LPR 1710.8
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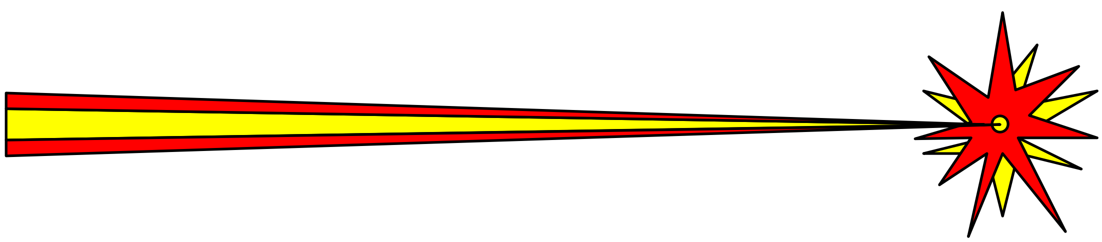
Langley Research Center

NON-IONIZING RADIATION



National Aeronautics and Space Administration

PREFACE

P.1 PURPOSE

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

b. This procedural requirement 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 procedural requirement 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 radiation producing equipment.
(2) assure a safe level of exposure of personnel to non-ionizing radiation from such equipment.
(3) assure 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 CID 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 procedures apply to all persons performing work at Langley Research Center (LaRC), including civil servants, contractors (to the extent required by their contracts), research associates, and others. Non-compliance with this LPR will result in appropriate disciplinary action or exclusion from the Center for a contractor employee.

b. The procedures and radiation protection practices as set forth in this procedural requirement applies to all organizational elements of LaRC and to all personnel working in or visiting areas under the administrative control of LaRC. 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. Questions concerning details of current practices and procedures or their applicability shall be referred to the LaRC Radiation Safety Officer (RSO), Health Physicist, Safety and Facility Assurance Branch (SFAB), Safety and Mission Assurance Office (SMAO).

c. It is the responsibility of contractors to provide and implement their own non-ionizing radiation program, to the extent required by their contracts. As a minimum, this program shall be in accordance with the LaRC program as described herein.

P.3 AUTHORITY

a. American National Standard for the Safe Use of Lasers (ANSI Z136.1-2000).
b. American National Standard for the Safe Use of Lasers Outdoors (ANSI Z136.6-2000)
c. American National Standard National Electric Code, ANSI/NFPA No. 70 1981, Articles 300 and 400.
d. American National Standard Safety Standard for Radio Receivers, Audio Systems and Accessories, ANSI/UL 127-1978.
e. Occupational Safety and Health Administration (OSHA) 29 Code of Federal Regulations (CFR) 1910.97- Non-ionizing Radiation.
f. Code of Federal Regulations (CFR), Title 21 Food and Drugs, Part 1040.10 - Laser Products
g. Threshold Limit Values (TLV) and Biological Exposure Indices, American Conference of Governmental Industrial Hygienists (2006) Edition.
h. Laser Safety Reference Book, Laser Institute of America
i. Federal Aviation Administration Order 7400.2E, Procedures for Handling Airspace Matters
j. The Institute of Electrical and Electronics Engineers (IEEE) C95.1, C95.3 and C95.7

P.4 APPLICABLE DOCUMENTS

a. CID 1150.2, "Councils, Boards, Panels, Committees, Teams, and Groups."
b. LAPD 1700.1, “Safety Program."
c. LPR 1740.6, “Personnel Safety Certification.”
d. NASA Langley Form 44A, “Radiation Hazard Form.”
e. NASA Langley Form 49, “Safety Permit Request Laser/Microwave.”
f. NASA Langley Form 66, “Worker Appointment and Certification Form.”
g. NASA Langley Form 492, “Radiation Worker’s Certification Card.”

P.5 MEASUREMENT/VERIFICATION

NONE

P.6 CANCELLATION

LPR 1710.8, dated October 3, 2004.

Original signed on file

Lesa B. Roe
Director

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305/Safety and Facility Assurance Branch, SMAO (25 copies)

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Chapter 1

1. NON-IONIZING RADIATION COMMITTEE (NIRC)

1.1 COMMITTEE AUTHORITY

a. Any member of the NIRC is authorized to investigate any questionable radiation source, equipment, system, procedure, and so forth; to act in the name of the LaRC Director to stop work; to prevent the use of equipment/procedure which is considered unsafe; and, to start action to eliminate the unsafe condition. This action shall be documented within 24 hours by formal letter to the Chairperson, NIRC. However, if line management is not in agreement with the corrective action recommended by the official who stopped the work, the line manager is to submit the reasons to the Chairperson, Executive Safety Council, who shall make an appropriate review. In these cases work shall not resume without the approval of the Chairperson, Executive Safety Council.

b. 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 4, “Routine Procedures and Requirements.”

1.2 STRUCTURE AND ORGANIZATION

a. 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, LaRC Organization for Radiation Safety.

b. Committee members (including Chairperson and Vice Chairperson) are appointed by the Vice-Chairperson, Executive Safety Council, by virtue of their technical and/or educational expertise in the field of non-ionizing radiation. A typical committee will consist of a Chairperson, Vice Chairperson, Secretary, and eleven additional qualified members. Members serve for a three-year term with the exception of the SFAB Representative and the Radiation Safety Officer (RSO) who serve as long as the committee continues to function. Committee members may serve multiple terms. Selection of committee member should be representative of the organizations which conduct work utilizing non-ionizing radiation sources.

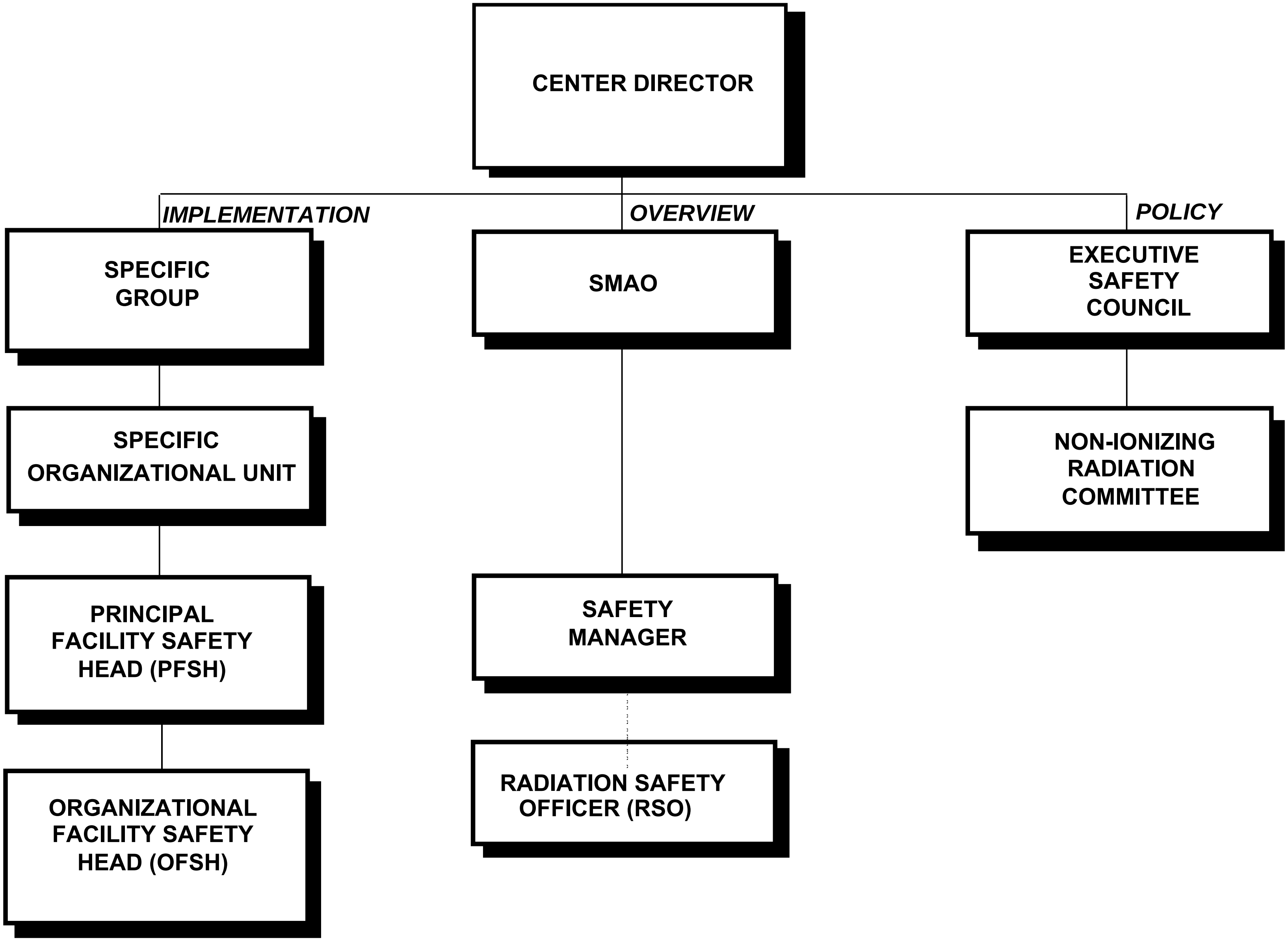


Figure 1.1, LaRC Organization for Non-ionizing Radiation Safety

1.3 DUTIES AND RESPONSIBILITIES

1.3.1 General

a. To prevent unnecessary non-ionizing radiation exposure to LaRC personnel and the surrounding populace, the NIRC shall exercise centralized control over sources of non-ionizing radiation at LaRC. This control shall be accomplished through the documented review and approval of all procurement, handling, and use of sources of hazardous non-ionizing radiation. In addition, the NIRC shall ensure that an audit is made of each facility's possession and use of sources of non-ionizing radiation no less than annually (Chapter 5).

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

1.3.2 Specific Duties and Responsibilities

1.3.2.1 Chairperson

The duties of the committee Chairperson are to:

a. prepare agenda and call meetings as required but, at least quarterly.
b. act as the presiding officer at committee meetings.
c. act as the signature authority for actions approved by the committee.
d. be cognizant of all matters pertaining to non-ionizing radiation at LaRC.

1.3.2.2 Vice Chairperson

The duties of the committee Vice Chairperson are to:

a. assist the Chairperson whenever necessary.
b. serve as the Chairperson when the Chairperson is absent.

1.3.2.3 Secretary

The duties of the committee Secretary are to:

a. prepare and distribute minutes of committee 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 committee.
b. distribute minutes to all members; Organizational Facility Safety Heads (OFSH's) concerned with non-ionizing radiation; the Chairperson, Executive Safety Council; and the Director, SMAO.
c. process official correspondence for the committee as needed.

1.3.2.4 Members

Member duties and responsibilities are to:

a. be cognizant of all matters pertaining to non-ionizing radiation safety at LaRC. This is chiefly, but not entirely, achieved by attending the committee meetings and participating in the decisions made by the committee.
b. serve on ad hoc committees, appointed by the Chairperson, when necessary.

Chapter 2

2. SAFETY AND HEALTH FUNCTIONS

2.1 GENERAL

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 ORGANIZATIONAL FACILITY SAFETY HEAD (OFSH)

The Principal Facility Safety Head (PFSH) of each facility where non-ionizing radiation operations are performed shall appoint an OFSH for each operation, which is functionally or generically distinct. The OFSH shall, in each case, be a representative of line management who is thoroughly familiar with the non-ionizing radiation operation and its hazards. In some cases, the OFSH may also be the prime user of the source(s) of non-ionizing radiation.

2.2.1 Interfaces

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

2.2.2 Responsibilities

Responsibilities of the OFSH of an operation involving sources of non-ionizing radiation are:

a. supervise and coordinate, in a safe manner, the procurement, use, and disposal of sources of non-ionizing radiation.
b. maintain a current inventory of all non-ionizing radiation sources used in operations. The inventory shall include locations of use, type of radiation emitted, and maximum radiation intensities produced by these sources.
c. maintain a current list of employees in the operation who are required to be certified as radiation workers. Chapter 5, “Special Procedures and Requirements,” presents the certification requirements.
d. accompany the RSO during audits of the operation and, when appropriate, attend meetings of the NIRC.

2.3 RADIATION SAFETY OFFICER (RSO)

The position of the RSO has been designated to a contractor located in the Safety and Facility Assurance Branch (SFAB). The RSO also has the title of Laser Safety Officer.

2.3.1 Interfaces

The RSO is a member of the NIRC and is responsible for reporting non-ionizing radiation information to SMAO and the Safety Manager. Recommendations to the committee for approval or disapproval of new uses of non-ionizing radiation are made by the RSO following pre-operational surveys and review of safety procedures. The RSO assists the radiation user as primary contact on a day-to-day basis for matters relating to radiation safety other than procurement.

2.3.2 Responsibilities

In general, the RSO provides administrative and technical guidance to LaRC personnel in the safe use of non-ionizing radiation. 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 assure conformity with applicable standards and good practice. Recommend to the NIRC approval or disapproval of these facilities.
c. Perform annual audits of non-ionizing radiation activity in each facility.
d. Perform periodic radiation protection surveys and radiation safety evaluations as an integral part of the audit function.
e. Assist line management in implementing radiation safety rules and procedures as promulgated by the NIRC.
f. Provide training and indoctrination of personnel in radiation safety.
g. Review all purchase requests for non-ionizing radiation sources for compatibility with approved policies and safety programs.
h. Review, sign and forward to the LaRC Safety Manager safety permit requests for the use of non-ionizing radiation sources (NASA Langley Form 49).
i. Regularly inform the NIRC of new developments in the field of non-ionizing radiation, as they are applicable to activities at LaRC.

2.4 SAFETY MANAGER

The Head, SFAB, SMAO, is the Safety Manager.

2.4.1 Interfaces

The Safety Manager 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.
d. representing the government as the liaison between the RSO and federal regulatory authorities (e.g. OSHA, Food and Drug Administration [FDA], Federal Aviation Administration [FAA]).

2.4.2 Responsibilities

The Safety Manager shall:

a. exercise general surveillance over all uses of non-ionizing radiation at LaRC, including on-site contractor activities to assure radiation use is in conformity with safe practice, pertinent regulations, and with provisions approved by the NIRC for specific radiation use authorizations (that is, safety permits).

b. choose to have the RSO perform the above function.

c. serve as the final reviewing and/or certifying authority on the following documents:
   (1) NASA Langley Form 66, “Worker Appointment and Certification Form.”
   (2) NASA Langley Form 44A, “Radiation Hazard Form.”
   (3) NASA Langley Form 49, “Safety Permit Request Laser/Microwave.”
   (4) NASA Langley Form 492, “Radiation Worker’s Certification Card.”

2.5 OCCUPATIONAL HEALTH OFFICER (OHO)

The LaRC Occupational Health Officer (OHO) is a member of the Office of Human Capital Management (OHCM).

2.5.1 Interfaces

The OHO’s interfaces include:

a. Contracting Officer’s Technical Representative (COTR) for medical support services at LaRC (specifically, the LaRC Occupational Medical Center (OMC), 10 West Taylor Street, Facility 1149).

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

2.5.2 Responsibilities

The OHO’s responsibilities are to:

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

b. review the medical disqualification of any LaRC employee as a non-ionizing radiation worker with the contract ophthalmologist and the LaRC Medical Director.

c. serve as a qualifying official for non-ionizing radiation worker appointment and certification on NASA Langley Form 66.

2.6 RADIATION WORKERS

The OFSH having direct involvement with sources of non-ionizing radiation shall forward recommendations for appointment of radiation workers and operators as described in Chapter 4, “Routine Procedures and Requirements.”

2.6.1 Interfaces

Radiation workers shall work under the direct authority of the OFSH.

2.6.2 Responsibilities

Radiation workers shall be:

a. cognizant of and comply with the LaRC regulations pertaining to non-ionizing radiation safety.
b. fully aware of the limitations given in the Description of Duties block on the appointment form, and notify the OFSH when:
   (1) a change in the definition of the limitations is needed.
   (2) the need to work in restricted areas has ended.

2.7 LASER OPERATOR

The laser operator 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 to all personnel not necessary for the laser research operations (Chapter 5).
d. exercise authority over the safe operation of the device to which the radiation operator is assigned.

Chapter 3

3. ROUTINE PROCEDURES AND REQUIREMENTS

3.1 GENERAL

Clearly defined procedures and requirements are a prerequisite for the orderly processing of documents and materials for any type of organizational structure. 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/OR RECEIPT

a. Prior to the procurement and receipt of any hazardous source of non-ionizing radiation, the intended user or operator of the source shall complete NASA Langley Form 44A, "Radiation Hazard Form," and route the form to the RSO as the final repository. Where an OFSH has not been appointed, the intended user submits NASA Langley Form 44A to the Principal Facility Safety Head (PFSH). The PFSH shall then appoint an OFSH for the organization, which is procuring the source of non-ionizing radiation.

b. Sources, which specifically require NASA Langley Form 44A, are:

(1) all class 3b, and 4 lasers and laser systems , which are the only lasers and laser systems that require NASA Langley Form 44A. Laser pointers and CD rom drives are not regulated and do not require a Langley Form 44A.
(2) ultraviolet light sources, radio frequency (RF) generators capable of propagating RF power into free space, and any other sources or systems that may exceed the exposure limits as outlined in this LPR.

3.2.1 Organizational Facility Safety Head (OFSH)

The OFSH is required to:

a. review and approve NASA Langley Form 44A for systems safety compatibility and/or compatibility with research objectives.
b. forward approved NASA Langley Form 44A to the RSO.

3.2.2 Radiation Safety Officer (RSO)

The RSO is responsible for:

a. scheduling a pre-operational review with the OFSH upon receipt of NASA Langley Form 44A. The purpose of this review is to provide the OFSH 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. approving or disapproving the NASA Langley Form 44A following the survey and forwarding it to the Safety Manager.

3.2.3 Safety Manager

The Safety Manager's responsibilities include:

a. On receipt of NASA Langley Form 44A, review the RSO's review and approve or disapprove the purchase of the non-ionizing radiation source.

b. If disapproved, return NASA Langley Form 44A to the OFSH with a written explanation of disapproval attached. The OFSH may appeal disapprovals, through the OFSH's Organizational Unit Manager, to the Executive Safety Council.

3.2.4 Contracting Officer, Office of Procurement

After receipt of an approved NASA Langley Form 44A, complete the information indicated in the upper right-hand corner of the form. If a contract is let for purchase of the material forward a copy to the Capital Assets and Logistics Branch (CA&LB).

3.3 AUTHORIZATION OF USE ("SAFETY PERMIT")

a. Laser/microwave sources of non-ionizing radiation require the completion and approval of a NASA Langley Form 49, "Safety Permit Request - Laser/Microwave," and a related safety plan before the source can be used or operated at any LaRC facility. (Appendix C, "Suggested Outline for NASA Langley Form 49, "Safety Permit Request - Laser/Microwave," Preparation"). This package of documents is referred to as the "safety permit." The RSO is responsible for the determination of safety permit requirements during the processing of NASA Langley Form 44A (Chapter 5).

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

(1) 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) (Chapters 5, "Special Procedures and Requirements").

(2) all class 4 lasers or laser systems.

(3) all radio frequency (RF) generators capable of propagating RF power into occupied areas in excess of those limits, which allow a whole body specific absorption rate of 0.4 w/kg in any 0.1-hour for a specific wavelength.

(4) ultraviolet light sources, as determined by the RSO, the use of which creates a significant probability that its 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). (Appendix A, "Exposure Standard for Non-laser Ultraviolet Radiation," presents the determination of the MPE for non-laser ultraviolet radiation.)

(5) magnetic field sources, as determined by the RSO, the use of which creates a significant probability that its users or operators will be exposed to magnetic flux densities in excess of the applicable TLV's as recommended by the ACGIH.
(6) static electric field sources, as determined by the RSO, with whose proposed use exists a significant probability that its users or operators will be exposed to electric flux densities in excess of the applicable TLV's as recommended by ACGIH.
(7) visible and infrared light sources, as determined by the RSO, whose use of which has the probability of exposing personnel to light levels in excess of the TLV's as recommended by the ACGIH.

c. The safety permit is a formal written designation that the particular research experiment, rig, or operation has been reviewed by technically qualified members of the LaRC staff and that all reasonable safety precautions and environmental requirements have been considered and subsequently implemented. The NASA Langley Form 49 shall describe the maximum potentially hazardous operating parameters (that is, maximum radiant power, radiant energy, kilovoltage, amperage, and so forth) expected during the life of the experiment or operation. Changes in the operational configuration which, (1) do not exceed the authorized maximum parameters, or (2) change the authorized safety features, will not require the processing of a modified NASA Langley Form 49. Other changes require additional review and approval by the NIRC. NASA Langley Form 49 is valid for a period of 1 year from date of issuance for new or modified facilities; and thereafter, for a period of 4 years.

3.3.1 Organizational Facility Safety Head (OFSH)

The OFSH shall:

a. review NASA Langley Form 49's, attached pertinent drawings, sketches, and supporting information (Appendix C, "Suggested Outline for NASA Langley Form 49, "Safety Permit Request - Laser/Microwave" Preparation.") prepared by researchers working in their facilities.
b. verify that a Worker Appointment and Certification Form (NASA Langley Form 66 for NASA employees) or its equivalent (for contractor employees) has been submitted for each radiation worker listed as a user/operator.
c. forward NASA Langley Form 49 and attachments to the RSO. Electronic media should be used whenever possible.
d. 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.
e. submit a NASA Langley Form 49 for renewal to the Safety Manager at least 30 calendar days prior to its expiration date or submit a new NASA Langley Form 49 through channels anytime a change is required in the authorized maximum operating parameters.

3.3.2 Radiation Safety Officer (RSO)

The RSO shall:

a. perform a radiation hazard analysis of the proposed operation upon receipt of NASA Langley Form 49 and attachments.
b. work closely with the OFSH during this analysis to provide guidance and assistance in the preparation and acquisition of safety procedures, protective equipment, and medical surveillance (if required).
c. forward NASA Langley Form 49, attachments, and the hazard analysis (with appropriate recommendations) to the NIRC for their review and action.
d. verify certification listings of radiation workers and laser operators.
e. review existing safety permits as part of the annual audit to ensure that they are valid (either not expired or have been reviewed before expiration date).

3.3.3 Non-ionizing Radiation Committee

The NIRC shall:

a. review NASA Langley Form 49 to determine that all reasonable precautions have been taken and whether the proposed operations can be carried out with an acceptable level of risk to personnel and equipment. Based on this review the NIRC shall:
   (1) approve issuance of the safety permit with conditions, if any.
   (2) disapprove the NASA Langley Form 49 and return to the OFSH if problem areas are evident.
   (3) withhold approval or disapproval until additional information is obtained. The OFSH shall be notified of this action.
b. review existing safety permits, that have been identified by the RSO during the annual audit, which require modification or are due for renewal.

3.3.4 Committee Chairperson

The NIRC Chairperson shall:

a. complete NASA Langley Form 49 and specify, when appropriate, any special conditions on which approval is based.
b. forward the approved NASA Langley Form 49 and attachments to the Safety Manager.

3.3.5 Safety Manager

a. The Safety Manager shall review NASA Langley Form 49 for impact on the environment or creation of safety hazards outside the scope of radiological health. Based on this review the Safety Manager will:

   (1) sign NASA Langley Form 49 and return all attached documentation to the OFSH.
   (2) return NASA Langley Form 49 and all attached documentation to the OFSH if problem areas are evident.

3.4 USE OF LASERS IN NAVIGABLE AIRSPACE

a. 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 will involve the propagation of laser light in navigable airspace shall be coordinated with the FAA in the planning stages to ensure control of any attendant hazard to airborne personnel and equipment.

b. FAA safety requirements for atmospheric lasers can be found in FAA Order 7400.2E. NASA LaRC complies with the requirements of this document. In addition, NASA LaRC has a written protocol agreement with Langley Air Force Base (LAFB) describing the requirements for use of lasers outdoors on Center property.

Chapter 4

4. SPECIAL PROCEDURES AND REQUIREMENTS

4.1 SPECIAL REQUIREMENTS FOR OFF-SITE RADIATION USE AUTHORIZATION

a. Additional requirement and approvals are needed for LaRC organizations wishing to operate lasers and/or 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:

(1) An OFSH 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. The OFSH 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.

(2) Include a safety review as part of the total design review process. The OFSH is responsible for notifying the NIRC of any design review meetings.

(3) Written authorization shall be obtained from the administration or authorities for the jurisdiction or site in which the non-ionizing radiation source is to be operated. Use of the non-ionizing radiation source shall be concurred with by the safety organization for that jurisdiction.

(4) To assure minimal radiation exposure to individuals, the OFSH with the cognizance or guidance of the RSO shall perform monitoring tasks as determined necessary by the NIRC.

(5) All records of the radiation surveys shall be maintained by the OFSH and submitted to the RSO at the completion of the authorized use. Any incident involving overexposure to individuals shall be reported immediately to the RSO and the NIRC Chairperson.

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

(1) act as the initial point of contact between the NIRC and the organization and/or individual wishing to operate a non-ionizing radiation source off site.
(2) maintain records of the off-site operations such as NASA Langley Form 49's, approval correspondence, safety violations or incidents, and other pertinent documentation.
(3) relay any reported incident or violation to SMAO, the Executive Safety Council, and the NIRC.
(4) assist with safety calculations.

4.1.1 Failure to Comply

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.

4.2 INTERIM APPROVALS

a. When an immediate use of non-ionizing radiation is determined necessary, the RSO, with verbal concurrence from the Chairperson, NIRC may temporarily modify the following previously approved authorizations to:

(1) extend an expiration date of a NASA Langley Form 49 for a period not to exceed 60 days.
(2) add to the sources of non-ionizing radiation named on an approved authorization.
(3) authorize a new use location and/or procedure provided the new location and/or procedure is equipped with safety features (interlocks, warning signs, area control, and so forth) which meet or exceed those authorized under the existing NASA Langley Form 49.

b. The NIRC shall evaluate these temporary modifications, and if satisfied that the RSO's action was proper, ratify the actions at the next committee meeting. However, approvals may be withdrawn at any time if safety violations occur or use of a source is found not to be in compliance with conditions of the approved authorization.

4.3 AUDITS

a. The RSO is responsible for conducting an audit of each facility possessing sources of non-ionizing radiation no less frequent than annually. The results of the audits are to be presented to the NIRC during their quarterly meetings.

b. Typical items covered during an audit are:

(1) inventories of:
 (a) lasers and laser systems.
 (b) RF sources/microwave sources.
 (c) ultraviolet sources.

(d) magnetic sources.
(e) electric field sources.
(2) records of:
(a) worker certification and training.
(b) medical surveillance (if required).
(3) compliance with terms of the approved safety permit for the operation.
(4) selection and care of personal protective equipment (PPE).
(5) adequacy and operability of safety interlocks.
(6) area posting and signage.
(7) conduct of routine radiation protection surveys by the RSO.

4.4 TRAINING AND CERTIFICATION

All personnel who operate, manipulate, or who have any other type of physical control over the use of radiation-producing equipment or material specifically authorized by a safety permit (new or existing) are required to be trained and certified as radiation workers in accordance with LPR 1740.6, "Personnel Safety Certification." It is the responsibility of each OFSH to ensure that personnel within the facility are trained and certified. Questions concerning this requirement should be directed to the RSO.

4.4.1 Qualifications

As a minimum, and prior to working with non-ionizing radiation, individuals shall have had experience and/or training on specific topics. NASA Langley Form 66, is used to determine and certify qualifications for worker training and safety certification described above and in accordance with LPR 1740.6. Contractor personnel shall use a form, which supplies the equivalent information contained in NASA Langley Form 66.

4.4.2 Safety Permits

All workers performing work under an approved safety permit must be certified and listed on the permit. Certified workers may be added to or removed from a permit by the OFSH or RSO without modifying the permit.

4.4.3 Certification Card

Based on the satisfactory completion of NASA Langley Form 66 and/or other documentation of the qualifying status of the worker, the RSO shall issue, revalidate, or terminate a NASA Langley Form 492, "Radiation Worker's Certification Card." The worker shall have the card on-hand or readily accessible, as proof of his/her certification, while performing applicable tasks. Contractor personnel may be issued equivalent cards by their employer.

4.5 MEDICAL SURVEILLANCE

Personnel requiring certification as laser workers shall be given a complete initial and termination eye examination by the Center's contract ophthalmologist prior to being issued and on termination of a NASA Langley Form 492 in accordance with LPR 1740.6. These examinations are normally accomplished through routine processing of NASA Langley Form 66 and in accordance with established LaRC Occupational Medicine Examination Protocol. The examination is based upon the medical surveillance procedures in Appendix E of ANSI Z136.1, *Safe Use of Lasers*. A medical disqualification of any LaRC employee as a non-ionizing radiation worker shall be the result of a decision made by the ophthalmologist in consultation with the LaRC OHO and the LaRC Medical Director. Contractor companies are responsible for conducting an equivalent medical surveillance program for their employees.

4.6 INTERNAL TRANSFER

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

Chapter 5

5. LASERS

5.1 GENERAL

The laser safety program at NASA Langley Research Center is based upon maintaining compliance with ANSI Z136.1, *Safe Use of Lasers*. 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 the more conservative requirement shall be adhered to. 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

The laser classification scheme is based on the accessible radiation during operation and the emission limit for that wavelength. Classification labeling which is used in conformance with the Federal Laser Product Performance Standard shall be used to satisfy this labeling requirement. Should it be necessary in the event that a laser or laser system has been modified subsequent to classification by the manufacturer, the RSO shall classify the laser or laser system following the criteria provided in the American National Standard for the Safe Use of Lasers (ANSI Z136.1-2000).

5.2.1 Class 1 or Exempt Lasers

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). In addition, higher hazard class lasers which 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.

5.2.2 Class 2 or "Low-Power" Laser Devices

Class 2 or “Low Power” laser devices are visible lasers which do not have enough power to injure a person under accidental exposure conditions (0.25 seconds or less). Class 2 lasers have a power limit of 1 mW.

5.2.3 Class 3 lasers

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.

5.2.4 Class 4 Lasers

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. In addition, laser sources with an irradiance of greater than 5 W/cm2 can be capable of igniting combustible materials.

5.2.5 Class 1M and 2M lasers

These classifications are for 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.

5.2.6 Class 2a and 3a lasers

Laser classifications 2a and 3a are no longer utilized, although the lasers themselves are still commonly available and used. Class 2a lasers represented Class 2 lasers that were not intended for prolonged viewing such as supermarket scanners and bar code readers.

5.3 CONTROL MEASURES AND PROCEDURES

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. For all lasers and laser systems, it is mandatory that the minimum radiation level be used for the required application.

5.3.1 Laser Classifications 1, 2 and 3R

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 (Labeling and Area Posting Requirements are described in this chapter, for label required).

Guidelines for the safe use of Class 3R (and Class 3a) laser are available from the RSO.

5.3.2 Laser Classification 3b

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

5.3.2.1 Education and Training

All persons using the laser or laser system shall be informed about the potential hazards of laser operations. All users and personnel present during use shall be certified as laser workers.

5.3.2.2 Engineering Controls

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, fail safe interlocks, and so forth.

5.3.2.3 Laser Controlled Area

Consideration shall be given to operation of laser devices in a controlled area. Special emphasis shall be placed on control of the path of the laser beam.

5.3.2.4 Spectators

Spectators shall not be permitted into the laser-controlled area unless appropriate supervisory approval has been obtained and protective measures taken.

5.3.2.5 Beam Enclosures

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

5.3.2.6 Alignment Procedures

Alignment of laser optical systems (mirrors, lenses, beam deflectors, and so forth) 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.

5.3.2.7 Optical Viewing Aids

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

5.3.2.8 Eye Protection

Eye protection devices, which are specifically designed for protection against radiation from the laser system, shall be used when engineering and procedural controls are inadequate to eliminate potential exposure in excess of the applicable MPE.

5.3.2.9 Equipment Labeling

Lasers shall have warning labels with the appropriate cautionary statement affixed to a conspicuous place on the laser housing or control panel, or on both the housing and control panel.

5.3.2.10 Diffusely Reflecting Materials

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

5.3.3 Laser Classification 4

a. 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.

b. Therefore, **in addition** to the control measure specified for class 3b lasers described above, the following controls shall apply to all class 4 laser systems at LaRC:

5.3.3.1 Laser Controlled Area

a. Specific laser controlled area requirements shall include:

(1) Laser devices shall be isolated in an area designated for laser operations.

(2) Access to such an area shall require appropriate authorization.

(3) 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. 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. For such emergency conditions, a “panic button” (control disconnect switch or equivalent device) shall be available for deactivating the laser. Interlock overrides are permissible in laser controlled areas with specific approval by the RSO. If a casual passersby can gain access to an interlock bypass key, the room must have a door which requires either a separate key or a pass code to open.

(4) 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.

(5) 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 which will outline all safety requirements during the service and maintenance procedures. 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.

(6) 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. In this case, all other optical paths (for example, 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. Specularly reflecting surfaces, which are not required when using the laser, shall be removed from the beam path.

(7) The purpose of control measures is to reduce the possibility of exposure to hazardous levels of laser radiation and to associated hazards. Therefore, it may not be necessary to implement all of the control measures given. 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.

5.3.3.2 Enclosed Beam Path

Whenever possible, the entire beam path, including the interaction area, that is, the area in which irradiation of materials by the primary or secondary beams occurs, shall be enclosed. Enclosures shall be equipped with interlocks so that the laser system will not operate unless such enclosures are installed. For pulsed systems, interlocks shall be designed so as to prevent firing of the laser, by dumping the stored energy into a dummy load. For cw lasers, the interlocks shall turn off the power supply or interrupt the beam by means of shutters. Interlocks shall not allow automatic re-energizing of the power supply, but shall be designed so that after tripping the interlock, the power supply or shutter shall be reset manually.

5.3.3.3 Remote Firing and Monitoring

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

5.3.3.4 Warning Systems

Warning systems are required for lasers as follows:

a. An alarm system, for example, an audible sound, or a warning light visible through protective eyewear, or a verbal “countdown” command, shall be used prior to laser activation.

b. The audible system may consist of a bell or chime which commences when a pulsed laser power supply is charged for operation, for example, during the charging of capacitor banks. Systems shall be used in which a warning will sound intermittently during the charging procedure (pulsed systems) and continuously when fully charged.

5.3.3.5 Key-Switch Master Interlock

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

High-pressure arc lamps and filament lamps in laser equipment shall be enclosed in housings, which can withstand the maximum explosive pressures resulting from lamp disintegration. The laser target and elements of the optical train which 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

The intended application of the laser equipment determines the method of electrical installation and connection to the power supply circuit (for example, conduit versus flexible cord). All equipment shall be installed as outlined in American National Standard National Electric Code, ANSI/NFPA No. 70 1981(as updated), or the most current issue, Articles 300 and 400. (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.)

5.4.2.1 Shock Hazard

Controls as follows are required 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. 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 operation. Bleeder resistors shall be of such size and rating as to carry the capacitor discharge current without burnout or mechanical injury. Circuits and components with peak open-circuit potentials of 2500 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. The grounding rod shall be firmly attached to ground prior to contact with the potentially live point. A resistor grounding rod (for example, 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.

5.4.2.2 Grounding

The frames, enclosures, and other accessible metal non-current carrying metallic parts of laser equipment shall be grounded. 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. Metal optical tables shall be bonded to the building grounding system.

5.4.2.3 Electrical Fire Hazards

Components in electrical circuits shall be evaluated with respect to fire hazards. Circuit components of combustible material, such as transformers, that do not pass a short-circuit test without ignition (American National Standard Safety Standard for Radio Receivers, Audio Systems and Accessories, ANSI/UL 127-1978 or the most current issue) shall be provided with individual noncombustible enclosures. Power supply circuit wiring shall be completely enclosed in noncombustible material.

5.4.2.4 Electrical Hazards from Explosion

Gas laser tubes and flash lamps shall be supported to ensure that their terminals cannot make any contact which will result in a shock or fire hazard in the event of a tube or lamp failure. 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 should be tested to make certain that 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

Some types of laser systems, such as dye and excimer lasers, utilize hazardous materials in their operations. Many laser dyes have not been completely characterized and many that have been analyzed have been found to possess hazardous properties such as being carcinogenic or mutagenic. 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 which are corrosive and/or toxic and require the appropriate ventilation systems to manage this hazard. Laser systems which use hazardous materials should have the process reviewed by the center’s Industrial Hygiene staff and may require a Potentially Hazardous Materials Permit.

5.4.4 Other Forms of Radiation

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 will review the potential for these hazards as part of the hazard analysis.

5.4.5 Laser Generated Airborne Contaminants

Laser systems which possess sufficient energy to cause material alteration or ablation have the potential to release laser generated airborne contaminants (LGAC’s). These contaminants may be a respiratory hazard and shall be adequately controlled through the use of ventilation and/or enclosure of the work area. Review of these types of systems shall be coordinated with the center’s Industrial Hygiene staff.

5.5 LASER PROTECTIVE EYEWEAR

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

5.5.1 Specification of Optical Density, OD

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

b. 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:

$$OD = \log_{10} (H_o / MPE)$$

where the units of H_o are the same as those of the appropriate MPE. 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. Attenuation through the protective material shall be determined from all anticipated viewing angles and at all wavelengths.

5.5.2 Visible Transmission

Adequate OD, at the laser wavelengths of interest, shall be weighed with the need for adequate visible transmission.

5.5.3 Identification of Eyewear

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

5.5.4 Comfort and Fit

Protective eyewear shall provide a comfortable and snug fit so that laser radiation is satisfactorily attenuated before reaching the viewer's eyes. The RSO has a variety of samples which can be tried on to ensure proper fit prior to ordering.

5.5.5 Inspection

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.

6. NON-COHERENT OPTICAL SOURCES

a. Non-coherent optical sources such as ultraviolet (UV), visible and infrared (IR) light are capable of causing injury to both the skin and to the eyes. All non-coherent optical sources capable of exposing workers to an irradiance level greater than the limits recommended in the Handbook of Threshold Limit Values (TLV's) and Biological Exposure Indices (BEI's) by the American Council of Government Industrial Hygienists (ACGIH) require the issuance of a safety permit by the RSO. Consult with the RSO to determine the appropriate exposure limits for these sources.

b. Types of optical radiation, the types of injury caused by them and typical sources are listed in the following table.

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, retinitis
Metal halide arc lamps	Ultraviolet, blue light	Cataracts, photosensitive skin reactions, photoretinitis

7. MICROWAVE/RF RADIATION SAFETY

7.1 GENERAL INFORMATION

The Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz, is given in IEEE C95.1-1991. It covers safe levels involving both controlled and uncontrolled environments. The recommendations are listed in Appendices G and H of this LPR.

7.2 RADIATION WORKER'S RESPONSIBILITIES

The radiation workers using microwave/Rf equipment are personally responsible for compliance with the microwave/Rf standard and LaRC regulations in all operations. Operations are authorized by the NIRC. Worker responsibilities include:

a. Preparation of an initial Safety Review document for new projects or modifications of existing facilities.
b. Providing safety instructions to personnel using equipment under his direction.
c. Prohibiting use of the equipment unless there is adequate control of hazards, including warning signs and interlocks as necessary.
d. Notifying the Radiation Safety Officer, within 24 hours, when known or suspected overexposure to microwave/Rf radiation has occurred, so the individual can receive an ocular examination at their employer’s expense.
e. Adopting practices that will not intentionally expose an individual to microwave/Rf radiation in excess of the Permissible Exposure Limits (PEL’s).

7.3 MICROWAVE/RF PROJECT SAFETY REVIEW

a. Prior to installing new microwave/Rf equipment or modifying existing equipment, a Project Safety Review (NASA Langley Form 49 and associated safety plan) document must be submitted by the radiation worker to the Radiation Safety Officer (RSO) for review by the NIRC.
b. The document should include:
    (1) A description of the system and its application
    (2) A diagram showing the beam path
    (3) Operating parameters
    (4) Frequency
    (5) Antenna dimension
    (6) Power out
    (7) Antenna type
    (8) Pulse description
    (9) Antenna gain
    (10) Polarization of transmitted wave

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

c. The project shall be reviewed by the RSO on an annual basis, or more frequently if the researcher's project deviated from approved standard operating procedures (SOP’s).

7.4 OPERATIONAL SAFETY

a. The following rules apply when Radio Frequency Radiation (RFR) exceeding the PEL’s is produced by equipment operated within NASA Langley except for household microwave ovens.

(1) Safety Permits must be posted near all operational equipment. The permit outlines suitable radiation protection procedures. A copy of the permit is on file in the SFAB.

(2) Only individuals who have been instructed in the potential hazards of microwave/Rf radiation and applicable SOP’s are permitted to use the equipment.

(3) Microwave/Rf warning signs must be posted to define controlled areas.

(4) Access to areas where RFR exceeds the PEL must be restricted. When appropriate, physical barriers shall be used.

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

(6) Free-space transmission within buildings is forbidden without prior approval from the RSO. As always, appropriate precautions must be taken to prevent overexposure to RFR.

CHAPTER 8

8. LABELING AND AREA POSTING REQUIREMENTS

8.1 GENERAL

Labeling and area posting is required for non-ionizing radiation.

8.2 RADIO-FREQUENCY SOURCES (RF)

Those stationary RF sources determined to require an approved NASA Langley Form 49 for their use are subject to the posting requirements of the OSHA Occupational Safety and Health Standards (29 Code of Federal Regulations (CFR) 1910.97). Copies of this standard are available from the RSO.

8.3 HIGH INTENSITY ARC LAMPS OR SOLAR SIMULATORS

All high intensity arc lamps, solar simulators, or other light sources capable of producing hazardous levels of ultraviolet radiation shall have their source housings labeled and each access to the immediate work area posted with the following warning statement:

CAUTION
HIGH INTENSITY ULTRA VIOLET ENERGY
PROTECT EYES AND SKIN

This requirement is not applicable to those sources, which are enclosed, or when operating procedures specify the work area is to be evacuated before the source is energized.

APPENDIX A

A. EXPOSURE STANDARD FOR NONLASER ULTRAVIOLET RADIATION

(Reference: Reprinted from the National Institute for Occupational Safety and Health recommended standard for Occupational Exposure to Ultraviolet Radiation, 1972. For more complete guidance consult the most current version of the American Conference of Governmental Industrial Hygienists, "Threshold Limit Values for Chemical Substances and Physical Agents").

RECOMMENDATIONS FOR AN ULTRAVIOLET RADIATION STANDARD

- The National Institute for Occupational Safety and Health (NIOSH) recommends that occupational exposure to ultraviolet energy in the workplace be controlled by compliance with the "Exposure Standards" below. Ultraviolet radiation (ultraviolet energy) is defined as that portion of the electromagnetic spectrum described by wavelengths from 200 to 400 nm. (Additional definitions and conversion factors are available in the referenced document.) Adherence to the recommended standards will, it is believed, prevent occupational injury from ultraviolet radiation, that is, will prevent adverse acute and chronic cutaneous and ocular changes precipitated or aggravated by occupational exposure to ultraviolet radiation.
- Sufficient technology exists to prevent adverse effects on workers, but technology to measure ultraviolet energy for compliance with the recommended standard is inadequate, so work practices are recommended for control of exposure in cases where sufficient measurement or emission data are not available.
- These criteria and the recommended standard will be reviewed and revised when relevant information warrants.

EXPOSURE STANDARDS

- For the ultraviolet spectral region of 315 to 400 nm, total irradiance incident on unprotected skin or eyes, based on either measurement data or on output data, shall not exceed 1.0 mW/cm^2 for periods greater than 1000 seconds, and for exposure times of 1000 seconds or less, the total radiant energy shall not exceed 1000 $mW.sec/cm^2$ (1.0 J/cm^2).
- For the ultraviolet spectral region of 200 to 315 nm, total irradiance incident on unprotected skin or eyes, based on either measurement data or on output data, shall not exceed the levels described below. Measurement techniques are discussed in the referenced document.
- If the ultraviolet energy is from a narrow band or monochromatic source, permissible dose levels for a daily 8 hour period can be read directly from Figure B.1, or, for selected wavelengths, from Table B.1.
- If the ultraviolet energy is from a broad band source, the effective irradiance, I_{eff}, relative to a 270 nm monochromatic source shall be calculated from the formula below. From I_{eff}, the permissible exposure time in seconds for unprotected skin or eyes shall be computed by dividing 0.003 J/cm^2, the permissible dose of 270 nm radiation, by I_{eff} W/cm^2.

$$I_{eff} = \sum I_{\lambda} S_{\lambda} \Delta\lambda$$

where: I_{eff} = effective irradiance relative to a monochromatic source at 270 nm
I_{λ} = spectral irradiance in $W/cm^2/nm$
S_{λ} = relative spectral effectiveness (unitless); see Table B-1 for values of S_{λ} at different wavelengths
$\Delta\lambda$ = bandwidth in nm

Table B-2 lists permissible exposure times corresponding to selected values of I_{eff} in $\mu W/cm^2$.

- If radiation intensity from a point source is known at some distance from the worker, for example, from measurement at another point or from output data at a known distance from the ultraviolet source, attenuation of radiation from that point to the worker can be calculated from the principle that radiation decreases with the square of the distance it must travel. For example, an object three feet away from a radiation source receives one-ninth the energy of an object one foot away. This assumption is conservative in some instances, since ultraviolet radiation, especially at very low wave-lengths, may be absorbed by some components of the atmosphere. Where information on atmospheric absorption of ultraviolet radiation is known, further correction may be applied. The calculation of intensity of radiation at any given point by use of the inverse square formula explained above does not take into consideration reflected energy.
- The recommended standard is not proposed for application as a standard to lasers. It should be recognized that significant non-occupational exposure to ultraviolet radiation can occur from exposure to sunlight, particularly during the summer months.

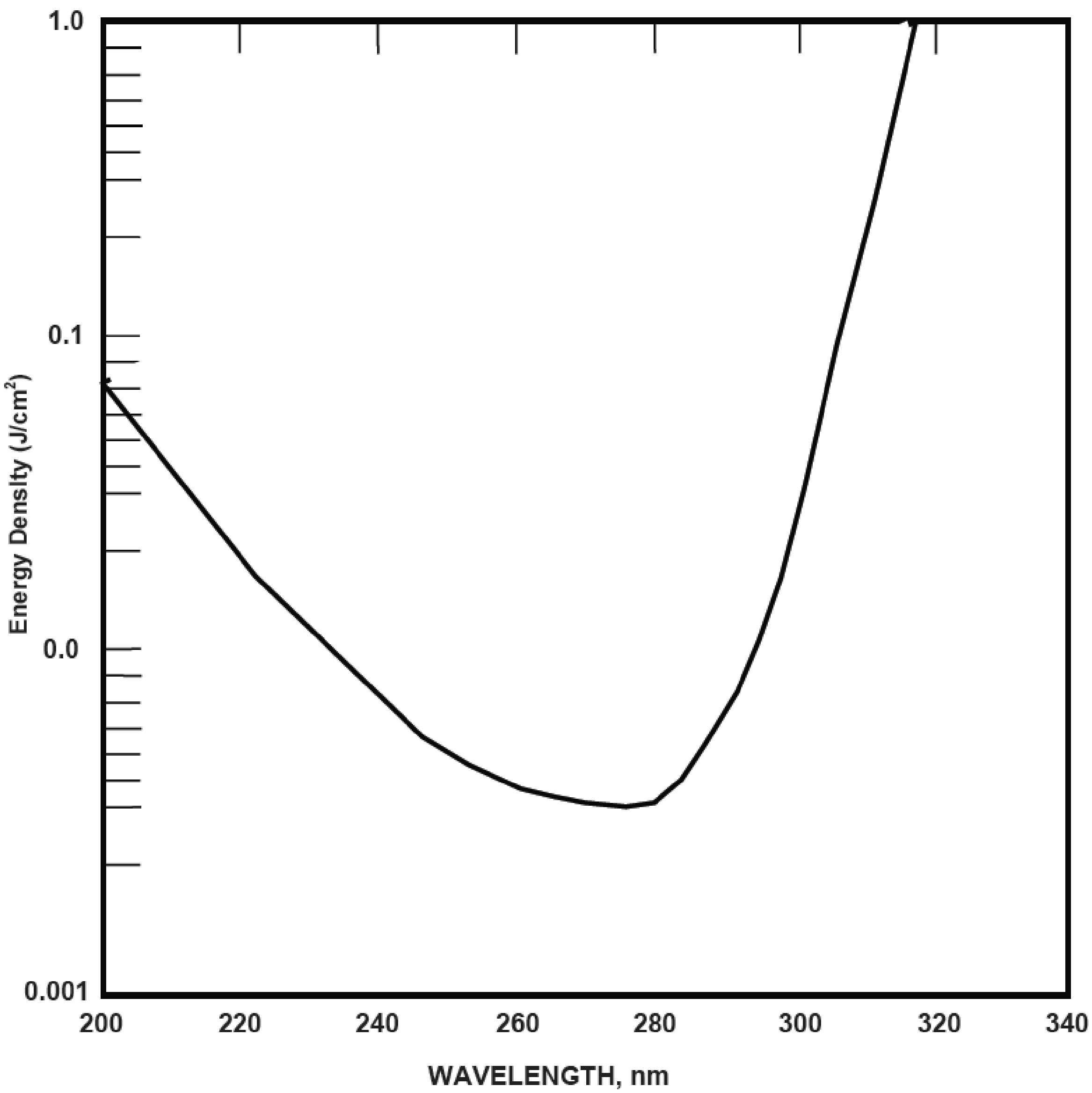


Figure B.1, Recommended Ultraviolet Radiation Exposure Standard.

TABLE B.1, Total Permissible 8 Hour Doses and Relative Spectral Effectiveness of Some Selected Monochromatic Wavelengths.		
Wavelength (nm)	**Permissible 8-Hour Dose (mJ/cm2)**	**Relative Spectral Effectiveness (Sλ)**
200	100.0	0.03
210	40.0	0.075
220	25.0	0.12
230	16.0	0.19
240	10.0	0.30
250	7.0	0.43
254	6.0	0.50
260	4.6	0.65
270	3.0	1.00
280	3.4	0.88
290	4.7	0.64
300	10.0	0.30
305	50.0	0.06
310	200.0	0.015
315	1000.0	0.003
This table was adapted from a table developed and published by the American Conference of Governmental Industrial Hygienists		

TABLE B.2, Maximum Permissible Exposure Times for Selected Values of Ieff.	
Duration of Exposure Per Day	**Effective Irradiance Ieff (µW/cm2)**
8 hr	0.1
4 hr	0.2
1 hr	0.8
30 min	1.7
15 min	3.3
10 min	5.0
5 min	10.0
1 min	50.0
30 s	100.0
This table was adapted from a table developed and published by the American Conference of Governmental Industrial Hygienists	

APPENDIX B

DEFINITIONS AND TERMINOLOGY

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 system may contain embedded lasers of more hazardous classifications.

Class 1M laser - Class 1M lasers produce large-diameter beams, or beams that are divergent. The Maximum Permissible Exposure (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 2a laser – Visible light lasers intended for a specific use (such as bar code readers) where the output is not intended to be viewed and the accessible radiant power does not exceed the Class 1 AEL for an exposure duration or less than or equal to 1000 seconds. The Class 2s designation is no longer used for newly manufactured lasers.

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 3a laser – Class 3a lasers include lasers that emit accessible laser light in excess of the Class 2 AEL but less than 5 times the Class 2 AEL. For visible wavelength CW lasers the power limit for a Class 3a laser is 5 mW. For nonvisible wavelengths the power

Class 3R laser - A Class 3R laser is a continuous wave laser which 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 315nm must not exceed 0.5 watts.

Class 4 laser – Class 4 lasers include lasers or laser system 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 10J/cm2 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, must 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.

Exposure (laser) – The product of irradiance and its duration.

Exposure (RF) – Generally expressed in terms of power density (mW/cm2) or equivalent electric field (V/m).

Far-field region – The region of the field from emitted from an antenna where the angular field distribution is essentially independent of the distance from the antenna. For an antennae focused at infinity, the far field region is sometimes referred to as the Fraunhofer region on the basis of analogy to optical terminology.

Fiber optics – The branch of optical technology concerned with the transmission of radiant power through fibers made of transparent materials such as glass, fused silica or plastic.

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 which 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/cm2.

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

Laser – A device which produces an intense, coherent and direction beam of light by stimulating electronic or molecular transition to lower energy states. Acronym: **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 eye wear – Protective eye wear designed and rated specifically for use with lasers. Laser eyewear has protection ratings (Optical Density or OD) for specific wavelengths.

Lasing medium – A material which 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 gasses.

Light emitting diode (LED) – A p-n junction semiconductor that emits incoherent optical radiation when biased in the forward direction. LED's 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 which 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. For an antennae focuses at infinity this region is sometimes referred to as the Fresnel region.

Nominal Hazard Zone (NHZ) – The space within which the level direct, reflected or diffusely reflected laser light exceed the applicable MPE.

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 diffusely reflected laser radiation during normal operation exceeds the applicable MPE. Exposure level beyond the boundary of the NHZ are below the MPE.

Non-ionizing radiation –

1. Electromagnetic radiation which 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 which includes the frequency and wavelength characteristics associated with ultraviolet, visible, infrared, radiofrequency, and microwave radiation.

Optical Density (OD) – Logarithm to the base ten of the reciprocal of the transmittance. For laser protective eye wear it represents to 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-cm2).

Radiant exposure – Surface density of the radiant energy received (J/cm2).

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

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 which have the same phase.

APPENDIX C

SUGGESTED OUTLINE FOR NASA LANGLEY FORM 49, "SAFETY PERMIT REQUEST - LASER/MICROWAVE" PREPARATION

I. Brief description of activity objectives.

II. List of all laser operators and radiation workers to be in controlled area during hazardous source operation and their operational responsibilities (NASA Langley Form 66s for new personnel should be forwarded with NASA Langley Form 49 and currently qualified personnel listed in Item 6 of the form).

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

IV. Safety operating plans:

A. Operational area security and control
B. Safety interlocks and overrides
C. Weather restrictions (if outside)
D. Any conditions that would preclude operations
E. Assignments of operational personnel
F. Operational countdown procedure or preparation steps
G. Safety eyewear (wavelength, density)
H. Order of action during laser operation
I. MPE calculations (if necessary)
J. Laser inventory if too numerous for cover sheet (include class, and so forth)

V. Sketches of operational area and actual experimental configuration (include map if outside)

APPENDIX D

NON-IONIZING RADIATION AND FIELDS

STATIC MAGNETIC FIELDS

These TLV's refer to static magnetic flux densities to which it is believed that nearly all workers may be repeatedly exposed day after day without adverse health effects. These values should be used as guides in the control of exposure to static magnetic fields and should not be regarded as fine lines between safe and dangerous levels.

Routine occupational exposures should not exceed 60 millitesla (mT), equivalent to 600 gauss (G), whole body or 600 mT (6000G) to the limbs on a daily, time-weighted average basis [1 tesla (T) = 10^4 G]. Recommended ceiling values are 2 T for the whole body and 5 T for the limbs. Safety hazards may exist from the mechanical forces exerted by the magnetic field upon ferromagnetic tools and medical implants. Cardiac pacemaker and similar medical electronic device wearers should not be exposed to field levels exceeding 0.5 mT (5G). Adverse effects may also be produced at higher flux densities resulting from forces upon other implanted devices such as suture staples, aneurysm clips, prostheses, etc.

These TLV's are summarized in Table 1.

TABLE 1. TLV's for Static Magnetic Fields

	8-hour TWA	**Ceiling**
Whole body	60 mT	2 T
Limbs	600 mT	5 T
Medical electronic device wearers		.5 mT

APPENDIX E

RECOMMENDATIONS FOR SUB-RADIO FREQUENCY STATIC MAGNETIC FIELDS STANDARDS

The ACGIH recommends that occupational exposure to static magnetic fields in the workplace be controlled by compliance with the "Exposure Standards" described below. Static magnetic fields are defined as those magnetic fields propagated from a magnetic source with frequencies at 30,000 Hertz and below. These criteria and the recommended standard will be reviewed and revised when relevant information warrants.

Exposure Standards - Sub-Radio Frequency (30 kHz and below) Magnetic Fields

These TLV's refer to the amplitude of the magnetic flux density (B) of sub-radio frequency (sub-RF) magnetic fields in the frequency range of 30 kHz and below to which it is believed that nearly all workers may be exposed repeatedly without adverse health effects. The magnetic field strengths in these TLV's are root mean square (rms) values. These values should be used as guides in the control of exposure to sub radio frequency magnetic fields and should not be regarded as a fine line between safe and dangerous levels.

Routine occupational exposure should not exceed:

$B_{TLVf} = 60 / f$

where: f is the frequency in Hz.

B_{TLV}= the magnetic flux density in millitesla (mT).

For frequencies in the range of 300 Hz to 30kHz (which includes the voice frequency [VF] band from 300 Hz to 3 kHz and the very-low-frequency [VLF] band from 3 to 30 kHz), occupational exposures should not exceed the ceiling value of 0.2 mT.

These ceiling values for frequencies of 300 Hz to 30 kHz are intended for both partial-body and whole-body exposures. For frequencies below 300 Hz, the TLV for exposure of the extremities can be increased by a factor of 10 for the hands and feet and by a factor of 5 for the arms and legs.

The magnetic flux density of 60 mT/f at 60 Hz corresponds to a maximum permissible flux density of 1 mT. At 30 kHz, the TLV is 0.2 mT, which corresponds to a magnetic field intensity of 160 amperes per meter (A/m).

Contact currents from touching ungrounded objects that have acquired an induced electrical charge in a strong sub-RF magnetic field should not exceed the following point of contact levels to avoid startle responses or severe electrical shocks:

A. 1.0 milliampere (mA) at frequencies from 1 Hz to 2.5 kHz;
B. 0.4f mA at frequencies from 2.5 to 30 kHz, where f is the frequency expressed in kHz.

Notes:

1. These TLV's are based on an assessment of available data from laboratory research and human exposure studies. Modifications of the TLV's will be made if warranted by new information. At this time, there is insufficient information on human responses and possible health effects of magnetic fields in the frequency range of 1 Hz to 30 kHz to permit the establishment of a TLV for time-weighted average exposures.
2. For workers wearing cardiac pacemakers, the TLV may not protect against electromagnetic interference with pacemaker function. Some models of cardiac pacemakers have been shown to be susceptible to interference by power-frequency (50-60 Hz) magnetic flux densities as low as 0.1 mT. It is recommended that, lacking specific information on electromagnetic interference from the manufacturer, the exposure of persons wearing cardiac pacemakers or similar medical electronic devices be maintained at or below 0.1 mT at power frequencies.

TABLE 1. TLV's for Sub-Radiofrequency (30 kHz and below) Magnetic Fields

Frequency Range	**TLV**
1-300 Hz	Whole-body exposure: 60/f ceiling value in mT
1-300 Hz	Arms and legs: 300/f ceiling value in mT
1-300 Hz	Hands and feet: 600/f ceiling value in mT
300 Hz – 30 kHz	Whole-body and partial-body ceiling value: 0.2 mT
1 Hz – 2.5 kHz	Point contact current limit: 1.0 mA
2.5 – 30 kHz	Point contact current limit: 0.4 mA where f = frequency in kHz

APPENDIX F

SUB-RADIOFREQUENCY (30 KHZ AND BELOW) AND STATIC ELECTRIC FIELDS

These TLV's refer to the maximum unprotected workplace field strengths of sub-radiofrequency electric fields (30 kHz and below) and static electric fields that represent conditions under which it is believed that nearly all workers may be exposed repeatedly without adverse health effects. The electric field intensities in these TLV's are root-mean-square (rms) values. The values should be used as guides in the control of exposure and, due to individual susceptibility, should not be regarded as a fine line between safe and dangerous levels. The electric field strengths stated in these TLV's refer to the field levels present in air, away from the surfaces of conductors (where spark discharges and contact currents may pose significant hazards).

Occupational exposures should not exceed a field strength of 25 kilovolts per meter (dV/m) form 0 hertz (Hz) (direct current [DC]) to 100 Hz. For frequencies in the range of 100 to 4 kilohertz (kHz), the ceiling value is given by:

$$E_{TLV}=2.5x10^{6}/f$$

Where: f = the frequency in Hz
E_{TLV} = the electric field strength in volts per meter (V/m)

A value of 625 V/m is the ceiling value for frequencies from 4 to 30 kHz. These ceiling values 0 to 30 kHz are intended for both partial-body and whole-body exposures.

Contact currents from touching ungrounded objects that have acquired an electrical charge in a strong static or sub-RF electric field should not exceed the following point contact levels to avoid startle responses or severe electrical shocks:

A. 1.0 mA at frequencies from 0 to 2.5 kHz;
B. 0.4 mA at frequencies from 2.5 to 30 kHz, where f is the frequency expressed in kHz.

Notes:

1. These TLV's are based on limiting currents on the body surface and induced internal currents to levels below those that are believed to produce adverse health effects. Certain biological effects have been demonstrated in laboratory studies at electric field strengths below those permitted in the TLV; however, there is no convincing evidence at the present time that occupational exposure to these field levels leads to adverse health effects.

Modifications of the TLV's will be made if warranted by new information. At this time, there is insufficient information on human responses and possible health effects of electric fields in the frequency range of 0 to 30 kHz to permit the establishment of a TLV for time-weighted average exposures.

2. Field strengths greater than approximately 5 to 7 kV/m can produce a wide range of safety hazards such as startle reactions associated with spark discharges and contact currents from ungrounded conductors within the field. In addition, safety hazards associated with combustions, ignition of flammable materials, and electro-explosive devices may exist when a high-intensity electric field is present. Care should be taken to eliminate ungrounded objects, to ground such objects, or to use insulated gloves when ungrounded objects must be handled. Prudence dictates the use of protective devices (e.g., suits, gloves, and insulation) in all fields exceeding 15 kV/m.
3. For workers with cardiac pacemakers, the TLV may not protect against electromagnetic interference with pacemaker function. Some models of cardiac pacemakers have been shown to be susceptible to interference by power-frequency (50/60 Hz) electric fields as low as 2 kV/m. It is recommended that, lacking specific information on electromagnetic interference from the manufacturer, the exposure of pacemaker and medical electronic device wearers should be maintained at or below 1kV/m.

TABLE 1. TLV's for Static and Sub-Radiofrequency (30 kHz and below) Electric Fields

Frequency Range	**TLV**
0 – 100 Hz	25,000 V/m in air (ceiling value)
100 Hz – 4 kHz	$2.5\text{x}10^6/f$ V/m in air (ceiling value) where: f – frequency in kHz
4 – 30 kHz	625 V/m in air (ceiling value)
0 – 2.5 kHz	Point of contact current limit: 1.0 mA
2.5 – 30 kHz	Point of contact current limit: 0.4 mA where: f = frequency in kHz

APPENDIX G

MAXIMUM PERMISSIBLE EXPOSURE FOR CONTROLLED ENVIRONMENTS (3 KHZ--300 GHZ)

Table 1—Maximum permissible exposure for controlled environments

Part A: Electromagnetic fields†				
Frequency range (MHz) 1	Electric field strength (E) (V/m) 2	Magnetic field strength (H) (A/m) 3	Power density (S) E-field, H-field (mW/cm^2) 4	Averaging time $\|E\|^2$, $\|H\|^2$ or S (min) 5
0.003–0.1	614	163	(100, 1 000 000)‡	6
0.1–3.0	614	$16.3/f$	$(100, 10\,000/f^2)$‡	6
3–30	$1842/f$	$16.3/f$	$(900/f^2, 10\,000/f^2)$	6
30–100	61.4	$16.3/f$	$(1.0, 10\,000/f^2)$	6
100–300	61.4	0.163	1.0	6
300–3000	—	—	$f/300$	6
3000–15 000	—	—	10	6
15 000–300 000	—	—	10	$616\,000/f$
Note—f is the frequency in MHz.				

* The current limits given above may not adequately protect against startle reactions and burns caused by transient discharges when contacting an energized object. See IEEE 95.1 1999 for additional information.

APPENDIX H

MAXIMUM PERMISSIBLE EXPOSURE FOR UNCONTROLLED ENVIRONMENTS (3 KHZ--300 GHZ)

Table 2—Maximum permissible exposure for uncontrolled environments

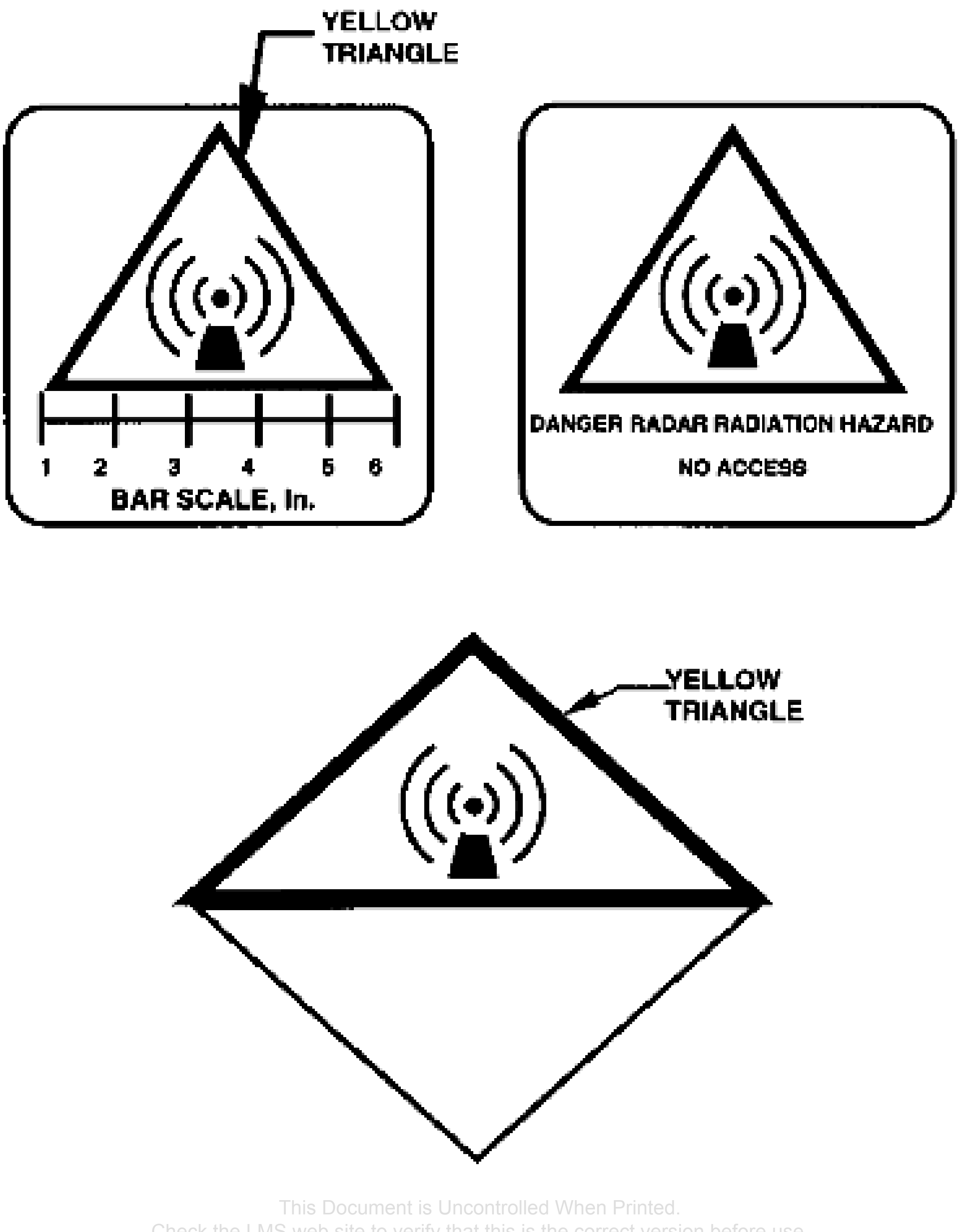
Part A: Electromagnetic Fields[†]					
Frequency range (MHz) 1	Electric field strength (E) (V/m) 2	Magnetic field strength (*H*) (A/m) 3	Power density (*S*) E-field, H-field (mW/cm²) 4	Averaging time $\|E\|^2$, *S* or (min) 5	$\|H\|^2$
0.003–0.1	614	163	(100, 1 000 000)[‡]	6	6
0.1–1.34	614	$16.3/f$	$(100, 10\,000/f^2)$[‡]	6	6
1.34–3.0	$823.8/f$	$16.3/f$	$(180/f^2, 10\,000/f^2)$	$f^2/0.3$	6
3.0–30	$823.8/f$	$16.3/f$	$(180/f^2, 10\,000/f^2)$	30	6
30–100	27.5	$158.3/f^{1.668}$	$(0.2, 940\,000/f^{3.336}$	30	$0.0636\,f^{1.337}$
100–300	27.5	0.0729	0.2	30	30
300–3000	—	—	$f/1500$	30	
3000–15 000	—	—	$f/1500$	$90\,000/f$	
15 000–300 000			10	$616\,000/f^{1.2}$	
NOTE—*f* is the frequency in MHz.					

- The current limits given above may not adequately protect against startle reactions and burns caused by transient discharges when contacting an energized object. See IEEE 95.1 1999 for additional information.

APPENDIX I

MICROWAVE/RF WARNING SIGNS

MICROWAVE/RF WARNING SIGN



APPENDIX J

ACRONYMS

ACGIH	American Conference of Governmental Hygienists
ANSI	American National Standards Institute
CA&LB	Capital Assets and Logistics Branch, Center Operations Directorate
CFR	Code of Federal Regulations
COTR	Contracting Officer's Technical Representative
cw	Continuous wavelength
DOT	Department of Transportation
FAA	Federal Aviation Administration
FDA	Food and Drug Administration
LAPD	Langley Policy Directive
LPR	Langley Procedural Requirements
LaRC	Langley Research Center
LSO	Laser Safety Officer
MPE	Maximum Permissible Exposure
NASA	National Aeronautics and Space Administration
NFPA	National Fire Protection Association
NIOSH	National Institute for Occupational Safety and Health
NIR	Non-ionizing Radiation
NIRC	Non-ionizing Radiation Committee
NRC	Nuclear Regulatory Commission
PR/PO	purchase request/purchase order
OD	Optical Density
OFSH	Organizational Facility Safety Head
OHO	Occupational Health Officer
OHCM	Office of Human Capital Management
OMC	Occupational Medical Center
SMAO	Safety and Mission Assurance Office
SFAB	Safety and Facility Assurance Branch
OSHA	Occupational Safety and Health Administration
PEL	Permissible Exposure Limit
PFSH	Principal Facility Safety Head
rem	Roentgen equivalent man
RF	Radio Frequency
RFR	Radio Frequency Radiation
RSO	Radiation Safety Officer
SAR	Specific Absorption Rate
SDL	Standard Distribution List
TLV	Threshold Limit Value
UL	Underwriters Laboratories (Incorporated)
YAG	Yttrium Aluminum Garnet