ORDER

Order No.: 3910.3B

Date: September 1996

Initiated By: AEE-200

Subject: RADIATION HEALTH HAZARDS AND PROTECTION

FOREWORD

This Order updates and supersedes Federal Aviation Administration (FAA) Order 3910.3A, "Radiation Health Hazards and Protection," dated October 19, 1983. It establishes the elements of an FAA Radiation Safety Program, including responsibilities, safety criteria, measurement and reporting standards, as well as procedures and guidelines for the recognition, evaluation, prevention, mitigation and control of potential health hazards associated with undue exposures to electromagnetic fields in all FAA workplaces.

This update has considerably expanded the scope of the previous Order. Under the Non-Ionizing Radiation (NIR) category are included: Radio-Frequency and Microwave (RF/MW) radiation; and Extreme Low Frequency Electric and Magnetic Fields (ELF/EMF), as well as static magnetic and electric fields. Under the Ionizing Radiation (IR) safety category are included X-Rays and radionuclides. Optical and infrared radiation from lasers in the FAA workplace is treated as a separate category.
This revision reflects the agency's continuing effort to prevent, manage and minimize losses due to occupationally related accidents, injuries, illnesses, and management deficiencies, or improper work procedures leading to potentially unsafe personnel exposures.

The FAA intends to provide a safe and healthful work environment and working conditions for all employees and contractors on its premises, as prescribed by the Occupational Safety and Health Act of 1970 (PL91-596 as amended); Executive Order EO 12196, Occupational Safety and Health Programs for Federal Employees; and Title 29 CFR part 1960, "Basic Program Elements for Federal Employee Occupational Safety and Health Programs and Related Matters."

/s/ David R. Hinson
Administrator

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CHAPTER 1. GENERAL

1. PURPOSE. This order establishes the elements of an FAA Radiation Safety Program, including responsibilities, safety criteria, measurement and reporting standards, as well as procedures and guidelines for the recognition, evaluation, prevention, mitigation, and control of potential health hazards from exposures to Non-Ionizing Radiation (NIR), Ionizing Radiation (IR), and laser radiation in FAA workplaces.

2. DISTRIBUTION. This Order is distributed to:

a. Within Washington headquarters, to the Associate Administrators in Administration, Regulation and Certification, Air Traffic Services, and Research and Acquisitions; to the Director of the Air Traffic Service; to the Federal Air Surgeon; to the Director and Program Directors within the Airway Facilities Service; and to the Director of the Office of Communication, Navigation, and Surveillance Systems.

b. In the regions and centers, to the Regional Administrators and the Center Directors; to the regional AF Divisions; to the Environmental, Safety, and Emergency Management Division; to the Facilities Management Division; to the Regional Flight Surgeons; to the Medical Field Staff; to the Director, Civil Aeromedical Institute; and to the Program Director of Aviation System Standards.

3. CANCELLATION. Order 3910.A, Radiation Health Hazards and Protection, dated October 19, 1983, is canceled.

4. EXPLANATION OF CHANGES.

a. This document updates, expands, and replaces FAA Order 3910.3A, dated October 1983. Although the earlier order has proven effective in protecting the health and safety of FAA workers from both IR and NIR potentially hazardous exposures, thanks to the conservative margin of safety provided to match the most restrictive public protection standards, an update is timely and necessary.

b. New safety and health protection standards for NIR, including Radio-Frequency (RF) and Microwave (MW) radiation; for IR; and for laser radiation, are adopted, established, and interpreted with respect to all sources of workplace exposures associated with FAA facilities and operations. Voluntary guidelines for power-frequency (PF) and static electric and magnetic fields (EMF) are also included.

c. This update also reflects restructured agency radiation protection responsibilities per FAA Notice 1100.234, Occupational Safety and Health Functions, dated 12/21/94. The Office of Environment and Energy (AEE) has policy and oversight/evaluation responsibility for FAA employee occupational safety and health programs. NAS Transition and Implementation (ANS) has implementation responsibility for the occupational safety and health program. The Resources Management Training Division (AFZ-100) has primary responsibility to develop updated training courses and materials for potentially exposed FAA employees. The Office of Spectrum Policy and Management (ASR) will continue its historical function as the organization responsible for all agency radiation hazard measurements.

5. AUTHORITY TO CHANGE THIS ORDER. Only the Director of Environment and Energy (AEE) may issue changes to this order necessary to enact policy which will safeguard the health and safety of FAA employees. Changes made to this order's Appendices which reflect updates issued by the FAA-adopted voluntary standard-setting organizations, or by the Occupational Safety and Health Administration (OSHA), shall be made at the discretion of AEE, and will require only headquarters approval. Other changes to the policy will be subject to the standard directives review process.

6. DEFINITIONS. Terms used in this Order are defined in Appendix 1.

7. POLICY.

a. It is FAA policy to protect all employees and contractors working at FAA facilities from potentially hazardous electromagnetic radiation workplace exposures to the maximum extent practical. This shall be accomplished through a comprehensive agency Radiation Safety Program. In addition, this protection shall be extended to other non-employee groups, such as authorized visitors and occupants of child care centers collocated at FAA facilities.

b. The FAA shall adopt the most appropriate current NIR (RF/MW), IR, and laser exposure safety standards for FAA employees, contractors, visitors, and occupants of child care centers on FAA property. Use of the guidelines and exposure criteria for Extremely Low Frequency (ELF) Electric and Magnetic Fields (EMF), and static fields, is voluntary at this time, due to the controversial and inconclusive evidence of potential for harm. Table 1 identifies the employee/non-employee category and the corresponding standards for each type of radiation hazard. See paragraph 9, Related Publications, for the appropriate standard citation. Fuller explanations of these standards are covered in Appendices 2-5.

Table 1. Radiation Exposure Safety Criteria
for Selected Employee Categories

Employee Category	Exposure Criteria
1. Employees and contract workers who are authorized to operate and/or perform repair and maintenance tasks on radar surveillance, navigation and communications equipment, including support equipment, such as engine generators. Example: Electronics and Environmental Technicians, Frequency Management Officers (FMO's). Note: These workers shall have successfully completed the FAA NIR and IR safety course for electronic and environmental technicians, or equivalent.	For NIR (RF/MW): ANSI/IEEE C95.1-1991- Uncontrolled Area Maximum Permissible Exposures (MPE's) as Action Threshold; not to exceed MPE's for Controlled Areas. (T.2-1, 2-2) For ELF/EMF: ACGIH Threshold Limit Values (TLV's) for Sub-Radiofrequency Electric and Magnetic Fields. (T.3-1) For Static Electric and Magnetic Fields: ACGIH TLV's. (T.3-3) For Ionizing Radiation: ICRP Occupational Limits (T.4-7; NCRP limits for embryo/fetus). For Laser Radiation: ACGIH Standards for Eye, Skin (T.5-3, 5-4)
2. Employees described in #1	For NIR (RF/MW): IEEE C95.1

above, but who have not yet completed the FAA NIR safety course. Also, all employees (including contract employees) not engaged in the functions covered in #1, and individuals with medical restrictions. Example: Office workers, pregnant employees, pacemaker wearers, safety and health personnel, etc.	Maximum Permissible Exposures (MPE's) for Uncontrolled Areas. (T.2-1) For ELF/EMF: IRPA Power Frequency Fields Exposure Safety Guidelines- Occupational, with Public Exposure Limits for workers with medical restrictions. (T.3-2) For Static Electric and Magnetic Fields: IRPA Public Exposure Limits, with warning for pacemaker wearers. (T.3-4) For Ionizing Radiation: ICRP Public Limits, except for occasional exposure to Occupational Limits (T.4-7, 4-8) For Laser Radiation: ACGIH Standards for Eye, Skin (T.5-3, 5-4)
3. Non-employees, such as visitors and occupants of child care centers on FAA property.	The most stringent Public Exposure Limits apply for all radiation hazard categories (Tables in Appendices 2-5).

c. It is FAA policy to:

(1) Conduct baseline and periodic surveys of typical NIR (RF/MW), IR, and laser workplace exposures, in order to document, assess, control and mark or restrict access to areas where employee exposures could exceed recommended exposure limits from a single, or multiple radiation sources. Surveys of Extremely Low Frequency (ELF) Electric and Magnetic Fields (EMF) and static fields will be performed only on an as-needed basis.

(2) Ensure that FAA personnel are trained or informed of potential NIR (RF/MW), IR, and laser exposure hazards, and also of the current scientific position regarding ELF/EMF and static fields. This shall be done in a manner appropriate to their employee category in order to prevent or mitigate unnecessary or excessive exposures.

(3) Archive all measured radiation levels by facility type, source type, configuration, location, date, and exposed employee category; and maintain a centralized resource file and data base on radiation exposures, augmented by informative reading materials to assist in responding to inquiries from concerning employees.

(4) Investigate and document any alleged workplace exposure incidents and levels which exceed the adopted exposure guidelines and standards, and recommend prevention and mitigation strategies.

8. RESPONSIBILITIES

a. The Assistant Administrator for Policy, Planning, and International Aviation (API) shall:

(1) As the Designated Agency Safety and Health Official (DASHO), represent top management support for the FAA Radiation Safety Program.

(2) Serve as liaison to the FAA Management Board in safety related matters involving potential radiation hazard to employees in accordance with the terms of the FAA Occupational Safety and Health Compliance Committee (OSHECCOM) Charter.

b. The Office of Environment and Energy (AEE) shall:

(1) Establish policy, including exposure criteria, for the agency Radiation Safety Program.

(2) Provide oversight of the Radiation Safety Program to ensure that all program elements established by AEE policy and by ANS program guidance are effective in preventing, minimizing, or mitigating potential radiation hazards to employees, contractors, visitors, and occupants of child care centers on FAA property.

(3) Coordinate with AAF in all policy changes relating to the Radiation Safety Program.

(4) Identify, and periodically update, minimum training requirements for employee radiation safety courses to be developed and maintained by AAF.

c. The Airway Facilities Service (AAF) shall:

(1) Implement and administer the Radiation Safety Program policy.

(2) Budget for funds required for the effective management of the program.

(3) Coordinate with other organizations, such as AEE, AAT, ABA, AND, and AAM, as required to ensure their support for program implementation.

d. The NAS Transition and Implementation (ANS) organization shall:

(1) Be responsible for the implementation and management of the Radiation Safety Program.

(2) Establish and provide for a Radiation Protection

Officer (RPO), who is qualified by training and experience to serve as the agency focal point for all employee radiation health and safety concerns.

(3) Be the budget advocate for funding for needed radiation hazard monitoring and measurement equipment, including initial calibration of the equipment, and for related training and educational needs.

(4) Collaborate with the Office of Spectrum Policy and Management (ASR-1) on the identification and resolution of any employee complaints alleging undue exposures to NIR (RF/MW), IR, laser, ELF/EMF and static fields exposures.

(5) Coordinate with AAM when seeking health and/or medical interpretation of any NIR (RF/MW), IR, laser, ELF/EMF and static fields measurement data.

(6) Coordinate periodic (at least annual) reviews of employees' work tasks and/or work environments to identify new operations or modifications to the workspace environment that may increase the potential for radiation exposure hazard. These reviews shall be documented and archived in a centralized data base (see para. e(7) below.)

(7) Develop and implement FAA radiation safety courses for FAA employees who must perform radiation measurement tasks, as well for employees who must perform work tasks or work in environments where potential exists for exposure at or above adopted exposure safety criteria. Also, provide informational resources to concerned employees upon request.

(8) Ensure that emerging or planned NAS systems and components, or modifications to existing systems, are evaluated for possible radiation and fields hazards in all phases of acquisition and lifecycle management processes.

(9) Ensure that the safety paragraphs in allied radar maintenance orders (6000-series) and related publications are revised to include this order and any ANS radiation safety guidelines, and that the safety information is current and sufficient to the needs of the publications' readers.

e. The Office of Spectrum Policy and Management (ASR) shall:

(1) Serve as the agency point of contact for the performance of all NIR (RF/MW), IR, laser, ELF/EMF and static fields measurements and archiving of data.

(2) Provide regional Frequency Management Officials (FMO's) with equipment and/or technical support required for laser, NIR (RF/MW), IR, laser, ELF/EMF and static fields measurements.

(3) Verify and document that equipment provided to FMO's is maintained in good condition and calibrated at least annually.

(4) Be the budget advocate for training courses for

FMO's appropriate to the level of knowledge and skill necessary for them to perform NIR (RF/MW), IR, laser, ELF/EMF and static fields measurements.

(5) Transfer to the RPO all employee requests for health and/or medical interpretations of NIR (RF/MW), IR, laser, ELF/EMF and static fields.

(6) Advise the RPO and AEE in writing of any employee complaint relating to potentially unsafe workplace exposure to NIR (RF/MW), IR, laser, ELF/EMF and static fields, so that policy and/or implementation guidance may be reviewed for possible revisions.

(7) Develop, in collaboration with ANS and AEE, a spectrum engineering data management system for logging and tracking all NIR (RF/MW), IR, laser, ELF/EMF and static fields measurement data, including baseline and periodic inspection data, as well as data arising from planned or unplanned investigations relating to possible hazardous exposures with potentially adverse health effects.

(8) Collaborate with the RPO in developing and recommending hazard prevention, control, and mitigation strategies as needed for coordination with appropriate headquarters, regional, and center Airway Facilities staff.

f. The Office of Aviation Medicine (AAM) shall:

(1) Provide health and/or medical interpretation of NIR (RF/MW), IR, laser, ELF/EMF and static fields measurements upon request by the RPO for measurement data collected by ASR as a result of an employee complaint of an unnecessary, excessive, undue or potentially hazardous exposure.

(2) Recommend, upon request by the RPO, an appropriate medical monitoring or treatment strategy when there has been a documented accidental or routine exposure to an employee in excess of the adopted exposure safety criteria.

g. The regional Airway Facilities Managers (AXX-400) shall:

(1) Provide regional assistance in the identification of and resolution of employee concerns of potential and alleged radiation hazards.

(2) Maintain a current list of regional employees who perform tasks, or work in environments, where potential exists for exposure at or above adopted exposure safety criteria.

(3) Ensure that all individuals per paragraph (2) above, are all informed and/or trained in safe work practices and radiation exposure prevention, and that this training is documented.

h. The regional Frequency Management Officials (FMO's) shall:

(1) Perform (or request ASR to perform on their behalf) radiation measurements for the commissioning and/or decommissioning of FAA facilities, including on-site or collocated child care centers, using the most current, peer-adopted procedures; estimate potential for radiation exposure to individual categories identified in Table 1. Coordinate with ASR if any potential exists for exposure above the adopted radiation and fields safety criteria.

(2) Perform radiation and fields measurements, in collaboration with ASR, when there has been a radiation-related complaint from an employee or a member of the public, or when a modification has been made to a facility, or work environment, or whenever a work practice may increase or enhance the likelihood of radiation or fields exposures in excess of the FAA adopted safety criteria to any employee, contractor, visitor, or occupants of child care facilities on FAA property.

(3) Log results of all radiation and fields measurements (baseline, periodic, and any others associated with planned or unplanned investigations) as standardized reports or data into the spectrum engineering data management system.

(4) Be familiar with the requirements of this policy, the ANS radiation and fields safety guidance, and the ASR Order 6050.32, Spectrum Management Regulations and Procedures Manual (in revision) for proper environmental survey and personal exposure assessment, data recording, analysis, and reporting procedures.

i. All employees meeting the employee category criteria of Table 1 shall:

(1) Be aware of the requirements of this policy.

(2) Share responsibility for obtaining or requesting radiation and fields exposure safety information and training commensurate with one's exposure potential and work duties.

(3) Adhere to all applicable proper work procedures and exposure safety guidelines.

9. RELATED PUBLICATIONS

(1) ANSI/IEEE C95.1-1991, Standard for Safety Levels With Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz, April 1992, developed by the Institute of Electrical and Electronic Engineers, Inc. (IEEE) and adopted by the American National Standards Institute (ANSI).

(2) IEEE Standard C95.3-1991, "IEEE Recommended Practice for the Measurement of Potentially Hazardous Electromagnetic Fields - RF and Microwave," 1992).

(3) The American Conference of Governmental Industrial Hygienists (ACGIH) 1995-96 Threshold Limit Values (TLVs) for Chemical Substances and Physical Agents and Biological Exposure

Indices. (Physical agents include RF/MW, Subradio frequency ELF/EMF and static fields, ionizing radiation and lasers).

(4) NCRP Report 119, A Practical Guide to the Determination of Human Exposure to Radiofrequency Fields, 1993, National Council on Radiation Protection and Measurements (NCRP).

(5) The World Health Organization Criteria 137: Electromagnetic Fields (300 Hz to 300 GHz), 1993.

(6) International Radiation Protection Association (IRPA/INIRC), "Interim 50/60 Hz ELF/EMF Exposure Guidelines, Health Physics" 58, 113-122, 1990.

(7) IEEE Std 1308-1994, April, 1995: "IEEE Recommended Practice for Instrumentation: Specifications for Magnetic Flux Density and Electric Field Strength Meters - 10 Hz to 3 kHz."

(8) NRC, "Health Effects of Exposure to Low Levels of Ionizing Radiation" (BEIR V), Washington, D.C., 1990, Nuclear Regulatory Commission.

(9) NCRP, "Limitation of Exposure to Ionizing Radiation," Bethesda, 1993.

(10) ICRP, 1990 "Recommendations of the International Commission on Radiological Protection," Oxford, 1991.

(11) ANSI Z136.1-1993 "American National Standard for Safe Use of Lasers", The Laser Institute of America, 1993.

(12) ACGIH "A Guide for Control of Laser Hazards", American Conference of Governmental Industrial Hygienists, Inc., 1990.

APPENDIX 1. DEFINITIONS

Definitions Pertaining to Ionizing and Non-Ionizing Radiation:

Absorbed Dose - The mean energy imparted by ionizing radiation per unit mass of irradiated material. The units of absorbed dose are the rad and the gray (Gy).

Administrative Dose - The total effective dose equivalent that a Radiation Safety Officer assigns when dosimetry is inaccurate or has been misused.

Alpha (alpha) Particles - One of the particles emitted in radioactive decay. It is identical with the helium nucleus, consisting of two protons and two neutrons bound together.

Annual Reference Levels of Intake (ARLI) - The activity of a radionuclide, that - if taken into the body during a year - would provide a Committed Effective Dose to a person equal to the Reference man (REM), or to 20 mSv. The ARLI is expressed in becquerels (Bq).

Average Absorbed Dose (D sub t,r) - The average dose of ionizing radiation of types r absorbed by tissue types t, measured in Grays (Gy).

Averaging Time (T sub avg) - The time period over which exposure is averaged for determining compliance with exposure criteria recommended by recognized safety standards and/or guidelines.

Becquerel (Bq) - The SI unit of radioactivity equivalent to one nuclear transformation per second.

Beta (beta) Particles - One of the particles that can be emitted by a radioactive atomic nucleus. A negatively charged (beta) particle (beta-) is identical to the electron, while the positively charged type (a positron, beta+) differs from the electron in having equal but opposite electrical properties.

Committed Effective Dose (E) - The sum of (i) the products of the tissue weighting factors (w sub T) applicable to each of the body organs or tissues that are irradiated due to the intake of radionuclides and (ii) the resultant committed equivalent doses H sub T(o) to each of these organs or tissues.

Committed Equivalent Dose, H sub T(tau) - The equivalent dose in a particular organ or tissue accumulated in a specific period time T, after intake of a radionuclide. H sub T(tau) is the integral over time of the equivalent dose rate in that organ or tissue (T), from the time of intake (t sub 0) to (t sub 0 + o), where o = 50 years is applicable to workers and o = 70 years is applicable to members of the public.

Controlled Environment/Area - Locations where Non-ionizing Radiation (NIR) exposures conform with occupational MPE's recommended by C95.1 for exposure safety; or work areas occupied by personnel whose potential NIR exposures are concomitant to work duties. Safety training and best work practices to prevent and control exposures are assumed, and posted warnings or access restrictions (e.g., fences, enclosures, physical barriers or shields) might apply to controlled areas.

Deterministic Effect - Effects for which the severity varies with dose, and for which a threshold usually exists or can be defined.

Effective Dose (E) - The sum of the products of (i) the equivalent doses (H sub T) absorbed by irradiated organs and tissues (T) and (ii) the weighting factors (w sub T) applicable to each of those body organs or tissues.

Electric Field (E) - The magnitude of the electric field component of an electromagnetic wave, expressed in units of volts/meter (V/m), or kilo-volts/meter (kV/m).

Electric and Magnetic Fields (EMF) - generally used to designate Electric and Magnetic Fields produced by Alternating Currents (AC) at Power Frequency (PF) or 60 Hertz (Hz) and harmonics, associated with electrical power generation, storage, transmission and utilization.

Electron volt (eV) - A unit of energy equal to 1.6×10^{-19} joule (see definitions of Ionizing vs. Non-Ionizing Radiation in terms of quantum energy in eV).

Electromagnetic (EM) Spectrum - A graphical representation of the radiant electromagnetic energy according to frequency (or wavelength), ranging from Non-Ionizing Radio-Frequency (RF) to infrared and visible optical frequency, and extending into the Ionizing Radiation range (from ultraviolet, UV, to X-rays and Gamma Rays), as depicted in Figure 1.

Figure 1. Electromagnetic Spectrum,
Band Designations, and Sample Applications

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 Frequency ] Wavelength  ]     Energy     ]
   (Hz)    ]    (m)      ]      (eV)      ]
 __________]_____________]________________]     ___
           ]       8     ]            -14 ]   ]   ]
     3     ]      10     ] 1.25 x 10      ] ~ j ^
           ]             ]                ] ] ]   ]
           ]       7     ]            -13 ] ] ]   ]
    30     ]      10     ] 1.25 x 10      ] ] ]   ]
           ]             ]                ] ] ] F ]   Power
           ]       6     ]            -12 ] ] ] L ]   Transmission
    300    ]      10     ] 1.25 x 10      ] ] ] E ]
           ]             ]                ] ] ]___]   Telephone
        3  ]       5     ]            -11 ] ] ] F ]
  3 x 10   ]      10     ] 1.25 x 10      ] ] ] L ]
           ]             ]                ] ] ] V ]
        4  ]       4     ]            -10 ] ] ]___]
  3 x 10   ]      10     ] 1.25 x 10      ] ] ] F ]
           ]             ]                ] ] ] L ]
        5  ]       3     ]            -09 ] ] ]___]
  3 x 10   ]      10     ] 1.25 x 10      ] ] ] F ]
           ]             ]                ] ] ] M ]
        6  ]       2     ]            -08 ] ] ]___]
  3 x 10   ]      10     ] 1.25 x 10      ] ] ] F ]   AM Radio
           ]             ]                ] ] ] H ]
        7  ]             ]            -07 ]   ]___]
  3 x 10   ]      10     ] 1.25 x 10      ] n ] F ]
           ]             ]                ] o ] H ]
        8  ]             ]            -06 ] i ] V ]
  3 x 10   ]       1     ] 1.25 x 10      ] t ]___]   FM Radio
           ]             ]                ] a ] F ]   Cellular
        9  ]             ]            -05 ] i ] H ]   Telephones
  3 x 10   ]     0.1     ] 1.25 x 10      ] d ] U ]   Microwave
           ]             ]                ] a ]___]   Ovens
       10  ]      -2     ]            -04 ] R ] F ]  \
  3 x 10   ]      10     ] 1.25 x 10      ]   ] H ]    \
           ]             ]                ] g ] S ]      \
       11  ]      -3     ]            -03 ] n ]___]        \
  3 x 10   ]      10     ] 1.25 x 10      ] i ] F ]          \
           ]             ]                ] z ] H ]   Approx.
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      12 ]        -4    ]           -02  ] i ] E ]   Spectral
3 x 10   ]      10      ] 1.25 x 10      ] n ]___]   Ray
         ]              ]                ] o ] F ]   Radars
      13 ]        -5    ]                ] i ] H ]   Operated by
3 x 10   ]      10      ]     0.125      ] n ] V ]
         ]              ]                ] o ]___]
      14 ]        -6    ]                ] N ] R ]
3 x 10   ]      10      ]     1.25       ]   ] I ]
         ]              ]                ] _ ]   ]
      15 ]        -7    ]                ]   ]   ]   Visible
3 x 10   ]      10      ]     12.5       ] n ]___]   Light
         ]              ]                ] o
      16 ]        -8    ]            2   ] i
3 x 10   ]      10      ] 1.25 x 10      ] t   UV
         ]              ]                ] a
      17 ]        -9    ]            3   ] i
3 x 10   ]      10      ] 1.25 x 10      ] d
         ]              ]                ] a   X-rays
      18 ]        -10   ]            4   ] R
3 x 10   ]      10      ] 1.25 x 10      ]
         ]              ]                ] g
      19 ]        -11   ]            5   ] n
3 x 10   ]      10      ] 1.25 x 10      ] i
         ]              ]                ] z
      20 ]        -12   ]            6   ] i   Gamma
3 x 10   ]      10      ] 1.25 x 10      ] n   Rays
         ]              ]                ] o
      21 ]        -13   ]            7   ] I
3 x 10   ]      10      ] 1.25 x 10      ]
         ]              ]                ] ]
      22 ]        -14   ]            8   ] ]
3 x 10   ]      10      ] 1.25 x 10      ] ]   Cosmic
         ]              ]                ] ]   Rays
      23 ]        -15   ]            9   ] ]
3 x 10   ]      10      ] 1.25 x 10      ] ]
         ]              ]                ] V
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Equivalent Dose (H sub T) - The product of (i) the average absorbed dose (D sub T) in a specific organ or tissue and (ii) the radiation weighting factor (w sub R). The units of equivalent dose are the rem and sievert (Sv).

Equivalent Dose Rate - The annual Equivalent Dose (in Sv) in any given future year that would result from intake of radionuclides.

Extremely Low Frequency (ELF) electromagnetic radiation - Electromagnetic radiation with a frequency less than 3 kHz.

Far-Field Region - The region far enough from an antenna where the radiated power density decreases with the squared distance and the electromagnetic fields are well characterized by the plane-wave approximation.

Gamma (gamma) Rays - Quanta of electromagnetic wave energy, of much higher and more penetrating energy than ordinary x rays, that may be emitted from radioactive substances.

Gray (Gy) - The SI unit of absorbed dose and specific energy imparted. One gray is equal to an absorbed dose of 1 joule/kilogram (100 rads).

Hertz (Hz) - Unit of electromagnetic radiation (EMR) frequency denoting 1 cycle per second (cps). EMR quanta of energy are characterized by their characteristic frequency and wavelength (product of frequency by wavelength equals the speed of light). Common units for spectral range designation for NIR are kilo-hertz (KHz), mega-hertz (MHz) for radiofrequency radiation (RFR), and Giga-hertz (GHz) for microwave (MW) radiation (Fig. 1-1).

Ionizing Radiation - Subatomic particles with kinetic energies greater than 12.4 eV, electromagnetic radiation with photon energies greater than 12.4 eV, and all free neutrons.

Infrared (IR) electromagnetic radiation - Electromagnetic radiation with wavelengths which lie with the range of 0.7 microns to 1 mm.

Magnetic Field (H) - Magnetic fields are produced by direct (DC) or alternating (AC) electric currents, and also represent one of the components of an electromagnetic field. Common units of magnetic flux density (B) to enable comparison with the ambient Earth's field are: Gauss (G), milli-Gauss (mG), or fractions of Tesla (1 T = 10,000 G). Earth's steady (DC) field is about 0.5 G. Another unit used for magnetic field strength (H) measurements related to EM radiation is Amperes per meter (A/m), where 1 G = 79.58 A/m (in free space).

Microwave Radiation (MW) - Electromagnetic radiation spanning the Radio Frequency (RF) portion of the EM spectrum from 300 MHz to 300 GHz, corresponding to wavelengths of 1 m to 10 mm. (see Figure 1-1)

Maximum Permissible Exposure (MPE) - This term, defined in IEEE/ANSI Standard C95.1-1992, denotes the recommended levels of power density, or equivalent electric or magnetic field strengths, for radiated non-ionizing electromagnetic energy, as a function of frequency range (or corresponding wavelength). No harm is expected below or at MPE threshold to the public (for uncontrolled environment MPE) nor workers (for controlled environment MPE) from repeated exposures to NIR. These safety limits have large safety margins (of over 10 to 25 for occupational, and 25 to 50 or even 100 for the public) provided to ensure that no potentially harmful bioeffects of NIR exposure can occur.

Near Field Region - The range of distances in close proximity to a radiating antenna, where the power density can vary considerably from point to point, does not vary with the inverse squared distance, and the plane wave approximation for electric and magnetic fields does not hold.

Negligible Individual Dose (NID) - A level of Effective Dose of Ionizing Radiation that can be dismissed. The NID is 0.01 mSv/year.

Non-Ionizing Radiation (NIR) - This term applies to electromagnetic radiation (Figure 1-1) with photon energies less than 12.4 eV. This energy is insufficient to ionize atoms and molecules. It includes all frequencies below the near-ultraviolet (UV) portion of the spectrum, namely:

- extreme low frequencies (ELF), f < 3000 Hz
- radio-frequency radiation (RFR), including microwaves (MW), 300 Hz < f < 300 Ghz
- optical radiation, with wavelengths longer than 100 nm and shorter than 1 mm, including infrared, visible and ultraviolet ranges.

Non-occupational Exposure - Exposure to employees that occurs outside a controlled area, or to a visitor to a controlled work area, or to persons and members of the public who are not FAA workers, nor approved contractors. Examples of non-occupational exposure to non-ionizing radiation (NIR) might refer to children and employees of daycare centers operated by contractors, co-located with FAA facilities.

Occupational Exposure - a) Exposure of an individual in the course of employment in which the individual's assigned duties involve exposure to radiation or radioactive material. Occupational dose does not include doses received from background radiation, from any medical administration the individual has received, from voluntary participation in medical research programs, or as a member of the public.

b) Exposures of FAA employees (and approved contractors) to ionizing radiation (IR) and/or NIR, incurred as part of work duties in either controlled or uncontrolled areas/environments. It is expected that the exposed fraction of the FAA workforce has been informed or trained in safe work practices, as needed.

Photon - A quantum of electromagnetic radiation.

Plane Wave - An EM wave is characterized by mutually orthogonal Electric (E) and Magnetic (H) fields, related by the impedance of free space (377 Ohms). For Plane Waves, the power density S is related to squared electric and magnetic field intensities by: S = (E squared)/3770 = 37.7(H squared); the units are mW/(cm squared) for S, V/m for E, and Amperes per meter, A/m for H. (S = (E squared)/377 in W/(m squared)).

Power Density (S for Poynting Vector, or PD) - The average power per unit area (in milliWatt per squared centimeter, mW/(cm squared) or Watt per squared meter, W/(m squared)), representing the intensity of electromagnetic radiation (EMR), which is proportional to squared electric field and to squared magnetic field intensities.

Public Exposure - A very general term denoting that members of the public might be unknowingly or unintentionally exposed to environmental levels of electromagnetic radiation, for certain periods of time, and which correspond to specific limits or other recommended standards or guidelines for exposure safety.

Rad - A unit of absorbed dose. One rad is equal to an absorbed dose of 0.01 Joule/kilogram (0.01 Gray).

Radiation Protection Officer (RPO) - The FAA official charged with serving as the principal point of contact and coordinator for employee health and safety issues for ionizing and non-ionizing radiation exposures. This individual is qualified by education, training, and experience to evaluate the potential for short or long term health effects associated with use of radar and radar components in FAA workplaces.

Radiation Weighting Factor (W sub r) - The dimensionless weighting factor applied to ionizing radiation of type r, when calculating Equivalent Dose (assumed to be tissue-independent).

Radio-Frequency Radiation (RFR) - EM radiation over the spectral range of frequencies 3 KHz to 300 GHz (see Fig. 1-1). There are designated RF frequency bands defined by the International Telecommunication Union (ITU) and by the IEEE, that have corresponding wavelength and energy ranges. For instance, Very Low Frequency (VLF) is 3 to 30 KHz, Medium Frequency (MF) extends from 0.3 to 3 MHz, High frequency (HF) from 3 to 30 MHz, Very High Frequency (VHF) from 30 to 300 MHz, Ultra High Frequency (UHF) from 300 MHz to 3 GHz, Super High (SHF) from 3 to 30 GHz, and Extremely High Frequency (SHF) from 30 to 300 GHz.

Radiofrequency (RF) Electromagnetic Radiation - The region of the electromagnetic radiation spectrum between the frequencies 3 kHz and 300 Ghz.

Radionuclides - Materials which releases ionizing radiation over time through nuclear decomposition. Through intake into the body (e.g., through inhalation), radionuclides may be a potential source of exposure for FAA employees.

Reference Man - A hypothetical set of human physical and physiological characteristics, which by international consensus, may be used by public health workers and researchers to normalize the biological damage from ionizing radiation.

Rem - Roentgen Equivalent Man, an ionizing radiation unit of any of the quantities expressed as Dose Equivalent.

Roentgen (R) - A unit of radiation exposure. It is defined as that quantity of x or gamma radiation which produces one electrostatic unit of positive or negative electrical charge per cubic centimeter of air at standard temperature and pressure, or 2.083 x 1,000,000,000 ion pairs per cubic centimeter of dry air.

Sievert - The SI unit of ionizing radiation Effective Dose and Equivalent Dose: 1 Sv = 100 rem = 1 J/kg.

Specific Absorption Rate (SAR) - This quantity is the time rate for absorption of non-ionizing EM radiated energy by a unit of biological tissue of body mass (in W/kg). Average whole body SAR represents the energy transferred per unit time, or the total RFR energy per total body mass. Partial body SAR can be calculated for localized radiation absorption (by brain, eye, or limbs) from a small antenna, such as a personal wireless or cellular telephone.

Stochastic Effect - Effects of ionizing radiation, for which the probability, rather than their severity depend on radiation dose, without a specified threshold.

Tissue Weighting Factor - A factor denoting the risk ratio attributable to ionizing radiation effects for a specific organ or tissue type, to the total risk of stochastic effects when the whole body is uniformly irradiated (measures organ sensitivity to radiation damage).

Threshold Limit Value (TLV) - Upper limits adopted by the American Conference of Governmental Industrial Hygienists (ACGIH) as good industrial hygiene practice for specific physical agents and chemical substances, representing conditions under which repeated daily work exposures can occur without expected adverse health effects.

Uncontrolled Environment/Area - Locations where NIR exposures do not exceed the public MPE's recommended in the C95.1 ANSI/IEEE NIR exposure safety Standards.

Ultraviolet (UV) electromagnetic radiation - The region of the electromagnetic radiation spectrum between the wavelengths 100 nm and 380-400 nm (Fig. 1-1).

Visible light - The region of the electromagnetic radiation spectrum between the wavelengths 380-400 nm and 760-780 nm (Fig. 1-1).

Working Level (WL) - That amount of potential alpha energy in a cubic meter of air that will result in the emission of 2.08 x 0.00001 joules of energy.

Working Level Month (WLM) - A cumulative ionizing radiation exposure, equivalent to exposure to a working level for a whole working month (170 hours), i.e., 2 x 0.00001 J/(m cubed) X 170 hr = 0.0035 J-hr/(m cubed).

X Rays - A type of electromagnetic radiation of higher frequency (i.e., shorter wavelength) than visible light but lower frequency (i.e., longer wavelength) than gamma rays. Usually produced by high energy electrons impinging on a metal target.
Definitions Pertaining to Lasers:

alpha sub max - The angular limit beyond which extended source TLVs for a given exposure duration are expressed as constant radiance or integrated radiance. This value is defined as 100 mrad.

alpha sub min (limiting angular subtense) - The apparent visual angle which divides intrabeam viewing from extended-source viewing.

Aperture - An opening through which radiation can pass.

Apparent Visual Angle - The angular subtense of the source as calculated from source size and distance from the eye. It is not the beam divergence of the source.

C sub A - Correction factor which increases the TLV values in the near infrared (IR-A) spectral band (700-1400 nm) based upon reduced absorption properties of melanin pigment granules found in the skin and in the retinal pigment epithelium.

C sub B - Correction factor which increases the TLV values in the red end of the visible spectrum (550-700 nm) because of greatly reduced photochemical hazards.

C sub C - Correction factor which increases the TLV values for ocular exposure because of pre-retinal absorption of radiant energy in the spectral region between 1150 and 1400 nm.

C sub E - Correction factor used for calculating the extended source TLV for the eye from the intrabeam TLV, when the laser source subtends a visual angle exceeding alpha sub min.

C sub P - Correction factor which reduces the TLV for repetitively pulsed exposure of the eye.

Continuous Wave (CW) - The output of a laser which is operated in continuous (i.e., for durations greater than or equal to 0.25 second) rather than pulsed mode.

Extended Source - A source of laser radiation subtending an angle at the eye which is greater than alpha sub min.

Intrabeam Viewing - The viewing condition where the source subtends an angle at the eye which is less than or equal to alpha sub min, the limiting angular subtense. This category includes most collimated beams and so-called point sources.

Irradiance - Quotient of the radiant flux incident on an element of the surface containing the point at which irradiance is measured, by the area of that element. Unit: Watt per square centimeter (W/(cm squared)).

Laser - A device which produces an intense, coherent, directional beam of light by stimulating electronic or molecular transitions from higher to lower energy levels. An acronym for Light Amplification by Stimulated Emission of Radiation.

Limiting Aperture (D sub f) - The maximum diameter of a circle over which irradiance and radiant exposure can be averaged.

Nominal Hazard Zone (NHZ) - The region within which the level of direct, reflected, and/or scattered laser radiation during operation exceeds the applicable laser MPE or TLV.

Radiance - Radiant flux or power output per unit solid angle per unit area. Unit: Watts per square centimeter per steradian (W/(cm squared)-sr).

Radiant Energy - Energy emitted, transferred, or received in the form of radiation. Unit: Joule (J).

Radiant Exposure - Surface density of the radiant energy received. Unit: Joules per square centimeter (J/(cm squared)).

Radiant Flux - Power emitted, transferred, or received in the form of radiation. Unit: Watt (W). Also called radiant power.

Steradian (sr) - The unit of measure for a solid angle. There are 4 pi steradians about any point in space.

Threshold Limit Value (TLV) - The level of laser radiation to which a person may be exposed without hazardous effect or adverse biological changes in the eye or skin.

APPENDIX 2.
NON-IONIZING RADIATION (NIR):
RADIOFREQUENCY AND MICROWAVE RADIATION

1. PURPOSE. This appendix to FAA Order 3910.3B establishes exposure criteria and guidelines for protection from non-ionizing radiation (NIR), particularly radiofrequency and microwave radiation, in FAA workplaces. The intent of this appendix is to ensure that sources of non-ionizing radiation are identified and inventoried, that personnel are properly trained to work with and around these sources, and that measurements are taken to evaluate emission rates and personnel exposures. Controls to mitigate hazards are implemented when surveys indicate that exposures can exceed acceptable limits.

2. GENERAL BACKGROUND.

a. The Occupational Safety and Health Administration (OSHA) has not yet updated or revised workplace exposure safety standards for NIR (29 CFR 1910.97), which was based on the 1966 American National Standards Institute (ANSI) Standard. While the OSHA Act of 1971 allows the automatic adoption of the most recent ANSI standard as a workplace exposure safety guide (under the "general duty" clause), OSHA guidelines for NIR are merely advisory and not strictly enforceable. The OSHA approach is to recommend adoption of peer-reviewed voluntary exposure guidelines, and to couple higher occupational exposure levels with a radiofrequency (RF) safety training program.

b. Well respected international (e.g., World Health Organization, WHO) and national health and safety standards organizations have issued in the past 5 years revised voluntary or advisory standards and guidelines. National organizations include: the National Council on Radiation Protection and Measurements (NCRP); the American Conference for Governmental Industrial Hygienists (ACGIH); and the Institute for Electrical and Electronic Engineers (IEEE) in cooperation with ANSI. These updated interim standards and guidelines for exposure safety from non-ionizing radiation, and guidance concerning measurement and evaluation procedures, are based on reviews of published research results on biological and potential health effects of NIR acute and chronic exposures.

c. The FAA has reviewed and evaluated all applicable safety and health radiation standards and guidelines for personnel and the public. Other Standards reviewed and evaluated include those recommended by recognized health standards organizations and trade association guidelines for occupational exposure safety and the voluntary industry-endorsed safety standards, such as:

(1) The World Health Organization Criteria 137: Electromagnetic Fields (300 Hz to 300 GHz), 1993;

(2) The NCRP Report 119, A Practical Guide to the Determination of Human Exposure to Radiofrequency Fields, 1993;

(3) The American Conference of Governmental Industrial Hygienists (ACGIH) 1995-96 Threshold Limit Values (TLVs) for Chemical Substances and Physical Agents and Biological Exposure Indices;

(4) The ANSI/IEEE C95.1-1991, Standard for Safety Levels With Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz, published in April 1992, which set public and occupational NIR exposure safety to radio-frequency and microwave radiation.

3. EXPOSURE CRITERIA ADOPTED BY THE FAA.

a. The FAA hereby adopts the current IEEE/ANSI C95.1 Standard for all FAA workplaces because it represents peer-reviewed consensus guidelines which reflect the latest scientific research findings. C95.1 is a dual exposure standard, which lists Maximum Permissible Limits (MPE's) for "uncontrolled" and "controlled" environments. Uncontrolled environments MPE's apply to public, or involuntary, exposure to NIR whereas controlled environments apply to workplace, or voluntary, exposures. The public MPE's have larger safety margins (typically by factors of 10 - 50) compared to the workplace MPE's (safety factors of about 10).

b. The FAA adopts the most protective MPE's for uncontrolled environments for all its workers, in order to provide the most conservative safety margins for NIR exposures in or near FAA facilities and operations where NIR may be a hazard. Limits for uncontrolled environments are shown in Table 2-1. The frequency dependence of MPE's for electric and magnetic fields, and the corresponding power density limits for uncontrolled environments, is shown in Figure 2-1A.

Table 2-1. RF/MW MPE's for Uncontrolled Environments

A. RF EMF

Frequency Range (f, MHz)	Electric Field (E, V/m)	Magnetic Field (H, A/m)	Power Density (S, mW/cm^2) (E^2 & H^2)	Tavg (min) (E^2, S or H^2)
0.003 - 0.1	614	163	10^2, 10^6	6, 6
0.1 - 1.34	614	16.3/f	10^2, $10^4/f^2$	6, 6
1.34 - 3	823.8/f	16.3/f	$180/f^2$, $10^4/f^2$	$f^2/.3$, 6
3 - 30	823.8/f	16.3/f	$180/f^2$, $10^4/f^2$	30, 6
30 - 100	27.5	$158.3/f^{1.668}$	0.2, $9.4 \times 10^5/f^{3.336}$	30, $.0636f^{1.337}$
100 - 300	27.5	0.0729	0.2	30, 30
300 - 3,000	-	-	f/1500	30, -
3,000 - 15,000	_	-	f/1500	90,000/f
15,000 - 300,000	-	-	10	$616,000/f^{1.2}$

B. RF INDUCED CURRENT RESTRICTIONS

Frequency Range (f, MHz)	Max. Current Through Both Feet (I, mA)	Max. I Through Each Foot (mA)	Contact Current (mA)
0.003 - 0.1	900 f	450 f	450 f
0.1 - 100	90	45	45

C. PULSED RF FIELDS

Frequency Range (f, MHz)	Peak Electric Field (E, kV/m)	Peak Power Density per Pulse (mW/cm^2) for Pulse Duration < 100 msec

0.1 - 300,000	100	MPE x T_{avg}/5x pulse width

D. PARTIAL BODY EXPOSURES

Frequency Range (f, MHz)	Peak Value of Mean Squared Field (V^2/m^2 or A^2/m^2)	Equivalent Power Density (mW/cm^2)
0.1 - 300	< $20E^2$, or $20H^2$	-
300 - 6,000	-	4
6,000 - 30,000	-	f/1,500
30,000 - 300,000	-	20

Source: C95.1-1991 "IEEE Standard for Safety Levels With Respect to Human Exposure to Radiofrequency Electromagnetic Fields, 3 KHz to 300 GHz."

Figure 2-1A. Maximum Permissible Exposure for Uncontrolled Environments
ƒFIGURE NOT INCLUDEDa

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c. For employees and contractors who are authorized to work with or in the vicinity of recognized sources of NIR (e.g., operation and/or maintainance), and who have successfully passed FAA's radiation safety course, the FAA shall permit occasional, short-term exposures above the MPE's for uncontrolled environments; however, exposures to these workers shall not exceed the higher MPE's for controlled environments, which are shown in Table 2-2. The frequency dependence of MPE's for electric and magnetic fields, and the corresponding power density limits for controlled environments, is shown in Figure 2-1B. In effect, the uncontrolled environment criteria become Action Levels for these workers, which will signal implementation of exposure control strategies.

Table 2-2. RF/MW MPE's for Controlled Environments

A. RF EMF

Frequency Range (f, MHz)	Electric Field (E, V/m)	Magnetic Field (H, A/m)	Power Density (S, mW/cm^2) (E^2 & H^2)	Tavg (min) (E^2, S or H^2)

0.003 - 0.1	614	163	10^2, 10^6	6
0.1 - 3	614	16.3/f	10^2, $10^4/f^2$	6
3 - 30	1842/f	16.3/f	$900/f^2$, $10^4/f^2$	6
30 - 100	61.4	16.3/f	1, $10^4/f^2$	6
100 - 300	61.4	0.163	1	6
300 - 3,000			f/300	6
3,000 - 15,000			10	6
15,000 - 300,000			10	$616,000/f^{1.2}$

B. RF INDUCED CURRENT RESTRICTIONS

Frequency Range (f, MHz)	Max. Current Through Both Feet (I, mA)	Max. I Through Each Foot (mA)	Contact Current (mA)
0.003 - 0.1	2,000 f	1,000 f	1,000 f
0.1 - 100	200	100	100

C. PULSED RF FIELDS

Frequency Range (f, MHz)	Peak Electric Field (E, kV/m)	Peak Power Density per Pulse (mW/cm^2) for Pulse Duration < 100 msec
0.1 - 300,000	100	MPE x T_{avg} /5x pulse width

D. PARTIAL BODY EXPOSURES

Frequency Range (f, MHz)	Peak Value of Mean Squared Field (V^2/m^2 or A^2/m^2)	Equivalent Power Density (mW/cm^2)
0.1 - 300	< $20E^2$, or $20H^2$	-
300 - 6,000	-	< 20

			0.25
6,000 - 96,000	-	< 20 (f/6,000)	
96,000 - 300,000	-	40	

Source: C95.1-1991 "IEEE Standard for Safety Levels With Respect to Human Exposure to Radiofrequency Electromagnetic Fields, 3 KHz to 300 GHz."

Figure 2-1B. Maximum Permissible Exposure for Controlled Environments
ƒFIGURE NOT INCLUDEDa

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d. In addition, the FAA shall adopt new requirements for measurement and evaluation of contact currents, induced body currents, and partial body exposures. Tables 2-1B and 2-2B specify the maximum safe current limits for either induced currents through limbs (for a free standing individual and no contact with metal objects), and for contact currents (associated with grasping or touching an ungrounded metal object), both of which can lead to RF burns. Grasping contact of unprotected hands or feet with RF energized metal objects can also cause startle reactions and shock discharges. Personnel safety training, posted warning signs in controlled areas and the use of protective gloves, or prohibition to touch metal objects in RF fields, can assure compliance with limits or induced or contact currents through the body. Limits for partial body exposures are shown in Tables 2-1D and 2-2D.

e. The FAA adopts new criteria for pulsed RF fields which are shown in Tables 2-1C and 2-2C. C95.1 prescribes MPE's for pulsed RF sources for short-duration pulses (< 100 msec) in terms of peak pulse power: peak MPE = MPE x Average Time (sec)/5 x pulse width (sec). In the case of high power radars, time averaging due to pulse repetition rate and spatial averaging due to radar rotation greatly diminish radiation hazards. For multiple pulsed sources, it is the average radiated power, averaged both in time and spatially, which is used to estimate the MPE, rather than peak power.

f. In the case of multiple exposure sources (mixed or broad-band fields), each having a different MPE, the FAA shall adopt procedures for determining the fraction of MPE for each specific frequency interval, and ensure that the sum of all fractional MPE's shall not exceed 1. Figures 2-2A and 2-2B illustrate the concept. The same summation of fractional MPE's shall apply to induced currents due to multiple radiating RF sources.

Figure 2-2A. Determining Compliance in Multisignal Environment. Case No. 1

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              Figure 2-2B.  Determining Compliance
             in Multisignal Environment.  Case No. 2

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g. Safe distance estimates for radars and communication systems have been calculated based on uncontrolled environment MPE's (referred to as "General" in the table, and for controlled environment MPE's, and are found in Table 2-3. Please note that these values do not take into consideration averaging of MPE's when there is more than one radar/communication system at a site. When there is such "clustering" of systems at a site, a site-wide survey is indicated to assess safe exposure distances.

Table 2-3. "Safe Distance" Estimates for Radars and Communication Systems, Using ANSI/IEEE C95.1 Standards

1. PRIMARY RADARS

A. RADARS (En Route)

Radar Model	Average Power (kW)	Average Frequency (MHz)	MPE General (mW/cm^2)
ARSR-3	3.6	1250	1
ARSR-4	3.0	1215	1
AN/FPS-115	152	420	0.18
AN/FPS-118	933.3	5	0.2
AN/FPS-120	224	420	0.12
AN/FPS-20	4.95	1250	1
AN/FPS-6	3.6	2700	1.8
AN/FPS-124	0.59	1215	1
AN/FPS-117	3.7	1215	1

Radar Model	Safe Distance General (meters)	MPE Controlled Env. (mW/cm^2)	Safe Distance Controlled Env. (meters)

ARSR-3	284	4	142
ARSR-4	252	4	126
AN/FPS-115	6820	1.2	2641
AN/FPS-118	15312	1	6847
AN/FPS-120	12592	1.4	3678
AN/FPS-20	354	4	177
AN/FPS-6	336	9	150
AN/FPS-124	74	4	37
AN/FPS-117	530	4	265

B. RADARS (Terminal)

Radar Model	Average Power (kW)	Average Frequency (MHz)	MPE General (mW/cm^2)
ASR-3	3.65	1250	1
ASR-4	3.0	1215	1
ASR-7	0.4	2700	1.8
ASR-8	1.2	2700	1.8
ASR-9	1300	2700	1.8

Radar Model	Safe Distance General (meters)	MPE Controlled Env. (mW/cm^2)	Safe Distance Controlled Env. (meters)
ASR-3	286	4	143
ASR-4	252	4	126
ASR-7	67	9	30
ASR-8	105	9	49
ASR-9	124	9	56

C. RADARS (Weather)

Radar Model	Average Power	Average Frequency	MPE General

	(kW)	(MHz)	(mW/cm^2)
TDWR	.55	5600	6
WSR-88	1.7	2700	1.8

Radar Model	Safe Distance General (meters)	MPE Controlled Env. (mW/cm^2)	Safe Distance Controlled Env. (meters)
ASR-3	270	10	210
ASR-4	518	9	232

D. RADARS (Surface)

Radar Model	Average Power (kW)	Average Frequency (MHz)	MPE General (mW/cm^2)
ASDE-3	2×10^{-3}	15700	10

Radar Model	Safe Distance General (meters)	MPE Controlled Env. (mW/cm^2)	Safe Distance Controlled Env. (meters)
ASDE-3	6.6	10	6.6

2. NAVIGATION AND COMMUNICATION AIDS

Radar Model	Average Power (kW)	Average Frequency (MHz)	MPE General (mW/cm^2)
DME (en route)	1	960	0.6
DME (terminal)	0.1	960	0.6
VOR (en route)	0.2	108	0.2
VOR (terminal)	0.05	108	0.2
TACAN	5	960	0.6
MLS	0.02	5000	6

ILS	.015	328	.2
Mode S Beacon	1.0	1,030	1

Radar Model	Safe Distance General (meters)	Average Frequency (MHz)	MPE General (mW/cm^2)
DME (en route)	3.7	1.4	2.4
DME (terminal)	1.2	1.4	0.8
VOR (en route)	3	1.0	1.3
VOR (terminal)	1.5	1.0	0.65
TACAN	8	1.4	5.4
MLS	14.7	10	11.4
ILS	24.5	1.5	9
Mode S Beacon	68	4	34

h. Although these limits were selected with large safety factors so that no adverse effects are expected for repeated or continuous exposures over a workday, they are no substitute for proper work procedures and precautions, use of protection (shielding), engineering controls, and worker safety training. All are necessary to an effective Radiation Safety Program.

4. HAZARDS AND HEALTH EFFECTS.

a. The primary biological effect of exposure to RF and MW radiation is heating (thermal effects), although there are documented non-thermal effects, which are not accompanied by detected temperature rise, but can have observable bioeffects (e.g., hearing microwave clicks, or changes in chemical reaction rates for certain cellular processes) exist at selected frequency ranges, and might affect specific organs or biological functions. Thermal effects are potentially harmful for specific population segments deemed to be "sensitive" because of impaired ability to dissipate heat effectively.

b. Depending on the wavelength of radio-frequency radiation (RFR), electromagnetic energy can produce whole body heating (for wavelengths comparable to whole body size, in the so called "whole body resonance" range from 70 to 100 MHz for adults and to higher frequency ranges for children); or organ heating ("hot spots") or superficial skin heating for microwaves, which penetrate to lower "skin depth" in biological tissues. The depth of RF heating of human tissue varies with frequency and corresponding wavelength:

(1) Above 10 GHz (3 cm wavelength) mainly the skin surface is heated, with efficient superficial cooling via perspiration;

(2) From 3 GHz (10 cm wavelength) to 10 GHz deeper heating can occur as a result of energy absorption in tissues and organs, and the main heat dissipation mechanism is via the blood circulatory system;

(3) From 150 MHz (2 m wavelength) to 1.2 GHz (25 cm) organ level and whole body heating can occur, possibly affecting the function of heat-sensitive organs, such as testes and the eye.

c. Incompleteness of Information About Health Effects of NIR. The NIR bioeffects literature is often incomplete and merely suggestive of the potential for adverse health effects. Research gaps exist for certain frequency ranges, and for whole animal and humans at realistic exposure levels. In effect, there is very little information on chronic health effects due to cumulative exposure to very low environmental levels, or continuous long-term exposure to work levels of NIR. The current Standards do not address specific health effects purported for some ELF-modulated RF fields, pulsed Radio Frequency Radiation (RFR), and the so-called non-thermal effects associated with sub-thermal bioeffects, or with resonant "window" biological responses at specific frequencies and/or intensities of RFR. The IEEE/ANSI and the NCRP are currently engaged in reviewing the literature and considering specific safety limits for workers and the public for such RF exposures.

d. Potentially sensitive target-population segments that might require greater than normal protection from heating due to RFR/MW exposures include: people who cannot dissipate body heat well or are sensitive to additional heating (such as hypertensive patients, obese people, or pregnant women); people with metallic prosthetic implants (such as aneurism clips, metallic rods or plates, or copper IUD) that can be selectively heated by RF radiation; wearers of certain types of cardiac pacemakers that might be susceptible to electromagnetic interference (EMI) from external RF radiators. Certain types of hearing aids might also be EMI-susceptible and be impaired in an RF environment. Selected organs known to be heat sensitive (such as eye corneas or testes) might be unusually sensitive to RFR when unhealthy, as was documented for glaucoma patients treated with certain medication when exposed to MW radiation even below safety thresholds.

e. Thermal Hazards as Basis for MPE's.

(1) Existing NIR standards are based on the assumed heating of the human tissue and body (to various penetration depths, dependent on NIR frequency). Thermal coupling of NIR to biological tissue leads to a rise in the internal temperature level, which the body compensates for through increased circulation or perspiration to maintain basal temperatures. The

guides also are designed to prevent potentially unsafe induced body or limb currents, and/or contact currents that might cause "RF Burns" upon inadvertently touching ungrounded metal objects immersed in RF fields (primarily below 3 MHz).

(2) Time Averaging. Thermal effects are predicated on time averaging (typically over 6 to 30 min intervals) and spatial averaging (whole body or partial body in the near field of far field regions with respect to the radiating antenna) by the human body of the absorbed incident radiation (time needed to reach thermal equilibrium and respond by dissipating excess body heat). Therefore, the MPE limits are set to reflect power averaged over a time interval: this allows exposures to NIR at higher power levels for shorter duration, as long as the time averaged MPE is not exceeded for any 6 min period.

(3) Specific Absorption Rate (SAR). All standard setting organizations have based their RF/MW exposure safety criteria on an agreed upon threshold for potential harm of about 4 W/kg, average whole-body SAR. In the RF spectrum the SAR in W/kg is the quantity denoting energy absorbed by tissue (averaged spatially and over time), which can potentially lead to internal temperature rise. However, the SAR is difficult to measure and estimate, so that exposure limits are set on surface (or incident radiation) power density in free space, at locations normally occupied by people (workers or the public). The damage threshold of about 4 W/kg is decreased by "safety factors" of 10 to 50 (0.4 to .08 W/kg) for the range of occupational to public NIR exposure limits on SAR.

(4) To reflect the possibility of whole body heating, the MPE's are most conservative in the range of Very-High Frequency (VHF, 30 to 300 MHz). The whole body resonance for adults (where a standing adult is considered to act as a receiving antenna) occurs at frequencies between 60 to 80 MHz, while smaller children are considered more susceptible in the frequency range 90 to 100 MHz. In this "valley," protective Specific Absorption Rate (SAR) values are of order 0.2-1 mW/(cm squared). Figures 2-1A and 2-1B also show that the equivalent power density and electric/magnetic field strength MPEs for the ANSI/IEEE C95.1-1992 Standards for both controlled and uncontrolled environments are U-shaped, with minima in this range.

f. For further reading, recent excellent and comprehensive technical reviews of available biomedical research findings concerning potentially adverse effects of cellular, organ, animal and human exposure to RF/MW radiation include:

(1) The International Radiation Protection Association (IRPA) "Guidelines on Protection Against Non-Ionizing Radiation," 1991 Pergamon Press, Ch. 1, Guidelines on Protection Standards for Exposure to Non-Ionizing Radiation.

(2) The World Health Organization "Electromagnetic Fields (300 Hz to 300 GHz), Environmental Health Criteria 137," WHO-137, 1993.

(3) The National Council on Radiation Protection and Measurements (NCRP) Report 119, "A Practical Guide to the Determination of Human Exposure to Radiofrequency Fields," 1993.

(4) Handbook of Biological Effects of Electromagnetic Fields, edited by Ch. Polk and E. Postow (CRC press, 1995, 2nd Edition).

(5) "Radio Frequencies and ELF Electromagnetic Energies - A Handbook for Health Professionals", R. Timothy Hitchcock and R. M. Patterson (Van Nostrand Reinhold, 1995).

5. EVALUATION OF HAZARDS. In order to identify the presence and characterize the nature of any potential workplace hazard associated with excessive or lengthy personnel exposure to NIR, the following components of a Radiation Safety Program must be implemented:

a. Survey Procedures. A systematic survey of the NIR workplace environment, both for baseline of typical facilities and work practices, and by scheduling additional assessment surveys each time NIR sources are added or operating specifications are changed, will ensure compliance with the adopted NIR exposure safety standards.

(1) Standardized survey protocols shall be prepared by ASR and ANS engineers, in consultation with AEE. The procedures shall be used by them and by regional Frequency Management Officers (FMO's) to conduct periodic workplace NIR surveys. Initial, baseline, surveys will be conducted, and followed up with additional surveys when there are deviations from the baselined equipment as the facility is modified or modernized or added.

(2) Survey procedures shall be guided by the measurement and analysis protocols illustrated in NCRP Report 119, "A Practical Guide to the Determination of Human Exposure to Radiofrequency Fields", 1993.

(3) Such surveys shall include both broad band measurements (for multiple NIR sources) where fractional contributions to the NIR MPE's in the presence of multiple NIR sources can be assessed, and narrow band (for single or dominant source) specific to NIR radiator of concern.

(4) The following standards for safe NIR measurement procedures by qualified and trained personnel shall be observed.

(a) Measurement methods for RF and Microwave fields shall comply with the IEEE Standard C95.3-1991, "IEEE Recommended Practice for the Measurement of Potentially Hazardous Electromagnetic Fields - RF and Microwave", 1992. This companion standard to the C95.1-1991 NIR exposure safety standard is a valuable guide to both near-field and far-field Power Density (P sub D) or electric and magnetic field levels measurement, as well as offering practical guidance for instrumentation performance and calibration checks, and theoretical calculations for fields and induced body and contact currents to aid radiation hazard assessments.

(b) For assessing the NIR environmental contributions from FAA equipment which is an "unintentional radiator" and has RF noise, the FAA shall use ANSI C63.4-1992 "American National Standard for Methods of Measurement of Radio-Noise Emissions from Low Voltage Electrical and Electronic Equipment in the Range of 9 kHz to 40 GHz", 1992.

(5) When measuring radiated power density (P sub D) or RF fields in the main beam of a radar, the beam size, shape and character, and the "safe distance" and MPE should be determined prior to measurements to avoid excessive personnel exposure. All such measurements should be made in close coordination with operating personnel.

(6) All operating RF sources should be approached from a safe distance, and remote measurements (e.g., using probes connected by long fiber optic cables to the recording and analysis station) should be performed to the extent practical. For surveys of operating radars, the area between the feedhorn and the reflector should be considered hazardous and carefully avoided.

b. Equipment. Standardized equipment for assessing ambient NIR levels and personnel exposures (spatial and temporal averaging) and appropriate survey procedures (narrow band for single or dominant NIR source, and broad band surveys for multiple or clustered NIR sources) must be used.

(1) Standardized NIR monitoring equipment (e.g., threshold based alarm/alert time-integrating or time averaging device) shall be used to alert personnel of excessive potential personal exposure in a given work area. An inventory of measurement equipment available at FAA Headquarters and in the regional spectrum engineering offices shall be maintained by ASR and made available to qualified personnel for surveys periodically and on request.

(2) Mobile laboratory equipment shall include both Power Density Devices and Field Intensity Devices, approved by ASR, and calibrated annually. In addition to traditional surveys, new measurement equipment and methods required by C95.1 and C95.3 involve induced body currents and contact current meters. Survey personnel shall be trained and certified in proper measurement, data analysis, and reporting procedures.

(3) The equipment shall consist of both narrow band antennae analyzers, and broad band (integrating) devices. Personal exposure monitors capable of alarm/alert upon exceeding safe NIR exposure (time averaged and broad-band) MPE limits, as well as area monitoring equipment (time and frequency-averaging) with alarm/alert capabilities shall be made available on request for suspected radiation hazard.

c. Documentation, Reporting, and Archiving NIR Data. Standardized measurement, analysis, and reporting of NIR fields and power levels, as well as estimated or measured RF induced body and contact currents shall be archived to compare findings with applicable MPE. NIR and other radiation emission or exposure limits data shall be entered in a standardized database (sorted by: facility, equipment, frequency, power level, and distance from the radiating source). ASR shall maintain a central repository of all such FAA radiation environmental survey data, and the regional FMO's shall archive NIR surveys results for FAA facilities and/or workplaces in their region.

6. PREVENTION AND CONTROL OF NIR EXPOSURE HAZARDS. Across the NIR spectrum, the number of sources, their intensity and frequency, the antenna radiating pattern, the location and duration of exposure, and other spatial and temporal characteristics of exposure must be taken into consideration in order to assess exposure, prevent, and control hazards. The basic methods of controlling, preventing, and minimizing personnel exposure to NIR in the FAA workplace are:

a. Limit Exposure Time. Although the potential health effects of NIR exposure are not considered to be cumulative, the recommended standards are based on time averaged incident power density (ranging from 6 minutes for RFR down to 10 sec for high frequency MW radiation). The time averaging is designed to limit the SAR to safe levels adopted by ANSI/IEEE. Therefore, it is good safety practice to limit personnel exposure times for a known harsher NIR environment, such as those expected for maintaining and testing a radar.

b. Increase Distance from NIR Radiating Sources. Since the power density in the beam of a NIR radiator decreases with the inverse squared distance from the antenna in the far field, and linearly with distance in the near field, the calculated "safe distances" (or, more exactly, hazard distances) from NIR sources listed in Table 2-3, based on the ANSI/IEEE C95.1 Standard, shall be observed if applicable. Estimated "safe distances" imply that the radar beam, if intersecting the ground or the target, might lead to exposure at the recommended limits. However, most radar sources are positioned on high towers and the beam has positive elevation (upwards tilt), so that the beam does not intercept human targets (with rare exceptions, such as an unauthorized tall office building erected in the vicinity.) The "uncontrolled safe distances" listed in Table 2-3 apply to all FAA personnel and contractors, as well as visitors, members of the public on the premises of FAA property, and FAA office workers. For comparison are listed the "controlled" safe distances, which would apply to military personnel on shared FAA/DOD facilities.

c. Use of Shielding Materials.

(1) RF radiation can be reflected, refracted, scattered, and absorbed. In most systems, the materials designed to enclose and direct NIR beams also provide protective shielding (e.g., radars waveguides, and metal cabinets). In some cases, metal surfaces reflect and thereby enhance radiation to which workers

are exposed. In most cases, concrete, glass, and fencing can provide attenuation to safe NIR levels, as needed.

(2) Table 2-4 shows the attenuation efficiency of known construction and building materials. In special cases, protective gloves or clothing might be necessary to protect from shock and RF burns personnel working in a radiation field likely to exceed prescribed MPE's (e.g., if work on a new radar proceeds in the vicinity of an older operating radar, and workers touch ungrounded metal ladders). In rare instances, primarily to prevent electromagnetic interference (EMI) with the operation of sensitive electronic systems, rather than for personnel protection, special shielding materials to attenuate incident RF and MW radiation can be selected.

Table 2-4. Attenuation of RF/Microwave Radiation Provided by Various Types of Shielding Materials (decibels, dB)

MATERIAL\\Frequency (GHz)	1 - 3	3 - 5	5 - 7	7 - 10
60 x 60 mesh screening	20	25	22	20
32 x 32 mesh screening	18	22	22	18
1/4" mesh (hardware cloth)	18	15	12	10
window glass	2	2	3	3.5
3/4" pine sheeting	2	2	2	3.5
8" concrete blocks	20	22	26	30

d. Warning Signs.

(1) RF radiation warning signs shall be posted at the entry to the antenna deck of each long range and short range radar. This is a precautionary measure in addition to the safety interlocks, which cut off power to the radar upon entry, to remind FAA personnel and contractors that the MPE for RF radiation can be exceeded in the vicinity of the radiating antenna. It does not mean that entry to the antenna deck will result in excessive NIR exposures, but rather that RF energy in this area is not as confined as in other parts of the radar system and that proper precautions by trained personnel should be observed.

(2) Warning signs may also be placed as necessary to mark the boundaries of "controlled areas" (as defined in the C95.1 Standard), in special cases when NIR levels from a single or multiple sources might exceed the MPE's for uncontrolled environments in Table 2-1. Also, the estimated "safe distances" in Table 2-3, based on MPE's listed in Tables 2-1 and 2-2, may be

used to guide the placement of warning signs to restrict access by visitors, members of the public, or unauthorized personnel to FAA facilities co-located with high power radar or multiple, clustered NIR radiators.

e. Safety Training. In view of limited knowledge on specific thresholds for biological effects of RF/MW exposure in the workplace, radiation hazard safety training is required for environmental/electronic maintenance workers; technical, scientific, and academic personnel; and for safety and health personnel. Specialized training is also required for all radiation hazard measurement personnel. Non-technical personnel, such as office workers and authorized visitors, may be provided informational materials which advise prudent avoidance strategies. Training strategies should be tailored to the need-to-know level of the employee category identified in Chapter 1, Table 1.

f. Proper Work Procedures. Observing proper operating procedures for equipment operation, testing, repair and maintenance are essential to preventing unnecessary and potentially hazardous NIR exposures in the workplace. For instance, although safety interlocks and radar tube shielding and warning signs are usually provided, maintenance and test workers may improperly bypass or ignore the safety interlocks.

g. Proper Installation. Proper grounding of susceptible metal structures, combined with insulating gloves for workers in the presence of operating radar transmitters or communication transceivers can prevent contact currents and "RF burns."

h. Temperature Control. To limit thermal effects in workers exposed to NIR, the ambient temperature contributions must be considered. Cool temperatures and dry air in the workplace can aid the thermal regulation of body temperature through thermal dissipation by transpiration and evaporation.

i. Environmental NIR Surveys. Since radiated power is proportional to squared electric and magnetic field strengths, field measurements shall be made periodically, when the operating parameters of radars have been changed, or when new equipment is installed, to confirm compliance with recommended NIR safety guidelines. For exposure from multiple sources, the exposure (power density of field squared) should be measured at each source frequency and divided by the corresponding MPE to obtain the fractional contribution from each NIR source. The basic limit is that the sum of fractional MPE's for the multiple sources should not exceed unity.

7. FAA SOURCES OF NIR.

a. Radar Systems.

(1) The sources of greatest concern for non-ionizing radiation hazard (radhaz) assessment and prevention are the high power, ground-based primary radars providing aircraft surveillance for Air Traffic Control (ATC) and weather

information within the National Air Space (NAS). Examples of these radars include:

(a) In the current architecture, primary high-power radars transmit pulses of electromagnetic energy, which are reflected by target aircraft ("skin tracking"). En-route surveillance uses the primary Air Route Surveillance Radars (ARSR), which transmit at 1.2 - 1.4 GHz over a range of 200 - 250 nmi. They have large antennae, rotating once every 10 - 14 sec. Primary radars, like the ARSR-1, -2, -3 and -4, have some weather detection capability, as well as aircraft target detection.

(b) Secondary surveillance radars (SSR), or beacon radars, transmit a pulse pair signal at 1.03 GHz to aircraft, whose transponder responds at 1.09 GHz with identification, altitude, and speed information. Secondary radars (such as the Mode-S transponder or interrogator) are normally collocated with primary ARSR radars, but a few sites (such as the Air Traffic Control Beacon Interrogator, ATCBI-3, 4 and -5 series) are beacon-only.

(c) Terminal area surveillance is provided by lower power, shorter range (60 nmi) airport surveillance radars (ASR) which transmit at 2.7 - 2.9 GHz. To track departing and approaching aircraft traffic, the ASR's rotate faster, once every 4 - 5 sec. ASR-4, -5, -6, -7, -8 and -9 units are now operating, but -4 through -6 series are being phased out, and a new ASR-11 with integrated monopulse secondary surveillance radar (MSSR) is now in development. A beacon SSR radar (series ATCBI-3, -4, -5 or Mode S) is collocated with each ASR.

(d) At larger airports, surface traffic surveillance is performed by a short range primary radar, the airport surface detection radars (ASDE). The ASDE-3, is the latest now deployed at about 25 busy hub airports. In addition, various weather radars, like the Terminal Doppler Weather Radar (TDWR), the Low Level Wind Shear Alert System (LLWAS), and the higher power next generation weather radar (NEXRAD or WSR-88D) systems are installed to detect and delineate hazardous weather conditions.

(e) Some weather radars, like the NEXRAD (or weather surveillance radar WSR-88D) and the Terminal Doppler Weather Radar (TDWR), scan and then dwell on regions of space in the "searchlight mode" at low angles, where bad weather features require resolution. For such radars, the dwell time of the beam at any one field of view (FOV is several degrees wide) is limited to 5 min, to meet the time averaging required by C95.1. Similarly, the NEXRAD average power at 2.7-3 GHz will not exceed .005 mW/(cm squared) at ground level and a maximum of 0.6 mW/(cm squared) at the radome, in compliance with C95.1 guidelines (see "Supplemental Environmental Assessment, SEA of the Effects of Electromagnetic Radiation from the WSR-88D Radar", April 1993).

(2) "Safe Distance" Estimates (SDE's).

(a) Background. The preceding order, FAA 3910.3A, estimated the safe distances (also called "keep-out" or "hazard distances" in the literature) based on power levels measured in the beam under worst case exposure conditions, with the radar beam stopped and the measurement device within the full beam. These "worst case" exposure estimates with stopped beam at peak power were unnecessarily conservative, and ignored power averaging for a rotating radar and with short on cycles (Pulse Repetition Rate, PRR). FAA now adopts the C95.1 and its companion ANSI/IEEE Standard C95.3-1991, "IEEE Recommended Practice for the Measurement of Potentially Hazardous Electromagnetic Fields - RF and Microwave" (August 21, 1992). These standards set both safe exposure limits and prescribe the proper measurement procedures for time and spatial consideration of radiated power, and for potential contact and induced body currents.

(b) Parameters For Calculating SDE's. The following parameters are used along with the allowable power density, "P sub D" from the ANSI/IEEE Tables 2-1 and 2-2 (where it's denoted by S, for Poynting Vector) to derive the SDE's.

1. Average power transmitted. In case average power is not directly available, peak power, pulsed beam width and pulse repetition frequency (PRF), may be collected;

2. Frequency, or if several frequencies are allotted to a radar, the lowest frequency (longest wavelength) must be used for safe distance, as it gives the lowest MPE;

3. Antenna gain: If antenna gain is not readily available it can be approximated by 32,400 divided by Azimuth beam width in degrees and elevation beam width in degrees;

4. Elevation beam width in degrees, and Azimuth beam width in degrees, Antenna dimensions in meters;

5. Tower height in meters;

6. Configuration of various kinds of radars and/or telecommunication equipment, capable of potentially unsafe radiation exposures including NIR at the site under investigation.

(c) The power density "P sub D" in mW/(cm squared) is calculated by employing

$$P_D = \frac{P_{T_{AVG}} \cdot G}{40 (\pi) \cdot d^2}$$

where P_T is the Average power transmitted

G_{AVG} is the Antenna Gain

d is the distance, in meters, at which calculations are being made. When P sub D from the MPE tables is used, then "d" becomes the estimate for safe distance.

The Antenna Gain can be approximated by $G = \dfrac{32,400}{B_{1d} \cdot B_{2d}}$

where B_{1d} is the Azimuth beam width in degrees

B_{2d} is the Elevation beam width in degrees.

Note: B_{1d}, B_{2d} are essential for ground/lobe patterns.

(d) Tower height is essential for assessing whether the nearby targets can be - intersected by the radar beam, and determining "blanking" angle needed

(e) The dimensions of antenna are essential, as (D squared)/(lambda) is the transition between the far field and near field calculations, where D is the largest dimension of the antenna in meters and lambda is the wavelength in meters. The longest lambda is taken for conservatism in estimation of "safe distance" corresponding to the lowest MPE in the chosen NIR exposure safety Standards, if the radar is operational at several different frequencies.

(f) The configuration is important because average power will be summed up from all the different radars and/or telecommunication antennae or beacons equipment (see Figures 2-2A and 2-2B for examples of summation needed to assess exposure safety in a multisource environment).

(g) Several beams maybe transmitted from a radar, but generally they do not get activated simultaneously. In this case, only the worst case scenario, i.e., lowest frequency and longest wavelength, is needed for safe distance calculations.

(3) Safety Interlocks. There is a built-in "safety interlock" feature provided for many rotating beam radars: as it stops rotating, it ceases transmitting, too. In view of this, "worst case" radhaz exposure measurements would require stopping the radar rotation and potentially risking exposure of personnel in the stationary beam, a situation now achievable only through manual override of the safety feature.

b. Navigation Aids (NAVAIDS): VORTAC and TACAN.

(1) Specifications for VOR/DME and TACAN. The Government (FAA, USCG, and DOD) operates radionavigation systems which meet most of the current and projected civil user requirements for safety of navigation, economic efficiency, and

positioning and time applications. These systems are adequate for the general navigation of civilian private and commercial aircraft, and of military aircraft as well. NIR emissions and exposure safety from the Very High Frequency Omnidirectional Range (VOR)/Distance Measuring Equipment (DME) and Tactical Air Navigation (TACAN) are considered below. Safe distances for the ground transmitters have been calculated, and are tabulated in section 3, "Navigation and Communication Aids," of Table 2-3.

(a) The VOR was developed as a Very High Frequency (VHF) radio ranging navigation aid to provide a bearing from any aircraft to the VOR transmitter. A collocated DME provides the distance from the aircraft to the DME transmitter. At most sites, the DME function is provided by the TACAN system, which also provides azimuth guidance to military users. Such combined facilities are called VORTAC stations.

(b) VOR's are assigned frequencies in the range 108 to 119 MHz, with 100 kHz separation between bands, and an ELF signal modulation at 30 Hz (the signal is quite complex with a frequency modulated reference phase and an amplitude modulated variable phase). The en route transmitter stations radiate approximately 200 watts average power, whereas terminal VOR's are rated at approximately 50 watts. Assuming the "worst case" zero dB gain, and MPE's of 0.2 mW/(cm squared) for uncontrolled exposures, the safe distances are: 3 meters for en route VOR, and 1 meter for terminal VOR. Based on earlier FAA measurements of power density for a transmitting VOR with the TACAN off, it was concluded that a potential hazard for NIR exposure existed only at the surface of the conical tower covering the rotating antenna.

(c) The TACAN is a shorter range Ultra-High Frequency (UHF) radionavigation system, which provides range and azimuth information. Because of propagation characteristics and radiated power, a TACAN is limited to line-of-sight use up to 180 miles range at higher altitudes. It transmits in one of two frequency bands: 962 to 1024, or 1151 to 1215 MHz. Its power output is higher, at 5 kW peak and 130 W average. Based on earlier FAA NIR survey data at 5 and 20 cm from the radome, it was concluded that a potential NIR hazards existed only at the radome surface. Again, assuming the "worst case" TACAN gain of zero dB and an MPE of 0.6 mW/(cm squared) based on the newer ANSI/IEEE standard (for uncontrolled environments), the calculated safe distance turns out to be 12 meters.

(d) A VOR/DME currently provides users with the primary means of air navigation in the National Air Space (NAS). The VOR/DME is in force through 1997, according to the joint FAA and International Civil Aviation Organization (ICAO) plans. Its phaseout will be completed by 2010. The DOD requirements for and use of VOR/DME will terminate when aircraft avionics are properly integrated with the more accurate navigation and positioning capability of the 24 satellites in the Global Positioning System (GPS) and when GPS is certified by the DOD to meet Required Navigation Performance (RNP) for national and international air space by year 2000. In order to satisfy the RNP criteria, the

TACAN will continue beyond 2005, when it, too, will be replaced by GPS in air space.

(2) Hazards and Safe Distances. According to the 1994 Federal Radionavigation Plan, DME's operate at 960 to 1213 MHz (with 1 MHz bands separation and paired pulsed signals). En route DME's radiate 1 kW average power, whereas terminal DME's radiate 100 Watts. Since these are omnidirectional transmitters, they exhibit zero dB gain. Since the MPE from the C95.1 Standard for uncontrolled environments is 0.6 mW/(cm squared) at its worst, the most conservative (lowest frequency and longest wavelength) safe distances are 3.7 meters for en route, and 1.2 meters for terminals DME's.

(3) Procedural Controls. FAA personnel practices require that they avoid unnecessary exposure and direct contact with TACAN radome surface and proximity to the VOR conical tower and transmitting antenna during maintenance work.

c. Communication Systems.

(1) Specifications. The FAA is currently modernizing the ground to air and ground to ground voice communications systems to include data links. The Aeronautical Telecommunications Network (ATN) partnership announced in 1995 that there will be an interconnected worldwide system combining satellite communication technology with ground-based distribution of data and voice messaging. This will replace the current VHF and UHF voice and data transmission aeronautical telecommunications network. Recent installations include:

(a) The Voice Switching Communications System (VSCS), which was recently commissioned at the first 3 (e.g., in Longmont, CO, Seattle, and Salt Lake City) of FAA's 21 Air Route Traffic Control Centers (ARTCC), with the rest of the ground installations to become operational by February, 1997. It uses fiber optic and digital technology for high speed message transfer to allow air traffic controllers and pilots to communicate faster and clearer by using menu-driven touch-activated computer screens to direct their calls and to automatically route voice communications from pilots to the correct air traffic controller.

(b) The Enhanced Terminal Voice Switch (ETVS) will provide to 336 FAA and DOD tower and terminal facilities the same benefit as the VSCS for ARTCC, using state-of-the-art, off-the-shelf components.

(c) Integrated Communications Switching System (ICSS), will combine navigation and weather information with communications and control capabilities in one console.

(d) The Advanced Oceanic Automation System (AOAS) will include a broad range of digital datalink services and use the Automated Dependent Surveillance (ADS), a satellite-based tracking system to provide controllers with precise position information of aircraft over the oceans. The ADS will use data links for transmission at 35 and 94 GHz, but NIR emissions depend on specific design and operational parameters.

(e) The Flight Data Input/Output (FDIO) System, which dates back to the 1960's, will be replaced by the enhanced oceanic sector workstations Oceanic Data Link (ODL), such as those recently installed at the Oakland and the New York ARTCC. This system will use two-way satellite connection for pilot to controller communication.

(f) New Generation Data Display Equipment.

1. Advanced Automation System (AAS) consoles and data processors, such as the new air traffic control computers called Display Channel Complex Rehost (DCCR). These integrated computer, communication, and display systems include various types of cathode ray tubes (CRT) used as display monitors, such as the Plan View Display (PVD), the Radar Bright Display (RDBE) and Plan Position Indicators (PPI) radarscopes, all of which are similar to any TV or computer Video Display Terminals (VDT's) commonly used as office equipment.

2. Although this equipment is too new to have been surveyed specifically for NIR emissions, OSHA and NIOSH have performed health studies concerning VDT use in the workplace and published a bibliography in 1991 (NTIS #PB92-109230). The weak RF associated with VDT's is in the 15-250 kHz range, and maximum operator exposures from such terminals were measured and found to be more than a factor of 5 below C95.1 MPE's.

(g) Automated Radar Terminal Stations (ARTS II and III) equipment and consist of advanced versions of workstations, display consoles and communication links for the nation's 70 terminal radar control facilities (TRACONs).

(h) The planned GPS-based Wide Area Augmentation System (WAAS) ground installations are in the planning, test, and evaluation stages. Frequencies for the GPS downlink and uplink are around the 1.5 GHz, but the WAAS bands are around 6 GHz. Specifics on power and antenna aperture and gain are needed to estimate safe distances. Environmental Assessments for the FAA WAAS network, and the USCG complementary coastal installations, will consider potential NIR issues and minimize radhaz impacts on the public and on workers.

(i) Currently, all voice communications for Air Traffic Control (ATC) utilize AM in these bands: 118.0 to 135.975 MHz; 225.0 to 328.699 MHz; and 334.4 to 400.0 MHz.

(j) Ground transmitter power is normally at one of three levels 10, 20 or 50 watts. The higher power is normally used only for difficult terrain. UHF coverage is less than VHF, even for the same power. Aircraft transmitter powers differ between aircraft. For practical purposes, however, all aircraft are assumed to have the same output Effective Isotropic Radiated Power (EIRP) as a low ground transmitter with feedline losses. Other communication systems, such as the NARACS (National Radio

Communication System) installed for emergency communications, operate in the HF band (at 4, 8 and 19.4 MHz) with proper siting safeguards to avoid NIR exposures.

(k) Most of the communication equipment complies with the limits for a Class A digital devices, pursuant to Part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. The equipment, however, could radiate RFR if not installed properly.

(2) Safe Distances. Since "worst case" MPE for communication devices, such as the VSCS, is 0.2 mW/(cm squared), according to the C95.1 MPE table for uncontrolled environments, a safe distance of 2 meters can be calculated for an assumed 50 Watts of transmitted power with gain of zero dB. However, most of the devices that have been investigated, power has been found to be below 3 Watts, and the corresponding safe distance for exposure is thus only half a meter. The assumption is made here that all FAA communication equipment are unintentional NIR radiators but, in reality, the equipment's housing, which protects it from electromagnetic interference (EMI), also limits its radiated emissions. Anti-interference housings, casings, and covers are normally provided by manufacturers for communication equipment. If these are not tampered with, and proper installation and operation, or maintenance procedures, are followed, then communication equipment should not radiate any appreciable power, and should be safe for operators and fellow workers.

(3) Procedural Controls. It is desirable to avoid direct contact with UHF and VHF transmitting antennas that operate at high power levels, and with metallic ungrounded objects (cars, or vehicles parked nearby) that might cause RF shock due to discharging through limbs upon touching. To avoid unnecessary exposure to RFR, it recommended that maintenance or other work on/near transmitters be performed only when they have been turned off.

c. Other sources of NIR.

(1) Microwave landing systems (MLS). The MLS provides a common civil/military landing system to meet the full range of user operational requirements as specified by ICAO for precision approach and landing system for the year 2000 and beyond. However, differential GPS (DGPS) systems are now envisioned to satisfy the majority of requirements originally envisioned for MLS. 29 "Category 1" MLS are currently installed or planned for near-term installation for precision approach and landing. The FAA has already terminated all R, E & D activity associated with MLS and allowed limited deployment in support of international operations

(a) Specifications.

1. The MLS signal is transmitted throughout a large volume of air space, thereby providing service to multiple

aircraft along multiple approach paths, during approach, flare, touch down, and roll out maneuvers. The system permits greater flexibility in air traffic procedures, enhancing safety, and permits curved and segmented approach paths for purposes of noise abatement. MLS allows steep glide path approaches for airports in mountainous terrain, and facilities short field operations for short and/or vertical and landing (STOL and VTOL) aircraft.

2. MLS transmits signals that enable airborne units to determine the precise azimuth angle, elevation angle, and range. The technique chosen for the angle function of the MLS is based upon Time-Referenced Scanning Beams (TRSB). All angle functions of the MLS operate in the 5 to 5.25 GHz band. For the existing systems, a special Super-High Frequency (SHF) option at 15.4-15.7 GHz is included, while ranging is provided by DME operating in the .96-1.215 GHz band.

(b) Safe Distances. The MLS transmits in the GHz microwave range where there is a flat MPE of about 1 mW/(cm squared), according to the C95.1 Standard for uncontrolled environments. The average power is 20 Watts, and the azimuth angle and elevation angle are 2 degrees each. Therefore, the estimated gain is 8,100 or 39 dB and the calculated safe distance is 14.7 meters for uncontrolled environments. Since the MLS system ground installation are on or near airport runways, it does not pose NIR safety hazards to workers or the public.

(c) Procedural Controls. In order to avoid unnecessary NIR exposures from MLS, personnel must avoid direct contact with antenna apertures of transmitting MLS equipment, and to work on such equipment only when it is turned off.

(2) Instrument Landing Systems (ILS).

(a) Specifications. The ILS is the current ICAO primary precision landing system worldwide, and is expected to stay operational until 2005 for "Category 2 and 3" landing. The ILS consists of a glide-slope beam and a localizer beam installed on the runways. The glide slope beacon provides vertical steering signals for landing on the front course of the runway, while the localizer beacon provides lateral steering signals for front course and back course approaches to the runway. Two or three marker beacons at 75 MHz provide spot checks of position along the glide path (at 4.5 mi range, at the 200 ft altitude "Category 1" decision height, and at the 100 ft altitude "Category 2" decision height along the front course). Each beacon radiates as a fan-shaped vertical beam which is 40 degrees wide along the glide path, by 85 degrees wide perpendicular to it. The localizer facility and antenna are typically located about 1000 ft of each runway and provides a UHF 328-335.4 MHz signal. Two 75 MHz marker beacons at 3500 ft and 7000 ft from the runway approach are also part of the ILS glide slope facility, and provide a UHF (328.6-335.4 MHz) signal.

(b) Safe Distances. Safe distance calculations were made based on power transmitted of 15 Watt, with an antenna gain of 20 dB, combined with limits listed in Tables 2-1 and

2-2. Safe distance estimates are 24.5 m for an uncontrolled environment MPE of 0.2 mW/(cm squared), and 9 m for controlled environments with an MPE of 1.5 mW/(cm squared).

(3) Mode S Beacon. The Mode S Beacon is a secondary surveillance radar (SSR) or beacon deployed in the 90's, collocated with and chin-mounted on the same revolving shaft above the antenna of en route primary radars like ARSR-4. Mode S operates at 830 MHz and 1090 MHz as a ground-air-ground data link system capable of providing aircraft surveillance and communication necessary to support ATC automation in a dense traffic environment. Mode S uses common channel interrogation integrated with current Air Traffic Control Radar Beacon System (ATCBS). Safe distance estimated based on a nominal power of 1 kW for the transmission frequency (1030 MHz), with an antenna gain of 27.5 dB, is 68 m for the uncontrolled environment MPE of 1 mW/(cm squared) and 34 m for the corresponding occupational controlled environment MPE of 4 mW/(cm squared) (see section 3 of Table 2-3).

APPENDIX 3. SAFETY GUIDELINES FOR POWER FREQUENCY ELECTRIC AND MAGNETIC FIELDS (EMF) AND STATIC FIELDS

1. PURPOSE. This appendix to FAA Order 3910.3B recommends guidelines for protection from power frequency electric and magnetic fields, as well as static electric and magnetic fields. These guidelines are voluntary, but should be useful in view of the great deal of employee interest that has been generated in recent years.

2. POWER FREQUENCY ELECTRIC AND MAGNETIC FIELDS (EMF).

a. General Background. An emerging safety, environmental and health issue of current research interest is the potential for adverse health effects from exposure to electric and magnetic fields (EMF). Of special concern to the public and to Congress are magnetic fields at extremely low frequency (ELF), in the spectral range of 3 to 3000 Hz, which includes the electrical power grid frequency (PF) to 60 Hz, and its harmonics.

(1) Current Research.

(a) Numerous recent studies, press articles, and TV programs have publicized suggestive, but so far inconclusive and mutually inconsistent evidence for possible association of exposure to EMF at or near power line frequencies and various adverse health impacts, including cancers and reproductive effects. Epidemiological studies of residential and occupational exposures to EMF, and laboratory studies on humans, animals and cells, carried out for a wide range of EMF exposure conditions, have yet to agree on a reproducible and validated causal mechanism for adverse bioeffects from chronic exposure to weak environmental EMF.

(b) Although some EMF bioeffects are recognized, there is no proven mechanism for causal linkage of EMF exposures to specific adverse health end effects. Also, the EMF characteristics that are bioactive have not yet been identified, nor have the "dose" metrics and "dose response" required for health risk assessment been established.

(c) Research findings on bio-effects of EMF to date, albeit controversial, have focused considerable public and governmental attention on the need for more research to resolve uncertainties, and for coordinated policies, pre-regulatory actions and communications on this issue. The present state of scientific knowledge is still too rudimentary to serve as a basis for regulations or guidelines limiting EMF emissions and exposures for the public and for workers. The Council on Scientific Affairs of the American Medical Association (AMA) issued a report in 1994 on "Effects of Electric and Magnetic Fields", which reviewed published research on EMF health effects and concluded:

"Most studies of magnetic field effects in children, workers and other populations do not meet accepted scientific criteria in terms of measuring past exposure, identifying comparable test and control groups, and accounting for potentially confounding factors. Findings of studies are inconsistent in terms of whether a risk exists, what conditions might be related to exposures, and risk magnitude. Positive studies indicate, for the most part, that the associated relative risks are low."

(d) The DOE, as the lead agency of an Interagency EMF Working Group (on which DOT/FRA was represented) has prepared a "National Strategic EMF Research Plan". The 1992 Energy Policy Act (EPACT) Section 2118 mandated that the DOE and the HHS' National Institute of Environmental Health Science (NIEHS) lead a coordinated $65M, five-year public-private cost-shared national EMF Research and Public Information Dissemination (RAPID) program. The DOT, based on the FRA R & D program on EMF assessment and health effects, is a designated participating member of the EMF Interagency Committee (IAC), which guides the RAPID planning and review efforts. Currently, the RAPID National EMF R & D program is developing standardized EMF measurement and environmental or personal exposure characterization and quantification guidelines and protocols.

(2) Status of Regulatory Rulemaking.

(a) The Committee on Interagency Radiation Research and Policy Coordination (CIRRPC) convened by OSTP included representatives from EPA, DOE, FDA, DOA, OSHA/DOL, DOD, as well as DOT/RSPA. Its Science subpanel on health effects of EMF has reviewed the current state of knowledge, to determine if regulatory actions are warranted. CIRRPC sponsored a review of EMF-related health effects, which concluded that no definite linkage of EMF with cancers and other adverse health outcomes has been proven in its report, "Health Effects of Low Frequency Electric and Magnetic Fields", 1992.

(b) The National Institute for Occupational Safety and Health (NIOSH), the research arm for the Occupational Safety and Health Administration (OSHA), convened a 1991 workshop to define a National Research Agenda on EMF effects in the workplace. NIOSH has developed a draft protocol for EMF workplace surveys, but did not publish it as yet and is currently pilot testing it in industrial work environments. NIOSH did not recommend to OSHA (as of January 1996) adoption of any interim EMF exposure standards or guidelines for workplace enforcement, since research has not yet resolved the issues of EMF dose and dose-response, nor the potentially hazardous aspects of EMF.

(3) Interim Guidelines for Workplace and Public Exposure. At present, given the uncertainties regarding potentially adverse health effects and the lack of an accepted dose metric and threshold for bioeffectiveness, there are no federal standards and guidelines for EMF exposure in the workplace or in specific environments. Indeed, the EMF typical of various work environments and numerous sources is just being characterized under the RAPID program, using common survey protocols, in order to assemble a consistent data base.

(a) International Standards and Guidelines.

1. Several countries and the European Community (EC) have adopted public and occupational exposure interim limits to 50/60 Hz EMF. The World Health Organization and the International Radiation Protection Association (IRPA) International Non-Ionizing Radiation Committee (INIRC) published the "Interim ELF/EMF Exposure Guidelines" in 1990, listed in Table 3-2. In 1994, after reviewing the literature on health effects - EMF links, the IRPA ruled that there was no reason to update and revise the guidelines. (Source: Health Physics 58: 113-122).

2. The IRPA/INIRC guidelines are based on well established bioeffects, such as nerve stimulation, or induced body and limbs currents, and are much higher than EMF levels typical of occupational and residential environments. The special provision for short term exposure to electric field is that the product of the Electric Field Strength times exposure time should not exceed 80 over a whole working day. Similarly, whole body exposure to alternating current (A/C) magnetic fields (up to 2 hours a day) should not exceed 50 Gauss. For comparison, the earth's steady or DC field is of order 0.5 Gauss. The 1 Gauss limit is adopted as a prudent limit for pacemaker wearers, to avoid potential electromagnetic interference (EMI).

3. In January 1995, the European Committee for Electrotechnical Standardization (CENELEC) adopted a European prestandard (ENV 50166-1, "Human Exposure to Electromagnetic Fields, Low-Frequency, 0-10 kHz"), and recommended methods for checking compliance with field limits and for controlling exposure. These limits are given as induced current density (in mA/(m squared), RMS) by frequency range, as well as limiting direct contact currents for workers and the public. Reference levels (to ensure compliance with induced current limits) are: (1) 30 kV/m for electric fields at 50-60 Hz for workers (10 kV/m for the general public); and (2) 16G for magnetic fields for workers (6.4 Gauss for the general public), with about 10 times higher values allowed for limbs.

4. The Swedish trade associations and workers unions have recently recommended the most restrictive, but voluntary for industry, guidelines for EMF (magnetic fields of order 2 mG and electric fields of about 10 V/m) produced by computer system modules and keyboards, as measured just in front of display screens. However, ergonomics, visual quality and other factors are considered more important than EMF for worker safety in Sweden. The rest of the world has not endorsed, nor adopted these voluntary industry guidelines.

(b) U.S. Voluntary Standards and Guidelines.

1. The American Conference of Governmental Industrial Hygienists (ACGIH) has also set voluntary occupational standards for EMF, which are reviewed annually. The 1995-96 Threshold Limit Values (TLV) for Sub Radio Frequency (30 KHz and below) Magnetic and Electric Fields are given in Table 3-1. The ACGIH also recommends the use of protective wear or devices (e.g., suits, gloves, insulation) for workers exposed to electric fields in excess of 25 kV/m, to avoid contact discharge currents.

Table 3-1. ACGIH 1995-96 Threshold Limit Values for Subradiofrequency (30 KHZ and Below) Magnetic and Electrical Fields

Occupational Exposure (60 Hz) TLV	Electric Field (kV/m)	Magnetic Field (Gauss)
Whole working day,	25 (DC to 100 Hz)	10
For workers with cardiac pacemakers	< = 1	< = 1
For 300 Hz-30 kHz partial and whole body	2.5/f (f in kHz), for 100 Hz-4 kHz .625 for 4-30 kHz	< = 2 (or 160 A/m) 600/f (x 5 for arms and legs) (x 10 for hands and feet)

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2. In the absence of U.S. federal guidelines for power frequency EMF, six states have issued their own regulations limiting electric and magnetic fields for electric power transmission lines at the edge of right-of-way. All of these guidelines are based on maintaining existing environmental levels of EMF due to transmission and distribution (T & D) power lines, and power companies strive not to exceed them when designing and erecting new power lines. The most restrictive state guidelines are in Florida, where electric fields are limited to 2 kV/m at the edge of right-of-way, and corresponding magnetic fields to 150-200 mGauss.

(3) Public Sources of Information.

(a) The RAPID program has produced an EMF public information booklet ("Questions and Answers about Electric and Magnetic Fields Associated with the Use of Electric Power", January 1995), which lists up-to-date research results and related EMF resources. NIOSH, NIEHS, and DOE have prepared a draft brochure, "EMF In the Workplace - Questions and Answers" (1996), summarizing the state of knowledge and EMF levels in typical work environments.

(b) In addition public information hotlines have been established by RAPID to answer specific EMF questions:

1. The EMF Infoline at EPA is 1-800-363-2383 (or 484-1803 in Washington, DC) responds to questions regarding state of science;
2. Questions about EMF exposures in the workplace are answered by NIOSH at 1-800-356-4674;

3. Environmental health and safety questions can be answered by the ENVIRO-HEALTH hotline maintained by NIEHS at 1-800-643-4794.

(c) The RAPID interagency program also funds an internet Information Clearinghouse site (EMF-Link at http://infoventures.com), reporting on EMF-related research results.

b. Effects and Potential Hazards.

(1) Direct and Indirect Effects. There are both direct and indirect (secondary) effects of external electric and magnetic fields on biological systems. In direct coupling of EMF to biological tissue, electric fields are easily screened by objects (e.g., trees or walls) and attenuated by biological materials by factors of about 1-10 million. In contrast, magnetic fields can permeate space, and might actually be enhanced by magnetic materials, or shielded due to induced currents in non-magnetic conductors (aluminum or copper). They are not attenuated by biological tissue, and are therefore considered to be of primary interest to potential health effects. As secondary effects of EMF, time changing electric fields can induce internal magnetic fields in the human body, and time changing magnetic fields can induce electric fields and currents.

(2) Published Reviews. There are numerous reviews of the potential health effects of EMF, which are so far inconclusive. In addition to the information sources on EMF and health effects listed above, more extensive discussions can be found in:

(a) The IRPA "Guidelines on Protection Against Non-Ionizing Radiation", 1990, Chapter 6, which discusses the underlying health and safety rationale for setting interim limits for exposure to 50/60 Hz EMF;

(b) An extensive collection of papers in

"Biological Effects of Electric and Magnetic Fields, Vol. 1: Sources and Mechanisms, and Volume 2: Beneficial and Harmful Effects,", D.O. Carpenter and S. Ayrapetyan, eds., 1994.

(3) Documented Bioeffects. There are a number of EMF bioeffects documented at high electric fields (e.g., sensing by hair cells of several kV/m) and magnetic fields (e.g., seeing magneto-phosphenes above a few hundred Gauss). Power line fields have, for certain exposure conditions, caused mild increases in heart rate, some changes in brain wave patterns, and, for a few subjects, changes in secreted nighttime melatonin. These bioeffects cannot be considered hazardous to health until and unless a long chain of causation is established linking EMF characteristics (such as, spatial, temporal, quantitative, directional), and direct or indirect coupling to biological cells, organs, or to functional effects of external EMF exposures to specific adverse health end effects.

(4) Laboratory Studies. A number of laboratory studies on cells, cell and organ level metabolism, and on animals behavior and hormonal, reproductive and cancer incidence and mortality have suggested a range of potentially adverse health effects. Only cancer co-promotion (i.e., enhancing under certain exposure conditions specific types of cancers initiated by known carcinogens), and not direct causation has been suggested for EMF factors (usually at high fields, above 10 Gauss) for certain cancers (skin, breast, brain and blood or lymph systems). However, no magnetic field threshold has been defined, and no clear combination of EMF parameters that can suppress the immune system, and thus promote cancer growth.

(5) Proposed Mechanisms. Several mechanisms for coupling EMF (primarily magnetic fields) to biological systems have been proposed, the most plausible involving calcium ion metabolic processes, free radical oxidation reaction, and effects on the master regulatory hormone melatonin, which is known to inhibit cancer growth. However, there are enormous problems in extrapolating from single cell or classes of cells under controlled laboratory exposure conditions to a single organ or, further, to response of complex organisms in a continually changing EMF environment.

(6) Human Research. Little research on primates and humans exposed to EMF under controlled conditions has been done, and results to date have indicated only temporary and reversible effects on heart rate, brain waves, or melatonin level, but these findings have not been consistent or reproducible. Worldwide, about a dozen epidemiology studies on children, the general population, and on occupational categories considered to be chronically exposed to higher than average EMF (e.g., electric utility workers) have yielded suggestive, but inconclusive, results for associations of certain types of cancers (e.g., leukemia or brain cancer). However, the most direct association has been with surrogate, or indirect, measures of EMF exposure. Whenever direct measurements of magnetic field intensities in residences or workplaces were done, the correlations were weakened or absent.

c. Sources of Exposure.

(1) General. ELF/EMF sources and emissions are pervasive in our technological society. Common sources of environment EMF are: power generation, transmission and distribution lines; industrial equipment and office computer, communication, xeroxing and lighting devices; home electric appliances; and electrically powered transportation systems. Most modern transportation systems and work environments involve electric power, propulsion, sensors, control and communication systems which have associated EMF. These will require first systematic characterization, quantification, evaluation and eventual mitigation when and if the hazardous EMF parameters are identified and regulated.

(2) FAA Sources of Exposure.

(a) Within the FAA environment, EMF sources are associated with power generation for surveillance, communication, and control equipment, as well as with common office communication and display equipment. Each electrically powered system or equipment may have several ELF (0-3 kHz) EMF sources associated with it, including power generation and conditioning units (e.g., converters, rectifiers, and choppers), as well as power storage, transmission (e.g., cabling), and utilization subsystems (e.g., motors, fans, display screens, cathode ray tubes). Each such source typically has a characteristic EMF signature, denoting spatial, temporal (duty cycle), and frequency domain variability. Magnetic and electric fields diminish with increasing distance from the source, depending on its power and current rating, and on its geometry.

(b) Since biologically significant EMF parameters and "exposure" metrics of interest to health risk assessment have not been determined so far, emission characteristics at and near sources are being measured in the interim in order to gather baseline information. The source geometry and current determine how rapidly magnetic fields fall of with distance. Single line sources decay with inverse of distance; double line sources, with distance squared; and compact sources (e.g., motors and generators), which can be considered magnetic dipoles, fall off rapidly with the inverse cubed distance.

d. FAA Recommended Guidelines.

(1) Measurements. The FAA recommends that measurements and characterization of ELF/EMF fields in FAA workplaces be conducted according to procedures described in "IEEE Recommended Practice for Instrumentation: Specifications for Magnetic Flux Density and Electric Field Strength Meters - 10 Hz to 3 kHz" (IEEE Std 1308-1994, published April 1995.

(2) Exposure Limits. The FAA encourages the collection of data that characterize and documents workplace ELF EMF exposures. Personnel exposure measurements should be compared with current interim ACGIH and IRPA standards, which are

tabulated in Table 3-1 and Table 3-2, respectively.

Table 3-2. IRPA/INIRC (1990) Interim Guidelines on Limits of Exposure to 50/60 Hz Electric and Magnetic Fields (ELF/EMF)

Exposure (50/60 Hz)	Electric Field (kV/m)	Magnetic Field (Gauss)
Occupational:		
Whole working day	10	5
Short term	30	50
For limbs	--	250
General Public:		
Up to 24 hours/day	5	1
Few hours/day	10	10

e. Prudent Avoidance Strategies for Control of EMF Exposure.

(1) General. On an interim basis, "prudent avoidance" has been adopted as best practice to prevent unnecessary or prolonged EMF exposure, but mostly as a personal risk avoidance matter. Prudent avoidance means avoiding prolonged EMF exposure and increasing one's distance from localized sources (e.g., electric devices in home and office environments).

(2) Electric Field Control. Corporate or public organizations (like electric utilities) have sometimes adopted ELF/EMF prevention and control strategies, but only if not costly, nor difficult to implement. For the workplace, metallic screens might be effective against low-frequency electric fields ("Faraday cages"), but these are not effective for low frequency magnetic fields.

(3) Magnetic Field Control. Rearranging the cabling (bunching conductors which carry currents of opposite phase, or changing current phasing for multiple 3-phase circuits) could reduce the magnetic field levels. Soft magnetic alloys (e.g., mu-metal) with special shielding characteristics might also be effective for magnetic field attenuation in the case of localized sources of unusually strong magnetic fields (such as transformers), but specific control methods must be designed based on source characteristics. Increasing a worker's distance from the magnetic field source is often very effective, especially for point-like sources (equivalent to a magnetic dipole, for which the field strength decreases rapidly, with cubed distance). Another prudent practice is time management, which limits the worker's access to and dwell time in known high EMF locations. This assumes that the "dose" of EMF is the product of time by field intensity over a work day (cumulative exposure), and that the "dose rate" is the time-weighted magnetic field average (TWA).

(5) Burial of Power Lines. Although some believe that burial of power lines (undergrounding) would lower EMF exposures,

unless shielding is provided (e.g., using metal tubes to enclose bunched cables), problems could arise, such as ground return currents; the enhanced proximity of power lines to people; increased costs of undergrounding and maintenance; and higher risk of short-outs due to bunching of cables.

(6) Barriers to EMF. Insulating covers to prevent contact currents, physical barriers, and warning signs to restrict access of pacemaker wearers to areas of higher than normal electric or magnetic fields might be advisable. For high electric fields, suitable insulating gloves can prevent contact currents, and special insulating suits and shoes might offer effective protection. As a rule, no one should work on or near a live high voltage line without proper electrical safety training and ground protection.

(7) Prudent Practices. In the absence of federal EMF limits, but in response to public concern of this perceived EMF health risk, some manufacturers are voluntarily and proactively adopting prudent and low cost practices that avoid unnecessary or unreasonably high EMF, such as:

(a) Redesign of consumer electrical devices and products (e.g., computer equipment);

(b) Reconfiguration of work environments (current phasing or bundling of cables to provide current return paths or phase cancellation that result in field reduction, or ergonomic redesign of office space and repositioning of work stations and copying or other electrical equipment) to provide lower exposures for office workers;

(c) Rescheduling of maintenance and other workplace operations associated with potentially higher occupational EMF exposures to prevent unnecessary exposure to electric and/or magnetic fields.

3. STATIC MAGNETIC AND ELECTRIC FIELDS.

a. General Background. Static, or direct current (DC), electric and magnetic fields do not change direction and intensity 60 times per second as do the fields associated with alternating currents (AC), which underlie conventional electrical power grid systems. Natural static fields are produced by the earth. Electric fields are produced by thunderstorm activity, whereas natural magnetic fields arise from movement of liquid iron over the solid inner core of the earth. On average the earth's magnetic field is larger than typical AC electric power magnetic fields, but DC fields do not create currents in objects in the way that AC fields do.

b. Potential Hazards of Workers Exposure to Static Electric Fields. Electric fields up to 12 kV/m were found not to have any adverse health or behavioral effects on animals or people. Surface charging effects on hair are perceived at and above about 20 kV/m. Fields up to about 600 V/m were found not to affect human circadian rhythm, although an effect on daily melatonin secretion similar to jet lag and fatigue was observed for laboratory rats. Electric vertical fields in fair weather are typically 100 V/m, and increase to double or triple that during electric storms. Static electric fields are perceived by people above 20 kV/m as a startle response, when the hair stands up, and at sufficiently high fields by a noticeable coronal discharge and electric shock and sparks upon touching a grounded object.

c. Potential Hazards of Workers Exposure to Static Magnetic Fields.

(1) Physical Effects. There is no direct experimental evidence of either acute or chronic health effects due to exposure to static magnetic fields below 2 Teslas (20,000 gauss) magnetic fields. However, body movement relative to high magnetic fields can induce electric fields, and therefore currents inside the body. These are perceived as "magneto-phosphenes" (flickering light) and sometimes as vertigo and nausea, and some effects (lower heart rate, neural effects, performance of learned tasks) have been reported in animal studies at fields in excess of 2 T. Chronic health effects are uncertain and unconfirmed for fields below 1-2 T, although some effects on circadian rhythm via the melatonin hormone were reported in animal studies. Induced electric currents due to movement across static magnetic fields can have some electrophysiological effects.

(2) Interference With Medical Implants. There are potential hazards to individuals vulnerable to strong static magnetic fields because of certain medical implants. The hazard derives from forces and torques that can displace or dislodge metallic prosthetic implants (deflection of magnetic hemostatic or aneurism clips, suture staples, shunt connectors, metallic rods and joints), that are susceptible to either induced magnetization, or to heating from induced electric currents. In addition, some types of heart pacemakers (those with a reed switch) were found to be reset by static and ELF magnetic fields, at an intensity threshold that varies with frequency.

d. Sources of FAA Workplace Exposure to Static Electric and/or Magnetic Fields. A number of traditional radar transmitters in operation, including klystron amplifiers, magnetron oscillators, and amplitrons require relatively high crossed static magnetic and electric fields acting on an electron beam. Voltages required can be from 1.5 to 100 kVolts, and magnetic fields produced either by large horseshoe magnets, smaller permanent magnets, or electromagnets often exceed 1 kGauss (range listed for various pulsed magnetrons is 1.4 - 6.1 kGauss). Although these fields are limited to the radar transmitter enclosed in the radome and fall off rapidly with distance from the localized source, radar facility maintenance employees who are working with magnetizable tools in the vicinity should adopt safe work practices and be advised of existing static fields exposure limits and potential exposure hazards.

e. FAA Recommended Exposure Criteria.

(1) Current American Conference of Government Industrial Hygienists (ACGIH) Threshold Limit Values (TLV's).

(a) Routine Daily Exposure. The ACGIH 1995-96 Threshold Limit Values (TLV) for routine daily exposure to static magnetic fields without adverse health effects are shown in Table 3-3. On a daily time-weighted average (TWA) basis, whole body exposures are limited to 600 gauss, and for limbs to 6,000 Gauss TWA. A ceiling value of 2 T is recommended for short term work exposures.

Table 3-3. ACGIH 1995-96 Threshold Limit Values (TLV's) for Static Magnetic and Electric Fields

Occupational Exposure (60 Hz) TLV	Electric Field (kV/m)	Magnetic Field (Gauss)
Whole working day, Whole body	25 (DC to 100 Hz)	600
For workers with cardiac pacemakers	< = 1	< = 5
Partial body, extremities (startle reaction, shock, spark discharge, contact currents)	25 (5 - 7)	6000 TWA, 20,000 ceiling

(b) Special Limits. For susceptible individuals with medical implants and for workers using ferromagnetic tools, limit of 5 Gauss is recommended. The ACGIH Guidelines (Table 3-3) advise that warnings to potentially susceptible individuals be posted for magnetic flux/field equal to or larger than 1 Gauss. Since Earth's magnetic field is commonly 0.5-0.8 Gauss, and is typically enhanced by iron and steel bearing structures (cars, trains, metallic desks and file cabinet) and by magnets (e.g. refrigerator and other door magnets) by factors of 5-10, the latter limit appears excessively conservative.

(2) IRPA/ICNIRP Guidelines ƒSource: Health Physics, Vol: 66, Number 1, pp. 100-106 in January, 1994.a. These were developed in cooperation with the World Health Organization (WHO) in 1987 to guide limits for occupational and public static magnetic field exposure (see Table 3-4.)

Table 3-4. 1994 IRPA/ICNIRP Guidelines of Exposure to Static Magnetic Fields

Exposure	Magnetic Field (Gauss)
Occupational:	

Whole working day (TWA)	2,000
Ceiling value	20,000
For limbs	50,000
General Public:	
Continuous exposure	400
Pacemaker wearers	5

APPENDIX 4. IONIZING RADIATION

1. PURPOSE. This appendix to FAA Order 3910.3B establishes exposure criteria and guidelines for protection from ionizing radiation hazards in FAA workplaces. The intent of this appendix is to ensure that sources of ionizing radiation are identified and inventoried, that personnel are properly trained to work with and around these sources, and that measurements are taken to evaluate emission rates and personnel exposures. Controls to mitigate hazards are implemented when surveys indicate that exposures can exceed acceptable limits.

2. GENERAL BACKGROUND.

a. Ionizing Radiation Terminology and Units.

(1) For purposes of FAA Order 3910.3B, ionizing radiation is presented as two major categories, (1) electromagnetic radiation, and (2) particulate ionizing radiation (see Table 4-1). Electromagnetic radiation is considered to be ionizing at wavelengths below 100 nm, i.e., photons of energy greater than 12.4 eV. Particulate ionizing radiation includes alpha and beta particles. Exposure to both categories potentially may contribute to employee exposures to ionizing radiation in FAA workplaces. Ingestion of radionuclides, materials which release ionizing radiation over time through nuclear decomposition, is also a potential source of exposure.

Table 4-1. Categories and Forms of Ionizing Radiation

Electromagnetic Radiation	x rays, gamma rays
Particulate Radiation	alpha particles, beta particles (e.g., electrons)

(2) The Gray and Sievert are both international system (SI) units, and replace the Rad and Rem as units for quantifying radiation doses. The Sievert is a measure of the biological harm that ionizing radiation may cause. The conversions are given in Table 4-2.

Table 4-2. Units of Effective, Equivalent, and Average Absorbed Dose

Measure	SI Units	Definition	Previous Units	Conversion
Effective, Equivalent Dose	Sievert (Sv)	1 Sv = 1 J/kg	rem	1 Sv = 100 rem
Absorbed Dose	Gray (Gy)	1 Gy = 1 J/kg	rad	1 Gy = 100 rad

(3) In general, exposure limits are expressed in terms of effective dose E, which is measured in Sieverts (Sv). As indicated in Table 4-3, the effective dose is defined as the sum over all organs and tissues of the equivalent doses H sub T absorbed by those tissues T multiplied by the applicable tissue weighting factors w sub T (Table 4-4). For each organ or tissue, the effective dose is defined as the sum over all forms of radiation R (e.g., x rays, gamma rays, alpha particles, etc.) absorbed by that tissue of the average absorbed dose D sub T,R, multiplied by the appropriate radiation weighting factor w sub R (Table 4-5). Either ICRP Publication 60 (1990) or NCRP Report 116 (1993) may be consulted regarding the definition and calculation of equivalent and effective dose.

Table 4-3. Measures Used in
Limiting Exposure to Ionizing Radiation

Quantity	Symbol	Units	Calculation
Effective Dose	E	Sievert (Sv)	$E = \sum_T (H_T w_T)$
Equivalent Dose	H_T	Sievert (Sv)	$H_T = \sum_R (D_{T,R} w_R)$
Average Absorbed Dose	$D_{T,R}$	Gray (Gy)	measured/calculated
Tissue Weighting Factor	w_T	dimensionless	see Table 4-4
Radiation Weighting Factor	w_R	dimensionless	see Table 4-5
			$H_T(\tau) = \int_{t_0}^{t_0+\tau} \dot{H}_T(t)\,dt$

Committed Equivalent Dose	$H_T(\tau)$	Sievert (Sv)	workers: tau = 50 years public: tau = 70 years
Equivalent Dose Rate	$\dot{H}_T(t)$	Sv/year	measured/calculated

Table 4-4. Tissue Weighting Factors

Organ or Tissue	Weighting Factor (w_T)[1]
Gonads	0.20
Red Bone Marrow	0.12
Colon	0.12
Lung	0.12
Stomach	0.12
Bladder	0.05
Breast	0.05
Liver	0.05
Esophagus	0.05
Thyroid	0.05
Skin	0.01
Bone Surface	0.01
Remainder	0.05

Source: NCRP, 1993

Note 1: Tissue and radiation weighting factors are assumed to be mutually independent.

Table 4-5. Radiation Weighting Factors

Form of Radiation	Weighting Factor (w_R)[1]
x and gamma rays	1
Electrons, Positrons, and Muons	1
Neutrons, Energy < 10 keV	5
Neutrons, 10 keV < Energy < 100 keV	10
Neutrons, 100 keV < Energy < 2 MeV	20
Neutrons, 2 MeV < Energy < 20 MeV	10
Neutrons, Energy > 20 MeV	5
Protons, Energy > 2 MeV	2
Alpha Particles	20
Fission Fragments, Nonrelativistic Heavy Nuclei	20

Source: NCRP, 1993.

Note 1: Tissue and radiation weighting factors are assumed to be mutually independent.

(4) For x and gamma rays, exposure to one Roentgen (R), which is defined as that amount of radiation that results in the

production of 2.083 x 1,000,000,000 ion pairs per cubic centimeter of dry air, may be assumed to be equivalent to 0.01 Gy (1 rad) of absorbed dose. In the absence of tissue-specific information, exposure to one R of x or gamma rays may also be assumed to be equal to 0.01 Sv of effective dose. Although determination and summation of the tissue- and radiation-specific absorbed doses in J/kg remains the preferred technical approach for evaluating effective dose, this will greatly facilitate the interpretation of measured x and/or gamma ray emission and/or exposure (as opposed to absorption) rates.

b. Sources of Exposure to Ionizing Radiation. Although some individuals are exposed to small or large doses of ionizing radiation from non-natural sources, everyone is continually exposed to natural sources of ionizing radiation, which range from high-energy cosmic rays to radioactive materials present in the atmosphere, the earth, and the human body. As shown in Figure 4-1, these are the dominant sources of effective dose (defined in Table 4-3) to the U.S. population, and medical radiation is the next most important. Occupational exposures represent about 0.3% of the total annual effective dose absorbed by the U.S. population.

Figure 4-1. SOURCES OF IONIZING
RADIATION EXPOSURES TO THE U.S. POPULATION.

Cosmic 7%
Terrestrial 8%
Internal 11%
Medical X-rays 11%
Nuclear Medicine 4%
Consumer Products 3%
Other 1%
Radon 55%
(Source: NRC, 1990)
ƒFIGURE NOT INCLUDEDa

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c. Currently Accepted Standards and Guidelines.

(1) There are Occupational Safety and Health Administration (OSHA) regulations for ionizing radiation in 29 CFR Section 1910.96. However, these limits have not been updated to account for currently-available data, and do not provide specific limits applicable to pregnant women.

(2) In 1990, the National Research Council (NRC) reported on the health effects of ionizing radiation, based on new data that was becoming available. Its findings were presented in Health Effects of Exposure to Low Levels of Ionizing Radiation -- BEIR V (NRC, Washington, D.C., 1990). In 1993, the National Council on Radiation Protection and Measurements (NCRP) issued updated guidance for Limitation of Exposure to Ionizing Radiation (NCRP, Bethesda, 1993), based on a review of the NRC findings. This is similar to guidance provided by the International Commission on Radiological Protection (ICRP) in 1991, in its 1990 Recommendations of the International Commission

on Radiological Protection, (ICRP, Oxford, 1991).

(3) The American Council of Governmental Industrial Hygienists (ACGIH) accepts the guidance of the NCRP in its 1995-1996 Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices, (ACGIH, Cincinnati, 1995), and recommends consideration of future guidance of both the NCRP and the ICRP.

(4) Exposure limits recommended by the NCRP are currently similar to those recommended by the ICRP, with differences in limitation of cumulative lifetime exposures, and of limits applicable to pregnant women. Unlike both the ICRP and NCRP recommendations, the OSHA regulations have not been updated in response to NRC's 1990 report, and do not provide special standards for protection of pregnant women.

3. POTENTIAL HEALTH EFFECTS. The potential health effects of exposure to ionizing radiation include deterministic effects and stochastic effects. Deterministic effects are somatic effects (i.e., loss or damage of functional cells resulting in clinically observable pathological effects on organs and tissues) which increase in severity with increasing radiation dose above a threshold dose. Examples include cataracts, temporary or permanent sterility, and reduced blood formation. Stochastic effects are those which increase in probability with increasing dose, but which do not demonstrate a threshold effect, and which exhibit severity independent of the absorbed dose. Examples include cancer and genetic effects.

4. FAA SOURCES OF IONIZING RADIATION.

a. Sources of ionizing radiation in FAA workplaces include high voltage electron tubes (e.g., thyratron tubes) and klystrons, which may emit x rays, and radionuclides that may be present in certain types of electron tubes and in radium-activated luminous paint used in many older flight instruments and obsolete radar equipment dials. For example, radiation levels of as high as 90 mRoentgen/hour have been measured during klystron tuning operations. Over approximately 23 hours, this exposure rate could lead to the absorption of radiation exceeding the 20 mSv annual limit for effective dose adopted by FAA. With proper shielding, levels well under 2.5 mRoentgen/hour are much more typical. Potential exposure sources most relevant to specific worker categories are summarized in Table 4-6.

Table 4-6. Potential Ionizing Radiation Exposures in FAA Workplaces

Worker Category	Potential Exposures
W1. Air Traffic Controllers	Video Display Terminals, Planned View Displays
W2. Airways Facilities (AF) Electronics/Environmental	Maintenance of radar power equipment; storage, handling,

Technicians	and disposal of electron tubes and older luminous instruments and dials
W3. Academy Instructors, Safety Personnel, HAZMAT personnel	Occasional and intermittent exposure to same sources of concern to W2 employees
W4. FAA Office and Computer Staff Support Workers	Video Display Terminals

b. All significant potential sources of ionizing radiation, including but not limited to, the components identified in the preceding paragraph, shall be maintained in a centralized file in each regional headquarters, and updated at least on an annual basis.

c. Although VDTs can emit x rays, they are generally not significant sources of exposure. FDA standards for television receivers (which are similar to VDTs) manufactured after 1969, for example, limit exposure rates (measured at 5 cm) to 0.5 mRoentgen/hour. At this exposure rate, it would take 4,000 hours at 5 cm from the receiver to reach the recommended 20 mSv limit for effective dose. Because of the relative insignificance of VDTs that comply with the above-mentioned standards, they need not be included in the regional inventory of ionizing radiation sources. On the other hand, special-purpose displays produced specifically for the FAA may exhibit higher emission rates, and measurements shall be taken to determine baseline exposure levels.

5. FAA-ADOPTED EXPOSURE CRITERIA. FAA employees should not normally be exposed to higher levels of radiation than are acceptable for the general population. When repair or testing of equipment is involved, however, higher levels of exposure may be permitted for those periods, subject to approval of the Radiation Protection Officer (RPO). Exposures shall not exceed the limits specified in this order. No FAA employee shall handle radiation emitting components or perform duties in work areas that have been labeled as radiation hazard areas without first receiving information and training in radiation hazards.

a. FAA adopts exposure limits for all employees that are fundamentally based on the ICRP recommendations, in part because of the international nature of aviation. In order to both maximize protection and minimize recordkeeping requirements, FAA is substituting the 50 mSv annual effective dose limit recommended by ICRP with a more stringent limit of 20 mSv, consistent with the 100 mSv 5-year limit recommended by the ICRP. Table 4-7 gives a summary of FAA limits for occupational exposures. Personnel and, if applicable, their fetuses shall not be exposed to ionizing radiation at levels exceeding those given in this table. Non-working visitors shall not be exposed to ionizing radiation exceeding levels given in Table 4-8.

Table 4-7. FAA Occupational Limits for Exposure to Ionizing Radiation

Measure	Limit
Annual Rate of Effective Dose[1]	20 mSv
Equivalent Dose to the Embryo-Fetus[1] (total after pregnancy has been declared)	2.0 mSv
Equivalent Dose to the Embryo-Fetus[1] monthly limit monthly limit pregnancy has been declared)	0.5 mSv
Annual Equivalent Dose to Lens of Eye	150 mSv
Annual Equivalent Dose to Skin, Hands, Feet	500 mSv
Annual Equivalent Dose to Skin, Hands, Feet	500 mSv

1 Including Committed Equivalent Dose (from intake of radionuclides). Not including medical or natural background exposures.

Table 4-8. FAA Limits for Public Exposure to Ionizing Radiation[1]

Measure	Recommended Limit
Annual Effective Dose from Continuous Exposure[2]	1 mSv
Annual Effective Dose from Infrequent Exposures[2]	5 mSv
Equivalent Dose to the Embryo-Fetus[2] (total after pregnancy has been declared)	2.0 mSv
Annual Equivalent Dose to Lens of Eye	15 mSv
Annual Equivalent Dose to Skin, Hands, Feet	50 mSv

1 Applies to non-working visitors to FAA facilities where potential for exposure to ionizing radiation exists.
2 Including Committed Equivalent Dose (from intake of radionuclides). Not including medical or natural background exposures.

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b. Significant Features of FAA Limits.

(1) The occupational effective dose absorbed by any non-pregnant adult in any twelve month period shall not exceed 20 mSv, including any committed dose from intake of radionuclides.

(2) The total occupational effective dose absorbed by any embryo-fetus carried by an employee shall not exceed 2.0 mSv after the employee provides management with written notification of her pregnancy, and shall not exceed 0.5 mSv in any single month during that time. For radiation protection purposes, the dose received by the abdomen of the pregnant mother is considered to be the same as the dose to the embryo-fetus.

(3) Medical exposures should not be included in estimates of occupational exposures.

(4) Non-working visitors shall not be exposed to ionizing radiation exceeding 1.0 mSv in any twelve month period.

6. CONTROL MEASURES.

a. This section contains requirements for limiting exposure to ionizing radiation, and intake (via ingestion or inhalation) of radionuclides. Engineering controls (e.g., shielding and isolation of sources) recommended by the RPO shall be used to limit exposure whenever practical.

b. Absorbed radiation is proportional to the total time of exposure, and varies inversely with the square of distance from the source. Therefore, limiting the duration of exposure and increasing the distance from sources of radiation can be very effective.

c. Although shielding of radiation sources is also very important, the absorbing material used and thickness required depend upon the size of the source, the type of radiation, its energy, and its flux. Alpha particles are stopped by an ordinary sheet of paper or a few inches of air. Gamma and x ray intensity decrease exponentially with thickness in absorbing materials. However, the attenuating value of such materials (e.g., lead, concrete) varies with the energy of the incident photons. The RPO shall be consulted regarding appropriate shielding for sources of ionizing radiation.

d. Signs and labels complying with good industrial practice, examples of which are shown in Figure 2, shall be conspicuously posted inside and at all entrances to areas described in this section, and on equipment that is known to emit ionizing radiation and/or contain radioactive materials.

Figure 2. Examples of Signs Used
in Protection from Ionizing Radiation.
ƒFIGURE NOT INCLUDEDa

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e. Incident Control. If an incident occurs which may have led to exposure of employees to ionizing radiation in excess of the exposure criteria, the employees' supervisor will immediately report the incident to the regional safety office, where action will follow to evaluate the need for medical attention, to request radiation measurements by the Frequency Management Officer (FMO), and/or to notify Washington headquarters.

(1) If measurements obtained by the FMO (or authorized designee) determine that one or more individuals were exposed to a cumulative dose that exceeds 10% of the recommended annual limit for a non-pregnant worker or the recommended limit for a pregnant worker, an incident report shall be prepared by the FMO within 2 working days following the incident for submittal to the regional safety office, the RPO, and the Manager of the Office of Spectrum Policy and Management (ASR).

(2) The incident report should include at least the following information: the equipment that was the source of the radiation; the radiation monitoring devices, if any, that were used; the individuals involved, and their functions; and details of the exposure, and medical assistance provided, if any.

(3) The RPO will prepare a report recommending steps to prevent future recurrences of the incident. Copies of the report will be sent to all regional safety offices, ASR, and AEE.

f. X Rays.

(1) Equipment that use high electrical voltages (e.g., amplitrons, klystrons, magnetrons, thyratron tubes, traveling-wave tubes) has the potential to produce harmful levels of ionizing radiation (x rays). Protection is provided by closed and locked metal doors and interlocks to prevent accidental exposures.

(2) The manufacturer usually provides a warning label. However, if there is no label, potential sources of exposure must be surveyed, identified, and labeled.

(3) The electrical power to the equipment normally should be turned off before doors are opened. If it is necessary that equipment remain operating when the doors are open and interlocks bypassed, the RPO must be contacted to determine necessity for exposure monitoring during the operation.

(4) Instruments for monitoring should be appropriate for the type of radiation. If the potential for radio-frequency (RF) radiation exists, ionizing radiation monitoring instruments should be RF shielded.

(5) Equipment capable of producing elevated x rays under specific operating conditions, such as during an electron tube's "burning in" period, should be surveyed when those conditions are present, and also whenever it is suspected that maintenance or operational changes have altered the radiation exposure

potential.

(6) In the event that equipment malfunctions in a manner that may lead to the emission of x rays (e.g., high-power output arcing, oscillation, sputtering), any corrective work in the vicinity of potential x ray sources shall be conducted with the equipment in a state that minimizes those emissions (e.g., with the high voltage off).

g. Radionuclides.

(1) The following controls are necessary for work areas where radionuclides exist. In FAA workplaces, electron tubes, instrument dials, and equipment control knobs that contain radioactive materials are of particular interest.

(2) Personnel shall take prudent precautions to avoid proximity and time exposed to components containing radioactive materials. For example, small tubes containing radionuclides should not be carried in pockets of clothing for long periods of time. Normal handling of intact electron tubes does not present a radiation hazard.

(3) Personnel shall exercise caution to ensure that equipment parts containing radionuclides are inventoried and stored in a manner that avoids random storage, storage of large quantities, and potential for breakage that could release radionuclides.

(4) All storage areas for large quantities of equipment parts containing radionuclides shall be clearly marked with radiation warning signs (samples are shown in Figure 2).

(5) In the event of breakage of components that may contain radionuclides, the RPO shall be contacted immediately regarding appropriate decontamination procedures.

(6) The RPO shall be contacted regarding appropriate disposal of any components that may contain radionuclides.

7. EVALUATION OF HAZARDS. The regional FMO, in collaboration with ASR, shall be consulted regarding current radiation measurement equipment and procedures, which are detailed in ASR's Spectrum Management Regulations and Procedures Manual (FAA Order 6050.32A, currently in revision.) The RPO will be contacted when measurement data suggests potential for excessive exposure to employees, contract employees, authorized visitors, or to occupants of child care centers co-located on FAA property, and will determine if personal dosimetry is indicated.

8. RADON (RESERVED).

APPENDIX 5. LASER RADIATION HEALTH HAZARDS AND PROTECTION

1. PURPOSE. This appendix to FAA Order 3910.3B establishes guidelines for protection from laser radiation hazards in FAA workplaces. The intent of this appendix is to ensure that all

lasers are identified and inventoried, that personnel are properly trained to work with and around lasers, and that measurements are taken to evaluate emission rates and personnel exposures. Controls to mitigate hazards are implemented when surveys indicate that exposures can exceed acceptable limits.

2. GENERAL BACKGROUND.

a. Description and Hazards.

(1) A laser is a quantum mechanical device which produces an intense, coherent, and highly directional beam of light. Potential health effects of exposure to laser radiation include damage to the skin (e.g., surface burns at high power levels, skin cancer following chronic exposure to UV lasers) and, of primary concern, the eyes (e.g., corneal and/or retinal damage). The potential for eye damage is highly dependent on wavelength, duration, and intensity of exposure.

(2) A laser is identified as Class 1, 2, 3a, 3b, or 4 based on an increasing potential to cause harm, in consideration of the accessible radiation during operation. For example, a Class 1 laser is considered to be incapable of producing damaging radiation during operation and maintenance. Class 2 lasers are of low enough power that the blink reflex normally provides sufficient eye protection. A Class 3 laser may be hazardous under direct and specular viewing conditions, but diffuse reflection is usually not a hazard. Direct and, sometimes, diffusely reflected light from a Class 4 laser is a hazard to the eye or skin and can present a range of non-beam hazards (discussed below). Existing guidelines regarding control measures are specific to the laser's class.

(3) Non-beam Hazards. Laser systems can present a range of non-beam hazards, for example, electric shocks from high-voltage components. Those associated with the laser beam itself include the generation of air contaminants when Class 3b and 4 laser beams interact with matter; collateral radiation (e.g., x radiation) from plasmas generated by high-power pulsed laser beams; and fire hazards (Class 4 lasers).

b. Currently Accepted Standards and Guidelines for Exposure.

(1) The American National Standards Institute (ANSI) has established laser safety standards, called Maximum Permissible Exposures (MPE's), for eye and skin exposures, which are contained in American National Standard for Safe Use of Lasers (ANSI Z136.1-1993).

(2) The American Conference of Governmental Industrial Hygienists (ACGIH) publication, 1995-1996 Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices (ACGIH, Cincinnati, 1995), contains Threshold Limit Values (TLV's) that are consistent with ANSI's MPE's. ACGIH also provides detailed guidelines (A Guide for Control of Laser Hazards, fourth edition, ACGIH, 1990) regarding laser hazard evaluation and control, protective eye wear, and medical

surveillance.

3. EXPOSURE CRITERIA.

a. The FAA adopts the current Threshold Limit Values (TLV's) recommended by the American Conference of Governmental Industrial Hygienists (ACGIH) for exposure to laser radiation.

b. Measurements made to evaluate radiant exposure or irradiance may be averaged over apertures indicated in Table 5-1.

Table 5-1. Limiting Apertures Applicable to Laser TLV's

Wavelength	Duration(s)	Limiting Aperture (mm) Eye	Limiting Aperture (mm) Skin
180 to 400 nm	10^{-9} to 0.25	1.0	3.5
	0.25 to 3×10^{4}	3.5	3.5
400 to 1400 nm	10^{-9} to 3×10^{4}	7.0	3.5
1.4 to 100 microns	10^{-9} to 0.25	1.0	3.5
	0.25 to 3×10^{4}	3.5	3.5
100 to 1000 microns	10^{-9} to 3×10^{4}	11.0	11.0

c. Correction factors given in Table 5-2 shall be applied in calculating applicable exposure limits.

Table 5-2. Parameters and Correction Factors

Correction Factor	Wavelength (microns)
T sub 1 = $10 \times 10^{20(\lambda - 0.550\ \text{microns})}$	0.550 to 0.700
C sub B = 1.0	0.400 to 0.550
C sub B = $10^{15(\lambda - 0.550\ \text{microns})}$	0.550 to 0.700
C sub A = 1.0	0.400 to 0.700
C sub A = $10^{2(\lambda - 0.700\ \text{microns})}$	0.700 to 1.050
C sub A = 5.0	1.050 to 1.400
C sub P = $n^{-1/4}$	0.400 to 1,000
C sub E = 1.0 (for alpha < alpha sub min)	0.400 to 1.400 *
C sub E = alpha/(alpha sub	0.400 to 1.400 *

min) (for alpha sub min < alpha < alpha sub max)	
C sub E = α^{2}/alpha sub max alpha sub min) (for alpha > alpha sub max)	0.400 to 1.400 *
C sub C = 1.0	1.050 to 1.150
C sub C = $10^{18(\lambda - 1.150 \text{ microns})}$	1.150 to 1.200
C sub C = 8	1.200 to 1.400

* alpha sub max = 100 mrad;
alpha sub min = 1.5 mrad for t < 0.7s;
alpha sub min = 2 $t^{3/4}$ mrad for 0.7s < t < 10s;
alpha sub min = 11 mrad for t > 10s

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d. Ocular exposures to single laser pulses (or CW laser radiation) shall not exceed the TLV's given in Table 5-3.

Table 5-3. TLV's for Direct Ocular Exposures (Intrabeam Viewing) to a Laser Beam

Spectral Region	Wavelength	Exposure Time t (seconds)	TLV mJ/cm^2	TLV mW/cm^2
UVC	180 to 280 nm	10^{-9} to 3×10^{4}	3	
UVB	280 to 302 nm	10^{-9} to 3×10^{4}	3	
	303 nm	10^{-9} to 3×10^{4}	4	
	304 nm	10^{-9} to 3×10^{4}	6	
	305 nm	10^{-9} to 3×10^{4}	10	
	306 nm	10^{-9} to 3×10^{4}	16	
	307 nm	10^{-9} to 3×10^{4}	25	
	308 nm	10^{-9} to 3×10^{4}	40	
	309 nm	10^{-9} to 3×10^{4}	63	
	310 nm	10^{-9} to 3×10^{4}	100	
	311 nm	10^{-9} to 3×10^{4}	160	
	312 nm	10^{-9} to 3×10^{4}	250	
	313 nm	10^{-9} to 3×10^{4}	400	

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]         ]               ]  -9          4 ]           ]            ]
]         ]    314 nm     ]10  to 3 x 10  ]        630 ]            ]
]         ]               ]                ]           ]            ]
]         ]               ]  -9            ]       1/4 ]            ]
]UVA      ]315 to 400 nm ]10  to 10       ]   560t    ]            ]
]         ]315 to 400 nm ]10 to 1000      ]      1000 ]            ]
]         ]               ]               4]           ]            ]
]         ]315 to 400 nm ]1000 to 3 x 10 ]           ]       1.0 ]
]         ]               ]                ]           ]            ]
]         ]               ]  -9            ]      -4   ]            ]
]Visible ]400 to 700 nm ]10  to 1.8 x   ]5 x 10     ]            ]
]Light   ]               ]  -5            ]           ]            ]
]         ]               ]10              ]           ]            ]
]         ]               ]        -5      ]       3/4 ]            ]
]         ]400 to 700 nm ]1.8 x 10  to 10]   1.8t    ]            ]
]         ]               ]        4       ]           ]            ]
]         ]400 to 549 nm ]10 to 10        ]         10 ]            ]
]         ]               ]                ]           ]            ]
]         ]550 to 700 nm ]10 to t         ]       3/4 ]            ]
]         ]               ]       1        ]   1.8t    ]            ]
]         ]               ]       4        ]           ]            ]
]         ]550 to 700 nm ]t to 10 s       ] 10C       ]            ]
]         ]               ] 1              ]    B      ]            ]
]         ]               ]  4         4  ]           ]            ]
]         ]400 to 700 nm ]10 to 3 x 10   ]           ]  C /1000  ]
]         ]               ]                ]           ]   B        ]
]         ]               ]  -9            ]      -4   ]            ]
]IRA      ]700 to 1049 nm]10  to 1.8 x   ]5 x 10  C  ]            ]
]         ]               ]  -5            ]         A ]            ]
]         ]               ]10              ]           ]            ]
]         ]               ]        -5      ]     3/4   ]            ]
]         ]700 to 1049 nm]1.8 x 10   to  ]1.8C t     ]            ]
]         ]               ]  3             ]    A      ]            ]
]         ]               ]10              ]           ]            ]
]         ]               ]  -9            ]      -3   ]            ]
]         ]1050 to 1400  ]10  to 5.0 x   ]5 x 10  C  ]            ]
]         ]nm             ]  -5            ]         C ]            ]
]         ]               ]10              ]           ]            ]
]         ]               ]        -5      ]    3/4    ]            ]
]         ]1050 to 1400  ]5.0 x 10  to   ]9C t       ]            ]
]         ]nm             ]1000          4]  A        ]            ]
]         ]700 to 1400 nm]1000 to 3 x 10 ]           ]0.32C C    ]
]         ]               ]                ]           ]     A C    ]
]         ]               ]  -9     -3     ]           ]            ]
]IRB, IRC]1.401 to 1.5  ]10  to 10       ]        100 ]            ]
]         ]microns        ]                ]           ]            ]
]         ]               ]  -3            ]       1/4 ]
]         ]1.401 to 1.5  ]10  to 10       ]   560t    ]            ]
]         ]microns        ]                ]           ]            ]
]         ]               ]  -9            ]           ]            ]
]         ]1.501 to 1.8  ]10  to 10       ]      1000 ]            ]
]         ]microns        ]                ]           ]            ]
]         ]               ]  -9     -3     ]           ]            ]
]         ]1.801 to 2.6  ]10  to 10       ]        100 ]            ]
]         ]microns        ]                ]           ]            ]
]         ]               ]  -3            ]       1/4 ]            ]
]         ]1.801 to 2.6  ]10  to 10       ]   560t    ]            ]
```

	microns			
	2.601 to 1000 microns	10^{-3} to 10^{-7}	10	
	2.601 to 1000 microns	10^{-7} to 10	$560t^{1/4}$	
	1.400 to 1000 microns	10 to 3×10^{4}		100

e. Skin exposures to single laser pulses (or CW laser radiation) shall not exceed the TLV's given in Table 5-4.

Table 5-4. TLV's for Skin Exposure to a Laser Beam

Spectral Region	Wavelength	Exposure Time t (seconds)	TLV J/cm^2	TLV W/cm^2
UVC *	180 to 280 nm	10^{-9} to 3×10^{4}	0.003	
UVB *	302 to 303 nm	10^{-9} to 3×10^{4}	0.003	
	303 nm	10^{-9} to 3×10^{4}	0.004	
	304 nm	10^{-9} to 3×10^{4}	0.006	
	305 nm	10^{-9} to 3×10^{4}	0.010	
	306 nm	10^{-9} to 3×10^{4}	0.016	
	307 nm	10^{-9} to 3×10^{4}	0.025	
	308 nm	10^{-9} to 3×10^{4}	0.040	
	309 nm	10^{-9} to 3×10^{4}	0.063	
	310 nm	10^{-9} to 3×10^{4}	0.100	
	311 nm	10^{-9} to 3×10^{4}	0.160	
	312 nm	10^{-9} to 3×10^{4}	0.250	
	313 nm	10^{-9} to 3×10^{4}	0.400	
	314 nm	10^{-9} to 3×10^{4}	0.630	
UVA *	315 to 400 nm	10^{-9} to 10	1/4	

	315 to 400 nm	10 to 1000	0.56t 1	
	315 to 400 nm	1000 to 3×10^{4}		0.001
Visible Light, IRA	400 to 1400 nm	10^{-9} to 10^{-7}	$0.02C_A$	
	400 to 1400 nm	10^{-7} to 10	$1.1C_A t^{1/4}$	
	400 to 1400 nm	10 to 3×10^{4}		$0.2C_A$
IRB, IRC	1.400 to 1000 microns	10^{-9} to 10^{-7}	0.01	
	1.400 to 1000 microns	10^{-7} to 10	$0.56t^{1/4}$	
	1.400 to 1000 microns	> 10		0.1

* or TLV = $0.56t^{1/4}$, whichever is lower

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g. Exposure to repetitively pulsed (or scanned CW) lasers between 400 and 1,400 nm shall not exceed TLV's corrected according to the following equation:

$$TLV_{repetitive} = n^{-1/4} \; TLV_{single,t}$$

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where n is the total number of pulses in a given exposure situation (i.e., the product of the pulse repetition rate in Hz and the total duration of exposure in seconds), and TLV sub single,t is the single pulse TLV for the applicable pulse width t, as given in either Table 5-3 or Table 5-4.

4. FAA SOURCES OF EXPOSURE.

a. Lasers currently deployed in FAA workplaces include Ga-As diode lasers used in upward-directed ceilometers, which rely on reflected laser radiation to determine cloud base altitude. These Class 3b lasers are operated in the pulsed mode between 904 and 912 nm. Pulse widths typically range from 50 to 150 nS, and repetition rates range from 200 to 2500 Hz. Pulsed power levels range from 20 W up to a maximum of about 40 W. In normal use, ceilometers are aligned so that the laser radiation is transmitted upward. Typical maintenance activities include cleaning optical lenses and filter, and aligning the ceilometer.

b. In addition to lasers, very bright incoherent light sources are used at many FAA facilities to enable efficient and safe operations, for examples to assist in approaches during inclement weather. Where exposure to the sources may be a concern, ACGIH TLV's for exposure to incoherent light should be consulted for reference, and compared to measured intensity and exposure levels.

5. CONTROL MEASURES.

a. Engineering controls recommended by the Radiation Protection Officer (RPO), and based on current ACGIH and ANSI guidelines, shall be used to limit occupational and public exposure to radiation from FAA lasers such that applicable ACGIH TLV's shall not be exceeded.

b. Typically, eye exposures are of much greater concern than skin exposures, particularly since most lasers operate within and/or just outside the visible spectrum. Although atmospheric attenuation reduces laser beam intensity over distances, the very small divergence of laser beam limits the protection provided by increased distance, and increases the importance of proper alignment.

c. Eye exposures may be minimized through (1) remote siting, (2) alignment of laser emitters and optical components such that beam pathways minimize the potential for eye exposures, (3) removal and/or covering of reflective surfaces within potential beam pathways, (4) use of protective eye wear appropriate for the class and wavelength of the laser(s), and (5) avoidance of direct staring into the laser.

d. In general, the power shall be disconnected prior to any laser maintenance or adjustment operations. In the event that it is necessary to operate the laser during such operations, eye protection indicated by the RPO shall be worn by personnel, and care shall be taken to avoid eye exposure to direct and/or reflected laser radiation.

e. During any in situ or other (e.g., classroom) demonstrations of laser systems, extreme care shall be taken to ensure that instructors and observers wear proper eye protection, that eye exposures are minimized, and that laser beams are appropriately terminated.

f. For Class 3b lasers used outdoors by the FAA and its contractors, the following control measures shall apply:

(1) The region/center Frequency Management Officer (FMO) in coordination with the RPO shall perform an analysis to establish the nominal hazard zone (NHZ) if it not provided as part of the documentation furnished by the manufacturer.

(2) The NHZ shall be clearly posted with laser warning signs and demarcated and identified as a laser hazard area.

(3) All personnel authorized to enter the NHZ shall be appropriately trained.

(4) Only personnel who have been authorized shall operate a laser or laser system.

(5) Appropriate combinations of physical barriers, screening, personnel protective equipment shall be provided and used by those personnel authorized within the NHZ.

(6) Appropriate administrative controls shall be used in personnel are permitted within the NHZ.

(7) Directing the laser beam toward automobiles, aircraft or other manned structures or vehicles shall be prohibited within the NHZ unless adequate training and protective equipment is provided and used by all personnel within those targets.

(8) The exposed laser beam path shall not be maintained at or near personnel eye level without specific authorization of the RPO.

(9) The beam path shall be confined and terminated whenever possible.

(10) When the laser is not being used, it shall be disabled in a manner that prevents unauthorized use.

(11) The operation of Class 4 lasers or laser systems during rain or snow-fall or in fog or dusty atmosphere may produce hazardous reflections near the beam. In such conditions, the RPO shall evaluate the need for, and specify the use of, appropriate protective equipment.