



AEROSPACE RECOMMENDED PRACTICE

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(R) Safety Considerations for Lasers
Projected in the Navigable Airspace

RATIONALE

On March 26, 1999, the Federal Aviation Administration (FAA) submitted a written request to the SAE for assistance in developing standards and regulations concerning outdoor laser operations. In December 1999, Aerospace Standard (AS) AS4970 was published by the SAE and forwarded to the FAA. AS4970 provides guidance on assessing the potential hazards of a particular laser beam. In August 2000, the ANSI Z136.6 standard was first published. Additionally, Aerospace Recommended Practices (ARP) ARP5535 and ARP5572 have been published by the SAE in support of this request.

This document provides guidance for operations of a laser system outdoors in the navigable airspace. It also includes training considerations for the outdoor use of lasers.

FOREWORD

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

This document describes the issues, duties, and training of laser proponents specific to the use of lasers in navigable airspace. It is assumed that the laser proponent is well versed on the general safety issues of indoor laser use.

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1. SCOPE

This document applies to laser proponents involved with the use of laser systems outdoors. It may be used in conjunction with AS4970, ARP5535, and ARP5572 and the ANSI Z136 series of laser safety standards.

1.1 Purpose

The purpose of this document is to describe the issues, duties, and training of laser proponents specific to the use of lasers in navigable airspace. It is assumed that the laser proponent is well versed on the safe use of lasers indoors.

1.2 Field of Application

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 exceed the maximum permissible exposure (MPE) limits or visual interference levels as defined in FAA Order 7400.2, ANSI Z136.1, and ANSI Z136.6. For this reason, mitigation and/or control measures may be required.

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
ARP5572	Control Measures for Laser Safety in the Navigable Airspace
ARP6378	Guidance on Mitigation Strategies Against Laser Illumination Effects
AS4970	Human Factor 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 Safe Use of Lasers
ANSI Z136.6	American National Standard for 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 AC 70-1	Outdoor Laser Operation(s)
FAA AC 70-2	Reporting of Laser Illumination of Aircraft
FAA Order 7400.2	Procedures for Handling Airspace Matters. [VI] Part 6 (Miscellaneous Procedures), Chapter 29 (Outdoor Laser Operations)
FDA 86-8260	Compliance Guide for Laser Products - U.S. Department of Health and Human Services
Title 14 CFR §91.11	Prohibition on interference with crewmembers
Title 21 CFR §1010	Performance Standards for Electronic Products: General
Title 21 CFR §1040	Performance Standards for Light-Emitting Products

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 list is not intended to constitute a dictionary of terms used in the laser field as a whole.

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

DAYTIME OPERATIONS: Any operations that occur between 30 minutes before sunrise and 30 minutes after sunset are considered daytime operations.

DISTRACTION: The redirection of attention from primary tasks due to sudden exposure to a stimulus, such as a bright light source.

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.

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

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 SAFETY SPECIALIST (LSS): An individual with the formal training or equivalent professional experience to correctly measure, calculate or determine laser beam parameters and hazards and be familiar with the use of control measures to mitigate those hazards.

MAXIMUM PERMISSIBLE EXPOSURE (MPE): The level of laser radiation to which a person may be exposed without hazardous effect or adverse biological changes in the eye or skin.

NATIONAL AIRSPACE SYSTEM (NAS): A complex, highly interactive "system of systems" involving large numbers of subsystems and components on the ground, and in the aircraft—including facilities, equipment, and computer hardware and software, as well as the people—which enables hundreds of thousands of users to fly safely every day.

NAVIGABLE AIRSPACE: For the purpose of this document, navigable airspace is that airspace that can contain aircraft. Navigable airspace is generally considered as airspace that is at least 500 feet from ground or any structure unless operated in remote, sparsely populated areas. In heavily populated areas, aircraft are required to allow more distances from structures. Near airports or heliports, navigable airspace extends to the runway. Helicopter operations may require additional considerations, since they are often flying below 500 feet.

NIGHTTIME OPERATIONS: Any operations that occur between 30 minutes after sunset and 30 minutes before sunrise are considered nighttime operations.

NOMINAL HAZARD ZONE (NHZ): The NHZ describes the space within which the level of the direct, reflected, or scattered radiation during operation exceeds the applicable MPE. Exposure levels beyond the boundary of the NHZ are below the applicable MPE level.

NOMINAL OCULAR HAZARD DISTANCE (NOHD): The distance along the axis of the laser beam beyond which the appropriate MPE is not exceeded.

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.

3. BACKGROUND

Since the early development of laser technology, it has been understood that lasers can pose serious hazards. Some laser beams can be well collimated and can create hazardous irradiance or radiant exposure levels at great distances from the laser source. Additionally, the ability of the human eye to focus collimated laser energy when exposed, and the potential use of magnifying optics, can significantly increase the distances from which lasers can pose a hazard. For lasers that emit in the visible spectrum, the distance to which exposure can cause temporary visual interference that could result in very hazardous situations (e.g., a pilot trying to land a plane who is unable to see the runway) is far greater.

Furthermore, as laser technology has advanced, there are ever-increasing number of uses for lasers. Many of these applications are outdoors. The result of this is that the use of lasers outdoors is increasing and many of these uses can produce hazards at great distances.

Various federal, state, and local regulations, as well as consensus standards, define requirements and best practices to protect people. The Food and Drug Administration (FDA) has regulatory authority over laser products in the United States. The laser proponent is required to ensure that the use of lasers complies with all applicable regulations. Additionally, it is good safety practice for laser proponents to adhere to applicable non-regulatory guidance (e.g., FAA Advisory Circular AC-70-1, ANSI Z136.1, ANSI Z136.6, AS6029, and ARP5572).

4. LASER SAFETY TRAINING REQUIREMENTS

The use of lasers outdoors poses many unique training needs for laser safety personnel. This training may be in the form of a formal course or may be administered through specific standard operating procedures (SOPs) and literature supplied by the laser safety officer (LSO). A proposed syllabus for laser safety training can be found in Appendix A. Additional information on laser safety training requirements can be found in ANSI Z136.1 and Z136.6.

4.1 Laser Safety Officer

In order to accomplish their duties, the LSO must be trained or have access to someone who has been trained to a level appropriate to allow them to perform their duties. The following training topics are suggested for an LSO.

- Hazards, control measures, evaluation procedures, and medical surveillance requirements unique for the use of lasers outdoors
- Organizational laser safety policy
- Applicable standards and regulations (federal, state, and/or local)
- Airspace and aircraft considerations

- Government notification/coordination requirements
- Laser safety specialist (LSS) services
- Incident investigation and reporting
- Preparing SOPs and training instructions for laser users
- Record keeping of laser operations

4.2 Authorized Laser Operator

Laser operators shall receive training commensurate with the specific lasers with which they will be associated. Operators of Class 3B and Class 4 lasers shall receive specialized training for the lasers that they will operate, including:

- Specific laser control measures
- Applicable SOPs (including emergency contingency procedures)
- Environments and conditions in which lasers may or may not be used
- Communication requirements
- Applicable standards and regulations (federal, state, and/or local)

4.3 Laser Safety Observer

For some laser systems, the safety observer may be the only practical control mechanism. For lasers that are operated for long periods of time and/or that can be hazardous at extremely long distances, it is important that the LSO not rely solely on safety observers to detect aircraft. For further explanation of training requirements for safety observers, refer to ARP5535.

4.4 Laser Safety Specialist (LSS)

Formal education in algebra, geometry, and trigonometry is required. A bachelor's degree or higher in physics, engineering, or mathematics is preferred. In addition, the LSS is required to have formal training or equivalent professional experience to calculate and determine laser hazards, and to recommend appropriate control measures.

Specialized training and experience is required concerning laser beam propagation, laser physics, electro-optics, radiometric measurement methods, consensus standards, federal and international laser safety standards, and biological effects of lasers on the skin and eyes. This training should include, but not be limited to, the following:

- Fundamentals of lasers and optics
- Biological effects of laser radiation
- Laser hazard evaluation
- Laser safety standards
- Control measures
- Laser safety program administration
- Laser safety measurements

4.5 Personnel in the Nominal Hazard Zone (NHZ)

For specific uses involving Class 3B and Class 4 lasers, personnel are sometimes required to be in the beam path. When the MPE could be exceeded at this location, personnel within the NHZ must receive hands-on training on the specific procedures contained in the laser safety SOP. This training should include:

- Hazards and control measures associated with the lasers being used
- Applicable SOPs (including emergency protocols, communication protocols, etc.)
- Proper use of required laser eye protection

5. AIRCRAFT CONSIDERATIONS

When visible laser beams are projected or reflected into the navigable airspace, there is potential for these beams to subject pilots to biological injury, distraction, and/or transient visual effects, such as glare, flash blindness, and afterimage. If the crew is subjected to these effects during critical phases of flight (e.g., taxi, takeoff, landing, and other flight operations conducted under 10000 feet, except cruise flight), the resulting impairment could have catastrophic results. An aeronautical assessment is therefore necessary to determine the effect these laser beams may have on aircrew and aircraft systems in the navigable airspace. A few high-power military and research lasers also have the potential to cause structural damage to aircraft. These lasers may be visible or non-visible. Control measures are used to mitigate adverse effects to the aircraft and its occupants.

5.1 High Altitude Aircraft Operations

High altitude aircraft (normally flown at altitudes above 18000 feet) include large turbo-jet aircraft (e.g., Boeing 747 and Airbus A319/320), corporate jets (e.g., Cessna Citation and Learjet), military aircraft, etc. Projected laser beams normally do not adversely affect aircrew at or above 18000 feet altitude; most reported cases occur under 18000 feet.

5.2 Low Altitude Aircraft Operations

Low altitude aircraft (normally flown at altitudes at or below 18000 feet) include the following:

- Aeromedical (usually helicopters)
- Military (helicopters and fixed-wing)
- Law enforcement (helicopters and fixed-wing)
- News agencies (usually helicopters)
- Agricultural crop dusting (helicopters and fixed-wing)
- Corporate or business (helicopters and fixed-wing)
- General aviation (small fixed-wing, gliders, hot air/gas balloons, blimps, dirigibles, etc.)

These aircraft are more susceptible to laser systems used outdoors due to factors including critical task operations and potentially higher laser beam irradiance. Since a single pilot normally flies these aircraft, the consequences of visual impairment from a laser exposure can be more serious since there is no additional person to take over or help out. Additionally, helicopters have the capability of ascending/descending vertically while flying at slow forward speeds, making them difficult to detect. In a situation where a laser beam is being projected from an elevated position, a helicopter has the capability of flying up from below the line of sight making timely detection almost impossible. Laser beam exposure to pilots during critical phases of flight could have adverse results including interruption of a mission (e.g., policing, rescue), missed approach, or could conceivably be a factor contributing to an accident. The users of the laser system should implement appropriate control measures whenever any outdoor propagation is being planned in order to avoid potential incidents.

5.3 Information Available to the Pilot on Outdoor Laser Operations

The locations, dates, durations, and eye-safe distances for certain long-term, outdoor laser operations are published in the Airport Facility Directory and aeronautical charts.

The FAA may issue a notice to airmen (NOTAM) for laser operations where appropriate. Air carrier dispatch or base operations offices, as well as general aviation pilots, should frequently contact the appropriate Automated Flight Service Station to receive the most up-to-date NOTAM on outdoor laser activity.

6. DEPARTMENT OF DEFENSE COORDINATION

Users of lasers operating near or across military operation areas (MOA), restricted areas, and prohibited areas should consider coordinating with the local military authorities to ensure that the use will not interfere with military operations.

Some other agencies share military airspace such as Department of Energy (DoE) and NASA that should also be coordinated with prior to laser operations. To avoid interference with aircraft operations, coordinate the use of lasers (primarily Class 3B and Class 4 lasers) through the appropriate agencies. Due to unique military operations, the military authority should be informed whenever laser beams cross into MOA and prohibited/restricted areas, even if the MPE is not exceeded in that airspace.

The Department of Defense (DoD) Laser Clearinghouse is responsible for protecting all active and inactive orbital assets. Some satellites have sensitive detectors that can be damaged by intense light sources originating from earth. U.S. Space Command can determine whether a laser has the potential for interference or damage to particular satellites. Lasers with very high peak powers and very small beam divergences probably have the greatest potential for producing damage to these very expensive systems. These lasers include those that exceed a peak irradiance of $1 \text{ mW} \cdot \text{cm}^{-2}$ at an altitude of 60000 feet (18 km) above sea level. Typically, this is limited to laser beams with a divergence on the order of less than $10 \text{ } \mu\text{rad}$.

Any propagation of lasers above 60000 feet (18 km) by DoD or DoD-sponsored activities requires coordination with the Laser Clearinghouse.

Non-DoD laser operations that meet the criteria above and could potentially propagate beyond the atmosphere should also contact the Laser Clearinghouse for a laser hazard evaluation. Lasers, such as LIDAR (light detection and ranging) or laser tracking systems, often have beams that exceed the MPE at altitudes far from the laser site. Scientific and research lasers utilizing unterminated beams may also constitute a hazard to aircraft or orbiting assets. U.S. Space Command will advise the laser operator if any potential adverse effects on orbiting assets are present, and provide operating conditions to mitigate these effects. The Laser Clearinghouse may be contacted at:

North American Aerospace Defense Command
CMOC/J3
Attn: Orbital Safety Officer
Cheyenne Mountain AFS, Colorado 80914-6020
PH: (805) 606-1282

This organization has the capability to determine if the specified laser has the potential for interfering with satellites. If the Laser Clearinghouse determines the laser may potentially interfere with satellite operations, a predictive avoidance schedule may be generated. The predictive avoidance schedule assigns laser operation times and orientations of the beam that would allow laser operations to be conducted safely to space. For any questions, or to report a missed predictive avoidance time, contact the Laser Clearinghouse as above.

7. AIRSPACE ISSUES

Regardless of the airspace category, aircraft may perform sudden changes in direction, speed, or altitude. Many of these aircraft are not required to file flight plans or be in radio contact with the FAA.

FAA can evaluate the effect that proposed outdoor laser operations would have on aircraft in the navigable airspace. While FAA has no direct regulatory authority over outdoor laser operations, many organizations and agencies have internal requirements to have FAA evaluate and not object to the proposed operations. In addition, FDA requires laser light shows in open (unterminated) airspace to receive a letter of non-objection from the FAA.