



AEROSPACE RECOMMENDED PRACTICE

ARP5572™

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(R) Control Measures for Laser Safety in the Navigable Airspace

RATIONALE

The Federal Aviation Administration (FAA) submitted a written request to SAE for assistance in developing standards and regulations concerning outdoor laser operations. This SAE Aerospace Recommended Practice (ARP) document provides guidance for control measures to be used optimally during operations of a laser system outdoors in the navigable airspace. It also recommends the control measure requirements for different outdoor laser systems.

FOREWORD

This document applies to control measures designed to mitigate a laser beam's potential hazards to aircrews when projected from an outdoor laser system. Related SAE documents are AS4970, AS6029, and ARP5535. Additional control measures may be applicable and are discussed in ANSI Z136.6 regarding outdoor laser operations and control.

This document provides guidance to laser operators, proponents, and regulatory authorities (e.g., FAA) on the optimal use of control measures during propagation of a laser beam in the navigable airspace. It also discusses control measures for systems that generate these beams.

The SAE G-10T Committee includes representation from many different entities including government, public, and private organizations, to identify the issues, technologies, and operational capabilities of outdoor laser use in navigable airspace.

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1. SCOPE

This SAE Aerospace Recommended Practice (ARP) provides information and guidance for the control of hazardous laser energy in the navigable airspace.

This ARP does not address techniques that pilots can apply to mitigate laser illuminations during a critical phase of flight. Such mitigation strategies are described in ARP6378.

1.1 Purpose

The purpose of this document is to provide recommended practices to mitigate hazards related to laser beam propagation in the navigable airspace.

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

ARP5535	Observers for Laser Safety in the Navigable Airspace
ARP6378	Guidance on Mitigation Strategies Against Laser Illumination Effects
AS4970	Human Factors Considerations for Outdoor Laser Operations in the Navigable Airspace
AS6029	Performance Criteria for Laser Control Measures Used for Aviation Safety

2.1.2 ANSI Accredited Publications

Copies of these documents are available online at <http://webstore.ansi.org/>.

ANSI Z136.1	American National Standard for the Safe Use of Lasers
ANSI Z136.6	American National Standard for the Safe Use of Lasers Outdoors

2.1.3 U.S. Government Publications

Copies of these documents are available online at <https://quicksearch.dla.mil>.

FAA JO7400.2	Procedures for Handling Airspace Matters. Part 6 (Miscellaneous Procedures), Chapter 29 (Outdoor Laser Operations)
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2.2 Definitions

The definitions of the terms listed below are based on a pragmatic, rather than a basic, approach. The terms defined are therefore limited to those actually used in this manual. This section is not intended to constitute a dictionary of terms used in the laser field as a whole.

AERODROME REFERENCE POINT (ARP): The designated geographical location of an aerodrome.

AFTERIMAGE: A transient image that persists in one's vision after a bright source of illumination has been removed.

BEAM: A collection of rays that may be parallel, divergent, or convergent.

BEAM DIVERGENCE: For the purposes of laser safety standards, the divergence is the increase in the diameter of the laser beam with distance from the exit aperture, based on the full angle at the point where the irradiance (or radiant exposure for pulsed lasers) is $1/e$ times the maximum value.

COLLECTING OPTICS: Lenses or optical instruments (such as telescopes, binoculars, or microscopes) having magnification and thereby producing an increase in irradiance or radiant exposure.

CONTAINMENT ZONE: A zone of airspace around the axis of laser propagation that includes all laser energy (includes beam divergence and buffer angles).

CRITICAL ZONE: See flight hazard zones.

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).

FLASHBLINDNESS: A temporary visual interference effect that persists as an afterimage after an intense source of illumination has been removed.

FLIGHT HAZARD ZONES: Areas of airspace specifically designated to mitigate the potential hazardous effect of laser radiation.

- a. **LASER FREE ZONE (LFZ):** Airspace in the immediate proximity to the aerodrome, up to and including 2000 feet AGL, extending 2 nautical miles (NM) in all directions measured from the runway centerline, plus an additional 3 NM extension 2500 feet each side of the extended runway centerline of each useable runway surface. Within this zone, the intensity of laser light is restricted to a level that would not be expected to cause any visual disruption ($<50 \text{ nW/cm}^2$).
- b. **CRITICAL FLIGHT ZONE (CFZ):** Airspace within ten nautical miles of the aerodrome reference point (ARP), up to and including 10000 feet AGL, where the intensity of laser light is restricted to a level unlikely to cause significant glare effects ($\leq 5 \text{ } \mu\text{W/cm}^2$).
- c. **SENSITIVE FLIGHT ZONE (SFZ):** Airspace outside the critical flight zone(s) that regulatory authorities have identified to be protected from laser lights that may cause flash blindness and afterimage effects ($\leq 100 \text{ } \mu\text{W/cm}^2$). The SFZ need not necessarily be contiguous with the other zones.
- d. **NORMAL FLIGHT ZONES (NFZ):** Airspace not defined by the laser free, critical, or sensitive flight zones. The use of lasers capable of exceeding the MPE in this airspace must be controlled to protect aircraft.

GLARE: Obscuration of an object in a person's field of vision due to a bright light source located near the same line of sight.
Note: Glare can have disabling or discomforting effects on vision.

IRRADIANCE: Irradiance is the radiant power per unit area. It is a means of expressing the intensity of the beam in watts per square centimeter (W/cm^2).

INFRARED RADIATION: For the purposes of visual interference levels, electromagnetic radiation with wavelengths that lie within the range of 780 nm to 1 mm. For hazard classification purposes, infrared radiation is defined as wavelengths that lie within the range of 700 nm to 1 mm.

LASER: (1) An acronym for “light amplification by stimulated emission of radiation.” (2) A device that produces an intense, coherent, directional beam of light by stimulating electronic or molecular transitions to lower energy levels.

LASER-FREE ZONE: See flight hazard zones.

LASER OPERATOR: The person in control of the operation of a laser system. A laser operator should be a knowledgeable person, present during laser operation, who has been given authority to operate the laser system in compliance with applicable safety standards, subject to recommendations of the laser safety officer.

LASER SAFETY OFFICER (LSO): One who has authority to monitor and enforce the control of laser hazards and to effect the knowledgeable evaluation and control of laser hazards. The LSO may, at times, delegate specific responsibilities to a deputy LSO or other responsible person. The LSO has ultimate responsibility for safe outdoor laser operations. Throughout the body of this document, it shall be understood that whenever duties or responsibilities of the LSO are specified, it will mean that the LSO either performs the stated task or ensures that the task is performed.

LASER SYSTEM: An assembly which includes a laser.

LIGHT (VISIBLE RADIATION): A form of electromagnetic radiation able to be detected by the human eye. Its wavelength range is between approximately 380 to 780 nm (between infrared and ultraviolet).

LINE-OF-SIGHT: A direct path between two points where no physical obstruction is present.

MAXIMUM PERMISSIBLE EXPOSURE (MPE): The highest level of laser radiation to which a person may be exposed without hazardous effect or adverse biological changes in the eye or skin. In general, MPE is expressed as W/cm² or J/cm².

NOMINAL OCULAR HAZARD DISTANCE (NOHD): The distance from the laser system beyond which the laser beam irradiance does not exceed the MPE for the eye.

OPTICAL RADIATION: Part of the electromagnetic spectrum comprising infrared, visible, and ultraviolet radiation.

POINTING ACCURACY: The maximum angle of expected error in beam direction during all expected uses of the device. For automatic tracking systems, the pointing accuracy includes the maximum error that could occur during a loss of track scenario before the laser is disabled.

POWER: The rate at which energy is emitted, transferred or received. Unit: watts (joules per second).

PROPONENT: Person or organization applying to conduct an outdoor laser operation at a specific time and location.

PULSED LASER: A laser that delivers its energy in individual pulses lasting less than 0.25 second.

RADIANT EXPOSURE (H): Surface density of the radiant energy received. Radiant exposure is computed from the emitted energy divided by the area of the laser beam. Unit: joules per square centimeter (J/cm²).

REFLECTION: Deviation of radiation following an incidence on a surface. A reflection can be either a diffuse reflection or a specular reflection.

- a. **DIFFUSE REFLECTION:** The component of a reflection from a surface which is incapable of producing a virtual image such as is commonly found with flat finish paints or rough surfaces.
- b. **SPECULAR REFLECTION:** A mirror-like reflection that usually maintains the directional characteristics of the beam.

SAFETY OBSERVER: One who has been tasked with observing the airspace through which a laser beam is being propagated to ensure that the beam does not illuminate any individual or object that could be injured, impaired, or damaged as a result of such an exposure. The observer must be trained and have the ability to immediately terminate the laser beam.

SENSITIVE ZONE: See flight hazard zones.

ULTRAVIOLET RADIATION: Optical radiation with wavelengths shorter than those of visible radiation; for laser safety standards, 180 to 380 nm.

VISIBLE RADIATION: See light.

WAVELENGTH: The distance between two successive points on a periodic wave of optical radiation. It is commonly used to provide a numeric description of the color of visible laser radiation.

3. LASER CLASSIFICATION AND HAZARD IDENTIFICATION

Some lasers may pose hazards to people, equipment, or the environment. ANSI Z136.1 describes a process of classifying lasers for the purposes of risk mitigation. Laser proponents are responsible to evaluate their laser systems and identify hazards. Some issues of concern include stability of the laser and platform, physical access to the laser, pointing accuracy of the laser beam, protective housings, unnecessary wavelengths, and laser energy. AS4970 and ANSI Z136.6 provide guidance and information for the evaluation of laser operations in navigable airspace. Due to operational/mission requirements, some laser beams may exceed the maximum permissible exposure (MPE) limits in ANSI Z136.1 or visual interference levels in FAA Job Order (JO) 7400.2 and ANSI Z136.6. Control measures intended to reduce or eliminate these risks to air navigation are discussed in this document.

4. LASER CONTROL MEASURES

Control Measures

Control measures mitigate risk by reducing the likelihood or severity (or both) of a hazard and are typically divided into three general categories (listed in order of preference): engineering controls, administrative/procedural controls, and personal protective equipment (PPE). Multiple control measures may be necessary to effectively control the hazard.

Engineering controls use physical means to minimize, contain, or eliminate the hazard. This is preferred, as it is understood that risk is best mitigated by controlling the hazard itself. The use of engineering controls simplifies overall risk mitigation by limiting the variability inherent in the reliance of people following administrative/procedural controls.

When the use of engineering controls to adequately mitigate risk is not practicable, risk mitigation can be done using administrative controls. Administrative controls are used to separate intrinsic hazards from people, material, or the environment to which they may cause harm. These types of control measure rely on rules, procedures, and their application, so they are subject to the inherent variability of human error. Additionally, administrative controls may have limited effectiveness against unanticipated hazardous eventualities.

Finally, when the use of both engineering and administrative controls cannot practicably be used to adequately reduce risk, PPE may be necessary. The need for PPE presumes that a person may be exposed to a hazard. This is the least desired means for mitigating risk and is considered the “last line of defense” against injury. Additionally, PPE requires both training and use, thus adding to the administrative controls necessary to mitigate risk.

4.1 Engineering Controls

The following are control measures that may be used to control laser hazards in the navigable airspace. Laser systems and control measures should be designed, installed, and operated in accordance with applicable federal, state, local regulations, and industry standards.

4.1.1 Primary Radar

Primary radar sends out a radio frequency (RF) signal and displays the signal return reflected from an object. The distance to the object is calculated from the amount of time the signal takes to travel to-and-from the object. Radar is restricted to line-of-sight. Aircraft maneuvers, such as steep turns, rapid climbs or descents, can degrade the radar reflection. Radar is subject to limitations including atmospheric conditions, missed targets, false returns, ground clutter, RF interference, etc.