•Radiation Safety Training

annually for all Accuray "Radiation Worker"
l

to provide the Knowledge, Skills and Abilities
o work safely with radiation

ul training completion involves:

ding and Understanding SOP 027444 "Radiation
ty Program"

ing 80% or higher on the Exam

mail all questions and comments to:
curay.com

- Training To

ic Radiation Theory and Fundamentals

rces of Ionizing Radiation

ogical Effects and Risks of Exposure to Ionizing liation

liation Protection Standards

trolling Radiation Dose

liation Monitoring

sponsibilities for Radiation Protection

ergency Response

liation Safety Training Exam

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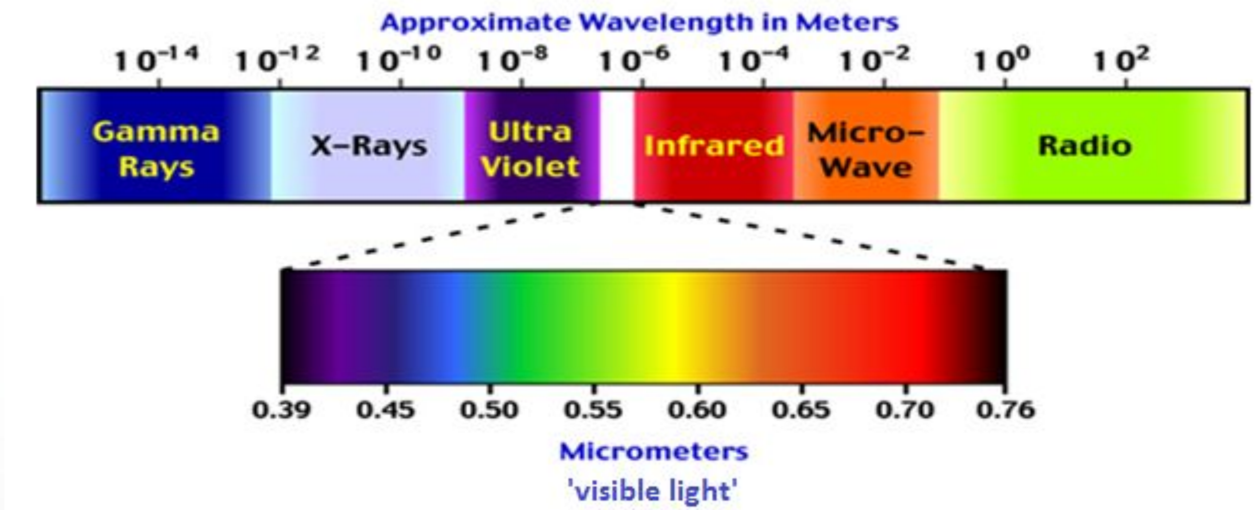
adiation Theory

Radiation is simply energy in the form of particles or waves

Particulate Radiation includes: Alpha, Beta and Neutron

Electromagnetic Radiation (Rays or Waves) includes:



X-rays are the most common type of radiation at Accuray

Atomic Structure

<u>Nucleus</u>: Contains Protons (+1 charge) and Neutrons (no charge)

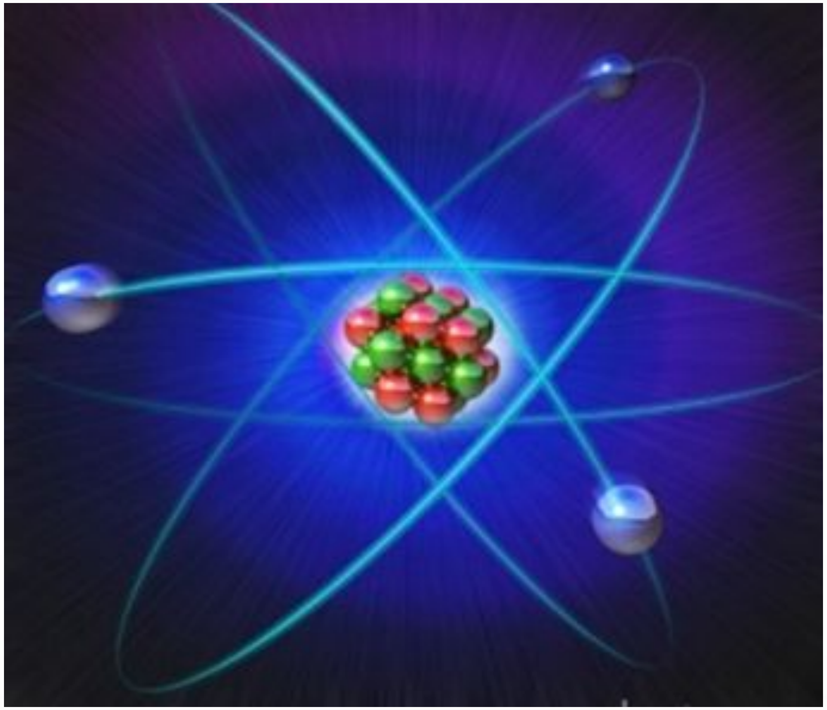
Nuclear Diameter ~ 10^{-15} m

<u>Electrons</u>: *orbit* the nucleus (-1 charge)

Atomic Diameter ~ 10^{-10} m

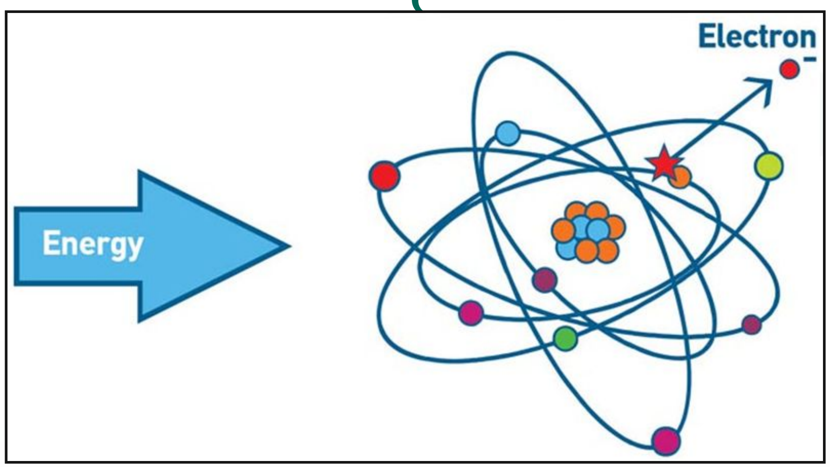
More than 99.9% of the atomic mass and all the positive charge are in the nucleus !

Atomic vs. Nuclear Dimensions !



nizing versus No Radiatio

Ionizing Radiation: Means radiation with sufficient energy to liberate an electron from an atom or molecule. Such an event can alter chemical bonds and produce ions or ion pairs.



The difference between ionizing and non-ionizing radiation is energy.

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Key 'Dose' Terms

Absorbed Dose The rad (**r**adiation **a**bsorbed **d**ose) is the energy deposited per unit mass by ionizing radiation in a material. One rad equals 100 ergs per gram.

The SI unit of absorbed dose is the Gray. 1 Gy = 1 Joule/kg = 100 rad

Dose Equivalent Takes into account the biological effectiveness, or *quality*, of different types of radiation. Dose Equivalent, measured in rems or Sieverts, is equal to the absorbed dose times a quality factor (Q).

Equivalent Dose Takes into account the different probability of effects that occur with the same absorbed dose delivered by radiations with different weighting factors (W_R).

The SI unit of Equivalent dose is the Sievert. 1 Sv = 100 rem

Exposure The unit of radiation exposure in air is the Roentgen (R). It is defined as that quantity of x-rays causing ionization in air equal to 2.58×10^{-4} coulombs per kilogram (C/kg).

Air Kerma **K**inetic **E**nergy **R**eleased per unit **Ma**ss of a small volume of air when it is irradiated by an x-ray beam. Kerma is measured in Gy.

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Key 'Dose' Terms Cont.

- 1 Sv = 100 rem
- 1 Gy = 100 rads = 100 cGy
- 1 cGy = 1 rad

Radiation	W_R	Q
X-Rays, β-Rays, γ-Rays	**1**	**1**
Protons	2-5	10
Alpha Particles, Fission Fragments	20	20

Equivalent Dose (H_T) = Absorbed Dose ($D_{T,R}$) x Weighting Factor (W_R)

$$\mathbf{H_T = D_{T,R} \times W_R}$$

Dose Equivalent (H) = Absorbed Dose (D) x Quality Factor (Q)

$$\mathbf{H = D \times Q}$$

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For X-RAYs: Q = W = 1

More Key Definitions

Radioactivity: The spontaneous decomposition or disintegration of unstable atomic nuclei is termed radioactivity. The energy and particles which are emitted during the decomposition /decay process are called radiation.

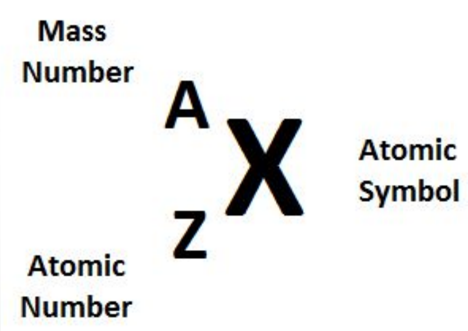
Units of Measure: Becquerel (1 disintegration per second)
Curie (3.7 x 10^{10} decays per second)

Contamination: Simply put, contamination is radioactivity where it is not wanted or controlled.

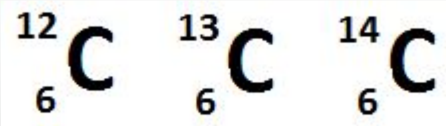
Units of Measure: Becquerels per liter (Bq/L) - if gas or liquid
Bq/cm^2 or $\mu Ci/m^2$ - if on a surface

Atomic Number (Z): Number of protons in the nucleus.

Mass Number (A): Number of neutrons and protons in the nucleus.



Isotopes: Chemical elements with the same Z number .



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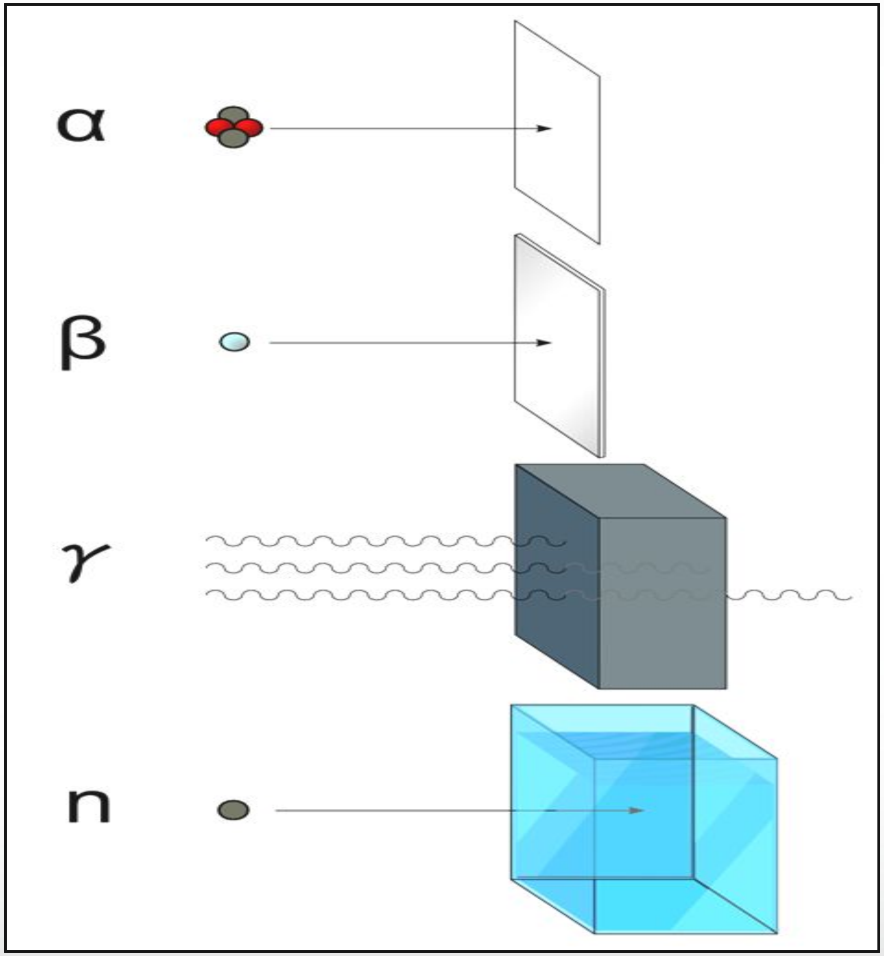
Types of Ionizing Radiation and Penetrating Ability

Alpha Particle
Massive; +2 charge

Beta Particle
Some Mass; +/- 1 charge

Gamma / X-Ray
No mass; No charge

Neutron
Massive; No charge



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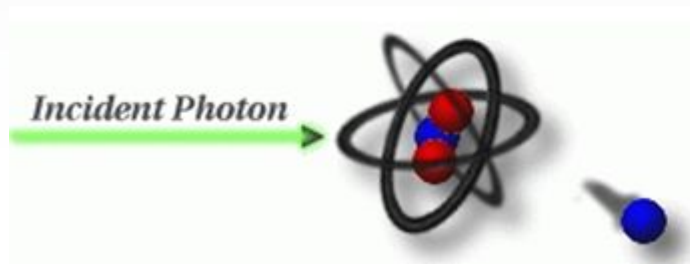
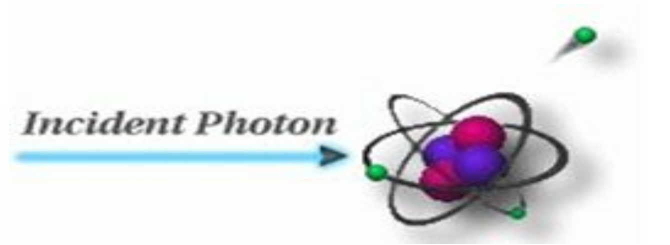
X-Ray (photon) Interactions with Matter

Photodisintegration



X-Ray disappears => liberates a proton, neutron or alpha particle

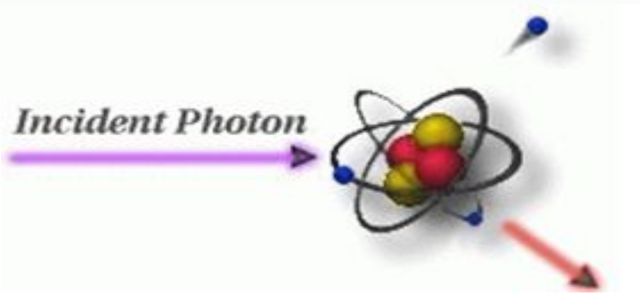
Photoelectric Effect



X-Ray disappears => liberates an atomic electron

X-Ray (photon) Interactions with Matter

Compton Scatter



X-Ray survives => liberates an electron while changing course and losing some energy

Pair Production

X-Ray disappears => creates an electron / positron pair mmon Sources of Ionizing Radiation

urces of Background Radiation Exposure

- Natural Background
- Medical Diagnosis and Treatment
- Manufactured/Industrial Sources

• Radiation So

urces of Occupational Radiation Exposure

diation Hazards in the Workplace

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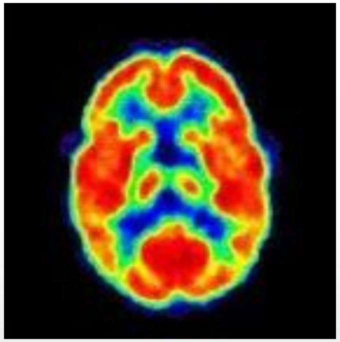
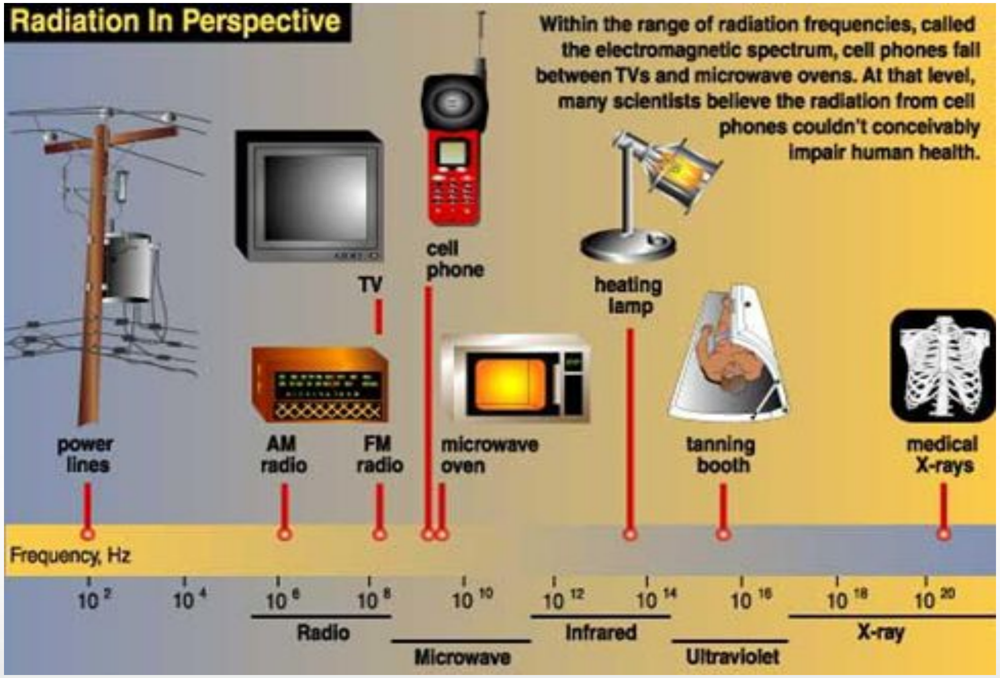
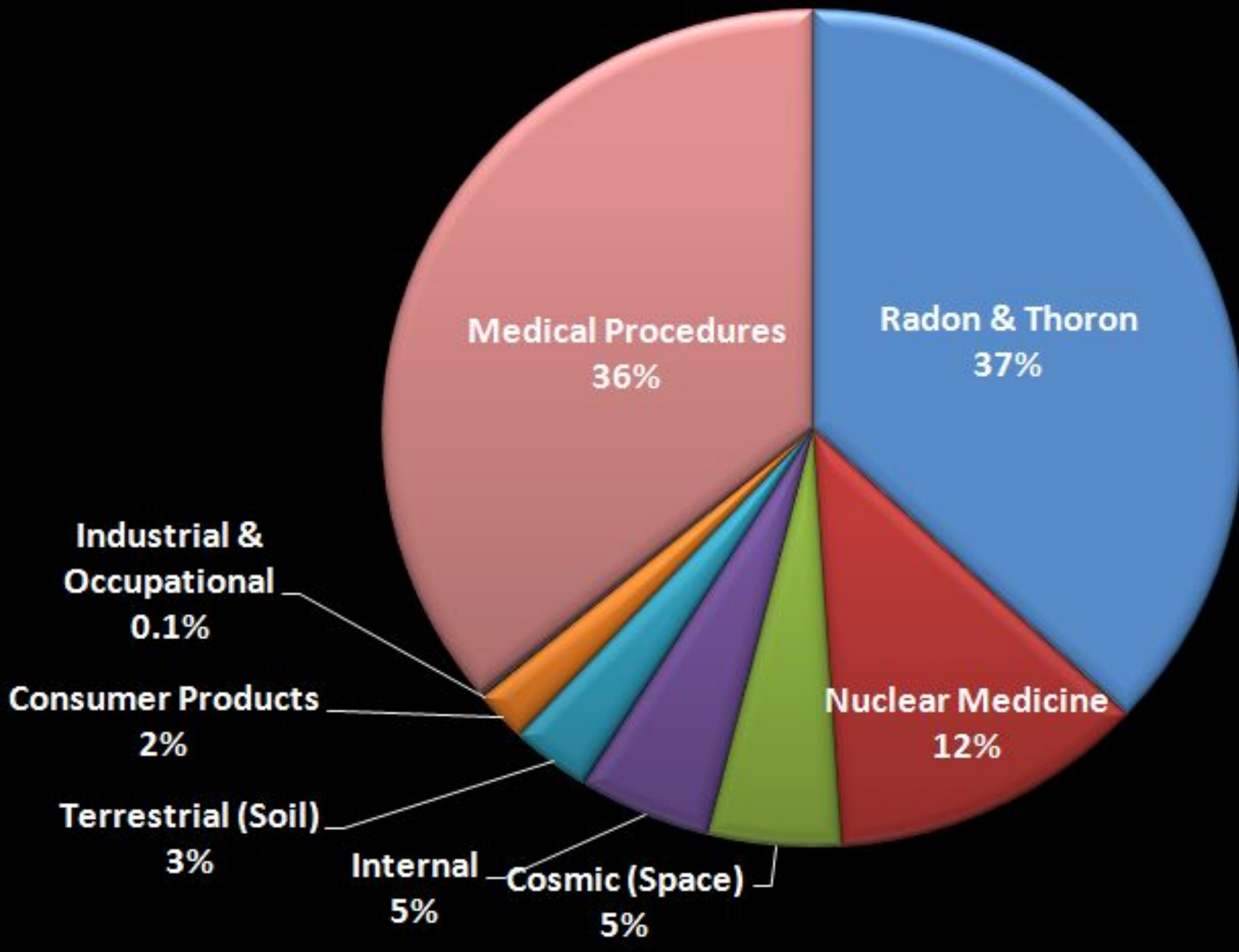



Radiation In Perspective
Within the range of radiation frequencies, called the electromagnetic spectrum, cell phones fall between TVs and microwave ovens. At that level, many scientists believe the radiation from cell phones couldn't conceivably impair human health.
power lines
AM radio
FM radio
TV
cell phone
microwave oven
heating lamp
tanning booth
medical X-rays
Frequency, Hz
10 2
10 4
10 6
10 8
10 10
10 12
10 14
10 16
10 18
10 20
Radio
Microwave
Infrared
Ultraviolet
X-ray

Sources of Radiation Exposure in the United States

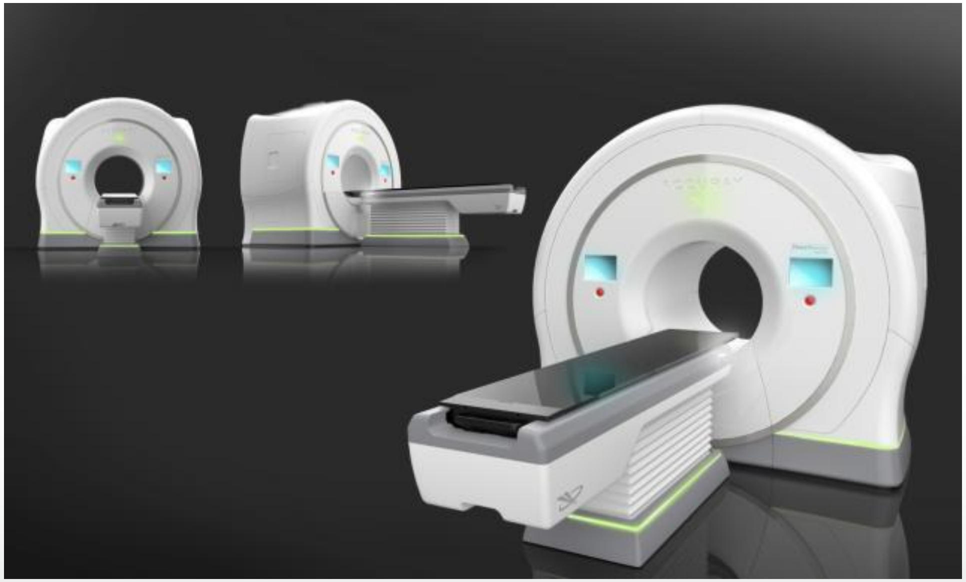
Average Annual Exposure: 620 mrem [6.2 mSv]



Accuray radiation generating machines (RGMs) are capable of creating intense radiation fields. However, if used safely and properly in well shielded environments, occupational exposures will be negligible.

CyberKnife
M6 Series

TomoTherap
y



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- Biological Effects and Risk
  Ionizing Radia

ical Response to Ionizing Radiation – Key

Somatic, Stochastic, Deterministic, Heritable

tion Biology – Mechanisms & Effects

rs Affecting Biological Response

Total Dose, Dose Rate, Radiation Type & Energy

Area of the Body Irradiated, Cell Sensitivity, Individual Sensitivity

tion Risks

Quantifying Risks

The acceptability of Risks

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Radiation Biology –

- Somatic Effects: biological effects that occur on the exposed individual

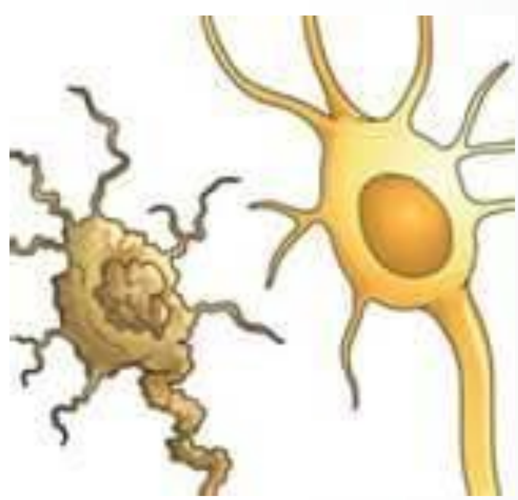
- Deterministic Effects: definite threshold;
  the severity of effect increases with dose

  (Examples: cataracts; erythema; infertility)

- Stochastic Effects: probabilistic in nature; existence of a threshold not clear; probability of occurrence increases with dose

  (Examples: cancer – DNA is the target of concern)

- Heritable Effects: a physical mutation or trait that is passed on to offspring; these have never been observed in humans but are believed to be possible.



Radiation Causes Io

- ATOMS
  - which may affect
- MOLECULES
  - which may affect
- CELLS
  - which may affect
- TISSUES
  - which may affect
- ORGANS
  - which may affect
- THE WHOLE BODY

Radiation Biology –

DNA is the Target of Concern

(Deoxyribonucleic acid [DNA] encodes the genetic instructions used in the development and functioning of all known living organisms)

Direct and Indirect Effects

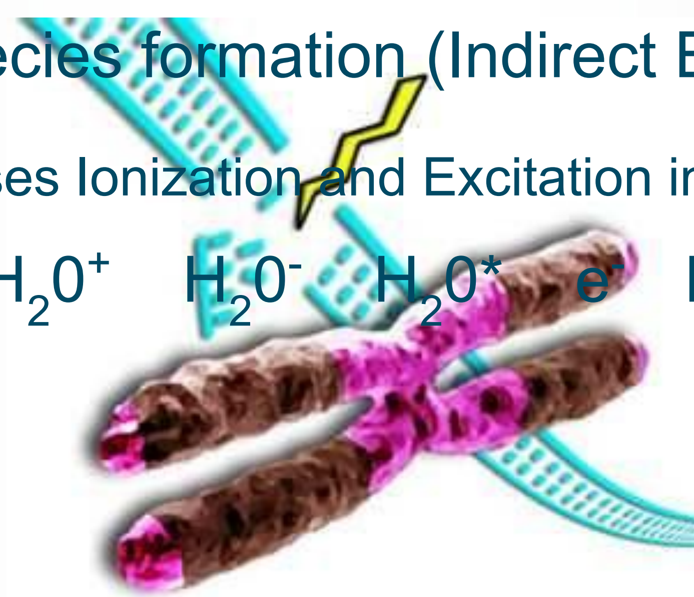
DNA strand breaks (Direct Effect)

Water molecule dislocation (Indirect Effect)

Reactive species formation (Indirect Effect)

Radiation Causes Ionization and Excitation in Water

(H^+ OH^- H_20^+ H_20^- H_20^* e^- H_20_2)



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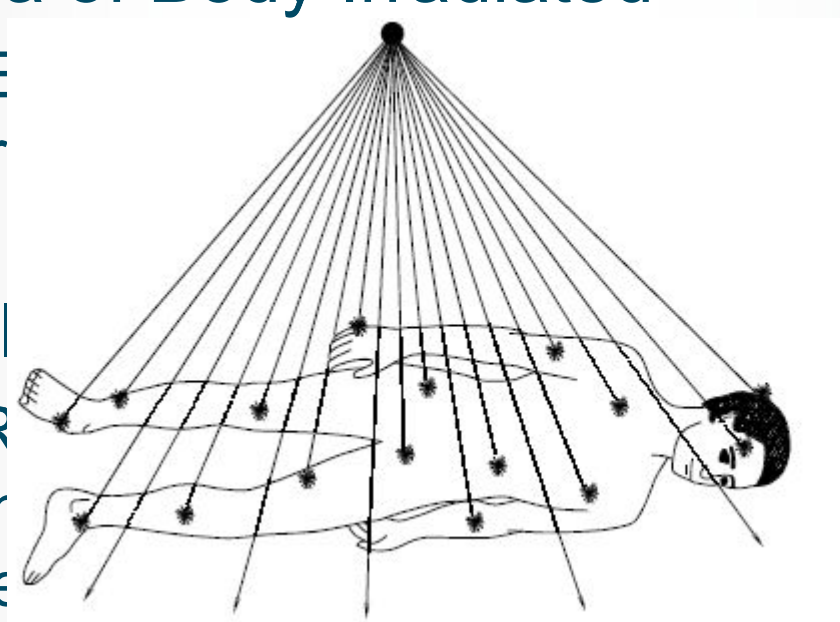
at can Happen after Direct or Indirect DNA mage?

- tection and Repair
- ll Death
- IA Changes ve Effects
- IA Changes s Effects

Radiation Biology – Factors Affec

- Total Dose Received & Dose Rate
  - Greater total dose and dose rates generally equate to more damage
- Type and Energy of Radiation
  - Alpha particles are more damaging than X-Rays
  - Higher energy = greater effect
- Area of Body Irradiated
  - E
    ir



- Cell
  - R
    th
    te

Dose	Possible Effect
0 – 5 rem (0 – 50 mSv)	None
5 – 50 rem (50 – 500 mSv)	Slight Blood Changes
50 – 200 rem (500 – 2000 mSv)	Nausea, Fatigue and Vomiting
200 – 450 rem (2 – 4.5 Sv)	Hair Loss, Severe Blood Changes, Possible Death in 2-6 weeks
480 – 540 rem (4.8 – 5.4	[LD $_{50/60}$] - Lethal Dose to 50% of

iation Exposure Is Assumed to Increase cer Risk

roximately 35 – 45% of all people will elop cancer in their lifetime – aside from ation exposure.

Radiation R

roximately 20% of all people will develop tal cancer in their lifetime – aside from ation exposure.

),000 people all received 1,000 mrem, (1) (10 mSv) of radiation exposure, we ld expect 5 or 6 to die from radiation ted cancer and 2,000 to die from all other cer sources

Risks In Perspective	
Category	**Average Life Lost (days)**
Smoking 20 cigarettes per day	1600
Being 15% overweight	900
Agricultural worker	320
Consuming alcohol (US Avg.)	230
Construction worker	227
Driving a car	200
Mining and quarrying workers	167
Manufacturing worker	40
Recreational swimming	40
Radon exposure	35
Skydiving	25
Radiation worker age 18 - 65 (300 mrem/yr, 3 mSv/yr)	**15**
All natural hazards	7
Riding a bicycle	6
Living within 10 miles of Nuclear Power Plant	0.4

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- Radiation Protectio

Principles of Radiological Protection

demiological Studies

e Response Models

onal / International Recommendations & Laws

cupational Limits

ility Control Levels

tection of the Embryo/Fetus

tection of the General Public (100 mrem; 1 mSv)

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The Principles of Radiation Protection

Justification – No practice shall be adopted unless its introduction produces a net positive benefit. This is a societal decision.

Optimization – All exposures shall be kept ALARA, economic and social factors being taken into account.

• Epidemiological

miology – the study of patterns, causes, and effects of health nd disease conditions in defined populations.

CEAR - United Nations Scientific Committee on the Effects of Atomic n

es of Human Population Radiation Epidemiological

Atomic Bomb Survivors

Radiotherapy Patients

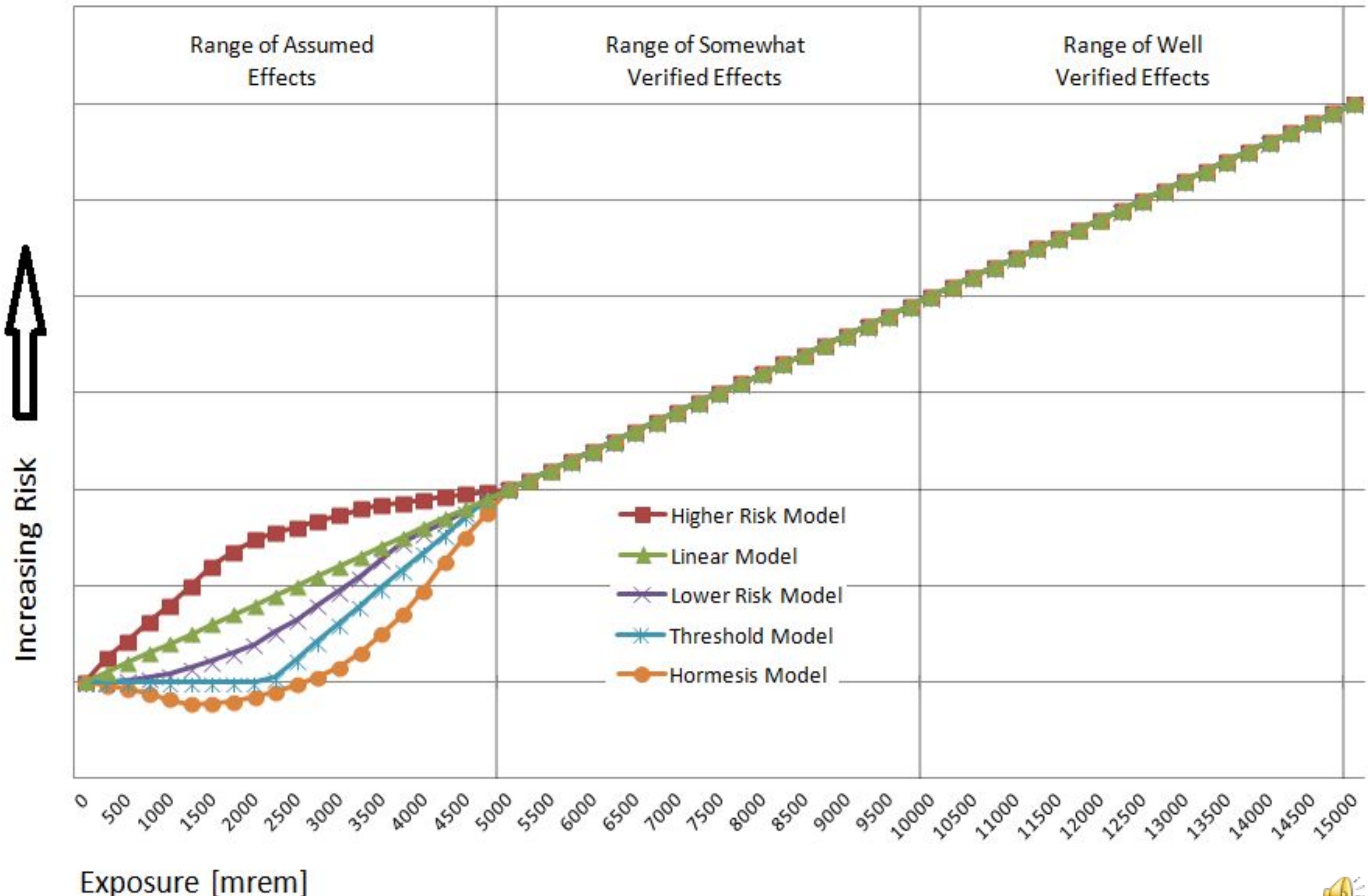
Occupational

- Radium Dial Painters, Miners (Radon Exposure), Radiologists, Nuclear Workers

Environment

- Chernobyl Accident, Weapons Test Fallout, Natural Background

Dose Response Models of Low-Level Radiation Effects



• National / Intern Recommendatio

demiological studies are performed and presented

- UNSCEAR
- World Health Organization

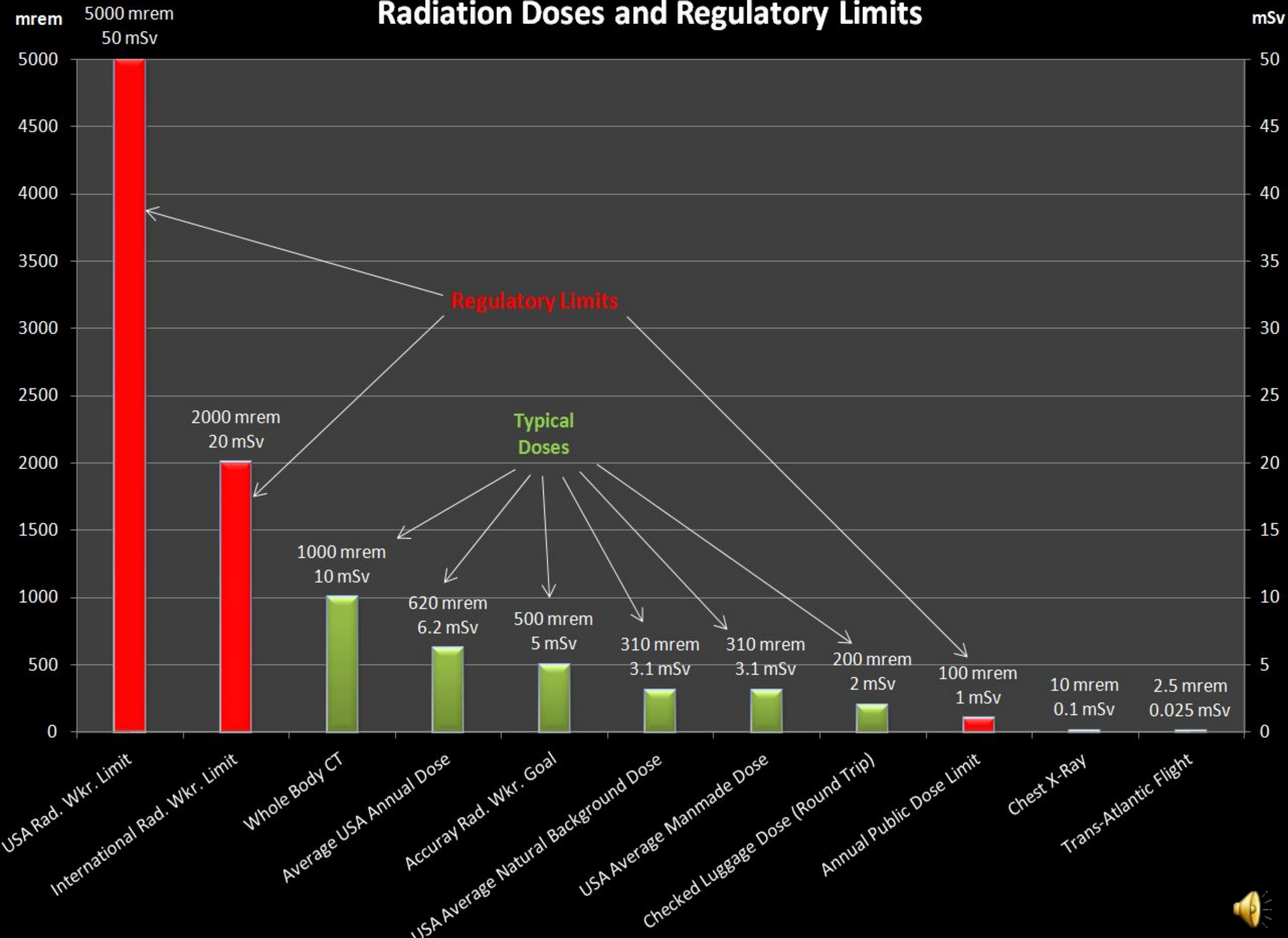
onal and International agencies make ommendations

- International Atomic Energy Agency (IAEA)
- International Commission on Radiological Protection (ICRP)
- National Council on Radiological Protection and Measurements (NCRP)

ntry, State and Local Laws

osure Limits and Guidance Documents

Radiation Doses and Regulatory Limits



- Facility Control

estricted Area – Any area that is not controlled for purposes of radiation safety (offices, break rooms, ting rooms, non-production, non-test areas)

trolled Areas – Access is controlled for radiation ection purposes (includes areas adjacent to mega ge enclosures)

tricted Areas – Access is prevented or limited for purpose of protecting individuals from undue risks radiation exposure (includes inside test cells / kers when radiation is being generated

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Protection of the Embryo/Fetus

e developing embryo/fetus, with rapidly iding cells, is sensitive to many vironmental factors including ionizing diation.

e embryo/fetus is most susceptible to veloping adverse health effects if posed during the time period 8-15 weeks er conception.

claration of Pregnancy

- Additional safety precautions are available to declared pregnant workers
- The declaration must be submitted (in writing) to the RSO
- Detailed training material and information will be

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• Protection of the Ge

ember of the Public: means an individual who is a radiation worker, has not received radiation ety training and who is not monitored for upational exposure

e strict exposure limit to a member of the public is:

100 mrem/yr (1 mSv/yr)

mbers of the public are not allowed unescorted ess to test cell or bunker areas.

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- Controlling Radia…

adiation Protection
olicies and ...dures

ne ALARA Concept (Time, Dist... nd
hielding)

gns, Labels, and Postings

ccess Controls

Radiation Protection Policies & Procedures

- The most important policy to remember is … never be inside a test cell or bunker while the beam is made!

- SOP 027444 is the main Radiation Safety Program Procedure

  * Personnel Dosimetry Request Form
  * Lost, Damaged, or Exposed Personnel Dosimetry Form
  * Declaration of Pregnancy Form
  * Declaration of Worker Status Form
  * Engineering and Administrative Controls Checklist
  * Request and Authorization for Radiation Exposure History Form
  * Notification of Nuclear Energy Worker Status

The ALARA Concept

ALARA is an acronym for As Low As Reasonably Achievable.

Since it is assumed that any radiation exposure involves some risk, doses shall be maintained as far below the regulatory limits as is practical. To keep doses ALARA, the three most commonly used techniques are: time, distance and shielding.

Time – whenever practical, minimize the time spent near sources of radiation and minimize the output from RGMs.

Distance – to the extent practical, maximize the distance between personnel and radiation sources.

Shielding – incorporate attenuating barriers between radiation sources and personnel whenever practical.

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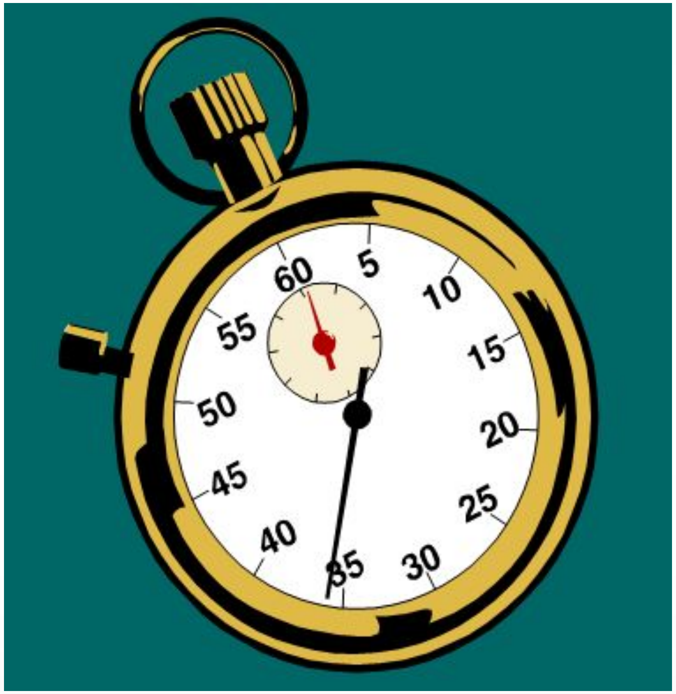
Reduce Exposures by Minimizing Time & Dose Rate



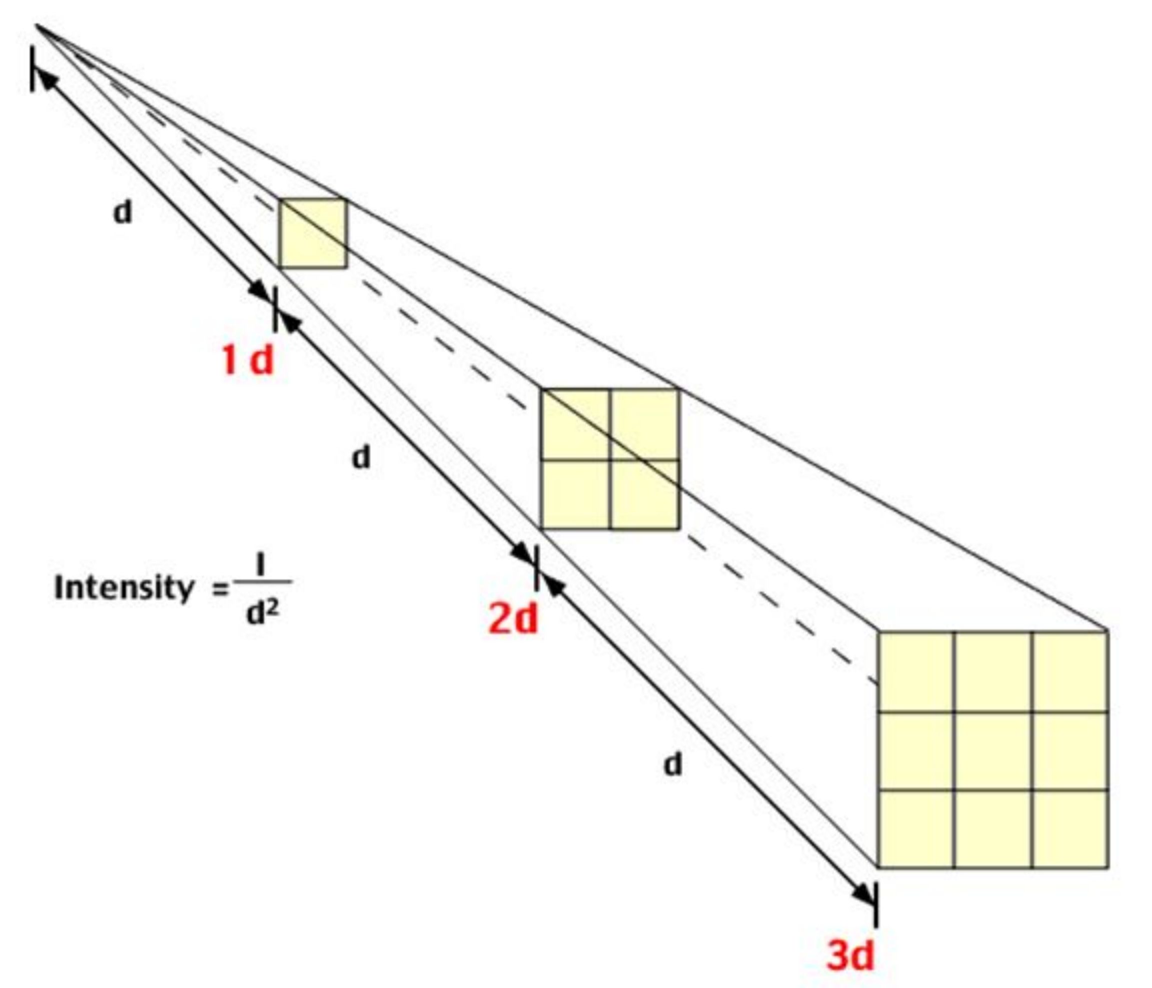
Dose = Dose Rate x Time

500 mrem = 10 mrem/hr x 50 hrs

Or

1000 cGy/min x 10 min = 10,000 cGy !!!

Reduce Exposures by Maximizing Distance



Inverse Square Law - Example

$$I_1 D_1^2 = I_2 D_2^2$$

I = intensity, dose, or dose rate

D = distance

$$\frac{I_1 D_1^2}{I_2} = D_2^2$$

$$\sqrt{\frac{I_1 D_1^2}{I_2}} = D_2$$

$$\sqrt{\frac{100mR/hr(1m)^2}{10mR/hr}} = D_2$$

$$3.2m = D_2$$

Isolate and Solve for D_2

Reduce Exposures by Using Shielding Materials

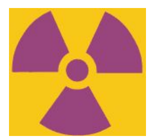
Close the Jaws/MLC, Plug Beam, and
Beam Down Whenever Possible/Practical

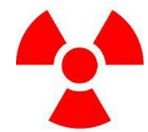
Radiation Hazard Communication

Some areas require specific authorization or an escort prior to entry. Be aware of and adhere to the following Hazard Communication: symbols, signs and other warnings located within and near restricted or controlled areas.

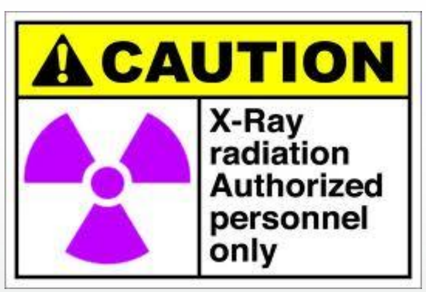
Radiation 'Trefoil' Symbols

Foreground and background colors may vary





Caution Signs



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Engineering Safety Controls

Note: Actuating an Emergency Button/Device, or opening the main test cell door/gate, will terminate or prevent radiation.

Emergency Buttons/Devices

Warning Lights

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Access Controls - Mandatory

perators must physically enter the test cell, bunker or shielded nclosure to ensure no persons are within the enclosure and it is safe all respects to generate radiation.

nce the test cell is cleared and the door closed, access must be ontinually monitored, otherwise the cell must be re-cleared prior to e next Beam-On.

ersonnel who need access to an enclosure must get permission om the operator prior to entry.

is absolutely forbidden to generate radiation while persons ar ithin an Accuray shielded enclosure.

is prohibited to enter a cell in which a radiation device is in use.

diation Mo

sonnel Monitoring

ility M

iation Detectors

Personnel Mo

imetry Use is a Requirement for all Radiation kers

ic Dosimetry Use Guidelines Include:

- Keep away from non-occupational radiation sources such as:
  - Airport checked luggage scans
  - Medical and dental imaging
- Prevent the dosimeter from receiving excessive exposure to heat, sunlight or moisture
- Promptly exchange at regular intervals (usually every three months)
- Notify radiation safety personnel when a dosimeter is lost, damaged or accidentally exposed

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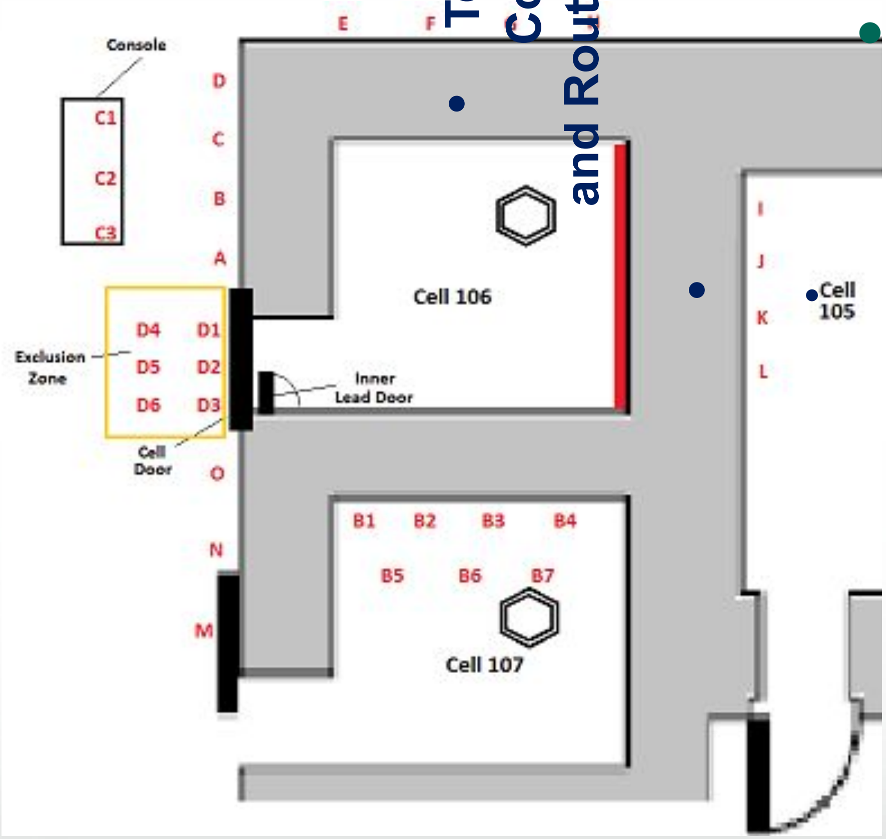
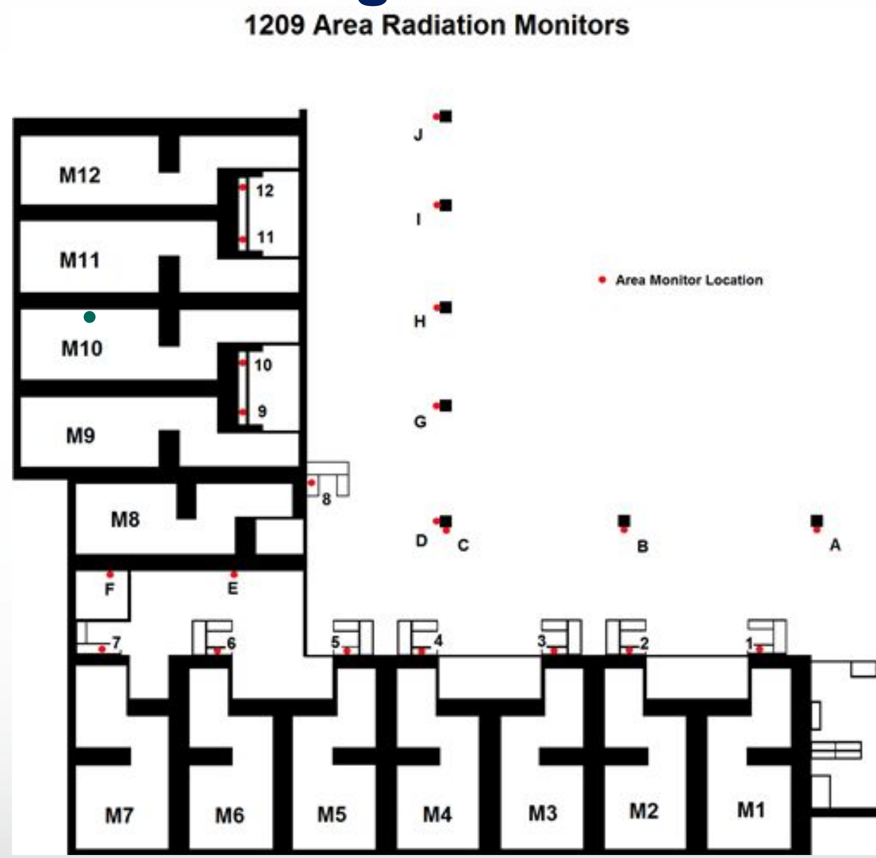
- Facility Monit
  - Test Cell/Bunker
  - Commissioning and Routine Leakage Surveys

Continuous Area Monitoring





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• Radiation Det

iati… …veys and Area Monitoring

… Filled Detectors –Ionization Chambers

…efits – rugged, inexpensive, appropriate for …uray … …cept primary beam …asur…

…entia… …ombination, dead time, pile … RF & magnetic field interference

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Use of Survey Ins

efly inspect the instrument for physical damage or
cessive wear.

sure the instrument has been recently calibrated.

wer on the instrument and perform a battery
eck.

te the natural background radiation level and
ctuations in instrument response.

ways lead with the detector, maximizing your
tance from radiation sources.

ink ALARA and caution is warranted as exposure
es approach or exceed: 10 mR/hr; 100 µSv/hr

Damaged or 'out of calibration' instruments cannot be used and must be taken out of service.

• Responsibilities fo
Protectio

agement Responsibilities

Promote a positive radiation safety culture and ensure adequate resources exist to develop/maintain a robust radiation safety program

ation Safety Organization Responsibilities

Ensure protection of persons, the environment and property

Ensure regulatory compliance and advise on technical issues

iduals’ Responsibilities

Adhere to all radiation worker requirements, postings, and controls

Demonstrate responsibility and accountability through an informed, disciplined and cautious attitude toward radiation

iduals’ Rights

Stay informed of all risks and associated controls prior to

• Emergency Re

t the radiation dose to involved persons … the first
on during any emergency is to turn off the
hine.

dioactive materials are involved, limit the spread of
amination.

k assistance from experienced radiation safety
essionals. Contact the Accuray RSO and local
iation Safety Personnel.

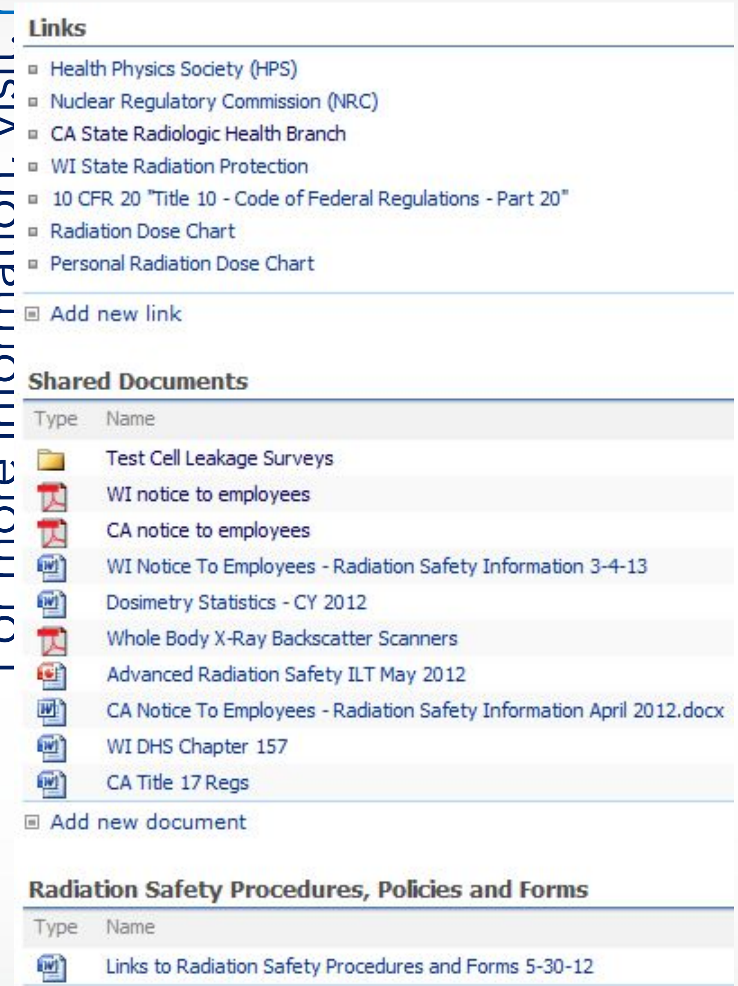
cuate the immediate area of the incident.

trol entry to the scene of the accident.

ntify and isolate persons who may have received
ificant radiation exposures.

ord all details of the event chronologically.

For more information, visit: http://shar



Procedures, forms, links, contact information, announcements, and more

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safety program. As a result, even our "Radiation Workers" are expected to receive less than 10% of the applicable limits (Accuray ALARA Policy).

Non-Radiation Workers are expected to receive truly negligible exposures: less than 1% of the natural background and typically below the limits of routine detection.

Everyone is encouraged to play an active role regarding

Radiation Safety Exam

Please email all questions and comments to:

RSO@accuray.com

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