Bioenvironmental Engineering Site Assessment I

Unit 8: Radiation Overview

Unit Description: For this unit, you will be stationed at Labrador Field, a bare base, in Tuapaat, Greenland. During your assignment you'll be reviewing basic information about radiation in order to prepare for mission activities. When you're finished, you will be able to describe the basic principles associated with radiation.

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Lesson 1: Principles of Radiation

Lesson Description

In this lesson, you will attend a workshop to review basic concepts related to radiation. Upon completion of this lesson, you will be able to describe principles of radiation.

Lesson Overview (Page 1 of 10)

The Air Force uses radiation sources for a variety of purposes. Therefore, BE encounters various forms of radiation frequently.

It's important to understand the basic properties of radiation in order to identify and analyze radiation health threats and keep personnel, as well as the general public, safe from Air Force radiation activities.

During the shop training to prepare for mission activities at Labrador Field, you will:

- Recall fundamental concepts of energy and mass.
- Recall key concepts related to the electromagnetic spectrum.
- Compare types of radiation.

Audio Script

OIC: Welcome to Labrador Field. We're having a shop training tomorrow to discuss some of the key principles of radiation. You'll need to be here at 08:00. Some of this information may be a review; however, because of the missions this base will be fulfilling, it's important to refresh us all for upcoming assignments.

Energy and Mass (Page 2 of 10)

Before you can effectively identify and analyze health risks associated with **radiation,** you must first be able to identify its basic principles.

Energy and **Mass** are basic concepts related to the study of radiation because radiation is a form of energy. Einstein's Theory of Relativity shows that mass and energy are interchangeable, as expressed in the equation below.

$$\textit{Energy (ergs)} = \textit{Mass (grams)} \times \textit{Velocity of Light}^2 \textit{ (m/sec)}$$

or

$$E = mc^2$$

Radiation

Radiation is energy in the form of waves or moving subatomic particles emitted by an atom or other body as it changes from a higher energy state to a lower energy state. Radiation can be classified as ionizing or non-ionizing radiation, depending on the amount of energy in the radiation and its potential interaction with matter.

Energy

Energy is defined as the ability to do work. The Law of Conservation of Energy states that energy can be neither created nor destroyed but can change from one form to another. In other words, the total amount of energy in a system remains constant and is neither increased nor decreased by any process but can be transformed into either potential or kinetic energy.

Mass

Mass is the description of how much matter there is present in an object. The mass of an atom is described using the atomic mass unit (amu). An amu is approximately equal to the mass of a proton or a neutron.

Because radiation is created when particles are emitted from an atom as it changes energy states, atomic mass becomes an important concept related to identifying sources of radiation and potential health effects.

Appraisal (Page 3 of 10)

Which one of the following concepts *best* describes the relationship between energy and mass?

A The Law of Conservation of Energy

B The Atomic Mass Unit (amu)

C Potential and Kinetic Energy

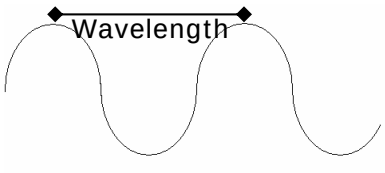
D Einstein's Theory of Relativity

Electromagnetic Spectrum (Page 4 of 10)

Wavelength and **frequency** are two more concepts important to the discussion of radiation. Variations in wavelength and frequency produce different types of wave radiation and have different **effects on the body**. These variations can best be seen using the **electromagnetic spectrum,** which can be viewed in three primary sections.

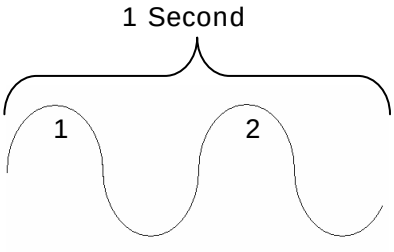
Wavelength

Wavelength is the distance from one peak of a wave to the next peak of a wave.



Frequency

Frequency is a value of how often a wavelength cycle occurs in a second.

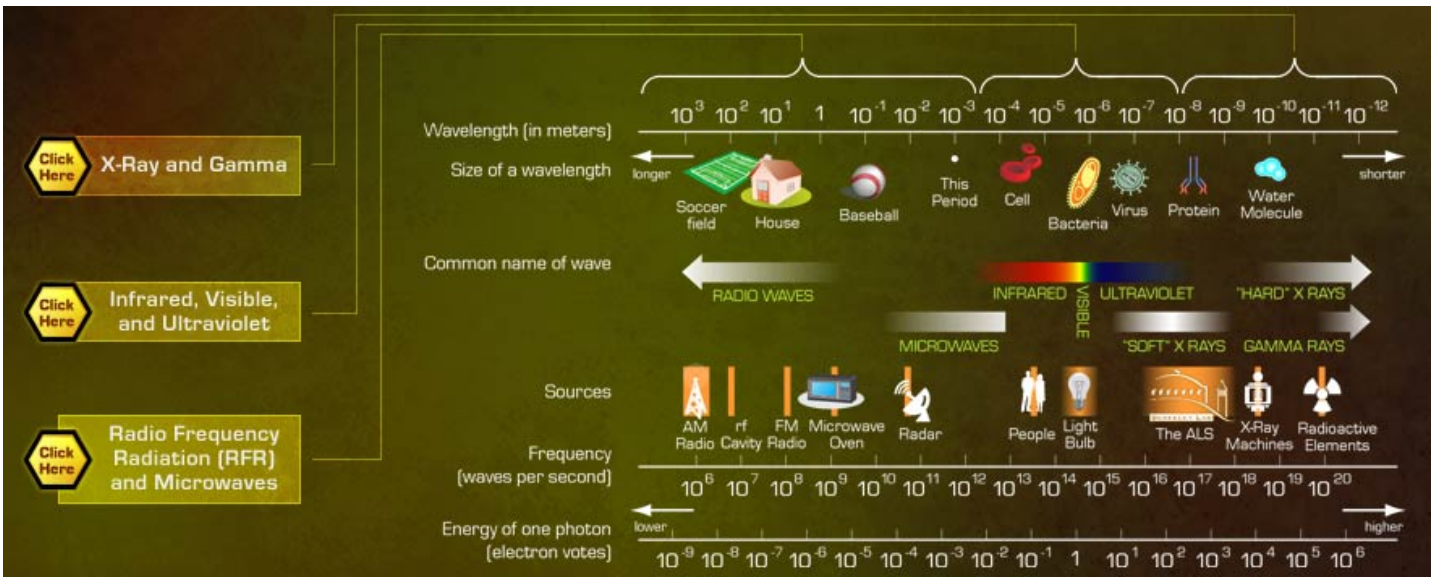


Effects on the Body

As a general rule, a shorter wavelength will produce higher amounts of energy, causing a higher degree of penetration to the human body. Consequently, a longer wavelength is less penetrating to the human body and causes more surface type effects from an exposure.

Electromagnetic Spectrum

The electromagnetic spectrum is the entire frequency range of electromagnetic waves, or wave radiation.



X-ray and Gamma

X-ray and gamma radiation produce the highest amount of energy and are referred to as the ionizing portion of the electromagnetic spectrum.

X-ray and gamma radiation is indirectly ionizing, which means that any damage sustained comes from by-products (e.g. free radicals) of the exposure caused when the water of the body or of a cell absorbs the radiation. Potential health effects associated with x-ray exposure could include cell membrane disruption or damage to cell performance.

Infrared, Visible, and Ultraviolet

Infrared means “below red” and can be found at the lower energy end of visible light. Infrared radiation can be detected through the production of heat or thermal energy and is produced by things such as food warmers, paint-drying lamps, and sunlamps.

Since infrared is usually found in the form of heat or thermal energy, there are few health concerns associated with this type of radiation. The primary health threats associated with infrared radiation are produced by the shorter infrared wavelengths. The potential biological effects include damage to the cornea, iris, retina, and lens of the eye.

Visible non-ionizing energy occurs between infrared and ultraviolet radiation on the electromagnetic spectrum. The wavelengths that are visible to the eye are different for each individual, so there is not one clear set point at which infrared radiation changes to visible or where visible changes into ultraviolet radiation.

Ultraviolet (UV) radiation is found at a higher energy level than visible light on the electromagnetic spectrum. Common emitters of UV radiation include the sun, tanning booths, and welding operations. UV radiation usually requires some form of protection to prevent injury to humans. For example, high intensity lamps are outfitted with glass shields around them to prevent harmful exposures to UV radiation. The earth also includes a natural shield from UV radiation emitted by the sun in the form of atmospheric gases and the ozone layer in the stratosphere.

Radio Frequency Radiation (RFR) and Microwaves

Radio Frequency Radiation (RFR) and microwave energy include the emissions from broadcast facilities that transmit television and radio signals and are located at the lower end of the electromagnetic spectrum. This type of energy is primarily used for communications; however, it can also be used for weather surveillance, search and detection radar, and remote control devices – all of which have applications in Air Force operations and missions.

Health effects associated with RFR and microwaves are thermal in nature. Surface tissue heating, deep-tissue heating, microwave hearing effects, and damage to the eyes are all health issues that may be associated with exposure to elevated levels of these types of radiation.

Appraisal (Page 5 of 10)

Match each form of radiation to the appropriate location on the electromagnetic spectrum.

Forms of Radiation
X-Ray and Gamma
Infrared, Visible, and Ultraviolet
Radio Frequency Radiation (RFR) and Microwaves

	Electromagnetic Spectrum Location
_____	Lower range of Electromagnetic Spectrum: 10^{3} to 10^{-3} meters
_____	Mid range of Electromagnetic Spectrum: 10^{-4} to 10^{-8} meters
_____	Higher range of Electromagnetic Spectrum: 10^{-8} to 10^{-12} meters

Types of Radiation (Page 6 of 10)

While radiation can be categorized based upon wavelength and frequency, it can also be categorized by the amount of energy it has and the sub-atomic interactions that take place.

If the radiation has enough energy to change the atomic structure of matter it interacts with, it is considered ionizing radiation. If the radiation does not have this ability, it is considered non-ionizing radiation.

Health threats are present with both ionizing and non-ionizing radiation and can be found in nature or as part of occupational situations, as well as when dealing with nuclear weapons.

Ionizing Radiation (Page 7 of 10)

Ionizing radiation is the most harmful type of radiation and is therefore a significant concern for BE. Ionizing radiation can be either machine-produced (e.g., x-rays) or the result of decay or transformation of unstable atoms.

There are several processes that an atom can undergo to achieve a more stable state. These different processes, or modes of decay, produce different types of radiation.

- **Alpha Particles (α)**
- **Beta Particles (β)**
- **X-rays**
- **Gamma**
- **Neutron**

Alpha Particles (α)

An alpha particle is heavy and slow compared to other types of radiation because it consists of two neutrons and two protons. Its double positive charge makes the alpha particle the heaviest ionizing radiation. It will strip electrons from other atoms or temporarily pull them into a higher energy shell. An alpha particle is formed when the nucleus is too heavy, meaning it does not have enough neutrons.

Since it is a relatively large charged particle, it interacts with matter within very short distances. Because of this, external shielding can be accomplished with something as thin as a sheet of paper or the surface layer of skin. Although easily shielded against, the alpha particle is a concern for BE because it is the most ionizing of all types of radiation and presents a significant health risk when alpha-emitting material is ingested or inhaled.

Beta Particles *(ß)*

Beta particles are negatively charged particles (-1) with the same mass as an electron. Beta particles are often considered high-speed electrons.

Because they are much lighter and faster than alpha particles, they travel farther but have less ionizing ability.

Although beta particles are less ionizing than alpha particles, they can cause both internal and external damage. External shielding can be accomplished with plastic, while respiratory protection is used for internal health threats.

X-rays

After an atom undergoes an alpha or beta decay, it often leaves the nucleus in an excited state. Then, when the atom transitions to a lower energy state, it produces x-ray or gamma radiation.

X-rays are emitted from the electron shell and are formed when electrons drop down from a higher shell to a lower shell. The electron gives up excess energy in the form of an x-ray. X-rays have no mass and no charge, and travel at the speed of light. They can pass through considerable amounts of matter before interacting with it. Lead can be used for shielding purposes when working with x-ray radiation.

Gamma

Gamma radiation is similar to x-rays because it has no mass and no charge, and travels at the speed of light. Unlike x-rays, which are emitted from the electron cloud of an atom, gamma rays are emitted from the nucleus and result when the nucleus transitions from a higher to lower energy state.

Although x-rays and gamma rays are less ionizing than alpha, beta, and neutron particles, they have greater penetrability than alpha and beta radiation. The most appropriate shielding material for gamma radiation is typically lead.

Neutron

Like alpha and beta radiation, neutrons are a particulate form of radiation. However, neutrons are encountered much less commonly than alpha or beta particles. Typically, they are only found when dealing with nuclear reactors or weapons.

Unlike the alpha or beta particle, the neutron has no electrical charge. Neutrons have variable ranges based on the amount of kinetic energy present and how the neutrons were produced.

Neutron radiation is the most penetrating type of particulate ionizing radiation, requiring thick layers of concrete or water for shielding purposes. This is important for BE when considering appropriate controls to protect personnel.

	Alpha (α)	Beta (β)	Gamma (γ) / X-ray	Neutron
Type:	particle	particle	photon	particle
Charge:	+2	-1	none	none
Mass (amu):	4	0.00055	none	slightly >1
Speed (c):	1/20	near	1	varies
Penetration:	least	low	high	high
Range in air:	mm	m	km	km?

Non-Ionizing Radiation (Page 8 of 10)

Non-ionizing radiation occurs when there is not enough energy present to alter the atomic structure of an atom. Therefore, no electrons are removed and no ionization can occur. Non-ionizing radiation is less harmful than ionizing radiation and can be found in the form of:

- Radio frequency radiation (RFR) and microwaves.
- Infrared radiation.
- Visible radiation.
- Ultraviolet radiation.

Non-ionizing radiation is still a concern to BE because adverse health effects can occur with overexposed individuals, such as thermal effects to the skin or deep tissue and adverse effects to portions of the eye including the lens, cornea, iris, and retina.

Appraisal (Page 9 of 10)

Match each type of radiation with its description by marking the appropriate blocks in the table.

Description	Radio Frequency Radiation (RFR)	Infrared	Alpha Particles	Beta Particles	Gamma
Located at the lower end of the electromagnetic spectrum.					
Identical in mass and charge (-1) to an electron.					
Heavy and slow as compared to other types of radiation.					
Found in the form of heat or thermal energy.					
Emitted from the nucleus and result when the nucleus transitions from a higher to lower energy state.					

Lesson Summary (Page 10 of 10)

You've learned that energy and mass are two basic concepts related to the study of radiation. Using the electromagnetic spectrum allows you to identify how changes in wavelength and frequency impact the type of radiation produced.

Radiation can take on many forms and types based on the energy being emitted and the atomic interactions that take place. Ionizing radiation and non-ionizing radiation are the two primary categories of radiation.

Ionizing radiation can exhibit properties of particles, such as alpha, beta, and neutrons, or waves, such as x-ray and gamma.

Non-ionizing radiation is categorized by the frequency and wavelength of the radiation and can be divided into radio frequency, microwave, infrared, visible light, and ultraviolet forms of radiation.

In this lesson you:

- Recalled fundamental concepts of energy and mass.
- Recalled key concepts related to the electromagnetic spectrum.
- Compared types of radiation.

Audio Script

OIC: Thank you for attending the shop training on radiation this morning. This training should've provided a refresher on the basic principles of radiation and how radiation impacts our responsibilities as BEs. This information will also prove to be important for upcoming assignments.

Resources

- *Bioenvironmental Engineer's Guide to Ionizing Radiation, 2005*
- *Fundamentals of Industrial Hygiene,* National Safety Council, 4th Edition

Answer Key: Appraisals / Scenario Challenge Points

Lesson 1: Principles of Radiation

Page 3 of 10

Which one of the following concepts *best* describes the relationship between energy and mass?

D Einstein's Theory of Relativity

Rationale: Einstein's Theory of Relativity shows that mass and energy are interchangeable. The Law of Conservation of Energy states that energy can be neither created nor destroyed but can change from one form to another. The mass of an atom is described using the atomic mass unit which is approximately equal to the mass of a proton or a neutron. Potential energy is the energy of position and kinetic energy is the energy of motion.

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Match each form of radiation to the appropriate location on the electromagnetic spectrum.

Forms of Radiation	Electromagnetic Spectrum Location
Radio Frequency Radiation (RFR) and Microwaves	Lower range of Electromagnetic Spectrum: 10^{3} to 10^{-3} meters
Infrared, Visible, and Ultraviolet	Mid range of Electromagnetic Spectrum: 10^{-4} to 10^{-8} meters
X-Ray and Gamma	Higher range of Electromagnetic Spectrum: 10^{-8} to 10^{-12} meters

Rationale: Radio Frequency Radiation (RFR) and microwave energy are located at the lower end of the electromagnetic spectrum. These forms of energy, which have longer wavelengths and are less penetrating than other forms, are primarily used for communications. They can also be used for weather surveillance, search and detection radar, remote control devices, and radio astronomy.

Infrared, visible, and ultraviolet radiation are located in the middle range of the electromagnetic spectrum. Sources of these forms of radiation include food warmers, visible light, paint drying lamps, and sunlamps.

X-ray and gamma radiation are located at the higher end of the electromagnetic spectrum. They produce the highest amount of energy, are the most penetrating, and are referred to as the ionizing portion of the electromagnetic spectrum.

Page 9 of 10

Match each type of radiation with its description by marking the appropriate blocks in the table.

Description	Radio Frequency Radiation (RFR)	Infrared	Alpha Particles	Beta Particles	Gamma
Located at the lower end of the electromagnetic spectrum.	X				
Identical in mass and charge (-1) to an electron.				X	
Heavy and slow as compared to other types of radiation.			X		
Found in the form of heat or thermal energy.		X			
Emitted from the nucleus and result when the nucleus transitions from a higher to lower energy state.					X

Rationale: Ionizing and non-ionizing forms of radiation each have specific characteristics which are largely determined by the atomic interactions that take place and whether there is enough energy present for ionization to occur.

Course Glossary

Acronyms

AAR
After Action Report

ACADA
Automatic Chemical Agent Detection Alarm

AFI
Air Force Instruction

AFMIC
Armed Forces Medical Intelligence Center

AFMS
Air Force Medical Service

AFMSA
Air Force Medical Support Agency

AFOSH
Air Force Occupational and Environmental Safety, Fire Prevention and Health

AFRRAD
Air Force Radiation and Radioactive Recycling and Disposal

ALARA
As Low As Reasonably Achievable

AMC
Aerospace Medicine Council

amu
Atomic Mass Unit

AO
Area of Operations

AOC
Area of Concern

AOR
Area of Responsibility

BE
Bioenvironmental Engineering Flight

CBRN
Chemical, Biological, Radiological, Nuclear

CE
Civil Engineering

COA
Course of Action

COC
Contaminant of Concern or Constituent of Concern

CONUS
Continental United States

CSM
Conceptual Site Model

CV
Coefficient of Variability

DIA
Defense Intelligence Agency

DF
Duty Factor

DOD
Department of Defense

DOE
Department of Energy

DOS
Department of State

DOT
Department of Transportation

D_{pel}
Estimated Hazard Distance

DRI
Direct Reading Instruments

EHF
Extremely High Frequency (Occurs between 30 and 300 GHz)

EMR
Electromagnetic Radiation

EPA
Environmental Protection Agency

EPD
Electronic Personal Dosimeters

FPWG
Force Protection Working Group

G_{abs}
Absolute Gain

HF
High Frequency (Occurs between 3 and 30 MHz)

HRA
Health Risk Assessment

HRE
Health Risk Estimate

HRM
Health Risk Management

IATA
International Air Transport Association

IPE
Individual Protection Equipment

LCL
Lower Confidence Limits

LET
Linear Energy Transfer

LF
Low Frequency (Occurs between 30 and 300 kHz)

MAJCOM
Major Command

MEDIC CD
Medical Environmental Disease Intelligence and Countermeasure CD

MIO
Medical Intelligence Officer

MF
Medium Frequency (Occurs between 300 and 3,000 kHz (3MHz))

MOPP
Mission Oriented Protection Posture

MPE
Maximum Permissible Exposure

MSP
Mission Support Plan

NFB
Near-Field Boundary

NGIC
National Ground Intelligence Center

NHZ
Nominal Hazard Zone

NIOSH
National Institute for Occupational Safety and Health

NOHD
Nominal Ocular Hazard Distance

NRC
Nuclear Regulatory Commission

OCONUS
Outside the Continental United States

OEH
Occupational and Environmental Health

OEHSA
Occupational and Environmental Health Site Assessment

OEL
Occupational Exposure Limits

OEL-C
Occupational Exposure Limits-Ceiling

OEL-STEL
Occupational Exposure Limits-Short Term Exposure Limit

OEL-TWA
Occupational Exposure Limits-Time Weighted Average

OH
Occupational Health

ORM
Operational Risk Management

OSHA
Occupational Safety and Health Administration

OSI
Office of Special Investigation

P_{avg}
Average Power

PEL
Permissible Exposure Limit

PH
Public Health

P_p
Peak Power

PPBS
Planning, Programming and Budgeting System

PPE
Personal Protective Equipment

PPM
Parts per million

PRF
Pulse Repetition Frequency

PW
Pulse Width

RFR
Radio Frequency Radiation

RSO
Radiation Safety Officer

S
Main-Beam Power Density

SAR
Specific Absorption Rate

S_{avg}
Power Density Average

SEG
Similar Exposure Group

SHF
Super High Frequency (Occurs between 3 and 30 GHz)

SLM
Sound Level Meter

S_{max}
Maximum Power Density

SPL
Sound Pressure Level

TLD
Thermoluminescent Dosimeters

TWG
Threat Working Group

UHF
Ultra High Frequency (Occurs between 300 and 3,000 MHz)

USACHPPM
United States Army Center for Health Promotion and Preventive Medicine

UTC
Unit Type Code

VA
Vulnerability Assessments

VHF
Very High Frequency (Occurs between 30 and 300 MHz)

VLF
Very Low Frequency (Occurs between 3 and 30 kHz)

Definitions

Absolute Gain (G_{abs})
The ratio of the power that would be required at the input of an ideal isotropic radiator to the power actually supplied to the given antenna, to produce the same radiant intensity in the far-field region.

Action Level
An airborne exposure level that dictates active air monitoring, medical monitoring, and employee training. The Action Level is one-half the Occupational Exposure Limit for time-weighted average (OEL-TWA) exposures, except where 29 CFR 1910 Subpart Z designates a different concentration or where the statistical variability of sample results indicates that a lower fraction of the OEL should be used as the Action Level.

Activity
The number of disintegrations or transformations of radioactive material per unit of time (usually expressed in seconds).

Antenna
The point on an RFR emitter where RFR energy radiates into free space.

Asbestos
A natural material that is made of tiny threads or fibers. The fibers can enter the lungs as a person breathes. Asbestos can cause many diseases, including cancer. Asbestos was used to insulate houses from heat and cold. It has also been used in car brakes and for other purposes. Some old houses still have asbestos in their walls or ceilings.

Asbestosis
A lung disease caused by breathing asbestos fibers over a period of time. The fibers eventually scar the lungs and make breathing difficult. Symptoms are similar to asthma.

Atomic Mass Unit (amu)
Approximately equal to the mass of a proton or a neutron and is used to describe the mass of an atom.

Becquerel (Bq)
The international standard for the unit of measurement for activity.

Breathing Zone
The location where exposure is measured in air sampling. The breathing zone is located forward of the shoulders within 9 inches of the nose and mouth. Breathing zone measurements are taken beneath a welder's helmet or face piece but outside of any respiratory protective devices.

Bremsstrahlung
An interaction that causes a form of x-ray production in which high-speed beta particles penetrate the electron cloud and interact with the nucleus.

Carcinogens
Hazardous materials that stimulate the formation of cancer.

Ceiling Limit (OEL-C)
The limit for an employee's exposure which shall not be exceeded during any part of the work day. If instantaneous monitoring is not feasible, the OEL-C will be evaluated during the worst-case 15-minute exposure period.

Chrysotile
The most common asbestos type. Chrysotile asbestos fibrils may appear crinkled, like permed or damaged hair, under plane-polarized light.

Coefficient of Variation (CV)
For an air sampling method, the CV is the standard deviation of the sampling and analytical error divided by the mean of the sample results. The CV is used to calculate the confidence limits for sampling. OSHA uses the term sampling and analytical error (SAE) to account for the total variation or error in the method.

Compton Scatter
A gamma/x-ray interaction which takes place between a photon and an outer electron where the photon has more energy than the electron can accept, so it imparts only a portion of its energy to the electron.

Conceptual Site Model (CSM)
Articulates the health threats and exposure pathways and begins when data or information is gathered during Predeployment and Baseline Activities.

Confidence Limits
The upper confidence limit (UCL) and lower confidence limit (LCL) are the boundaries for a single sample or a series of samples that have a specified probability (usually 95 percent) of including the true value of the level of exposure.

Controlled Environments
An area where personnel are aware of the potential for RFR exposures associated with their employment or duties.

Counts per minute (cpm)
The amount of radiation detected by an instrument each minute.

Diffuse Reflection
Situations where a laser beam is bounced off a dull or uneven surface that breaks the beam apart.

Disintegration per minute (dpm)
The number of atoms that decay or transform in a given amount of material per minute.

Disintegration per second (dps)
The number of atoms that decay or transform in a given amount of material per second.

Dose
The quantity of radiation absorbed.

Dose Rate
The quantity of radiation absorbed per unit of time.

Duty Factor (DF)
A unit-less number which only applies to pulsed wave systems that describes the ratio of time an RFR emitter is on to the total operating time.

Electromagnetic Radiation (EMR)
Waves of energy that can travel through space and matter.

Electromagnetic Spectrum
The entire frequency range of electromagnetic waves, or wave radiation.

Energy
The ability to do work.

Estimated Hazard Distance (D_{pel})
The distance from the antenna to the point where the power density equals the permissible exposure limit (PEL).

Excitation
Occurs when there is an addition of energy to an atomic system, changing the atom from a "ground" state to an excited state.

Exposure
Exposure occurs when an employee is subjected to a hazardous material through any of these routes: inhalation, ingestion, skin contact, or skin absorption. Airborne exposures are specified as the duration and concentration of hazardous materials measured in the breathing zone of an individual worker without regard for personal protective equipment used by the worker.

Exposure Assessment
An exposure assessment is a process of estimating or calculating potential exposure of a health threat for an individual or population at risk. The assessment includes professional judgment, calculations based on estimates or models, actual measurements, collection and analysis of samples, and statistical evaluation.

Exposure Pathway
Includes a threat and the opportunity for the population to come into contact with the threat.

f
Algebraic express that means, "a function of."

Fission
The splitting of the nucleus of an atom into nuclei of lighter atoms, accompanied by the release of energy.

Frequency
A value of how often a wavelength cycle occurs in a second.

Gain
The antenna's ability to concentrate its energy in a certain direction.

Hazardous materials
Materials that pose a hazard and require a Material Safety Data Sheet as defined in FED-STD 313, Federal Standard, Material Safety Data, Transportation Data and Disposal Data for Hazardous Materials Furnished to Governmental Activities.

Health Risk
The health risk equals threat "combined with" vulnerability (health risk = (threat) + (vulnerability)). A health risk is an identified health threat and the vulnerability of the population at risk of coming into contact (i.e., completion of an exposure pathway) with the health threat.

Health Risk Assessment (HRA)
Health risk assessment is the process of identifying and analyzing or evaluating (exposure and toxicity assessments) OEH threats in populations or at locations over time (HRA = f [(health risk) "+" (HRE) "+" (COA)]). The HRA "product" is the validated health threat, qualified by the HRE, and the COA which includes overall mission impact, recommended control options, associated uncertainties, risk mitigation estimate(s), and a cost-benefit analysis if applicable.

Health Risk Communication
Health risk communication is the process of effectively communicating potential health effects, outcomes, and control measures to all stakeholders (i.e., commanders, supervisors, AF personnel, military, families, and the public). It provides detailed information about the HRA and should occur throughout the HRA process.

Health Risk Estimate (HRE)
Health Risk Estimate is the probability and severity of loss from exposure to the health threat. The HRE is a function of probability and severity when either or both increase the Health Risk Estimate increases. The HRE is also referred to as a health risk level.

Health Risk Management (HRM)
Health risk management is a decision-making process to evaluate and select COAs, minimize OEH risks, and maximize benefits for operations and missions. HRM is the health component of the ORM process and health risk management recommendations and decisions are integrated into the commander's ORM decision-making.

Health Threat
A health threat is a potential or actual condition that can cause short or long-term injury, illness, or death to personnel. A health threat can be occupational or environmental in origin; internal or external to the installation; or continuous, intermittent, or transient; and includes enemy capability and intent.

Ionization
Occurs when beta particles interact with nearby atoms causing an electron to be removed, creating an ion pair.

Ionizing Radiation
Radiation which has enough energy to change the atomic structure of matter.

Isotope
Elements with the same number of protons, but a different number of neutrons.

Kinetic Energy
Energy of motion.

Laser
Light amplification by stimulated emission of radiation.

Linear Energy Transfer (LET)
Energy lost by particles along the path through which they are traveling.

Mass
Description of how much matter there is present in an object.

Maximum Permissible Exposure (MPE)
The level of laser radiation to which a person may be exposed without hazardous effects or adverse biological changes in the eyes or skin.

Mesothelioma
Cancer that generally occurs in the chest, abdominal region, and areas surrounding the heart. It is typically associated with exposure to asbestos.

n
Algebraic express that means, "Number of samples."

Nominal Hazard Zone (NHZ)
The area within a laser workplace in which the exposure from direct beam, specular reflection, and diffuse reflection could exceed the Maximum Permissible Exposure (MPE).

Nominal Ocular Hazard Distance (NOHD)
The distance along the laser beam beyond which the exposure is not expected to exceed the appropriate Maximum Permissible Exposure (MPE).

Non-aqueous Phase Liquids (NAPLs)
Non-aqueous phase liquids are liquids that are sparingly soluble in water. Because they do not mix with water, they form a separate phase. For example, oil is an NAPL because it does not mix with water, and oil and water in a glass will separate into two separate phases. NAPLs can be lighter than water (LNAPL) or denser than water (DNAPL). Hydrocarbons, such as oil and gasoline, and chlorinated solvents, such as trichloroethylene, are examples of NAPLs.

Non-ionizing Radiation
Radiation which does not have enough energy to change the atomic structure of matter.

Nuclear Stability
Describes the certain combinations of neutrons and protons within a nucleus of an atom which are required for that atom to be considered stable.

Occupational and Environmental Health Site Assessment (OEHSA)
The key operational health tool for producing data or information used for health risk assessments (HRA) and to satisfy Occupational and Environmental Health (OEH) surveillance requirements.

Occupational Exposure Limit (OEL)
The limit for the airborne concentrations of a specified substance for a specified time. Employees will not be exposed to concentrations greater than the OEL. The term OEL includes all OEL-TWAs, OEL-STELs, OEL-Cs, and acceptable ceiling concentrations, that apply to a specific substance. For each hazardous material, the OELs are the most stringent limits found in the latest edition of the TLV Booklet published annually by the American Conference of Government Industrial Hygienists, in 29 CFR 1910 Subpart Z, and in AFOSH Standards for specific substances. OELs apply to occupational exposures for each individual worker for a single 8-hour work shift except where 29 CFR 1910 Subpart Z allows 40-hour averages. Exposure during work shifts that exceed 8 hours must be adjusted before applying an OEL.

Operational Risk Management (ORM)
A systematic process of identifying hazards, assessing risk, analyzing risk control options and measures, making control decisions, implementing control decisions, accepting residual risks, and supervising/reviewing the activity for effectiveness.

Optical Cavity
The component that houses the laser.

Pair Production
Occurs when a photon disappears in the vicinity of a nucleus, and an electron and positron appear in its place.

Particulate Radiation
Fast-moving atomic or subatomic particles that may be charged positively or negatively or not at all.

Peak Power (P_p)
The maximum power density during the on time for a pulsed wave system.

Permissible Environment
Operational environment in which host country military and law enforcement agencies have control as well as the intent and capability to assist operations that a unit intends to conduct.

Permissible Exposure Limit (PEL)
The value to which an individual may be exposed without exhibiting damaging biological effects and is based on the emitter's frequency.

Photochemical Reaction
A chemical reaction which is induced by the absorption of energy in the form of visible, infrared, or ultraviolet radiation.

Photoelectric Effect
An "all or none" energy loss where gamma rays impart all of their energy into an electron.

Pleural Effusion:
When too much fluid collects between the lining of the lung and the lining of the inside wall of the chest.

Positron
Created when a proton changes into a neutron and a positron because there are too many protons in the n:p ratio.

Potential Energy
Energy of position.

Pulse Repetition Frequency (PRF)
The number of times the signal is on per unit of time.

Pulse Width (PW)
The length of time the signal is on for a pulsed wave system.

Quality Factor (Q)
A dimensionless quantity assigned to each type of radiation that allows doses to be normalized in relation to each other.

Radiation
Energy in the form of waves or moving subatomic particles emitted by an atom or other body as it changes from a higher energy state to a lower energy state.

Radiation Absorbed Dose (RAD)
The amount of radiation absorbed by the tissue.

Radioactive Decay
The spontaneous disintegration or transformation of an atom in an attempt by that atom to reach a stable state.

Radioactive Material (RAM)
Material which contains unstable (radioactive) atoms that give off radiation as they decay or transform.

Radioactivity
The spontaneous emission of matter or energy from the nucleus of an unstable atom.

Radioisotopes
Unstable isotopes that, in an attempt to become a stable atom, emit energy in the form of radiation.

Regulated Area
An area under the supervisor's control where entry and exit are restricted and controlled to prevent exposure to hazards. An area shall be established when a requirement in 29 CFR 1910 or 29 CFR 1926 exists, or when BE determines that employees entering the area might be exposed to a hazard unless access is controlled.

Short Term Exposure Limit (OEL- STEL)
A time-weighted exposure for a 15 minute (or shorter) period which shall not be exceeded during the work day. The definition of STEL is different in 29 CFR 1910.1000 (a) (5) (ii) and in the TLV Booklet. The definition must correspond to the reference being cited. As with other OELs, OEL-STELs are the most stringent limits found in the latest TLV Booklet, in 29 CFR 1910 Subpart Z, and in AFOSH Standards for specific substances.

Short-Term Public Emergency Exposure Guideline (SPEGL)
An acceptable peak concentration for unpredicted, single, short-term emergency exposures of the general public. These limits do not apply to occupational exposures.

Specific Absorption Rate (SAR)
An expression of how much RFR energy is imparted to each kilogram of biological body mass per second. SAR is expressed in units of watts per kilogram (W/kg).

Specular Reflection
Situations where a laser beam is reflected from shiny, mirror-like surfaces.

Spontaneous Fission
Spontaneous fission is a natural mode of decay in which nuclei disintegrate.

Stakeholders
Any individual who is affected by the content of the communication and/or will be making decisions based on the information provided.

Stratigraphy
The layering of rock or ice strata, from which information on succession, age relations, and origin can be deduced.

Threshold Limit Values—(TLVRs)
Exposure guidelines published annually by the American Conference of Governmental Industrial Hygienists (ACGIH) in Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices. TLVRs are employed as OELs when they are more stringent than the OSHA PELs.

Time-Weighted Average (OEL-TWA)
Eight-hour average concentration for which the average is mathematically adjusted for the duration of exposure. The method for calculating OEL-TWAs is shown in 29 CFR 1910.1000 (d) and in the TLV Booklet.

Toxicology Assessment
Process of estimating the human toxicological impact of a specific material based on published and unpublished literature sources and taking into consideration: uptake, metabolism/biotransformation, transport and storage, and excretion including acute (short-term) and chronic (long-term) human health endpoints.

Transmission Line
Carries the RFR signal from the transmitter to the antenna.

Transmitter
The part of an RFR emitter that generates the RFR signal.

Uncontrolled Environments
An area where exposures may be incurred by people who have no knowledge or control of the hazard.

Wavelength
The distance from one peak of a wave to the next peak of a wave.