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Observers for Laser Safety in the Navigable Airspace

INTRODUCTION

On March 26, 1999, the FAA submitted a written request to SAE for assistance in developing standards and regulations concerning outdoor laser operations. In December 1999, the SAE Aerospace Standard 4970 (AS4970) "Human Factors Considerations for Outdoor Laser Operations in the Navigable Airspace" 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 Z-136.6-2000 "American National Standard for Safe Use of Lasers Outdoors," was published.

This Aerospace Recommended Practice (ARP) document provides guidance for the use of laser safety observers during operations of a laser system outdoors in the navigable airspace. It also recommends the minimum requirements and training issues for those laser safety observers.

FOREWORD

This document applies to laser safety observers so as to mitigate a laser beam's potential hazard to aircrews when projected from an outdoor laser system. A related Society of Automotive Engineers (SAE) document is Aerospace Standard (AS4970) “Human Factors Considerations for Outdoor Laser Operations in the Navigable Airspace”. Additional control measures may be applicable and are discussed in ANSI Z-136.6-2000, “American National Standard for Safe Use of Lasers Outdoors,” which is the most recent and authoritative reference regarding outdoor laser operations and control.

The purpose of this document is to provide guidance to all laser operators, including industry and government, and to the Federal Aviation Administration (FAA) on the optimal use of laser safety observers during propagation of a laser beam in the navigable airspace. It also recommends the minimum requirements and training issues for those laser safety observers.

The SAE G-10T Committee has convened during the past 7 years with representation from at least 17 different entities, public and private, to identify the issues, technologies, and operational capabilities of outdoor laser use in navigable airspace.

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1. SCOPE:

This document applies to safety observers or spotters involved with the use of outdoor laser systems. It may be used in conjunction with SAE Aerospace Standard (AS4970) "Human Factors Considerations for Outdoor Laser Operations in the Navigable Airspace." Additional control measures may be applicable and are listed in ANSI Z-136.6-2000.

1.1 Purpose:

The purpose of this document is to provide guidance to proprietors for the optimal use of safety observers during operation of a laser system. It also recommends the minimum requirements for a safety observer.

1.2 Field of Application:

SAE 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 or visual interference levels as defined in FAA Order 7400.2, ANSI Z136.1, and ANSI Z136.6. The use of laser safety observers as control measures to reduce the laser beam hazards to air navigation are discussed.

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 is provided. In the event of conflict between the text in 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, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

AS4970 Human Factors Considerations for Outdoor Laser Operations in the Navigable Airspace

2.1.2 ANSI Publications: Available from Laser Institute of America, Suite 128, 13501 Ingenuity Drive, Orlando, FL 32826.

ANSI Z136.1 American National Standard for the Safe Use of Lasers. June 2000.

ANSI Z136.6 American National Standard for the Safe Use of Lasers Outdoors. August 2000.

2.1.3 U.S. Government Publications: Available from Subsequent Distribution Office, SVC-121.23, Ardmore East Business Center, 3341 West 75th Avenue, Landover, MD 20785.

FAA Order 7400.2E Procedures for Handling Airspace Matters. [VI] Part 6 (Miscellaneous Procedures), Chapter 28 (Outdoor Laser Operations). December 2000.

Code of Federal Regulations. Title 14, Part 91.17. Jan 2000.

2.2 Other Applicable References:

Goldstein HP, Scott AB, Nelson LB. "Ocular motility," in Tasman W. Jaeger EA, (eds.), Duane's Biomedical Foundation of Ophthalmology Vol. 2, J.B. Lippincott Company, Philadelphia, 1989, pp 51.

Bennett AG, Rabbetts RB. "Anisometropia and aniseikonia," in Bennett AG, Rabbetts RB, (eds.), Clinical Visual Optics, Butterworths, Boston, 1984, pp 312.

Parks MM. "Alignment," in Tasman W. Jaeger EA, (eds.), Duane's Biomedical Foundation of Ophthalmology Vol. 1, J.B. Lippincott Company, Philadelphia, 1989, pp 7.

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

AFTERIMAGE: An image that remains in the visual field after an exposure to a bright light.

FLASHBLINDNESS: The inability to see (either temporarily or permanently) caused by bright light entering the eye that persists after the illumination has ceased.

2.3 (Continued):

GLARE: A temporary disruption in vision caused by the presence of a bright light (such as an oncoming car's headlights) within an individual's field of vision. Glare is not associated with biological damage and its effect only lasts as long as the light source is present within the individual's field of vision.

LASER SAFETY OFFICIER (LSO): An individual with both the authority and the responsibility to monitor and enforce the control of laser hazards and to effect the knowledgeable evaluation and control of laser 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.

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 have the ability to immediately terminate the laser beam.

3. BACKGROUND:

Laser beams can be hazardous to human tissue. There are documented incidents of laser beams striking aircraft in flight within the United States, which resulted in injury to flight crewmembers. Physical injuries can result to the skin or eyes, but temporary impairments to vision are much more prevalent. Approximately 90% of the information a pilot uses to safely operate an aircraft is obtained through the sense of vision; therefore, it is imperative that hazardous laser exposure be eliminated or attenuated to safe vision levels. Unfortunately, fully automated laser control systems are not readily available as “off-the-shelf” items. In addition, the effectiveness of most new technologies used to control laser propagation in the NAS is unproven with mechanical control failure being a chronic concern. However, safety observers are an effective alternative or enhancement to an automated laser control system. Furthermore, for some laser systems, the safety observer may be the only practical control mechanism. For more powerful lasers, it is important that the LSO not rely solely on safety observers to detect aircraft. Safety observers have been demonstrated to be reliable in detecting aircraft up to three miles away. Safety observers may be capable of detecting aircraft at much greater distances in semi-populated areas and in remote locations where city lights are less numerous. The safety observer or spotter may be the last line of defense against laser beams striking aircraft.

3.1 Laser Biological Effects:

The biological effects associated with laser illumination are dependent on the laser beam characteristics, environmental factors, and vulnerability of the target at the time of exposure. These effects include startle, distraction, glare, flashblindness, afterimages, and biological damage (blind spots, burns, and hemorrhages). Visible laser beams can be psychologically disruptive without causing actual biological damage. An individual would be more susceptible to biological effects, such as glare, flashblindness, and afterimages under low-light conditions. Pulsed lasers may have a reduced MPE for the same average power than continuous wave (CW) lasers and, therefore, are more likely to induce biological damage. Additional information on the biological hazards of lasers is available in the Appendix. Biological effects from laser illumination may include:

3.1.1 Distraction: When presented with a bright light source, particularly at night, it is difficult to prevent a change in direction of gaze from the task at hand to the new source. Training and normal biological reflexes result in diverting attention toward any new and unexpected light source in order to assess its significance. If the new light source proves to be a minor distraction, attention can be rapidly refocused back to the task at hand.

3.1.2 Glare: Glare refers to temporary disruptions in vision without biological damage. Glare is particularly disruptive under nighttime viewing conditions and especially when the eyes are fully dark-adapted. Glare is a source-fixed effect, in that as the position of gaze shifts away from the light source, glare effects are diminished, e.g., headlights from an oncoming car at night. Glare only occurs when the light source is on.

3.1.3 Flashblindness: Flashblindness is a visual interference effect that persists after the bright light is terminated, e.g., from a camera flash. Flashblindness can last from several seconds to several minutes.

3.1.4 Afterimages: Afterimages refer to perceptions that persist following illumination with a bright light source, and are described as light, dark, or colored spots, e.g., image that remains after a camera flash. Its effects may last for more prolonged periods of time than flashblindness effects and can persist minutes, hours, or several days.

3.1.5 Scotomas: A scotoma (blind spot in the visual field) can either be temporary or permanent. If permanent, it is a sign of biological tissue damage and is a blind spot in the visual field. The location of the corresponding tissue damage on the retina will determine the resulting level of functional visual acuity. A retinal burn from a hazardous laser beam can cause a scotoma.

3.1.6 Hemorrhages: A hemorrhage (bleeding) can occur if a laser beam disrupts a blood vessel in the eye. Vision recovery will depend on the location of the blood and other induced cellular disruption, as well as the rate of re-absorption of the blood.

4. LASER SAFETY OBSERVER RECOMMENDATIONS:

Qualified healthcare providers should examine and validate the medical and visual fitness of a safety observer to ensure his or her ability to perform safely and effectively in this capacity.

4.1 Minimum Criteria:

Safety observers should meet the following minimum criteria:

Distance visual acuity. 20/20 or better binocularly with or without corrective lenses.

No significant ocular pathology. Eye diseases that can affect vision performance of the observer should be documented. These include diabetes, macular degeneration, cataract, glaucoma, amblyopia, and monocularity.

Ocular surgery. No significant visual performance loss (increased glare sensitivity, reduced contrast sensitivity, fluctuating visual acuity) due to ocular surgery, such as to correct refractive error, cataract, and traumatic injury.

Normal visual field. The field of vision should be evaluated for both eyes, and no significant scotoma should exist.

Normal color vision. Individuals with color vision deficiency may not be good candidates as safety observers, since they may not be able to distinguish aviation position lights on aircraft.

Normal hearing acuity. Normal hearing is advantageous to safety observers, since they may hear an approaching aircraft that is not yet visible due to inclement weather or mountainous terrain.

Drugs and medications. No drug usage that may compromise the individual's physical or visual performance. Certain medications known to cause drowsiness, decreased color vision, blurred vision, and other problems should be avoided.

Alcohol. Observers should be counseled regarding alcohol consumption. Alcohol usage has been shown to cause visual complications of decreased vision, double vision, chronic lacrimation, pupillary dysfunction, reduced dark adaptation, nystagmus (an involuntary, rapid movement of the eyeball), and to increase central processing time, thus interfering with accurate tracking and saccadic (rapid involuntary small movements of both eyes simultaneously) eye movements. Federal Aviation Regulation (FAR) 91.17 states that no person may act or attempt to act as a crewmember of a civil aircraft within eight hours after consumption of any alcoholic beverage. Although this FAR does not apply to laser safety observers, the provisions are strongly recommended as a pre-work limitation for these individuals.

4.2 Medical Surveillance:

If the safety observer is at risk of being illuminated by an eye hazardous laser beam, medical surveillance is recommended. This surveillance may include:

Snellen visual acuity.

Slit-lamp examination.

Visual field.

Amsler grid.

Color vision.

Dilated fundus examination. (Retinal photography is preferred.)

4.3 Training:

Training should encompass the following:

4.3.1 Optical Scanning Patterns: Scanning in regular patterns allows the observer to view a specified sector of space efficiently. It also discourages the manifestation of illusions, such as the "empty-field myopia" or "night myopia." Detection of aircraft is increased with scanning of smaller areas of space. It is recommended that when laser beams are projected in larger airspace, more than one safety observer be used.

4.3.2 Collateral Duties: When performing the duties of an observer, there shall be no other collateral duties.

4.3.3 Proper Use of Ophthalmic Devices: Eyeglasses with tinted lenses should not be used during night laser operations because they may reduce vision performance and result in missed detection of aircraft. Additionally, tints that alter color perception, such as blue blockers, should not be used. Contact lenses that change the color of the iris are also discouraged during night laser operations as they can reduce both central and peripheral vision.

4.3.4 Communication Requirements and Equipment: To ensure proper communication with air traffic service and other laser personnel, observers should be properly instructed on the use of radio, cell phone, telephone, or other communication equipment.

4.3.5 Safe Operating Procedure Logbook: Such a logbook should be filled out appropriately each time the laser is operated. The location and maintenance of this book is the responsibility of the LSO.

4.3.6 Use of Control Measures: The protocol for laser beam termination should be provided to all laser personnel in writing.

4.3.7 Training on Visual Illusions: Visual illusions are more common at night. In the darkness, a condition of "dark-field or night myopia" occurs as the individual becomes more nearsighted. When looking into empty space or a featureless field of vision, “empty-field myopia” can occur. A recommended reference on visual illusions is: Night Vision Manual for the Flight Surgeon, Chapter 3: Operational Aspects of Night Vision; Robert E. Miller, II, Thomas J. Tredici. AL-SR-1991-0002. August 1992. Armstrong Laboratory, Brooks AFB, TX.

4.3.8 Fatigue Recognition: Individuals should be trained to recognize fatigue while scanning for aircraft. Common side effects of fatigue include distraction or cognitive disruption. It is recommended that observers be provided periodic rest breaks to ensure optimal performance. A 10-minute break for each 60-minute period of observation duty is usually adequate. In high traffic areas, breaks may need to be more frequent. At higher altitudes (i.e., > 5,000 feet above sea level), where altitude hypoxia can be a factor, fatigue may occur at shorter time intervals.

4.3.9 Viewing Conditions: Prolonged exposure to bright lights can result in fatigue. Also, glare can result in visual acuity and contrast sensitivity decrements. In nighttime conditions, the visual illusions previously mentioned need to be considered.

4.3.10 Effects of Environment: In an urban environment, artificial lights can affect the contrast between aircraft and the background. In a rural environment, lack of surface detail can result in illusions. Haze can scatter light affecting visibility and reducing detection range. Inclement conditions, such as rain, snow, mist and fog, can affect visual performance. Natural or man-made obstructions such as mountains, trees, or buildings can block the view of safety observers. A bright star-filled sky can mask aircraft position lights.

4.3.11 Multiple Tasking: When an individual is tasked with multiple assignments, distraction and fatigue are increased. A laser safety observer should only be tasked with pertinent duties that affect safety, which include scanning for aircraft, communicating with air traffic services and/or laser personnel, and terminating laser beams, if illumination of aircraft is imminent.

4.3.12 Judgment: Training should include how to anticipate aircraft flight characteristics and also the potential for hazardous illumination of the aircraft and pilot. Observers should always be alert for the unexpected movements of a particular aircraft or of the unexpected appearance of aircraft in a portion of the sky. For example, the angle between the laser beam and the aircraft that results in termination of the beam should be standardized and an observer properly trained on making such a judgment.

4.3.13 Performance Requirements: Moderate, steady air traffic is less likely to induce fatigue. In an environment with very few or many aircraft, a safety observer is more likely to have fatigue, resulting in effects ranging from boredom to sensory overload. Reducing the field of view with multiple observers or reducing the duty time of the observer can minimize these side effects.

4.3.14 Physiological Effects: Certain situations or conditions may have significant effects on human physiology, and as such may impact visual performance. On average, it takes about 30 minutes for an individual to fully adapt to the dark. When an individual has prolonged exposure to bright lights, the time for dark adaptation will be lengthened. Use of appropriate sunglasses in daylight hours can improve dark adaptation. Use of tobacco products can delay dark adaptation. As we age, adaptation to bright lights and to the dark can be affected. Use of certain drugs or alcohol can affect judgment and physiology. The use of micronutrients and antioxidants has been recommended to improve vision and resist the progression of eye diseases. For example, vitamin A can improve night vision capability.

4.3.15 Visual Stimuli: Visual stimuli have unique characteristics, and some stimuli are easier to detect than others. For example, a moving or flickering light source is easier to detect than a steady light source. Aircraft navigation lights are aviation red (left wing) and green (right wing), indicating the direction of flight. Due to the eye's inherent peak sensitivity, green lights are easier to see than red lights. Off-axis viewing is a technique used to enhance aircraft acquisition at night. Looking directly at the target at night decreases the ability to detect that aircraft. The observer must look slightly away (off-axis) from the aircraft to see it.

4.3.16 On-The-Job Training: A laser safety observer should be provided the appropriate amount of on-the-job training commensurate with the laser operation.

4.3.17 Local Air Traffic Patterns: When available, the LSO should provide information on local air traffic and facilities to safety observers prior to laser operation. This will assist the observers in scanning for aircraft near the area of laser beam propagation. Radio scanners tuned to air traffic frequencies may also assist in acquiring aircraft.

4.4 Physical Aids to the Safety Observer:

4.4.1 Binoculars: Binoculars can be used to magnify the image and aid in early identification of aircraft. However, use of such devices can drastically reduce the observer’s field of view and the area being scanned.

4.4.2 Night Vision Goggles (NVGs): Safety observers have used NVGs to detect aircraft in nighttime conditions. However, NVGs exposed to bright lights can cause blooming from the light and glare or flashblindness to the observer. Also, NVGs can reduce the observer’s field of view, reducing the airspace that can be scanned. Observers should be instructed in the proper use of NVGs prior to their use. In particular, proper focusing of the NVG is critical.

4.4.3 Visible Alignment Beam: A visible alignment beam may be used to indicate the location of an invisible laser beam.

4.5 Evaluation of Observer Effectiveness:

4.5.1 Direct Observation: LSOs should periodically review the procedures of the safety observer. This can be done through direct observation of observers during laser operations. Evaluation of scanning patterns, use of optical aids, logbook review, rest breaks, etc., should be performed.

4.5.2 Historical Safety Data: LSOs can evaluate the effectiveness of control measures by reviewing the safety data from past laser operations. Any incidents (near misses, operator errors, etc.) should be reviewed to evaluate the effectiveness of safety observer procedures.

4.5.3 Questionnaires for Observers: Safety observers should be periodically queried to get their opinions regarding the effectiveness of current safety procedures. A questionnaire may be used, but anonymity should be ensured to obtain honest and more constructive criticism of procedures. To ensure safety observer effectiveness is optimized, the LSO and laser operators should carefully evaluate these questionnaires.

4.5.4 Refresher Training: Provided as needed.

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