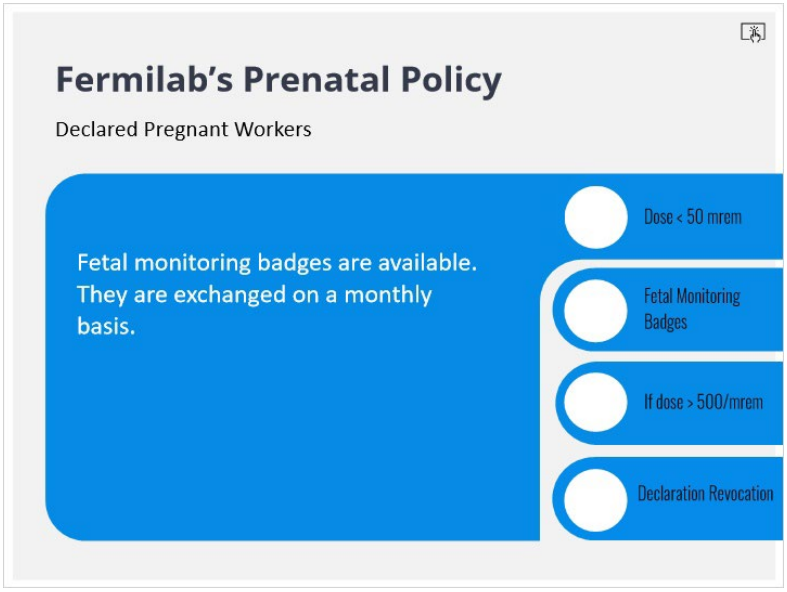
## *9.7 Fermilab's Prenatal Policy Cont.*



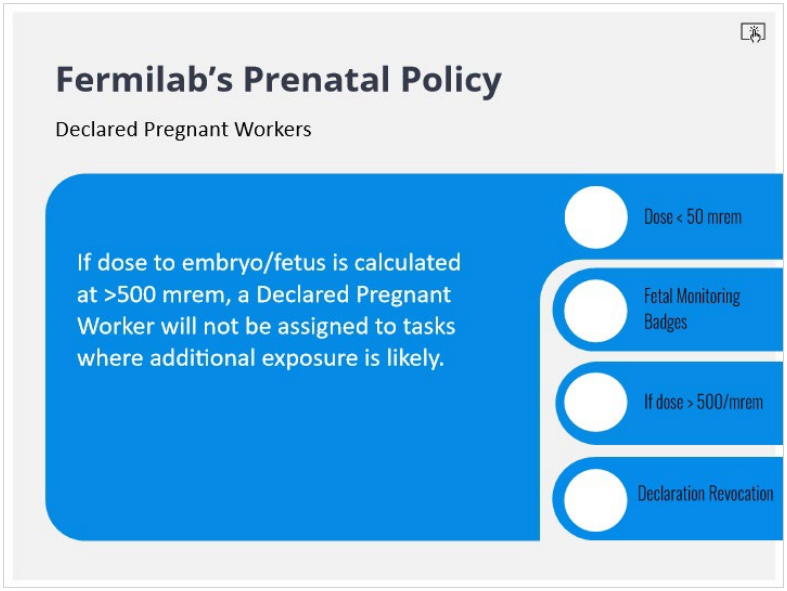

**Dose < 50 (Slide Layer)**



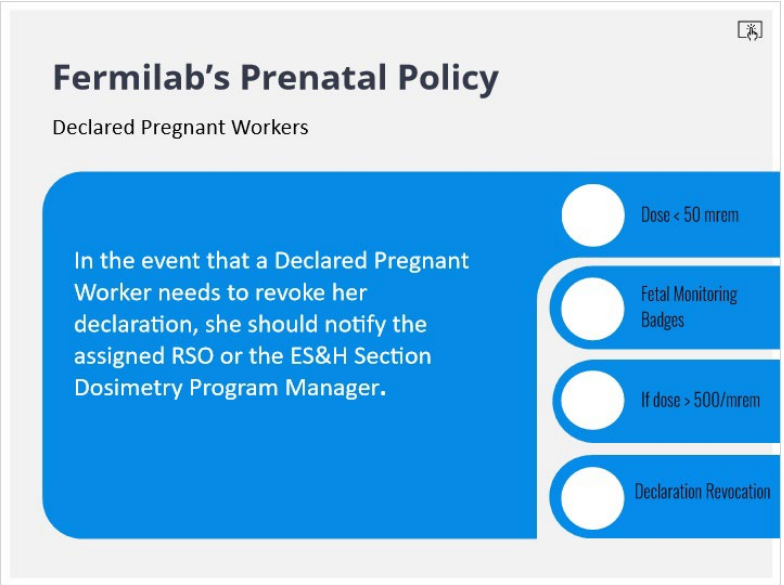
**Fetal Monitoring (Slide Layer)**




**Dose > 500 (Slide Layer)**



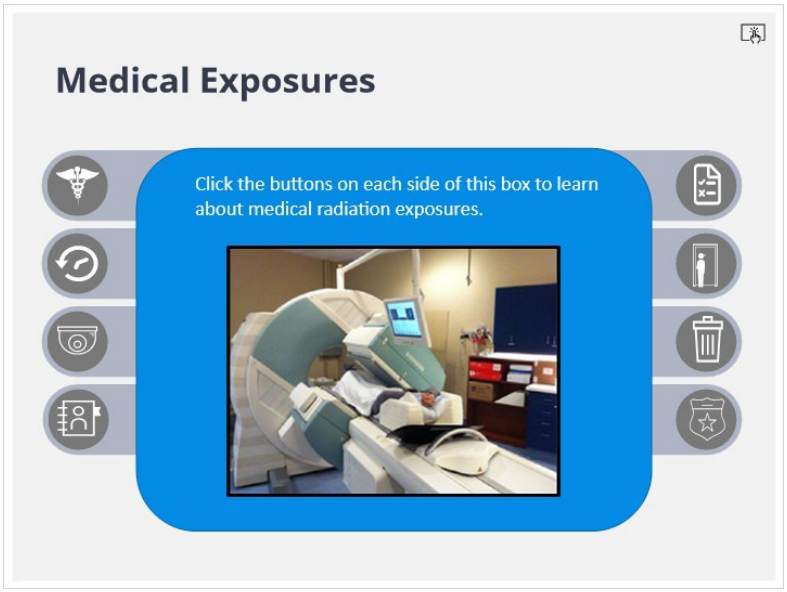
**Declaration Revocation (Slide Layer)**



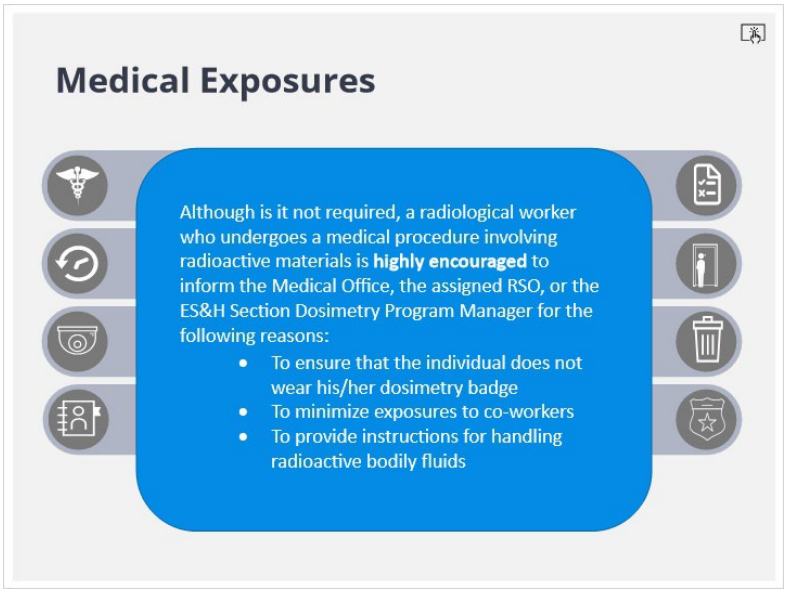

## 10. Medical Radiation Exposures

### *10.1 Medical Radiation Exposure*

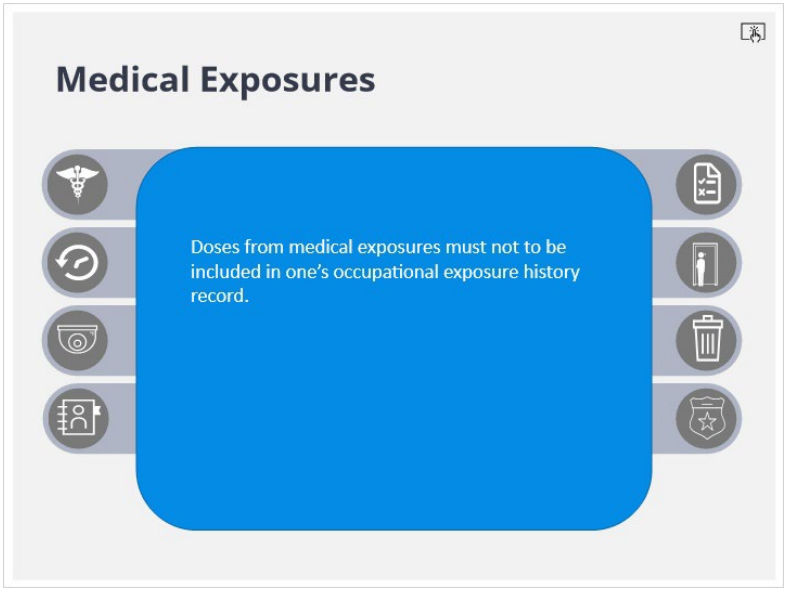
## *10.2 Medical Exposures*



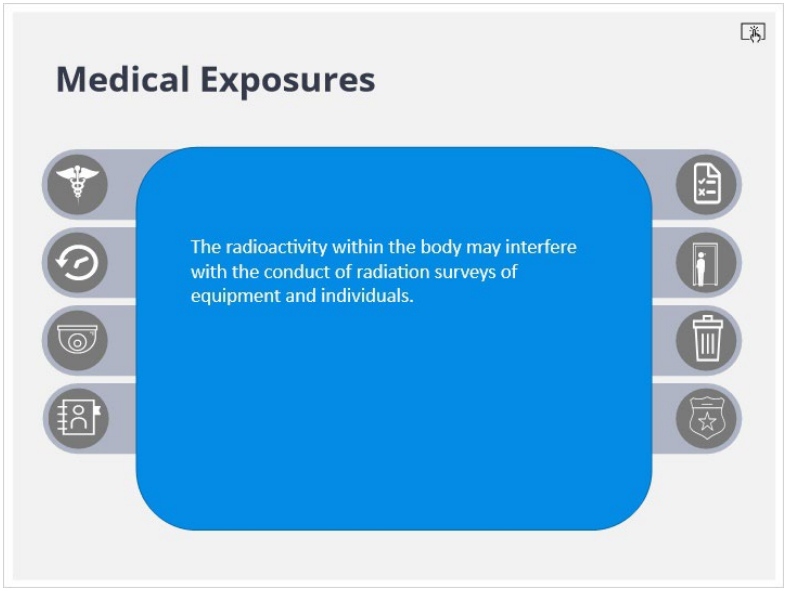

**Inform medical (Slide Layer)**



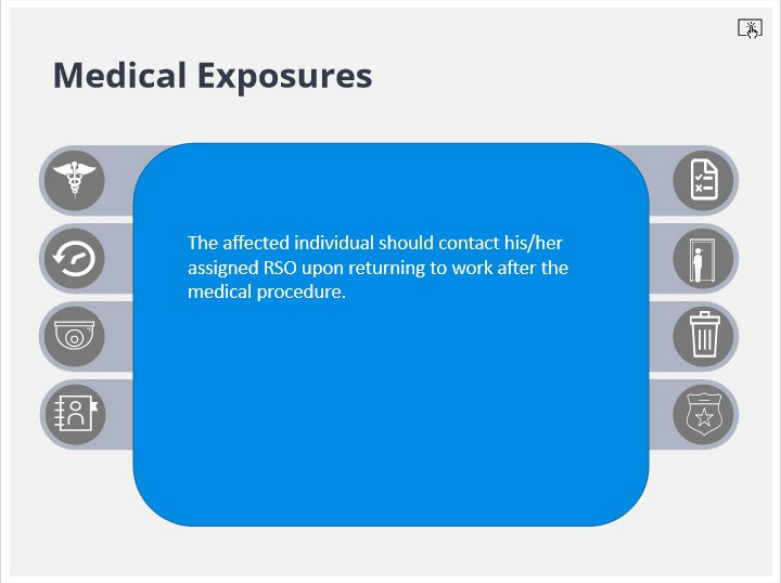
**Not included in history (Slide Layer)**



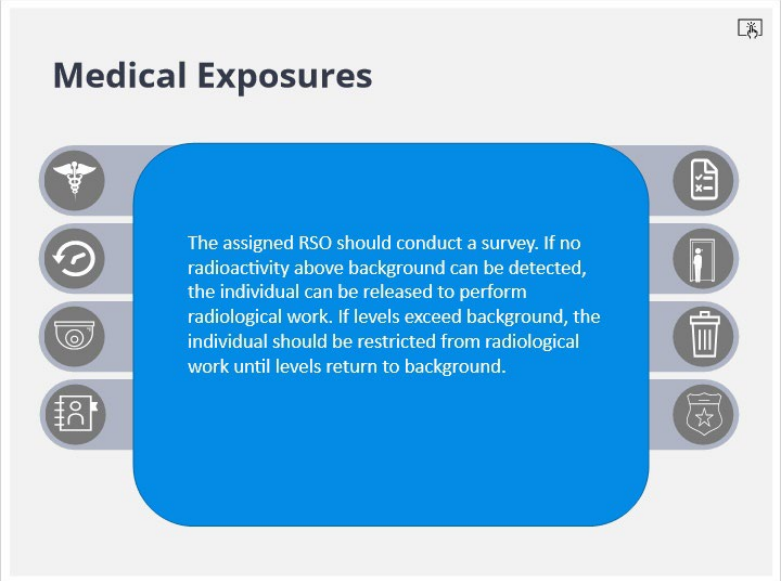

**May interfere with surveys (Slide Layer)**



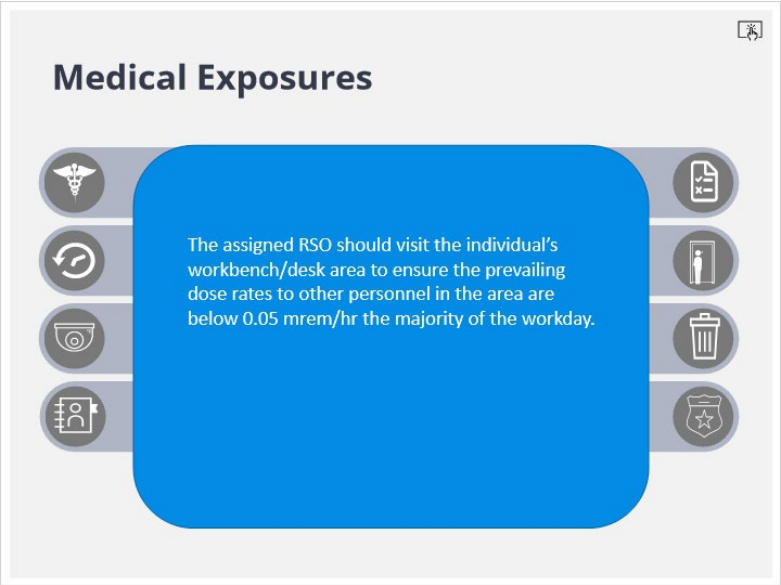
## Contact RSO after procedure (Slide Layer)



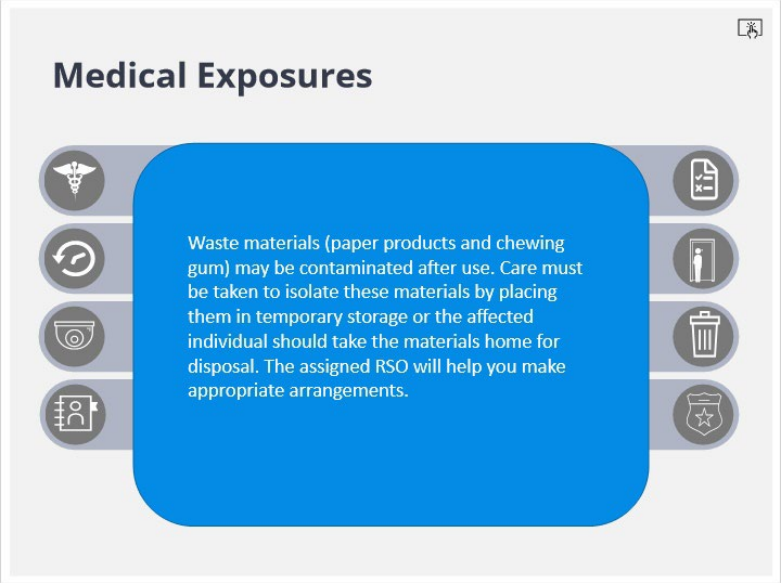

## RSO conducts survey (Slide Layer)



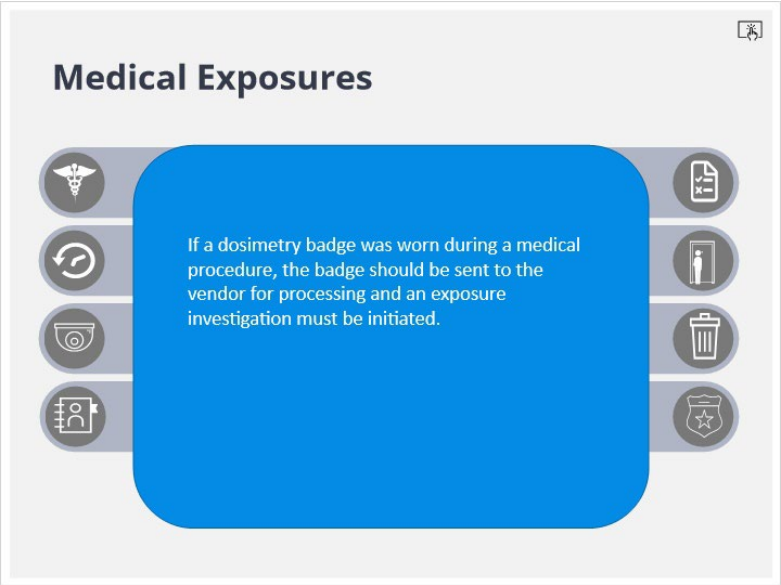
**RSO visits work area (Slide Layer)**




**Waste materials (Slide Layer)**



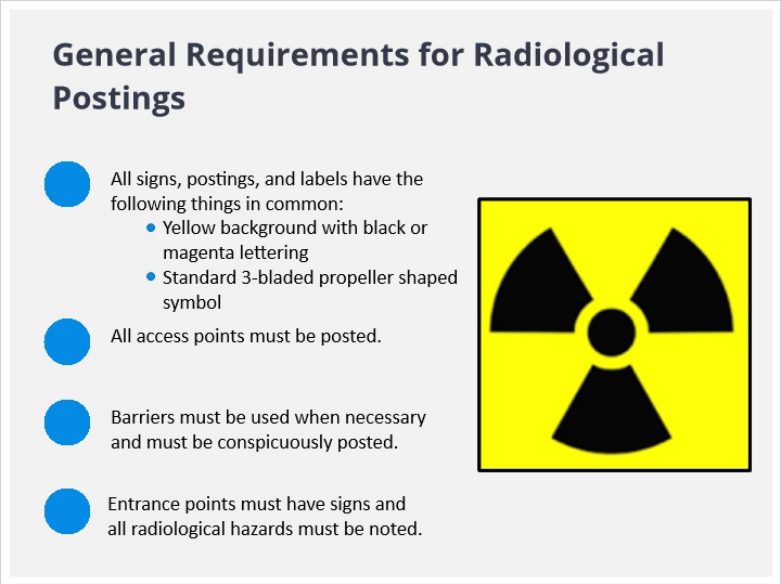
**Badge worn during procedure (Slide Layer)**




## 11. Radiological Posting

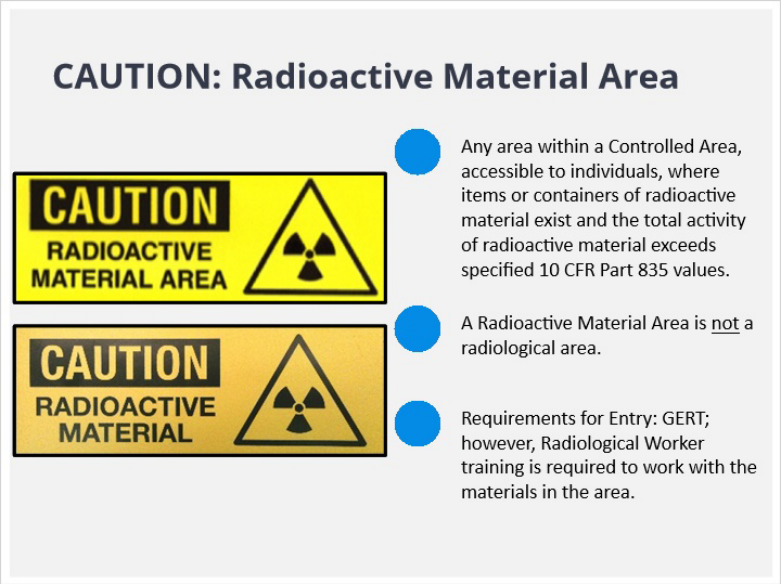
### *11.1 Radiological Postings*

## *11.2 General Requirements for Radiological Postings*

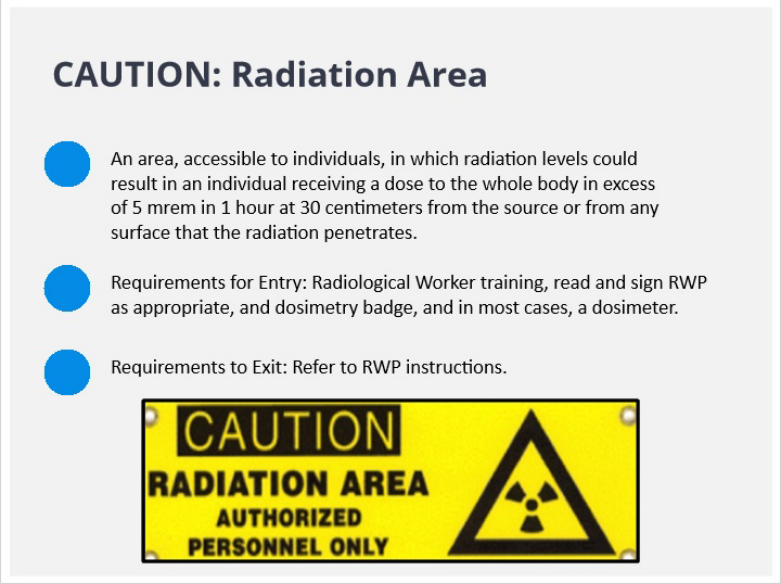



## *11.3 CAUTION: Controlled Area*

## *11.4 CAUTION: Radioactive Material Area*




## *11.5 CAUTION: Radiation Area*



## *11.6 DANGER: High Radiation Area*

### DANGER: High Radiation Area

- An area, accessible to individuals, in which radiation levels could result in an individual receiving a dose to the whole body in excess of 100 mrem in 1 hour at 30 centimeters from the radiation source or from any surface that the radiation penetrates.
- Requirements for Entry: Radiological Worker training, read and sign RWP as appropriate, dosimetry badge, and pocket dosimeter.
- Requirements to Exit: Refer to RWP instructions.

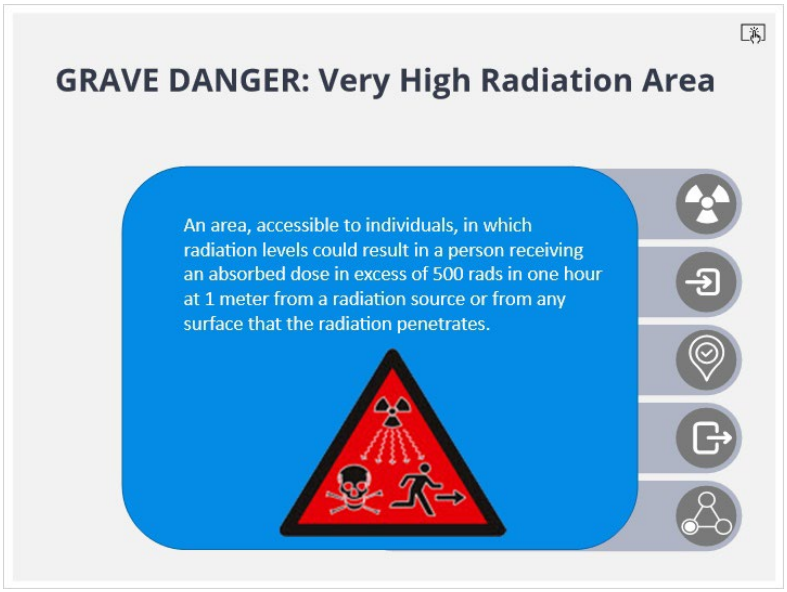

## *11.7 DANGER: High Radiation Area*

### DANGER: High Radiation Area

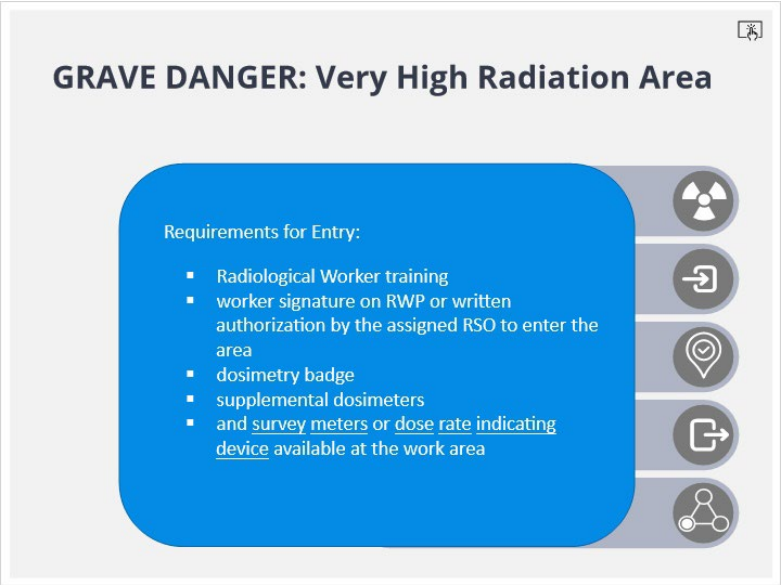
- If the work requires handling of objects where the dose to the hands can be expected to exceed 1 rem/quarter, ring badges should also be worn.
- Additional requirements will be imposed by the assigned RSO when dose rates exceed 1000 mrem/hr.

## *11.8 GRAVE DANGER: Very High Radiation Area*

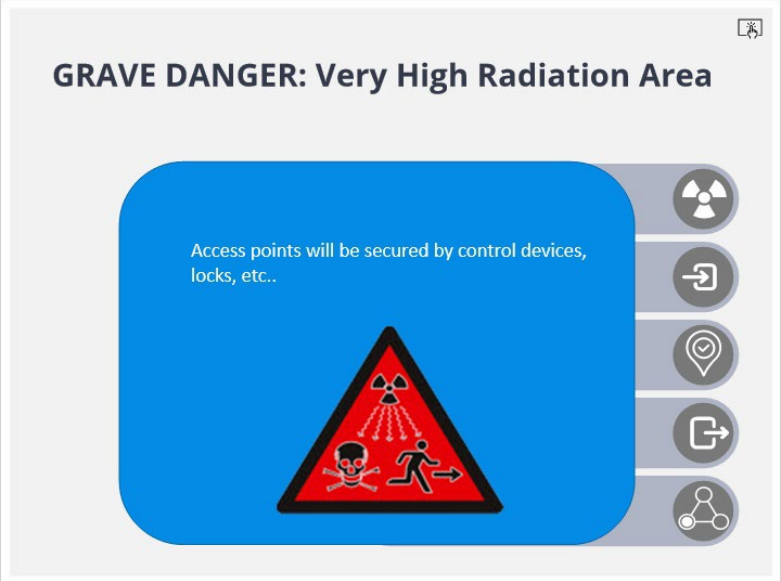

**> 500 rads (Slide Layer)**



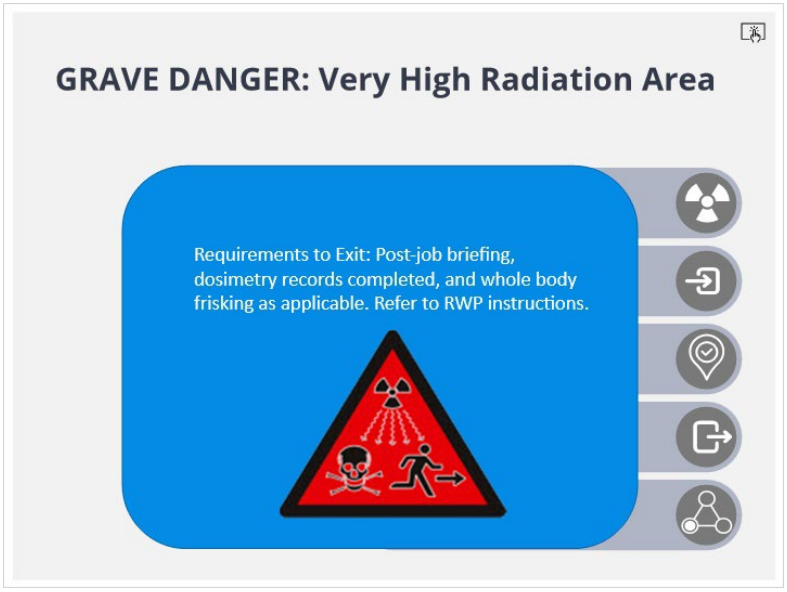
## Entry requirements (Slide Layer)



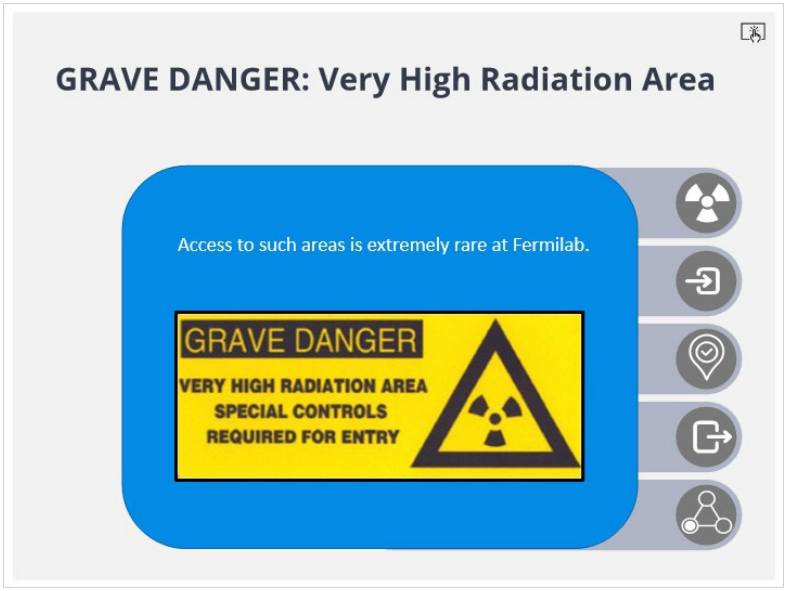

## Access points (Slide Layer)



**Requirements to exit (Slide Layer)**




**rare at Fermi (Slide Layer)**



## *11.9 CAUTION: Contamination Area*

### CAUTION: Contamination Area

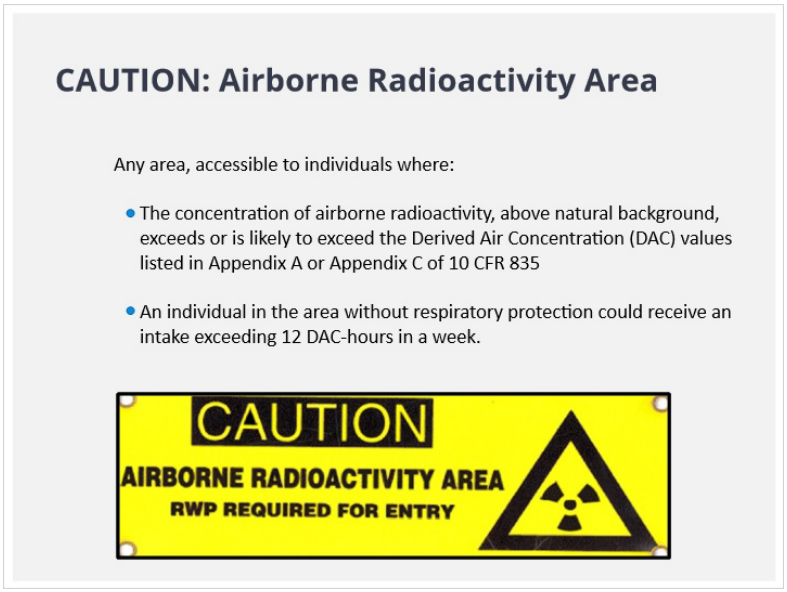
Any area, accessible to individuals, where removable surface contamination levels exceed or are likely to exceed the removable surface contamination values specified in Chapter 2, Table 2-2 of the FRCM, but do not exceed 100 times those values.


## *11.10 DANGER: High Contamination Area*

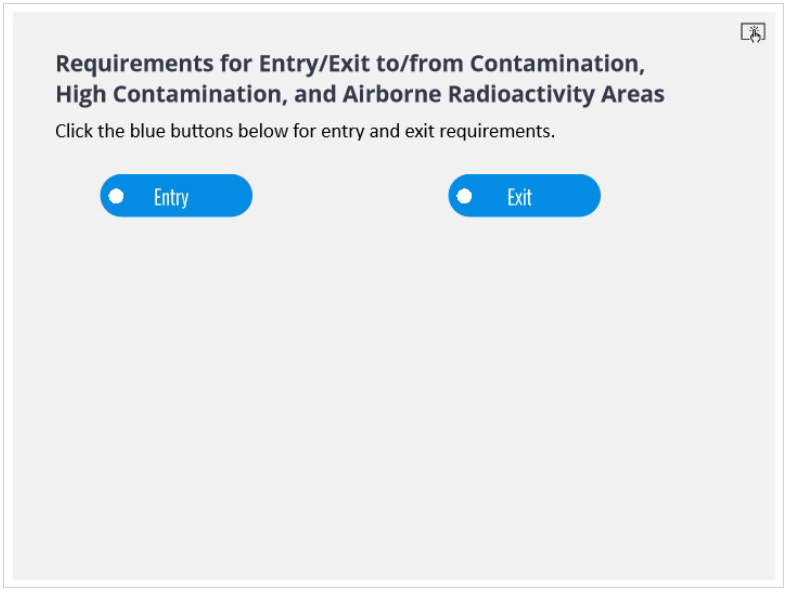
### DANGER: High Contamination Area

Any area, accessible to individuals, where removable contamination levels exceed or are likely to exceed 100 times the removable surface contamination values specified in Chapter 2, Table 2-2 of the FRCM.

## *11.11 CAUTION: Airborne Radioactivity Area*

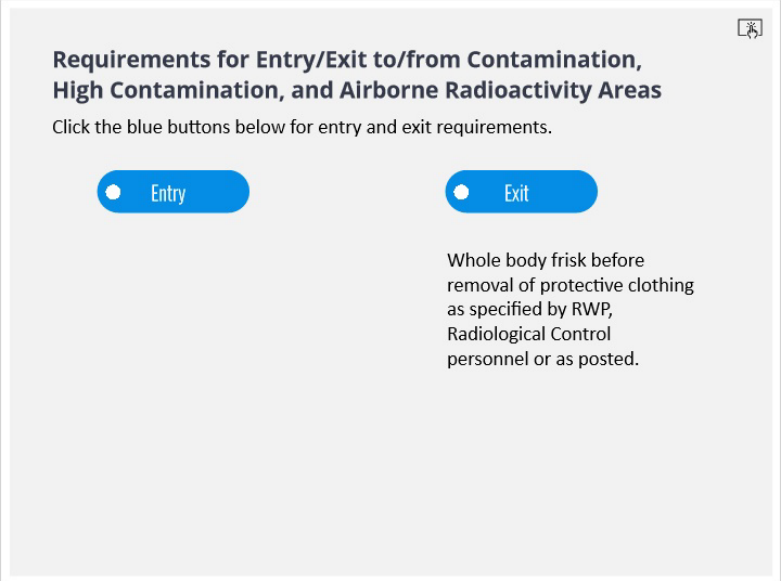



## *11.13 Requirements for Entry/Exit to/from Contamination, High Contamination, and Airborne Radioactivity Areas*



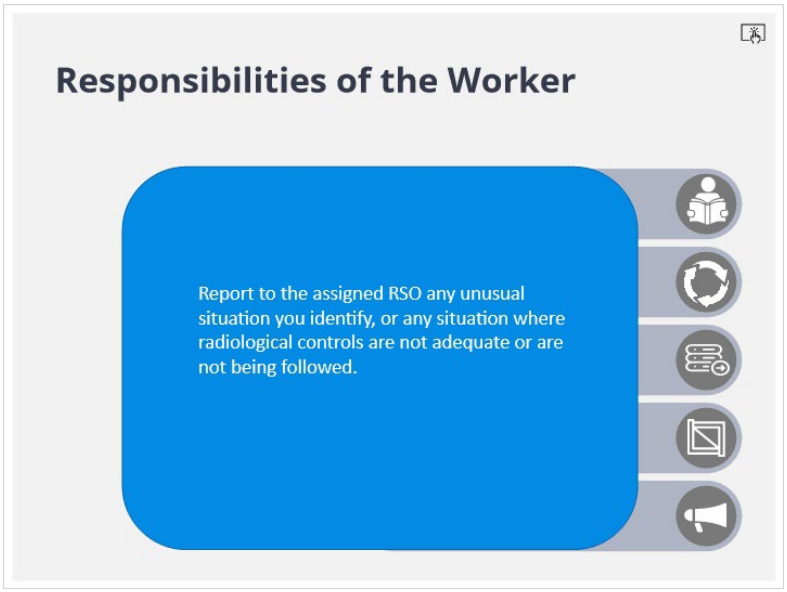
## Entry (Slide Layer)


## exit (Slide Layer)



## *11.14 Responsibilities of the Worker*


**Report to RSO (Slide Layer)**

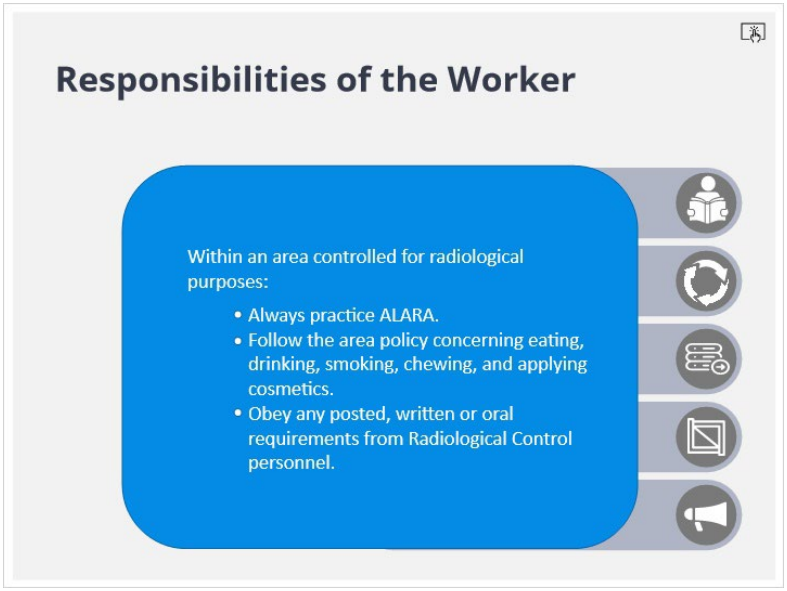


**Read signs (Slide Layer)**


**Comply with info (Slide Layer)**

**Disregarding (Slide Layer)**

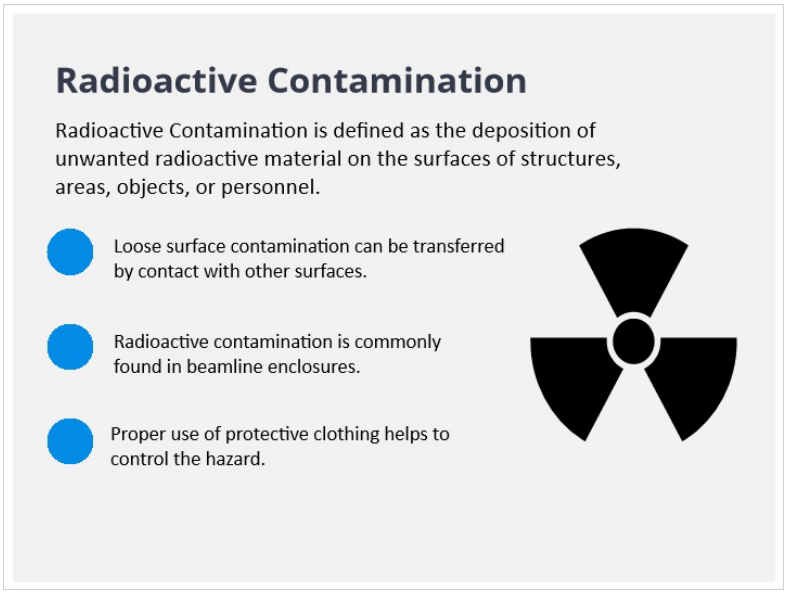

**Within a controlled area (Slide Layer)**



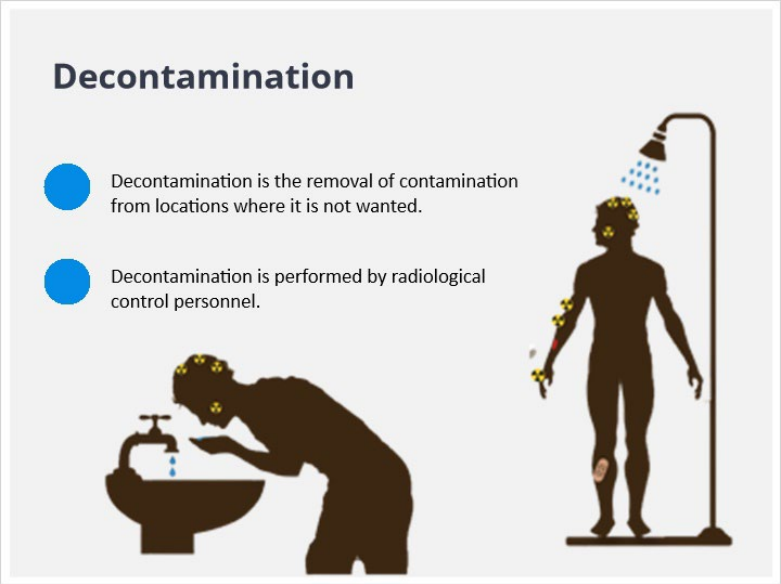
## 12. Contamination Control

### *12.1 Contamination Control*

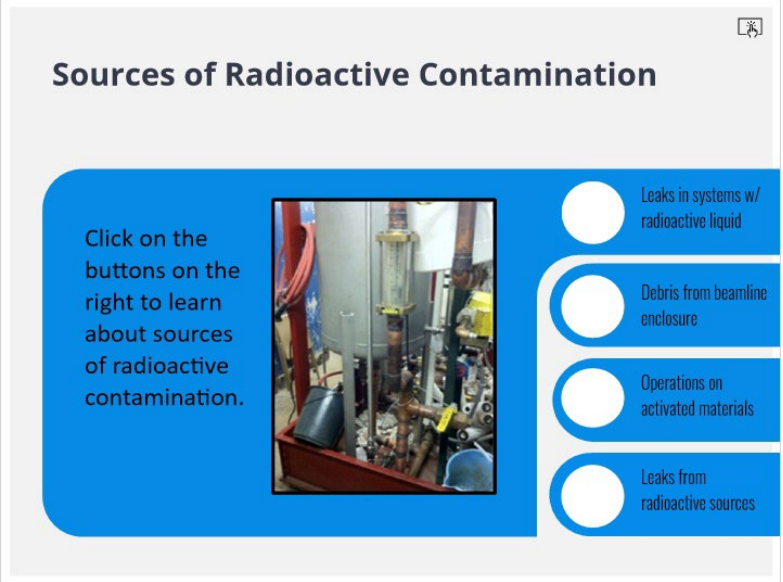

### *12.2 Radioactive Contamination*



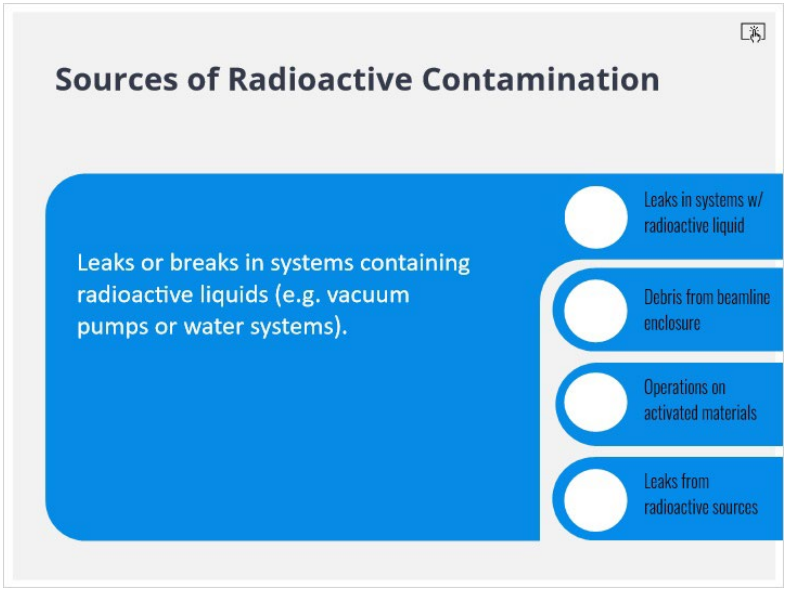
## *12.4 Decontamination*



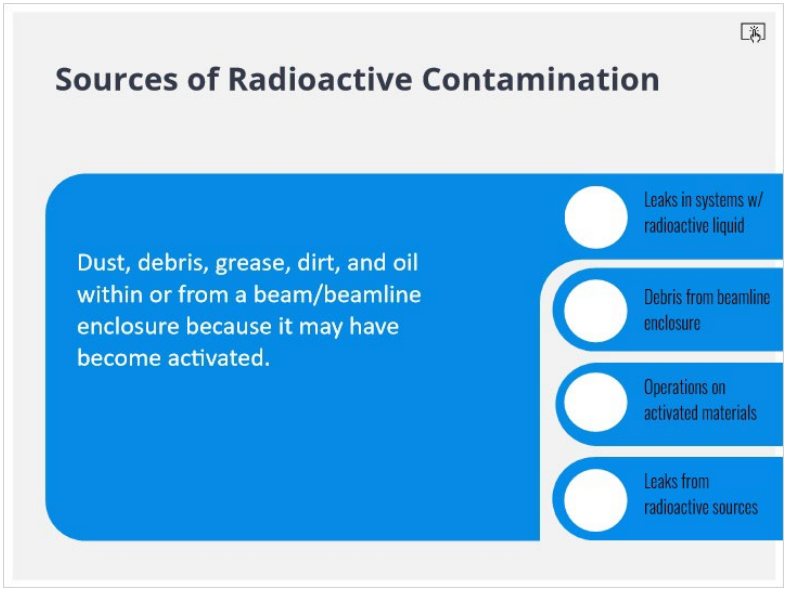

## *12.5 Sources of Radioactive Contamination*



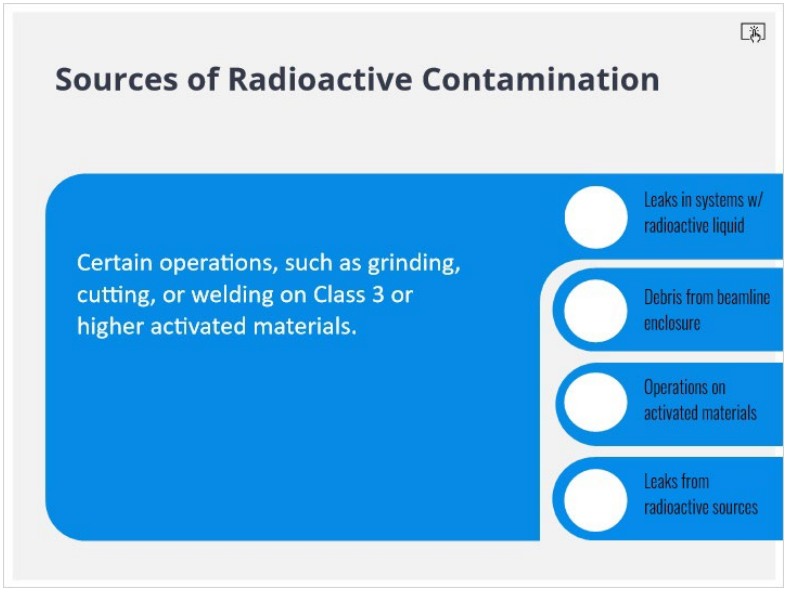
**Leaks in systems with radioactive Liquid (Slide Layer)**



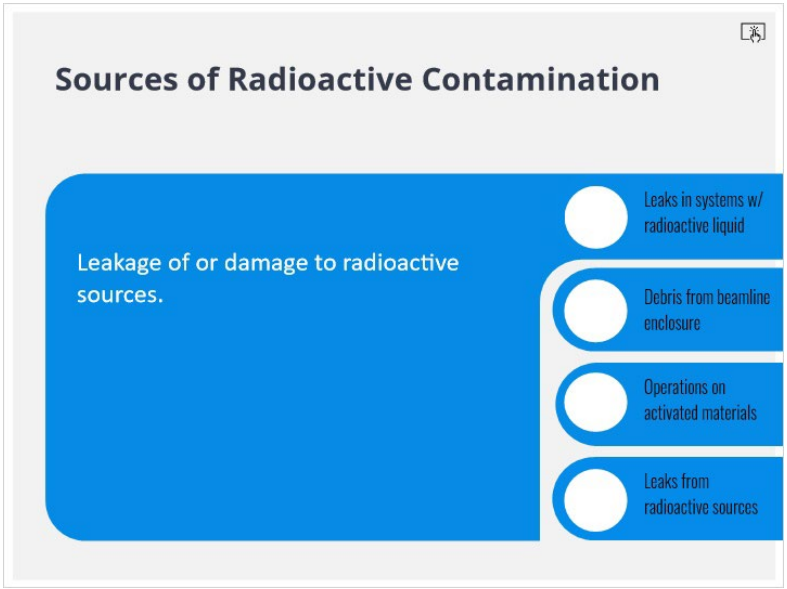

**Debris from beamline enclosure (Slide Layer)**



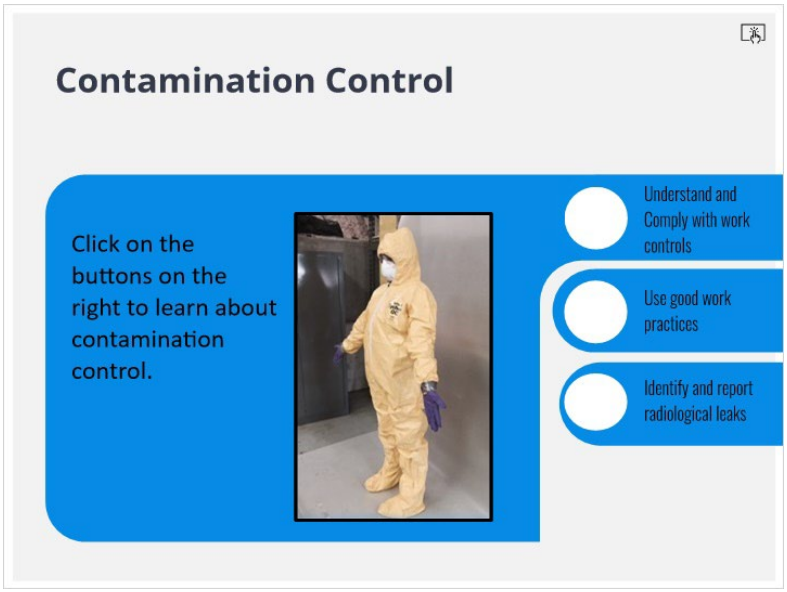
**Operations on activated materials (Slide Layer)**



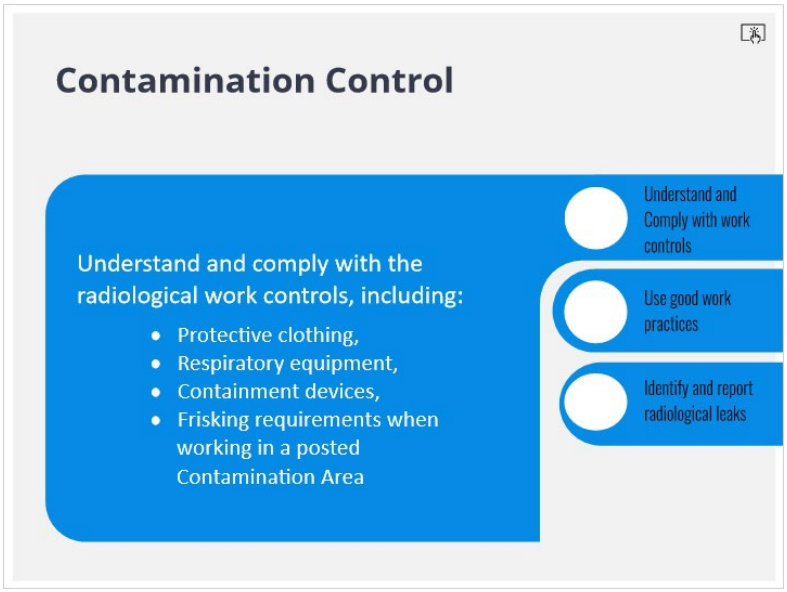

**Leaks from radioactive sources (Slide Layer)**



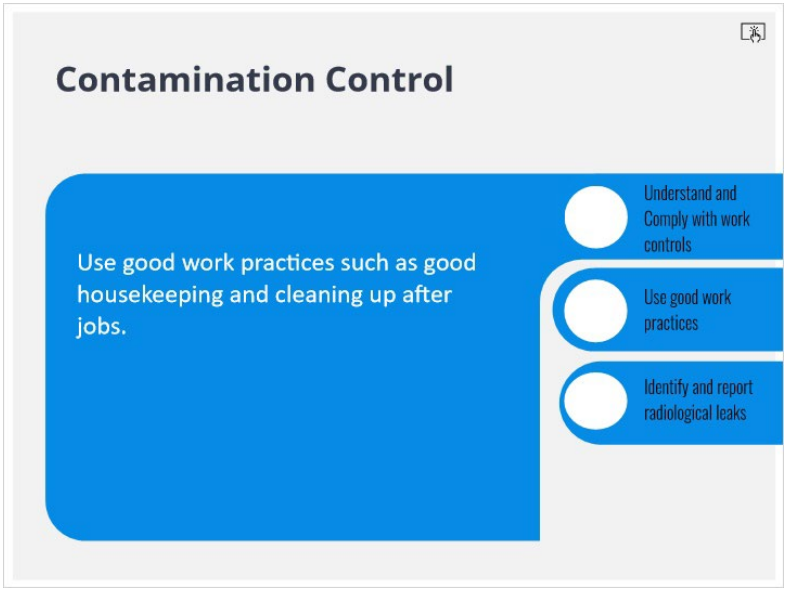
## *12.7 Contamination Control*



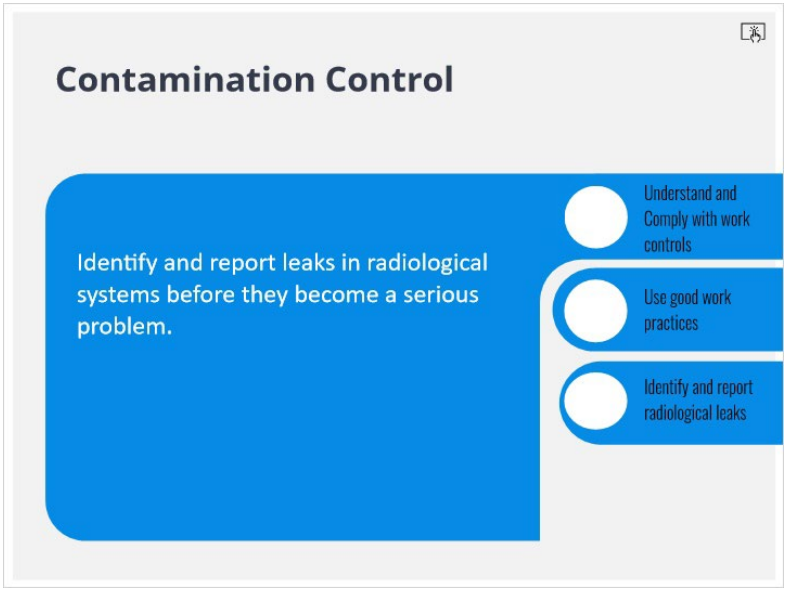

**Understand and comply (Slide Layer)**



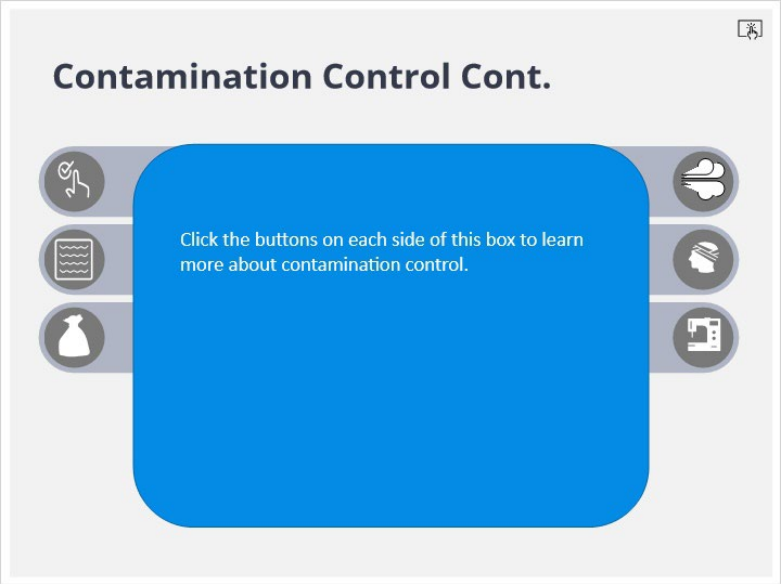
**Good work practices (Slide Layer)**



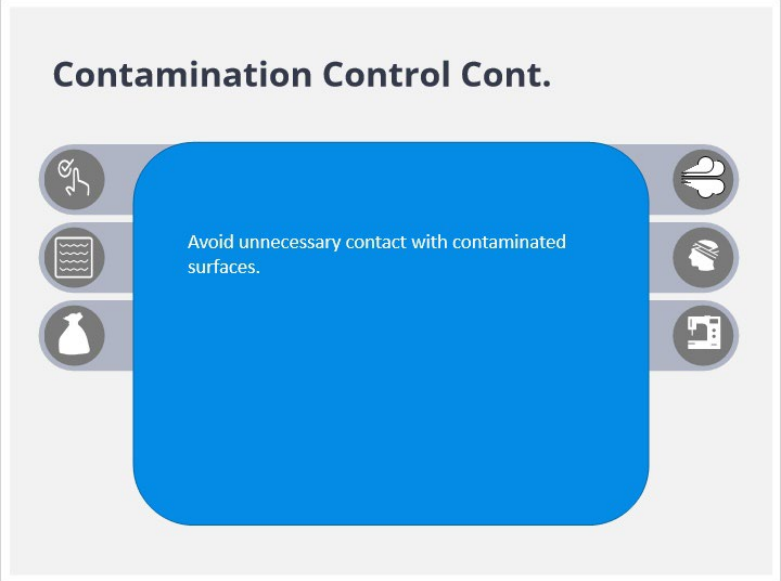

**Identify and report leaks (Slide Layer)**



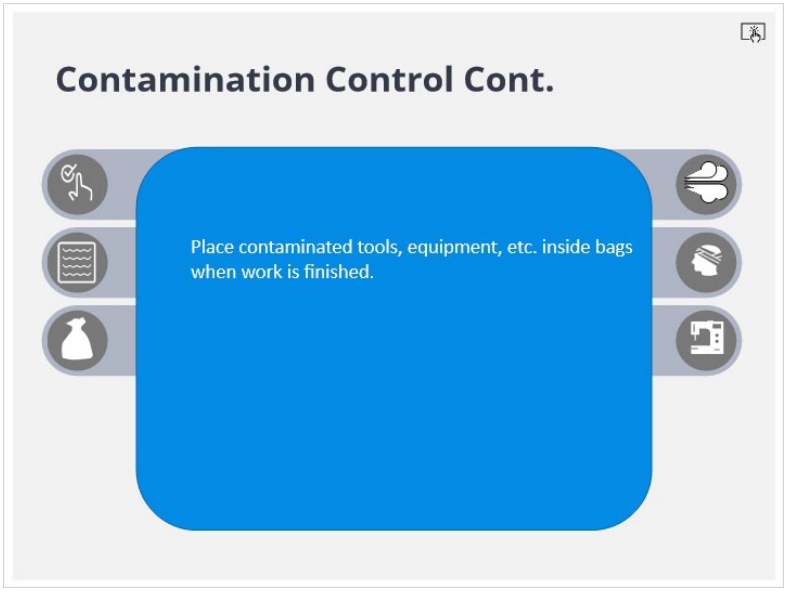
## *12.8 Contamination Control Cont.*




**Avoid unnecessary contact (Slide Layer)**

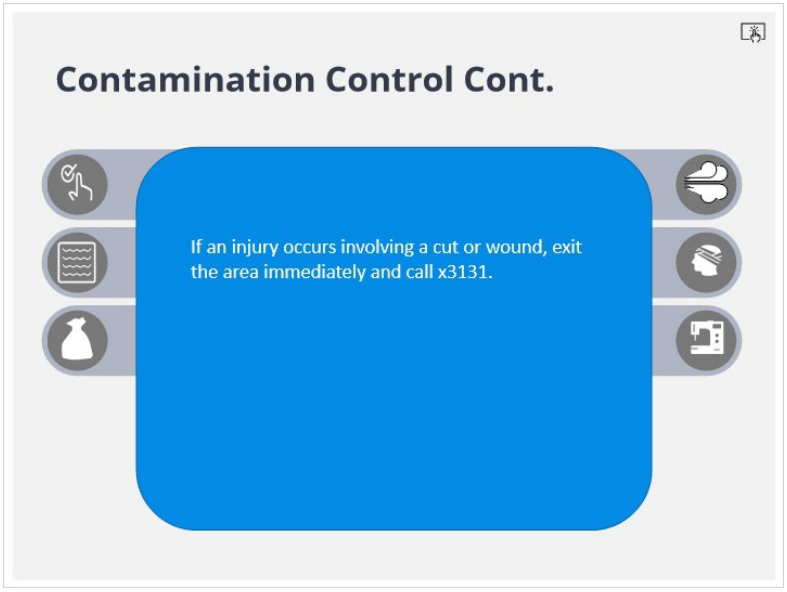


**Place tools in bag (Slide Layer)**



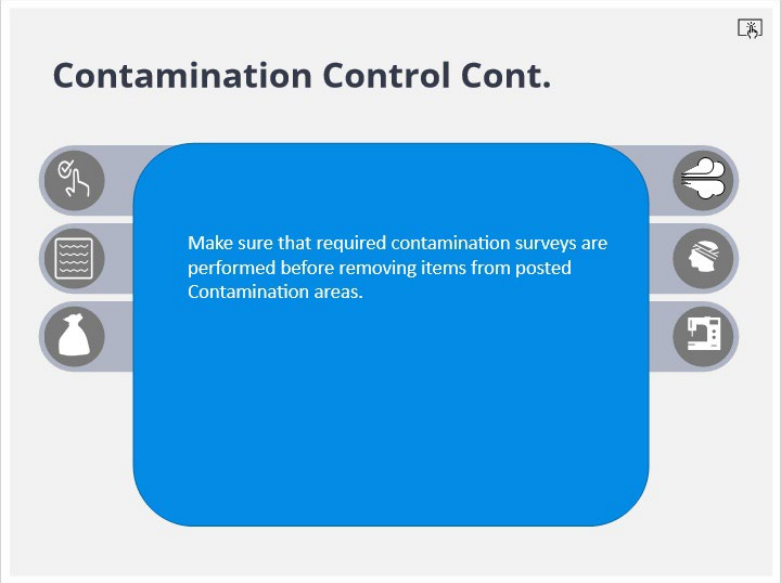

**Avoid stirring up (Slide Layer)**

**Avoid injury (Slide Layer)**

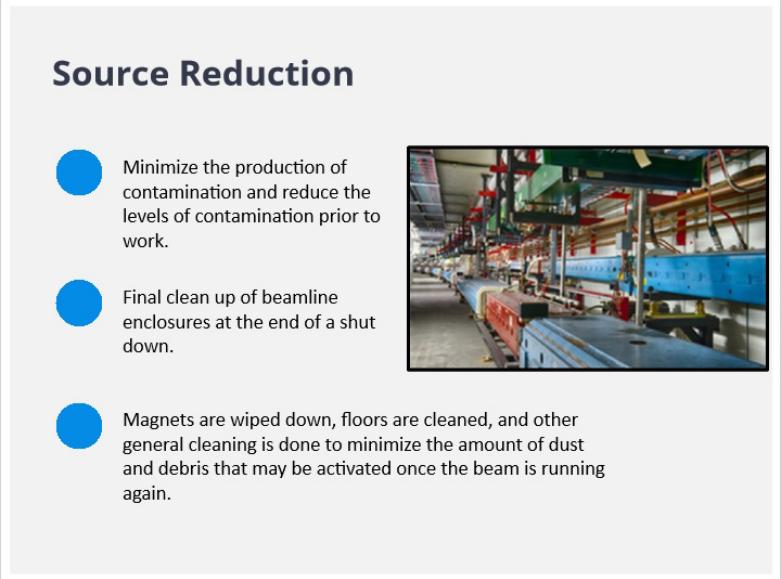



**No machining (Slide Layer)**

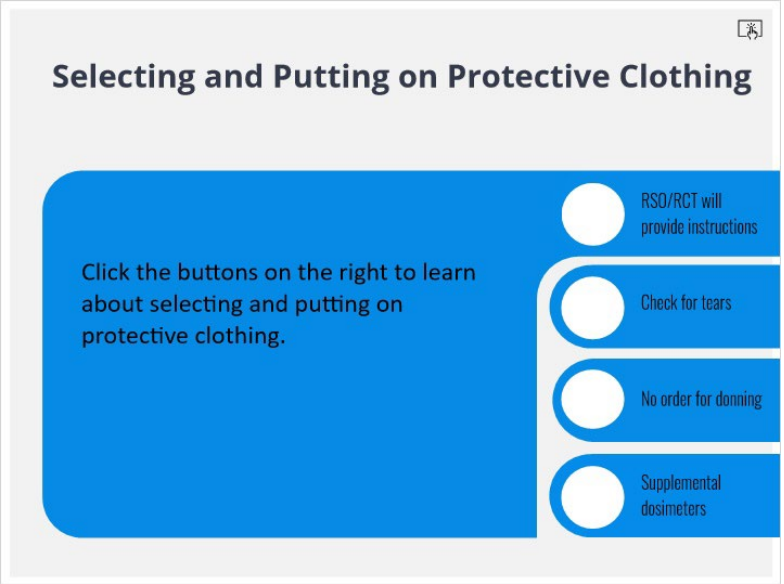
**Perform before removing (Slide Layer)**



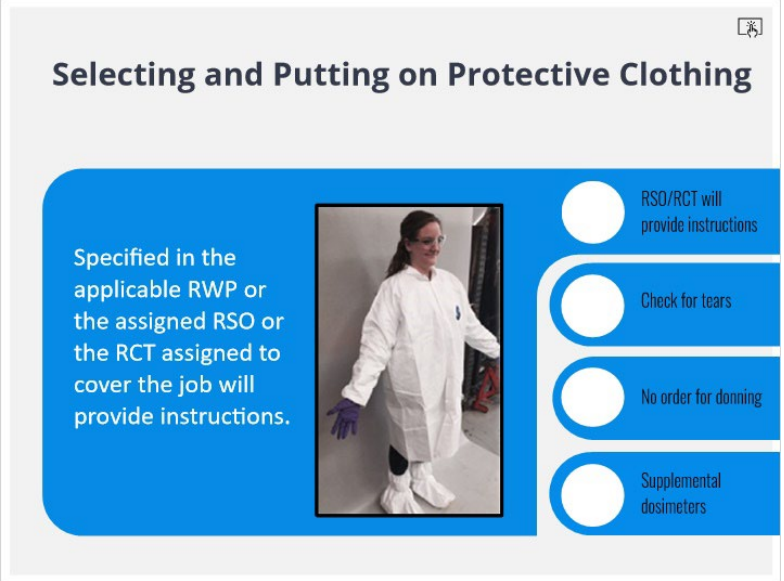

## *12.10 Source Reduction*



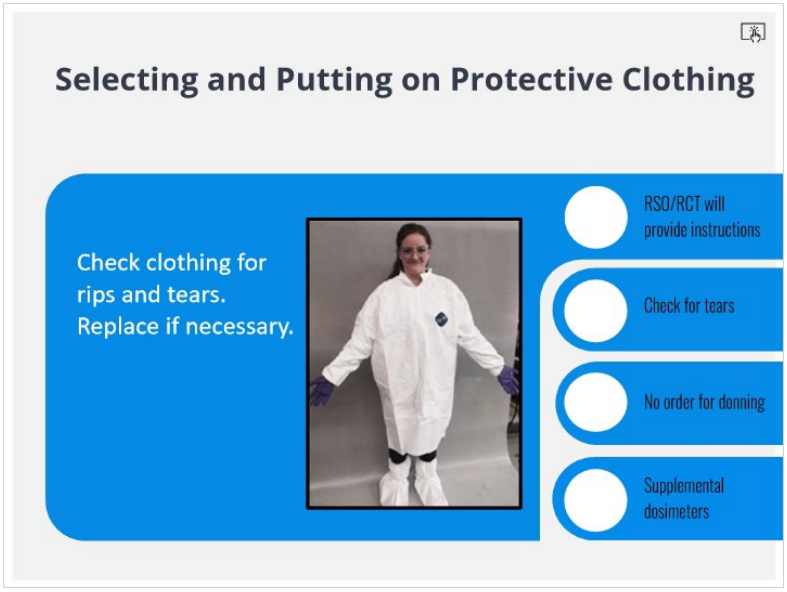
## *12.11 Selecting and Putting on Protective Clothing*




**RSO/RCT will provide instructions (Slide Layer)**

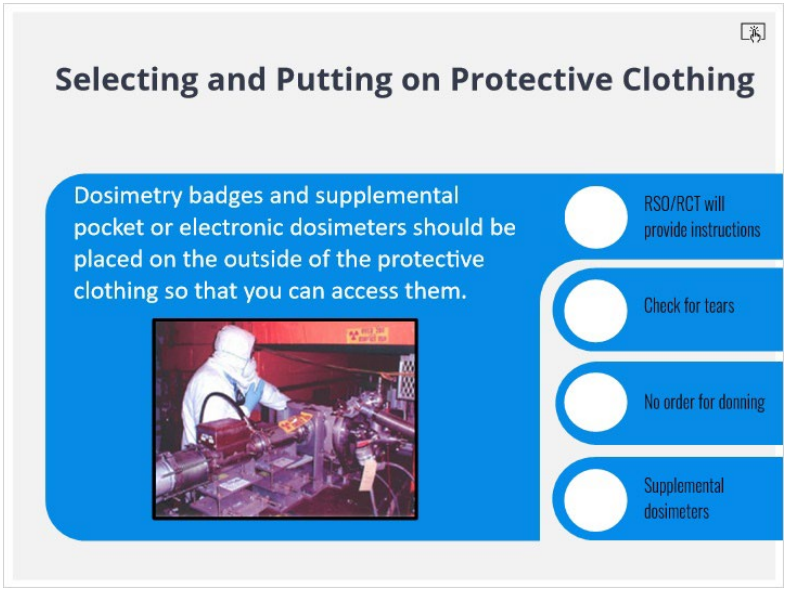


**Check for tears (Slide Layer)**

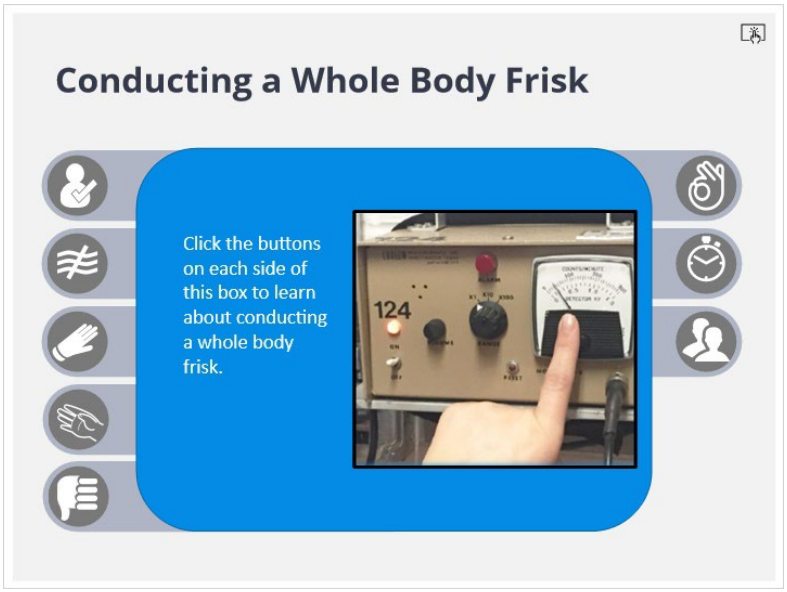



**No order (Slide Layer)**

**Supplemental dosimeters (Slide Layer)**

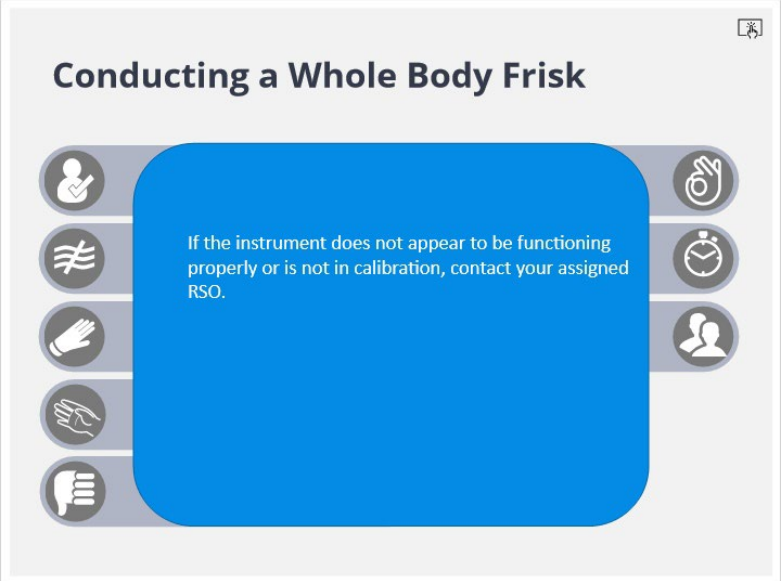



## *12.12 Conducting a Whole-Body Frisk*

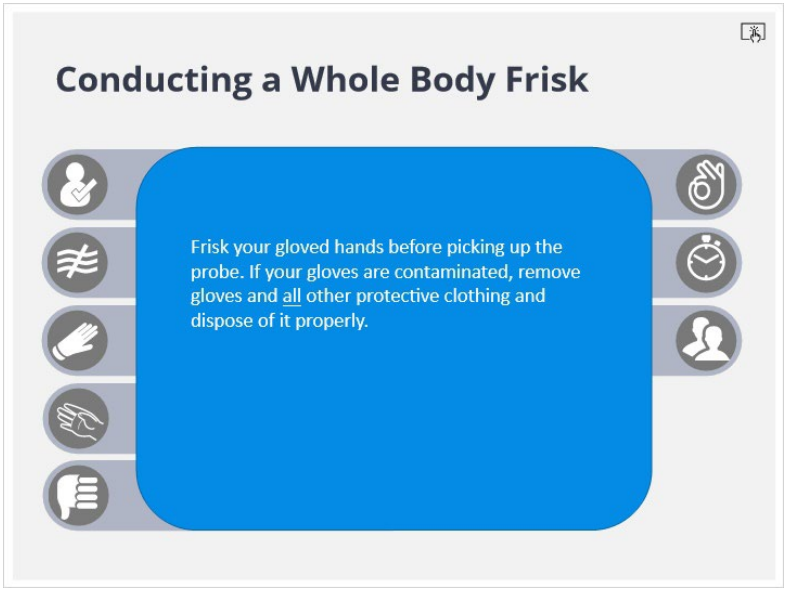


**Verify (Slide Layer)**

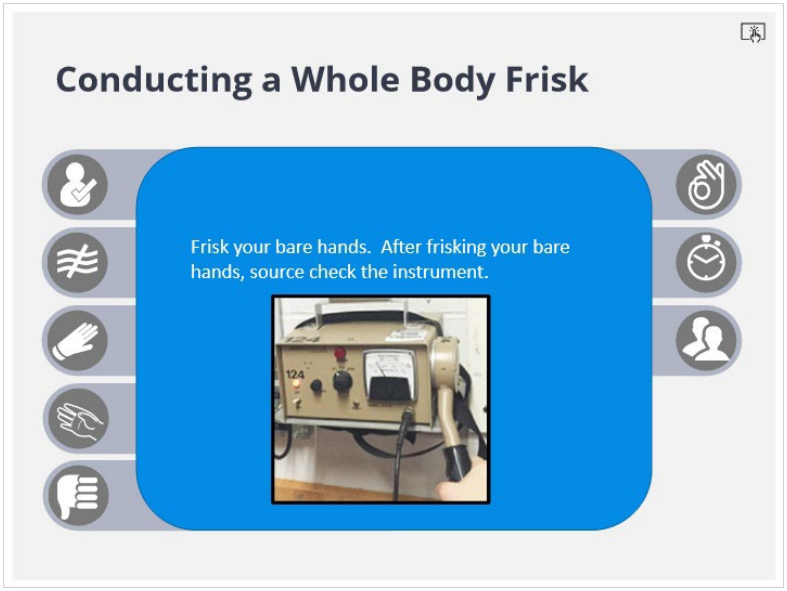

**If not functioning (Slide Layer)**



**Frisk Gloved Hand (Slide Layer)**




**Frisk bare hand (Slide Layer)**

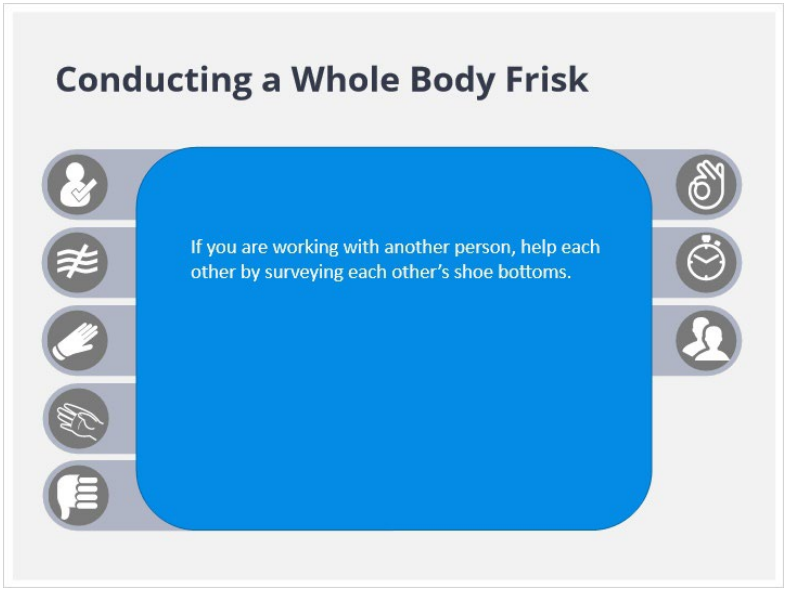


**IF check fails (Slide Layer)**

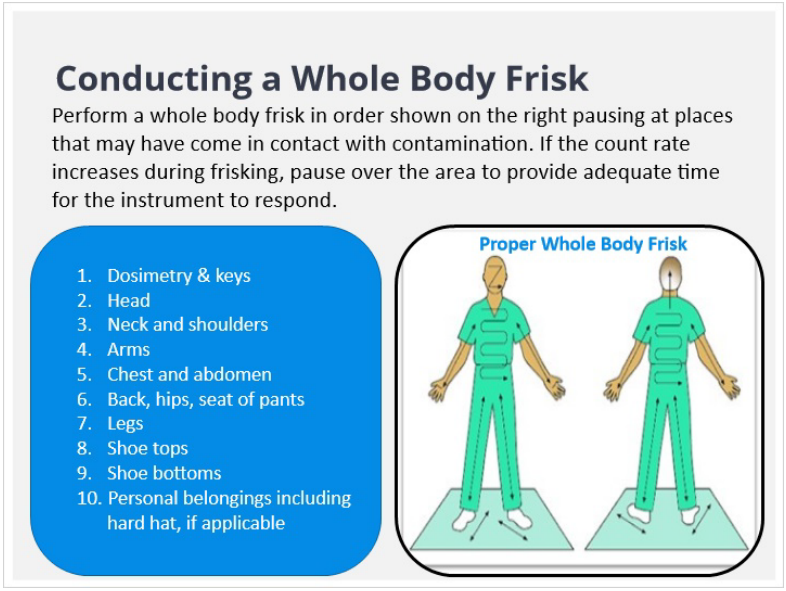

**If check is satisfactory (Slide Layer)**

**Takes 3-5 minutes (Slide Layer)**

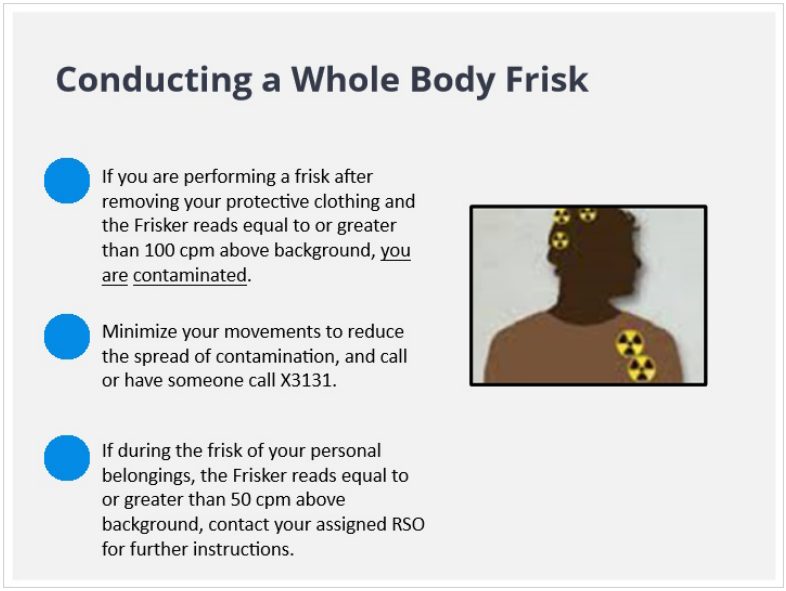

**Working with others (Slide Layer)**



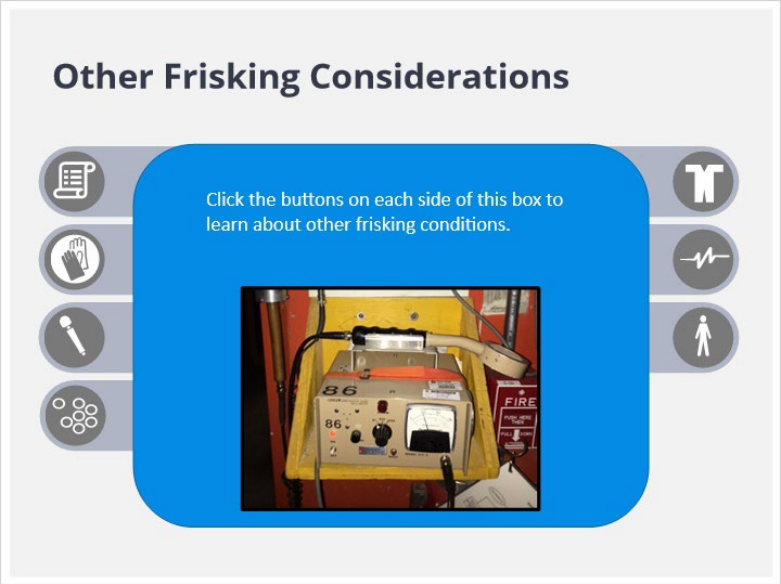
## *12.14 Conducting a Whole Body Frisk Cont.*



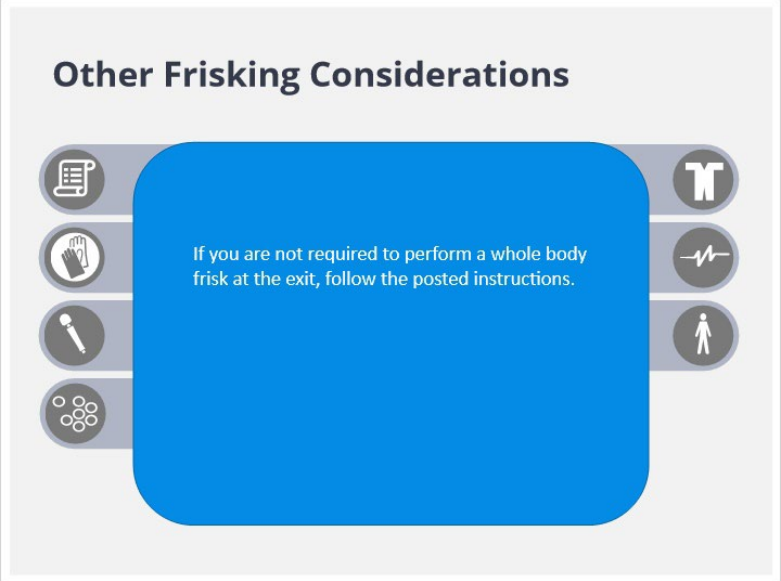

## *12.15 Conducting a Whole Body Frisk Cont.*



## *12.17 Other Frisking Considerations*

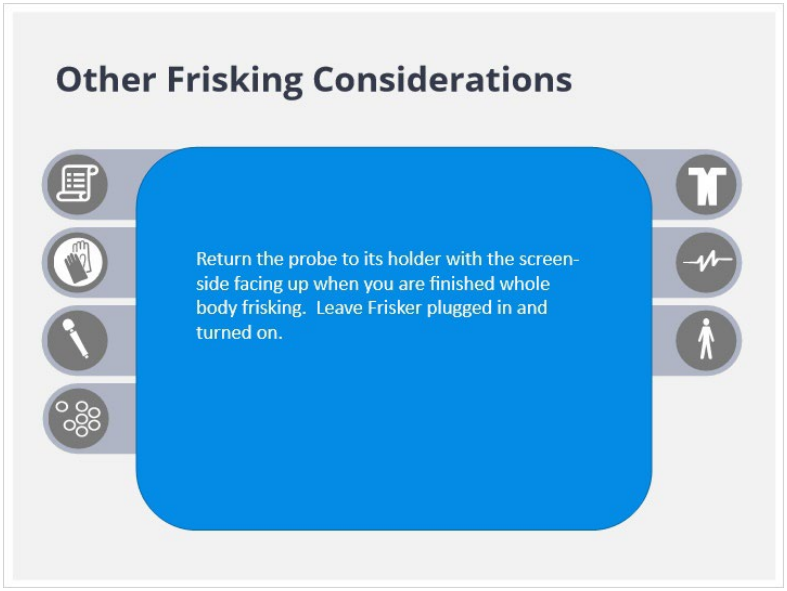



**Follow posted instructions (Slide Layer)**

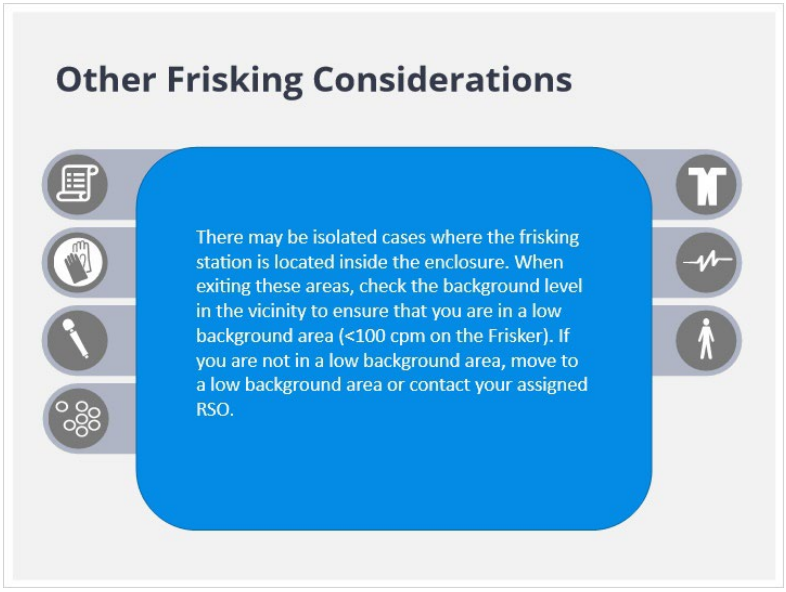


**Remove gloves (Slide Layer)**

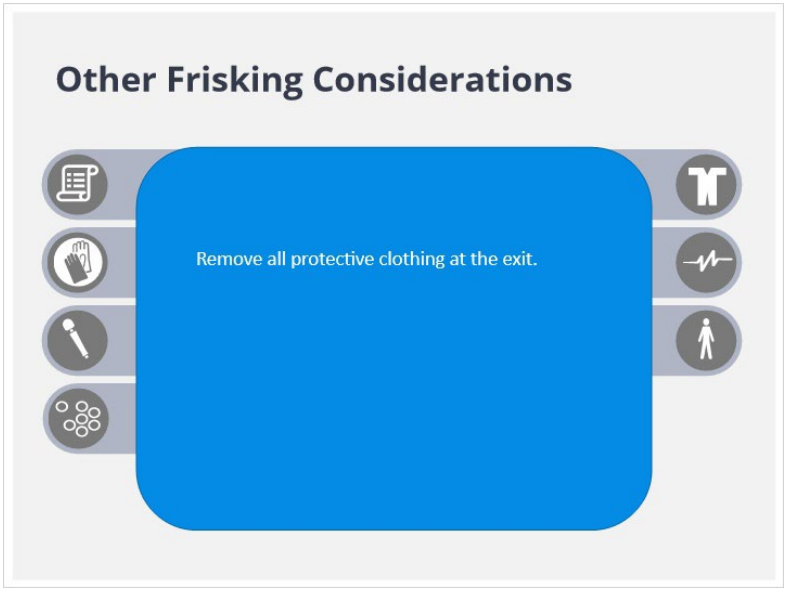

**Return probe (Slide Layer)**



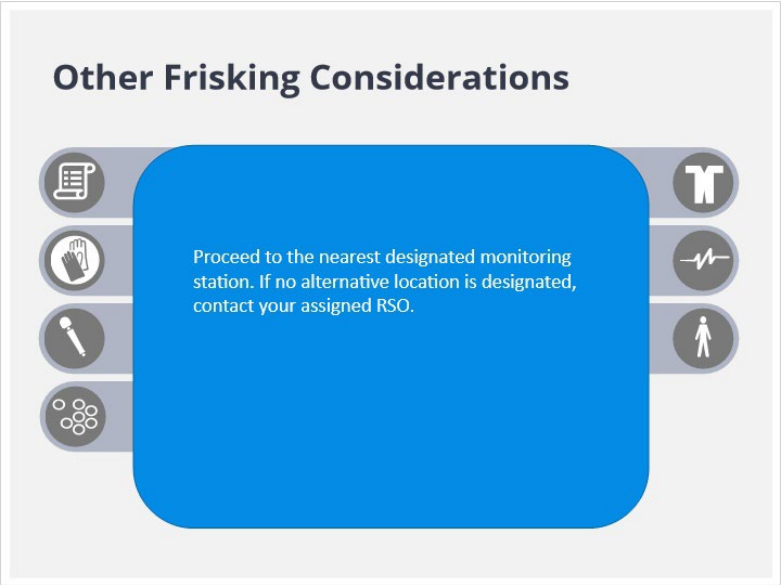
**Isolated cases (Slide Layer)**




**Remove protective clothing (Slide Layer)**



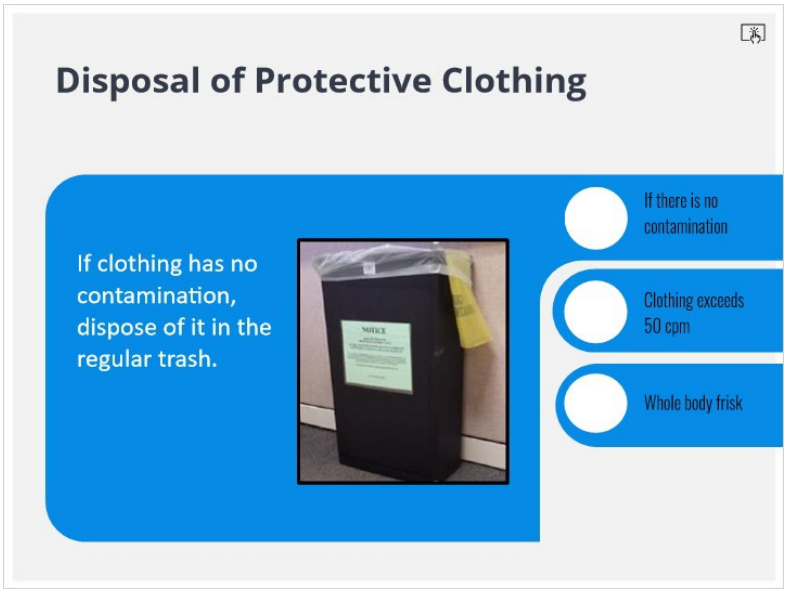
**Proceed to monitoring station (Slide Layer)**



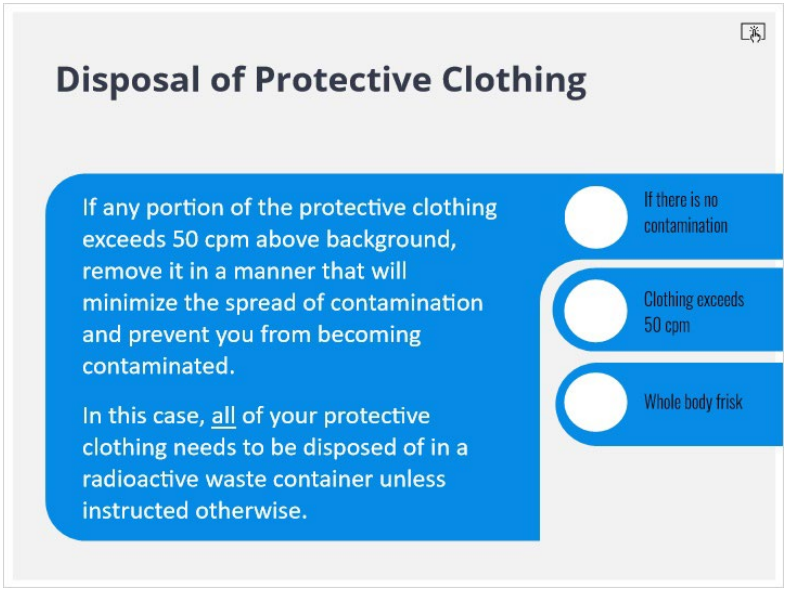

**Conduct frisk (Slide Layer)**

## *12.18 Disposal of Protective Clothing*

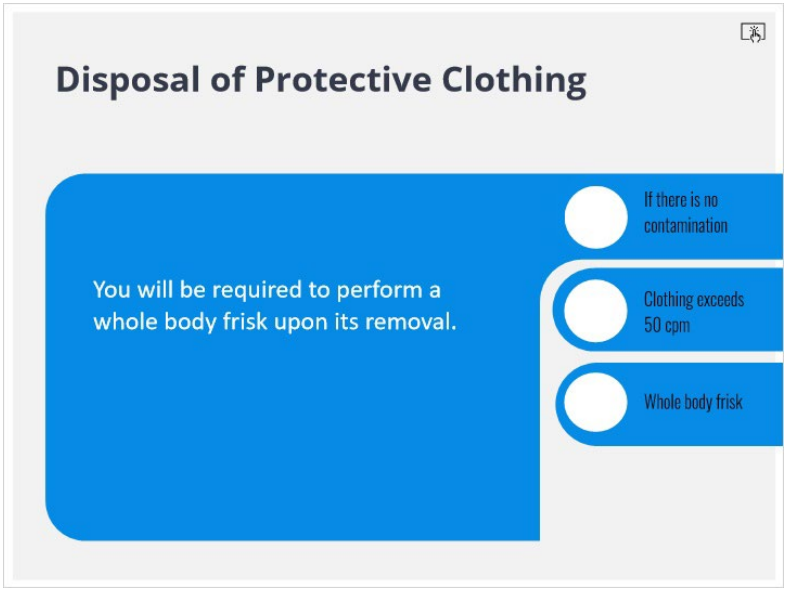

**If there is no contamination (Slide Layer)**



**Clothing exceeds 50 cpm (Slide Layer)**



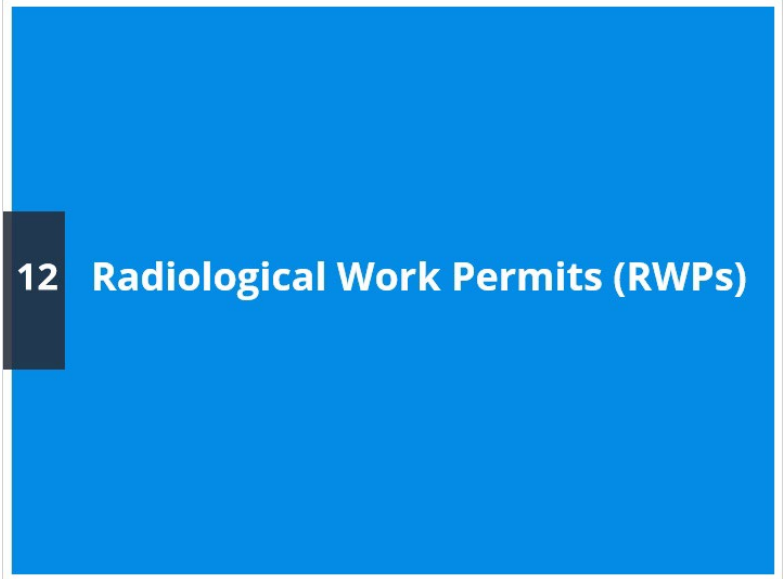

**Whole body frisk (Slide Layer)**



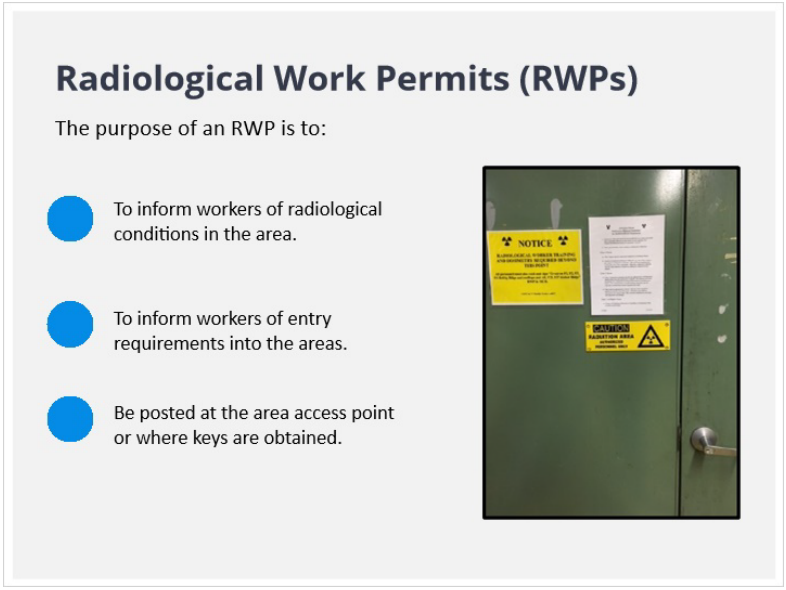
### *12.19 Frisking Procedure When No Protective Clothing is Worn*


## 13. Radiological Work Permits

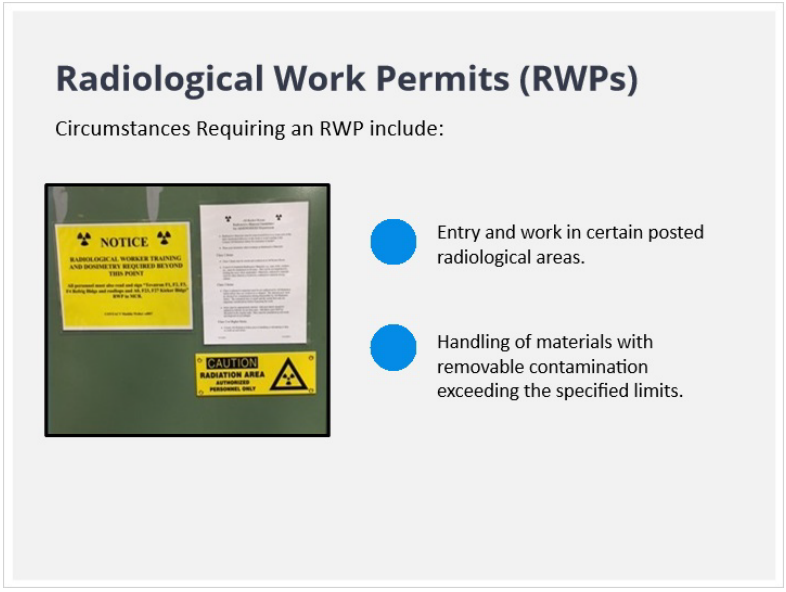
### *13.1 Radiological Work Permits (RWPs)*



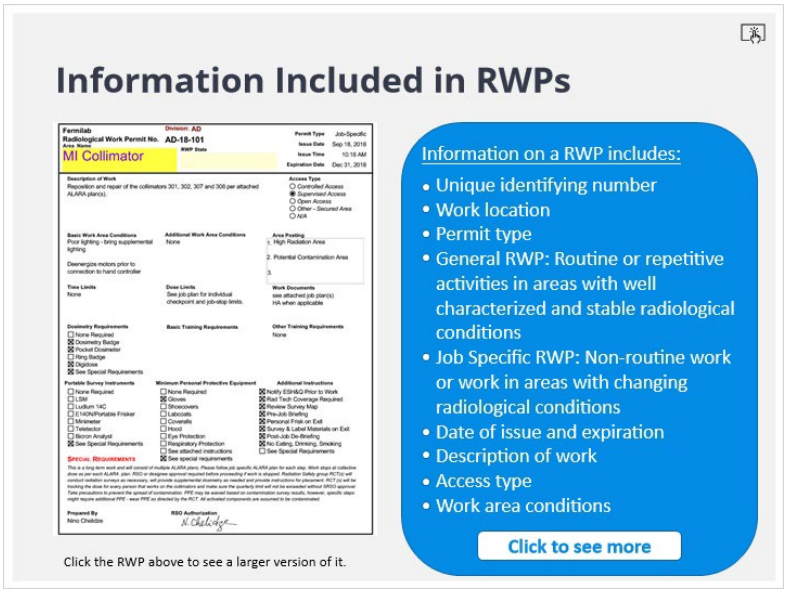
## *13.2 Radiological Work Permits (RWPs)*



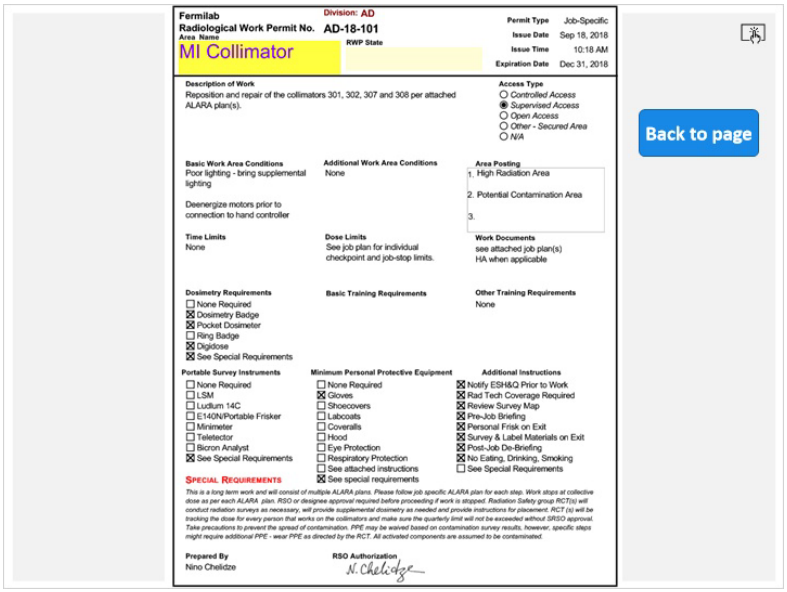

## *13.3 Radiological Work Permits (RWPs) Cont.*



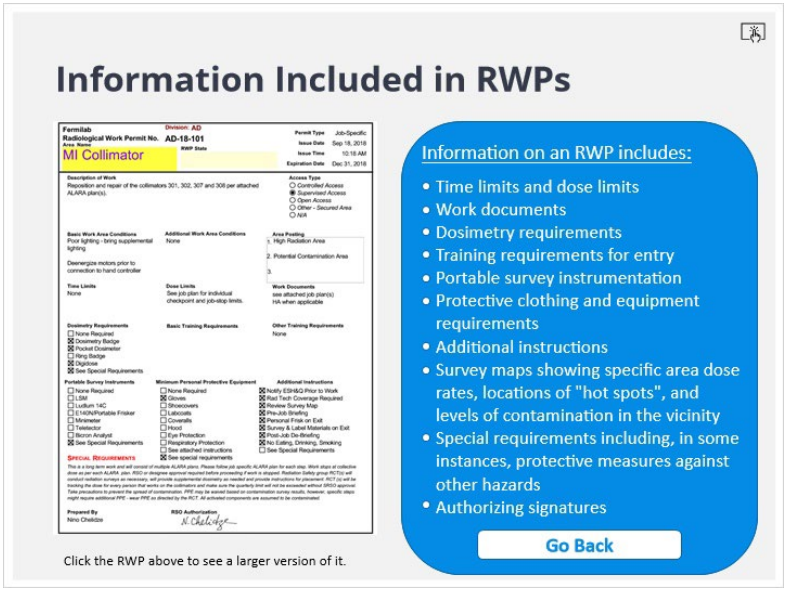
## *13.4 Information Included in RWPs*



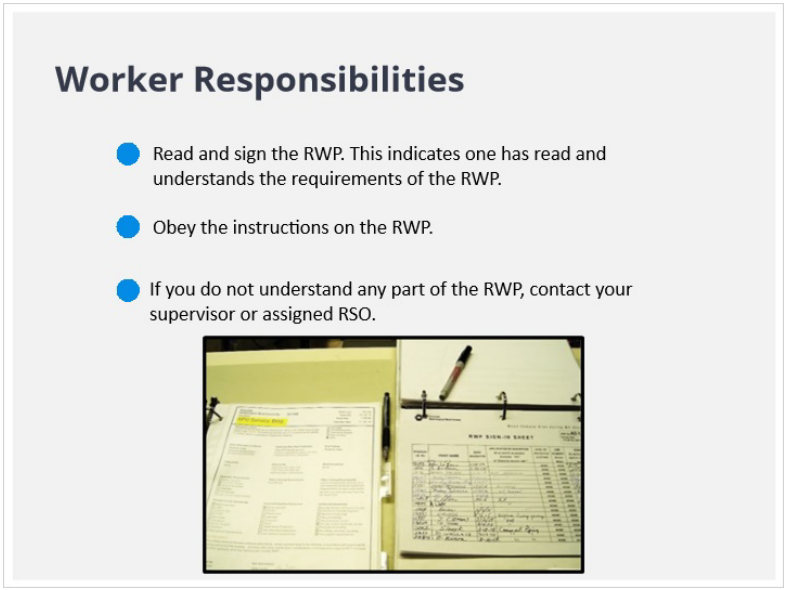

### Large RWP (Slide Layer)



## More information (Slide Layer)

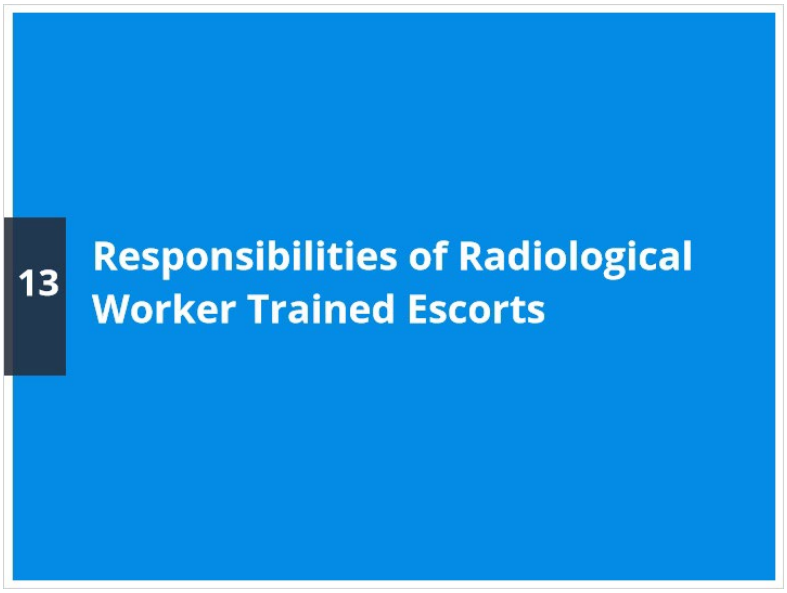



## *13.6 Worker Responsibilities*

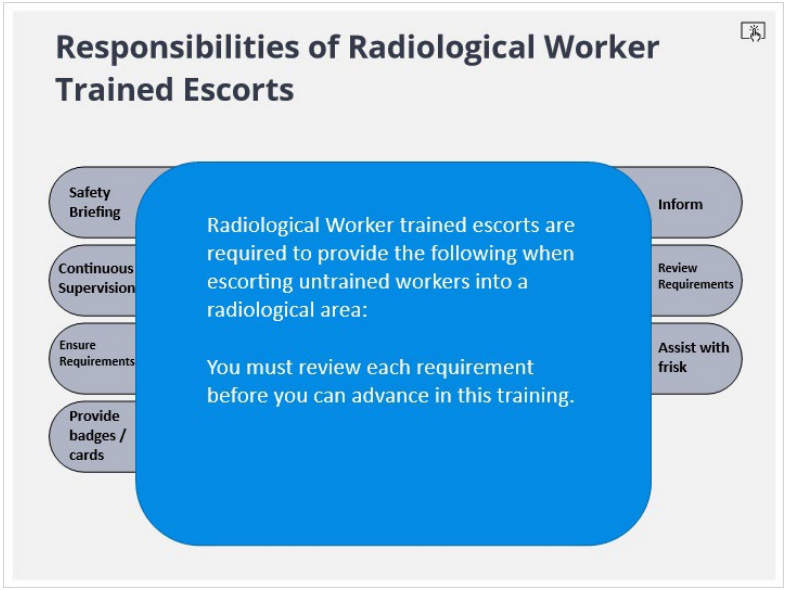


## 14. Responsibilities of Radiological Worker Trained Escorts

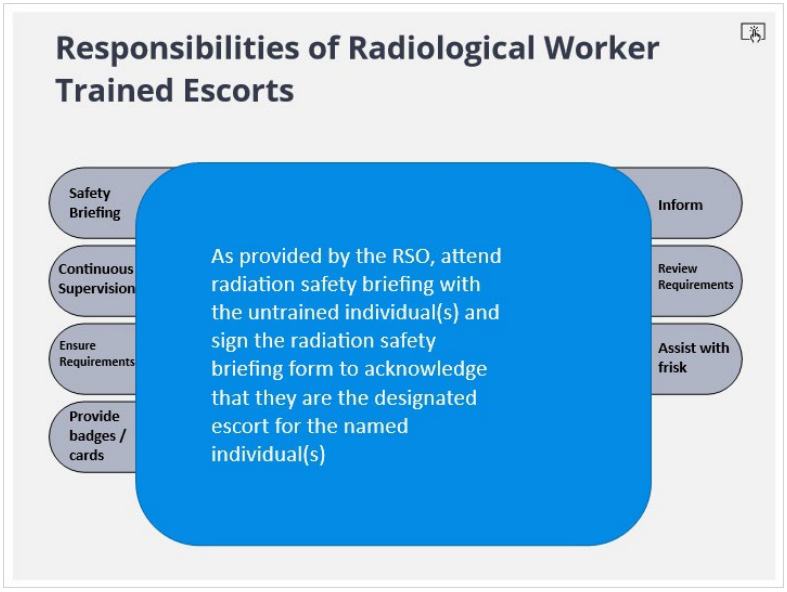
### *14.1 Radiological Work Permits (RWPs)*



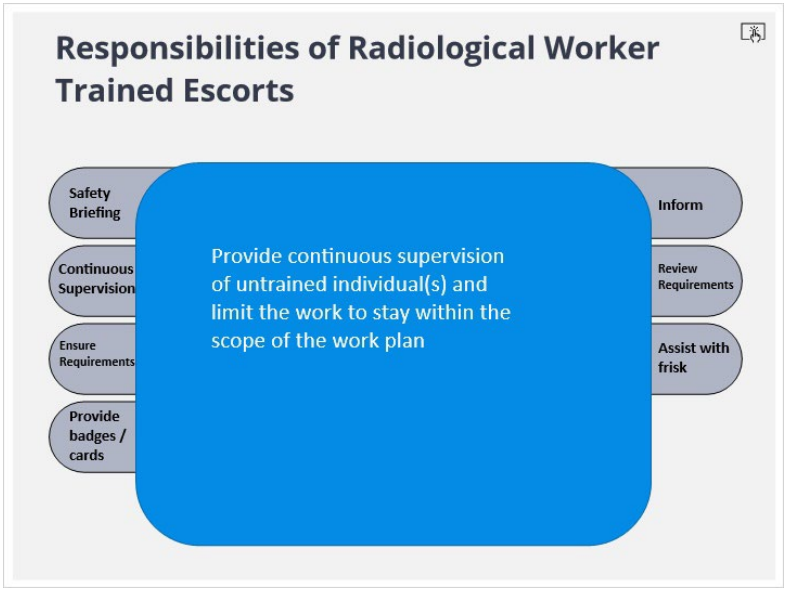

### *14.2 Responsibilities of Radiological Worker Trained Escorts*



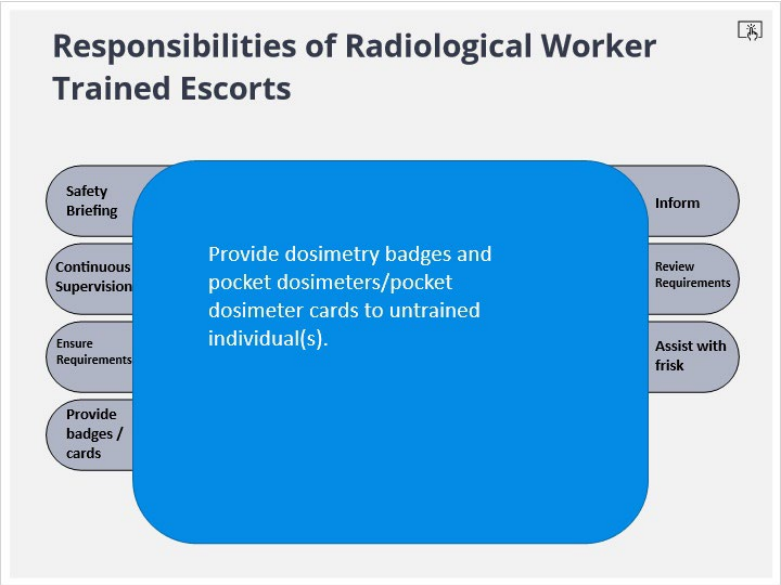
## Radiation Safety Briefing (Slide Layer)




## Provide continuous supervision (Slide Layer)

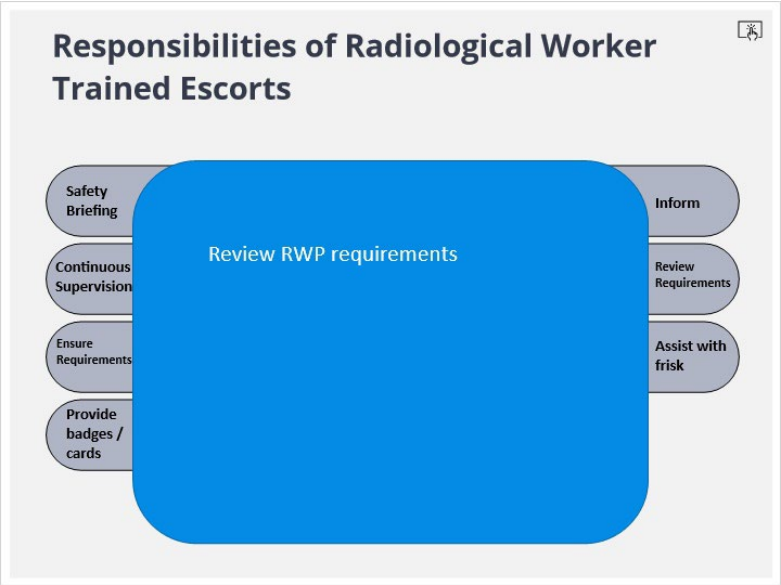


## Provide Badges/Cards (Slide Layer)

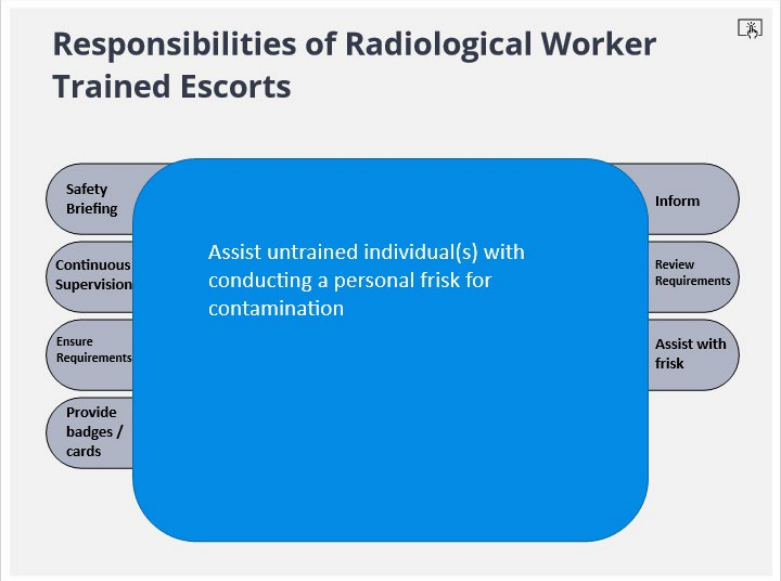



## Inform about postings (Slide Layer)

## Review Requirements (Slide Layer)



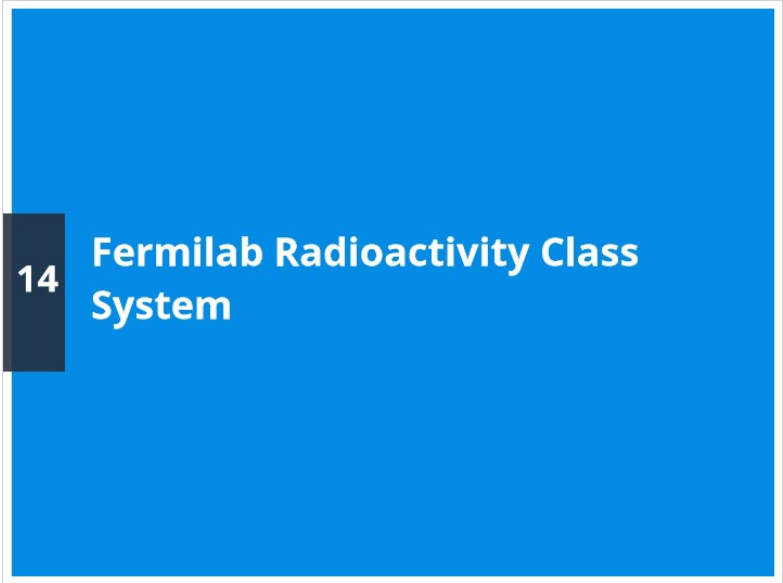

## Assist with frisk (Slide Layer)



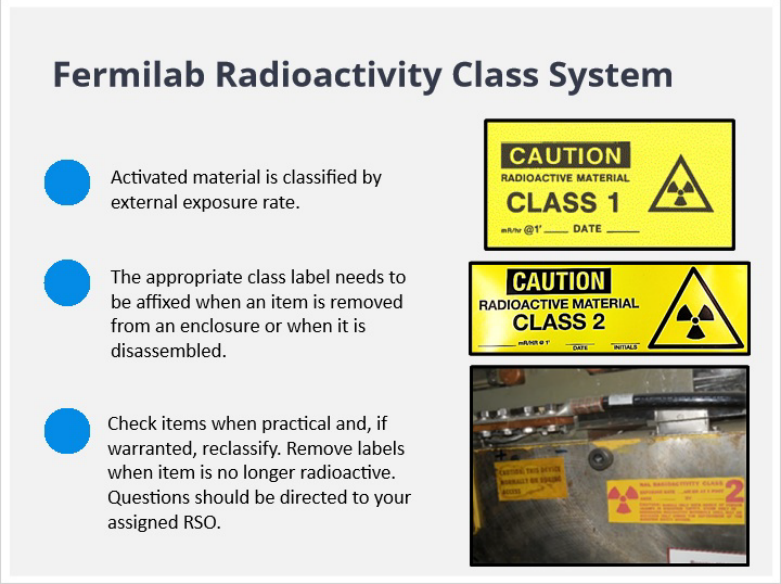
## Ensure Requirements (Slide Layer)

# 15. Fermilab Radioactivity Class System

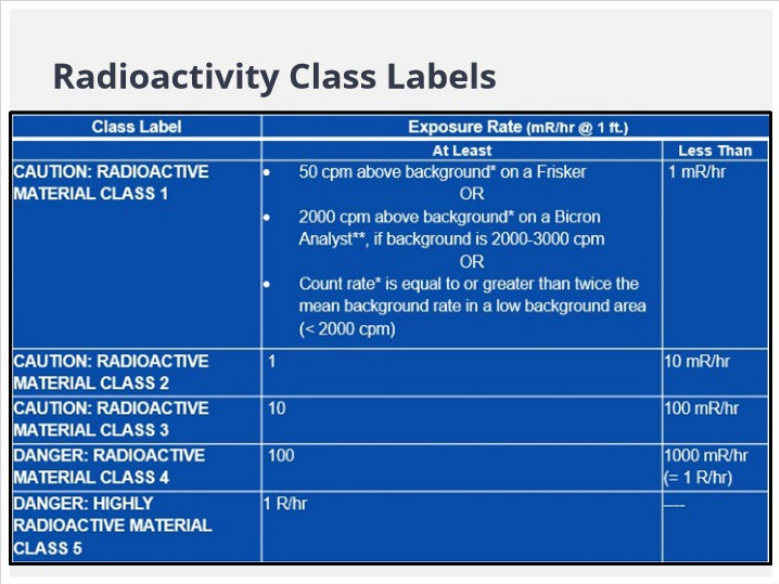
## *15.1 Fermilab Radioactivity Class System*




## *15.2 Fermilab Radioactivity Class System*



### *15.3 Radioactivity Class Labels*



Radioactivity Class Labels

| Class Label | Exposure Rate (mR/hr @ 1 ft.) | |
|---|---|---|
| | At Least | Less Than |
| CAUTION: RADIOACTIVE MATERIAL CLASS 1 | • 50 cpm above background* on a Frisker<br>OR<br>• 2000 cpm above background* on a Bicron Analyst**, if background is 2000-3000 cpm<br>OR<br>• Count rate* is equal to or greater than twice the mean background rate in a low background area (< 2000 cpm) | 1 mR/hr |
| CAUTION: RADIOACTIVE MATERIAL CLASS 2 | 1 | 10 mR/hr |
| CAUTION: RADIOACTIVE MATERIAL CLASS 3 | 10 | 100 mR/hr |
| DANGER: RADIOACTIVE MATERIAL CLASS 4 | 100 | 1000 mR/hr (= 1 R/hr) |
| DANGER: HIGHLY RADIOACTIVE MATERIAL CLASS 5 | 1 R/hr | --- |

## 16. Radioactive Material Surveying and Labeling

### *16.1 Radioactive Material Surveying and Labeling*

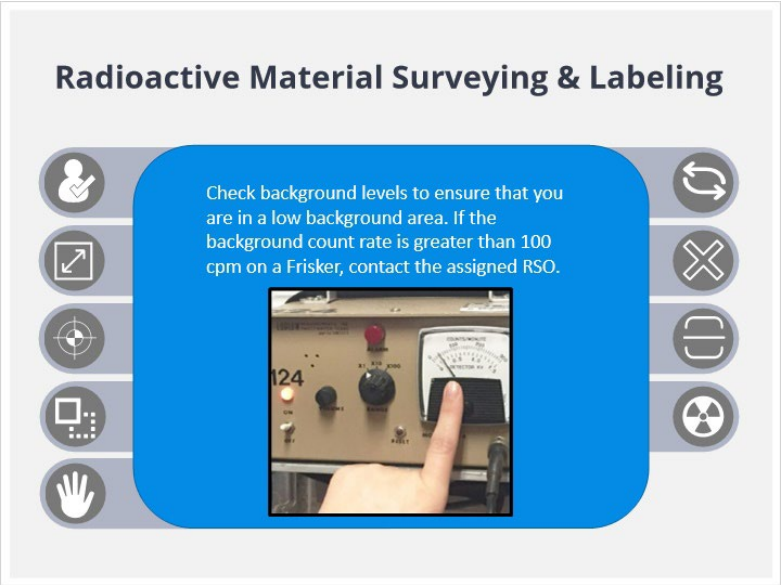
## *16.2 Radioactive Material Surveying & Labeling*


**Verify (Slide Layer)**

## Set to proper scale (Slide Layer)


## Verify calibration (Slide Layer)

**Check background level (Slide Layer)**

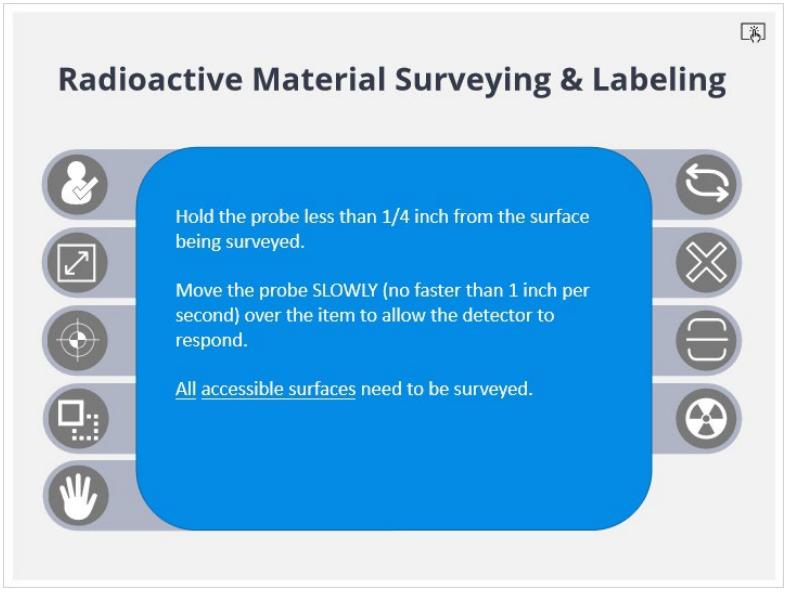



**Frisk your hand (Slide Layer)**

**Response check (Slide Layer)**

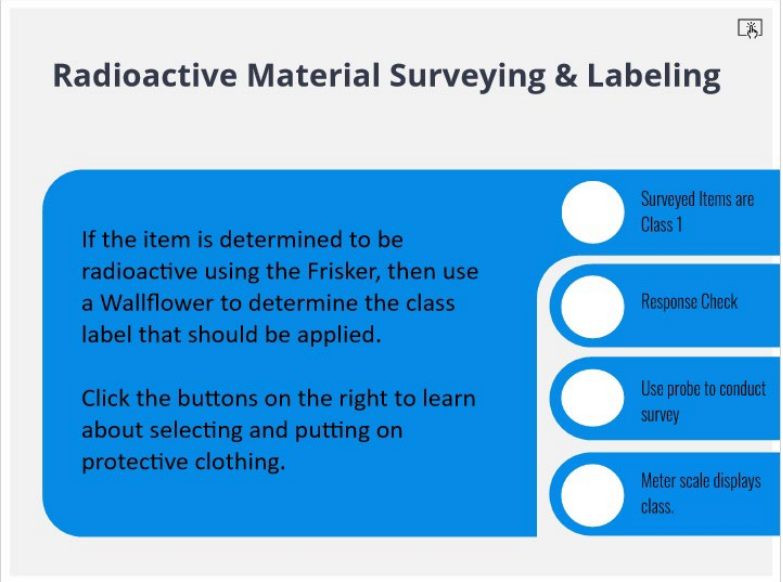

**Source check fails (Slide Layer)**

## Hold the probe (Slide Layer)

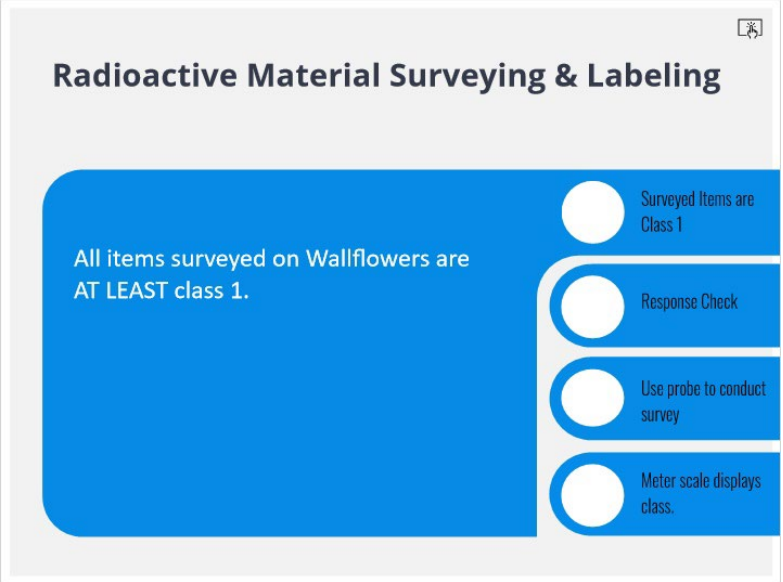



## Reads over 50 (Slide Layer)

## *16.4 Radioactive Material Surveying & Labeling*

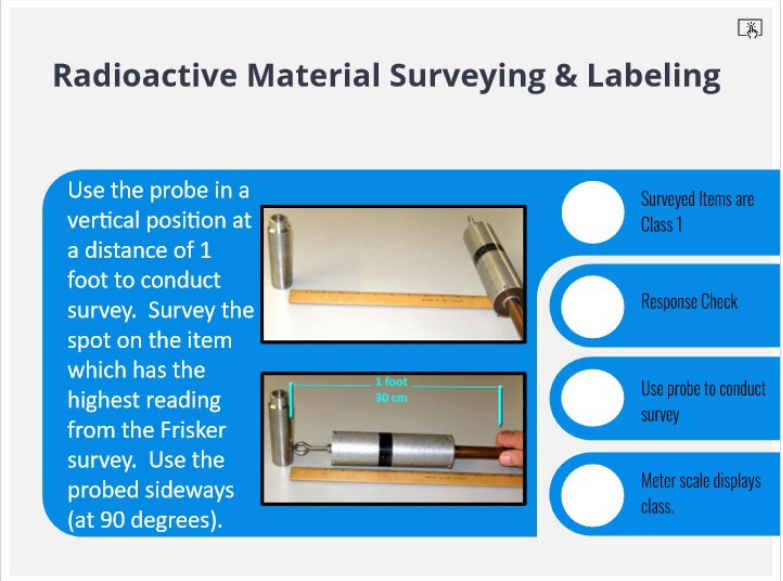



**Items surveys (Slide Layer)**

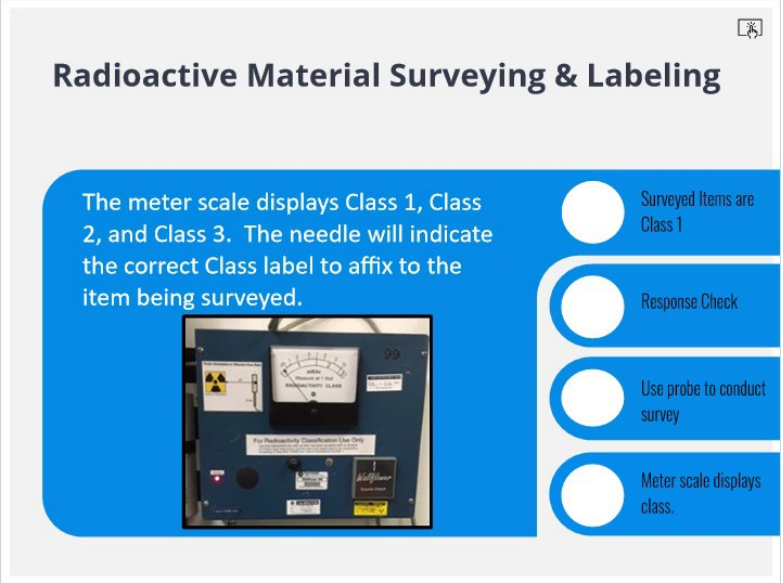


**Response check (Slide Layer)**

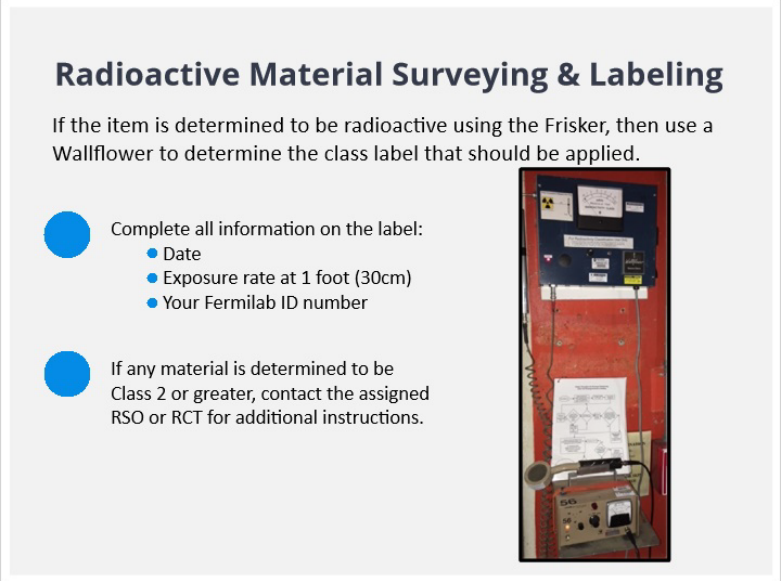

**Use probe to conduct survey (Slide Layer)**



**Meter scale displays class (Slide Layer)**

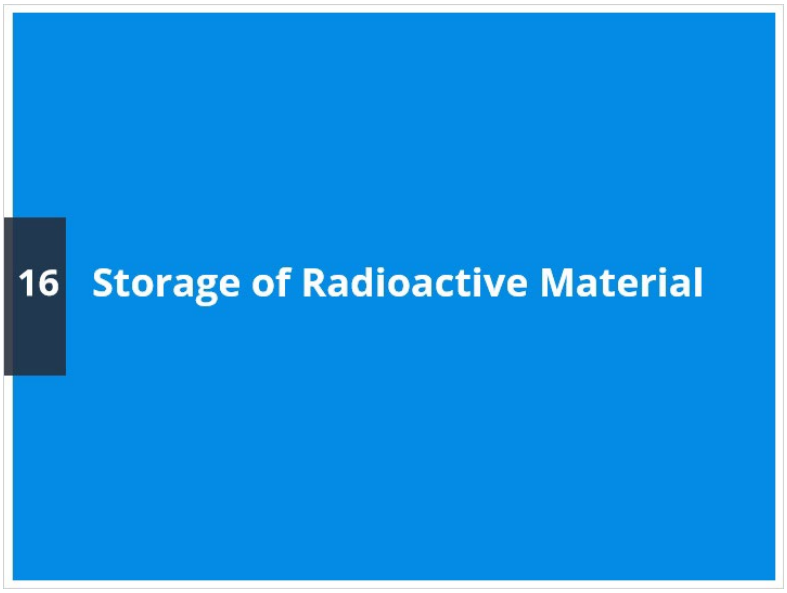



## *16.5 Radioactive Material Surveying & Labeling Cont.*



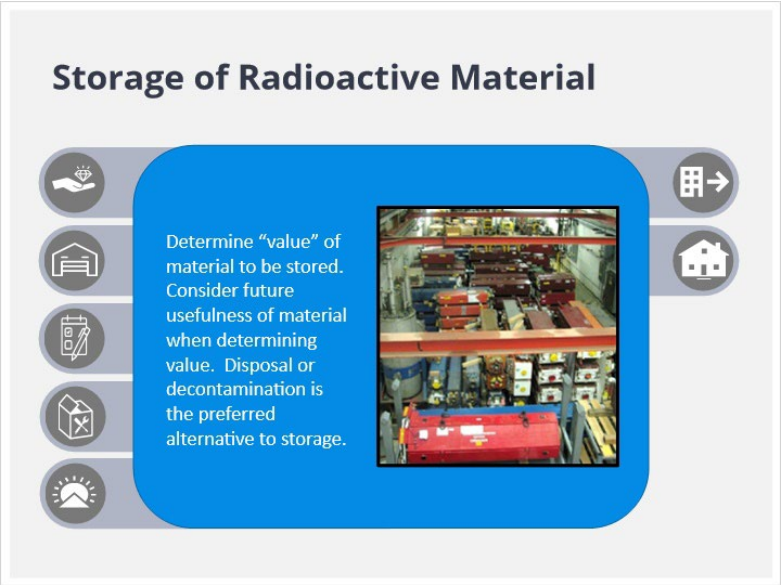
## 17. Storage of Radioactive Material

### *17.1 Storage of Radioactive Material*




### *17.2 Storage of Radioactive Material Cont.*

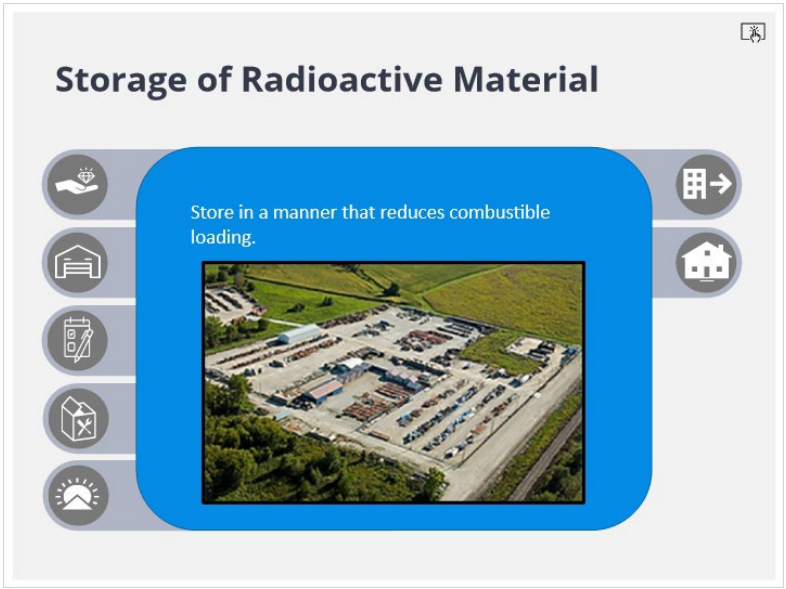
**Determine value (Slide Layer)**



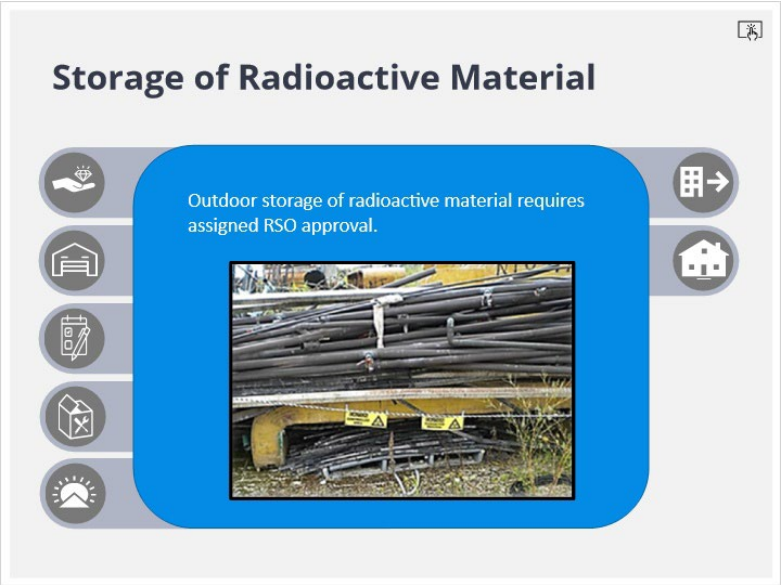

**Store in designated areas (Slide Layer)**

**Items must be surveyed (Slide Layer)**


**Store in a manner (Slide Layer)**



**Outdoor storage (Slide Layer)**

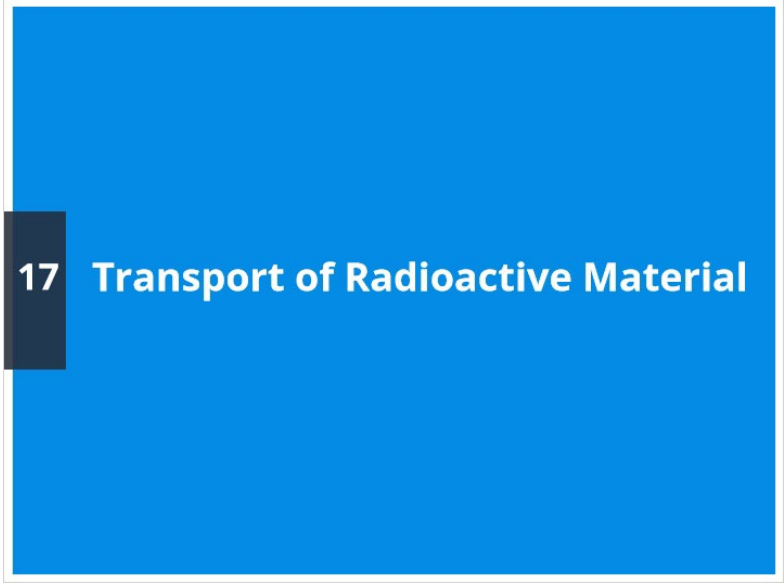



**Not stored off-site (Slide Layer)**

**Not stored in housing (Slide Layer)**

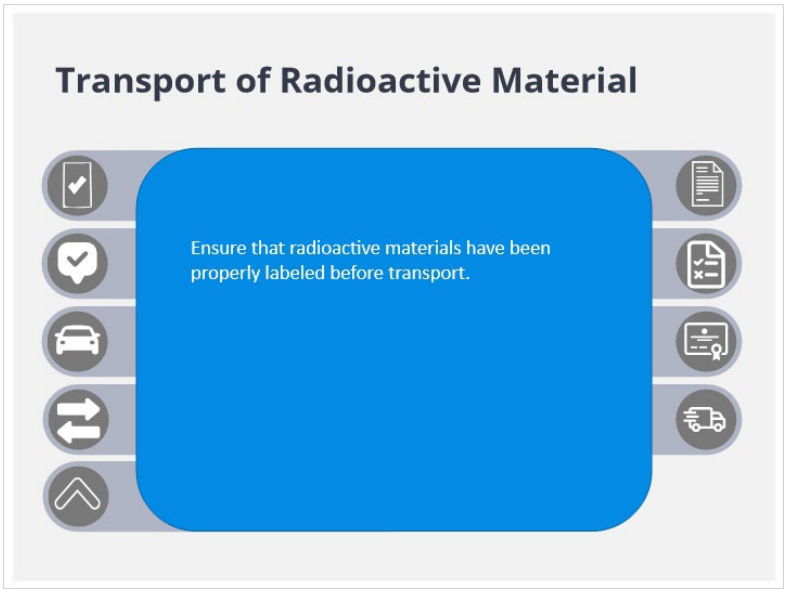

## 18. Transport of Radioactive Material

### *18.1 Transport of Radioactive Material*

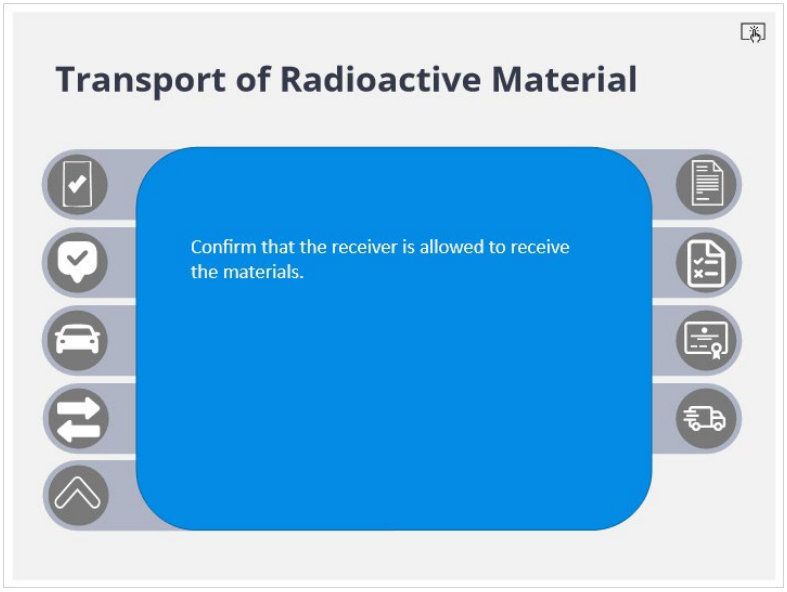


## *18.2 Transport of Radioactive Material*

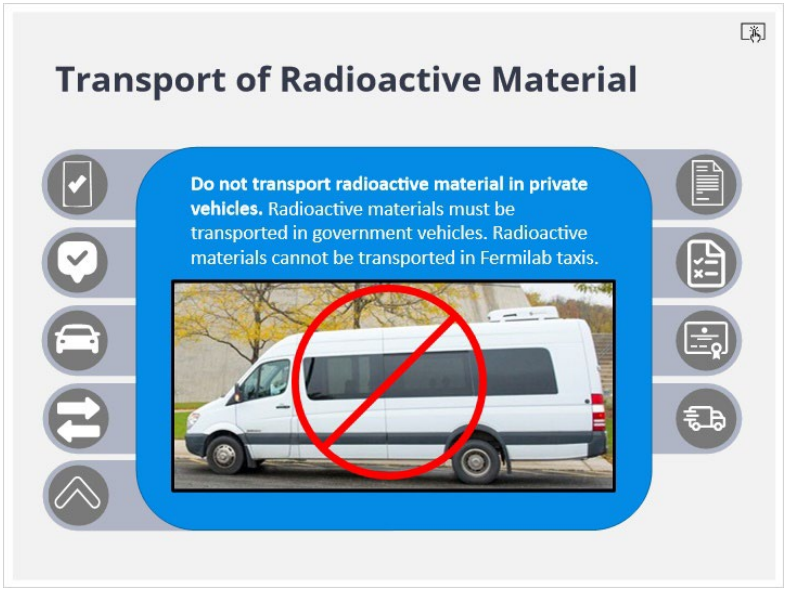

**Ensure (Slide Layer)**



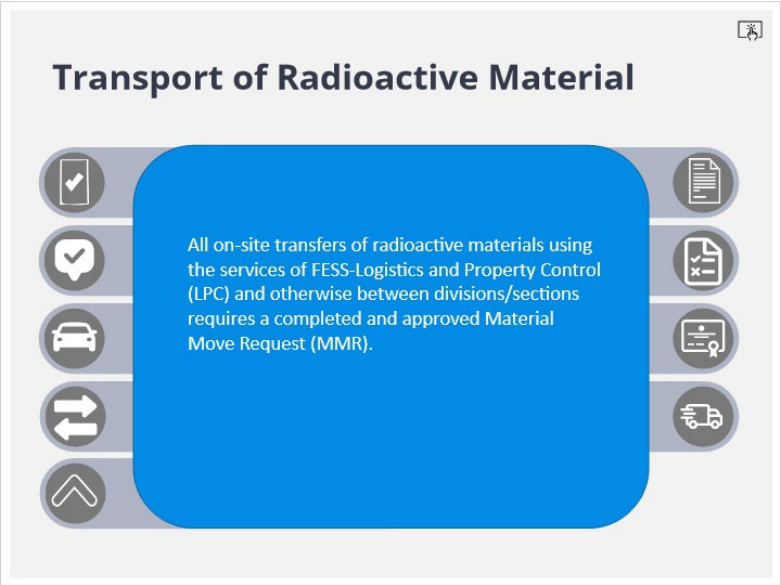
**Confirm the receiver (Slide Layer)**



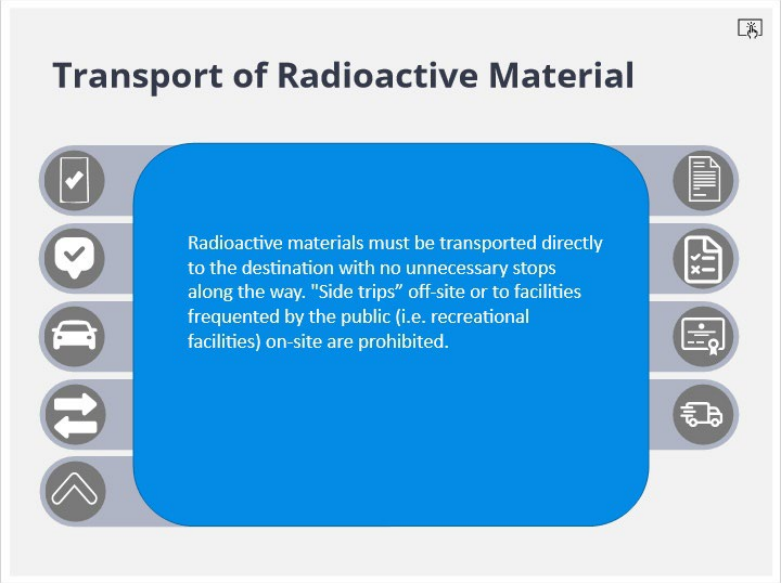

**Do not transport in private vehicles (Slide Layer)**



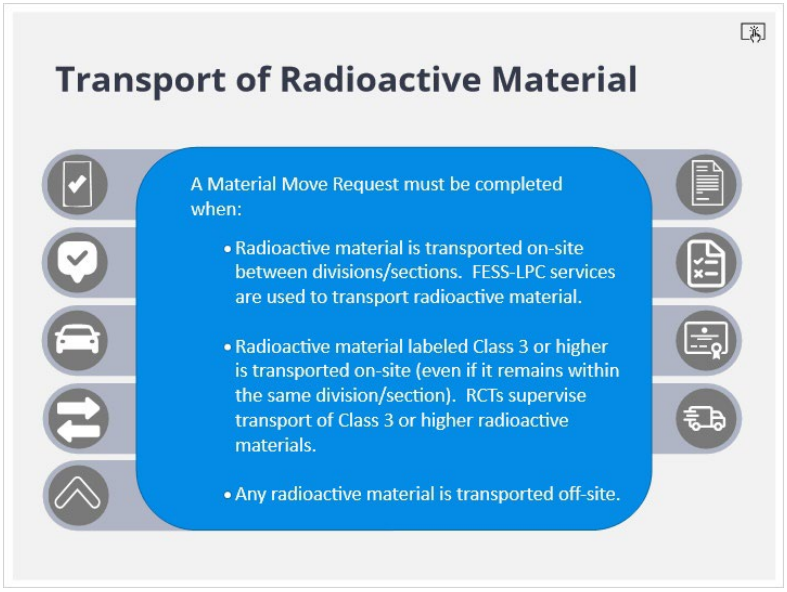
## On-site transfers (Slide Layer)




## Transport Directly (Slide Layer)



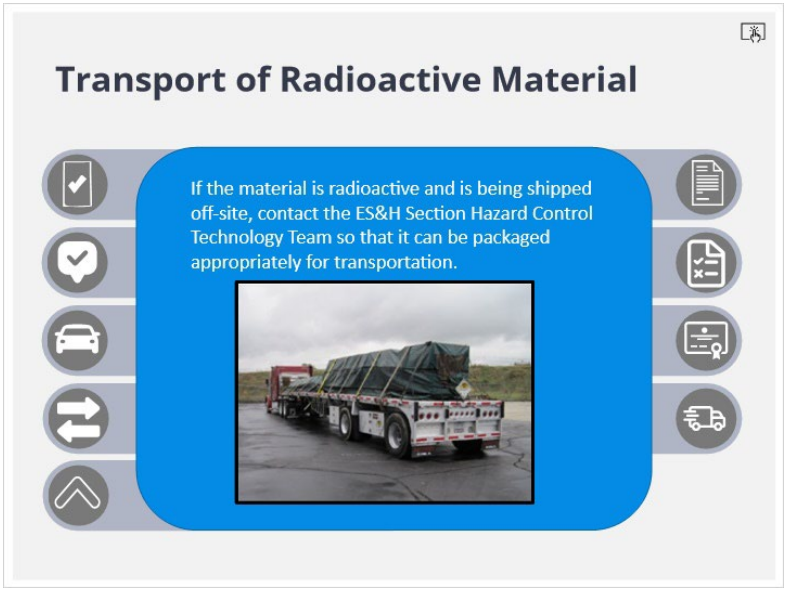
## MMR (Slide Layer)




## Radiation Survey (Slide Layer)

**Trained personnel (Slide Layer)**

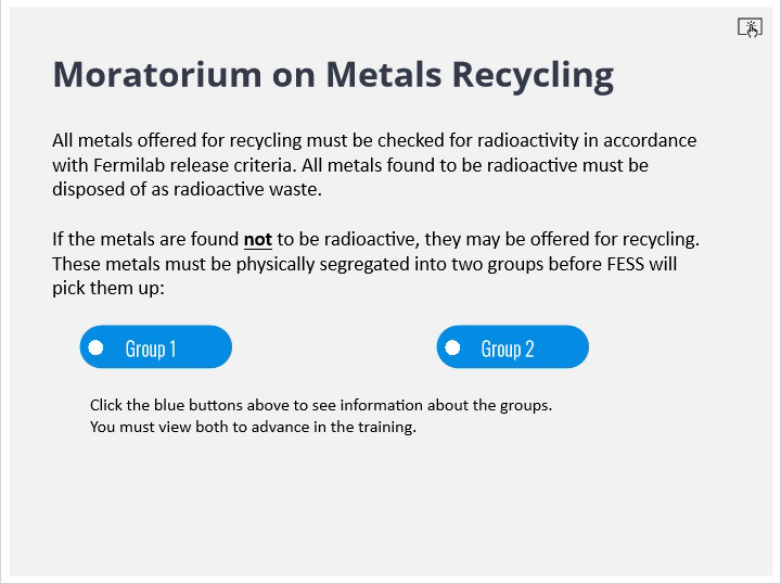

**Shipped Offsite (Slide Layer)**



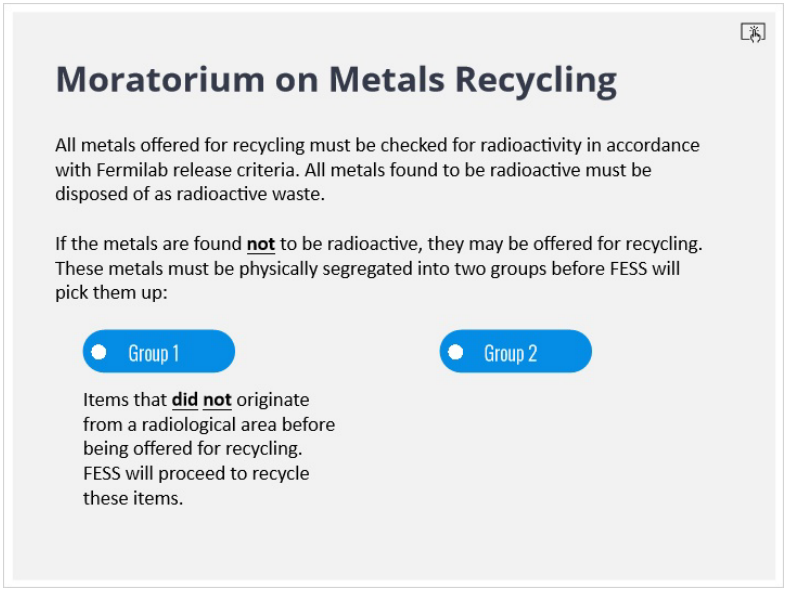
# 19. Moratorium on Metals Recycling

## *19.1 Moratorium on Metals Recycling*

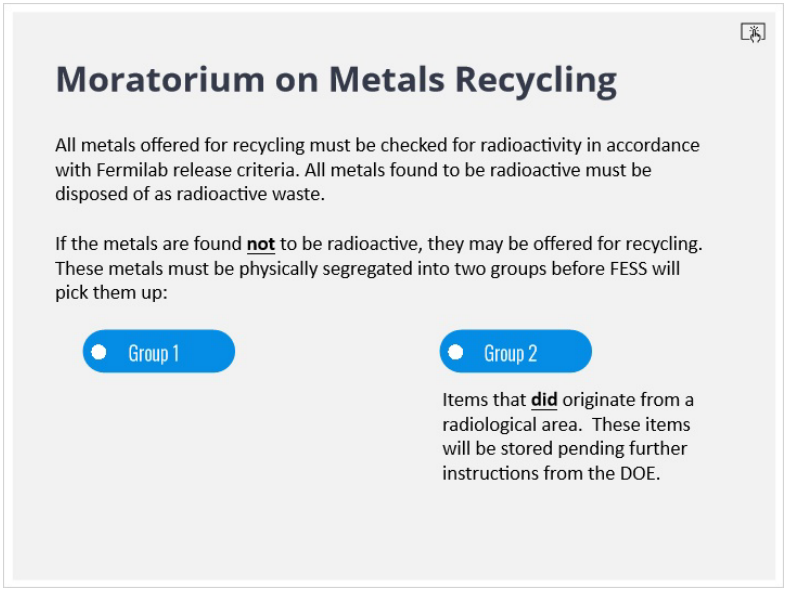

## *19.2 Moratorium on Metals Recycling*



## Group 1 (Slide Layer)

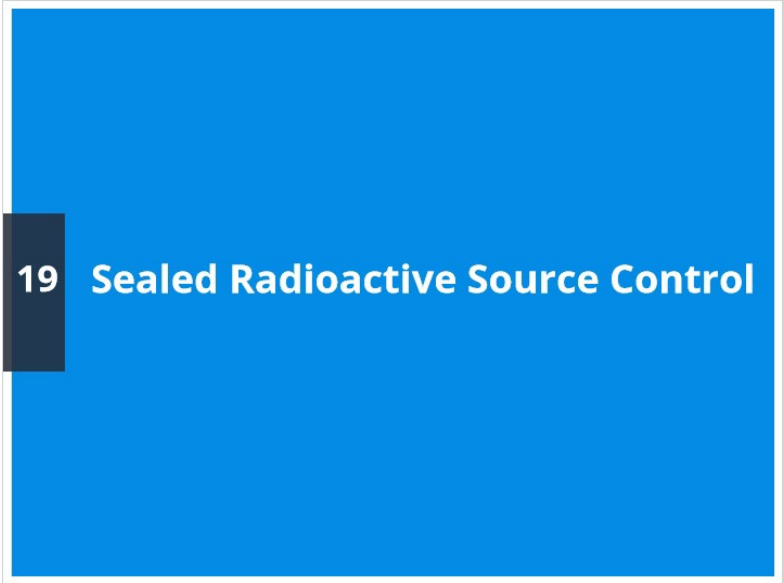



## Group 2 (Slide Layer)



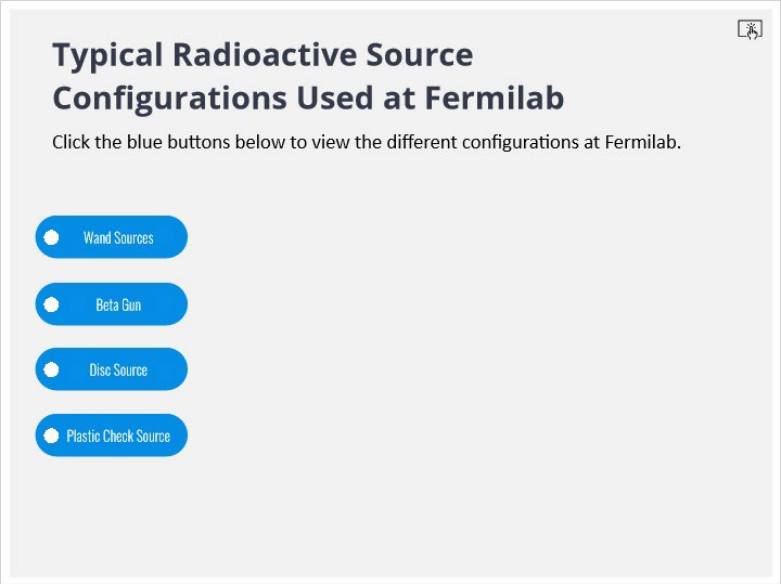
# 20. Sealed Radioactive Source Control

## *20.1 Sealed Radioactive Source Control*

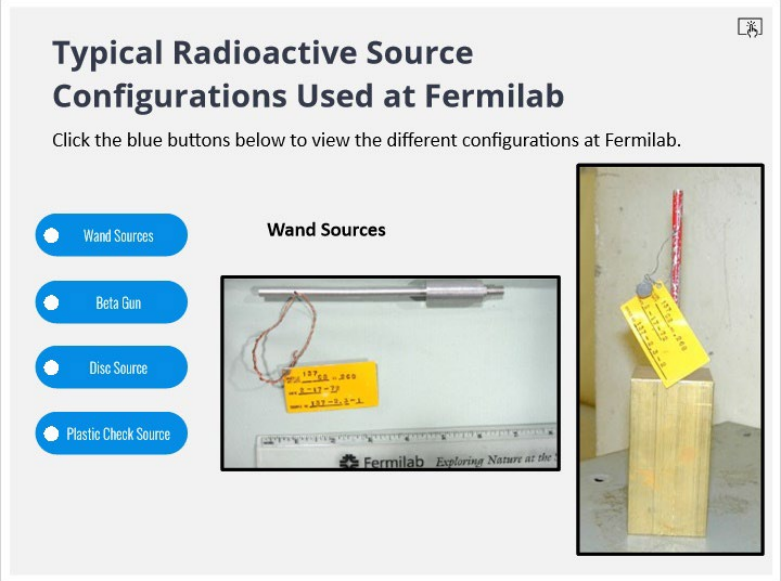



## *20.2 Sealed Radioactive Source Control*

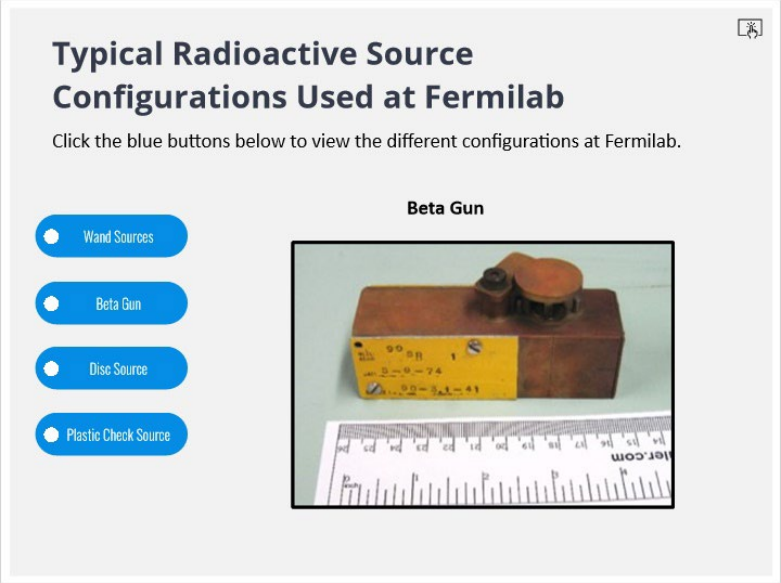
## *20.3 Typical Radioactive Source Configurations Used at Fermilab*



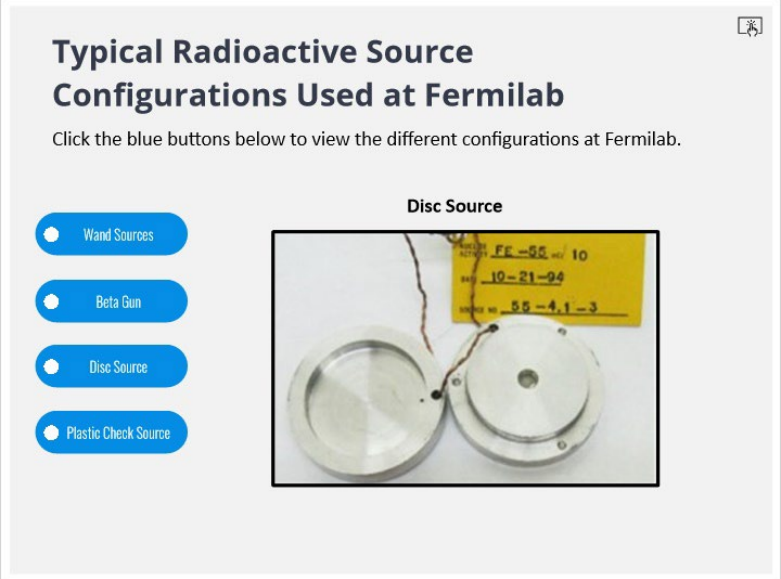

### Wand Sources (Slide Layer)



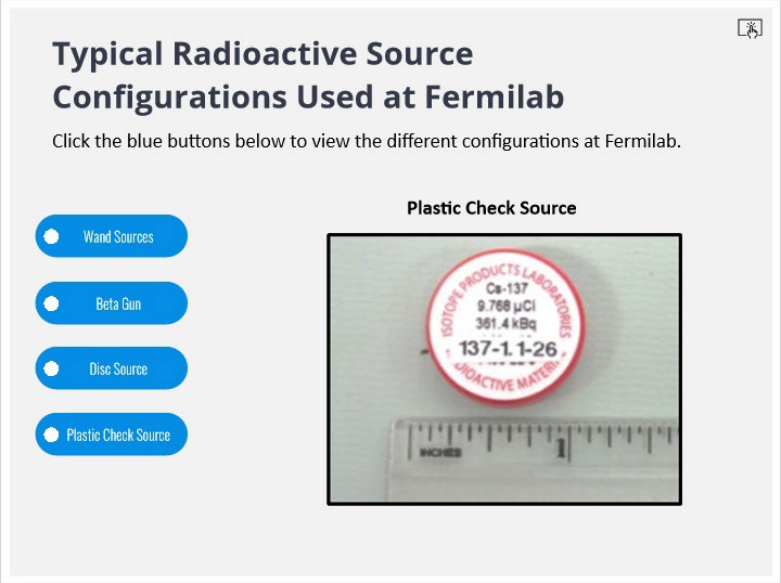
## Beta Gun (Slide Layer)



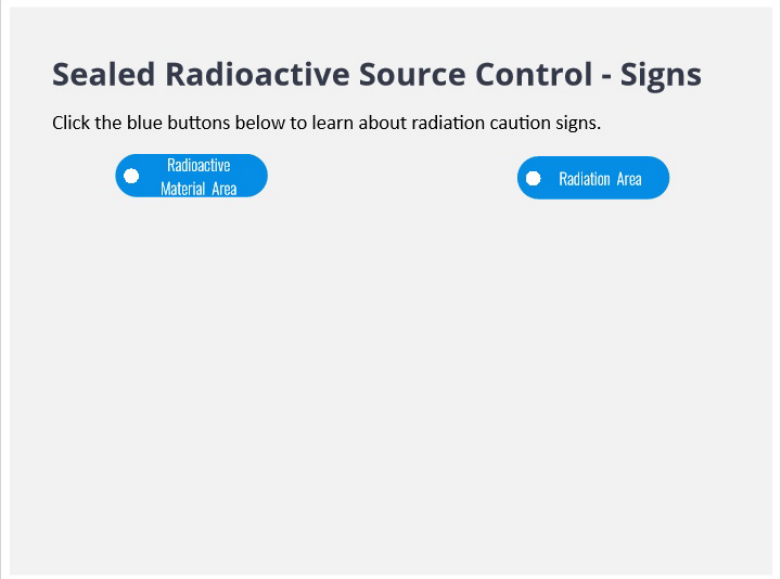

## Disc Source (Slide Layer)



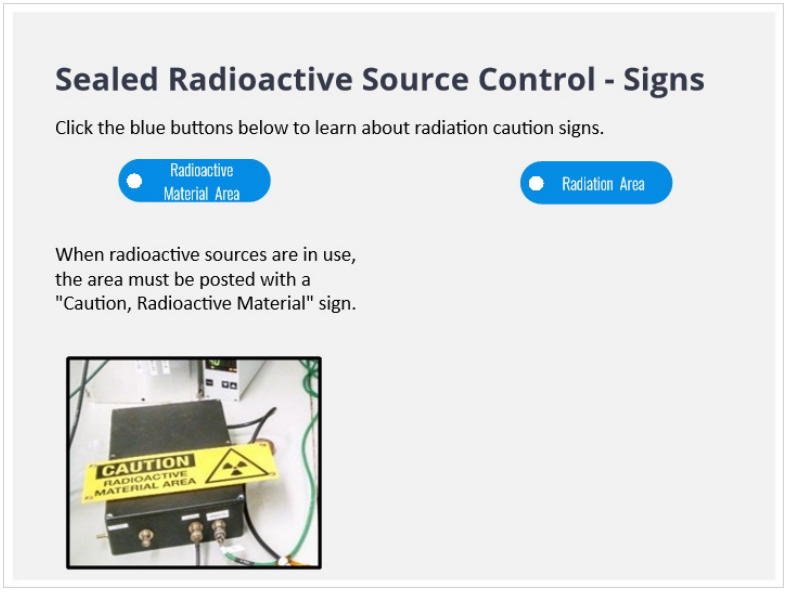
**Plastic Check Source (Slide Layer)**



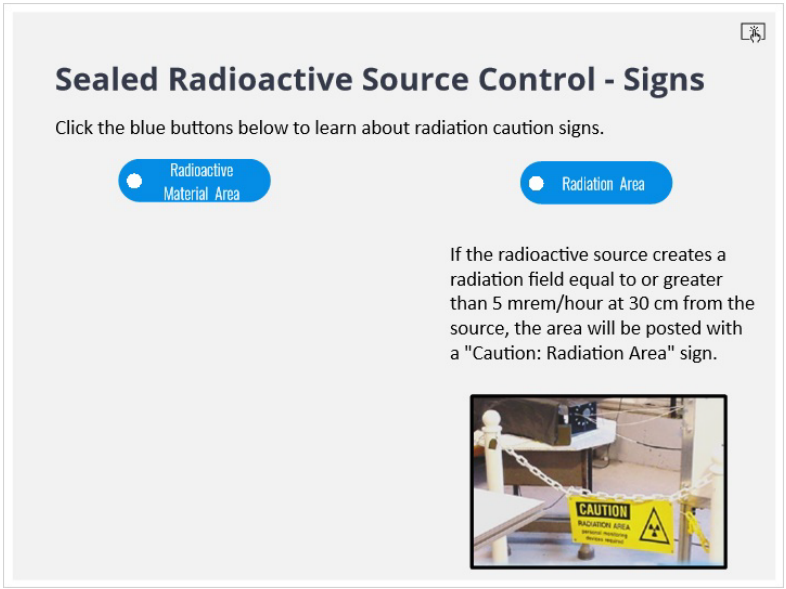

## *20.4 Sealed Radioactive Source Control - Signs*



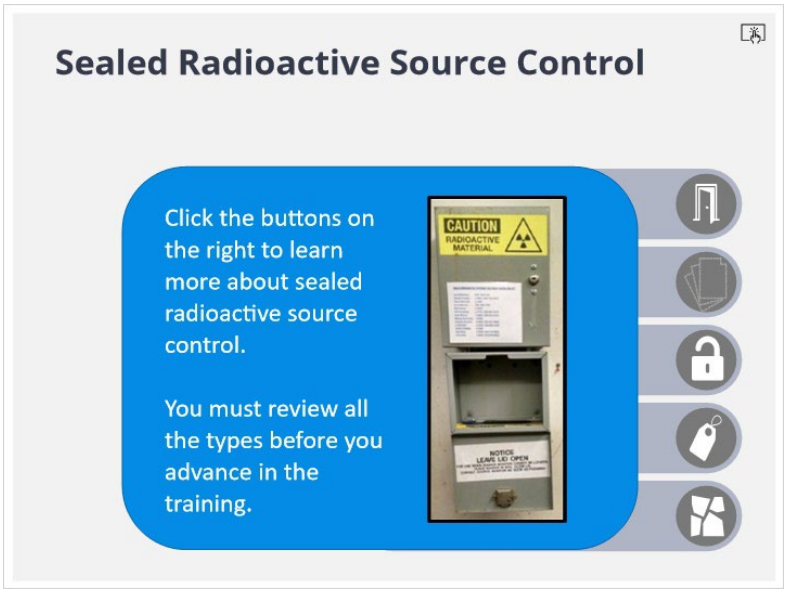
## Radioactive Material Area (Slide Layer)



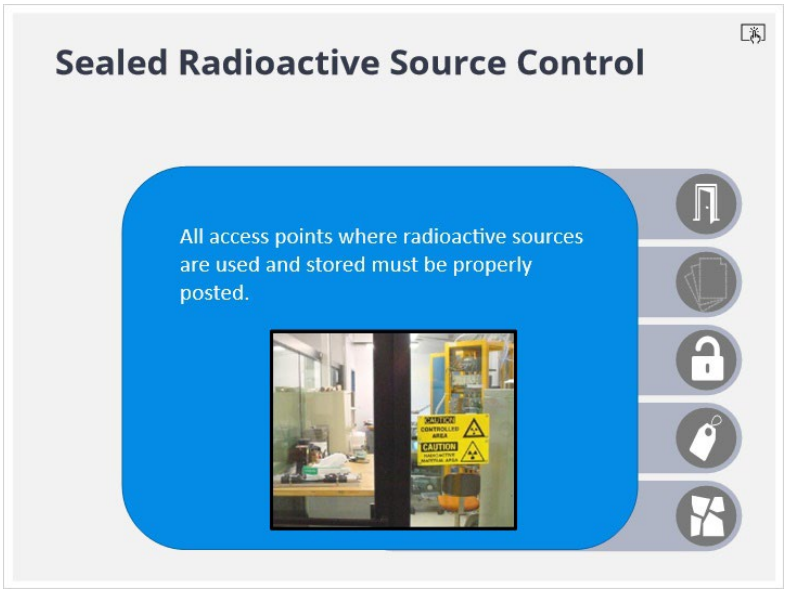

## Radiation Area (Slide Layer)



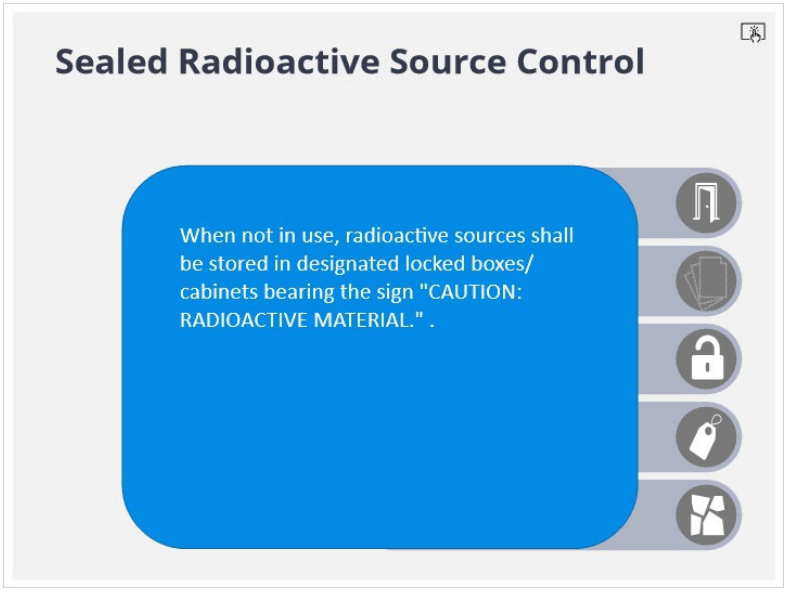
## *20.5 Sealed Radioactive Source Control Cont.*



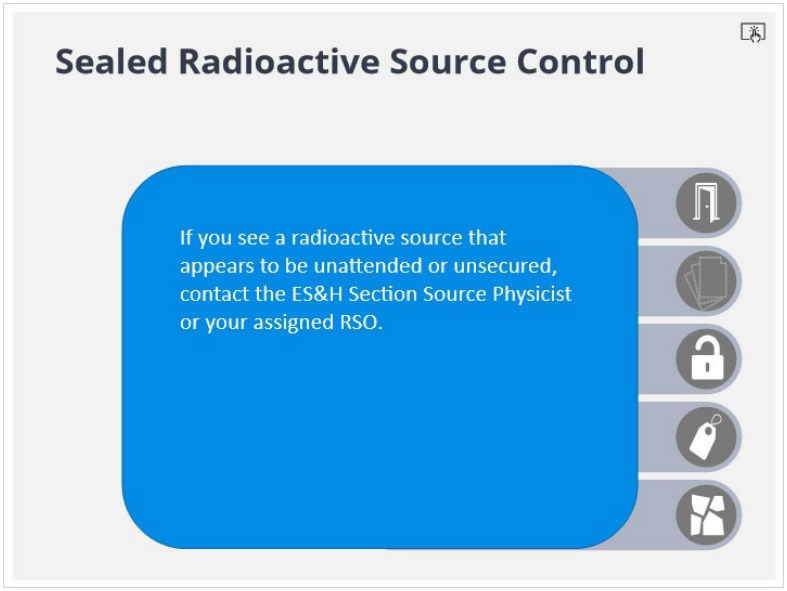

**Access points (Slide Layer)**



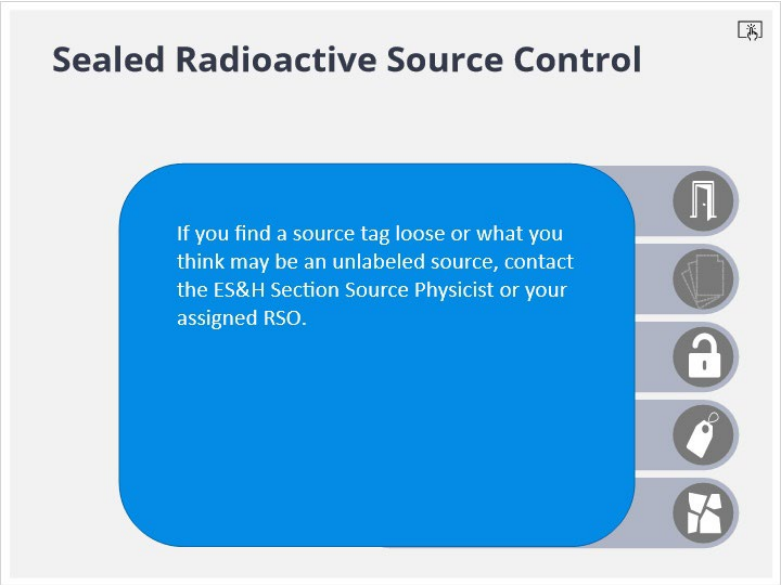
**When not in use (Slide Layer)**



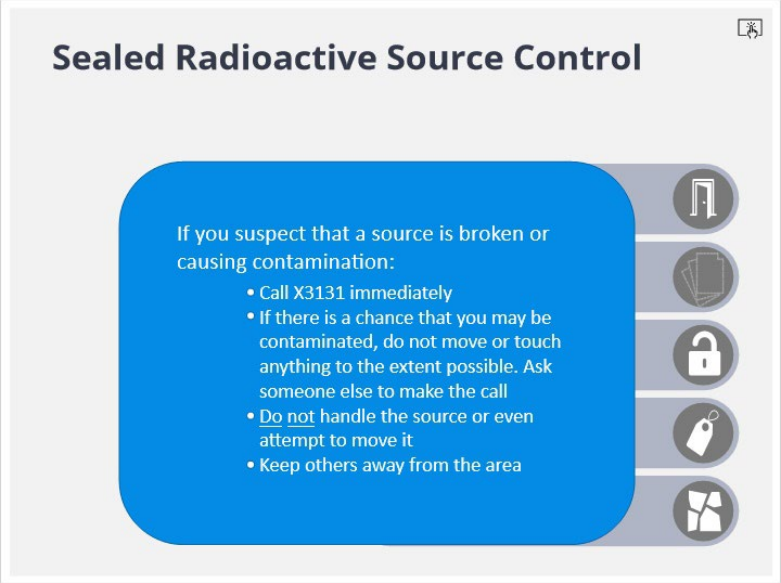

**Un-attended or unsecured (Slide Layer)**



**Loose source tags (Slide Layer)**




**Broken source (Slide Layer)**



# 21. Radioactive Waste Management

## *21.1 Radioactive Waste Management*

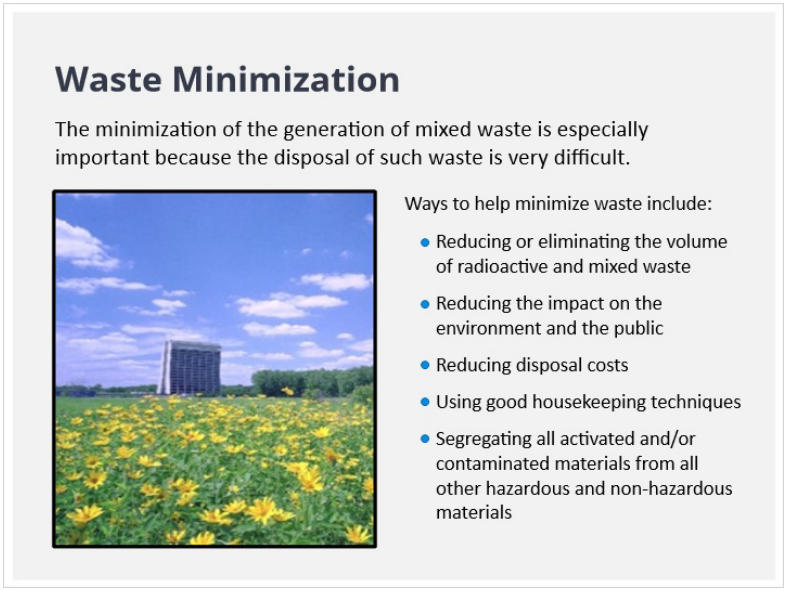

## *21.2 Radioactive Waste Management*

## *21.3 Radioactive Waste Management Cont.*


## *21.4 Mixed Waste*

## *21.6 Mixed Waste Cont.*


## *21.7 Waste Minimization*



## *21.8 Waste Minimization Cont.*

### Waste Minimization

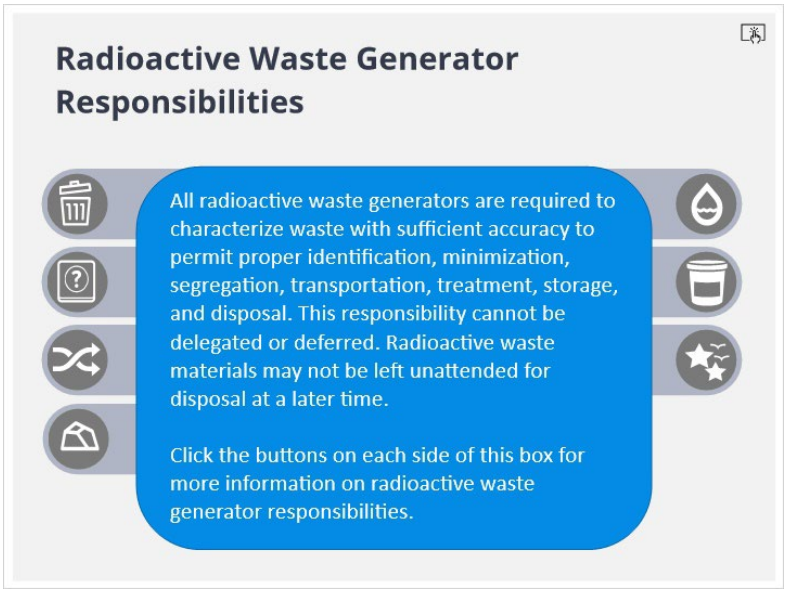
- Remove unneeded materials upon completion of the work.
- Prevent the generation of mixed waste by substituting non-hazardous materials for hazardous materials.
- Do not use hazardous materials to clean radioactive components unless the components have no removable radioactive contamination present. Except for certain special circumstances, water and KPC 820N are the only approved cleaners which may be used on radioactive materials.

## *21.10 Radioactive Waste Generator Responsibilities*

### Radioactive Waste Generator Responsibilities

- Radioactive waste generators must comply with the guidelines outlined in the next several slides.
- You must contact your supervisor and/or rad waste coordinator to discuss the details of how your area handles its radioactive waste. You must contact one of these individuals prior to generating any waste.

## *21.11 Radioactive Waste Generator Responsibilities Cont.*

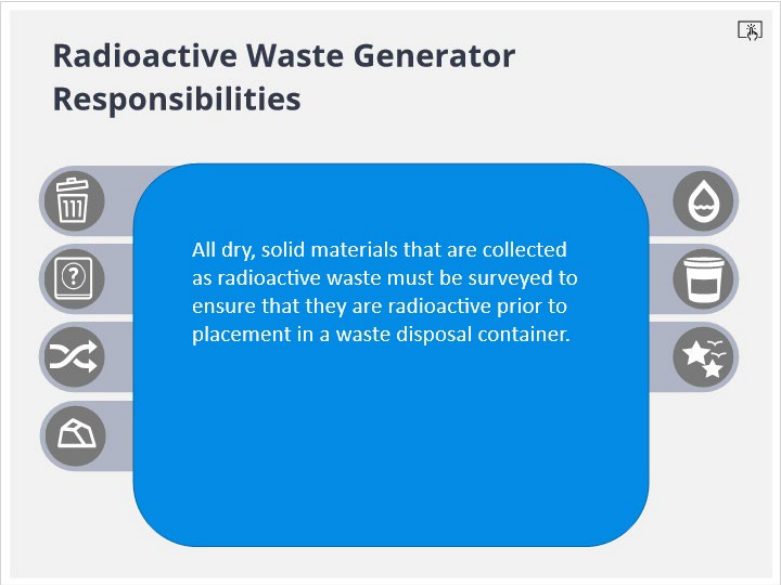



**Proper disposal (Slide Layer)**

**Do not generate unknown waste (Slide Layer)**

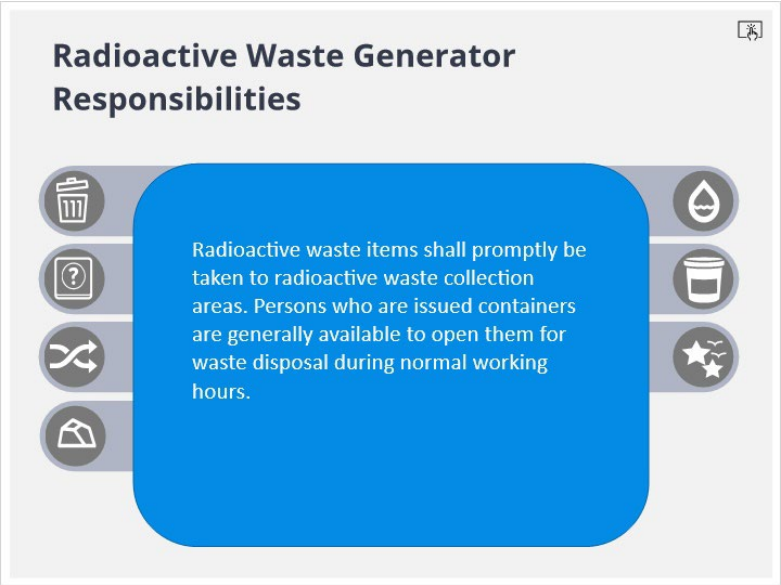

**Do not generate mixed waste (Slide Layer)**

**Solid materials (Slide Layer)**




**Water (Slide Layer)**

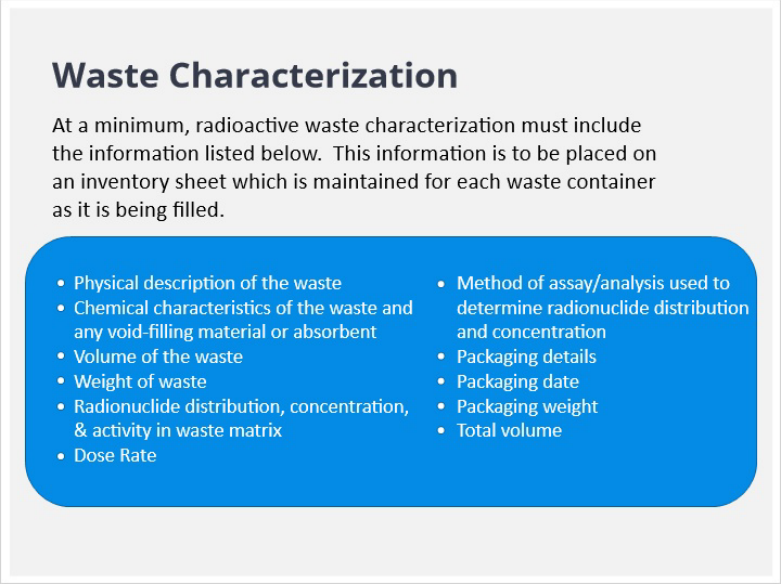
**Radioactive waste to collection areas (Slide Layer)**



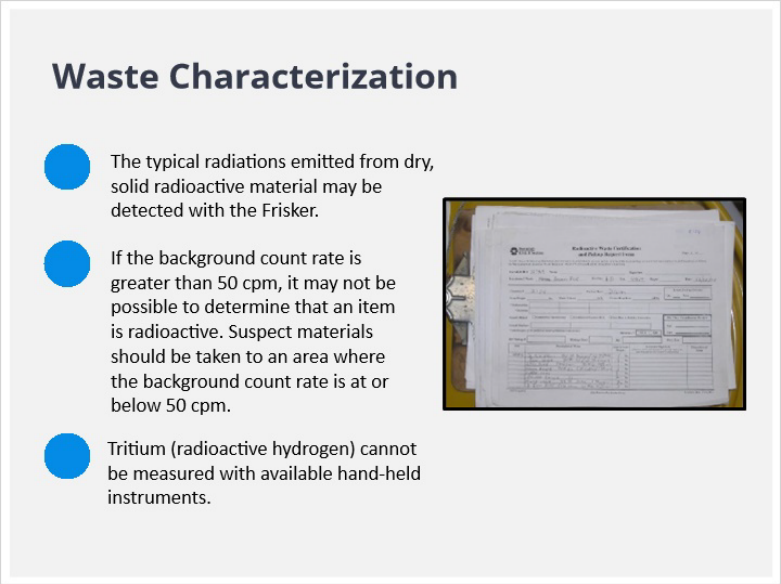

**Off hours (Slide Layer)**

## *21.12 Radioactive Waste Generator Responsibilities - Transporting Radioactive Waste*

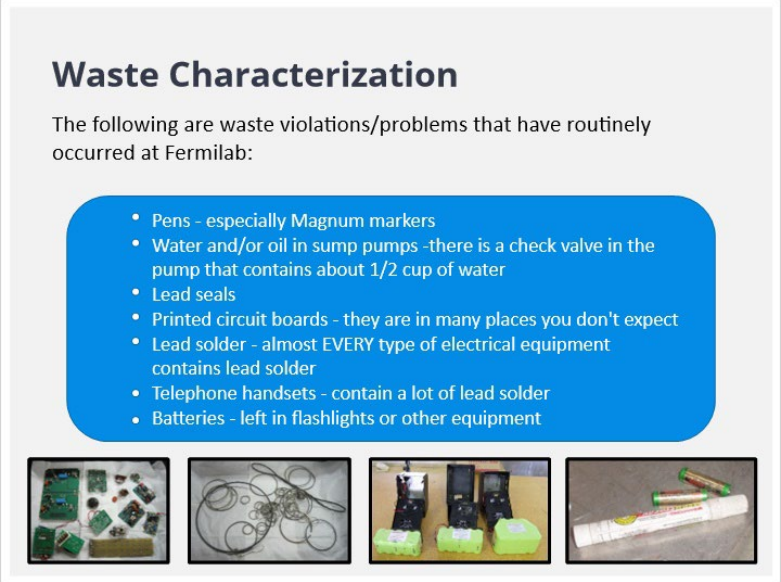

## *21.13 Waste Characterization*



## *21.14 Waste Characterization Cont.*




## *21.15 Waste Characterization Cont.*

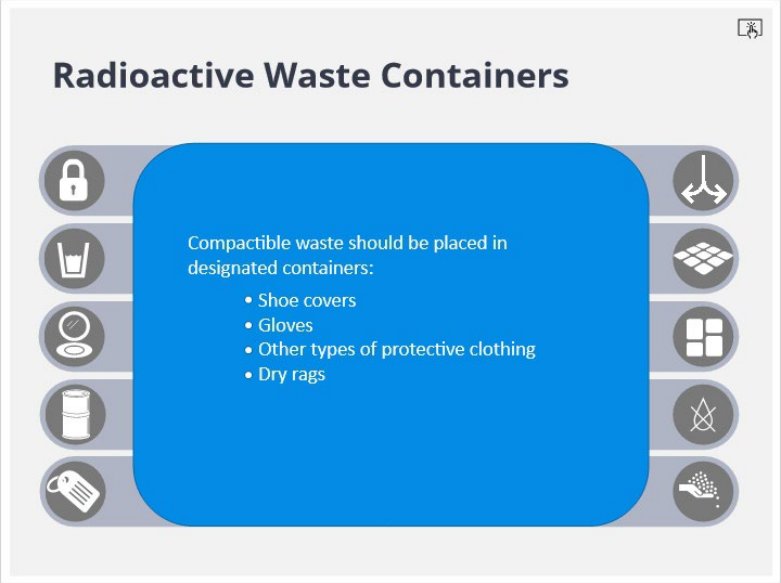


## *21.16 Radioactive Waste Containers*


**Locked (Slide Layer)**

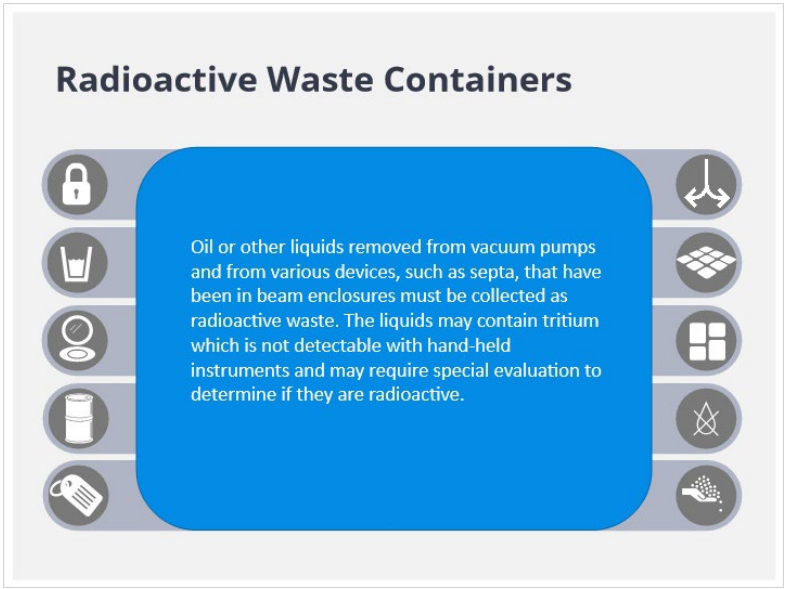
**Liquids (Slide Layer)**


**Compactible waste (Slide Layer)**

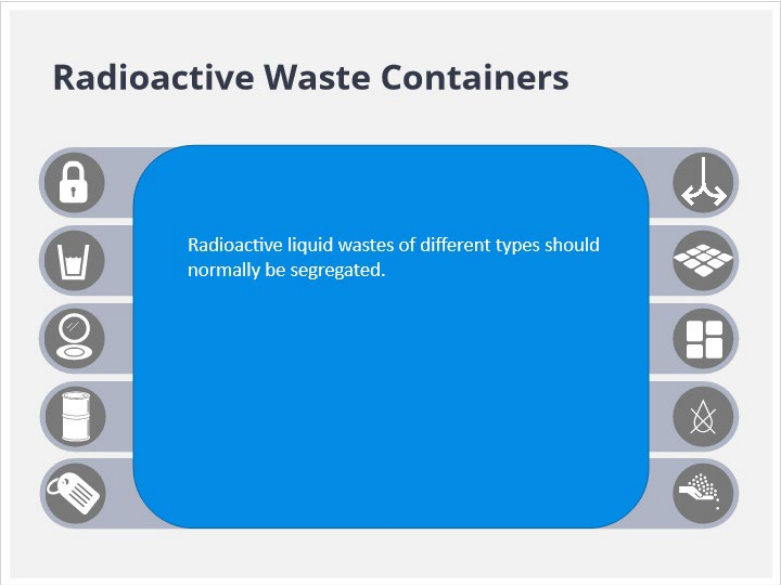


**Liquid labeled (Slide Layer)**

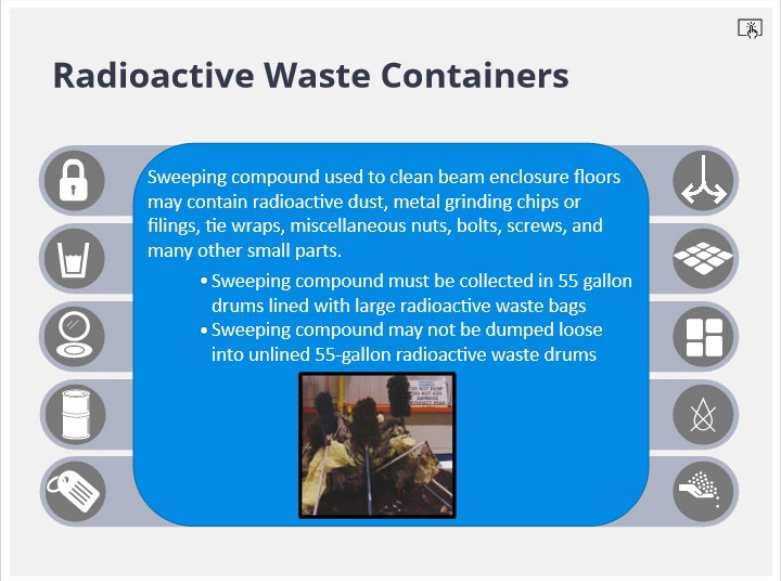

**Oil or liquids (Slide Layer)**



**Segregate liquids (Slide Layer)**

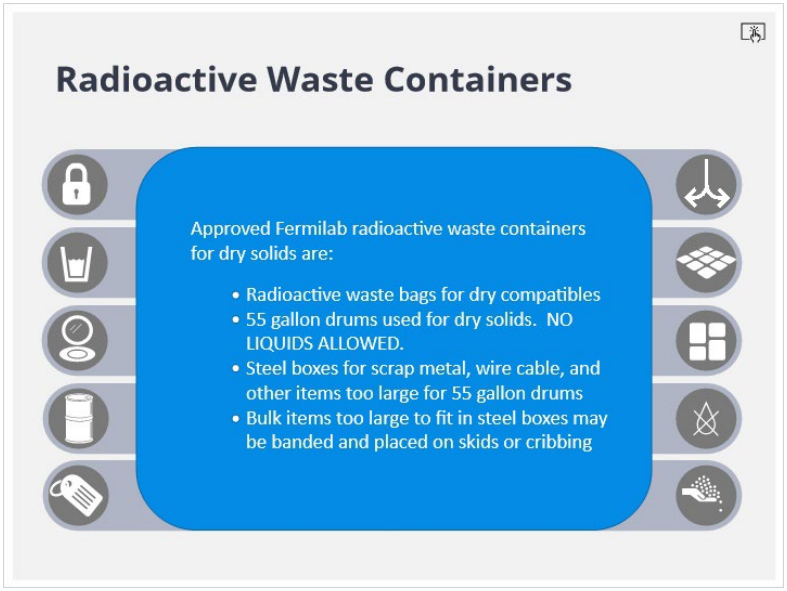



**Beam Enclosure Floor (Slide Layer)**



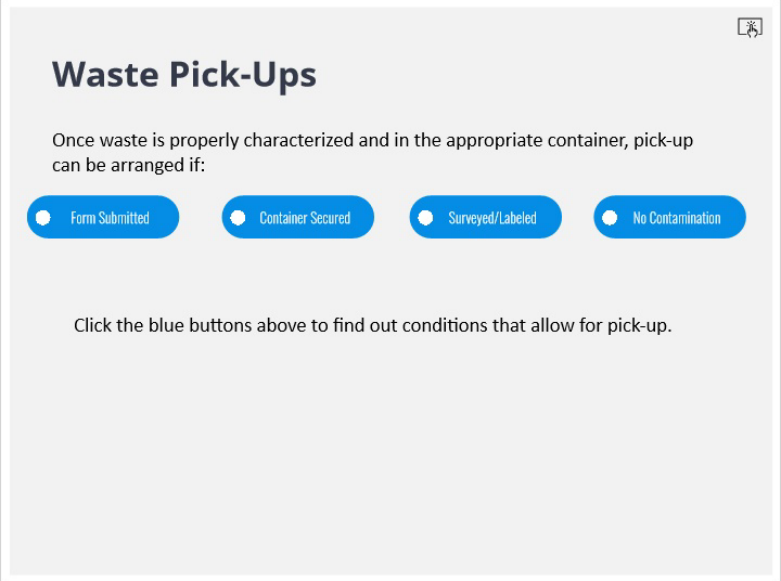
**Non-compactible waste (Slide Layer)**


**Dry solids (Slide Layer)**

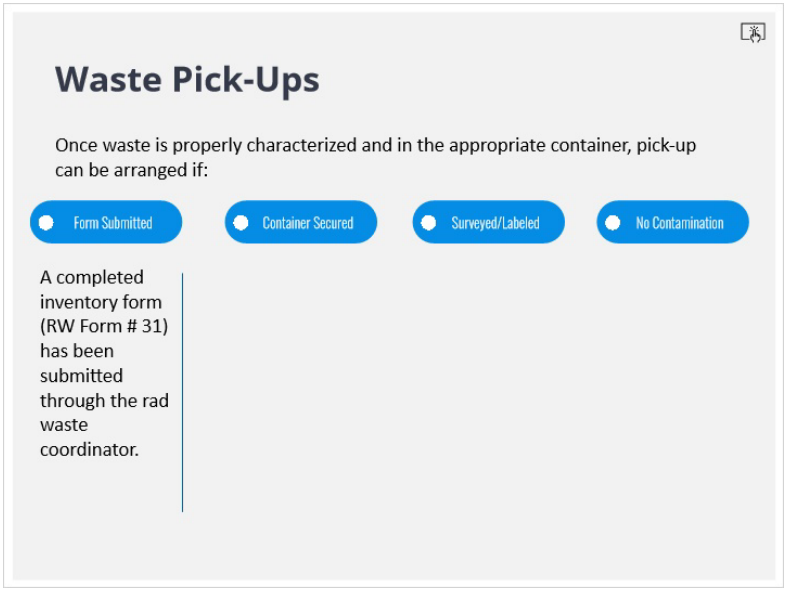


**Large quantities (Slide Layer)**

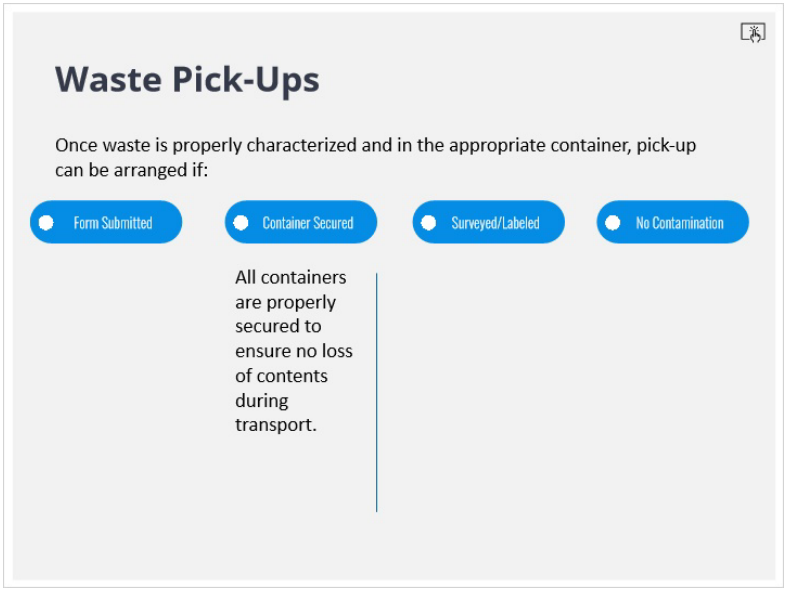

## *21.17 Waste Pick-Ups*



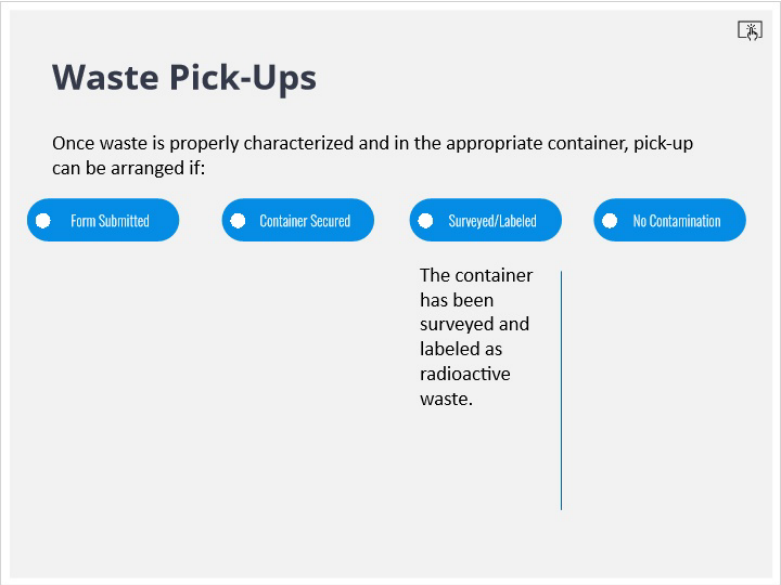
## Form Submitted (Slide Layer)



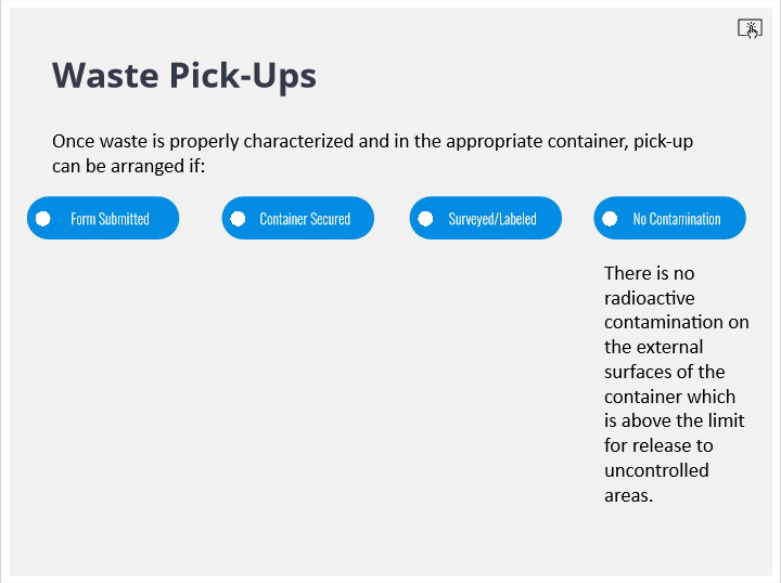

## Containers Secured (Slide Layer)



## Surveyed/Labels (Slide Layer)

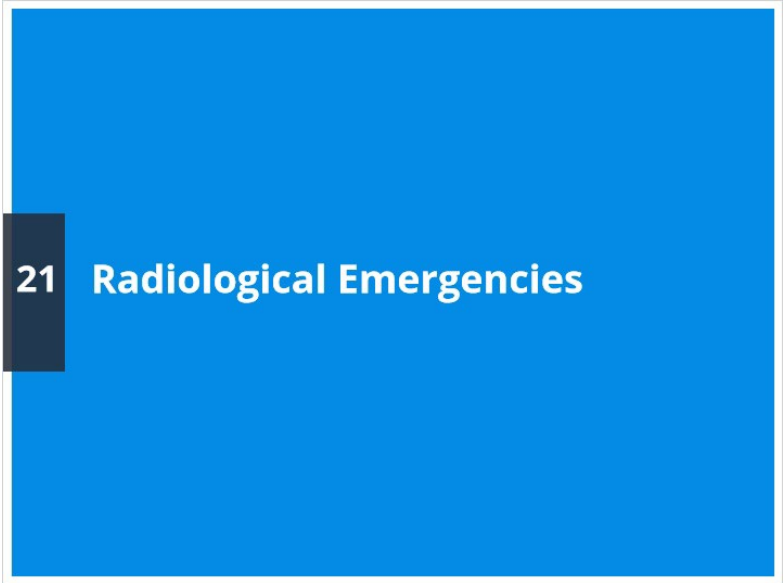



## No radioactive contamination (Slide Layer)



# 22. Radiological Emergencies

## *22.1 Radiological Emergencies*



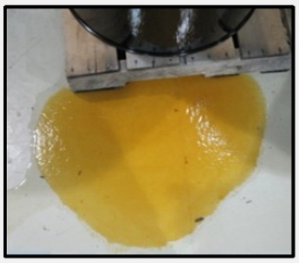

## *22.2 Emergency Situations*

## *22.3 Area Contamination*

### Area Contamination

In some instances, there may be possible area contamination where none is expected. Two potential indicators would be alarming contamination monitors and leaks, spills, or standing water around or near radioactive water systems. If you have reason to suspect this type of contamination:

- Do not enter the area
- Keep others from entering the area
- Immediately report the situation by contacting the assigned RSO via the Main Control Room

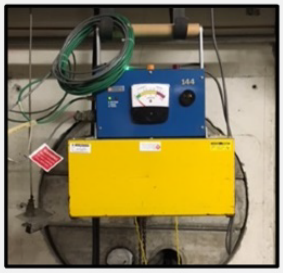


## *22.4 Elevated Radiation Levels*

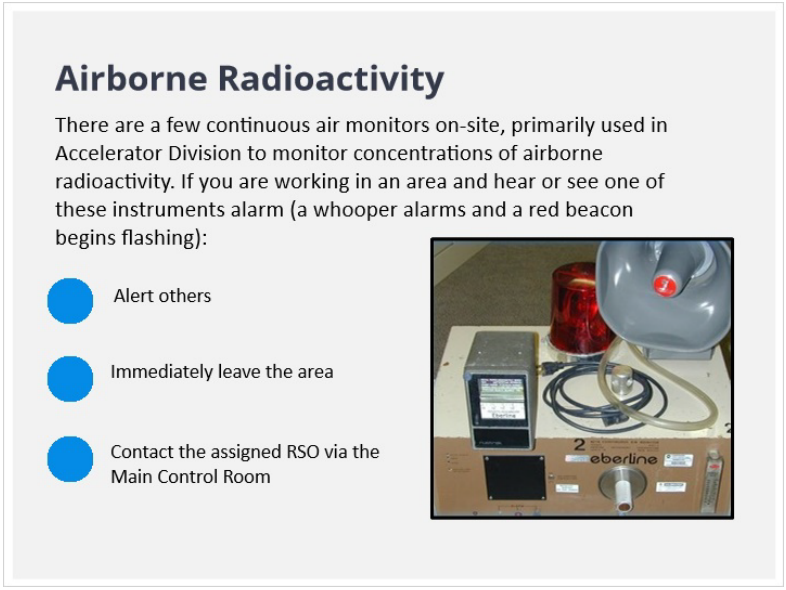
### Elevated Radiation Levels

Chipmunks and Scarecrows are used to monitor radiation fields due to accelerator operations. If you are working in an area and hear one of these instruments unexpectedly alarm:

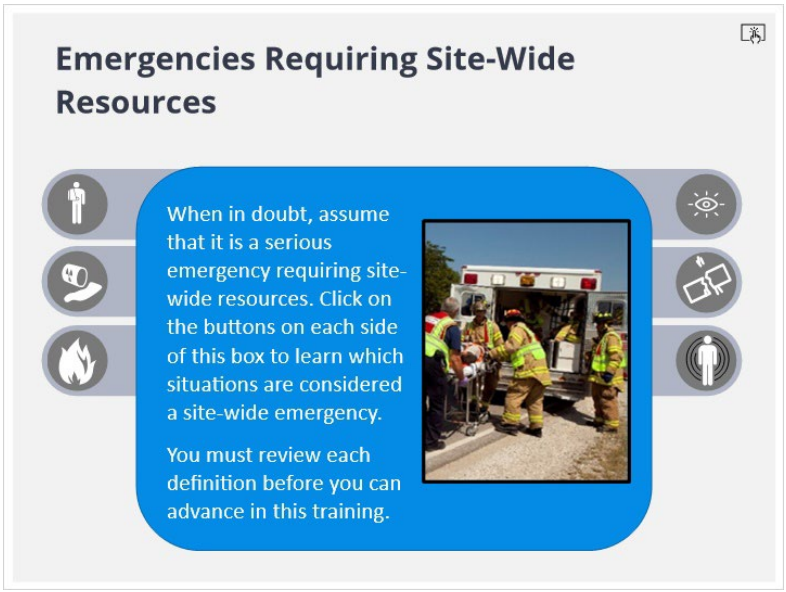
- Alert others
- Immediately leave the area
- Contact the assigned RSO via the Main Control Room



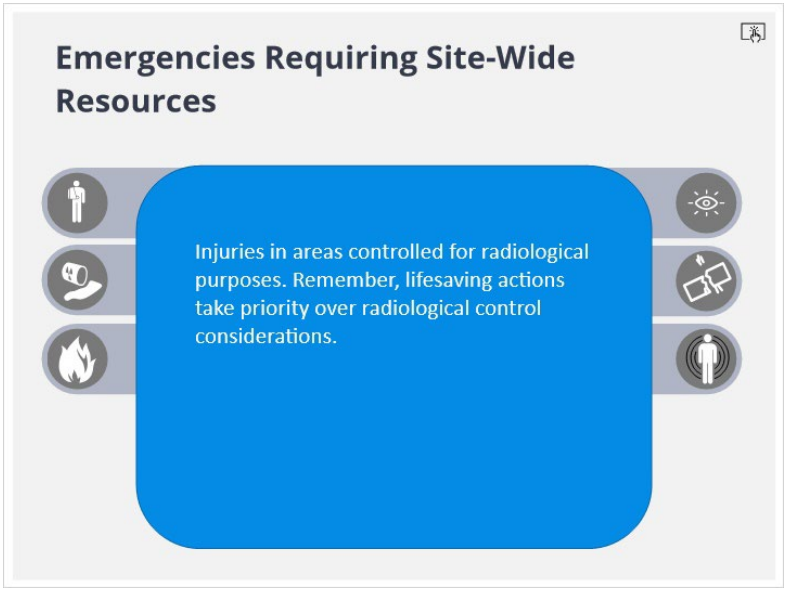
## *22.5 Airborne Radioactivity*




## *22.6 Emergencies Requiring Site-Wide Resources*

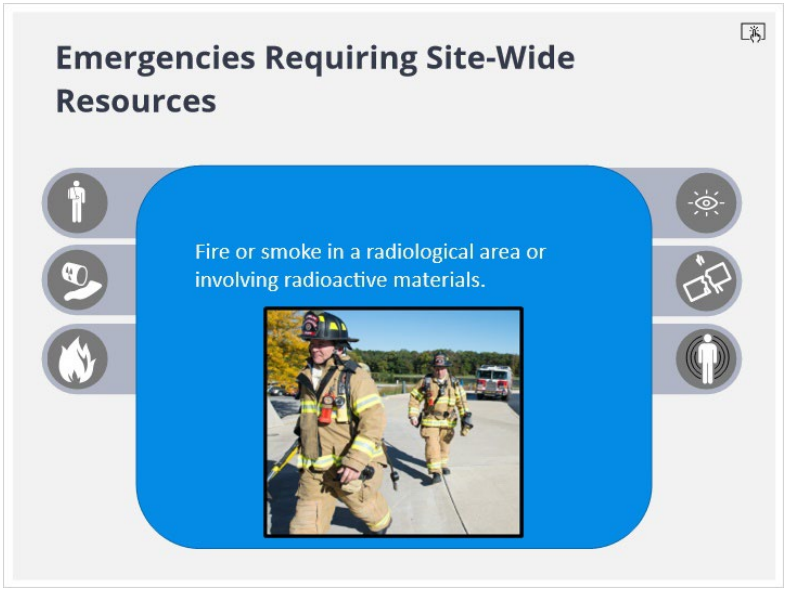


**Injuries in controlled area (Slide Layer)**



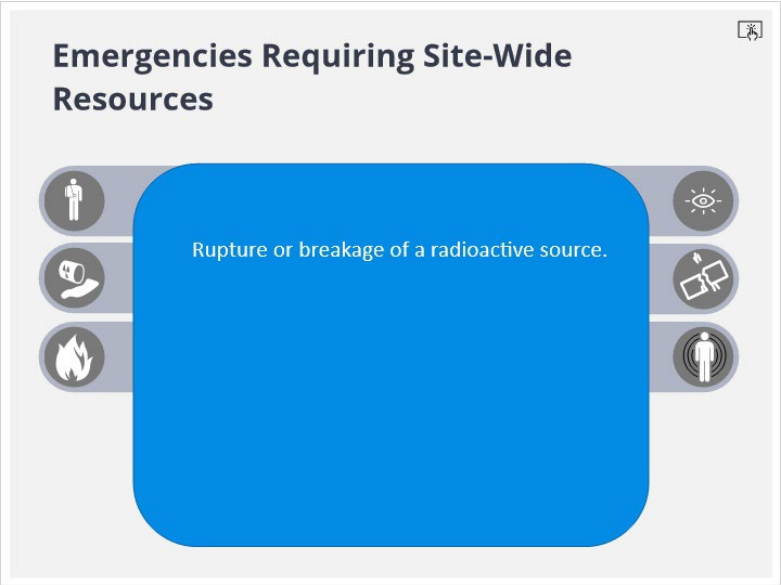

**Leak or spill (Slide Layer)**

**Fire or smoke (Slide Layer)**




**Exposure (Slide Layer)**

**rupture or breakage (Slide Layer)**




**Personnel contamination (Slide Layer)**

## 23. Test

### *23.1 Test*