LPR 1710.8 M
Effective Date: December 19, 2023
Expiration Date: December 19, 2028

Subject: Non-Ionizing Radiation

Responsible Office: Safety and Mission Assurance Office

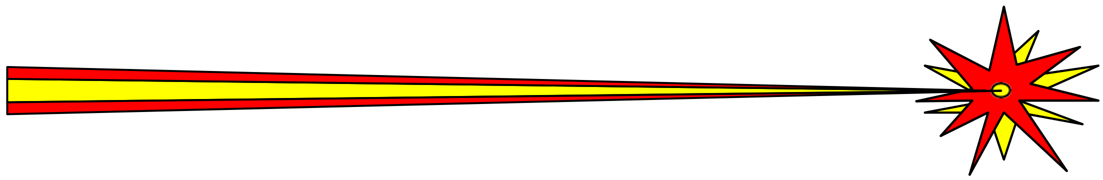

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Change History Log

Revision	Date	Description of Change
M	TBD	Updated language to remove term “principle safety head” to reflect current and accurate roles. Refined roles and responsibilities. Added more information about RF and UV radiation. Added program exemptions. Added more information about coordinating with the Spectrum Management Office. Added a list of best practices for lasing through wind tunnel windows.

PREFACE

P.1 PURPOSE

a. This Langley Procedural Requirement (LPR) describes the organization, procedures, and requirements for the radiation health and safety activity of the Langley Research Center (LaRC), as they specifically pertain to non-ionizing radiation activities at LaRC.

b. This LPR defines requirements for the procurement, use, and handling of sources of non-ionizing radiation. It also indicates sources from which more detailed information on non-ionizing radiation may be obtained when necessary.

c. This LPR ensures compliance with all NASA regulations and Federal laws applicable to non-ionizing radiation and serves to:

(1) Exercise centralized control over operations involving use of hazardous non-ionizing radiation producing equipment.

(2) Ensure that occupational exposure to non-ionizing radiation is maintained As Low As is Reasonably Practicable (ALARP).

(3) Ensure compliance with applicable Federal, State, and Local regulations.

d. A Non-Ionizing Radiation Committee (NIRC) is established under the authority of Langley Policy Directive (LAPD) 1700.1 Safety Program and LAPD 1150.2 Councils, Boards, Panels, Committees, Teams, and Groups. The committee responsibilities are presented in Chapter 1 of this LPR.

P.2 APPLICABILITY

a. These procedural requirements apply to all persons performing work at LaRC, including civil servants, contractors, research associates, and others.

b. Non-compliance with this LPR will result in appropriate disciplinary action that may include termination for a civil servant employee or exclusion from the Center for a contractor employee.

c. The procedures and radiation protection practices as set forth in this procedural requirement shall apply to all organizational elements of LaRC and to all personnel working in or visiting areas under the administrative control of LaRC.

(1) Although intended primarily to apply to the use of lasers or laser systems, these procedures and practices may also apply to hazardous non-coherent sources of non-ionizing radiation such as radars, solar simulators, and high- intensity arc lamps.

(2) Questions concerning details of current practices and procedures or their applicability shall be referred to the LaRC Radiation Safety Officer, the Lead Industrial Hygienist, the Safety and Facility Assurance Branch, or the Safety and Mission Assurance Office.

d. Contractors shall provide and implement their own non-ionizing radiation program, to the extent required by their contracts. At a minimum, their programs shall be in accordance with the LaRC program as described herein.

e. In this directive, all mandatory actions (i.e., requirements) are denoted by statements containing the term “shall.” The terms “may” denotes a discretionary privilege or permission, “can” denotes statements of possibility or capability, “should” denotes a good practice and is recommended, but not required, “will” denotes expected outcome, and “are/is” denotes descriptive material.

f. In this directive, all document citations are assumed to be the latest version, unless otherwise noted.

P.3 AUTHORITY

a. Laser Products, 21 Code of Federal Regulations (CFR) §1040.10.

b. Nonionizing Radiation, 29 CFR §1910.97.

c. NPR 1800.1, NASA Occupational Health Program Procedures.

d. Federal Aviation Administration Order JO 7400.2, Procedures for Handling Airspace Matters.

P.4 APPLICABLE DOCUMENTS AND FORMS

a. Federal Performance Standard for Electronic Products: General, 21 CFR Part 1010.

b. LAPD 1150.2, Councils, Boards, Panels, Committees, Teams, and Groups.

c. LAPD 1700.1, Safety Program.

d. LPR 2570.5, Radio Frequency Spectrum Management.

e. LPR 1740.6, Personnel Safety Certification.

f. LPR 1710.12, Potentially Hazardous Materials-Hazard Communication Standard

g. U.S. Department of Transportation, Federal Aviation Administration (FAA), Advisory Circular (AC) 70-1.

h. NF 1707, Special Approval and Affirmations of Requisitions.

i. LF 44a, Radiation Hazard Form.

j. LF 49, Safety Permit Request - Laser/Microwave.

k. LF 498, Safety Permit.

l. American Conference of Governmental Industrial Hygienists (ACGIH), Threshold Limit Values (TLV) and Biological Exposure Indices (BEIs).

m. ANSI Z136.1, American National Standard for Safe Use of Lasers.

n. ANSI Z136.6, American National Standard for Safe Use of Lasers Outdoors.

o. IEEE C95.1, IEEE Standards for Safety Levels with Respect to Human Exposure to Electric, Magnetic, and Electromagnetic Fields, 0 Hz to 300 GHz.

p. IEEE C95.7, IEEE Standard for Electromagnetic Energy Safety Programs, 0 Hz to 300 GHz.

q. NFPA 70, National Electric Code (NEC), Articles 300 and 400.

r. SAE AS6029A, Performance Criteria for Laser Control Measures Used for Aviation Safety.

P.5 MEASUREMENT/VERIFICATION

Compliance with these requirements is accomplished through annual non-ionizing radiation audits, through the issuance and periodic review of non-ionizing radiation safety permits, and through triennial occupational health audits conducted by the NASA Office of the Chief Health & Medical Officer (OCHMO).

P.6 CANCELLATION

LPR 1710.8 L-1, dated December 19, 2017

____

Title Date

DISTRIBUTION

Approved for public release via the Langley Management System; distribution is unlimited

CHAPTER 1: NON-IONIZING RADIATION COMMITTEE (NIRC)

1.1 COMMITTEE AUTHORITY

1.1.1 Any member of the NIRC is authorized to:

a. Investigate any questionable radiation source, equipment, system, or procedure.

b. Act in the name of the LaRC Center Director to stop work.

c. Prevent the use of equipment and procedures that are considered unsafe.

d. Start action to eliminate the unsafe condition.

1.1.1.1 Actions to eliminate the unsafe condition shall be documented within 24 hours by formal letter to the Chairperson, NIRC.

1.1.1.2 If management is not in agreement with the corrective action recommended by the official who stopped the work, the manager shall submit the reasons to the Chairperson, Executive Safety Council, who shall make an appropriate review.

1.1.1.3 In the case specified in Section 1.1.1.2, work shall not resume without the approval of the Chairperson, Executive Safety Council.

1.1.2 Due to the need for the NIRC to maintain an overview of non-ionizing radiation activities at LaRC, a safety permit review system is established for major radiation facilities. This review system is described in Chapter 3 of this LPR.

1.2 STRUCTURE AND ORGANIZATION

1.2.1 The NIRC functions as a committee of the Executive Safety Council. Its position in the organization for radiation safety is shown in Figure 1-1.

1.2.2 Committee members (including Chairperson and Vice Chairperson) are nominated by the NIRC Chairperson, or by the outgoing Chairperson, in the case of a new Chairperson, by virtue of their technical and/or educational expertise in the field of non-ionizing radiation. This nomination shall be approved by the immediate supervisor of the new member; the Director, Safety and Mission Assurance Office (SMAO); and the appropriate Organizational Director.

1.2.2.1 A typical committee shall consist of a Chairperson, Vice Chairperson, and additional qualified members, including the Safety Manager or their designated representative from the Safety and Facility Assurance Branch (SFAB), and the Radiation Safety Officer (RSO) as ex-officio members.

1.2.2.2 Members, except for the Chairperson, the Vice Chairperson, the SFAB representative, and the RSO shall serve for a three-year term. The Chairperson and Vice Chairperson will serve for a one-year term with the positions rotating equally among personnel from the Engineering Directorate, the Science Directorate, and the Research Directorate. The RSO and the SFAB representative will serve as long as the Committee continues to function.

1.2.2.3 Committee members may serve multiple terms consecutively or nonconsecutively.

1.2.2.4 Selection of committee members should be representative of the organizations that conduct work utilizing non-ionizing radiation sources.

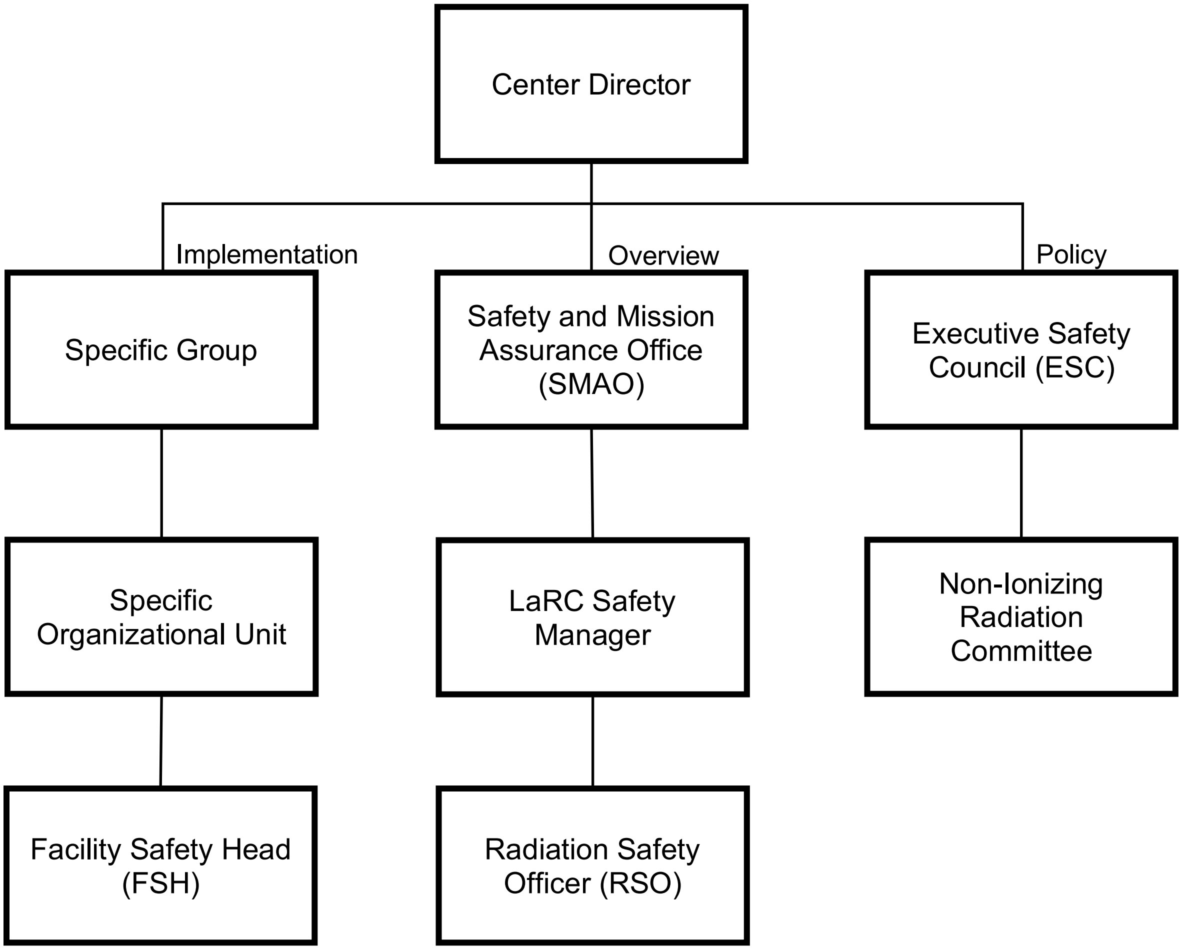

Figure 1-1. LaRC Organization for Non-Ionizing Radiation Safety

1.3 DUTIES AND RESPONSIBILITIES

1.3.1 General

1.3.1.1 To prevent unnecessary non-ionizing radiation exposure to LaRC personnel and the surrounding population, the NIRC shall exercise centralized control over sources of non-ionizing radiation at LaRC.

1.3.1.1.1 This centralized control shall be accomplished through the documented review and approval of all procurement, handling, and use of sources of hazardous non-ionizing radiation.

1.3.1.1.2 The RSO shall ensure that an audit is made of each facility's possession and use of sources of non-ionizing radiation on an annual basis.

1.3.1.2 The NIRC is responsible for providing oversight in the modification of this procedural requirement as NASA regulations and Federal laws are updated.

1.3.2 Specific Duties and Responsibilities

1.3.2.1 The NIRC Chairperson shall:

a. Prepare agendas and call meetings as required, but at least quarterly.

b. Act as the presiding officer at NIRC meetings.

c. Act as the signature authority for actions approved by the NIRC.

d. Be cognizant of all matters pertaining to non-ionizing radiation at LaRC.

1.3.2.2 The NIRC Vice Chairperson shall:

a. Assist the Chairperson whenever necessary.

b. Serve as the Chairperson when the Chairperson is absent.

1.3.2.3 The NIRC Secretary shall:

a. Prepare, distribute, and store the minutes of NIRC meetings, which shall contain, as a minimum, a record of persons present and a description of matters discussed and conclusions reached, including the opinions of dissenting members, and copies of all reports issued or approved by the NIRC.

b. Process official correspondence for the NIRC as needed.

1.3.2.4 NIRC Members shall:

a. Be cognizant of all matters pertaining to non-ionizing radiation safety at LaRC. This is chiefly, but not entirely, achieved by attending the NIRC meetings and participating in the decisions made by the NIRC.

b. Serve on ad hoc committees, appointed by the Chairperson, when necessary.

CHAPTER 2: SAFETY AND HEALTH FUNCTIONS

2.1 GENERAL

2.1.1 The responsibility for implementing the policies of these procedural requirements is divided among five safety and health functions. The interface requirements of these functions and their duties and responsibilities are presented in this Chapter.

2.2 FACILITY SAFETY HEAD (FSH)

2.2.1 The FSH is often the first point of contact for the individual who has a requirement for the procurement, use, or disposal of sources of non-ionizing radiation.

2.2.2 The RSO shall be the first point of contact for the FSH.

2.2.3 Responsibilities

2.2.3.1 The FSH of an operation involving sources of non-ionizing radiation shall be responsible for:

a. The procurement, use, disposal, and safe supervision and coordination of sources of non-ionizing radiation.

b. Accompanying the RSO during audits of the operation and, when appropriate, attending meetings of the NIRC.

2.3 RADIATION SAFETY OFFICER

2.3.1 The RSO also has the title of Laser Safety Officer (LSO).

2.3.2 Interfaces

2.3.2.1 The RSO is a member of the NIRC and shall be responsible for reporting non-ionizing radiation information to the LaRC Safety Manager.

2.3.2.2 The RSO shall make recommendations to the committee for approval or disapproval of new uses of non-ionizing radiation following pre-operational surveys and review of safety procedures.

2.3.2.3 The RSO shall assist the radiation user as primary contact on a day-to-day basis for matters relating to radiation safety.

2.3.3 Responsibilities

2.3.3.1 The RSO shall provide administrative and technical guidance to LaRC personnel in the safe use of non-ionizing radiation and ensure that activities involving the use of non-ionizing radiation sources are conducted in accordance with Federal, State, and Agency requirements.

2.3.3.2 The RSO shall:

a. Prepare incident and overexposure reports required by the Occupational Safety and Health Administration (OSHA).

b. Perform pre-operational surveys and radiation hazard analyses of all proposed uses of facilities for non-ionizing radiation to ensure compliance with applicable standards and good practice. Recommend to the NIRC approval or disapproval of the use of non-ionizing radiation generating devices in these facilities.

c. Perform annual audits of non-ionizing radiation activities in each facility.

d. Perform periodic radiation protection surveys and radiation safety evaluations as necessary.

e. Assist facility management in implementing radiation safety rules and procedures as promulgated by the NIRC.

f. Provide training of personnel in radiation safety.

g. Review all purchase requests for non-ionizing radiation sources for compliance with approved policies and safety programs.

h. Maintain a current inventory of all permit-required, hazardous sources of non-ionizing radiation at LaRC.

i. Review, sign, and forward to the LaRC Safety Manager safety permit requests for the use of non-ionizing radiation sources (i.e., Langley Form (LF) 49).

j. Regularly inform the NIRC of new developments in the field of non-ionizing radiation, as applicable to activities at LaRC.

2.4 LaRC SAFETY MANAGER

2.4.1 Interfaces

2.4.1.1 The LaRC Safety Manager's interfaces include:

a. Technically managing contractual health physics services at LaRC.

b. Serving as a member of the NIRC or assigning a designee.

c. Acting as the primary contact for LaRC management on matters relating to radiation safety.

2.4.2 Responsibilities

2.4.2.1 The LaRC Safety Manager shall serve as the final certifying authority on the following documents:

a. LF 44a, "Radiation Hazard Form."

b. LF 49, "Safety Permit Request - Laser/Microwave."

c. LF 498, "Safety Permit."

2.4.2.2 The LaRC Safety Manager shall exercise general surveillance over all uses of non-ionizing radiation at LaRC, including onsite contractor activities to ensure radiation use is in compliance with safe practice, pertinent regulations, and with provisions approved by the NIRC for specific radiation use authorizations (i.e., safety permits). This function may be delegated to the RSO.

2.4.2.3 The LaRC Safety Manager may delegate some or all of these responsibilities to the Lead Industrial Hygienist, SFAB, SMAO.

2.5 OCCUPATIONAL HEALTH OFFICER

2.5.1 The LaRC Occupational Health Officer (OHO) is a member of SMAO.

2.5.2 Interfaces

2.5.2.1 The OHO’s interfaces include:

a. Contracting Officer’s Representative for medical support services at LaRC (specifically, the LaRC Occupational Health Clinic, 17 Langley Boulevard, Building 1216).

b. Center’s prime contact for matters relating to occupational illnesses or injuries.

2.5.3 Responsibilities

2.5.3.1 The OHO shall:

a. Review the adequacy of physical examination requirements for non-ionizing radiation workers at LaRC and new developments in the area of medical surveillance for these workers.

2.6 RADIATION WORKERS

2.6.1 Interfaces

2.6.1.1 When performing radiation work, radiation workers shall work under the guidance of their operational FSH.

2.6.2 Responsibilities

2.6.2.1 All non-ionizing radiation workers shall:

a. Be cognizant of and comply with LaRC regulations pertaining to non-ionizing radiation safety.

b. Fully understand and comply with all written procedures in the specific use authorization (i.e., safety permit) under which they are authorized to work.

c. Be fully aware of the limitations given in the “Description of Duties” block on the appointment form, and notify the FSH when:

(1) A change in the definition of the limitations is needed.

(2) The need to work in restricted areas has ended.

2.6.2.2 The Principal Investigator (PI) or primary radiation worker responsible for the project should attend NIRC meetings to present their safety controls and procedures to the Committee regarding their safety permit proposals.

2.7 LASER OPERATOR

2.7.1 The laser operators shall:

a. Prevent unauthorized personnel from entering a controlled area during hazardous operations.

b. Be responsible for the overall safety of all personnel in the laser work area.

c. Limit access to the laser work area from all personnel not necessary for the laser research operations per Chapter 5 of this LPR.

d. Exercise authority over the safe operation of the device to which they are assigned.

CHAPTER 3: ROUTINE PROCEDURES AND REQUIREMENTS

3.1 GENERAL

3.1.1 Procedures and requirements relating to non-ionizing radiation at LaRC are included in this Chapter. Questions concerning procedures and requirements shall be directed to the RSO.

3.2 PROCUREMENT AND RECEIPT

3.2.1 Prior to the procurement and receipt of hazardous sources of non-ionizing radiation, the intended user or operator of the source shall complete an LF 44a via the electronic routing system in Langley's Chemical Material Tracking System (CMTS).

3.2.2 Sources that specifically require LF 44a are:

a. All class 3b and 4 lasers and laser systems. Lower classes of lasers do not require an LF 44a.

b. Any other non-ionizing sources of radiation (e.g., ultraviolet light sources, radio frequency generators propagating into free space, high intensity optical sources) that have the potential to exceed human exposure safety limits established by federal regulations or consensus standards.

3.2.3 Facility Safety Head (FSH)

3.2.3.1 The FSH shall:

a. Review and approve LF 44a for systems safety compatibility and compatibility with research objectives.

b. Forward approved LF 44a to the RSO.

3.2.4 Radiation Safety Officer (RSO)

3.2.4.1 The RSO shall:

a. Schedule a pre-operational review with the radiation workers upon receipt of LF 44a. The purpose of this review is to provide the radiation workers with guidance and assistance in the following areas:

(1) Applicability of safety permit requirements.

(2) Preparation of safety procedures.

(3) Preparation of authorizing documents specified in this Chapter.

b. Approve or disapprove the LF 44a following the review.

3.2.5 LaRC Safety Manager

3.2.5.1 The LaRC Safety Manager(s) shall:

a. Upon receipt of LF 44a, review the RSO's review and approve or disapprove the purchase of the non-ionizing radiation source.

3.2.6 Contracting Officer Representative (COR)

If the procurement will result in the acquisition, production, or use of any hazardous or potentially hazardous forms of non-ionizing radiation, examples of which are listed in NPR 1800.1, the COR or requirements owner will ensure the appropriate items are selected from the list below on NASA Form 1707:

a. Lasers and Sources of Hazardous Non-Laser Optical Radiation,

b. High Intensity, Ultraviolet, and Infrared Lights,

c. Radio Frequency (RF) and Microwave Emitters,

3.3 AUTHORIZATION OF USE (SAFETY PERMIT)

3.3.1 Some sources of non-ionizing radiation require the completion and approval of an LF 49, an LF 498, and a related safety plan before the source can be used or operated at any LaRC facility (see Appendix C for guidance on document preparation). This package of documents is referred to as the safety permit.

3.3.1.1 The RSO is responsible for the determination of safety permit requirements during the processing of an LF 44a.

3.3.2 As a general rule, the following sources of non-ionizing radiation shall require the issuance of a safety permit:

a. Class 3b lasers or laser systems, the use of which creates a significant possibility that its users or operators will be exposed to radiation levels in excess of the applicable Maximum Permissible Exposure (MPE) (see Chapter 4 of this LPR).

b. All class 4 lasers or laser systems.

c. All radio frequency (RF) generators capable of propagating RF power into occupied areas in excess of the limits defined in IEEE C95.1.

d. Ultraviolet light sources, as determined by the RSO, which create a significant probability that users or operators will be exposed to ultraviolet radiation levels in excess of applicable Threshold Limit Values (TLV) as recommended by the American Conference of Governmental Industrial Hygienists (ACGIH).

e. Magnetic field sources, as determined by the RSO, which create a significant probability that the users or operators will be exposed to magnetic flux densities in excess of the applicable TLVs as recommended by the ACGIH.

f. Static electric field sources, as determined by the RSO, which create a significant probability that the users or operators will be exposed to electric flux densities in excess of the applicable TLVs as recommended by ACGIH.

g. Visible and infrared light sources, as determined by the RSO, whose use has the probability of exposing personnel to light levels in excess of the TLVs as recommended by the ACGIH.

3.3.3 The LF 49 shall describe the maximum potentially hazardous operating parameters (e.g., maximum radiant power, radiant energy, kilovoltage, amperage) expected during the life of the experiment or operation.

3.3.4 Changes in the operational configuration which (1) do not exceed the authorized maximum parameters or (2) do not change the authorized safety features will not require the processing of a modified safety permit.

3.3.5 Other changes shall require additional review and approval by the NIRC.

3.3.6 A safety permit is valid for a period of one year from date of issuance the first time a facility is issued a safety permit or if an existing safety permit is modified. Subsequent issuances of a safety permit are valid for a period of four years unless the facility is modified such that a revised safety permit shall be issued.

3.3.6.1 If a permit expires, the facility operator shall cease operation until the permit has been renewed or received approval from the branch head and RSO to continue operating under the expired permit while it is being reviewed.

3.3.7 The FSH shall:

a. Review all LF 49s, LF 498s, attached pertinent drawings, sketches, and supporting information prepared by personnel working in their facilities.

b. Sign the LF 49 and LF 498 and forward with attachments to the RSO.

c. Post the approved safety permit in a conspicuous place at the specified site, or if more practical, in the applicable control center for the site.

d. Submit forms for renewal to the RSO at least 30 calendar days prior to its expiration date or submit a new LF 49 anytime a change is required to the authorized maximum operating parameters.

3.3.8 The RSO shall:

a. Perform a radiation hazard analysis of the proposed operation upon receipt of an LF 49 and attachments.

b. Work closely with the radiation worker during this analysis to provide guidance and assistance in the preparation and acquisition of safety procedures, protective equipment, and medical surveillance (if required). Schedule an onsite visit with the radiation worker if necessary.

c. Forward the LF 49, the LF 498, attachments, and recommendations from the hazard analysis to the NIRC for review and action.

d. Verify training/certification listings of radiation workers and laser operators.

e. Review existing safety permits as part of the annual audit to ensure that the permits are not expired and contain up to date information.

3.3.9 The NIRC shall:

a. Review each LF 49, LF 498, and attachments to determine that all reasonable precautions have been taken and that the proposed operations can be carried out with an acceptable level of risk to personnel and equipment.

b. Approve issuance of the safety permit with conditions, if any.

c. Disapprove the safety permit and return to the FSH if problem areas are evident.

d. Withhold approval until additional information is obtained if required. The FSH shall be notified of this action.

e. Review existing safety permits that have been identified by the RSO during the annual audit that require modification or are due for renewal.

3.3.10 The NIRC Committee Chairperson shall:

a. Review all LF 49s, LF 498s, attached pertinent drawings, sketches, and supporting information, and specify, when appropriate, any special conditions on which approval is based.

b. Sign the LF 49 and LF 498 and forward with attachments to the RSO.

c. The NIRC Vice Chairperson may sign an LF 49 and LF 498 in the Chairperson's absence.

d. Forward the approved LF 49, LF 498, and attachments to the LaRC Safety Manager.

3.3.11 The LaRC Safety Manager shall:

a. Review the safety permit for impact on the environment or creation of safety hazards outside the scope of radiation health.

b. Sign the LF 49 and the LF 498 and return all attached documentation to the FSH.

c. Return the safety permit to the FSH if problem areas are evident.

CHAPTER 4: SPECIAL PROCEDURES AND REQUIREMENTS

4.1 USE OF LASERS IN NAVIGABLE AIRSPACE

4.1.1 The Federal Aviation Administration (FAA) is responsible for regulating the safe and efficient utilization of navigable air space and ensuring the safety of aircraft. Laser experiments or programs that should submit FAA form 7140-1 as advised by the FAA Advisory Circular AC 70-1 shall coordinate outdoor laser mission details with, and request a Letter of Determination from, the FAA at least 30 days prior to propagation of the related mission's laser beam through the U.S. navigable airspace. The RSO usually acts as the liaison between the FAA and the laser operation.

4.1.2 FAA safety requirements for atmospheric lasers can be found in FAA Advisory Circular AC 70-1. NASA LaRC complies with the requirements of FAA Advisory Circular AC 70-1 as well as ANSI Z-136.6, SAE AS6029A, and the NASA Laser Safety Review Board (LSRB)

4.1.3 Outdoor laser projects shall also request a letter of concurrence from the NASA LSRB prior to operations unless specifically exempt from LSRB review according the LSRB’s charter and bylaws.

4.1.4 Outdoor laser projects will coordinate with, and obtain permission from, the controlling authority (e.g., military base command), when operating lasers in restricted airspace.

4.2 SPECIAL REQUIREMENTS FOR OFF-SITE RADIATION USE

4.2.1 Additional requirements and approvals are needed for LaRC organizations wishing to operate lasers and other non-ionizing radiation sources off-site. The term off-site refers to any facility not under the administrative control of LaRC, such as another NASA facility, a contractor’s site, open-air operations, or air and space flights. In these circumstances, the following requirements shall be satisfied in addition to the safety permit:

a. A safety representative from the requesting organization, having primary responsibility for all safety aspects associated with the operation of such system, shall be appointed for the off-site operation.

(1) The safety representative shall be the point of contact for any issues or concerns the NIRC might have regarding the use of the source or sources for the off-site operations.

b. A safety review shall be included as part of the total design review process. The safety representative is responsible for notifying the NIRC of any design review meetings.

c. Authorization shall be obtained from the administration or authorities for the jurisdiction or site where the non-ionizing radiation source is to be operated.

d. Use of the non-ionizing radiation source shall be concurred with by the safety organization for that jurisdiction.

e. To assure minimal radiation exposure to individuals, the safety representative, with the cognizance or guidance of the RSO, shall perform monitoring tasks as determined necessary by the NIRC.

f. All records of the radiation surveys shall be maintained by the safety representative and submitted to the RSO at the completion of the authorized use.

g. Any incident involving overexposure to individuals shall be reported immediately to the RSO and the NIRC Chairperson.

4.2.2 The RSO, in support of off-site operations, shall:

a. Act as the initial point of contact between the NIRC and the organization or individual wishing to operate a non-ionizing radiation source off site.

b. Maintain records of off-site operations, such as safety permits, approval correspondence, safety violations or incidents, and other pertinent documentation.

c. Relay any reported incident or violation to SMAO, the Executive Safety Council, and the NIRC.

d. Assist with safety calculations.

4.2.3 Failure To Comply

4.2.3.1 Failure to comply with this LPR, or any regulation cited by this LPR, may result in the suspension or termination of the non-ionizing radiation safety permit.

4.3 INTERIM SAFETY PERMIT APPROVALS

4.3.1 When an immediate use of non-ionizing radiation is determined necessary, the RSO, with concurrence from the Chairperson, NIRC, may approve a new safety permit or modify/renew an existing one outside of the normally scheduled NIRC meeting provided that the NIRC is informed and the action is ratified at the next NIRC meeting.

4.3.2 Approvals may be withdrawn at any time if safety violations or use of a source out of compliance with conditions of the approved authorization occur.

4.4 AUDITS

4.4.1 The RSO shall be responsible for conducting an audit of each facility possessing sources of non-ionizing radiation at least annually.

4.4.1.1 The results of the audits are to be presented to the NIRC during their periodic meetings.

4.4.1.2 Typical items covered during an audit are:

a. Inventories of:

(1) Lasers and laser systems,

(2) RF sources/microwave sources,

(3) Ultraviolet sources,

(4) Magnetic sources, and

(5) Electric field sources.

b. Records of:

(1) Worker certification and training and.

(2) Medical surveillance (if required).

c. Compliance with terms of the approved safety permit for the operation.

d. Selection and care of personal protective equipment (PPE).

e. Adequacy and operability of safety interlocks.

f. Area posting and signage.

g. Conduct of routine radiation protection surveys by the RSO as necessary.

4.5 TRAINING AND CERTIFICATION

4.5.1 All personnel who operate, manipulate, or have any other type of physical control over the use of non-ionizing radiation equipment specifically authorized by a safety permit (new or existing) shall be trained and certified as radiation workers in accordance with LPR 1740.6.

4.5.1.1 Each FSH shall ensure that personnel within the facility are trained and certified. Questions concerning this requirement should be directed to the RSO.

4.5.2 Safety Permits

4.5.2.1 All workers performing work under an approved safety permit shall be certified and listed on the permit.

4.5.2.2 Certified workers may be added to or removed from a permit by the RSO without modifying the permit.

4.6 INTERNAL TRANSFER

4.6.1 All sources of non-ionizing radiation authorized by a NASA Langley safety permit and located in a particular facility shall not be transferred to the accountability of another organization or transferred from one location to another, either within LaRC or external to LaRC, without prior notification of the RSO and subsequent modification of the existing safety permit, as described in this Chapter.

4.6.1.1 This requirement is in addition to any action required for NASA property control procedures.

CHAPTER 5: LASERS

5.1 GENERAL

5.1.1 The laser safety program at LaRC is based upon maintaining compliance with ANSI Z136.1. The following information is provided as a brief synopsis of the safety requirements in the ANSI standard and to point out any Center-specific requirements that exist. In general, if there is a disagreement between the requirements of this document and the ANSI standard, personnel shall adhere to the more conservative requirement. Deviations from the requirements of the ANSI standard may be granted on a case-by-case basis with the approval of the RSO and the NIRC.

5.2 LASER HAZARD CLASSIFICATION

5.2.1 The laser classification scheme is based on the accessible radiation during operation and the emission limit for that wavelength. Classification labeling used in conformance with the Federal Laser Product Performance Standard shall be used to satisfy this labeling requirement.

5.2.1.1 In the event that a laser or laser system has been modified subsequent to classification by the manufacturer, the RSO may classify the laser or laser system following the criteria provided in ANSI Z136.1.

5.2.2 Class 1 or Exempt Lasers

5.2.2.1 Class 1 or exempt lasers can be thought of as inherently safe lasers. Class 1 lasers have no accessible light in excess of the accessible emission limit (AEL). Higher hazard class lasers that have been enclosed in such a manner as to prevent exposure of personnel to laser light in excess of the AEL may be classified as a Class 1 laser system.

5.2.3 Class 2 or "Low-Power" Laser Devices

5.2.3.1 Class 2 or “low power” laser devices are visible lasers that do not have enough power to injure a person under accidental exposure conditions (i.e., 0.25 seconds or less). Class 2 lasers have a power limit of 1 mW.

5.2.4 Class 3 lasers

5.2.4.1 Class 3 lasers are sub-classified as either class 3R or class 3b. Class 3 lasers may be capable of causing injury to the eye if the laser beam is viewed either directly or by specular reflection. Class 3R lasers typically have a power limit of 5 mW. Class 3b lasers typically have a power limit of 500 mW.

5.2.5 Class 4 Lasers

5.2.5.1 Class 4 lasers are capable of causing injury to both the eye and the skin. The hazard posed by Class 4 lasers may be from directly or indirectly viewing the laser beam or its reflection and may come from diffusely reflected light. Laser sources with an irradiance of greater than 0.5 W/cm^2 can be capable of igniting combustible materials.

5.2.6 Class 1M and 2M lasers

5.2.6.1 These classifications are for a laser whose beams would exceed the exposure limit for a Class 1 or Class 2 laser if viewed with an optical aid, such as binoculars.

5.3 CONTROL MEASURES AND PROCEDURES

5.3.1 Appropriate control measures and procedures shall be used for all lasers and laser systems at LaRC to reduce the possibility of exposure of the eye and skin to hazardous laser radiation and to other hazards associated with operation of laser devices.

5.3.1.1 For all lasers and laser systems, operators shall use the minimum power or energy necessary for the application.

5.3.2 Laser Classifications 1, 2 and 3R

5.3.2.1 The only required control measure applicable to these lasers shall be an appropriate warning label affixed to a conspicuous place on the laser housing or control panel, or both the housing and control panel. Guidelines for the safe use of Class 3R lasers are available from the RSO.

5.3.3 Laser Classification 3b

5.3.3.1 Those Class 3b lasers which have been determined to require the issuance of an approved safety permit for their use shall comply with the control measures and procedures in this document. The RSO may waive some of the requirements of this section for low power Class 3b lasers on a case-by-case basis.

5.3.3.2 Education and Training

5.3.3.2.1 All personnel using the laser or laser system shall be informed of the potential hazards of the laser operation.

5.3.3.2.2 All users and personnel present during use shall be certified as laser workers per LPR 1740.6.

5.3.3.3 Engineering Controls

5.3.3.3.1 Priority shall be given to the incorporation of appropriate safety mechanisms as an integral part of the laser or laser system. Examples include beam stops, beam enlarging systems, enclosures, shutters, and fail-safe interlocks.

5.3.3.4 Laser Controlled Area

5.3.3.4.1 Upon completion of a hazard analysis of the lasers or laser systems to be used in a particular location, the RSO shall define the boundaries of the laser-controlled area.

5.3.3.4.2 The boundaries of the laser-controlled area will be marked with laser warning signs. Typically, an entire laboratory or room will be considered the laser-controlled area, its walls and ceiling defined as the boundary, and laser warning signs placed on all doors/entrances into the laboratory or room.

5.3.3.4.3 Special emphasis shall be placed on control of the path of the laser beam. Some examples of good beam control include creating a well-defined beam path prior to operation, making slow deliberate adjustments during alignment, looking for and blocking any stray reflections, and blocking the beam at the shortest distance needed for the application.

5.3.3.5 Spectators

5.3.3.5.1 Spectators shall not be permitted into the laser controlled area unless appropriate supervisory approval has been obtained, protective measures taken, and laser eyewear provided and worn at all times while the laser is operating.

5.3.3.5.2 Spectators shall be accompanied at all times by a laser certified worker who is knowledgeable of the particular laser operation.

5.3.3.6 Beam Enclosures

5.3.3.6.1 The emitted laser radiation shall be contained within enclosures whenever practicable.

5.3.3.6.2 Laser beams emitted by non-enclosed systems shall be terminated at the end of the useful beam path when the exposure level is greater than the MPE for direct irradiation of the eye and a possibility of human exposure exists.

5.3.3.7 Alignment Procedures

5.3.3.7.1 Alignment of laser optical systems (e.g., mirrors, lenses, beam deflectors) shall be performed in such a manner that the primary beam, or a specular reflection of the primary beam, does not expose the eye to a level above the MPE for direct irradiation of the eye.

5.3.3.8 Optical Viewing Aids

5.3.3.8.1 Optical systems such as lenses, telescopes, and microscopes may increase the hazard to the eye when viewing a laser beam; therefore, special care shall be taken in their use.

5.3.3.8.2 Microscopes and telescopes may be used as optical instruments for viewing, but shall be provided with an interlock or filter, if necessary, to prevent ocular exposures above the appropriate MPE for irradiation of the eye.

5.3.3.9 Eye Protection

5.3.3.9.1 Eye protection devices specifically designed for protection against laser radiation shall be used when engineering and procedural controls do not fully eliminate potential exposure in excess of the applicable MPE.

5.3.3.10 Equipment Labeling

5.3.3.10.1 Lasers shall have warning labels with the appropriate cautionary statement affixed to a conspicuous place on the laser housing or control panel. Such labels should be placed on both the housing and the control panel if these are separated by more than two meters.

5.3.3.11 Diffusely Reflecting Materials

5.3.3.11.1 In addition to beam stops, shields, and enclosures, materials that will diffusely reflect any stray or incidental laser beams shall be used in laser areas whenever possible.

5.3.4 Laser Classification 4

5.3.4.1 The probability of injury and the extent of injury increases with increasing laser output power. High-power lasers require more rigid control measures, not only because there is a greater likelihood that specular reflections will have sufficient power to cause injury, but because of the greater risk of injury from hazardous diffuse reflections. The entire beam path capable of producing hazardous diffuse reflections shall be controlled. Controls shall rely primarily on more positive methods, such as enclosures and interlocks, and secondarily upon procedural safeguards.

5.3.4.2 Specific Laser Controlled Area Requirements:

a. Laser devices shall be isolated in an area designated for laser operations.

b. Access to such an area shall require appropriate authorization and all users and personnel present during use shall be certified as laser workers.

c. Under conditions where the entire beam path is not enclosed, safety latches or interlocks shall be used to prevent unauthorized entry into laser-controlled areas.

(1) Such measures shall be designed to allow both rapid egress by laser personnel at all times and admittance to the laser-controlled area in an emergency condition.

(2) For such emergency conditions, an emergency stop, i.e., E-stop, button shall be available for deactivating the laser.

(3) Interlock overrides are permissible in laser-controlled areas with specific approval by the RSO.

(4) If a casual passersby can gain access to an interlock bypass key, the room shall have a door that requires either a separate key or a passcode to open.

d. During tests requiring continuous operation, the person in charge of the controlled area shall be permitted to momentarily override the safety interlocks to allow access of other authorized personnel if it is clearly evident that there is no radiation hazard at the point of entry, and if the necessary protective devices are worn by the entering personnel.

e. Should removal of the protective covers or the overriding interlocks become necessary for special training, service adjustments, or maintenance procedures, a temporary laser-controlled area shall be devised following specific procedures approved by the RSO outlining all safety requirements during the service and maintenance procedures.

(1) Such a temporary laser-controlled area shall nevertheless provide for all safety requirements for all personnel, both within and without the temporary laser-controlled area during the service or maintenance procedure.

f. Under conditions where the entire beam path is not completely enclosed and the laser is capable of emission, access to the laser-controlled area shall be limited to persons wearing laser protective eyewear.

(1) In this case, all other optical paths (e.g., windows) from the facility shall be covered or restricted in such a way as to reduce the transmitted intensity of the laser radiation to levels at or below the MPE for direct irradiation of the eye.

(2) Specularly reflecting surfaces that are not required when using the laser shall be removed from the beam path.

g. The purpose of control measures is to reduce the possibility of exposure to hazardous levels of laser radiation and to associated hazards.

(1) Therefore, it may not be necessary to implement all of the control measures given.

(2) Whenever the application of any one or more control measures reduces the possible exposure to a level at or below the applicable MPE, the application of additional control measures should not be necessary.

5.3.4.3 Enclosed Beam Path

5.3.4.3.1 Whenever possible, the entire beam path shall be enclosed. This includes the interaction area, where irradiation of materials by the primary or secondary beams occurs.

5.3.4.3.2 Enclosures shall be equipped with interlocks so that the laser system will operate only when enclosures are installed.

5.3.4.3.3 For pulsed systems, interlocks shall be designed so as to prevent firing of the laser by dumping the stored energy into a dummy load.

5.3.4.3.4 For continuous wave (CW) lasers, the interlocks shall turn off the power supply or interrupt the beam by means of shutters.

5.3.4.3.5 Interlocks shall not allow automatic re-energizing of the power supply nor opening of the shutter, but shall be designed so that after tripping the interlock, the power supply or shutter shall be reset manually.

5.3.4.4 Remote Firing and Monitoring

5.3.4.4.1 Whenever possible, the laser system shall be fired and monitored from remote positions.

5.3.4.5 Warning Systems

5.3.4.5.1 Warning systems are required for lasers as follows:

a. An alarm system (e.g., an audible sound, a warning light visible through protective eyewear, a verbal “countdown” command) shall be used prior to laser activation.

b. The audible system may consist of a bell or chime that commences when a pulsed laser power supply is charged for operation (e.g., during the charging of capacitor banks).

5.3.4.6 Key-Switch Master Interlock

5.3.4.6.1 Any laser or laser system designated as class 4 shall be provided with an operative keyed master interlock or switching device.

5.3.4.6.2 The key shall be removable, and the device shall not be operable when the key is removed.

5.4 NON-BEAM HAZARDS AND CONTROLS

5.4.1 Control of Laser Explosion Hazards

5.4.1.1 High-pressure arc lamps and filament lamps in laser equipment shall be enclosed in housings that can withstand the maximum explosive pressures resulting from lamp disintegration.

5.4.1.2 The laser target and elements of the optical train that may shatter during laser operation shall also be enclosed or equivalently protected to prevent injury to operators and observers.

5.4.2 Control of Laser Electrical Hazards

5.4.2.1 The intended application of the laser equipment determines the method of electrical installation and connection to the power supply circuit (e.g., conduit versus flexible cord). All equipment shall be installed as outlined in NFPA 70, Articles 300 and 400.

> *Note: Such installed equipment is acceptable to the U.S. Department of Labor, OSHA, if accepted, certified, listed, labeled, or otherwise determined safe by a qualified testing laboratory, such as, but not limited to, Underwriters Laboratories (UL) Incorporated and Factory Mutual Corporation.*

5.4.2.2 Shock Hazard

5.4.2.2.1 The following controls are recommended to avoid laser electrical shock hazards:

a. Live parts of circuits and components with peak open circuit potentials over 42.5 volts are considered hazardous, unless limited to less than 0.5 mA. Such circuits require positive protection against contact.

(1) For equipment intended for general use, interlock switches (and capacitor bleeder resistors, if applicable) or their equivalent shall be installed to remove the voltage from accessible live parts to permit servicing operations.

(2) Bleeder resistors shall be of such size and rating as to carry the capacitor discharge current without burnout or mechanical injury.

(3) Circuits and components with peak open-circuit potentials of 2,500 volts or more shall be adequately covered or enclosed if an appreciable capacitance is associated with the circuits.

b. If servicing of equipment requires entrance into an interlocked enclosure, a solid metal grounding rod shall be utilized to assure discharge of high voltage capacitors.

(1) The grounding rod shall be firmly attached to ground prior to contact with the potentially live point.

(2) A resistor grounding rod (e.g., a large wattage ceramic resistor) may be used prior to application of the aforementioned solid conductor grounding rod to protect circuit components from overly rapid discharge, but not as a replacement.

5.4.2.3 Grounding

5.4.2.3.1 The frames, enclosures, and other accessible metal, non-current carrying metallic parts of laser equipment shall be grounded.

5.4.2.3.2 Grounding shall be accomplished by providing a reliable, continuous, metallic connection between the part or parts to be grounded and the grounding conductor of the power wiring system.

5.4.2.3.3 Metal optical tables shall be bonded to the building grounding system.

5.4.2.4 Electrical Fire Hazards

5.4.2.4.1 Components in electrical circuits shall be evaluated with respect to fire hazards.

5.4.2.4.2 Circuit components of combustible material, such as transformers, that do not pass a short-circuit test without ignition shall be provided with individual noncombustible enclosures.

5.4.2.4.3 Power supply circuit wiring shall be completely enclosed in noncombustible material.

5.4.2.5 Electrical Hazards from Explosion

5.4.2.5.1 Gas laser tubes and flash lamps shall be supported to ensure that their terminals can make no contact that will result in a shock or fire hazard in the event of a tube or lamp failure.

5.4.2.5.2 Components such as electrolytic capacitors may explode if subjected to voltages higher than their ratings, with the result that ejected metal may bridge live electrical parts. Such capacitors shall be proof tested to make certain they can withstand the highest probable potentials should other circuit components fail unless the capacitors are adequately contained so as not to create a hazard.

5.4.3 Hazardous materials

5.4.3.1 Some types of laser systems, such as dye and excimer lasers, utilize hazardous materials in their operations. Many laser dyes have been found to possess hazardous properties such as carcinogenicity or mutagenicity. In addition, some of the solvents used to dissolve the laser dyes have hazardous properties of their own or enhance the hazardous properties of the dyes. Excimer lasers may use gases that are corrosive and/or toxic and require appropriate ventilation systems to manage this hazard. Laser systems that use hazardous materials should have the process reviewed by the Center's industrial hygiene staff and may require a Potentially Hazardous Materials (PHM) permit in accordance with LPR 1710.12.

5.4.4 Other Forms of Radiation

5.4.4.1 Lasers may be capable of emitting other forms of non-ionizing or ionizing radiation during their operation, such as x-rays or radiofrequency waves. The RSO shall review the potential for these hazards as part of the hazard analysis.

5.4.5 Laser Generated Airborne Contaminants

5.4.5.1 Laser systems that possess sufficient energy to cause material alteration or ablation have the potential to release laser generated airborne contaminants (LGACs). These contaminants may be a respiratory hazard and shall be adequately controlled through the use of ventilation and/or enclosure of the work area.

5.4.5.1.1 Review of these types of systems shall be coordinated with the Center's industrial hygiene staff.

5.5 LASER PROTECTIVE EYEWEAR

5.5.1 Laser protective eyewear shall be worn when engineering and/or administrative controls are impractical or insufficient to reduce eye exposure to laser radiation below the applicable MPE.

5.5.1.1 The RSO shall be consulted regarding the selection of eyewear.

5.5.1.2 The following factors shall be considered in determining the appropriate protective eyewear:

a. Wavelength of laser output.

b. Radiant exposure or irradiance.

c. MPE value.

d. Optical density of eyewear at the specific laser output wavelength visible light transmission requirement.

e. Minimum radiant exposure or irradiance at which damage to the laser protective eyewear might be expected to occur.

f. Need for prescription glasses.

g. Comfort.

h. Degradation of absorbing media.

i. Need for peripheral vision.

5.5.2 Specification of Optical Density

5.5.2.1 The attenuation of Optical Density (OD) of laser protective eyewear at a specific wavelength shall be specified.

Note: Many lasers radiate at more than one wavelength; thus, eyewear designed to have an adequate OD for a particular wavelength could have a completely inadequate OD at another wavelength radiated by the same laser. This problem may become particularly serious with lasers that are tunable over broad frequency bands.

5.5.2.2 If the Actual Eye Exposure is given by H_o, then the OD required of protective eyewear to reduce this exposure to the MPE is given by:

$$OD = \log10 \, (H_o / MPE)$$

where the units of H_o are the same as those of the appropriate MPE.

Note: It should be noted that optical densities greater than three or four (depending on exposure time) could reduce eye exposures below the ocular MPE, but leave the unprotected skin surrounding the eyewear exposed to values in excess of the MPE for skin exposure.

5.5.2.3 Attenuation through the protective material shall be determined from all anticipated viewing angles and at all wavelengths.

5.5.3 Visible Light Transmission

5.5.3.1 Adequate OD, at the laser wavelengths of interest, shall be weighed with the need for adequate visible light transmission (VLT). It is recommended to use eyewear with a VLT of 20% or more wherever possible to allow the user sufficient visual acuity while working.

5.5.4 Identification of Eyewear

5.5.4.1 All laser protective eyewear shall be clearly labeled with OD values and wavelengths for which protection is afforded.

5.5.5 Comfort and Fit

5.5.5.1 Protective eyewear shall provide a comfortable and snug fit so that laser radiation is satisfactorily attenuated before reaching the viewer's eyes.

5.5.6 Inspection

5.5.6.1 Periodic inspections shall be made by each user of protective eyewear to ensure the maintenance of satisfactory conditions, to include:

a. Inspecting the attenuator material for pitting, crazing, cracking, and so forth.

b. Inspecting the goggle frame for mechanical integrity and light leaks.

c. Ensuring that labeling of protective eyewear is in compliance with this Chapter.

5.6 SUSPECTED OVEREXPOSURE AND MEDICAL SURVEILLANCE

5.6.1 Personnel with an actual or suspected laser-induced injury should be evaluated by a medical professional as soon as possible after the exposure and usually within 48 hours.

5.6.2 The personnel should report the incident to their supervisor, the LaRC Occupational Health Clinic, and the LaRC LSO as soon as possible after the suspected or actual injury.

5.6.3 Pre-assignment medical examinations are not required at LaRC for laser workers based on the rationale provided in ANSI Z136.1.

CHAPTER 6: NON-COHERENT OPTICAL SOURCES

6.1 GENERAL INFORMATION

6.1.1 Non-coherent optical sources, such as ultraviolet (UV), visible, and infrared light, are capable of causing injury to the skin and eyes. All non-coherent optical sources capable of exposing workers to an irradiance level greater than the limits recommended in the ACGIH's TLVs and Biological Exposure Indices (BEIs) guidelines require the issuance of a safety permit by the RSO and NIRC.

6.1.1.1 Users of non-coherent optical sources shall consult the RSO to determine the appropriate exposure limits for these sources.

Table 6-1. Types of Optical Radiation, Injury Caused, and Typical Sources

Source description	Emission type	Potential effects
Sunlight	Ultraviolet, visible, near infrared	Skin cancer, cataracts, sunburn, premature skin aging, retinitis
Arc lamps	Ultraviolet, visible, near infrared	Photokeratitis, erythema, skin cancer, retinal injury
Germicidal lamps	Ultraviolet	Erythema, photokeratitis, premature skin aging, skin cancer
Carbon arc lamps	Ultraviolet, blue light	Photokeratitis, erythema, photoretinitis
Metal halide arc lamps	Ultraviolet, blue light	Cataracts, photosensitive skin reactions, photoretinitis

6.2 ULTRAVIOLET RADIATION USE SPECIFIC SAFETY REQUIREMENTS

6.2.1 UV Exposure General Information

a. Ultraviolet light is defined as electromagnetic radiation in the spectral region between 180 and 400 nanometers (nm). It is further divided into UV-A (315 nm to 400 nm), UV-B (280 nm to 315 nm), and UV-C (100 nm to 280 nm).

b. The ability of UV radiation to penetrate human tissue depends on wavelength. UV-A is the most penetrating among the UV groups and it can cause skin damage and cataract formation. UV-B is the most destructive form of UV, and it can cause erythema (i.e., sunburn) and corneal burn. The UV-B erythema threshold is 1,000 times lower that the erythema threshold of UV-A, and it is much more effective in causing damage to live tissue then UV-A. UV-C cannot penetrate the dead layer of human skin; however, it can produce corneal burn. UV-C kills bacteria and it is used in germicidal lamps.

c. Immediate or prolonged exposure to UV light can result in painful eye injury, skin burn, premature skin aging, or skin cancer. Individuals who work with or in areas where UV sources are used are at risk for UV exposure if the appropriate shielding and protective equipment are not used.

6.2.2 Applications

a. UV sources are used in a variety of applications and locations. Sources that create a potential for exposure to UV light include, but are not limited to:

(1) Arc welding;

(2) Mercury-Xenon Arc Lamps;

(3) UV curing lamps;

(4) Black lights;

(5) Germicidal UV lights, including biological safety cabinets;

(6) Transilluminators; and

(7) Mercury vapor lamps with broken or missing envelopes.

b. For some of the sources described, the user may not be fully protected from UV light exposure by any inherent shielding around the source, interlocks, or may not be aware of the hazard of UV light.

6.2.3 Hazards associated with UV radiation

a. Eye Hazards

(1) The cornea and lens are the main areas of the eyes affected by UV radiation. Various components of the human eye are susceptible to damage arising from photochemical effects as a result of extended exposure to direct/reflected UV radiation. The UV wavelength is the determining factor as to which part(s) of the eye may absorb the radiation and suffer biological effects.

(2) The cornea is similar to the skin in that it can be burned by exposure to too much UV radiation. This is called keratoconjunctivitis (i.e., snow blindness or welders flash) and is a condition where the corneal (epithelial) cells are damaged or destroyed. This condition usually does not present until 6 to 12 hours following the UV exposure. Although very painful (often described as having sand in the eyes) this condition is usually temporary (e.g., a few days) because the corneal cells will grow back. In very severe cases, the cornea may become clouded and corneal transplants may be needed to restore vision. Exposure to UV-C and UV-B presents risk to the cornea.

(3) The lens of the eye is unique in that it is formed early in human development and is not regenerated should it become damaged. For normal vision, it is essential that the lens remains clear and transparent. Unfortunately, UV-A exposure is suspected as a cause of cataracts (i.e., clouding of the lens).

b. Skin Hazards

(1) UV radiation is a known carcinogen for human skin. In addition to cancer induction, erythema (i.e., sunburn), and skin aging are also known effects of UV skin exposure. Because the biological effects are dependent on the time of exposure, the specific UV wavelength, and the susceptibility of the individual exposed, it is considered prudent to prevent unnecessary skin exposure to UV sources. Elimination of unnecessary skin exposure is advisable as most

individuals will receive substantial UV exposure from the sun during normal outdoor activities over a human lifetime.

6.2.4 UV Radiation Exposure Guidelines

a. The TLVs for UV radiation incident on the skin or eye, from the ACGIH's TLVs and BEIs guidelines, shall be followed when personnel are potentially exposed to this form of non-ionizing radiation.

b. These values do not apply to UV lasers, exposure to photosensitive individuals or individuals concomitantly exposed to photosensitizing agents/medications, or for eye exposures to individuals who have had the lens of the eye removed in cataract surgery (e.g., aphakes).

6.2.5 Control Measures

a. Engineering Controls

(1) The preferred control method is the use of engineering controls to contain UV radiation. UV enclosures and interlocks supplied by the manufacturer shall be used at all times.

(2) UV radiation is easily shielded by opaque materials such as metal, wood, and cardboard. Polycarbonate materials are also a good UV shield. Some types of clear glass (e.g., quartz, borosilicate) and plastics (e.g., polystyrene, Plexiglas, polyethylene) may transmit significant amounts of UV-A radiation and should not be relied on for UV protection unless the shielding is verified adequate by the health and safety staff.

b. Administrative Controls

(1) Procedures should be developed to control and minimize UV exposure to personnel where engineering controls cannot adequately protect personnel from UV exposure. The procedures would include controls such as preventing unauthorized access to UV hazard areas and limiting time in the area.

(2) Warning or Caution signs should be used to identify UV hazards.

c. Personal Protective Equipment

(1) If engineering and administrative controls cannot protect personnel from UV exposure, PPE should be used. Commonly used PPE against UV are as follows:

(a) UV safety glasses/goggles,

(b) Polycarbonate face shields,

(c) Fully buttoned lab coat,

(d) Long pants,

(e) Closed toe shoes, and

(f) Gloves.

6.2.6 Equipment and Area Label

a. To prevent eye and skin injuries, sources of UV light shall be conspicuously labeled with a warning attached to the housing of the source. The warning sign should state something similar to these statements:

(1) Warning: This device produces potentially harmful UV light. Protect eyes and skin from exposure.

(2) Warning: UV hazard. Protect eyes and skin from exposure.

(3) Warning: UV Light. Do not look directly at light.

(4) Warning: UV hazard. Do not operate this equipment with the interlocks or covers removed.

6.2.7 UV Radiation Protection from the Sun

a. Outdoor workers can minimize solar UV exposure by:

(1) Use of shade where practical.

(2) Avoiding the outdoors when the sun is most intense, 11 a.m. to 4 p.m.

(3) Use of wide brimmed hats and long and tightly woven clothing to cover skin.

(4) Use of sunscreen, minimum Sun Protection Factor (SPF) 30.

(5) Use of UV-blocking sunglasses.

6.2.8 UV Radiation Use

a. Projects involving sources of UV radiation shall contact the Langley RSO prior to use so an evaluation of the hazard can be completed. In certain cases where a high UV hazard is present, a safety permit and specific approval by the NIRC shall be required.

6.2.9 Training

a. Individuals who use UV sources require training that is commensurate with the associated hazards. UV training will be provided by the LaRC RSO as required.

6.2.10 Suspected Overexposure and Medical Surveillance

a. If an eye or skin injury related to UV exposure is suspected, the individual should proceed directly to the Langley Occupational Health Clinic or an outside medical professional for evaluation.

b. The individual should report the incident to their supervisor, the LaRC Occupational Health Clinic, and the LaRC RSO as soon as possible after the suspected or actual injury.

c. Pre-assignment medical examinations are not required at LaRC for UV radiation workers.

CHAPTER 7: RF RADIATION SAFETY

7.1 GENERAL INFORMATION

7.1.1 This section outlines the requirements to minimize the negative impact that exposures to electric, magnetic, and electromagnetic radiation can have on personnel health. IEEE C95.1 covers safe levels involving both restricted and unrestricted environments. Safety limits for static fields and sub-radiofrequencies are provided in the ACGIH's TLVs and BEIs guidelines.

> *Note: The recommendations in IEEE C95.1 may not prevent interference with medical and implantable electronic devices that may be susceptible to Electromagnetic Interference (EMI). The recipient and provider of these devices should be aware of the potential for hazards and precautions that might be necessary with such devices while working around EMI. Refer to the* personnel's *medical practitioner and/or the manufacturer of the device for limit precautions. Examples of such devices where there are concerns for interactions include pacemakers, defibrillators, drug delivery pumps, neuro-stimulators, hearing aids, powered wheelchairs and AEDs. The ACGIH offers static magnetic field exposure limit guidelines for medical implant device wearers in the ACGIH's TLVs and BEIs guidelines.*

7.1.2 Radiofrequency (RF) radiation refers to electromagnetic fields with frequencies between 3 kHz and 300 MHz, while microwave radiation covers fields from 300 MHz to 300 GHz. As they have similar characteristics, RF and microwave radiation are usually treated together.

7.1.3 RF radiation is produced by devices such as radio and TV transmitters, induction heaters, and dielectric heaters (also known as RF sealers). Microwave radiation is produced by microwave ovens, parabolic (i.e., dish) antennas, radar devices, and diathermy applicators.

7.2 POTENTIAL BIOLOGICAL EFFECTS OF RF EXPOSURE

a. The nature and the degree of the health effects of overexposure to microwave/RF fields depend on the frequency and intensity of the fields, the duration of exposure, the distance from the source, any shielding that may be used, and other factors.

b. The main effect of exposure to microwave/RF fields is heating of body tissues as energy from the fields is absorbed by the body. Prolonged exposure to strong microwave/RF fields may increase the body temperature producing symptoms similar to those of physical activity. In extreme cases, or when exposed to other sources of heat at the same time, the body's cooling system may be unable to cope with the heat load, leading to heat exhaustion and heat stroke.

c. Localized heating may lead to burns to external and internal tissues. Hot spots can be caused by non-uniform fields, by reflection and refraction of microwave/RF fields inside the body or by the interaction of the fields with metallic implants (e.g., cardiac pacemakers or aneurism clips). There is a higher risk of damage to organs which have poor temperature control, such as the lens of the eye and the testes.

d. Other hazards include contact shocks and RF burns. These can result from the electric currents which flow between a conducting object and a person who comes into contact with it while they are exposed to RF fields; these effects should not be confused with shocks from static electricity.

7.3 RF RADIATION WORKER'S RESPONSIBILITIES

7.3.1 The radiation workers using microwave/RF equipment are personally responsible for compliance with the microwave/RF IEEE C95 safety standards and LaRC regulations in all operations. Operations are authorized by the NIRC through the issuance of a safety permit. Worker responsibilities shall include:

a. Preparation of an initial safety plan document for new projects or modifications of existing facilities.

b. Providing safety instructions to personnel using equipment under their direction.

c. Completing radiofrequency electromagnetic radiation safety training as specified by the RSO.

d. Prohibiting use of the equipment unless there is adequate control of hazards, including warning signs and interlocks as necessary.

e. Notifying the RSO, within 24 hours, when known or suspected overexposure to microwave/RF radiation has occurred.

f. Adopting practices that will not intentionally expose an individual to microwave/RF radiation in excess of the AELs.

7.4 MICROWAVE/RF PROJECT SAFETY REVIEW

7.4.1 Prior to installing new microwave/RF equipment or modifying existing equipment that requires a safety permit as determined by the RSO, a written safety plan shall be submitted by the radiation worker to the RSO for review by the NIRC.

7.4.1.1 The document shall include:

a. A description of the system and its application.

b. A diagram showing the location of operation and emission path of the RF radiation.

c. Operating parameters.

d. Frequency.

e. Antenna dimensions.

f. Power output.

g. Antenna type.

h. Pulse description.

i. Antenna gain.

j. Polarization of transmitted wave.

k. Standard operating procedures (SOPs), which will be posted near the equipment, and which are designed to minimize hazards to personnel.

7.4.2 The project shall be reviewed by the RSO on an annual basis, or more frequently if there are changes to the researcher's project that affect RF safety.

7.5 LANGLEY RF SPECTRUM MANAGEMENT

7.5.1 In addition to meeting requirements in this LPR for human safety, RF users should also contact the Langley Spectrum Management Office prior to transmitting RF signals on the Center to ensure that the proper licensing/authorizations are received. The Spectrum Management Office ensures that RF interference is avoided, and permission is granted to transmit on specific bands whereas the Langley Radiation Safety program as described in this LPR is concerned with human safety and ensuring that human exposures to RF radiation are ALARP.

7.5.2 The Langley RF spectrum management procedural requirements are contained in LPR 2570.5, and RF radiation workers can contact the Spectrum Management Office at (757) 864-6737.

7.6 OPERATIONAL SAFETY

7.6.1 The following rules apply when RF radiation exceeding applicable limits is produced by equipment operated at LaRC.

a. Safety permits shall be posted near all operational equipment. The permit outlines suitable radiation protection procedures.

b. Emphasis should be placed on using engineering controls such as interlocks, shielding, and physical barriers wherever practical.

c. Only individuals who have been instructed in the potential hazards of microwave/RF radiation and applicable SOPs are permitted to use the equipment.

d. Microwave/RF warning signs shall be posted to define controlled areas (see Section 7.7).

e. Access to areas where RF radiation exceeds the limits shall be restricted. When appropriate, physical barriers shall be used.

f. Dummy loads shall be used whenever free-space radiation is not required by the mission.

g. Radiating antennas shall not be positioned in such a manner as to intercept occupied facilities, structures, or personnel within the identified hazard zone.

h. The RF beam path shall not exceed the established elevation and azimuth restrictions.

i. When the microwave/RF system is not being used, it shall be disabled in a manner to prevent unauthorized use.

j. Free-space transmission within buildings is forbidden without prior approval from the RSO.

k. Electrically activated explosive devices shall not be placed near sources of radiofrequency electromagnetic field radiation. Contact the NASA Langley Explosive Safety Officer at (757) 864-4345 if radiofrequency radiation will be used near explosive storage, use, or transportation areas.

l. Radiofrequency electromagnetic field radiation devices should not be used in flammable or explosive atmospheres.

m. Only qualified repair technicians using proper safety controls shall perform maintenance or repair of devices used to produce radiofrequency electromagnetic field radiation.

7.7 RF CATEGORIES AND WARNING SIGN REQUIREMENTS

7.7.1 The IEEE C95 safety standards use a tiered approach to hazard categories and required signage (see Appendix E of this LPR for examples of posted signs). Figure 7-1, taken from IEEE C95.7, shows a graphical representation of the RF hazard categories.

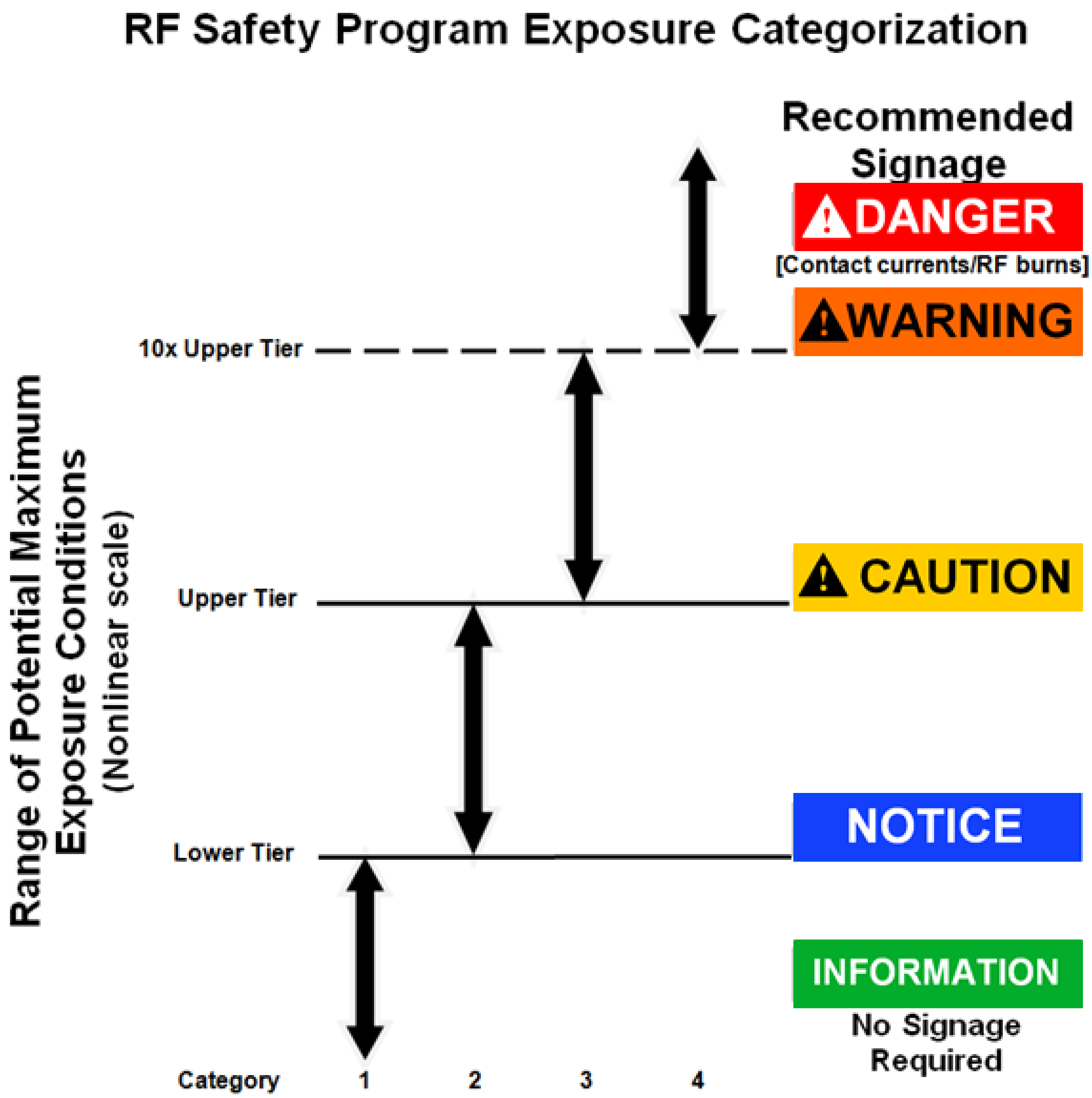

Figure 7-1. RF Safety Program Exposure Categorization

7.7.2 Unrestricted (Lower) Versus Restricted (Upper) Exposure Limits

7.7.2.1 The IEEE C95.1 safety standard uses two sets of exposure limits. The unrestricted (lower) limits are meant to protect members of the public who are untrained or unaware of the RF hazard. The restricted (upper) limits are the exposure limits given to trained RF workers who are aware of the hazard.

7.7.2.2 Any person at LaRC who has not been formally trained and entered into the Langley RF training program is considered a member of the public and thus the unrestricted (lower) limits would apply.

7.7.3 Recommended Signage by RF Hazard Category

7.7.3.1 **Category 1** is considered the area far enough away from an RF transmitter where neither the lower nor the upper human exposure safety limits would be exceeded. No signs are required here but may be posted for informational purposes.

7.7.3.2 **Category 2** is the area near an RF transmitter where the unrestricted (lower), public limit could possibly be exceeded. Blue “Notice” signs would be posted here, and only trained RF workers could enter this area.

7.7.3.3 **Category 3** is the area near an RF transmitter where RF worker limits (restricted, upper tier) might be exceeded if mitigating controls were not applied. Yellow “Caution” signs would be posted here, and trained RF workers could only enter this area using specific safety controls such as calculated stay times defined by the RSO.

7.7.3.4 **Category 4** is the area near an RF transmitter where human exposure will exceed 10 times the upper tier exposure limit in accessible areas. Red “Danger” or orange “Warning” signs would be posted here, and all personnel shall keep out of this zone.

7.8 SUB-RADIOFREQUENCY FIELDS, TIME-VARYING UP TO 3 KHZ (ACGIH TLVs)

7.8.1 Exposure to sub-radiofrequency (sub-RF) electric and magnetic fields are typically encountered near high-powered electrical equipment or in the vicinity of power generation, transmission, and distribution systems. Activities involving sub-RF sources or occurring around sub-RF sources shall be evaluated to assess the potential for delivering worker exposures that could exceed action levels or exposure limits. Appropriate administrative and engineering control measures shall be implemented based upon the assessment.

7.9 STATIC ELECTRIC AND MAGNETIC FIELDS, 0 HZ (ACGIH TLVs)

7.9.1 Static electric fields result from the flow of direct current (DC). Static magnetic fields result from either fixed magnets or the magnetic flux resulting from the flow of DC. Activities involving static field sources shall be evaluated to assess the potential for delivering worker exposures that could exceed action levels or exposure limits. Appropriate administrative and engineering control measures shall be implemented based upon the assessment.

7.10 RADIOFREQUENCY SURVEYS

7.10.1 RF surveys and calculations should be performed by the RSO to ensure compliance with current IEEE C95 safety standards and to verify that members of the general public and RF workers are not directly exposed to any direct emission from any RF transmitters. This would be done for new installations or devices, as well as after any malfunction or repair that might affect the radiation levels.

7.11 RF PROGRAM EXEMPTIONS

7.11.1 A variety of commercially available consumer, business, and industrial application RF radiation devices are exempted from the authorization requirements of the LaRC Radiation Safety Program because of their common usage and negligible potential for hazardous exposure under conditions of normal use. However, such exemption is valid only when certain conditions are met. The conditions listed below shall be met for exempted items. Personnel should consult with the RSO if there is a question regarding applicability of program exemption to their particular situation or requirement.

7.11.2 Exempted Categories

7.11.2.1 The following general categories of microwave/RF radiation devices are exempted:

a. Devices with transmitter power of 7 watts or less and an antenna gain of unity (e.g., two-way radios, car phones, cellular phones) at frequencies between 100 kHz and 900 MHz;

b. Speed monitoring devices (e.g., radar guns);

c. Automotive radar detectors;

d. Microwave ovens designed for heating food;

e. Microwave/RF radiation devices designed for and operated in a completely enclosed configuration where no open-air transmission is possible; this includes the Electromagnetic Interference (EMI) test chambers;

f. RF radiation devices designed to operate in a hard-lined, closed-loop configuration where no open-air transmission is possible; and

g. Devices or systems which have been shown by documented worst case analysis that they are incapable of emitting radiation levels greater than current applicable maximum permissible exposure levels.

7.11.2.2 Exemptions are valid for the general categories of equipment, instruments, and systems identified above provided that:

a. The individual item is maintained in its original design configuration and used for its originally intended use over the useful life of the item;

b. The design and manufacture of the item is in accordance with the specifications of 21 CFR Part 1010;

c. The item is operated in accordance with the manufacturer's recommended operating procedures; and

d. Maintenance, service, or repair activities that could expose personnel to accessible levels of radiation equal to or greater than the levels described in IEEE C95.1 shall be performed only by appropriately authorized and qualified personnel.

7.11.3 General Precautions for Exempted Items

7.11.3.1 Exemption of radiation devices from the authorization requirements of the LaRC Non-Ionizing Radiation Protection Program shall not be construed to exempt the user from other safety requirements relating to potential hazards associated with operation of the item such as electrical hazards.

7.11.3.2 Despite the negligible hazard characteristically represented by exempted sources, users should avoid close or prolonged exposure to emissions of devices, and intra-beam exposure conditions of any duration.

7.12 SUSPECTED OVEREXPOSURE AND MEDICAL SURVEILLANCE

a. If an eye or skin injury related to RF exposure is suspected, personnel should proceed directly to the LaRC Occupational Health Clinic or an outside medical professional for evaluation.

b. Personnel should report the incident to their supervisor, the LaRC Occupational Health Clinic, and the RSO as soon as possible after the suspected or actual injury.

c. Pre-assignment medical examinations are not required at LaRC for RF radiation workers.

APPENDIX A. DEFINITIONS

Absorption. Transformation of radiant energy to a different form of energy by interaction with matter.

Accessible Emission Limit (AEL). The maximum accessible emission level permitted for a particular laser classification.

Antenna. An apparatus for radiating and/or receiving electromagnetic waves.

Aperture. An opening through which radiation can pass.

Attenuation. A general term used to denote a decrease in magnitude between two points of measurement.

Aversion response. The eye's natural protective response to bright light sources. The aversion response time is assumed to be an average of 0.25 seconds for visible wavelengths.

Beam. A collection of rays that may be parallel, divergent, or collimated.

Beam diameter. The distance between diametrically opposed points in that cross section of the beam where the power unit area is 1/e times that of the peak power per unit area.

Beam divergence. The full angle of the beam spread between diametrically opposed 1/e points; usually expressed in milliradians (one degree = 17.5 mrad).

Class 1 laser. Class 1 lasers and laser systems include any laser or system that cannot emit accessible laser light in excess of the Class 1 AEL for the maximum duration of exposure inherent in the design or intended use of the laser. Class 1 laser systems may contain embedded lasers of more hazardous classifications.

Class 1M laser. Class 1M lasers produce large-diameter beams or beams that are divergent. The MPE for a Class 1M laser cannot normally be exceeded unless focusing or imaging optics are used to narrow down the beam. If the beam is refocused, the hazard of Class 1M lasers may be increased and the product class may be changed.

Class 2 laser. Visible light lasers that emit accessible level of laser light in excess of the Class 1 AEL but less than 1 milliwatt.

Class 2M laser. A Class 2M laser emits in the visible region in the form of a large diameter or divergent beam. It is presumed that the human blink reflex will be sufficient to prevent damaging exposure, but if the beam is focused down, damaging levels of radiation may be reached and may lead to a reclassification of the laser.

Class 3R laser. A Class 3R laser is a continuous wave laser that may produce up to five times the emission limit for Class 1 or Class 2 lasers. Although the MPE can be exceeded, the risk of injury is low. The laser can produce no more than 5 mW in the visible region.

Class 3b laser. A Class 3b laser produces light of an intensity such that the MPE for eye exposure may be exceeded and direct viewing of the beam is potentially serious. Diffuse radiation (i.e., that which is scattered from a diffusing surface) should not be hazardous. CW emission from such lasers at wavelengths above 315 nm shall not exceed 0.5 watts.

Class 4 laser. Class 4 lasers include lasers or laser systems that emit average accessible radiant power in excess of 0.5 W for exposure durations equal to or greater than 0.25 seconds, or that produce a radiant exposure of 10 J/cm^2 for an exposure duration of less than 0.25 seconds. Class 4 lasers are of high power (typically up to 500 mW or more if CW, or 10 J/cm^2 if pulsed). These are hazardous to view at all times, may cause devastating and permanent eye damage, may have sufficient energy to ignite materials, and may cause significant skin damage. Exposure of the eye or skin to both the direct laser beam and to scattered beams, even those produced by reflection from diffusing surfaces, shall be avoided at all times. In addition, they may pose a fire risk and may generate hazardous fumes.

Collimated beam. A beam with very low divergence or convergence.

Continuous wave (CW). A term used to describe any non-ionizing radiation emitting device with a continuous output for periods of greater than or equal to 0.25- seconds.

Diffuse reflection. The change in the spatial distribution of a beam when it is reflected in many directions by a surface or by a medium.

Electromagnetic radiation. The flow of energy consisting of orthogonally vibrating electric and magnetic fields lying in transverse to the direction of propagation. X-rays, ultraviolet, visible, and infrared light, and radio waves occupy various portions of the electromagnetic spectrum.

Embedded laser. A laser with an assigned classification number higher than the inherent capability of the laser system in which it is incorporated, where the systems lower classification is appropriate to the engineering features limiting the accessible emission.

Far-field region. The region of the field emitted from an antenna where the angular field distribution is essentially independent of the distance from the antenna.

Gain. General term used to denote an increase in signal power in transmission from one point to another. Gain is usually expressed in decibels (dB).

Hertz (Hz). The unit that expresses the frequency of oscillations in cycles per second.

Infrared (IR). Electromagnetic radiation with wavelengths that lie within the range of 700 nanometers to 1 millimeter.

Intrabeam viewing. The viewing condition whereby the eye is directly exposed to all or part of a laser beam.

Irradiance. Quotient of the radiant flux incident on an element of the surface containing the point, by the area of that element. Unit: W/cm^2.

Joule (J). A unit of energy: 1 joule = 1 watt-second.

Laser. A device that produces an intense, coherent and direction beam of light by stimulating electronic or molecular transition to lower energy states. Laser is an acronym of **L**ight **A**mplification by **S**timulated **E**mission of **R**adiation.

Laser diode. A laser employing a forward-biased semiconductor junction as the active medium. Also called a semiconductor laser.

Laser protective eyewear. Protective eyewear designed and rated specifically for use with lasers. Laser eyewear has protection ratings (i.e., optical density) for specific wavelengths.

Lasing medium. A material that has the ability to emit coherent radiation by virtue of stimulated electronic or molecular transitions to lower energy states. Lasing mediums may be solids, liquids, or gases.

Light emitting diode (LED). A p-n junction semiconductor that emits incoherent optical radiation when biased in the forward direction. LEDs may be capable of emitting injurious levels of light.

Limiting aperture. The maximum diameter of a circular area over which irradiance and radiant exposure can be averaged.

Maximum permissible exposure (MPE). The maximum level of laser radiation a person may be exposed to with no hazardous effects or adverse biological changes in the skin or eye.

Microwave radiation. Electromagnetic radiation with frequencies that lie between 300 MHz and 300 GHz.

Modulation. The process, or result of the process, whereby some characteristic of one wave is varied in accordance with another wave or signal.

Multiple pulse laser. A laser system using recurrent pulses with a pulse repetition frequency (PRF) of more than 1 Hz.

Near-field radiation. The region of the field of an antenna between the reactive near field region and the far field region wherein radiation fields dominate and the angular field distribution is dependent upon distance from the antenna.

Nominal Ocular Hazard Distance (NOHD). The linear distance from the point of emission of a laser beam to where the beam irradiance or radiant exposure drops below applicable ocular MPE.

Nominal Hazard Zone (NHZ). The space within which the level of direct, reflected, or scattered radiation may exceed the applicable MPE. Exposure levels beyond the boundary of the NHZ are below the applicable MPE.

Non-ionizing radiation.

1. Electromagnetic radiation that is not capable of producing ionization when interacting with matter but is capable of producing thermal or other effects resulting in a personnel health hazard.
2. That portion of the electromagnetic spectrum that includes the frequency and wavelength characteristics associated with ultraviolet, visible, infrared, radiofrequency, and microwave radiation.

Optical Density (OD). Logarithm to the base 10 of the reciprocal of the transmittance. For laser protective eyewear it represents the magnitude of the filtration provided by the eyewear for the specified wavelength.

Pulse duration or width. The time duration of a laser or RF pulse; usually measured as the time interval between the half power points on the leading and trailing- edges of the pulse.

Pulse repetition frequency (PRF). In a system using recurrent pulses, the number of pulses per unit of time.

Radiance. Radiant flux or power output per unit solid angle – unit area (W/sr- cm^2).

Radiant exposure. Surface density of the radiant energy received (J/cm^2).

Radiofrequency (RF) radiation. Electromagnetic radiation with frequencies that lie within the range of 10 kHz to 100 GHz.

Safety permit. A written set of standard operating procedures indicating that the particular research experiment, rig, or operation has been reviewed by the RSO, NIRC, the LaRC Safety Manager, and the applicable FSH. The safety permit identifies all reasonable safety precautions and safety controls to be implemented.

Specular reflection. A mirror-like reflection of an optical beam where there is minimal alteration of the divergence.

Ultraviolet (UV) radiation. Electromagnetic radiation with wavelengths that lie within the range of 180 nanometers to 400 nanometers.

Visible radiation. Electromagnetic radiation with wavelengths that lie within the range of 400 nanometers to 700 nanometers. The frequency range is defined for safety analysis purposes rather than as an indicator of absolute barriers where visual perception of light begins and ends.

Watt (W). The unit of power, or radiant flux. 1 Watt = 1 Joule per second.

Wavelength. The distance between two identical points in a periodic wave that have the same phase.

APPENDIX B. ACRONYMS

ACGIH	American Conference of Governmental Hygienists
AEL	Accessible Emission Limit
ALARP	As Low As is Reasonably Practicable
ANSI	American National Standards Institute
BEI	Biological Exposure Indices
CFR	Code of Federal Regulations
cm	Centimeter
CMTS	Chemical Material Tracking System
CW	Continuous Wave
dB	Decibels
DC	Direct Current
FAA	Federal Aviation Administration
FSH	Facility Safety Head
EMI	Electromagnetic Interference
IEEE	Institute of Electrical and Electronics Engineers
Hz	Hertz
GHz	Gigahertz
IR	Infrared
J	Joule
LAPD	Langley Policy Directive
LaRC	Langley Research Center
LED	Light Emitting Diode
LGACs	Laser Generated Airborne Contaminants
LPR	Langley Procedural Requirements
LSO	Laser Safety Officer
LSRB	Laser Safety Review Board
m	Meter
mA	Milliamps
MHz	Megahertz
mm	Millimeter

MPE	Maximum Permissible Exposure
mrad	Milliradian
mW	Milliwatt
NASA	National Aeronautics and Space Administration
NF	NASA Form
NFPA	National Fire Protection Association
NHZ	Nominal Hazard Zone
nm	Nanometers
NOHD	Nominal Ocular Hazard Distance
NIRC	Non-Ionizing Radiation Committee
ns	Nanosecond
OD	Optical Density
OCHMO	Office of the Chief Health & Medical Officer
OHO	Occupational Health Officer
OSHA	Occupational Safety and Health Administration
PHM	Potentially Hazardous Materials
PI	Principal Investigator
PPE	Personal Protective Equipment
PRF	Pulse Repetition Frequency
RF	Radio Frequency
RSO	Radiation Safety Officer
SFAB	Safety and Facility Assurance Branch
SMAO	Safety and Mission Assurance Office
SOP	Standard Operating Procedures
SPF	Sun Protection Factor
sr	Steradian
sub-RF	Sub-radiofrequency
TLV	Threshold Limit Value
UL	Underwriters Laboratories (Incorporated)
UV	Ultraviolet
VLT	Visible Light Transmission
V	Volt

W Watt

APPENDIX C. SUGGESTED OUTLINE FOR WRITTEN PROCEDURE TO ATTACH TO NASA LANGLEY FORM 49, "SAFETY PERMIT REQUEST - LASER/MICROWAVE" PREPARATION

I. Brief description of activity objectives.

II. List of all radiation devices to be used under the requested safety permit including the make, model, serial number, and full specifications of the system.

  A. For specifications of the system(s) using lasers as an example, provide the wavelength (nm), whether it is pulsed or CW, the average power (W) or energy per pulse (J), pulse width (ns), pulse rate frequency (Hz), beam size (mm), and beam divergence (mrad).

III. A laser calculation table provided by the RSO which shows the Nominal Ocular Hazard Distance (NOHD), the optical density, and diffuse hazard calculations.

IV. Sketches of operational area and actual experimental configuration (e.g., beam propagation path).

V. List of all laser operators and radiation workers to be in controlled area during hazardous source operation.

VI. Planned schedule of operations and estimated frequency of operation.

VII. Safety operating plans should include:

  A. Operational area security and control.

  B. Safety interlocks and overrides.

  C. Any conditions that would preclude operations.

  D. Assignments of operational personnel.

  E. Operational countdown procedure or preparation steps.

  F. Safety eyewear and its wavelength and optical density.

  G. Order of action during laser operation.

  H. A specific alignment plan for class 4 lasers.

APPENDIX D. LASER SAFETY BEST PRACTICES

D.1 BEST PRACTICES FOR THE LAYOUT OF LASER OPTICS:

a. Use the fewest number of optics necessary.

b. Unless absolutely necessary, do not have the beam travel on multiple planes.

c. If vertical beam steering is needed, use fixed angle optical mounts rather than crossed post mounts, which could rotate accidentally.

d. If beams are to travel between tables or be transmitted somewhere off the table, barricade or otherwise label the position of the beam.

e. If beams are located at an unusual height off the table, place signs warning of the hazard of leaning over the table.

f. If angled optics such as polarizers are to be used, ensure that any stray back reflections are safely terminated.

g. Consider the ability to perform future beam alignments and plan for the ability to use low-power alignment beams when possible.

h. If there is a need for any vertically directed beams, such as with a periscope, enclose the turning optics as much as possible to prevent personnel exposure.

D.2 PROCEDURES FOR LASER BEAM ALIGNMENT

D.2.1 The techniques for laser alignment listed below are to be used to help prevent accidents during alignment of this laser or laser system.

D.2.2 **Procedural Considerations**

a. To reduce accidental reflections, watches, rings, dangling badges, necklaces, or reflective jewelry should be removed before any alignment activities begin.

b. Use of non-reflective tools should be considered.

c. Access to the room or area is limited to authorized and necessary personnel only.

d. Consider having at least one other person present to help with alignment. This other person is to be cognizant of the optical configuration and the alignment procedure being performed.

e. All equipment and materials needed are present prior to beginning the alignment.

f. All unnecessary equipment, tools, combustible materials (if the risk of fire exists) have been removed to minimize the possibility of stray reflections and non-beam accidents.

g. Persons conducting the alignment have been authorized by the lab supervisor.

h. There should be no intentional intrabeam viewing with the eye.

i. Coaxial low-power lasers should be used when practical for alignment of the primary beam.

j. Reduce beam power by reducing power at the power supply or with neutral density filters, beam splitters, or dumps. Whenever practical, avoid the use of high-power settings during alignment. The power and its stability should be verified by measurements or tests prior to alignment.

k. Laser protective eyewear should be worn at all times during the alignment, within the parameters and notes specified in the accompanying laser table.

l. Skin protection should be worn on the face, hands, and arms when aligning at UV wavelengths.

m. The beam is enclosed as much as practical. The shutter is closed as much as practical during course adjustments. Optics and optics mounts are secured to the table. Beam stops are secured to the table or optics mounts.

n. Areas where the beam leaves the horizontal plane should be labeled.

o. Any stray or unused beams are safely terminated at the shortest distance possible.

p. Invisible beams are viewed with IR/UV cards, business cards, card stock, craft paper, viewers, 3 × 5 cards, thermal fax paper, or Polaroid film or by a similar technique. Operators are aware that such materials may produce specular reflections or may smoke or burn.

q. Pulsed lasers are aligned by firing single pulses when practical.

r. Intra-beam viewing is prohibited unless specifically evaluated and approved by the LSO. Intra-beam viewing should be avoided by using cameras or fluorescent devices.

s. Normal laser hazard controls should be restored when the alignment is completed.

t. Controls should include replacing all enclosures, covers, beam blocks, and barriers and checking affected interlocks for proper operation.

D.3 BEST PRACTICES TO MINIMIZE THE RISK OF LASER DAMAGE TO WIND TUNNEL WINDOWS

a. Operate the laser at the minimum power required for the test.

b. For pulsed lasers, use long pulse mode when possible (e.g., de-optimize Q-switch delay, turn down amplifier lamp energy).

c. Shutter the laser when it is not being actively used. Remotely operated shutters can be very useful in this regard.

d. Use a low power alignment laser for as much of the alignment as possible. Cage-mounted optics including a flip-mounted mirror can make this much more feasible.

e. Make the beam diameter as large as practical as it goes through the window(s).

f. Use smaller, thinner, cheaper windows inside larger blanks. Where possible, design blanks and inserts that can be rotated or flipped to allow various laser-window positions.

g. Remove, block, or replace with blanks any windows that are in the path of the laser but are not required for the specific test being conducted.

h. Avoid sending the laser through the exact same part of a window for extended periods of time (e.g., by aligning the laser away from the window's center and then moving the laser or rotating and/or flipping the window within its mount periodically).

i. Use cheaper, expendable windows and have contingency plans in applications where burning, damaging, or breaking a window is likely.

j. Incorporate beam profile and pulse energy measurements into pre-test procedures. Having beam profiling equipment available would decrease uncertainty in testing and mishap investigations.

k. Consider surface reflections in detail prior to operations.

l. Incorporate the use of "Laser Startup" and "Laser Shutdown" checklists into operations.

m. Have the FSH review and approve any configuration changes outside of what was agreed to in either the Pre-Test Meeting or the Test Readiness Review.

n. Hold a pre-test briefing on safe facility operation procedures for all customers (e.g., evacuation procedures, FOD procedures, configuration change procedures, reporting procedures).

o. Have laser serviced routinely. Perform preventative maintenance at recommended intervals.

p. Routinely inspect windows during laser operations (e.g., between runs). Have monitoring cameras in areas where windows are not easily accessible to inspection.

APPENDIX E. EXAMPLES OF RF NOTICE, CAUTION, AND WARNING SIGNS

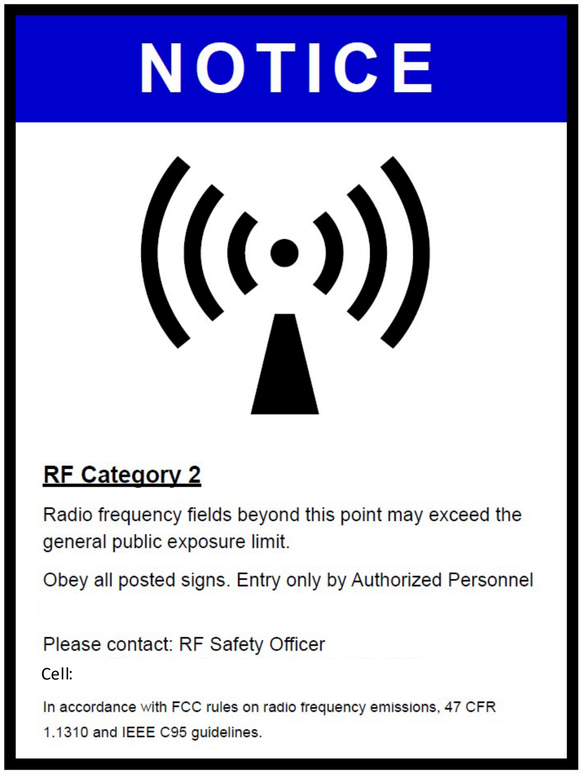

Figure E-1. RF Notice Sign

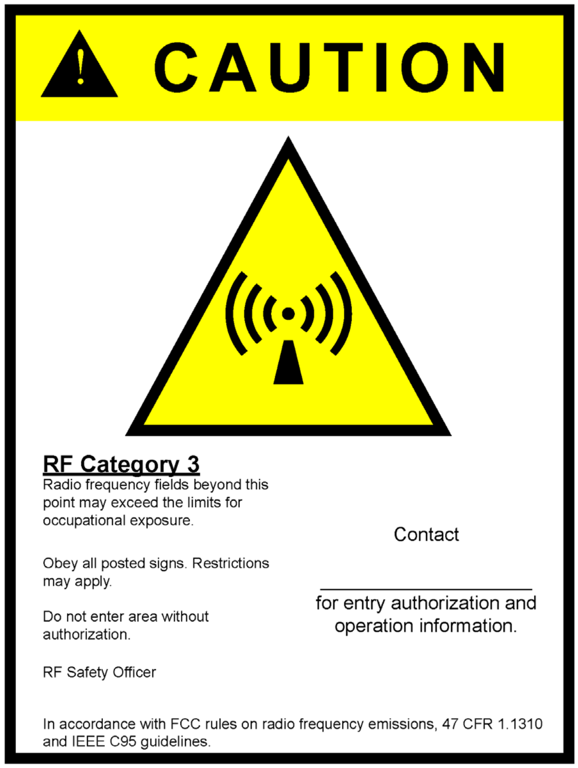

Figure E-2. RF Caution Sign

Figure E-3. RF Warning Sign