Ames Procedural Requirements

APR 8715.1

Effective Date: March 5, 2025

Expiration Date: March 5, 2028

COMPLIANCE IS MANDATORY

Subject: Chapter 8 – Laser, Microwave, and Other Nonionizing Radiation Safety

Responsible Office: Code QH/Occupational Safety, Health, and Medical Service Division

DOCUMENT CHANGE LOG

Status [Baseline /Revision /Cancelled]	Document Revision	Date of Change	Description
Revision	2	9/11/2014	Changed Formatting to comply with AMS requirements, added document change log and preface.
Revision	3	10/28/2019	Corrected grammatical errors throughout and changed “will” or “must” to “shall” as required. Changed “Nonionizing Radiation Safety Officer/ Laser Safety Officer (NRSO/LSO)” to simply “Nonionizing Radiation Safety Officer/NRSO” or “NRSO”. Laser Safety Officer or LSO is used where appropriate for lasers. Changed the required pre-laser use eye exam to voluntary. Edited wording in medical to more closely match NPR 1800 guidance. Added more description to project permissions description. Updated outdoor laser use requirements.

			Removed appendices where reference to document should have been used or that are more appropriately covered in training.
Revision	4	8/14/2024	Clarified responsibilities for purchasing/use/transfer and disposal of Nonionizing Radiation Sources. Allow for Nonionizing Radiation Safety Committee discretion on designating ALUs on a laser permit. Revised language for Associate Laser Users to operate lasers independently under specific conditions allowed by the NRSC. Added new verbiage on exempted RF/MW sources in compliance with NPR 1800.1. Removed information on Microwave oven safety since these are included in the exempt sources section. Expanded UV radiation safety section to include all optical radiation in order to also include high intensity visible light and infrared hazards. Added table of Risk Groups for helping define categories of hazardous lamps as recommended by ANSI/IES RP-27.3-17 and IEC/EN 62471.

TABLE OF CONTENTS

PREFACE

P.1 Purpose

P.2 Applicability

P.3 Authority

P.4 Applicable Documents and Forms

P.5 Measurement/Verification

P.6 Cancellation

CHAPTER 8 LASER, MICROWAVE, AND OTHER NONIONIZING SAFETY

8.1 Responsibilities

8.2 Medical Surveillance

8.3 Laser Use Specific Safety Requirements

8.4 Laser Safety Controls and Use Approval Paths

8.5 Radiofrequency Electromagnetic Field Specific Safety Requirements

8.6 Static Magnetic Field Use Specific Safety Requirements

8.7 Non-laser optical Radiation Use Specific Safety Requirements (Ultraviolet (UV) Radiation, Infrared (IR), and High Intensity Light)

APPENDIX A. DEFINITIONS

APPENDIX B. ACRONYMS

APPENDIX C. REFERENCES

PREFACE

P.1 PURPOSE

This chapter provides requirements for the safe use of nonionizing radiation devices. Nonionizing radiation as defined in this chapter includes lasers, microwave, radio frequency (RF) energy, electromagnetic fields, and optical radiation (ultraviolet radiation (UV), Infrared (IR), and high intensity visible light).

P.2 APPLICABILITY

a. This directive applies to all Ames employees, Ames contractors and grantees as specified in their contracts or grants; and to other organizations (i.e., commercial partners, other Federal agencies, international parties, and Ames tenants) as specified and described in written operating agreements.
b. The controls and permissions included in this directive are specific to nonionizing radiation hazards. These controls and approvals may be a part of a larger or parallel approval process. Other approvals and institutional reviews may be required for other hazards especially for projects of a large scope or those involving hardware or software reviews, payload reviews, or overall system safety reviews.
c. In this directive, all mandatory actions (i.e., requirements) are denoted by statements containing the term "shall." The terms: "may" or "can" denote discretionary privilege or permission, "should" denotes a good practice and is recommended, but not required, "will" denotes expected outcome, and "are/is" denotes descriptive material.
d. In this directive, all document citations are assumed to be the latest version unless otherwise noted.

P.3 AUTHORITY

NASA Procedural Requirements NPR 1800.1 NASA Occupational Health Program Procedures

P.4 APPLICABLE DOCUMENTS AND FORMS

a. 21 CFR 1040.10 Laser products
b. 29 CFR 1910.97 Nonionizing Radiation
c. 29 CFR 1910.133 Eye and Face Protection
d. American National Standard Z136.1- 2022 Safe Use of Lasers
e. American National Standard Z136.6 – 2015 Safe Use of Lasers Outdoors
f. American National Standard Z136.8 – 2021 Safe Use of Lasers in Research, Development, or Testing
g. Institute of Electrical and Electronics Engineers (IEEE) C95.1 - 2019 Standard for Safety Levels with Respect to Human Exposure to Electric, Magnetic, and Electromagnetic Fields, 0 kHz to 300 GHz
h. American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Values (TLVs) and Biological Exposure Indices (BEIs)
i. Federal Aviation Administration Advisory Circular AC 70-1B - Outdoor Laser Operations

P.5 MEASUREMENT/VERIFICATION

Verification of conformance to requirements in this directive are measured through Center and Responsible Organizational management reviews, self-assessments, and subsequent analysis and reports of conformance to requirements, as well as periodic internal audits. Verification and measurement for compliance to this directive

will be tracked through the Ames Annual Voluntary Protection Program (VPP) self inspections and internal audits by Code QH and the Nonionizing Radiation Safety Committee.

P.6 CANCELLATION

APR 8715.1 Chapter 8, Laser, Microwave, and Other Nonionizing Safety effective 8/11/2014

Eugene Tu
Director

DISTRIBUTION STATEMENT:

APR 8715.1 Ames Health and Safety Manual Chapters shall be made available via procurement website to anyone bidding a job here at Ames. The exceptions are Chapter 10 – Pressure Systems Safety, Chapter 12 – Explosives Safety and Chapter 23 – Control of Narcotics and Other Controlled Drugs, which shall not to be made public but can be viewed onsite.

CHAPTER 8 – LASER, MICROWAVE, AND OTHER NONIONIZING SAFETY

8.1 Responsibilities

8.1.1 Nonionizing Radiation Safety Committee

The responsibilities for the Nonionizing Radiation Safety Committee (NRSC) are listed in Chapter 2.

8.1.2 Nonionizing Radiation Safety Officer (NRSO)

a. The NRSO is appointed by the Director of Code Q, Safety and Mission Assurance Directorate, and approved by the Executive Safety Committee and is responsible to the NRSC for the operation of the Nonionizing Radiation Safety Program.

b. The NRSO normally serves as the NASA Ames Research Center Laser Safety Officer (LSO). A separate Laser Safety Officer may be appointed to assist the NRSO at the discretion of the Director of Code Q, Safety and Mission Assurance Directorate.

c. The NRSO serves as a voting member on the NRSC. If a separate LSO is appointed, they also will serve on the NRSC as a voting or non-voting member as determined by the NRSC.

d. The NRSO shall have the authority to suspend use of nonionizing radiation devices if safety controls are inadequate.

e. The NRSO shall perform the following tasks:

(1) An initial review of all nonionizing radiation projects with the capability of emitting hazardous levels of energy for safety and compliance to applicable standards and regulations. This includes, but is not limited to, the use of: radio frequency radiation emitting devices, research microwave radiation, ultraviolet radiation, electromagnetic/static magnetic field generators, outdoor laser use, and all Class 3B and Class 4 laser experiments. The NRSO may require an evaluation of laser systems with classifications below 3B if optics or other means are used to focus or increase the energy of the laser. This review will be presented to the NRSC to assist them in their review and approval of projects. Ongoing projects will be reviewed and approval renewed annually.

(2) Review/Inspect nonionizing radiation systems for compliance with applicable nonionizing radiation safety requirements. Re-inspections are required when changes to approved safety features or controls occur.

(a) Laser systems – initially with NRSC, annual reinspection by Code QH health physics staff.

(b) High energy or complex nonionizing systems - initially with NRSC, annual reinspection by Code QH health physics staff.

(c) Commercial communications transmitters – initially by Code QH health physics staff and annual verification. NOTE: Additional review is required by spectrum management and explosives safety.

(d) Commercial purchased or low hazard nonionizing radiation systems - initially by Code QH health physics staff and annual verification that equipment has not been altered.

(3) Ensure training for specific nonionizing radiation sources (e.g., lasers, radars) is available and provided to personnel using these sources.

(4) Maintain an inventory of nonionizing radiation emitting equipment.

(5) Review and approve purchase requests for Class 3B and Class 4 lasers, non-laser optical radiation sources,

RF/MW emitters (radar systems, communication systems, MW diathermy units, RF generators, RF heat sealers, etc.), high intensity ultraviolet and infrared lights to ensure that appropriate tracking of equipment and users is accomplished.

(6) Investigate accidents and procedural safety violations for nonionizing radiation projects and providing consultation to mishap or accident investigations involving nonionizing radiation.

(7) Maintain records of all nonionizing radiation research projects.

(8) Ensure that the most current version of ANSI Z136.1 is available to all Authorized Laser Users (ALUs) and IEEE C95.1 is available for all Authorized Users of RF/MW radiation. The users are required to become familiar with those parts applicable to their installation and operations. ANSI Z136.6 for outdoor laser use and ANSI Z136.8 for research laser use will be made available if applicable. The provisions of the ANSI Z136 Standards will be interpreted by the Ames NRSC for local applications.

(9) In the absence of the NRSO, the NRSO will either designate a qualified alternate or the Chairperson of the NRSC to act as the NRSO.

8.1.3 System Safety and Mission Assurance Division (Code QS)

a. The Division Chief of the System Safety and Mission Assurance Division shall assign a representative to the Nonionizing Radiation Safety Committee. The System Safety and Mission Assurance Representative responsibilities shall include:

(1) Reviewing nonionizing projects for overall system safety when these projects involve laser systems using Class 3b and Class 4 lasers, outdoor laser use, and other nonionizing radiation systems where personnel could be exposed at or near the applicable Maximum Permissible Exposure (MPE) for that radiation. This review will include a procedure review and an overall system safety inspection when possible.

(2) Approving by signature on the Laser Safety Permit or nonionizing radiation project authorization when the systems safety review has been completed.

(3) Approving by signature any modifications to the system that affect system safety.

(4) Determining if other safety or engineering specialties need to be consulted, such as a pressure system safety or explosive safety, and consulting with these experts in the performance of the systems safety review.

8.1.4 Authorized Laser Users (ALU)

a. Authorized Laser Users at Ames are certified by the Nonionizing Radiation Safety Committee for Class 3B and Class 4 Laser or laser system use. Four requirements shall be met before the NRSC will consider the laser user qualification as an ALU:

(1) Experience. An ALU shall have at least one year of experience using Class 3B or Class 4 laser systems of a similar or greater hazard to the system for which they seek approval. In certain cases, an existing Ames ALU can recommend a researcher to become an ALU before a year if the NRSC agrees and approves. The NRSC will evaluate the researcher's submitted experience form to determine if the researcher's experience meets this requirement and may request additional information if needed.

(2) Laser Safety Theory Training. The laser user shall complete comprehensive laser safety theory training approved by the NASA Ames NRSO. An online course specific to NASA Ames is currently the preferred method for meeting this requirement. Other training will only be approved on a case-by-case basis by the NRSO.

(3) Laser Safety System Planning and Procedure Writing. The ALU shall demonstrate an ability to apply the concepts studied in the laser safety theory course. The ALU will work closely with the NRSO and NRSC to design a safe laser laboratory or research area, obtain the proper PPE, have interlocks or safety systems evaluated by appropriate engineers, and to author safe operating procedures for their laser systems. Other training and procedures may be identified as the system is designed, such as "lockout/tagout" or Hazardous Communication (HAZCOM) training. While these auxiliary procedures are not inherently part of the ALU certification process, they may be part of the laser system certification and therefore, shall be obtained if required.

(4) System Inspection and Permit Issuance. Once the procedures are acceptable to the NRSC and the system is constructed, an inspection will be conducted by the NRSO or designee. Members of the NRSC shall attend the inspection either physically, virtually, or by reviewing a video recording of the inspection. The procedure and system will be inspected for overall laser safety (hazard area control, PPE, posting, interlock functionality, etc.). During this time, the prospective ALU shall be required to demonstrate a thorough knowledge and practical application of laser safety principles. The NRSO or designee and NRSC representative(s) will also discuss any additional laser safety devices or practices that may be required before the Laser Safety Permit is issued. Once all of the above conditions have been met, the NRSO and the NRSC are satisfied with the safety of the system, and the procedures are revised where required, a Laser Safety Permit listing the ALU will be issued in order to approve the system and complete the ALU certification process.

b. The ALU shall be responsible for the following:

(1) Compliance with all safety regulations as outlined in the Ames Health & Safety Manual, APR 8715.1, not simply those relating to laser safety.

(2) The safe operation for their laser system. Deviations from safe and approved operating procedures or actions that are not in accordance with laser safety training or requirements is not permitted.

(3) Ensuring that personnel using lasers under the ALU's Laser Safety Permit are properly instructed and trained to the level of responsibility authorized on that permit.

(4) Providing on-the-job laser safety training to all personnel associated with the operation of the ALU's laser system. This is especially true in the case of Associate Laser Users (AsLU) who are working towards ALU certification. This training will reinforce the training in laser safety they have already received and will provide practical knowledge of the safety devices, equipment and procedures of the specific laser system.

(5) Maintaining a current laser inventory, including the location of portable lasers. This shall include all research lasers in the ALU's possession, Class 3B through Class 4 research lasers inclusive. If a laser is transferred to another ALU, offsite, or disposed, the ALU shall notify the NRSO.

(6) Ensuring that Standard Operating Procedures (SOPs) are available at the location where the lasers will be used and with the NRSO and NRSC for all Class 3B and Class 4 activities. These procedures shall be approved by the NRSC and the NRSO before being posted with the laser. The ALU shall not permit the operation of a laser unless there is adequate control of laser hazards as defined by the NRSC, the SOP, and laser safety training.

(7) Submitting laser safety plans for review by the NRSC at least annually.

(8) Obtaining approval of the NRSC whenever the laser system is modified or deviates from the previously approved laser safety plan.

(9) Ensuring that the ALU and all laser users on their project complete the required initial and continuing education (refresher) laser safety training approved by the NRSO.

(10) Ensuring all personnel working on the project wear the appropriate approved personal protective equipment (PPE) when and where required.

(11) Notifying the line supervisor and the NRSO immediately when the ALU believes a laser accident has occurred and send the person potentially exposed to laser radiation to the Ames Health Unit. Serious injuries should be reported immediately via the Center emergency services number 650-604-5555 or 911 for medical attention.

(12) Providing a pre-shift briefing on the laser system, the safety features, and emergency procedures to the ancillary personnel, whenever personnel other than the personnel specifically listed on the Laser Safety Permit (ancillary personnel) will be working on or near the laser system or on an associated test involving the laser system

(13) Ensuring that all personnel listed as an AsLU or laser worker on the ALU's Laser Safety Permit(s) are informed that pre-use eye exams are voluntary. The Ames Health Unit (AHU) will provide these for NASA Ames Civil Servants and NASA sponsored students and interns. Contractors and other personnel will need to make arrangements through their employers if voluntary pre-work eye exams are desired.

8.1.5 Associate Laser Users (AsLU)

a. AsLUs are approved by the Nonionizing Radiation Safety Committee to work with Class 3B and Class 4 laser or laser systems under the direct supervision of an Authorized Laser User (ALU). The NRSC may under its discretion relax this requirement on a case-by-case basis and only by specific condition outlined on the Laser Safety Permit. In order to be authorized as an AsLU on a project, the following minimum requirements shall be met:

(1) Experience. The NRSC will evaluate each potential AsLU's qualifications and experience to ensure he/she is a good candidate for laser user. Students or researchers without any experience in the safe use of lasers will not normally be considered as an AsLU without further documentation of their qualifications to use hazardous energy and their understanding of safety procedures and theory.

(2) Laser Safety Theory Training. The laser user shall complete comprehensive laser safety theory training. An online course specific to NASA Ames is currently the preferred method for meeting this requirement. Other training will only be approved on a case-by-case basis by the NRSO. Refresher training is required annually.

(3) Mentor/ALU Supervisor. The ALU will place the AsLU(s) name in the laser safety plan and will be listed on the Laser Safety Permit as an AsLU to be approved by the NRSC.

8.1.5.1 The responsibilities of the AsLU are as follows:

a. The AsLU shall follow the instructions of the ALU regarding safety.

b. The AsLU shall read and understand the laser safety plan for the laser system and follow the procedures as written.

c. The AsLU shall comply with all safety regulations as outlined in the Ames Health & Safety Procedural Requirements APR 8715.1, not simply those relating to laser safety.

d. The AsLU shall operate the laser system only under the direct supervision of the ALU unless a specific condition listed on the Laser Safety Permit allows otherwise (typically lower power class 3B systems). Deviations from the laser safety plan or actions that are not in accordance with laser safety training or requirements are not permitted.

e. The AsLU shall complete required continuing education laser safety training approved by the ARC NRSO.

f. The AsLU shall wear appropriate eye protection and other required personal protective equipment (PPE).

8.1.6 Laser Workers and Laser System Observers

a. Laser Workers and Laser System Observers are personnel who will either assist in the system design, construction, alignment, or operation or may need access to the laser hazard area to observe a test or study. These personnel will not be authorized to operate a laser or laser system. Laser Workers and Laser System Observers at Ames are approved by the NRSC to work in Class 3B and Class 4 laser-controlled areas under the direct supervision of an ALU. To be authorized as a Laser Worker or Laser System Observer on a project, the following minimum requirements shall be met:

(1) Laser Safety Theory Training. The laser worker or observer shall complete laser safety training. An online course specific to NASA Ames is currently the preferred method for meeting this requirement. Other training will only be approved on a case-by-case basis by the NRSO. Refresher training is required annually if access is needed.

(2) ALU Supervisor. Laser Workers and Laser System Observers shall always be supervised by an ALU. Entry into the laser hazard area will only be allowed when the ALU is present and has approved the entry. The ALU will place the Laser Worker or Laser System Observers' name in the Laser Safety Plan and on the Laser Safety Permit as a Laser Worker or Laser System Observer.

b. Laser Workers and Laser System Observers responsibilities are as follows:

(1) Following the instructions of the ALU regarding safety procedures.

(2) Being responsible for reading, understanding, and following the Laser Safety Plan for the laser system and following the procedures as written. Deviations from safe operating procedures or actions that are not in accordance with laser safety training or requirements are not permitted.

(3) Being responsible for compliance with all safety regulations as outlined in the Ames Health & Safety Procedural Requirements APR 8715.1, not simply those related to laser safety.

(4) Completing required continuing education laser safety training approved by the NRSO as long as they are listed on a Laser Safety Permit.

(5) Shall wear appropriate eye protection and other required personal protective equipment (PPE).

8.1.7 Ancillary Non-Laser Personnel Responsibilities

a. Ancillary personnel are those workers who are not authorized to enter the laser-controlled area but who may be performing work near or around the controlled area. It is important that they are aware of the hazards and understand the posting and boundaries of the controlled area. Ancillary personnel shall receive a pre-job briefing from the ALU on applicable laser hazards.

b. Ancillary personnel shall: Obey and comply with the ALU(s) directions and orders concerning laser safety and the laser system.

c. Work near or around a laser-controlled area shall not be conducted without a safety briefing from the ALU for the laser or laser system.

8.1.8 Authorized Users of Other Sources of Nonionizing Radiation Responsibilities

a. The Authorized User of sources of nonionizing radiation emitting equipment is personally responsible for compliance with the applicable standard (C95.1 for RF/MW sources) as specified by the NRSO and Ames policies on operations. Operations are authorized by the NRSC. The responsibilities of a nonionizing radiation source user other than lasers are similar to those specified for Authorized Laser Users.

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

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

d. Provide safety instructions to personnel using equipment under his or her direction.

e. Ensure personnel with suspected injuries from radiofrequency electromagnetic field radiation are taken to the Ames Health Unit immediately for severe injuries but no later than 24 hours for other injuries for an examination for care and evidence of injury.

f. Notify the NRSO within 24 hours when known or suspected overexposure to radiofrequency electromagnetic radiation has occurred.

g. Adopt practices and procedures that prevent exposure to radiofrequency electromagnetic field radiation in excess of the Maximum Permissible Exposure Limit (MPE).

h. Maintain a current inventory of all hazardous nonionizing sources in the AU's possession. If a nonionizing source is removed from service, transferred to another AU, transferred offsite, or disposed, the AU shall notify the NRSO.

i. Notify the NRSO after repairs or modifications are made to nonionizing radiation producing equipment in clduing RF transmitters and UV radiation producing equipment.

j. The AU is responsible for compliance with all safety regulations as outlined in the Ames Health and Safety Manual, APR 8715.1, not simply those relating to nonionizing radiation safety.

k. Provide NRSO with a minimum of (RF/UV/High intensity Optical) safety plan. The safety plan should include applicable sections of the manufacturer(s) manuals, wavelength or frequency of the source, the power of the unit, dish, and emitter dimensions, the experience level of the user, and a description of the proposed use of the source.

l. The NRSC and the NRSO will approve the use of the source once they are confident it will be used safely, and no personnel will be exposed to levels of nonionizing radiation above the applicable MPE.

m. The user shall contact the NRSO or health physics staff for consultation and for requirements for authorization for the specific nonionizing radiation source because there are many sources of nonionizing radiation and the means of control for most are unique.

8.2 Medical Surveillance

8.2.1 Pre-use medical examinations

a. There are no medical surveillance requirements for users or operators of RF and microwave systems.
b. Pre-use physical, eye, or skin examinations for laser use are not normally required. Personnel taking medications that cause sensitivity of the skin or eyes to light or who have existing eye or skin conditions that may cause light sensitivity shall notify their NASA supervisor or Mentor of their need for a basic pre-use examination. These examinations shall be requested by the NASA Supervisor or Mentor and should be provided by the NASA Ames Health Unit for NASA Civil Servants and NASA sponsored interns and students. NASA Contractors, Non-NASA personnel, and interns and students from other institutions requesting these examinations should receive these examinations from their employer's or institutions' medical services or personal medical provider. Descriptions of basic examination guidelines are provided in ANSI Standard Z136.1, Appendix D.
c. Pre-use physical examinations specifically for other nonionizing radiation sources are not required.

8.2.2 Medical Evaluation Following Suspected or Known Injury

a. Medical examinations shall be performed as soon as practical (usually immediately but at most within 24 hours) when a suspected injury or adverse effect from a laser exposure occurs. In addition to acute symptoms, consideration shall be given to the exposure wavelength, emission characteristics, and exposure situation to ensure appropriate medical referral. Initial evaluation may be provided by a physician, but follow-up is required by an ophthalmologist within 48 hours, especially for injuries or suspected injuries from lasers operating in the retinal hazard region (optical radiation with wavelengths between 400 nm and 1400 nm where the principal hazard is to the retina). Descriptions of basic examination guidelines are provided in ANSI Standard Z136.1, Appendix D.
b. Employees with laser skin injuries shall be seen by a physician immediately or within 48 hours depending on the seriousness of the injury.

c. Employees with injuries from established adverse health effects for other nonionizing radiation sources shall be seen by a physician immediately or within 24 hours depending on the seriousness of the injury. Established adverse health effects from other nonionizing sources include 1) aversive or painful electrostimulation due to excessive radiofrequency (RF) internal electric fields, 2) RF shocks or burns due to contact with excessive RF voltages, 3) heating pain or tissue burns due to excessive localized RF exposure, 4) behavioral disruption, heat exhaustion or heat stroke due to excessive whole body RF exposures, 5) eye problems or skin burns from acute UV exposure, and 6) cardiac pacemaker or implant disturbance from high energy static magnetic fields.

d. Any injured or potentially injured personnel, civil servant, or contractor, will report to the Ames Health Unit if the injury occurs during normal working hours. Injured or potentially injured employees will call Dispatch for assistance after hours. In either case, the on-call Ames Health Unit doctor and the Laser Safety Officer will be notified of the injury as soon as possible.

e. Normal working hours: Health Unit at 4-5287 and the Laser Safety Officer at 4-3979. Emergency/after hours/off shift: For Medical Assistance or to reach the Laser Safety Officer, call Dispatch at 9-1-1, 4-5416, or 604-5555.

8.3 Laser Use Specific Safety Requirements

8.3.1 Laser Acquisition

No Class 3B or Class 4 laser is allowed at NASA Ames Research Center without clearance from the Laser Safety Officer except intact common commercial embedded laser products (e.g., copy machines, DVD players, etc.). Other types of embedded lasers also require approval. NASA Ames civil servants and NASA contractor personnel are required to notify the NRSO of intent to purchase, fabricate, or otherwise acquire these types of lasers for use at NASA Ames Research Center. The applicable portion of NASA Form 1707 can be used to document the approval.

8.3.2 Laser Classification

a. Laser safety standards are derived from government-mandated regulations and voluntary standards. Safety rules governing the manufacture of lasers are established by the Federal Government. Laser products manufactured after August 2, 1976, shall conform to performance standards established by the Food and Drug Administration (FDA) (21 CFR 1040.10) or equivalent if meeting the guidance issued by FDA Laser Notice No. 50 and No. 56. The standard requires that lasers are properly classified by the manufacturers. Thus, for most lasers, measurements or calculations to determine the hazard classification are unnecessary. In addition, the standard establishes certain engineering requirements for each class and requires warning labels that state maximum output.

b. Lasers are classified according to the ability of the primary or reflected beam to injure the eye or skin. The appropriate class is determined from the wavelength, power output, and duration of pulse (if pulsed). Classification is based on the maximum accessible output power. There are six major laser classes, with Class 1 representing the least hazardous. All lasers, except Class 1, shall be labeled with the appropriate hazard classification.

(1) Class 1 Laser:

(a) Class 1 lasers or laser systems do not emit harmful levels of radiation during normal operation and are, therefore, exempt from user control measures with the exception of requirements applicable for embedded higher class lasers where the embedded beam will be accessible (e.g., service and maintenance). The exemption strictly applies to emitted laser radiation hazards and not to other potential hazards. As a matter of good practice, unnecessary exposure to Class 1 laser light should be avoided.

(b) Class 1 lasers can be used without restriction in the manner intended by the manufacturer and without special training or qualification of operating personnel. These personnel, however, should not be exposed to laser light unnecessarily.

(c) Class 1M lasers or laser systems are considered to be incapable of producing hazardous exposure conditions during normal operation unless the beam is viewed with an optical instrument such as an eye-loupe (diverging beam) or a telescope (collimated beam) and exempt from any control measures other than to

prevent potentially hazardous optically aided viewing; and is exempt from other forms of surveillance. If Class 1M lasers are to be used with any possibility of being viewed with collecting optics, the proposed use and controls will be provided to the Laser Safety Officer for review and possible NRSC approval.

(2) Class 2 Lasers:

(a) Class 2 lasers or laser systems emit accessible laser light in the visible region (400 nm to 700 nm) and are capable of causing eye damage through chronic exposure. In general, the human eye will blink within 0.25 second when exposed to Class 2 laser light. This blink reflex provides adequate protection. It is possible, however, to overcome the blink reflex and to stare into Class 2 laser long enough to cause damage to the eye. The upper power limit for Class 2 lasers is 1 milliwatt (mW). Class 2 lasers are commonly utilized during alignment applications and in construction levels.

Class 2 lasers can be used without restriction in the manner intended by the manufacturers and without special training of operating personnel. Personnel, however, should not be exposed to laser light unnecessarily.

(b) Class 2M lasers or laser systems emit in the visible portion of the spectrum (400 nm to 700 nm) and eye protection is normally afforded by the aversion response for unaided viewing. However, Class 2M is potentially hazardous if viewed with certain optical aids.

(3) Class 3 Lasers:

(a) Class 3 lasers or laser systems may be hazardous under direct and specular reflection viewing conditions but is normally not a diffuse reflection or fire hazard.

(b) There are two subclasses for Class 3 lasers:

(i) A Class 3R laser or laser system is potentially hazardous under some direct and specular reflection viewing condition if the eye is appropriately focused and stable, but the probability of an actual injury is small. The laser will not pose either a fire hazard or diffuse-reflection hazard.

(ii) A Class 3B laser or laser system may be hazardous under direct and specular reflection viewing conditions but is normally not a diffuse reflection or fire hazard.

(4) Class 4 Lasers:

Class 4 lasers or laser systems include all lasers with power levels greater than 500 mW continuous wave or greater than 0.03 J for a pulsed system. They pose eye hazards, skin hazards, and fire hazards. Viewing of the beam and of specular reflections or diffuse reflections can cause eye and skin injuries. Class 4 lasers may also produce laser-generated air contaminants (LGAC) and hazardous plasma radiation. All of the control measures explained in this document shall be implemented.

c. Laser Systems

(1) Safety controls for lasers are normally based on the accessible laser energy that exits the optics and enclosures containing lasers. The entire system is evaluated to determine the classification of the laser system regardless of the energy of the laser embedded inside that system. When the accessible laser energy emitted from the system is less than the embedded laser class, the system will be classified based on the accessible laser energy. For example, many commercial scanning devices contain class 4 lasers that have their energy

reduced by diverging optics, filters, and distance such that the emerging beam is reduced to the energy of a class 1 laser. The warning label for such devices will classify them as class 1 laser products and also contain an additional label specifying the embedded class 3B or 4 laser.

(2) Disassembly of enclosures or defeating interlocks for laser systems results in lasers at the maximum power of the embedded laser. Controls for the higher class laser shall be in effect prior to exposing the higher energy laser. Additional procedures and approvals are required for purposeful use of, maintenance, repair, or any other procedure that results in compromising the enclosures for embedded higher energy lasers.

8.4 Laser Safety Controls and Use Approval Paths

8.4.1 Class 1, Class 2, and Class 3R Indoor Laser or Laser System Use

a. Normally no additional laser safety controls or approvals are required for indoor use of Class 1, Class 2, or Class 3R lasers or laser systems with the following exceptions:

(1) Class 1M lasers and laser systems are considered incapable of producing hazardous exposure conditions during normal operation unless the beam is viewed with collecting optics (e.g., telescope). If a Class 1M laser or laser system is to be used consult with the NASA Ames Laser Safety Officer to ensure controls are in place to prevent viewing with collecting optics. If viewing with collecting optics is required, the Nonionizing Radiation Committee shall review and approve the use. See requirements for submittal for authorization and approval under Class 3B and 4 laser systems.

(2) Class 2M lasers and laser systems are considered incapable of producing hazardous exposure conditions during normal operation unless the beam is viewed with collecting optics (e.g., telescope). If a Class 2M laser or laser system is to be used consult with the NASA Ames Laser Safety Officer to ensure controls are in place to prevent viewing with collecting optics. If viewing with collecting optics is required, the Nonionizing Radiation Committee shall review and approve the use. See requirements for submittal for authorization and approval under Class 3B and 4 laser systems.

(3) Class 3R lasers and lasers systems are potentially hazardous under some direct and specular reflection viewing conditions if the eye is appropriately focused and stable, but the probability of an actual injury is small. Intentional direct viewing of Class 3R laser radiation or its spectral reflection is prohibited. If direct viewing of the laser radiation or its spectral reflection of if collecting optics will be used the Nonionizing Radiation Committee shall review and approve the use. See requirements for submittal for authorization and approval under Class 3B and 4 laser systems.

(4) During periods of service, maintenance, repair, or any other condition that will expose higher Class embedded laser radiation shall have control measures implemented appropriate to the embedded laser. A laser safety plan shall be developed and reviewed and approved by the NRSC prior to operations. See requirements for submittal for authorization and approval under Class 3B and 4 laser systems.

8.4.2 Class 3B and Class 4 Indoor Laser Use

8.4.2.1 Authorization and Approval for Use

a. Only personnel who have been authorized by the NRSC may operate the laser or be allowed in laser-controlled areas. This approval will be specific to each laser and each laser system configuration. The actions required for approval for indoor hazardous laser operations at NASA Ames Research Center are:

(1) Contact Health Physics Staff and NRSO for consultation (e.g., how to access training, suggested templates and examples for submittal, laser safety calculations, etc.)

(2) All personnel complete NASA Ames Laser Safety Training

(3) All personnel read Chapter 8 of the Ames Procedural Requirements

(4) Obtain ANSI Z136.1 American National Standard for Safe Use of Lasers to be used as a reference for procedures, controls, and regulations in conjunction with site specific controls. This is available free from NASA technical standards.

(5) Authorized Laser User submits a Laser Safety Plan to the NRSO for approval by the Nonionizing Radiation Safety Committee that contains the following information:

(a) Laser description for evaluation and inventory:

(i) Manufacturer, model, serial number(s)

(ii) Max power (for continuous wave lasers) or energy/pulse (for pulsed lasers)

(iii) Type (e.g. Nd:YAG, Argon, etc.)

(iv) Wavelength

(v) Laser Class

(vi) Pulse Width (for pulsed lasers)

(vii) Pulse Rate (for pulsed lasers)

(viii) Beam Diameter

(ix) Divergence

(b) Experience Documentation for all personnel listed in the laser safety plan

(c) Standard Operating Procedures:

(i) Alignment Procedures

(ii) Normal Operating Procedures

(iii) Specific Laser Safety Procedures (interlocks, safety glasses, posting)

(iv) Diagram of system showing layout, posting, interlocks (schematics for complicated interlocks), warning lights, etc.

(6) Nonionizing Radiation Safety Committee Reviews and Approves Procedure

(7) Laser Safety Officer/Nonionizing Radiation Safety Committee Inspection of Laser System and Controlled Area

(8) Laser Safety Permit Issued Approving Laser Operations

(9) Annually Renew Project

(10) Annually Renew Training

8.4.2.2 Indoor Laser Controlled Area Minimum Requirements (Class 3B or Class 4) shall include all of the following:

a. Controls that only allow laser operation by personnel who have been trained in laser safety and in the operation of the laser or laser system and who have approval from the Nonionizing Radiation Safety Committee:

(1) Non-defeatable safety latches, entryway or area interlocks (e.g., electrical switches, pressure sensitive floor mats, infrared, or sonic detectors) shall be used to deactivate the laser or reduce the output to levels at or below the appropriate MPE in the event of unexpected entry into the laser Control Area. Note: may be relaxed at the discretion of the NRSC for some Class 3B laser systems.

(2) A door, blocking barrier, screen, curtains, etc. shall be used to block, screen, or attenuate laser radiation exceeding the MPE at the entryway.

b. An appropriate warning sign shall be posted at the entryway(s) and, if deemed necessary by the Laser Safety Officer, may also be posted within the laser-controlled area. There shall be a visible laser warning light (normally red unless this conflicts with existing safety lighting schemes of the facility) indicating that the laser is energized and operating.

c. The laser system shall have a well-defined beam path known to the personnel allowed entry to the Nominal Hazard Zone (NHZ).

(1) In situations requiring open laser beams it may be necessary to define the NHZ, within the larger Control Area.

(2) The NRSO or designee and the ALU will determine the NHZ.

(3) The NHZ may in some situations comprise the entire Control Area.

d. Require appropriate laser eye protection to be worn by personnel within the laser–controlled area when the laser is operating unless the beam is enclosed.

e. Be under the direct supervision of an ALU who is approved by the Nonionizing Radiation Safety Committee.

f. Be located to preclude spectators or contain a limited safe spectator area if approved by the Nonionizing Radiation Safety Committee.

g. Have any potentially hazardous beam terminated in a beam stop, beam dump, or appropriate material.

h. Have only diffusely reflecting materials in or near the beam path, where feasible.

i. Have the laser secured such that the exposed beam path is above or below eye level of a person in any standing or seated position, if possible. Vertical beams or beams at eye level shall be clearly labeled.

j. Have all windows, doorways, open portals, etc., from an indoor facility either covered or restricted in such a manner to reduce the transmitted laser radiation to levels at or below the applicable MPE.

k. Have high voltage sources and terminals enclosed. Capacitors shall have bleeder resistors, discharge devices, or automatic shorting devices. Electrical circuits shall evaluate with respect to fire hazards.

l. Have hazardous materials, chemicals, and gasses controlled per applicable controls in corresponding chapters in the Ames Procedural Requirements.

m. Be earthquake safe. In California, natural disaster conditions such as earthquake need to be considered in the designs and use of equipment. Examples would be fastening electronic racks to the floor or walls and having at least two locking wheels on rolling racks and tying down computer monitors. When possible, bolt down heavy laser equipment. One should be aware of tall objects (bookcases, optical storage racks) that if tipped over would block access into or out of a workspace.

n. Have adequate lighting. Adequate lighting is a standard recommendation. If low light levels are required, the area shall have luminescent strips, arrows or floor level lighting to show the way to exits and emergency equipment.

o. Have provisions for rapid egress from a laser control area under all normal and emergency conditions. Any control area interlock system shall not interfere with emergency egress. In addition, access control measures shall not interfere with the ability of emergency response personnel (fire, paramedical, police) to enter the laser control area in the event operating personnel become injured or incapacitated.

p. Require storage or disabling (e.g., removal of the key and control or lock-out/tag-out (LOTO) of the laser or laser system when not in use to prevent unauthorized use).

(1) LOTO is required whenever servicing, maintenance, or modification is being performed on equipment in which the unexpected energization or startup of the equipment, or the release of stored energy, could cause injury to people or damage to equipment. All sources of hazardous energy shall be shut off and secured. LOTO shall be performed by each person who works on the equipment. Refer to APR 8715.1 Chapter 31 for LOTO procedures and regulations.

8.4.3 Outdoor Use of Laser

a. Laser use outdoors shall meet most of the same requirements listed above but outdoor use requires additional controls due to the potential for the hazard zone to be extended for much greater distances when unable to be confined and because lasers in the wavelengths from 380 nm to 780 nm, even if below the Maximum Permissible Exposure (MPE) levels, can cause potentially dangerous adverse visual effects to operators of aircraft and other vehicles.

b. Lower class lasers and laser systems (Class 1, Class 1M, Class 2, Class 2M, and Class 3R) in addition to high power lasers (Class 3B, Class 4) are required to undergo review and approval by the NRSC when used in an outdoor setting. Examples of outdoor uses of lasers include lasers used for telecommunications, laser research being performed outdoors, lasers mounted on Unmanned Aerial Vehicles (UAV) or Autonomous Vehicles (AVs), and lasers used for entertainment or public viewing. These operations almost always require additional approval by agencies outside of NASA Ames Research Center such as the NASA Laser Safety Review Board (LSRB), other NASA Centers, the Federal Aviation Administration (FAA), the U.S. Strategic Command Laser Clearinghouse, the Department of Defense or Energy, and/or local authorities. It is important to involve the NASA Ames Safety Office (Laser Safety Officer and staff) early in the process to determine jurisdiction and properly coordinate the approval process.

8.4.3.1 Authorization and Approval for Outdoor Laser Use

a. The path to approval to use laser outdoors is not as clear-cut as that for indoor laser use. The expansion of the nominal hazard zone, the addition hazardous of adverse visual effects below the MPE, the multiple agents involved in use and control of the lasers, the multiple locations where the laser beam is generated and the areas it transverses (including high altitude space), the multiple jurisdictions that have regulatory authority over the use, and the actual variety of outdoor uses makes safety a major concern and getting comprehensive approval complicated.

b. The first step for any outdoor use is to contact the Laser Safety Officer and health physics staff for consultation and to determine the appropriate approvals required including whether it is appropriate for NASA Ames Research Center's Nonionizing Radiation Committee to review and approve the laser use.

c. Obtain ANSI Z136.6 American National Standard for Safe Use of Lasers Outdoors to be used as a reference for procedures, controls, and regulations in conjunction with site specific controls.

d. Coordinate with all applicable outside agencies to obtain appropriate approval:

(1) FAA: The regional FAA service center shall be contacted for a determination on airspace activity prior to operation, to ensure that the laser beam will not interfere with FAA flight operations. A letter of non-objection, if required, shall be obtained from the FAA before the NASA Ames Nonionizing Radiation Safety Committee (NRSC) can issue a permit for operations to begin.

(2) DoD/DOE: For outdoor laser use in coordination with or on DoD and/or DOE property additional approvals may be required.

(3) FDA/CDRH: The operators of laser systems used for entertainment are required by law to file a "Report on Laser Light Show Display" (or a variance document), with the Food and Drug Administration's Center for Devices and Radiological Health (FDA/CDRH).

(4) US Space Command: Operators of lasers that have a divergence less than 10 mrad, or that exceed a peak irradiance greater than 1 mW/cm2 above 60,000 feet shall contact US Space Command regarding "Laser Clearinghouse" screening. Space command will then advise the laser operator if any potential adverse effects on orbiting satellites are present and provide operating conditions to mitigate these effects.

(5) Other: Specific circumstances may require additional coordination and approval from other agencies.

e. Below are examples of requirements that need to be met to obtain approval for a variety different outdoor laser uses. They are not all-inclusive as each use has intricacies specific to the use:

(1) Class 1, Class 2, and Class 3R lasers operating at wavelengths less than 380 nm or greater than 780 nm: No approvals specific to this laser use are required.

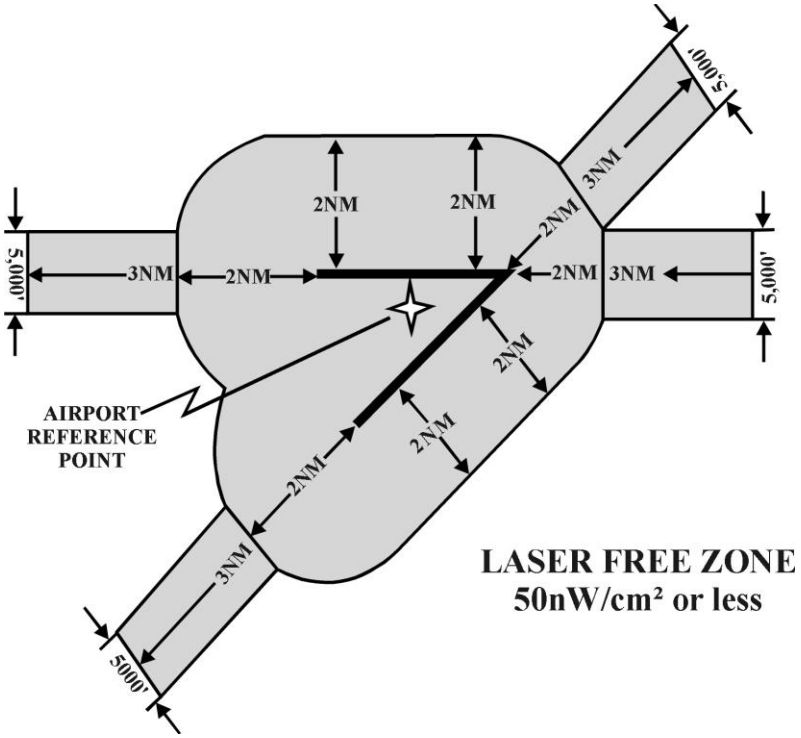
(2) Lasers operating in wavelengths (380 nm – 780 nm) that may cause visual adverse effects below the MPE:

(a) Flight Hazard Zones: locations within navigable airspace (airspace that can contain aircraft) for which the FAA has established levels of effective irradiance and effective radiant exposure that are below the MPE. Laser irradiance and effective radiant exposure shall be below the limit for each zone, unless alternative control measures are approved and used, to give equivalent safety.

(i) Determine zone the laser output will be purposely or potentially transverse. There are 4 Flight Hazard Zones:

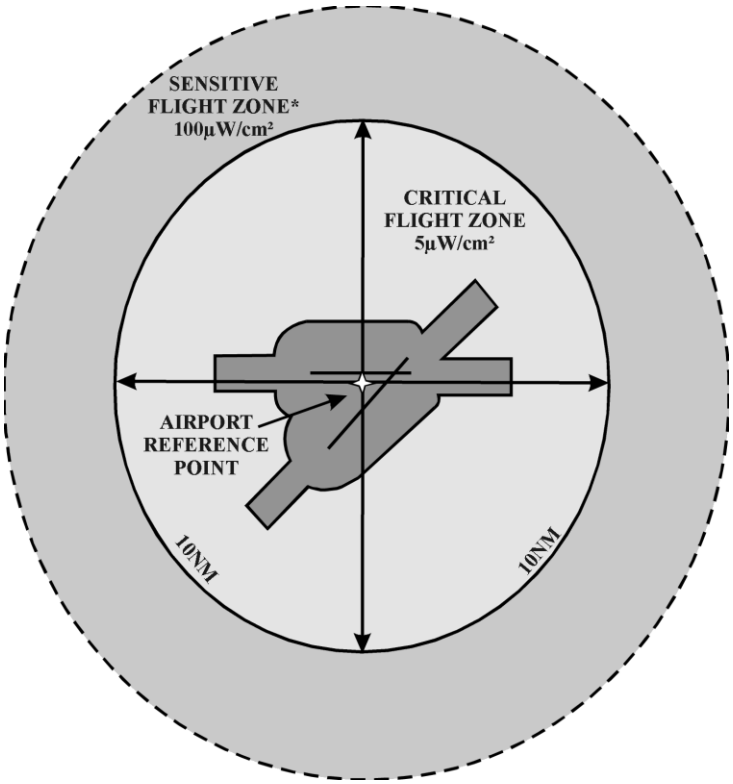
(1) Laser Free Zone (LFZ): Airspace in the immediate proximity of the airport, up to and

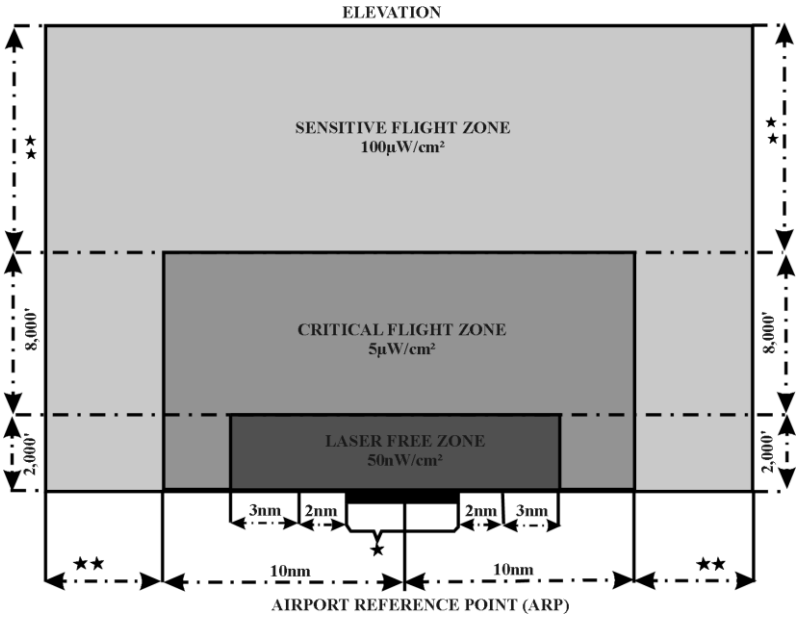
including 2,000 feet above ground level, extending 2 nautical miles in all directions measured from the runway centerline. Additionally, the LFZ includes a 3 nautical mile extension, 2,500 feet each side of the extended runway centerline, of each usable runway surface, up to 2,000 feet above ground level of each useable runway surface. The effective irradiance of a visible laser beam is restricted to a level that should not cause any visual distraction or disruption (50 nW/cm^2 or less).



(2) Critical flight zone: Airspace within a 10 nautical mile radius of the airport reference point and extends upward to and including 10,000 feet. The above ground level effective irradiance of a visible laser beam is restricted to a level that should not cause transient visual effects (e.g., glare, flash-blindness, or afterimage) (5 microW/cm2 or less).

(3) Sensitive flight zone: Airspace outside the critical flight zones that authorities (e.g., FAA, local departments of aviation, military) identify to be protected from the potential visual effects of laser beams (100 microW/cm2 or less).





(4) Normal flight zone: Airspace not defined by the Laser Free, Critical, or Sensitive Flight

Zones. As with all the above zones, the NFZ shall be protected from a visible or invisible laser beam that exceeds the MPE.

(ii) Contact Health Physics Staff and Laser Safety Officer for consultation (e.g., how to access training, suggested templates and examples for submittal, laser safety calculations, etc.)

(iii) All personnel read Chapter 8 of the Ames Procedural Requirements

(iv) Obtain appropriate approvals from outside agencies

(1) FAA (navigable airspace)

(2) DoD/DOE (military applications and airspace)

(3) FDA/CDRH (light shows)

(v) Authorized Laser User submit a Laser Safety Plan to the Laser Safety Officer for the Nonionizing Radiation Safety Committee. Include documentation of outside agency approval(s).

(vi) Laser description for evaluation and inventory:

(1) Manufacturer, model, serial number(s)

(2) Max power (for continuous wave lasers) or energy/pulse (for pulsed lasers)

(3) Flight Zone(s)

(4) Type (e.g. Nd:YAG, Argon, etc.)

(5) Wavelength

(6) Class (1M, 2M, 3R, 3B, 4)

(7) Pulse Width (for pulsed lasers)

(8) Pulse Rate (for pulsed lasers)

(9) Beam Diameter

(10) Divergence

(11) Specific location, angle of operation, and complete beam path

(12) Experience Documentation for all personnel on Permit

(13) Standard Operating Procedures

(14) Alignment Procedures

(15) Normal Operating Procedures

(16) Specific Laser Safety Procedures (interlocks, safety glasses, posting)

(17) Diagram of system showing layout, posting, interlocks (schematics for complicated interlocks), warning lights, etc.

(18) Detailed schematics and description of controls to be used to ensure personnel and aircraft

are protected from exposure to radiation levels above the MPE or adverse visual effects levels. If software is used to perform safety assurance coordinate with NASA System Safety Engineers (Code QS) to ensure in meets NASA safety software assurance standards.

(vii) Nonionizing Radiation Safety Committee Reviews and Approves Procedure

(viii) Laser Safety Officer/Nonionizing Radiation Safety Committee Inspection of Laser System and Controlled Area if possible

(ix) NASA Laser Safety Review Board reviews procedure

(x) NASA Laser Safety Review Board and NASA Ames Nonionizing Radiation Safety Committee approve project

(xi) Laser Safety Permit Issued Approving Laser Operations

(xii) Annually Renew Project

(b) Navigable ground areas and public roads (unrestricted areas accessible to vehicles and equipment or areas where the general public could be put in hazard by visual adverse effects):

(i) Contact Health Physics Staff and Laser Safety Officer for consultation

(ii) If the laser beam has the potential to purposely or accidently result in exposure in navigable airspace the approvals and conditions for flight hazard controls above apply.

(iii) Lasers capable of causing adverse visual effects shall be controlled to prevent exposure to personnel, especially personnel operating machinery, vehicles, or crossing the paths of such.

(iv) Each use will be evaluated, and a determination made on appropriate controls and approvals. The exposure limit criteria for flight zones above will be used as a guide.

(c) Construction: Construction lasers are limited to Class 3R and are not often used at night and would not be expected to create a direct or indirect hazard when operated as intended. Occupational Safety and Health Administration (OSHA) regulations require authorized construction laser operators to carry proof of qualification to operate the laser (29 CFR 1926.54) and contain controls appropriate to use. No additional control measures are required when used as intended.

(3) Unattended lasers:

(a) Unattended lasers are controlled remotely or can function autonomously (e.g., unmanned aerial vehicles (UAV) or uncrewed aerial vehicles, commonly known as drones, Unmanned Vehicles (UV), experimental systems, etc.).

(b) These systems should be Class 1, when possible, or have a reliable shutdown mechanism to prevent exposure above the MPE. Remotely controlled lasers shall include adequate control measures to protect against laser hazards created by loss of communication.

(c) Embedded laser systems below the threshold for visual adverse effects or the MPE for the wavelength emitted that contain embedded lasers that exceed either condition with a higher-than-normal risk for exposure to the internal laser radiation due to damage shall also meet the requirement for adequate control measures to protect against laser hazards due to loss of communication and/or damage causing event.

(4) Class 1M and Class 2M lasers:

(a) The controls and approvals for visual adverse effects above for wavelengths 380 nm – 780 nm if applicable.

(b) Submit a safety plan to the Laser Safety Officer specifying controls to prevent optical magnification viewing of projected beam.

(c) Nonionizing Radiation Safety Committee to review and approve

(5) Class 3B or Class 4 lasers or laser systems:

(a) Contact Health Physics Staff and Laser Safety Officer for consultation (e.g., how to access training, suggested templates and examples for submittal, laser safety calculations, etc.)

(b) All personnel complete NASA Ames Laser Safety Training

(c) All personnel read Chapter 8 of the Ames Procedural Requirements

(d) Obtain appropriate approvals from outside agencies:

(i) FAA (navigable airspace)

(ii) DoD/DOE (military applications and airspace)

(iii) FDA/CDRH (light shows)

(iv) US Space Command (for upward pointing lasers potentially capable of causing adverse effects on orbiting satellites)

(e) Authorized Laser User submit a Laser Safety Plan to the Laser Safety Officer for the Nonionizing Radiation Safety Committee. Include documentation of outside agency approval(s):

(i) The controls and approvals for visual adverse effects above for wavelengths 380 nm – 780 nm if applicable.

(ii) Laser description for evaluation and inventory

(iii) Manufacturer, model, serial number(s)

(iv) Max power (for continuous wave lasers) or energy/pulse (for pulsed lasers)

(v) Type (e.g. Nd:YAG, Argon, etc.)

(vi) Wavelength

(vii) Class (3B, 4)

(viii) Pulse Width (for pulsed lasers)

(viii) Pulse Rate (for pulsed lasers)

(ix) Beam Diameter

(x) Divergence

(xi) Specific location, angle of operation, and complete beam path

(xii) Experience Documentation for all personnel on Permit

(xiii) Standard Operating Procedures

(xiv) Alignment Procedures

(xv) Normal Operating Procedures

(xvi) Specific Laser Safety Procedures (interlocks, safety glasses, posting)

(xvii) Diagram of system showing layout, posting, interlocks (schematics for complicated interlocks), warning lights, etc.

(xviii) Detailed schematics and description of controls to be used to ensure personnel and aircraft are protected from exposure to radiation levels above the MPE or adverse visual effects levels.

(xix)If software is used to perform safety assurance coordinate with NASA System Safety Engineers (Code QS) to ensure in meets NASA safety software assurance standards.

(f) Nonionizing Radiation Safety Committee Reviews and Approves Procedure

(g) Laser Safety Officer/Nonionizing Radiation Safety Committee Inspection of Laser System and Controlled Area if possible

(h) NASA Laser Safety Review Board reviews procedure

(i) NASA Laser Safety Review Board and NASA Ames Nonionizing Radiation Safety Committee approve project

(j) Laser Safety Permit Issued Approving Laser Operations

(k) Annually Renew Project

(l) Annually Renew Training

(6) Control of outdoor laser ranges and controlled areas:

(a) The controls for outdoor use of lasers are essentially similar or the same as the controls for indoor Class 3B and Class 4 laser use adapted for the larger area and unique challenges of using a laser outdoors.

(b) Control rooms containing lasers and laser systems will be controlled and posted as for indoor lasers.

(c) Ranges will need increased controls (sighters, radar, interlocks, coordination with flight control towers) to ensure no personnel are exposed to hazardous energy or light conditions.

(d) Beams that can be terminated at a beam stop, beam dump, or target shall be.

(e) Standard Operating Procedures (SOP) shall include controls agreed upon by all entities that have jurisdiction.

8.4.4 Temporary Laser Control Areas

Temporary laser control areas can be created for the servicing and alignment of Class 1 laser products (e.g., embedded lasers, enclosed lasers) and in special cases where permanent laser control areas cannot be provided. They are subject to the same approval process as above. Vendor safety procedures for performing alignment and /or service are acceptable if deemed adequate by NRSC.

8.4.5 Substitution of Alternate Control Measures

Upon documentation review by the LSO and the NRSC, the engineering control measures recommended by ANZI Z136.1 for Class 3B and Class 4 lasers or laser systems may be replaced by administrative or other alternate engineering controls that provide equivalent protection. Approvals of these controls are subject to the same review procedure as described in this chapter.

8.4.6 Changes to Control Areas or Control Measures

Once a control area or control measure is approved by the NRSC all but minor changes to that control area or measure shall be approved by the NRSC. An example of a minor change would be to add a curtain or move a sign or beacon in such a manner as to not decrease the functionality of the barrier. Movement of lasers, reconfiguration of interlocks, increasing or decreasing the size of the control zone, or any other similar modification, requires NRSC approval. The LSO will be contacted to obtain this approval.

8.5 Radiofrequency Electromagnetic Field Specific Safety Requirements

8.5.1 General Information

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

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

c. The use of any RF radiation source that emits radiation that could expose personnel above the lower tier (Public) exposure reference level (ERL) shall only be permitted with the authorization of the NRSO or designee.

8.5.2 Potential Bioeffects of Exposure to Radiofrequency Electromagnetic Field Radiation

a. The nature and the degree of the health effects of overexposure to MW/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 MW/RF fields is heating of body tissues as energy from the fields is absorbed by the body. Prolonged exposure to strong MW/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 MW/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).

8.5.3 Standard for Radiofrequency Electromagnetic Field Radiation Exposure Protection

The most current edition of the "Standard for Safety Levels with Respect to Human Exposure to Electric, Magnetic, and Electromagnetic Fields, 0 kHz to 300 GHz", is given in IEEE C95.1. It covers safe levels involving both controlled and uncontrolled environments.

8.5.4 Identification and Controls for Radiofrequency Electromagnetic Field Radiation Hazards

a. Acquisition/use/transfer

(1) NASA Ames civil servants and NASA contractor personnel are required to notify the NRSO or designee of intent to purchase, fabricate, or otherwise acquire RF radiation sources for use at NASA Ames Research Center.

(2) Notify the NRSO or designee of any transfer or disposal of RF radiation sources.

USE OF RF RADIATION SOURCES SHALL BE REVIEWED AND APPROVED BY THE NRSO or designee **EXCEPT FOR THOSE DEVICES SPECIFICALLY EXEMPTED FROM CONTROL (SEE 8.5.**8 **FOR A LIST OF EXEMPTED ITEMS) THE NRSO MAY DEEM EXEMPT OTHER SOURCES FOLLOWING REVIEW.**

b. The NRSO and health physics staff will identify and assess microwave/RF radiation hazards in and around the Center. Due to the difficulties of performing microwave/RF radiation surveys (near field measurement issues, high hazard location, cost of equipment, other hazards preventing survey, etc.), it is often necessary to use calculations and/or manufacturers recommendations in place of physical measurements in evaluating hazards.

c. Antennas and Antenna Arrays

Operation of radio, microwave, and other communication systems using electromagnetic radiation, and carrier-current systems require prior review by the NRSO or designee. For operations that will exceed public exposure limits, review and approval is also required by the Nonionizing Radiation Safety Committee (NRSC). The NRSC will advise on operational issues, regulations, and perform a hazard assessment. The NRSO maintains an inventory of all transmission antennas on center. Additional approval is also required by spectrum management and the explosives safety officer.

d. Other Potential Radiofrequency Electromagnetic Field Radiation Sources (Leakage Sources)

For waveguides, co-axial cables, generators, dielectric heaters, and ovens, the most important aspect of controlling microwave/RF radiation hazards is a careful physical inspection of the source. Leaking sources will normally show misalignment of doors or plates, missing bolts, or physical damage to plane surfaces. If these types of sources are suspected of leaking, the Authorized User (AU) or equipment owner needs to lock out and tagout the equipment and contact the health and safety office or qualified equipment technical support to request a survey to evaluate if a hazard is present. Only qualified technical personnel may repair equipment capable of hazardous nonionizing radiation.

8.5.5 Controlling Radiofrequency Electromagnetic Field Radiation

a. Engineering Controls

(1) Sources of radiofrequency electromagnetic field radiation should be properly shielded to minimize stray radiation.

(2) Devices which can produce acute thermal injuries (e.g., industrial MW ovens) should have interlocked doors.

(3) Devices which produce high levels of stray radiation (e.g., induction heaters and dielectric heaters) should be operated remotely whenever possible.

b. Administrative Controls

(1) Exposure of workers to radiofrequency electromagnetic field radiation shall not exceed the recommended ERLs in IEEE C95.1 for the lower tier (general public) or the upper tier for trained RF workers.

(2) Areas where worker exposure to radiofrequency electromagnetic field radiation is suspected to exceed the recommended limits should be surveyed to determine the exposure levels.

(3) Needless exposure to radiofrequency electromagnetic field radiation should be avoided.

(4) Exposure times should be kept as short as reasonably possible.

(5) Potentially hazardous radiofrequency electromagnetic radiation devices should be appropriately labeled, and areas of excessive exposure around them clearly demarcated. Notices with warnings and the necessary precautions should be posted.

(6) Electrically activated explosive devices shall not be placed near sources of radiofrequency electromagnetic field radiation. Contact the NASA Ames Explosive Safety Officer (650) 604-3791 if radiofrequency radiation will be used near explosive storage, use, or transportation areas.

(7) Radiofrequency electromagnetic field radiation devices should not be used in flammable or explosive atmospheres.

(8) Equipment sensitive to radiofrequency electromagnetic field radiation, such as telephone switchboards or control panels, should not be installed near sources of radiofrequency electromagnetic radiation.

(9) Only qualified technical personnel using proper safety controls shall perform maintenance or repair of devices used to produce radiofrequency electromagnetic field radiation.

c. Personal Protective Equipment (PPE)

(1) PPE is typically not necessary and should not be relied upon as a sole source of protection to radiofrequency electromagnetic field radiation.

(2) In instances where exposures cannot be reduced to levels deemed safe by the NRSO, radiofrequency electromagnetic field radiation protective suits, including head and eye protection, can be used to reduce exposure.

8.5.7 Radiofrequency Electromagnetic Radiation approval for use

a. Prior to installing new microwave or radiofrequency equipment or modifying existing equipment, equipment specifications and a description of the proposed use shall be submitted by the AU to the NRSO or designee for review.

b. The document should include:

(1) A description of the system and its application

(2) A diagram showing the emission path

(3) Operating parameters

(4) Manufacturer’s safety documentation and recommendations (if applicable)

(5) Frequency

(6) Antenna dimension (if applicable)

(7) Power output

(8) Antenna type (if applicable)

(9) Pulse description

(10) Antenna gain (if applicable)

(11) Polarization of transmitted wave

(12) Standard operating procedures (SOPs) for equipment where the radiation hazard exceeds the ERL and is accessible to personnel shall be completed and submitted to the NRSO for review. A form QH20R can be used to provide this information.

c. Complete radiofrequency electromagnetic radiation safety training available from code QH.

d. Equipment that is accessible and exceeds the MPE shall be reviewed by the NRSC initially and on an annual basis, or more frequently if there are changes to the researcher's project that effect radiofrequency electromagnetic radiation safety.

e. Standard communication dish antennas that are permanently mounted will be reviewed only when modification to the antenna or the antenna surroundings may cause a new hazard to personnel. Contact the Nonionizing Radiation Safety Officer for an evaluation if modifying an existing antenna or if situations exist that will place personnel near a permanently mounted antenna.

8.5.8 Exempted item Categories

a. A variety of commercially available consumer, business, and industrial application RF and microwave radiation devices are exempted from the authorization requirements of the requirements of this chapter 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. Consult with the NRSO if it is not clear if a particular item meets this exemption.
b. The following general categories of radio frequency/microwave radiation devices are exempted from the requirements of this chapter:
(1) Devices for voice communication with power of 7 watts or less and an antenna gain of unity (walkie-talkies, cell phones) at frequencies between 100 kHz and 900 MHz.
(2) Speed monitoring devices (radar guns)
(3) Automotive radar detectors
(4) Electric, magnetic, and electromagnetic field radiation devices designed for and operated in a complete enclosed configuration where no open-air transmission is possible (e.g., microwave ovens)
(5) Electric, magnetic, and electromagnetic field radiation devices designed to operate in a hard-lined, closed loop configuration where no open-air transmission is possible.
(6) Devices or systems which have no reasonable possibility or have been shown by documented worst case analysis that they are incapable of emitting radiation levels greater than applicable maximum permissible exposure levels based on transmitter power, gain, and frequency (e.g., wireless routers, commercial utility scanning devices).
c. Exemptions are valid for the general categories of equipment, instruments, and systems identified 8.5.8 b provided the following is met:
(1) The individual item is maintained in its original design configuration and used for its originally intended use over the useful life of the item.

(2) The design and manufacture of the item is in accordance with the specifications of the Performance Standards for Electronic Products: General, 21 CFR pt. 1010.
(3) The item is operated in accordance with the manufacturer's recommended operating procedures.
(4) Maintenance, service, or repair activities which could expose employees to accessible levels of radiation, equal to or greater than the applicable exposure level, are performed only by appropriately authorized and qualified employees.

8.6 Static Magnetic Field Use Specific Safety Requirements

8.6.1 General Information

a. Static magnetic fields result from either fixed magnets or the magnetic flux resulting from the flow of direct current (DC). Sources producing these fields include (but not limited to) the following:

(1) Nuclear Magnetic Resonance Imaging and spectroscopy devices

(2) Electron Paramagnetic Resonance devices

(3) Electromagnets

(4) Helmholtz Coils, Solenoids, DC Motors, etc.

b. Standards for exposure to static magnetic fields

The most recent edition of the American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Values (TLVs) and Biological Exposure Indices (BEIs) TLVs for static magnetic fields shall be followed when generating or exposing personnel to this form of nonionizing radiation.

8.6.2 Factors Affecting Static Magnetic Field Hazards

a. Under certain conditions, sources of static magnetic fields can present health hazards. Factors affecting the potential hazards include:

(1) Magnetic flux intensity associated with the source

(2) Design of the magnetic field source

(3) Accessibility of the magnetic field

(4) Equipment/hazardous materials associated with the magnetic field source

b. Sources of large static magnetic fields will require controls be put in place to mitigate the potential hazards. Sources of this type will require Nonionizing Radiation Safety Committee (NRSC) review and approval.

8.6.3 Bioeffects of Exposure to Static Magnetic Fields

a. There are no known adverse bioeffects for flux densities below the American Conference of Governmental Hygienist (ACGIH) exposure limits.

b. Implanted medical devices present a potential hazard to individuals exposed to fields above the ACGIH Limits. The following is a list of some devices that are of concern:

(1) Cardiac Pacemaker

(2) Cochlear implants

(3) Swan-Ganz catheters

(4) Ferromagnetic unidentifiable aneurysm clips of the brain

(5) Implanted neuro-stimulators

(6) Metal or unidentifiable foreign bodies in the eyes

(7) Shrapnel near a vital organ

c. Persons with these types of medical devices should contact their physicians about the possible health risk before entering a facility with high magnetic fields.

8.6.4 Kinetic Energy Hazards

a. Due to the large fields associated with NMR magnets, ferrous objects can be accelerated toward the magnet with sufficient energy to seriously injure persons and /or damage the magnet.

b. Personnel entering rooms containing static magnetic fields should be screened as a precaution to prevent any ferrous objects flying into the magnet. Even small objects (screws, tools, razor blades, paper clips, etc.) should be kept outside the 0.5 mT (5 Gauss) perimeter of the magnet.

c. Large ferrous objects (equipment racks, tool dollies, compressed gas cylinders, etc.) should be moved with extreme caution in the presence of a strong magnetic field. Magnetic resonance safe materials and equipment should be used whenever possible to alleviate the magnetic field hazard.

8.6.5 Posting of Magnetic Field Hazards

a. NMR magnets commonly produce core fields from 0.2 T to 20 T. These fields decrease in intensity as the distance from the core increases at a rate corresponding approximately to the inverse cube of the distance.

b. Magnetic fields shall be evaluated by the health and safety staff to determine the extent of the hazards present.

c. ALL access points to rooms containing magnets fields in excess of 0.5 mT (5 Gauss) shall be marked with magnetic field hazard signs. The 0.5 mT (5 Gauss) threshold line shall be clearly identified with floor tape or equivalent markings. If greater hazards exist inside this boundary they may be depicted as well.

d. Persons with cardiac pacemakers or other implanted medical devices shall be restricted to areas outside the 0.5 mT (5 Gauss) threshold line. Security (locked doors) and proper door markings shall be maintained to prevent unauthorized access to the magnet area.

8.6.6 Use of Devices Producing a Static Magnetic Field

a. Projects involving sources of static fields shall contact the NRSO or designee prior to use so an evaluation of the hazard can be completed. In cases where the static field presents a high hazard, written procedures and specific approval by the Nonionizing Radiation Safety Committee will be required. In other application precautions and PPE spelled out in the lab safety plan may be sufficient. The NRSO or designee will make this determination.

b. The health and safety staff have specific instrumentation to accurately measure static fields and can determine the 0.5 mT (5 Gauss) boundary and any other specific safety boundary associated with the magnet.

8.6.7 Training

a. Individuals who use devices that produce static magnetic fields require specific training that is commensurate with the associated hazards. Training is available from Code QH. The training course includes:

(1) Background on magnetism

(2) Your role in magnet safety

(3) Metallic screening

(4) Nonmagnetic hazards typically associated with electromagnets including cryogens, magnet quench, and physical hazards

8.7 Non-Laser Optical Radiation Use Specific Safety Requirements (Ultraviolet (UV), Infrared (IR), and High Intensity Light

8.7.1 General Information

a. UV is defined as electromagnetic radiation in the spectral region between 100 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. IR is defined as electromagnetic radiation in the spectral region between 780 nm and 1 millimeter (mm). It is further divided into IR-A (780-1400nm), IR-B (1400-3000nm), and IR-C also known as far-IR (3000nm-1mm).

c. High Intensity Light is defined as electromagnetic radiation in the spectral region between 380 and 780 nm. Many HIL sources may also produce UV along with visible and infrared radiation.

8.7.2 Applications

a. UV, IR, and High Intensity Light sources are used in a variety of applications and locations. The area or source for which there is a potential for exposure 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

(7) Mercury vapor lamps with broken or missing envelopes (excess UV hazard)

(8) UV curing systems

(9) UV crosslinkers

(10) Solar Simulators

(11) Compact arc lamps

(12) Tungsten-halogen lamps, electronic flash lamps

(13) High intensity Light emitting Diodes (LED)

b. Many of the sources described, emit radiation across the IR, visible and UV spectrum. the user may not be fully protected from UV light exposure by any inherent shielding around the source, interlocks, or the user may not be aware of the hazard of UV light.

8.7.3 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 (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 (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 (clouding of the lens).

b. Skin Hazards

UV radiation is a known carcinogen for human skin. In addition to cancer induction, erythema (sunburn), and skin aging are also known effects of ultraviolet 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 since most individuals will receive substantial UV exposure from the sun during normal outdoor activities over a human lifetime.

8.7.4 Optical Radiation Exposure Guidelines

a. The most recent edition of the American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Values (TLVs) and Biological Exposure Indices (BEIs) TLVs for visible (blue light hazard), infrared, and UV radiation incident on the skin or eye shall be followed when generating or exposing personnel to this form of nonionizing radiation.

b. These values do not apply to coherent sources of nonionizing radiation (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 (aphakes). Occupational exposure for personnel in these categories requires medical evaluation and clearance and appropriate controls to prevent overexposure.

c. ANSI/IES RP-27.3-17 *Recommended Practice for Photobiological Safety for Lamps – Risk Group Classification and Labeling* and IEC/EN 62471*, Photobiological Safety of Lamps and Lamp Systems* have defined risk groups for lamps based on potential for exposure. Those groups are as follows:

Risk Group (RG)	**Photobiological basis**
RG0 (exempt)	No photobiological hazard

RG1 (Very Low Risk)	No photobiological hazard under normal behavioral limitations on exposure.
RG2 (Low Risk)	Does not pose a hazard due to the aversion response to bright light or thermal discomfort.
RG3 (High Risk)	Hazardous even for momentary exposure

8.7.5 Control Measures

a. Acquisition/use/transfer

(1) NASA Ames civil servants and NASA contractor personnel are required to notify the NRSO of intent to purchase, fabricate, or otherwise acquire hazardous optical radiation sources for use at NASA Ames Research Center. These are defined as light sources capable of exceeding the applicable ACGIH TLV. These are typically sources categorized as RG3 and in some cases RG2.

(2) Notify the NRSO of any modification, transfer or disposal of optical radiation sources.

(3) Use of optical radiation sources that are capable of exceeding the applicable ACGIH TLV shall be reviewed and approved by the NRSO. These are generally sources that are classified as RG3 and under certain circumstances RG2 sources.

b. Engineering Controls

(1) The preferred control method is the use of engineering controls to contain optical radiation. Enclosures and interlocks supplied by the manufacturer shall be used at all times unless specifically authorized by the NRSO.

(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 (quartz, borosilicate) and plastics (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.

c. Administrative Controls

(1) Procedures should be developed to control and minimize exposure to personnel where engineering controls cannot adequately protect personnel from optical radiation exceeding the applicable TLV.

(2) Exposures may also be minimized by limiting exposure time and increasing the distance between personnel and the UV source. Prevent unauthorized personnel from entering the UV radiation area.

d. Personal Protective Equipment (PPE)

(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 (verified by measurement or certification)

(c) Fully buttoned lab coat

(d) Long pants

(e) Closed toe shoes

(f) Gloves

(g) Application of sunscreen with high sun-protection factor (>15) against UV-A and UV-B may provide some protection. However, the use of UV skin blocks is considered inadequate for protection against the high irradiance of man-made UV radiation sources and will not be considered as PPE.

8.7.6 Equipment and area labels

(1) To prevent eye and skin injuries, sources of optical radiation shall be conspicuously labeled with a warning attached to the housing of the source. The warning sign should state something similar to these statements.

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

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

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

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

(2) Warning signs are available from commercial vendors and may be available from the Health and Safety Office.

8.7.7 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 SPF 30 (sun-protection-factor)

(5) Use of UV blocking sunglasses

8.7.8 First Aid

a. The symptoms of UV overexposure to the skin are well known and characteristically called sunburn. However, the symptoms of overexposure to the eyes are not widely known, they include:

(1) a burning and painful sensation in the eye

(2) a sensitivity to light

(3) the sensation of a foreign object in the eye, sometimes described as sand in the eye

(4) tearing

b. These symptoms usually develop several hours after the overexposure occurred.

c. If an eye or skin injury related to UV exposure is suspected, the individual should proceed directly to the Ames Health Unit to be examined.

8.7.9 Optical Radiation Source Use

a. Projects involving sources of optical radiation shall contact the NRSO or designee prior to use so an evaluation of the hazard can be completed. In certain cases where a significant hazard is present, written

procedures and specific approval by the Nonionizing Radiation Safety Committee will be required. In most cases, precautions and PPE identified in the lab safety plan are sufficient. The NRSO or designee will make this determination

b. Based upon the intensity of the radiation source and the duration of worker exposure, health physics staff will recommended controls be put in place. Health Physics evaluations will also confirm the performance of safety equipment already in-place including equipment shielding and PPE.

c. If an accidental exposure is suspected and it is necessary to determine the potential extent of injury. Items of this nature include (Biological Safety Cabinets, UV light microscopes). Sources may also be surveyed at the discretion of the NRSO. Overexposures to UV light often occur when the exposed individual is not aware of the hazards of the UV source.

8.7.10 Training

a. Individuals who use optical radiation sources capable of exceeding the TLV require training that is commensurate with the associated hazards. Computer based training is available from Code QH. The training class includes:

(1) Sources of Optical Radiation (UV, IR, and visible)

(2) Health Effects of UV, Visible and IR light

(3) Radiometric Terminology

(4) Exposure limits

(5) Radiation Safety Program

(6) Personal Protective equipment and shielding

(7) Handling medical emergencies

APPENDIX A. DEFINITIONS

Absorption	Transformation of radiant energy to a different form of energy by interaction with matter.
Accessible Radiation	Radiation to which it is possible for the human eye or skin to be exposed in normal usage.
Antenna	A device employed as a means for radiating or receiving electromagnetic energy.
Antenna Beam	The major lobe of the radiation pattern, usually that portion of the emitted radiation beam within the beam diameter.
Antenna Gain (relative)	The ratio of the power gain of antenna relative to a standard antenna. The relative gain may be in decibels or it may be numeric. The standard antenna is usually an isotropic antenna.
Aperture	An opening through which radiation can pass.
Attenuation	The decrease in the radiant flux as it passes through an absorbing or scattering medium.
Average power	The available transmitter power averaged over a modulation cycle (the power actually available to do the work). The average power is the peak power multiplied by the duty cycle. In continuous wave (CW) systems the average power is equal to the peak power since the duty cycle is one.
Authorized Laser User (ALU)	A person appointed by the Nonionizing Radiation Safety Committee to be responsible for laser operations on a specified laser safety permit.
Beam	A collection of light and photonic rays characterized by direction, diameter (or dimensions), and divergence (or convergence).
Beam Diameter	The distance between diametrically opposed points in that cross section of a beam where the power or energy is 1/e (0.368) times that of the peak power or energy.
Carcinogen	An agent potentially capable of causing cancer.
Coherent	A light beam is said to be coherent when the electric vector at any point in it is related to that at any other point by a definite, continuous function.
Collimated Beam	Effectively, a “parallel” beam of light with a very low divergence or convergence.
Continuous Wave (CW)	A laser operating or modeled as having a continuous output for a period for a duration >0.25 second is regarded as a CW laser.
Controlled Area	An area, where the occupancy and activity of those within is subject to control and supervision for the purpose of protection from radiation hazards.

Cornea	The transparent, outer layer of the human eye that covers the iris and the crystalline lens. The cornea is the main refracting element of the eye.
Decibel (dB)	The unit used to express a power or voltage ratio with an arbitrary defined reference level. The equation n (db0 = 10 log10 (p1/p2) express the decibel equal to 10 times the logarithm of a power ratio.
Diffuse Reflection	change in the spatial distribution of a beam of radiation when it is reflected in many directions by a surface or a medium.
Divergence	The increase in the diameter of the laser beam with distance from the exit aperture. Divergence is taken as a full angle, expressed in radians, of the beam diameter measured between those points that include laser energy or irradiance equal to 1/e of the maximum value. Divergence is sometimes referred to as beam spread.
Dummy Load	Any device introduced into an RF or microwave system for the purpose of absorbing RF/microwave energy.
Duty Cycle	Ratio of "on time" to total exposure duration for a repetitively pulsed system. The duty cycle is the product of the pulse duration and pulse repetition frequency.
Electromagnetic Radiation	The flow of energy consisting of orthogonally vibrating electric and magnetic fields lying transverse to the direction of propagation. X-ray, ultraviolet, visible, infrared, and radio waves occupy various portions of the electromagnetic spectrum and differ only in frequency and wavelength.
Energy	The capacity for doing work. Energy content is commonly used to characterize the output from pulsed lasers and is generally expressed in joules (J).
Exposure	The product of an irradiance and its duration.
Far-Field Region	That region of the radiation field of an antenna where the power density variation is inversely proportional to the square of the distance from the source.
Field Strength	A measure of electric (E) or magnetic (H) field potential in an electromagnetic field, usually expressed in volts per meter (V/m) or amperes per meter (A/m).
Gauss (G)	Unit of magnetic flux density which is equal to a centimeter-gram-second or one Maxwell per square centimeter.
Grounding	The process of physically providing a metallic surface or wire with a low impedance path to reference or ground potential.
Half-Power Beam Width (HPBW)	The angular width of the antenna radiation pattern between points where the HPBW power level has decreased to one-half of the maximum value.
Hertz (Hz)	The unit that expresses the frequency of a periodic oscillation in cycles per second.
Infrared Radiation	Electromagnetic radiation with wavelengths that lie within the range of 0.7 to 1.0 mm.

Intrabeam Viewing	The viewing condition whereby the eye is directly exposed to all or part of the laser beam
Ionizing Radiation	Electromagnetic radiation of a sufficient energy to directly ionize atomic or molecular systems with a single quantum event.
Iris	The circular, pigmented membrane that lies behind the cornea of the human eye. The iris is perforated by the pupil.
Isotropic Antenna	A hypothetical antenna, capable of radiating or receiving electromagnetic energy equally in all directions.
Joule (J)	A unit if energy; 1 joule = 1 watt second. Joules per pulse is a common measurement for pulsed laser systems.
Laser	The device that produces radiant energy predominantly by stimulated emission. Laser radiation may be highly coherent temporally, spatially, or both. An acronym for Light Amplification by the Stimulated Emission of Radiation.
Laser Safety Officer (LSO)	A person, appointed by the Director of Safety and Mission Assurance (Code Q) and approved by the Executive Safety Committee, who has the authority and responsibility to monitor and enforce the control of laser hazards ensuring safe operations of laser systems at the Center.
Laser System	An assembly of electrical, mechanical, and optical components that includes a laser.
Lasing Medium	A material emitting coherent radiation by virtue of stimulated electronic or molecular transitions to lower energy levels.
Limiting Angular Subtense	The apparent visual angle that divides α-min intrabeam viewing from extended source viewing.
Maintenance	Performance of adjustments or procedures specified in user information provided by the manufacturer, and considered preventative, to maintain optimal performance of the laser or laser system that are to be carried out by the user to ensure the intended performance of the product. Maintenance does not include *operation* or *service* as defined in this section.
Maximum Permissible Exposure	The maximum power density or energy exposure (MPE) level of Exposure electromagnetic radiation that an individual may be exposed to.
Microwave Radiation	Electromagnetic radiation with a frequency of 300 MHz to 300 GHz.
Near-Field Region	That region of the radiated field of an antenna where the power density variation is not inversely proportional to the square of the distance from the source. In this region the power density increases irregularly with range to a maximum level, then decreases approximately at a linear rate to the onset of the far-field region**.**
Nominal Hazard Zone (NHZ)	The space within which the level of the direct, reflected, or scattered radiation may exceed the applicable MPE. Exposure levels beyond the boundary of the NHZ are below the applicable MPE.

Nominal Ocular Hazard Distance	The distance along the axis of an unobstructed beam from the laser to the Distance (NOHD) human eye beyond which the irradiation or radiant exposure during normal operation is not expected to exceed the appropriate MPE.
Operation	The performance of the laser or laser system over a full range of its intended functions. It does not include maintenance or service as defined in this section.
Optical Density	Logarithm to the base ten of the reciprocal of the transmittance at a particular wavelength. Used for laser protection calculations.
Optically Pumped Laser	A laser in which the electrons are excited into an upper energy state by the absorption of light from an auxiliary light source.
Point Source	A source of radiation whose dimensions are small enough compared with the distance between source and receptor for them to be neglected in calculations.
Power	The time rate at which energy is emitted, transferred, or received; usually expressed in watts (or joules per second).
Power Density	The intensity of electromagnetic radiation present at a given point. Power density is measured in milliwatts per square centimeter (mw/cm2).
Power, Peak	The maximum power amplitude produced in an individual pulse of energy.
prf	Abbreviation for pulse-repetition frequency. (see repetitive pulse laser)
Protective Housing	An enclosure that surrounds the laser or laser system that prevents access to laser radiation above the applicable MPE. The aperture through which the useful beam is emitted is not part of the protective housing. The protective housing limits access to associated radiant energy emissions and to electrical hazards associated with components and terminals and may enclose optics and a workstation.
Pulse Duration	The duration of a laser pulse; usually measured as the time interval between the half-power points on the leading and trailing edges of the pulse.
Pulsed Laser	A laser that delivers its energy in the form of a single pulse or a train of pulses. A laser with an output of < 0.25 seconds is considered a pulsed laser.
Pupil	The variable aperture in the iris through which light travels to the interior of the eye.
Q-switch	A device for producing short (3-250 ns), intense laser pulses by enhancing the storage and releasing energy in and out of the lasing medium, respectively.
Radar	A system that radiates electromagnetic waves and processes the reflection of such waves from distant objects to determine their existence and position. Radar is an acronym for radio detection and ranging.
Radian (rad)	A unit of angular measure equal to the angle subtended at the center of a circle by an arc whose length is equal to the radius of the circle. 1 radian is approximately = 57.3 degrees; 2 pi radians=360 degrees.

Radiance (L)	Power output per unit solid angle per unit area expressed in watts per square centimeter per steradian ($w/cm^2/sr$)
Radiant Energy (Q)	Energy emitted, transferred, or received in the form of radiation. Unit: Joule (J).
Radiant Exposure (H)	Surface density of the radiant energy received. Unit: joules per square centimeter (J/cm^2).
Radiant Power (ϕ)	Power emitted, transferred, or received in the form of radiation. Unit: watt (W); also called radiant power.
Radiant Intensity (I)	Quotient of the radiant flux leaving the source, propagated in an element of solid angle containing the given direction, by the element of solid angle. Unit: watts per steradian (W/sr).
Reflectance	The ratio of total reflected radiant power to total incident power. Also called reflectivity.
Repetitively Pulsed Laser	A laser with multiple pulses of radiant energy occurring in sequence.
Retina	The sensory tissue that receives the incident image formed by the cornea and lens of the human eye.
Rf Band	That portion of the electromagnetic spectrum that is useful for radio transmission. The current practical limits of RF are approximately 3 kHz to 300 MHz.
Service	The performance of procedures typically defined as repair, to bring the laser or laser system or laser product back to full and normal operational status. Service does not include maintenance or operation as defined in this section.
Shall	The word “shall” is to be understood as mandatory.
Should	The word “should” is to be understood as advisory.
Solid Angle	The ratio of the area on the surface of a sphere to the square of the radius of that sphere. Unit: steradians (sr).
Source	A laser or laser-illuminated reflecting surface.
Specular Reflection	A mirror-like reflection.
Standard Operating Procedure (SOP)	A document prepared by the authorized user that describes the purpose of operations, detailed instructions on operation from startup to shutdown, and any special case operations such as alignment.
Static Magnetic Field	Magnetic fields that do not vary with time (frequency of 0 Hz). They are created by a magnet or by the steady flow of electricity, for example in appliances using direct current (DC).
Steradian (sr)	The unit of measure for a solid angle. There are 4 pi steradians about any point in space.
Tesla (T)	The SI Unit of magnetic flux density. One tesla is equal to one weber per square meter.

Transmission	Passage of radiation through a medium.
Transmittance	The ratio of transmitted power (energy) to incident power (energy).
Ultraviolet Radiation	Electromagnetic radiation with wavelengths between 180 and 400 nm.
Visible Radiation (Light)	Electromagnetic radiation that can be detected by the human eye. This term is commonly used to describe wavelengths that lie in the range from 400 to 700 nm.
Watt (W)	The unit of power or radiant flux. 1 watt = "1" joule per second.
Wavelength	The distance in the line of advance of a sinusoidal wave from any one point to the next point of corresponding phase (e.g. the distance from one peak to the next).

APPENDIX B.	ACRONYMS
ACGIH	American Conference of Governmental Industrial Hygienists
ALU	Authorized Laser User
ANSI	American National Standards Institute
APR	Ames Procedural Requirements
AsLU	Associate Laser User
AU	Authorized User
AV	Autonomous Vehicle
BEI	Biological Exposure Index
CDRH	Center for Devices and Radiological Health
DoD	Department of Defense
DOE	Department of Energy
ERL	Exposure Reference Level
FAA	Federal Aviation Administration
FDA	Food and Drug Administration
ICNIRP	International Council on Non-Ionizing Radiation Protection
IEEE	Institute of Electrical and Electronic Engineers
LSO	Laser Safety Officer
MPE	Maximum Permissible Exposure
MW	Microwave
NLSRB	NASA Laser Safety Review Board
NMR	Nuclear Magnetic Resonance
NPR	NASA Procedural Requirements
NRSC	Nonionizing Radiation Safety Committee
NRSO	Nonionizing Radiation Safety Officer
OSHA	Occupational Safety and Health Administration
PEL	Permissible Exposure Limit
PPE	Personal Protective Equipment
RF	Radiofrequency
SOP	Standard Operating Procedure
TLV	Threshold Limit Values
UAV	Unmanned Aerial Vehicle
UV	Ultraviolet

APPENDIX C. REFERENCES

C.1 21 CFR 1040.10 Laser products

C.2 29 CFR 1910.97 Nonionizing Radiation

C.3 29 CFR 1910.133 Eye and Face Protection

C.4 American National Standard Z136.1- 2022 Safe Use of Lasers

C.5 American National Standard Z136.6 – 2015 Safe Use of Lasers Outdoors

C.6 American National Standard Z136.8 – 2021 Safe Use of Lasers in Research, Development, or Testing

C.7 American National Standard/Illuminating Engineering Society RP-27.3-17 *Recommended Practice for Photobiological Safety for Lamps – Risk Group Classification and Labeling*

C.8 IEC/EN 62471*, Photobiological Safety of Lamps and Lamp Systems*

C.9 IEEE C95.1 - 2019 Standard for Safety Levels with Respect to Human Exposure to Electric, Magnetic, and Electromagnetic Fields, 0 kHz to 300 GHz

C.10 American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Values (TLVs) and Biological Exposure Indices (BEIs)

C.11 Federal Aviation Administration Advisory Circular AC 70-1 - Outdoor Laser Operations