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DEPARTMENT OF DEFENSE HANDBOOK

RANGE LASER SAFETY

THIS HANDBOOK IS FOR GUIDANCE ONLY.
DO NOT CITE THIS DOCUMENT AS A REQUIREMENT.

AMSC NA **AREA SAFT**

FOREWARD

This handbook provides uniform guidance for the safe use of military lasers and laser systems on DOD ranges. Each military service has previously established normal procedures for approving laser ranges, and as directed by Title 10, have the responsibility to organize, train, and equip their forces. Services will establish a range laser safety program as part of their overall range safety program. This guidance is intended to supplement these procedures and training requirements. It does not replace those procedures nor release individuals from compliance with the requirements of their particular service. The authority for this handbook is the Department of Defense (DOD) Laser System Safety Working Group (LSSWG) established by DODI 6055.15 “DOD Laser Protection Program.” Guidance for laser systems not addressed here should be obtained from the LSSWG.

a. The aim of this DOD handbook is to establish range safety for the evaluation and control of lasers under military control in order to reduce to a minimum the hazards to personnel, property, and the environment.

b. The installation commander is responsible for laser range operations while day to day operations are managed through the Installation Laser Range Authority.

c. This handbook applies to laser systems with optical radiation emission in the wavelength range of 100 nm to 1 mm, pulsed and continuous wave systems.

d. This handbook does not apply to medical or laboratory uses, where additional professional review may be needed to establish adequate health and safety controls; other outdoor use is described in ANSI Z136.6, Safe Use of Lasers Outdoors.

e. This handbook applies to all hazard categories or hazard classifications defined by ANSI Z136.1, Safe Use of Lasers, and IEC 60825-1.2-2001, Radiation Safety of Laser Products.

f. The intent is for this document to provide sufficient guidance for laser system use on an established range.

Comments, suggestions, or questions on this document should be addressed to USN Space and Warfare Center 4250 Pacific Highway, San Diego, CA 92110 mail stop OT-3 2824 or emailed to fred.stewart@navy.mil. Fred Stewart is Mike M. Stewart in the GAL [858-537-0279]

Since contact information can change, you may want to verify the currency of this address information using the ASSIST Online database at https://assist.daps.dla.mi.

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1. SCOPE

1.1. Application This handbook applies to all ranges where systems-certified laser systems are employed or where laser systems are being evaluated. This handbook addresses the roles of several levels of authority including institutional, installation, and unit, and subsequent laser positions within the services. While these functions may be combined in some services, the range of expertise and capability extends from unit application throughout the highest certifying authority. This handbook is for guidance only and cannot be cited as a requirement.

1.2. Content. This handbook contains appendices which give general and detailed guidance to be followed in evaluating and recommending range laser safety procedures. Appendix A contains a sample of a laser safety standard operating procedure (SOP). Appendix B contains checklists to be used for the laser safety pre-survey, the site survey, and the laser range certification reports. Appendix C provides the equations used to conduct laser hazard analysis.

The contents of this handbook are intended to serve as a guide to the safe use of laser systems used on military operational and test ranges.

This document is applicable to all DOD member ranges and all DOD laser operations conducted on non-DOD controlled ranges. The guidance in this document does not replace other procedures or release individuals from compliance with the requirements of their particular service.

This document implements the information and methodologies contained within STANAG 3606.

Suggestions for any amendment, revision, or cancellation of this handbook are to be submitted through the DOD LSSWG.

2. APPLICABLE DOCUMENTS

2.1. General. Unless otherwise specified, the following documents are those listed in the latest issue of the Department of Defense Index of Specifications and Standards (DODISS) and supplement cited in the solicitation and form a part of this handbook to the extent specified herein.

2.2. Government Documents.

2.2.1. Specifications, Standards, and Handbooks.

MILITARY

MIL-STD-1425A	–	Safety Design Requirements for Military Lasers and Associated Support Equipment

INTERNATIONAL STANDARDIZATION AGREEMENTS

STANAG 3606	–	Evaluation and Control of Laser Hazards on Military Ranges

NATO STANDARDIZATION AGREEMENTS

ASRP 1 Vol III	–	Deterministic Methodology: Factors for lasers and applications to lasers
ASRP 2 Vol V	–	Probabilistic Methodology: Application to lasers
ASRP 3 Vol V	–	Data Acquisition and Analysis: laser Data
ASRP 4 Vol III	–	Software Requirements and Test plans: probabilistic methodology for lasers

(Unless otherwise indicated, copies of the above standards are available from the Standardization Document Order Desk, 700 Robbins Avenue, Building 4D, Philadelphia, Pennsylvania 19111-5094.)

2.2.2. Other Government Publications. This standard supplements, but does not supersede the regulations for each Service. All offices responsible for laser safety should have a copy of the references applicable to their Service. The following government publications are referenced in this standard:

JOINT CHIEFS OF STAFF

JCS PUB 3-09.1 (JLASER)	–	Joint Laser Designation Procedures JFIRE

DEPARTMENT OF DEFENSE

DOD Directive 3200.22	–	Operation on National Ranges and Test Facilities
DOD Instruction 6055.15	–	PDOD Laser Protection Program, 4 May 2007
DOD RCC Document 316-91	–	RCC Document Laser Range Safety, Range Safety Group, DOD Range Commanders Council

US ARMY

AMCR 385-29	–	Safety-Laser Safety
AR 385-10	–	The Army Safety Program
AR 385-30	–	Safety Color Code Markings and Signs
AR 40-5	–	Preventive Medicine
DA PAM 385-24	–	The Army Radiation Safety Program
DA PAM 385-63/ MCO P3570.1	–	Range Safety
TB MED 524	–	Control of Hazards to Health from Laser Radiation

US NAVY/MARINE CORPS

BUMED Instruction 6470.2A	–	Laser Radiation Health Hazards
EO410-BA-GYD-010	–	Technical Manual, Laser Safety
MCO 3550.9	–	Marine Corps Ground Range Certification and Recertification Program
MCO P3550.10	–	Policies and Procedures for Range and Training Area (RTA) Management
MCO P3570.1	–	Policies and Procedures for Firing Ammunition for Training, Target Practice and Combat
MCO 5104.1	–	Marine Corps Laser Hazards Control Program
NSWCDD/MP-94/289	–	Descriptions of Navy and Marine Corps Laser Systems, September 1995
SECNAV Instruction	–	Exemption of Military Laser Products

5100.14B		
SPAWAR Instruction 5100.12B	–	Navy Laser Hazards Prevention Program

US AIR FORCE

AFI 13-212	–	Weapons Range Management
AFOSH Standard 161-10	–	Health Hazards Control for Laser Radiation
USAFOEHL Report AL-TR-1991-0112	–	Base-Level Management of Laser Radiation Protection Program
USAFOEHL Report 87-091RC0111GLA	–	Laser Range Evaluation Guide For Bioenvironmental Engineers

CODE OF FEDERAL REGULATIONS (CFR)

21 CFR Part 1040	–	Performance Standards For Light-Emitting Products

OCCUPATIONAL SAFETY AND HEALTH ADMINISTRATION (OSHA)

OSHA Publication 8-1.7	–	Guidelines for Laser Safety and Hazard Assessment

FEDERAL AVIATION ADMINISTRATION (FAA)

FAA 7930.2B	–	Notices To Airmen (NOTAM)

(Copies of specifications, standards, handbooks, drawings, publications, and other government documents required by contractors in connection with specific acquisition functions should be obtained from the contracting activity or as directed by the contracting officer.)

2.3. Non-Government Publications. The following document applies to the extent specified in this document. Unless otherwise specified, documents which are DOD adopted are those listed in the latest issue of the DODISS cited in the solicitation. Documents not listed in the DODISS are the issues of the documents cited in the solicitation.

AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)

ANSI Z136.1	–	Safe Use of Lasers

ANSI Z136.6 – Safe Use of Lasers Outdoors

(Copies of this document may be obtained through DOD publication channels for government activities. For all others, requests for copies should be addressed to American National Standards Institute (ANSI), 1430 Broadway, New York, New York.)

2.4. Order of Precedence. In the event of a conflict between the text of this standard and the references cited, the conflict should be referred to the military service specialists who have jurisdiction over the laser range. Nothing in this standard should supersede applicable laws and regulations unless a specific exemption has been obtained.

3. DEFINITIONS

3.1. Definitions The following definitions and terms are used in this handbook. For other definitions associated with laser safety, refer to ANSI Z136.1, Safe Use of Lasers.

3.1.1. Administrative Controls. A category of control measures used to eliminate hazards or reduce the degree of risk to personnel. Administrative controls reduce risks through specific administrative actions. Administrative controls include controls that can be established and managed by range personnel as well as the documentation and training that is required of participating personnel.

3.1.2. Atmospheric Attenuation. Atmospheric conditions (e.g., smoke, haze, cloud, precipitation, fog) which can cause a laser beam to diffuse more, attenuate, or reflect the laser beam, thereby preventing reflection or redirection from the target of sufficient energy for lock-on by laser spot trackers or laser-guided weapons.

3.1.3. Attenuation. The decrease in the energy of any optical radiation beam as it passes through an absorbing or scattering medium or both.

3.1.4. Autonomous Laser Systems. Lasers which can operate in an autonomous mode (i.e. that are not directly under the operator's control).Backscatter. A portion of the laser energy that is scattered in the direction of the seeker by an obscurant.

3.1.6. Beam Divergence. The spread of the laser beam.

3.1.7. Buffer Angle. The calculation based on the pointing accuracy and stability of the laser system used to establish the buffer zone.

3.1.8. Buffer Zone. The zone located to the left of the training area's left lateral limit and to the right of the right lateral limit with its apex at the aperture of the laser. The laser beam will be contained within the buffer zone with a high degree of certainty. The buffer zone is determined by the buffer angle.

3.1.9. Controlled Area. An area where the occupancy and activity of personnel within is subject to control and supervision for the purpose of protection from radiation hazards.

3.1.10. Danger Zone. An area determined by analysis of weapons characteristics and historical patterns to present risk to personnel and/or equipment within a designated three-dimensional perimeter.

3.1.11. Diffuse Reflection. Reflection from a surface in which the beam is scattered in all directions, for example, a reflection from a rough surface.

3.1.12. Engineering Controls. A category of control measure used to eliminate hazards or reduce the degree of risk to personnel. Engineering controls use engineering methods to reduce risks by design, material selection, or substitution.Exclusion Zone. A designated area which attack headings should avoid because of the possibility of false target indications caused by atmospheric scatter from the laser beam within short distances from the laser exit port. An exclusion zone is established as a sector whose apex is at the target and extends equidistant (10 degrees) either side of the target-to-laser designator line. This zone extends vertically to infinity and has a horizontal limit of 20 degrees.

3.1.14. Flash Blindness. Dazzle and momentary flash blindness can occur from visible laser exposures below maximum permissible exposure (MPE) levels.

3.1.15. Fratricide. Death caused by an ally; friendly fire.

3.1.16. Installation Laser Range Authority. The organization that provides oversight to range laser activities at the installation level [e.g. Installation Range Laser Safety Officer (Air Force, Navy, Marine Corps), Installation Range Control Officer (Army)].

3.1.17. Institutional Laser Range Authority. The organization that provides oversight to range laser activities at the institutional level (e.g., Institutional Range Laser Safety Specialist).

3.1.18. Laser. A laser is a device that emits light (electromagnetic radiation) through a process called stimulated emission. The term laser is an acronym for Light Amplification by Stimulated Emission of Radiation.

3.1.19. Laser Footprint. The projection of the laser beam and buffer zone on the ground or target area.

3.1.20. Laser-guided Weapon. A weapon that homes in on reflected laser energy to strike a target. The laser is used to guide the munitions to a target. The acquisition device, which is a seeker and guidance kit mounted on the laser-guided weapon, guides on coded laser energy.

3.1.21. Laser Range. A laser range is a range designated for laser systems employment.

3.1.22. Laser Range Certification. Process conducted to ensure adequate safety margins are determined to allow for the diverse application of the many lasers that may be used on a range, defining the degree of laser radiation hazard possible and to recommend control measures to the installation commander.

3.1.23. Laser Spot Tracker. Type of laser acquisition device, normally mounted on fixed-wing aircraft or helicopters, that are used to aid visual acquisition of the target to be attacked by another weapon.

3.1.24. Laser Spot Size. The laser beam's impact on a target. The laser spot size is a function of beam divergence and the distance from the laser designator to the target.

3.1.25. Laser Surface Danger Zone (LSDZ). Designated region or ground area where laser radiation levels may exceed maximum permissible exposure levels, thereby, requiring control during laser operation. Unauthorized personnel are not permitted, and laser eye protection is required for personnel who may engage in intrabeam viewing within this area.

3.1.26. Laser Training Area (LTA). A training area on which laser systems are employed singularly or with other weapon systems.

3.1.27. Laser Target Designator. Used to designate targets or to guide munitions, delivered via ground or airborne, to the target via a seeker.

3.1.28. 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.

3.1.29. Medical Surveillance. A program in which personnel suspected of experiencing potentially damaging eye exposure from laser radiation will be evacuated immediately to the nearest medical facility and undergo an eye examination.

3.1.30. Milliradian (mrad). Unit of angular measure. One mrad equals one thousandth of a radian. One degree equals 17.7 milliradians.

3.1.31. Night Vision Goggles/Devices. Any individual or crew-served viewer which employs a nonthermal image intensification device to permit night vision.

3.1.32. Nominal Hazard Zone (NHZ). The NHZ is a volume of space around the target based on the laser reflection.

3.1.33. Nominal Ocular Hazard Distance (NOHD). The distance from an operating laser to the point where the laser is no longer an eye hazard, i.e., the irradiance or radiant exposure during operation is not expected to exceed the appropriate Maximum Permissible Exposure (MPE) level.

3.1.34. NOHD-M. The NOHD for viewing with magnifying optics.

3.1.35. Ocular Interruption (OI) Devices. Laser systems that are used to intentionally illuminate the eyes of individual(s) approaching to provide a warning to them. They are fielded as a non-lethal device to be used as part of the force continuum for de-escalating a situation when used early as part of the escalation of force procedures with vehicle checkpoints, entry control points, perimeter security, and convoys.

3.1.36. Optical Density. The amount of protection afforded by a particular set of eye protection for a particular laser wavelength.

3.1.37. Optically Aided Viewing. Viewing using an optical aid such as binoculars or a scope.

3.1.38. Personal Protective Equipment (PPE). Control measures used to protect personnel from the hazardous effects (eye and skin hazards) of lasers. PPE include goggles and spectacles to protect the eyes and clothing and gloves to protect the skin.

3.1.39. Specular Reflection. Reflection of a laser beam off of smooth surfaces, causing the beam to reflect and remain concentrated upon leaving the surface.

3.1.40. Spillover Reflection. Scattered reflections off objects near the target. Spillover reflection occurs when the laser spot is larger than the intended target, or when there is unsteady tracking of the target from the designator.

3.1.41. Seeker. Laser acquisition device; it identifies laser designated targets so they can be attacked with a ground, airborne, or naval weapon.

3.1.42. Surface Danger Zone (SDZ).

The ground and airspace designated within the training complex (to include associated safety areas) for vertical and lateral containment of projectiles, fragments, debris, and components resulting from the firing, launching, or detonation of weapon systems to include explosives and demolitions.

3.1.43. Unit Laser Range Authority. The organization that provides oversight to range laser activities at the unit level [e.g. Unit Laser Safety Officer (Air Force, Navy), Laser Range Safety Officer (Marine Corps, Army)].

3.1.44. Weapon Danger Zone (WDZ). The ground and airspace for lateral and vertical containment of projectiles, fragments, debris, and components resulting from the firing, launching, and detonation of aviation-delivered ordnance. It reflects the minimum land and air requirement, to include terrain mitigation, needed to safely employ a given weapon. This zone accounts for inaccuracy, failures, ricochets, and broaching/purposing of a specific weapon/munitions type delivered by a specific aircraft type. The WDZ ‘footprint’ is based on the specific weapon characteristics, type of delivery being executed, the type of platform (aircraft) delivering the ordnance, and level of containment acceptable to the installation commander.

4. GENERAL LASER INFORMATION

4.1. Laser. A laser is a device that emits light (electromagnetic radiation) through a process called stimulated emission. The term laser is an acronym for Light Amplification by Stimulated Emission of Radiation. Lasers emit light in a narrow, coherent beam of energy. The increased directional intensity of the optical radiation generated by a laser results in a concentrated optical beam at considerable distances, which may present a hazard to personnel.

4.2. Laser System. A laser system is an assembly of electrical, mechanical, and optical components which includes a laser. All references to lasers within this document will be referred to as laser systems.

4.3. Laser Range. A laser range is a range on which laser systems are employed singularly or with weapon systems.

4.4. Laser System Applications. Developments in laser technology have resulted in an increase in the use of laser systems for military application. Military lasers are used primarily for target acquisition, range-finding, fire control, ocular interruption, directed energy weapon, and non-verbal communications.

4.4.1. Laser Target Ranging and Designation. Laser target ranging and designation systems can provide accurate range, azimuth, and elevation information to locate enemy targets. Some laser systems can accurately determine target range. In combination with global positioning system (GPS), lasers can provide accurate enemy target locations. Laser target designators mark targets for engagement. When within range, the laser designator can be aimed so the energy precisely designates a chosen spot on the target. These systems vary from fixed/handheld to aircraft-mounted devices and perform similar functions from the ground or the air with varying degrees of accuracy.

4.4.2. Laser Spot Tracker. Laser spot trackers are used to aid visual acquisition of a target to be attacked by another weapon. This type of laser acquisition device is normally mounted on fixed-wing aircraft or helicopters. The laser spot tracker identifies the laser energy output from a laser designator and displays the target's position on a cockpit display panel.

4.4.3. Laser-guided Weapon. Laser-guided weapons home in on reflected laser energy to strike a target that is producing that reflected energy. The laser is used to guide the munitions to a target. The acquisition device, which is a seeker and guidance kit mounted on the laser-guided weapon, guides on coded laser energy. Laser-guided weapons require laser target illumination before launch or release and/or during the entire time of flight; some require illumination only during the terminal portion of flight.

4.4.4. Laser Marking. Laser marking involves using a laser marker/pointer/illuminator to get an individual's attention (from a distance on the ground or in an aircraft) in order to point out the location of a target using the laser.

4.4.5. Ocular Interruption (OI) Devices. OI devices such as dazzlers are used to intentionally obscure the vision of individual(s) approaching to provide a warning to them. OI laser systems use bright light to cause visual field obscuration in targeted individuals and is intended to be primarily a warning device, with an inherent (and secondary) capability to achieve ocular suppressing effects. They are fielded as a non-lethal/directed energy device to be used as part of the force continuum for de-escalating a situation when used early as part of the escalation of force procedures with vehicle checkpoints, entry control points, perimeter security, and convoys. OI devices should meet stringent safety criteria and be able to deliver a warning effect to targeted personnel by obscuring their vision. The devices currently in use may be Class 3R or greater laser systems that can be employed in training safely, but due to the intensity of the laser beam it poses an eye hazard within the NOHD if not employed correctly. If exposure distances approach the NOHD of the system (known and briefed prior to use), the laser system must be terminated automatically or, if not, manually.

4.5. Laser Operations

4.5.1. Air-to-Ground. Air-to-ground laser operations involve employment of a laser system from an aircraft (e.g., fixed wing, rotary wing, or unmanned aerial system (UAS)) to acquire a target on the ground, perform illumination and/or pointing, designate a target on the ground, guide a weapon to a target on the ground, or range-finding. Laser systems of this type may be mounted on the aircraft or hand-held within the aircraft.

4.5.2. Ground-to-Ground. Ground-to-ground laser operations involve employment of a laser system from the ground to acquire a target on the ground, perform illumination and/or pointing, designate a target on the ground, guide a weapon to a target on the ground, range-finding, nonverbal communication, or to provide ocular interruption. These laser systems may be mounted on a platform or a weapon, or they may be hand-held. Aircraft acquiring targets on the ground from ground-based designators are also considered to be ground-to-ground laser operations.

4.5.3. Ground-to-Air. Ground-to-air laser operations involve employment of a laser system from the ground to acquire a target in the air, perform illumination and/or pointing, designate a target in the air, guide a weapon to a target in the air, or range-finding.

4.5.4. Air-to-Air. Air-to-air laser operations involve employment of a laser system from an aerial system to acquire a target in the air, perform illumination and/or pointing, designate a target in the air, guide a weapon to a target in the air, weapons fusing, or range-finding.

4.5.5. Ship-to-Target. Ship-to-target laser operations involve employment of a laser system from a ship to acquire a target, perform illumination and/or pointing, designate a target, guide a weapon to a target, or range-finding. These laser systems may be mounted on a platform or a weapon, or they may be hand-held. The target can be air, ground, or water-based.

4.5.6. Underwater. Underwater laser operations involve employment of a laser system to a subsurface target.

4.5.7. Force-On-Force Operations. Force-on-force laser operations involve combat simulation, target acquisition, illumination and/or pointing, target designation, weapons guidance, or range-finding against friendly and/or opposing forces. Force-on-force lasers should be addressed on an individual basis by the local range authority with assistance from range safety specialists. Tactical exercises involving force-on-force components using laser systems other than Multiple Integrated Laser Engagement System (MILES) may be approved by the installation commander.

4.6. Laser Beam Reflection. A laser beam reflects off surfaces it comes into contact with. The magnitude of the reflection is dependent upon the material surface and the angle of incidence (i.e., light striking a surface will reflect back at an angle perpendicular to the surface).

4.6.1. Specular Reflection (Mirror-like Surface). Reflection of a laser beam off of smooth surfaces such as a mirror, a calm body of water, clean ice, plate glass, or flat chrome-plated metal produces a type of reflection known as specular reflection. Specularly reflected laser beams retain much of their collimation and may be a hazard.

4.6.2. Diffuse Reflection. Reflection of a laser beam off of rough surfaces such as paper, terrain, and roadways produces a type of reflection known as diffuse reflection. Examples of diffuse reflectors include dry foliage, rock, camouflage, soil, matte paint, aluminum cans, and old ordnance. Diffuse targets reflect light and laser energy in a spheroid centered at the point of impact (see **Error! Reference source not found.**). A diffuse surface is one that distorts (or iffuses) the beam shape, normally resulting in a safe-to-view reflection from outside the target area. The radiation will scatter in many different directions depending on the angle of incidence. Diffuse reflecting objects reflect energy in all possible directions including toward the laser. Note that a hazardous diffuse reflection can only be produced by a Class 4 laser system.

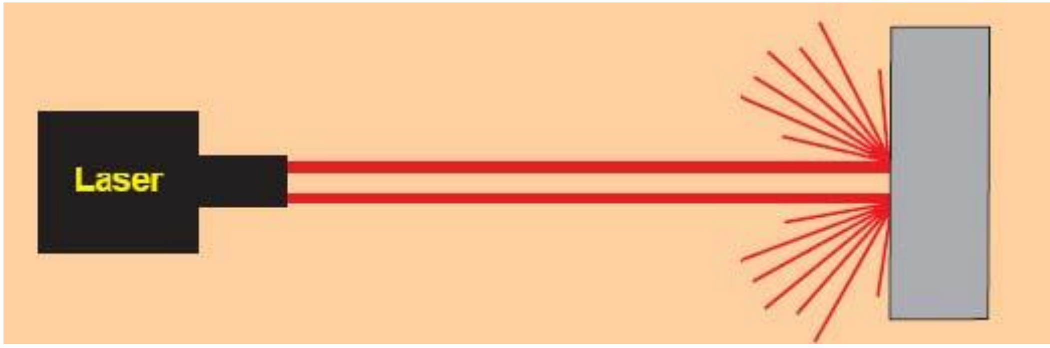


FIGURE 1. Diffuse reflection.

4.7. Hazards Associated with Range Laser Operations

4.7.1. Eye Damage. The widespread use of laser systems increases the probability of personnel exposure to levels of laser radiation above MPE levels, possibly resulting in injury. The principal hazard associated with exposure to laser radiation is damage to the eye including the retina, the cornea, and lens, depending on the laser wavelength. Laser systems can seriously injure the unprotected eyes of individuals within the hazard zone of the laser beam.

a. Intrabeam viewing of either the direct beam or a beam reflected from a surface may expose unprotected eyes to a potential injury (see FIGURE 2 and FIGURE 3).

b. Intrabeam viewing of either the direct beam or a beam reflected from a surface may expose unprotected eyes to a potential injury (see FIGURE 2 and FIGURE 3).

c. Specular reflections greatly affect the hazard potential of a laser system.

d. Direct intrabeam viewing of a specular reflection while using an optical aid such as binoculars or a scope could greatly increase the hazard potential of the laser because these devices magnify the beam intensity.

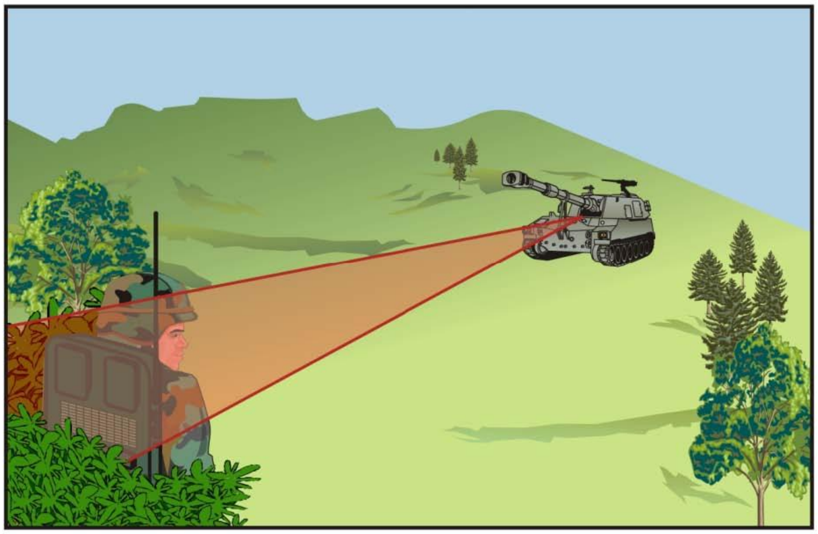


FIGURE 2. Direct intrabeam viewing.

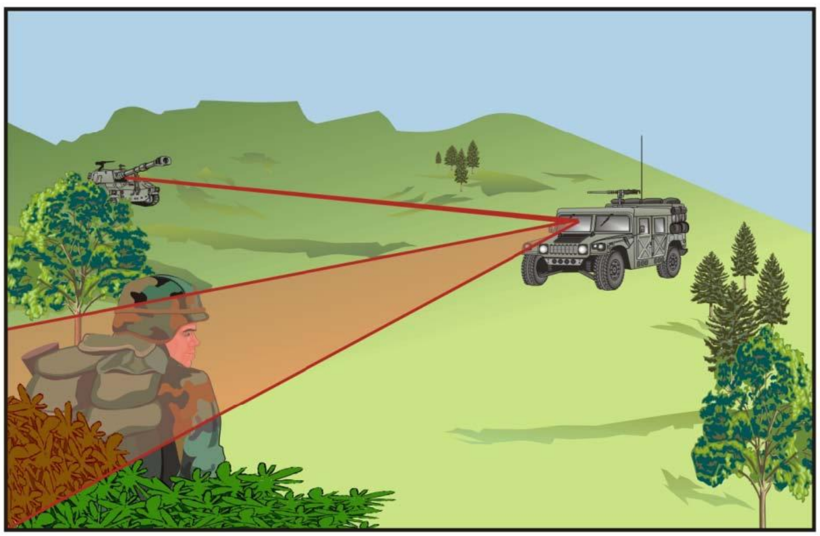


FIGURE 3. Reflected intrabeam viewing.

4.7.2. Skin Damage. Class 3B and Class 4 laser systems have the potential for producing skin damage.

4.7.3. Flash Blindness. A visual interference effect that persists after the source of illumination has been removed. Momentary flash blindness can occur from visible laser exposures below MPE levels.

4.7.4. Dazzle. To lose clear vision from looking at a bright light such as a visible wavelength laser.

4.7.5. Disability Glare. Obscuration of an object in a person's field of view due to a bright light source located near the same line-of-sight.

4.7.6. Startle. An involuntary movement or reaction resulting from a sudden or unexpected stimulus, such as a visible wavelength laser's light abruptly appearing in one's field of view. Personnel may be distracted or startled by unexpected sub-MPE visible laser exposure.

4.7.7. Fratricide. In laser operations involving laser guided munitions or other laser detectors, the detector may unintentionally acquire radiation sources within the field of detection other than the target if certain precautions are not taken. This will result in fratricide if the munitions are guided to the laser designator rather than the target. Designated areas and tactics should be planned to ensure the angle between the laser designator line of sight and laser detectors will not mistakenly aim the munitions at the laser source or scattered radiation from the laser platform.

5. LASER TARGET AND LASER TARGET AREA CONSIDERATIONS

5.1. Target Types. The targets employed in conjunction with a laser operation are selected based on the weapons employed and the testing and training requirements. Operators and crews should conduct laser operations only on approved targets and in approved target areas.

5.2. Target Material.Diffuse Reflectivity. In a laser operation involving a laser-guided weapon, the target is designated using a laser. A laser-guided weapon homes in on diffuse reflected laser energy to strike the target. This means that the target must reflect a certain amount of laser energy for the laser seeker to lock on. Certain materials reflect laser energy better than others. TABLE I presents the amount of diffuse reflectivity for various types of material. Optimum targets for this type of operation must produce a certain amount of diffuse reflectivity. For targets with higher reflectivity, the probability of a laser seeker picking up the laser spot is increased.

TABLE I. Amount of diffuse reflectivity.

Material	Amount (%) of Diffuse Reflectivity
Olive drab metal (dirty)	2 – 30%
Concrete	10 - 15%
Asphalt	10 – 25%
Unpolished aluminum	55%
Vegetation	30 – 70%
Brick	55 – 90%

5.2.2. Specular Reflection. Approved laser targets should not contain specular reflective (mirror-like) surfaces unless testing or training dictates. Specular reflection increases the hazard potential for eye and skin damage, flash blindness, etc. Examples of flat specular reflectors that may be targets include flat glass, flat window, still water, instrument gauge, vehicle rear view mirror, vision viewblock, etc.

5.2.2.1. Off of Flat Specular Surfaces. If a mirror-like surface is perpendicular to a laser beam, the beam will be reflected directly toward the laser position (see Figure 4).

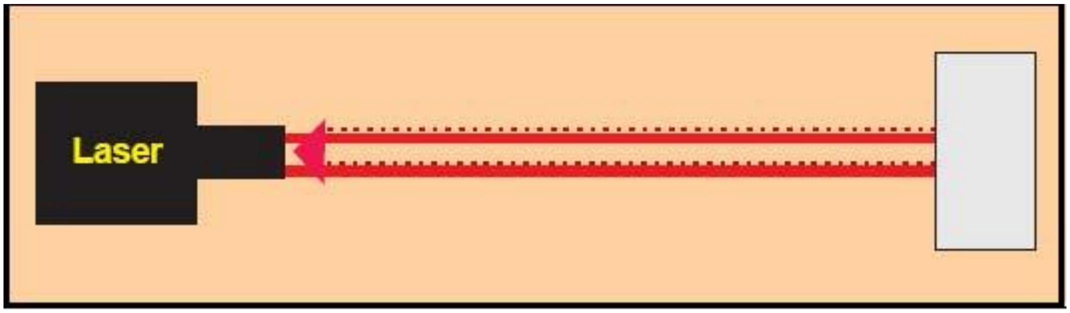


FIGURE 4. Specular (mirror-like) reflection from perpendicular surface.

If the mirror is at an angle to the laser beam, the beam reflects and remains concentrated upon leaving the surface and will be reflected at an angle equal to the angle of the incident beam (see FIGURE 5).

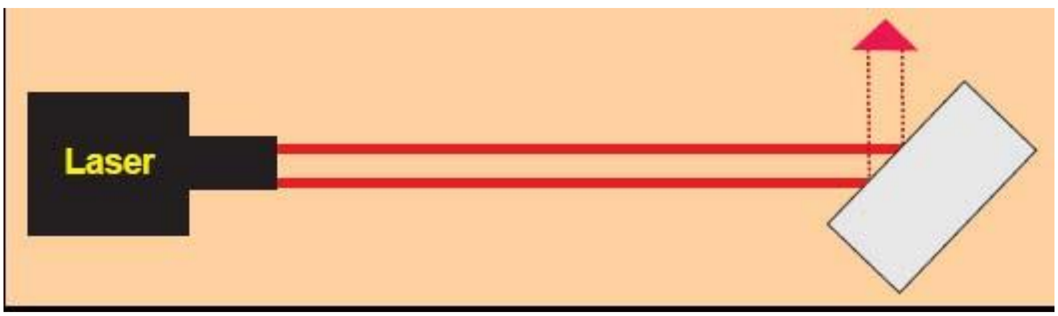


FIGURE 5. Specular (mirror-like) reflection from angular surface.

5.2.2.2. Reflection Off of Curved Specular Surface. If the surface is curved, the radiation will be reflected in the direction of the curve (see FIGURE 6).

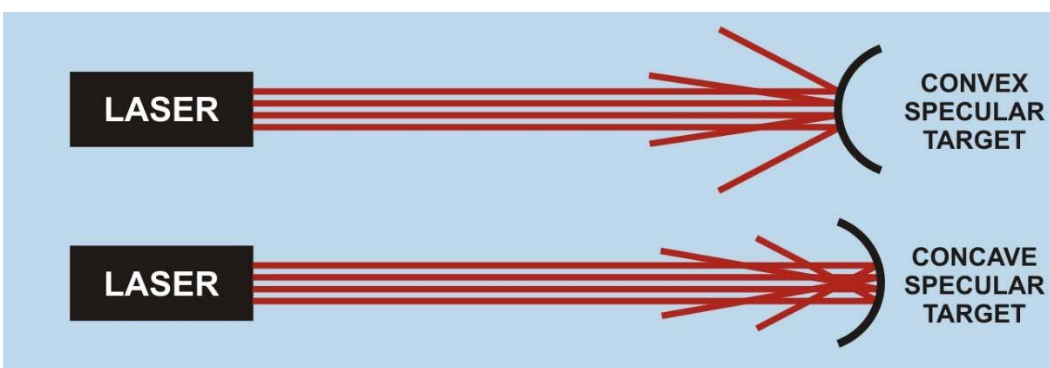


FIGURE 6. Reflection off curved specular surface.

Concave reflective surfaces can focus the reflected beam and cause the reflection to be more hazardous than the incident beam. Normally, these reflections are of little concern because it is improbable that the surface is perfectly concave (focuses the beam to a single point) or perfectly reflective. Examples of curved specular reflectors include glossy paint, optical sight, curved window, vehicle bumper, bottle, etc. Glossy foliage, raindrops, fog, and most other natural objects are not considered to be specular surfaces that would create ocular hazards. This is because their curved reflective surfaces cause the beam to spread and the reflected energy decreases quickly with distance.

5.3. Target Size. Target size impacts the effectiveness of laser operations.

5.3.1. Laser Spot Size. The laser spot size is the diameter of the beam at any given distance.

5.3.2. Laser Beam Divergence. Beam divergence is the spread of the laser beam over distance. Laser spot size is a function of beam divergence and the distance from the laser system to the target. If a designator has a beam spread or divergence of 0.25 milliradian, its spot would have a diameter of approximately 0.25 meters at a distance of 1,000 meters in front of the designator. At 5,000 meters, the beam would spread to 1.25 meters; at 10,000 meters, the beam would spread to 2.5 meters (see FIGURE 7).

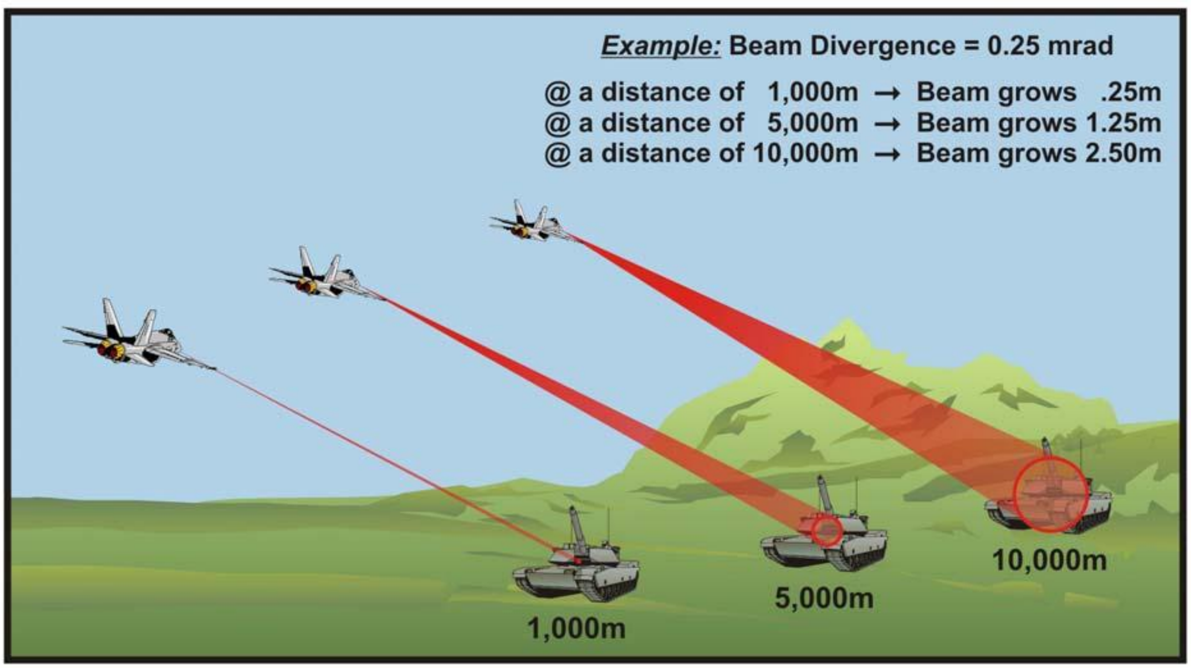


FIGURE 7. Beam divergence.

5.3.3. Overspill. Overspill occurs when some of the laser energy goes beyond the target and impacts an object or terrain behind the intended target. Overspill allows the energy to reflect off of background behind the target, potentially creating stronger reflected energy than from the target itself. For planning purposes, laser spot size should be determined and ideally equal to no more than half the target surface area. If not, the potential for overspill and subsequent misdirection of the weapon increases with the magnitude of the spot size in relationship to the target.

5.4. Target Placement. On laser training areas, targets are placed to accommodate the weapon system and training and test requirements. However, there are additional considerations for placement when employing lasers:

a. Targets should be oriented so the laser hazard can be contained within range boundaries/constraints. This can be accomplished by elevating the lasing platform, using a backstop, adjusting the distance from laser to target, etc.

b. Targets should be oriented so that there is an uninterrupted line of sight from the lasing position to the target.

c. Targets should be oriented so the diffused reflected energy can be detected. This includes adjusting their position laterally as well as vertically. From a ground laser position (low elevation), a vertical target is required to reflect laser energy and preclude significant overspill, which could redirect the weapon away from the target.

d. Targets should be staged/positioned so that specular reflections are eliminated.

5.5. Target Maintenance. Specular surfaces should be removed from all targets designated as laser targets prior to engagement. If it is not feasible to remove all specular surfaces from the target, these surfaces should be covered with a diffuse material prior to use as a target. Targets should be regularly inspected by Installation Laser Range Authority personnel to ensure they do not produce a specular reflection. Target maintenance includes the following:

5.5.1. Target Condition. Because targets are selected based on the weapon employed, they should be checked to ensure they can be safely used during a laser operation. Target condition should be checked on a regular basis by Installation Laser Range Authority personnel. Careful attention should be paid to the condition of the target. A specular hazard can present itself upon ordnance impacts or explosions which cause target materials to break apart. Munitions impacts can alter the target surface and may cause a reflection. Broken or bent specular surfaces can have an adequately large flat surface remaining to generate a specular reflection.

a. Specular reflectors should be covered, removed, or rendered diffuse by painting with a flat (non-specular reflecting) paint, sand-blasting, scuffing up, etc., so they do not produce a reflection.

b. Concave (bowl-shaped) surfaces with a large radius of curvature which could focus the reflected beam at longer distances outside the controlled area should be removed.

5.5.2. Target Area Condition. Target area condition should be reviewed periodically as determined necessary by the local range safety authority. The target area should be inspected following any exercise in which munitions could alter the impact area. Careful attention should be paid to the condition of the surrounding laser hazard area to ensure there are no reflectors. Underspill can occur when some of the laser energy impacts either terrain or an object short of the intended target.

This energy spillover is capable of providing scattered reflections off objects near the target. Terrain, unexploded ordnance, glossy painted surfaces, trash, and standing water can produce diffuse and specular reflectors within the target area. Snow is not a specular surface, but if thawed and refrozen, hazardous reflections can be found especially at low angles of incidence. Calm, smooth water and clean ice can also reflect laser beams, especially at low angles of incidence. FIGURE 8 illustrates the reflection that can take place when a laser beam strikes still water.

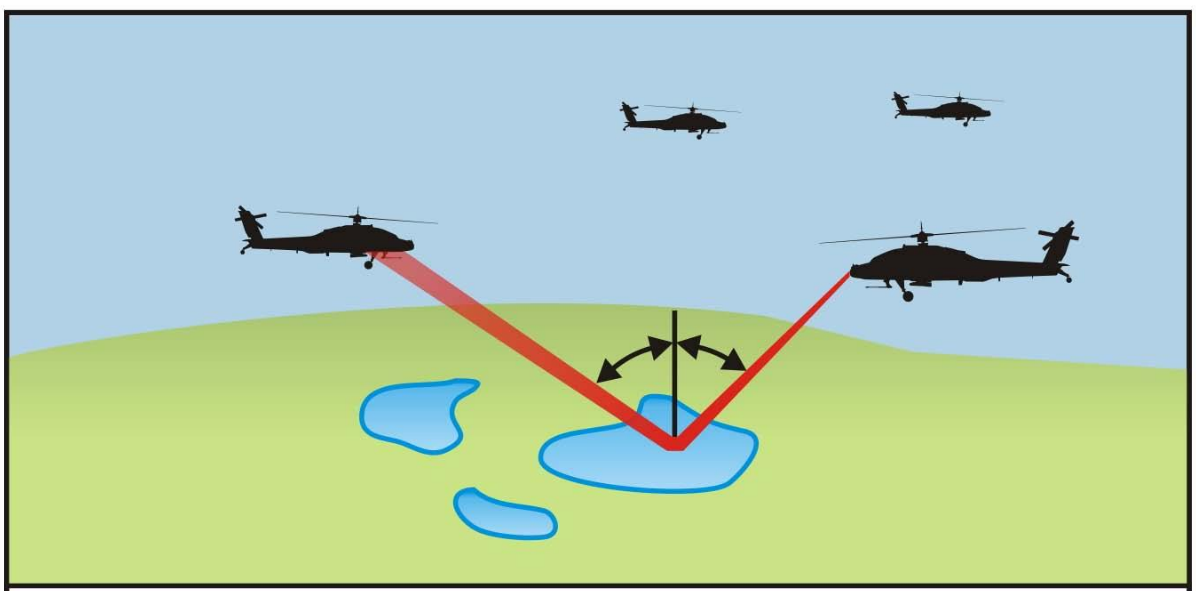


FIGURE 8. Example of airborne laser beam reflection.

a. All specular reflectors should be removed from the laser training area. If potential reflections have not been considered for the approved target area, ranges will be closed when, for example, water begins pooling on the ground.

b. Target location should be checked on a regular basis by Installation Laser Range Authority personnel to ensure the location has not changed due to munitions impact. A change in target location can affect the angle of the laser beam to the target, thereby affecting the danger zone for that laser system.

c. The position and orientation of any specular reflectors that cannot be removed or rendered diffuse should be noted, so they can be considered during the laser range certification. It may be possible to position the specular reflector away from the laser impact so that it will not be a hazard.

6. GENERAL RANGE LASER SAFETY

6.1. Fundamentals. The fundamental concept of range laser safety is to prevent direct and collateral injury or damage resulting from laser use. Personnel using or supervising the use of . The fundamental concept of range laser safety is to prevent direct and collateral injury or damage resulting from laser use. Personnel using or supervising the use of lasers should be thoroughly familiar with all aspects of laser operations and associated dangers. The following guidelines should be used in conjunction with the guidance provided in referenced publications when employing lasers.

a. Lasers should be treated as direct-fire weapons. Precautions associated with direct-fire weapons should be applied to all lasers operated on military ranges.

b. AR 385-10, DA PAM 385-63, MCO 5104.1, MCO 3570.1, OPNAVINST 5100.27, and AFI 13-212 outline general service range laser safety requirements. Prior to laser use, the Unit Laser Range Authority should brief personnel on use of lasers.

c. The use of unfiltered Class 2, 2M, 3R, 3B, 4, or DOD exempt lasers on test and training ranges should only be conducted at installations that have been certified for the safe use of lasers in accordance with service-specific requirements.

d. A survey of the proposed lasing and target area should be accomplished to determine laser elevation and azimuth limits within the laser footprint. Restrictions should be applied to prevent lasing above the horizon unless authorized.

6.2. Laser Systems

a. Laser systems should only be directed at approved targets and only from approved operating positions/areas or on designated headings and altitudes.

b. Laser systems should only be used on ranges approved for such use.

c. Stationary Continuously Operating Lasers. Uses of lasers such as the light detection and ranging (LiDAR), space probes, or laser warning lights operating continuously in airspace may require additional controls. These emissions should be coordinated with the FAA and Laser Clearinghouse (LCH) if the laser operates above the horizon and is not terminated into the ground (backstop).

d. When lasers are not in use, hazardous laser output should be prevented by removing batteries, or implementation of engineering controls such as output covers or rotating the laser into the stowed position, unless otherwise specifically authorized by the local SOP.

e. The laser exit port should be covered or laser otherwise stowed and turned off when not engaged in training. Non-laser operations such as viewing through common optics can be conducted in a non-laser controlled area with the laser exit port cover removed. This non-laser operation can be accomplished by instituting procedures that ensure power to the laser is turned off.

f. When laser systems have both training and combat operating modes, only the training mode will be employed on laser training/test ranges/areas. Installation SOPs should enforce this measure.

g. SOPs should be obtained for all laser systems employed on a range.

h. SOPs should be established for range laser operations (see Appendix A).

6.3. Unprotected Personnel. Unprotected personnel must not be exposed to laser radiation within the Nominal Ocular Hazard Distance (NOHD) of the laser system.

6.4. Protected Personnel. Personnel within the LSDZ should wear Laser Eye Protection (LEP) during laser operations. Eye wear must be approved for the wavelength and corresponding optical density of the laser system being used. Skin protection should be worn when appropriate.

6.5. Aided Viewing. Aided viewing involves the use of optical devices including binoculars, scopes, rangefinders, etc. The magnification of laser energy can significantly increase the probability of eye injury. The use of magnifying optical devices to observe the target during laser operation is permitted if specular surfaces have been removed from the target area, appropriate filters are used, or it is being viewed beyond the NOHD-M (Nominal Ocular Hazard Distance - Magnified). Optical devices not marked with the level of protection should be assumed to offer no protection unless verified Personnel should not deliberately view direct laser radiation with optical instruments within NOHD-M unless optical devices are considered “laser safe” for the type of laser being used.

6.6. Night Vision Devices (NVD). NVDs may be used to detect lasers. Night vision devices should not be used for LEP. These devices are not ‘cover-all’ goggles. Laser energy may enter the eye from offset angles where protection is not afforded. The damage threshold for NVDs may be as low as or lower than the damage threshold for the human eye. These devices can be bloomed (white out), damaged, or destroyed from exposure to laser radiation.

6.7. Laser Accident/Incident Reporting. Report all suspected laser accidents/incidents regardless of injury. in accordance with AR 385-10, DA PAM 385-24, DA PAM 385-40, TB MED 524, MCO 5104.1, NAVMEDCOMINST 6470.2, AFI 13-212, and AFOSH 48-139. Pertinent medical guidance for such emergencies is available from the Walter Reed Army Institute of Research Detachment at Fort Sam Houston, or through the Tri-Service Laser Injury

Hotline at 1-800-473-3549. The expeditious examination and treatment of laser eye injuries is critical in minimizing loss of visual acuity.

7. RANGE LASER OPERATIONS

7.1. Considerations for Laser Operations. General considerations and tenets apply to all types of laser operations whether they involve range finding, target marking (pointing), guidance, illumination, identification, or designation for guided munitions.

7.1.1. Line of Sight. An unrestricted line of sight must exist between the laser system and the target. Since lasers are line of sight, their energy will reflect objects in their path. If the laser beam reflects off of any object other than the target, the laser may not designate the target correctly. Obstructions such as trees, limbs, leaves, grass, hills, and buildings between the laser system and target may prevent a clear, unobstructed view. Seasonal considerations come into play as well since the terrain in summer months may have more vegetation than in winter months. Jungle operations and weather conditions (e.g., fog, low clouds) could preclude the use of laser systems when a clear line of sight cannot be obtained.

7.1.2. Atmospheric Attenuation.

7.1.2.1. Definition. Atmospheric conditions must be suitable for laser operations. As a laser beam passes through the atmosphere, the light interacts with suspended matter which absorbs and scatters a fraction of the beam. This atmospheric absorption can reduce the effectiveness of the beam on the target.

7.1.2.2. Factors Affecting Atmospheric Attenuation. The degree of atmospheric attenuation depends on the path length through and the optical density of the atmosphere. Environments that contain dust, smog, battlefield obscurants, and water vapor may absorb more light than a particle-free environment, thus attenuating the laser even more.

7.1.2.3. How Atmospheric Attenuation Affects Laser Delivery. Smoke, haze, cloud, precipitation, and fog conditions can cause a laser beam to diffuse more and thereby degrade delivery accuracy (see FIGURE 9). Positioning of the laser system is a key to reducing the obscurants that can degrade laser performance. Possible considerations include positioning lasers on high ground where smoke is likely to be less heavy along the line of sight and repositioning from an obscured to a non-obscured position.

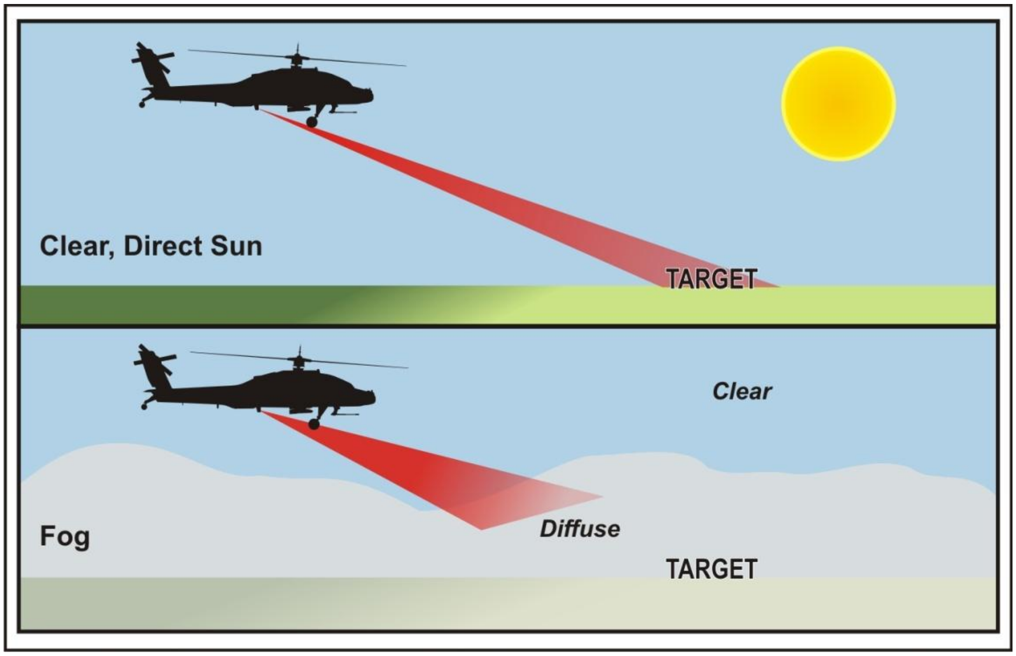


FIGURE 9. Atmospheric attenuation.

7.1.3. Laser Operations Planning. It is essential that both the unit and installation laser range authorities understand the details of proposed laser employment tactics as well as the technical aspects of all laser systems used on their ranges. Laser operation planning will vary with the type of laser operation. Laser marking, illuminating and range finding do not require as much detailed planning with regard to coordination with other operators as laser designation does. Laser designation is covered in paragraph 7.2.

As laser systems are often used to identify, illuminate, or range a target in support of munitions delivery, laser operators should ensure their position is located outside the weapons danger zone to be safe from weapons effects. If it is necessary to be within the perimeter, ensure the position is outside minimum safe distances for the weapon system per service range safety regulations.

7.2. Laser Target Designator/Seeker Operations. In a laser operation involving a laser target designator and a seeker, a laser designator is used to designate targets and a seeker is used to acquire the laser designated targets. The primary factors of consideration with regard to range laser safety include ensuring that:

a. Munitions are delivered on target and not directed toward the laser designator and

b. The laser designator position is outside of the LSDZ and the munitions danger zone.

Installation Laser Range Authority and unit range personnel should employ precautions to ensure the safety of personnel during a laser operation involving laser-guided munitions. Specific operational considerations for employing a laser target designator and a seeker are provided in paragraph 7.2.3.

7.2.1. Seeker. A seeker is a laser acquisition device. It detects laser designated targets so they can be attacked with ground, airborne, or naval weapons. In a laser operation involving a laser-guided weapon, the target is designated using a laser. A seeker homes in on diffuse reflected laser energy off the target. The target cue provided by a seeker may be required because of the difficulty in seeing camouflaged targets at long ranges and high aircraft speeds. Seekers must be set to identify the specific laser code (or Pulse Repetition Frequency (PRF)) used by the designator. There are two types of laser acquisition devices.

7.2.1.1. Laser Spot Tracker (LST). A laser spot tracker is used to aid visual acquisition of the target to be attacked by another weapon. This type of laser acquisition device is normally mounted on fixed-wing aircraft or helicopters. Laser codes can be selected by the LST operator to match the designator code.

7.2.1.2. Laser-Guided Weapon. A second type of acquisition device is a seeker and guidance kit mounted on laser-guided weapons which guide on coded laser energy. Laser codes, generally, cannot be changed on the munitions once the aircraft is airborne.

7.2.2. Laser Target Designator. Laser designators are used to illuminate targets to create a diffuse reflection for a seeker. Laser designators have selectable laser codes that must be the same as the laser guided weapon in order to achieve target lock-on.

7.2.3. Laser Designation Operations Planning. Laser guided munitions and other laser detectors may unintentionally acquire radiation sources within the field of detection other than the target if certain precautions are not taken. This can result in fratricide if the munitions are guided to the laser rather than the target. Designated areas and tactics should be planned to ensure the angle between the laser designator line of sight and laser detectors (e.g., laser-guided weapon, laser spot tracker) will not mistakenly identify the target and/or aim the munitions at the laser source or scattered radiation from the laser platform. The Installation Laser Range Authority should be familiar with the tactics and technical aspects of all laser systems used on their ranges.

7.2.3.1. Laser Code. Laser seekers look for laser designator energy on a specific PRF code. Designators and seekers must work together as a team on a specific code because seekers will not detect designators set on other codes. This allows for multiple targets to be identified and targeted by different systems/operators at the same time. To ensure the correct targets are prosecuted by the correct weapons, the PRF code of the laser target designator and seeker must be compatible.

7.2.3.2. Line of Sight. An unrestricted line of sight must exist between the designator and the target and between the target and the seeker (see FIGURE 10). For laser-guided weapons, line of sight must exist prior to launch or after launch. If the laser beam reflects off of any object other than the target, the laser may not designate the target correctly, causing the seeker not to identify the target correctly.

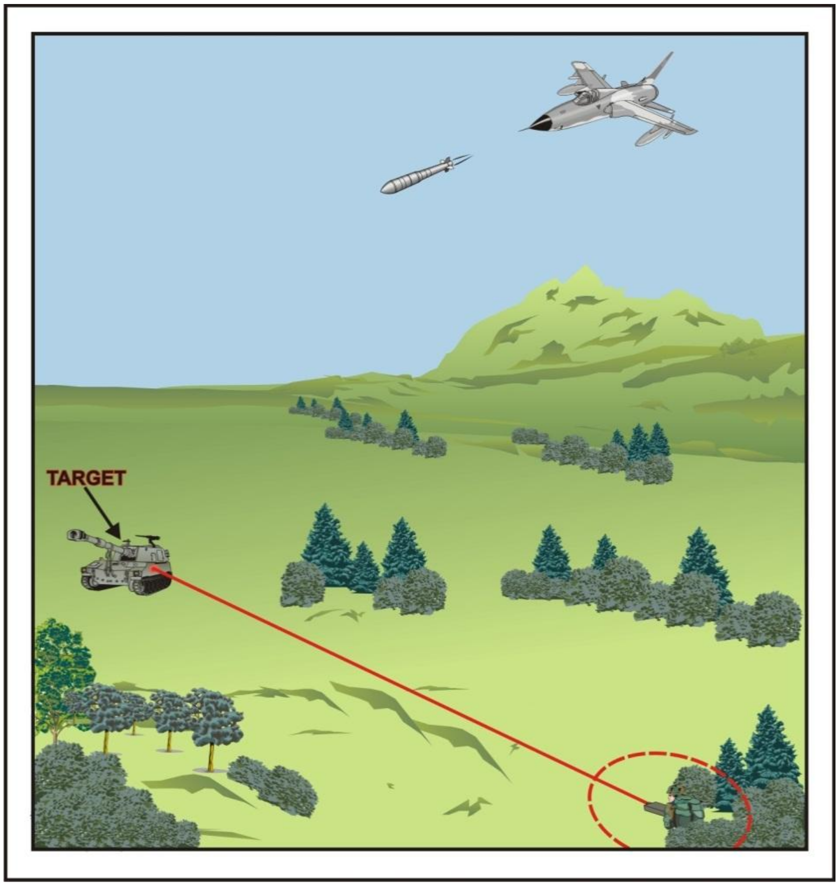


FIGURE 10. Line of sight.

7.2.3.3. Field of View. All seekers have a limited field of view and therefore must be oriented so that the target falls within that field of view so the seeker is able to acquire the laser energy reflecting from the target.

7.2.3.4. Atmospheric Attenuation. Particulates in the beam path may attenuate or reflect the laser beam, thereby preventing reflection or redirection from the target with sufficient energy for lock-on by laser spot trackers or laser-guided weapons. Laser energy reflected from such particles may also present a false target to the tracker or the munitions.

7.2.3.5. Wind Effects on Laser Designator Position. Wind direction is an important consideration for laser designator operator positioning for target areas where multiple weapon releases are anticipated. Laser designators should be positioned so that successive targets will not be obscured by smoke, dust, and debris from previous weapons impacts (i.e., the laser target designator should be set upwind of targets and the targets designated from the farthest downwind first to the most upwind last).

7.2.4. Laser Designation and Weapons Delivery Tactics. Laser-guided munitions delivery tactics may involve two separate lasing operations performed by the same aircraft, multiple aircraft, and from an aircraft and the surface (ship)/ground. The aircraft delivering the weapon may not be the same aircraft that is designating the target, and subsequently may impact the target from a different direction than the lasing platform.

7.2.4.1. Attack Heading. Terminal controllers should provide aircrews with an attack heading and, if providing the laser designation, the laser-to-target line. The direction of attack must allow the seeker to sense sufficient diffuse laser energy reflecting from the designated target, minimize false target indications, and preclude the laser-guided weapon from tracking the laser target designator (see FIGURE 11). These efforts should be coordinated by the exercise controller to ensure designators for other targets on the range are not using the same laser codes.

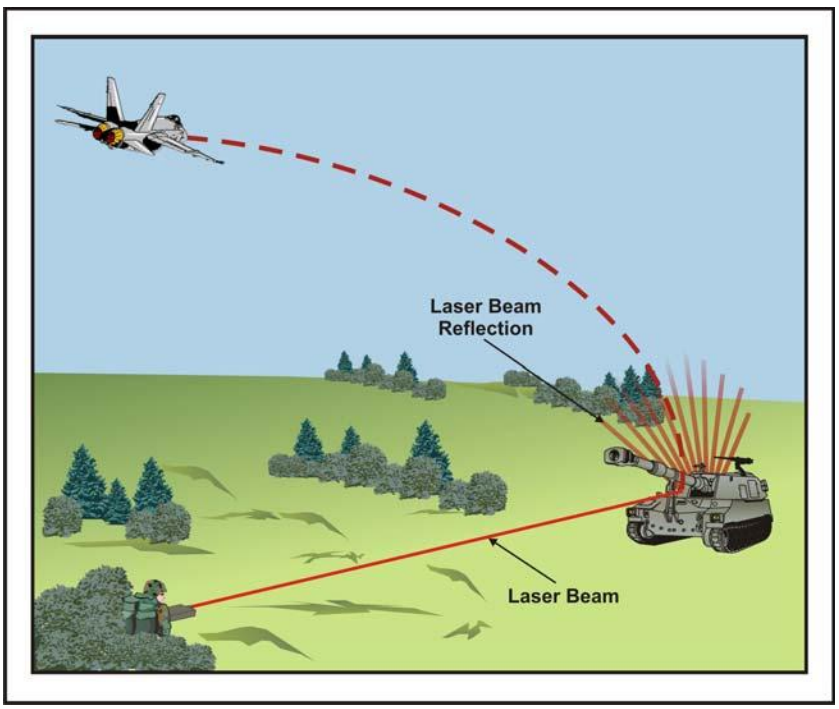


FIGURE 11. Attack heading.

7.2.4.2. Optimal Attack Zone. The optimal attack zone is inside a 120-degree cone whose apex is at the target and extends to 60 degrees on either side of the target-to-laser designator line and is outside an exclusion zone, both laterally and vertically (see FIGURE 12 and FIGURE 13). This leaves an ideal attack zone of 50 degrees on either side of the exclusion zone and at an elevation that will ensure adequate target acquisition and weapons function.

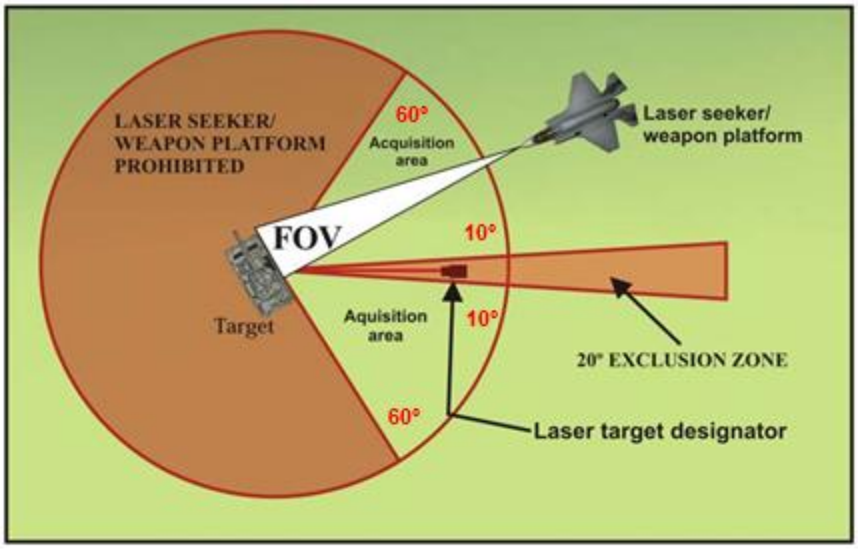


FIGURE 12. Optimal attack zone.

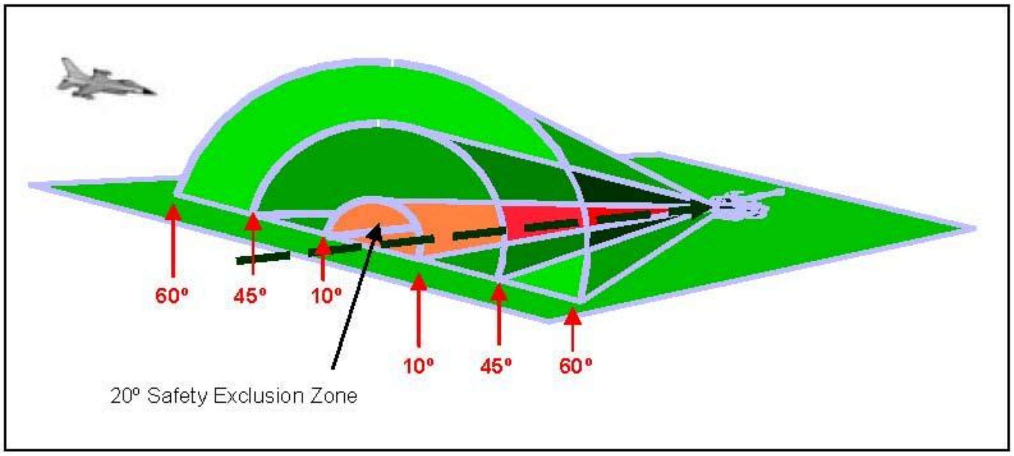


FIGURE 13. Optimal Attack Zone (vertical perspective).

7.2.4.2.1. Exclusion Zone. An exclusion zone is established as a sector whose apex is at the target and extends equidistant (10 degrees) either side of the target-to-laser designator line. This zone extends vertically to infinity and has a horizontal limit of 20 degrees. Weapons release may occur in any area within weapons limits outside the exclusion zone that does not put the designator in jeopardy. Because of the possibility of false target acquisitions caused by atmospheric scatter from the laser beam within short distances from the laser exit port, attack headings should avoid designator exclusion zones unless the tactical situation can safely dictate otherwise.

7.2.4.2.2. Angle of Attack. The degree of hazard to ground personnel operating the laser target designator varies with the attack angle of laser-guided munitions from the laser line of sight. The risk of acquiring the laser designator instead of the target in the optimal attack zone varies from high to low as the angle increases.

a. Risk to the laser designator operator may be reduced by increasing the delivery aircraft altitude and/or offset angle or the designator-to-target distance.

b. While increasing the delivery offset angle improves safety, it may degrade the seeker's ability to acquire the laser spot.

7.2.4.3. Timing of Lasing, Seeking, and Munitions Delivery Tactics. The timing for laser target detection must support seeker operations. Laser seekers have a limited amount of time to detect the laser spot, lock on, and guide to the target. Laser-guided weapons require a minimum amount of time to acquire and track a target. The laser designator must designate the target at the correct time and for the proper duration. The delivery system must release the weapon within the specific weapon's delivery envelope.

a. If laser designation time is too short, it may not provide the seeker time to lock on to the target, which further degrades laser-guided weapon accuracy, resulting in failure to achieve objectives and increased potential for fratricide.

b. Laser spot tracker-equipped aircraft may not have enough time to acquire the target under short designation time conditions. Required acquisition time is mission-specific, and should be pre-briefed and coordinated by operators. Communications among aircrew and ground participants are crucial.

7.2.4.4. Backup Method for Target Acquisition. During training, aircrews should not use a laser spot tracker as the sole source for target verification since the seeker may lock-on to atmospheric backscatter or the laser target designator.

At a minimum, the laser spot cue provided in the cockpit must be evaluated and compared to the expected target location. Aircrews should verify they are attacking the target through additional means such as visual description, terrain features, or non-laser target marks.

7.2.5. Seeker Lock-on Errors. The seeker must correctly lock on to the laser spot so the target can be accurately engaged. This applies to aerial, ground, and surface-launched projectiles. Laser seekers may occasionally lock on to other reflected energy instead of the target. Even in optimum conditions the seeker may incorrectly lock onto the laser target designator or the atmospheric scatter present along the laser beam. In this case, a seeker is most likely to detect stray energy only in the immediate vicinity of the designator. Errors include:

7.2.5.1. Seeker Locks On to Laser Target Designator. This could happen because the designator, rather than the target, is the only return in the seeker field of view. The following precautions should be taken to prevent seeker lock-on errors:

7.2.5.1.1. Coordination of Laser Codes. Ensure the laser target designator and the laser-guided weapon are on the same laser code.

7.2.5.1.2. Seeker Field of View. Whenever possible, planned attacks should avoid placing the designator in the field of view of the seeker. The seeker field of view must cover the target but not the area where scatter might be detected by the seeker.

7.2.5.1.3. Aircraft Headings. Aircraft attack headings should be close to the laser designator-target line, but outside the 20-degree exclusion zone (10 degrees on either side of this line). Approach paths should be designated and briefed to both the designating and forward air controller personnel and the aircrews prior to conducting the mission. Aircraft approach paths should be planned to preclude crossing laser designator beams with the laser seeker. The laser seeker should intersect the designator beam well forward of the laser firing point, angling toward the target.

7.2.5.1.4. Positive Knowledge of Designator and Target. The pilot of the attacking aircraft should have positive knowledge of the location of the designator and the target area before releasing munitions. Munitions should not be launched or released on a heading toward the laser designator.

7.2.5.1.5. Target Placement. Targets should be placed to provide enough offset to accommodate the laser operator position so the aerial-, ground-, or naval-delivered munitions does not follow the laser to the operator rather than the target (see FIGURE 14).

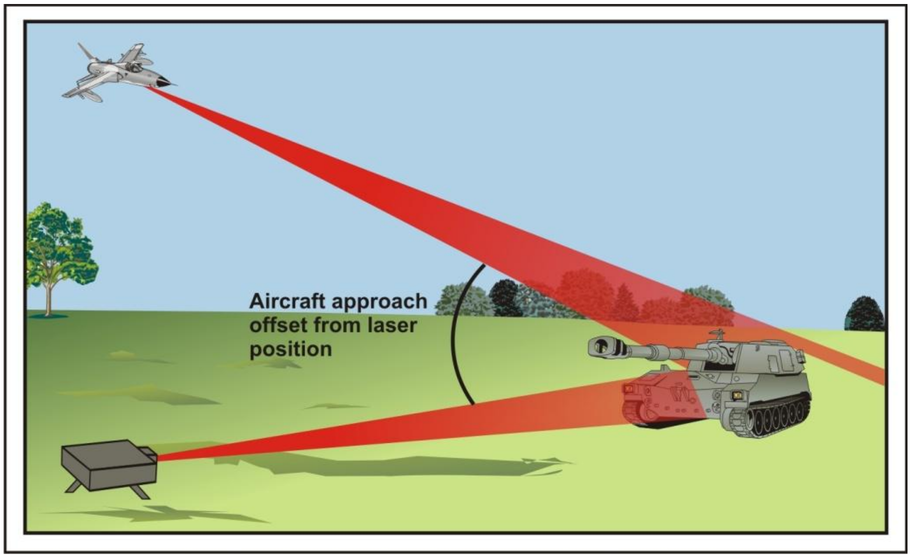


FIGURE 14. Target placement to provide offset.

7.2.5.1.6. Screening Designator Position. If possible, ground designator operators should screen the sides of the designator position from the seeker field of view (out to several meters in front) using vegetation, tarps, and other related materials. **WARNING:** This does not guarantee that the laser seeker will not lock onto the laser designator.

7.2.5.2. Seeker Locks On to Backscatter. Backscatter is of sufficient intensity in a portion of the laser beam to cause the seeker to lock on. Backscatter refers to a portion of the laser energy that is scattered back in the direction of the seeker by an obscurant such as dust, smoke or clouds. Since backscatter energy competes with the diffuse reflected energy from the target, a seeker may attempt to lock onto the obscurant rather than the target (see FIGURE 15).

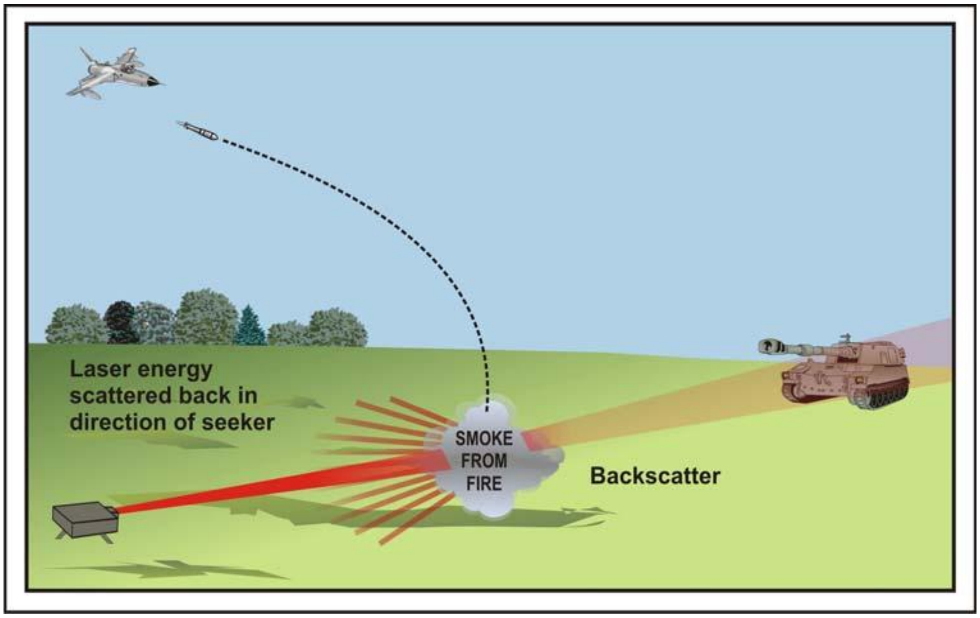


FIGURE 15. Backscatter.

7.2.5.3. Seeker Locks On to Spillover. If spillover energy (overspill or underspill) is of sufficient intensity to cause the seeker to lock on, a potential for fratricide or collateral damage may exist. Spillover reflection occurs when the laser spot is larger than the intended target, or when there is unsteady tracking of the target from the designator. Laser spot size depends on the laser system's beam divergence, the relative elevation of the designator compared to the target, distance of the designator to the target, and backstop/terrain around the target. This laser spillover is capable of providing scattered reflections off objects around the target (see FIGURE 16). Laser designator operators should generally aim at the center of mass of the portion of the target that produces the best reflectivity or in such a way as to avoid overspill and accomplish the intent of the weapon strike. Generally, a steeper angle to the target will results in a smaller laser spot. Additionally, for airborne lasing, as the lasing aircraft gets closer to the target, the laser footprint will lessen reducing the spillover.

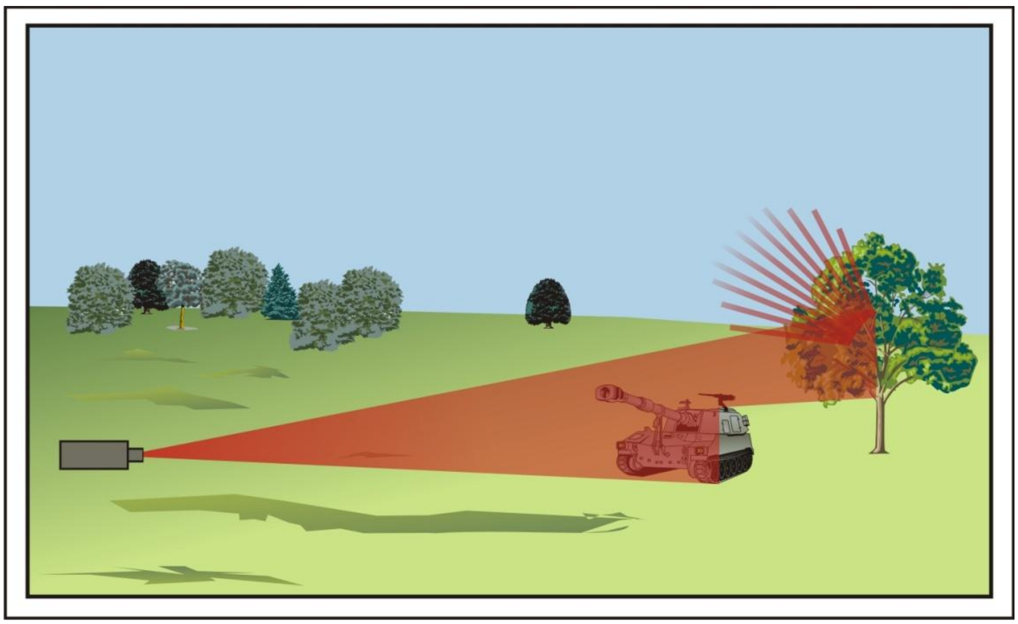


FIGURE 16. Spillover

7.2.5.4. Seeker Fails to Lock On to Anything. This could happen due to a variety of factors:

a. The laser designator and seeker are not set to the same code.

b. Poor aiming of designator.

c. Aircraft seeker position is such that the laser target designator, laser beam, and target are not in the seeker field of view.

7.2.6. Aircraft-mounted Laser Designators. Laser-guided weapons can erroneously lock onto the scattered radiation from 'buddy lase' or wingman aircraft laser designators. Caution will be taken when using a target-designating laser in conjunction with ordnance delivery aircraft. The potential exists for the on-board laser seeker to lock on to the designator or its radiated energy (that is, beam or reflected beam) instead of the target.

7.2.7. Aircraft-released Laser Guided Missiles. Two methods of laser designation can be used with aircraft-released laser guided missiles: Lock-On-Before Launch (LOBL) and Lock-on-After Launch (LOAL). In LOBL, the weapon system acquires the target designation (laser spot) prior to release from the aircraft. In LOAL, the weapon system does not acquire the target designation until after it is released. Even if LOBL is planned, the aircrew should be prepared to employ the weapon in a LOAL mode in case a laser spot is not received before the clearance to launch has been given.

7.2.7.1. Lock-On-Before-Launch (LOBL). In the LOBL mode, the laser-guided weapon line of sight can be displayed in most launch aircraft.

a. If the line of sight cue is well above the horizon, then the missile is probably locked onto an erroneous spot such as the designator aircraft or atmospheric scatter instead of the desired target spot, and the mission should be aborted.

b. If the missile properly locks onto the target in an LOBL mode, the only risk to the designator would be a midair collision potential if the designator aircraft is operating below the missile trajectory apex. In an LOBL mode, the wingman aircraft altitude should remain substantially above the nominal laser-guided weapon apex altitude, keeping in mind that missiles can climb to altitudes well in excess of their nominal apex values especially if they are tracking a laser designator.

7.2.7.2. Lock-On-After-Launch (LOAL). In the LOAL mode, no laser-guided weapon line of sight cueing is provided prior to launch of the weapon.

a. When employed in an LOAL mode, the laser guided missile will execute a climbing profile searching for a laser coded energy signal prior to tipping over and scanning its field of view along the ground.

b. The risk to the wingman designator is highest during the initial starting phase of the laser-guided weapon profile. If it locks onto the designating aircraft, there is a high probability that it will track and kill the laser designator. The dimensions of the instantaneous fields of view of the laser-guided weapons are not absolute, and some are capable of detecting forward or back scattered radiation at many degrees off boresight.

8. CONTROL MEASURES

The purpose of range laser safety is to prevent injury to both military personnel and the general public from laser radiation and to ensure that only intended target areas are engaged by the laser. The goal is to accomplish this objective without placing unnecessary restrictions on laser system use. Therefore, control measures should be implemented to control these risks. Different control measures are required depending on the class of the laser, the operational environment, and the training of personnel. Most control measures fall into the category of common sense practices aimed at limiting the laser exposure, thus reducing the risk. Generally, controls are required for all laser systems. There are three categories of control measures in order of preference: Engineering, Administrative, and Personal Protective Equipment (PPE). These measures can be used to eliminate hazards or reduce the degree of risk.

8.1. Engineering Controls. Engineering controls reduce risks by design, material selection, or substitution. Examples of engineering controls include:

8.1.1. Controls Built Into Laser System. Control measures built into the design of the laser system are considered engineering controls. These include switches, interrupt, interlocks, protective housing or guards, dual safety, training filter, key control, beam stop, etc. For example, a training filter can attenuate the radiation level of a laser beam below the MPE limit. Laser systems should not be altered to remove or modify these controls. (See additional information in MIL–STD–1425A for military lasers and 21 CFR 1040 for commercial lasers).

8.1.2. Backstop. The most important aspect to range laser safety is the assurance that the laser hazard is terminated within a controlled area. A man-made or natural backstop on the range, such as a hill or mountain, can be used to terminate the laser beam.

8.1.3. Range Maintenance. A range maintenance program is considered an engineering control.

8.1.3.1. Vegetation Control. A maintenance program for vegetation control should be established to ensure a clear line of sight can be maintained between the laser firing point and the target. Trees, shrubs, etc., are trimmed or cut down to maintain line of sight as environmental policy allows.

8.1.3.2. Removal of Specular Reflection. A maintenance program for the removal of specular reflectors should be established. This can be accomplished via range area cleanup, draining ponds, etc.

8.1.4. Target/Lasing Position Placement. Target and lasing position placement can reduce risk. Examples of engineering controls for target/lasing position placement include:

a. Target and lasing positions should be oriented to ensure a clear line of sight between them. A platform erected to lase a target that establishes a clear line of sight between the laser firing point and the target is an engineering control. A platform can be used to increase the angle between the laser and the target to use the ground or water as a backstop to the laser beam. The platform can be erected from construction material or simply by building a dirt mound.

b. Target and lasing positions should be oriented to ensure adequate diffuse reflectivity.

c. Targets should be oriented so that specular reflectors are positioned away from the laser source. If specular reflectors cannot be positioned away from the laser source, their effects should be mitigated as much as possible. For example, solar panels and windows around a target can be scratched, or etched.

d. Targets should be placed to provide enough offset to accommodate the laser operator position so an aircraft- or ground-delivered munitions does not follow the laser to the operator rather than the target.

8.2. Administrative Controls. Administrative controls reduce risks through specific documented policies, procedures and actions. Administrative controls include those controls that can be established and managed by range personnel as well as the documentation and training that is required of participating personnel.

8.2.1. SOPs. Formal written descriptions of the safety and administrative procedures to be followed in performing a specific task are the most important administrative control.

8.2.2. Training. Laser safety training and education for personnel (institutional, installation, and unit laser range authorities) to recognize hazards and take appropriate precautionary actions are control measures. Training requirements are dictated by service policy.

8.2.3. Range Personnel. Designation of installation and unit laser range authorities in writing is an administrative control to ensure range operations run safely and smoothly.

8.2.4. Warning Signs and Notices. Warning signs should be posted around the installation training complex to warn and prohibit entry by unauthorized persons, and to alert authorized personnel entering a hazard area where lasers are employed (see FIGURE 17). For surface and underwater ranges, buoys and water markers used to indicate the location of training areas should have signs, or notices, posted on them.

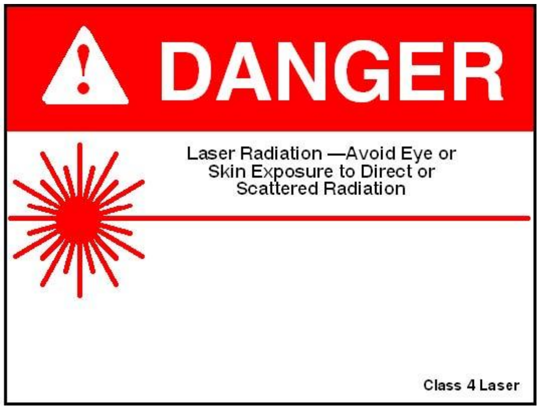


FIGURE 17. Warning sign.

Similar to the land signs, these signs should warn and prohibit entry by unauthorized persons, and to alert authorized personnel entering a hazard zone where lasers are employed. Warning signs should be placed to ensure they are visible to individuals attempting to enter training complex areas at any point around its perimeter. Local SOP should provide for the placement and inspection of laser warning signs at the boundaries of the controlled areas and the access points in a way that will ensure that a person cannot enter the range without seeing at least one sign within a legible distance.

8.2.5. Access Control. To limit exposure to a laser hazard, access to a laser training area (LTA) should be controlled. Access controls should prevent unprotected personnel from entering the LSDZ during laser operations. This objective can be met by determining where the laser hazard is expected to be and using the same control measures that are in place for live weapons fire including road blocks, gates, Notice to Mariners (NOMAR), Notice to Airmen (NOTAM), cameras where the range is unmanned, etc.

8.2.6. Coordination of Special Use Airspace (SUA). Any activity considered hazardous to nonparticipating aircraft or requiring SUA to segregate it from other users of the National Airspace System, or in airspace of host countries, should not be conducted until appropriate SUA has been designated and activated for that purpose. SUA is required to be designated and activated prior to conducting any activity over 45m above ground level that would be hazardous to aircraft. Types of SUA that may be established include, but are not limited to:

8.2.6.1. Restricted Areas. Airspace identified by an area on the surface of the earth within which the flight of aircraft, while not wholly prohibited, is subject to restrictions. Restricted areas should be designated when determined necessary to confine or segregate activities considered to be hazardous to nonparticipating aircraft (see FIGURE 18).

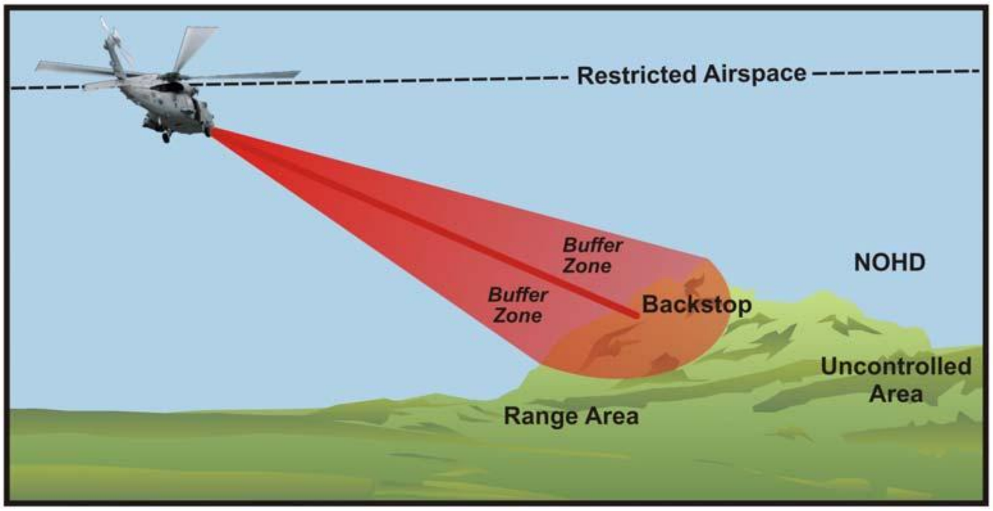


FIGURE 18. Restricted Air Space.

8.2.6.2. Warning Areas. Airspace of defined dimensions that contains activity that may be hazardous to nonparticipating aircraft. The purpose of such warning areas is to warn nonparticipating pilots of the potential danger. A warning area may be located over domestic or international waters or both.

8.2.6.3. Military Operations Area (MOA). Airspace of defined vertical and lateral limits established for the purpose of containing certain military training activities that include, but are not limited to, air combat tactics, air intercepts, acrobatics, formation flying, and low-altitude tactics in airspace as free as possible from nonparticipating aircraft.

8.2.6.4. Controlled Firing Area (CFA). A CFA is established to contain activities that, if not conducted in a controlled environment, would be hazardous to nonparticipating aircraft. The distinguishing feature of a CFA, as compared to other SUA, is that its activities are suspended immediately when spotter aircraft, radar, or ground lookout positions indicate an aircraft might be approaching the area.

8.2.7. Coordination of Navigable Waterways. Water traffic requirements that apply to lasing over navigable waters, to include intracoastal waterways, can only be waived by U.S. Army Corps of Engineers (USACE). Installation commanders should notify the USACE division or district commanders and the U.S. Coast Guard District Office of the waterway involved, operations to be conducted, and sector of waterway needed for closure.

8.3. <u>Personal Protective Equipment (PPE).</u> PPE is considered a control measure because it protects personnel from the hazardous effects (eye and skin hazards) of lasers. PPE should be used when engineering and administrative controls do not reduce the hazard to acceptable levels. PPE include goggles and spectacles to protect the eyes and clothing and gloves to protect the skin.

a. On some ranges, personnel and moving targets may be required to be on the range during laser operations for instrumentation operations, munitions impact spotting, and other required activities. The type of laser protective devices required, if any, should then be determined for each occupied location.

b. Personnel within the LSDZ should wear LEP and protective clothing, if applicable, during laser operations. LEP must be selected for the appropriate optical density and wavelength of the laser system being used. LEP provides a measure of protection for a particular wavelength associated with a laser. A laser filter designed to protect against one wavelength may not provide protection against lasers operating at different wavelengths. If more than one type of laser is used, LEP must provide adequate protection for all wavelengths involved; the highest optical density required for all systems of the same wavelength should be used. All LEPs should have protection parameters permanently labeled for each set.

c. The wavelength, optical density, and LEP requirements for currently fielded laser systems may be obtained from the Installation/Institutional Laser Range Authority.

9. DANGER ZONES

9.1. Types of Danger Zones. A danger zone is an area determined by analysis of weapons characteristics and historical patterns to present risk to personnel and/or equipment within a designated three-dimensional (3D) perimeter.

9.1.1. Laser Surface Danger Zone (LSDZ). An LSDZ is the designated region or ground area where laser radiation levels may exceed maximum permissible exposure levels, thereby requiring control during laser operation. Unauthorized personnel are not permitted, and laser eye protection is required for personnel who may potentially engage in intrabeam viewing within this area.

9.1.2. Surface Danger Zone (SDZ). The ground and airspace designated within the training complex (to include associated safety areas) for vertical and lateral containment of projectiles, fragments, debris, and components resulting from the firing, launching, or detonation of weapon systems to include explosives and demolitions.

9.1.3. Weapon Danger Zone (WDZ). A WDZ encompasses the ground and airspace for lateral and vertical containment of projectiles, fragments, debris, and components resulting from the firing, launching, and detonation of aviation-delivered ordnance. It reflects the minimum land and air requirement, to include terrain mitigation, needed to safely employ a given weapon. This zone accounts for inaccuracy, failures, ricochets, and broaching/purposing of a specific weapon/munitions type delivered by a specific aircraft type. The WDZ 'footprint' is based on the specific weapon characteristics, type of delivery being executed, the type of platform (aircraft) delivering the ordnance, and level of containment acceptable to the installation commander.

9.2. Laser Footprint. A laser footprint is the projection of the laser beam and buffer zone on the ground or target area. A laser footprint serves as the foundation for the worst-case LSDZ calculations.

a. An LSDZ only extends as far as the NOHD. If targets are placed beyond the NOHD at a distance where the laser is no longer hazardous, the laser footprint would indicate this area to show target placement. The laser footprint may be part of the LSDZ if the laser footprint lies within the NOHD of the laser.

b. If a visible laser extends beyond the NOHD, the laser footprint accounts for this area.

9.3. Factors Affecting an LSDZ. An LSDZ is generated based on the hazard potential of the laser system which includes:

9.3.1. Maximum Permissible Exposure (MPE) Limit. MPE is the level of laser radiation to which a person may be exposed without hazardous effect or adverse biological changes in the eye or skin. Laser beams and the associated buffer zone should be terminated by backstops, if possible, or the radiation level attenuated below the MPE limit within the controlled range or in controlled airspace. If energy below the MPE is allowed to leave the range, the possibility of optically aided viewing by unprotected individuals should be considered in the laser range certification.

9.3.2. Laser Classification. Laser systems are classified according to their relative hazards from Class 1 (least hazardous) to Class 4 (most hazardous).

9.3.2.1. Class 1. Class 1 laser systems pose no hazard under any normal viewing conditions.

9.3.2.2. Class 1M. Class 1M laser systems are only hazardous when viewed by magnifying optics.

9.3.2.3. Class 2. Class 2 laser systems are low power visible wavelength lasers which are not considered hazardous for momentary (0.25 s) unintentional exposure because the normal observer will blink or look away before eye damage can occur.

9.3.2.4. Class 2M. Class 2M laser systems are low-power visible wavelength lasers similar to Class 2, but are hazardous when viewed with magnifying optics even for a momentary exposure.

9.3.2.5. Class 3. Class 3 laser systems are medium power lasers. They are hazardous to personnel who are in the beam path and viewing the source directly or by specular reflection. They usually do not present a diffuse reflection or skin hazard.

9.3.2.5.1. Class 3R. Class 3R laser systems are considered safe if handled carefully, with restricted intrabeam viewing. With a class 3R laser, the MPE can be exceeded, but with a low risk of injury.

9.3.2.5.2. Class 3B. Class 3B laser systems are powerful and can cause serious eye injury for exposures of very short duration. They can be hazardous for long distances downrange from the laser system.

9.3.2.6. Class 4. Class 4 laser systems are very powerful and the most dangerous laser systems. They can be hazardous for extremely long distances downrange from the laser system. They can also present a potential diffuse reflection viewing, skin, and fire hazard.

9.3.3. Nominal Ocular Hazard Distance (NOHD).

9.3.3.1. Definition. NOHD is the distance from an operating laser to the point where the laser is no longer an eye hazard, i.e., the irradiance or radiant exposure during operation is not expected to exceed the appropriate MPE. Beyond the NOHD the laser is safe for intrabeam viewing. The NOHD for laser systems may be obtained from the Installation/Institutional Laser Range Authority.

9.3.3.2. NOHD-M. Viewing a laser beam (intrabeam viewing) or reflections through optical instruments such as binoculars or a scope can significantly increase the degree of hazard for the eyes and thereby increase the NOHD, which now becomes an NOHD-M. The NOHD-M for optically aided viewing of laser systems may be obtained from the Installation/Institutional Laser Range Authority.

9.3.3.3. Laser Platform Stability. The stability of the laser platform determines the pointing accuracy of the laser system which, in turn, determines the size of the buffer angle (see paragraph 9.4.2). The more stable the platform, the greater the pointing accuracy; the less stable the platform (i.e., hand-held, vehicle mounted, tripod mounted, fixed or rotary wing mounted), the poorer the pointing accuracy.

9.4. LSDZ. The LSDZ consists of a conical volume extending from the laser system to a backstop, terrain (ground or water), or through NOHD (see FIGURE 19). An LSDZ will always exist if laser-to-target distance is less than the NOHD. An LSDZ consists of the following components:

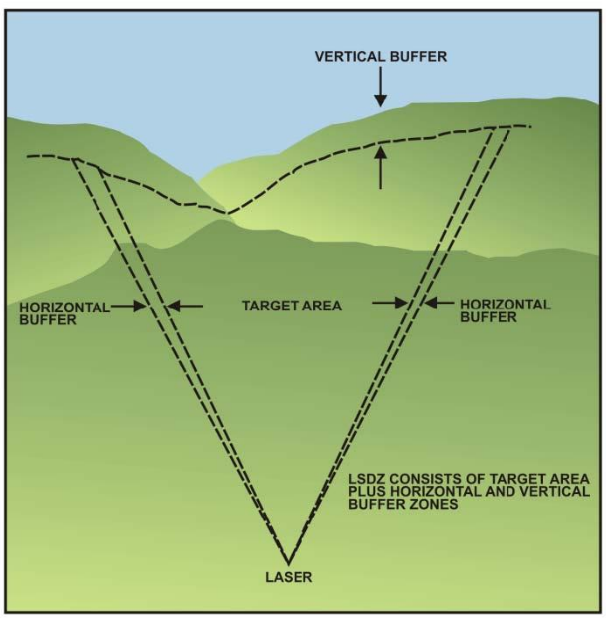


FIGURE 19. Laser surface danger zone (LSDZ).

9.4.1. NOHD. On the ground, the LSDZ normally extends out to the NOHD or beam backstop (e.g., hill, mountain) and to the edges of the laser beam buffer zone.

9.4.1.1. Use of Optics. The use of optics affects the size of the LSDZ. When viewing the laser beam with optics (telescope, binoculars), the hazardous range can be greatly increased. For example, a 10-km NOHD would be increased to 80 km (NOHD-M) for an individual looking back at the laser from within the beam with 13 power optics (see FIGURE 20). Such large amounts of real estate are difficult to control. The solution is to use a natural backstop behind the target. If no natural backstop is available, the possibility of optically aided viewing by unprotected individuals should be considered in the laser range certification.

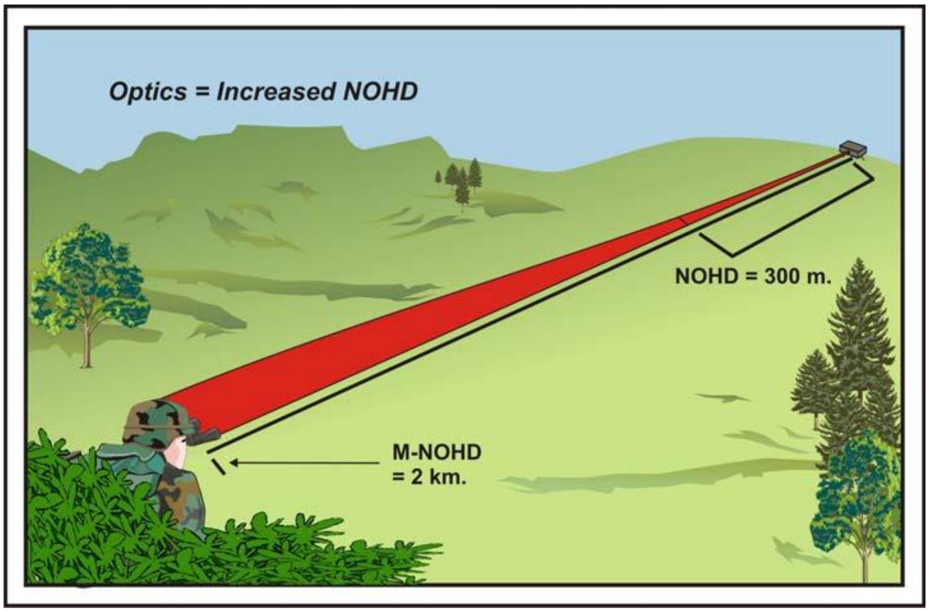


FIGURE 20. NOHD and NOHD-M.

9.4.1.2. Use of Backstop. The use of a natural or man-made backstop affects the size of the LSDZ (see FIGURE 21 and FIGURE 22). Laser beams and the associated buffer angles can be terminated by backstops.

a. When the distance to the backstop is less than the NOHD, the backstop determines the absolute hazard distance and the NOHD is of academic value (see FIGURE 21 , Beam 1).

b. When an adequate backstop is present, laser energy is prevented from leaving the controlled area or training area.

c. In cases where there is no backstop, the LSDZ extends downrange to the NOHD in the airspace and to the skyline on the ground as seen from the laser position (see FIGURE 21, Beam 2). Laser operations at targets on the horizon are permitted as long as airspace is controlled to the NOHD. Laser operations at targets above the horizon are permitted as long as the NOHD of the laser does not penetrate the upper atmosphere; if this occurs, laser operations should be approved by the Laser Clearinghouse.

d. NOHD should be contained within the range boundary or military controlled area.

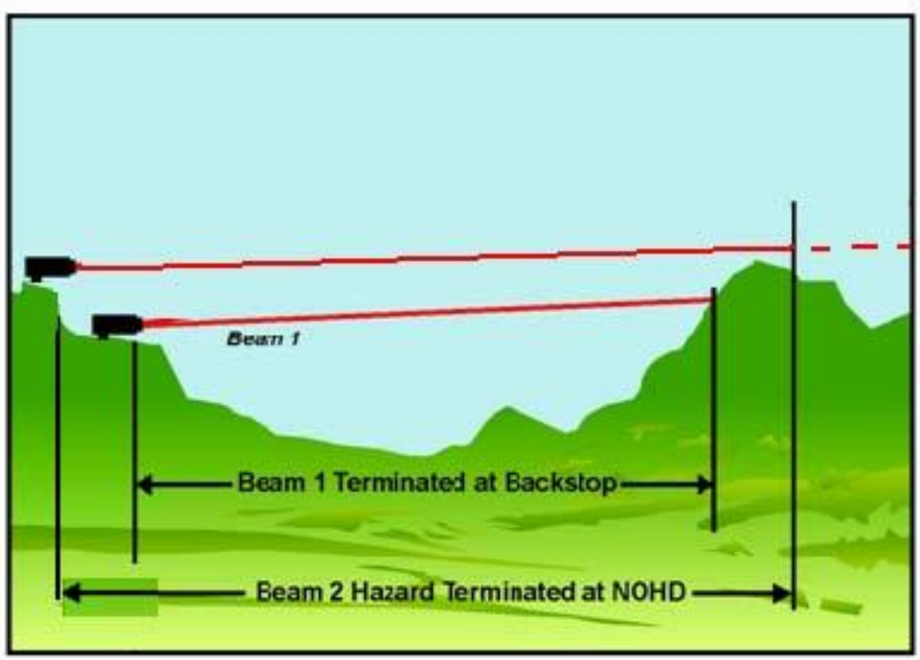


FIGURE 21. Effects of backstops.

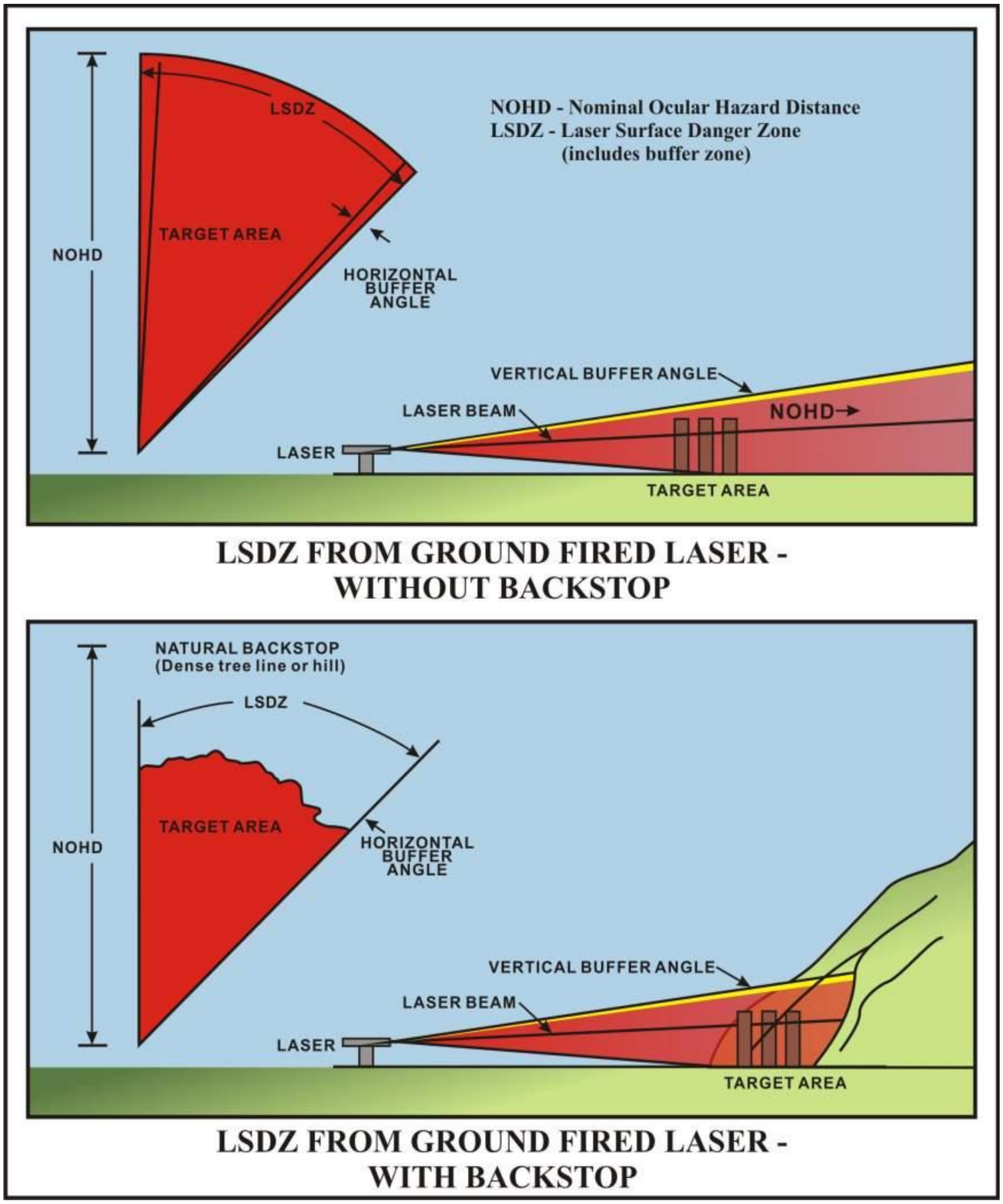


FIGURE 22. LSDZ without and with backstop.

9.4.2. Buffer Angle.

9.4.2.1. Factors Affecting Buffer Angle. The buffer angle depends on the aiming accuracy and platform stability of the laser system. Therefore buffer angles are dependent upon the laser system mounting; that is, a hand-held laser system has a larger buffer zone than a tripod mounted system. The buffer angle increases as the stability of the system decreases. Some laser systems are designed to be used from a variety of mounting configurations.

9.4.2.2. Determining Buffer Angle. The buffer angle is measured in milliradians to the left and right of the laser-target line, out to the NOHD (see FIGURE 23). (Note: 17.7 milliradians is equal to one degree.)

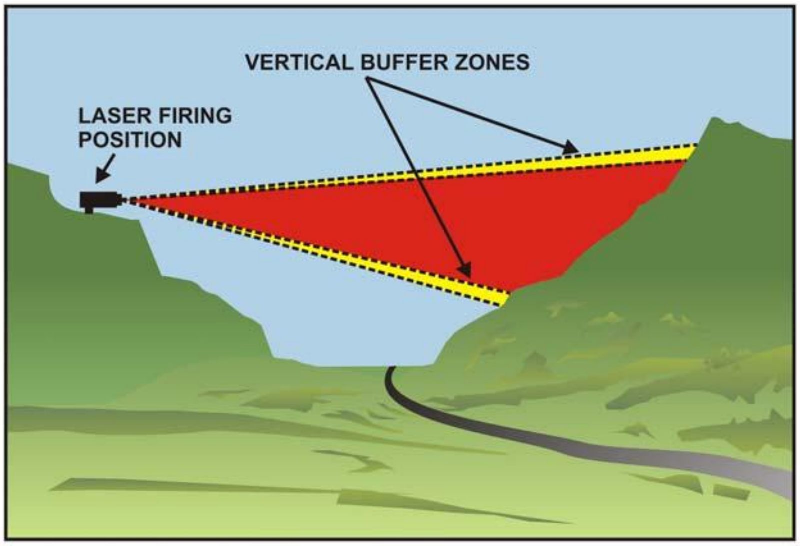


FIGURE 23. Buffer angle.

a. If multiple targets are being lased, the buffer angle is measured in milliradians to the left of the left-most target and to the right of the right-most target, out to the NOHD.

b. If the laser is moving (e.g., mounted on a vehicle), the buffer angle is measured at both the initial and final lasing positions for both the left-most and right-most targets.

c. Minimum buffer angle requirements for currently fielded laser systems under their intended mounting configurations may be obtained from the Installation/Institutional Laser Range Authority. If the laser platform is unknown, the buffer angle will be 15 milliradians on either side of the beam, which may be the worst case scenario.

9.4.3. Nominal Hazard Zone (NHZ). Backstop and target areas where the energy of the incident beam is capable of producing a specular or diffuse reflection hazard around targets within the NOHD could result in an NHZ. The NHZ is a volume of space around the target based on the laser reflection. The size, location (distribution), and type of targets to be lased on a range are of primary importance in determining NHZ.

9.4.3.1. Specular NHZ. When specular reflectors cannot be removed from the target area due to training requirements, a specular NHZ should be calculated. To calculate the specular NHZ, determine the difference between the distance from the laser system to the target and the NOHD distance. This distance is the radius of the volume around the target that constitutes the specular NHZ.

9.4.3.2. Diffuse NHZ. If the LSDZ encompasses the target, there is no need to calculate a diffuse NHZ.

9.5. Airborne LSDZ. To maximize training capabilities for airborne lasing, an LSDZ is a 360-degree generated composite around the target unless dictated by range or training constraints.

Aircraft heading may or may not coincide with the laser-to-target bearing. The lasing aircraft may move in a circular, curvilinear, figure eight, or other pattern as it lases the target. For example, after bomb release, the flight path of the aircraft will vary while it continues to lase. The delivery aircraft may fly directly over the target, or it may turn away from the target after target identification before turning on the laser designator to guide the weapon to the target. In this case, the laser beam may be offset by more than 90º from the initial aircraft heading.

9.6. Activities on a Range. Existing munitions danger zones for direct fire weapons are usually large enough to encompass the LSDZ associated with ground-to-ground laser operations provided the beam is contained within the LTA.

10. LASER RANGE CERTIFICATION

10.1. Introduction. Prior to any laser range operations, the hazards of using the system on the range should be fully evaluated via a laser range certification. Laser use on ranges requires special considerations when considered in association with other training and live fire events. The laser range certification process is conducted to ensure adequate safety margins are determined to allow for the diverse application of the many lasers that may be used on the range, defining the degree of laser radiation hazard possible and to recommend control measures to the installation commander. An evaluation of the range area to include the airspace and area around the target, coupled with the delivery method and laser system to be used, will allow for a clear depiction of the LSDZ.

10.2. Certification Requirements

10.2.1. Laser Range Certification Period. Laser range certifications are valid for a period of time based on service policy or unless something changes that causes the laser range to be recertified. Laser ranges should be scheduled for certification well prior to the expiration of the last evaluation, whenever a new laser range is considered or range changed, and any time a new system exceeding the limits of the previous certification is to be used. The Institutional/Installation Laser Range Authority should prepare for the laser range certification well in advance of the certification.

10.2.2. Multiple Laser Systems. Based on service policy, a laser range certification can be performed for a specific laser system or for a group of similar lasers with similar NOHD and dispersion properties. A certification of a group of similar lasers is recommended if available land permits and the mission is not severely impacted. To perform this general certification, the worst case conditions of all possible systems and missions are used. If these conditions are too restrictive, a separate certification for each system should be performed.

10.3. Preparation for Certification.

10.3.1. Certification Checklist. At the time that notification is received that a laser range requires certification, the Institutional Laser Range Authority, in concert with the Installation Laser Range Authority, can begin to assemble the material needed and review what information has been gathered. The Installation Laser Range Authority should use the applicable service's Laser Range Presurvey Checklist to provide the Institutional Laser Range Authority with the information necessary to perform the certification (Appendix B provides sample checklists). The checklist provides an orderly approach toward preparing for the certification and identifying areas that require additional consideration.

10.3.2. Certification Kit. A certification kit consists of essentials such as a laptop to run a Geographic Information System (GIS) based laser range management tool, GPS unit for position and elevation, laser rangefinder, compass, waterproof notebook, binoculars, video camera, digital camera, distance measuring equipment, backup equipment, etc. In addition, the Laser Range Certification Checklist found in Appendix B is used by the certifier to annotate findings during the certification process.

10.3.3. Scheduling. The Installation Laser Range Authority should determine a suitable timeframe for the range evaluation after coordination with the prospective Institutional Laser Range Authority while considering the laser range certification due date.

10.4. Certification Process. A laser range certification may be performed to certify a range for laser employment for the first time or it may be performed to recertify existing laser ranges. Once preliminary data have been gathered and reviewed, the Institutional Laser Range Authority performs the certification. The Institutional Laser Range Authority may annotate the results of the certification on the Laser Range Certification Checklist (see Appendix B). The certification process is as follows:

a. Gather and review preliminary data.

b. Perform preliminary data analysis.

c. Conduct a range survey.

d. Analyze data, identify risk, and recommend risk mitigation.

e. Compile and report results.

10.5. Gather and Review Preliminary Data. Prior to a site visit, the Institutional Laser Range Authority should gather and review preliminary data provided by the Installation Laser Range Authority. Preliminary data includes:

10.5.1. Range Information

a. Range owner.

b. Name of each range requiring certification.

c. General description/location of the range(s) to be certified.

d. Baseline range data provided by the range management of the installation.

e. Detailed maps. A range map, a National Geospatial Intelligence Agency (NGA) resources (CADRG, DNC, USGS Digital Master Graphic, DTED, OrthoPhoto, Satellite Imagery), an airspace map of the area, Elevation Data/Models, and Digital Nautical Charts/Navigation Maps are reviewed as part of the Laser range certification.

1. Range Map. Range maps are essential to show authorized laser firing locations, firing lanes, firing areas, target locations, artificial backstops, populated areas, public roads, and no lase areas. Range maps should include boundaries (lateral and vertical), declination angles, and geographic items such as towers and buildings. The range maps should be assembled using both the GIS and GPS data to ensure accuracy. The datum/projection of the GIS data should also be provided (e.g., World Geodetic System 1984, Universal Transverse Mercator).

2. Elevation Data/Models. These usually provide a more accurate representation of elevation compared to range maps due to the increased accuracy of specific elevation data/models. Range maps do not usually have accurate elevation data. As an example, a standard range map is compiled using either 1:50,000 or 1:100,000 base data compared to a USGS 1:24,000 map. USGS 1:24,000 maps, without an elevation model, can be used when elevation data is of the same accuracy (as the horizontal accuracy). However, elevation data/models are much easier to conduct analysis on than looking for contour intervals and spot heights on a USGS image.

3. Digital Nautical Charts/Navigation Maps. These maps show restricted areas, sea bottom depth, points of interests, and navigation routes on surface and underwater ranges.

4. Airspace Map. Airspace maps/charts showing restricted airspace, flight paths, laser flight profiles, aircraft orbit points, and no lase areas are required. Controlled airspace is that airspace associated with the range having specific, possibly non-coincident lateral boundaries and a specific minimum and maximum altitude. It is important that this controlled airspace and any other special conditions are made known. Laser operations are not normally authorized outside the controlled airspace or when other aircraft are between the laser and the target. In addition, if the beam is directed up or above the horizon, or if hazardous reflections could exceed the height of the controlled airspace, additional controls will be necessary, including approval from the FAA and Laser Clearinghouse (LCH).

f. Aerial photos or commercially available satellite imagery are reviewed to look at vegetation, natural, and man-made backstops.

g. Laser range certification, if available.

h. Previously determined LSDZs, if available.

10.5.2. Laser Information. Information gathered about the laser systems includes:

a. Description of the lasers authorized to be employed on ranges. Only service-approved lasers are authorized for use on a range.

b. Engineering control measures.

c. The laser classification for the laser being evaluated.

d. The NOHD and/or NOHD-M (optically aided viewing) for the laser being evaluated.

e. Maximum buffer angles by allowable systems to be used on each particular target and range.

f. Optical density requirements. Optical density is the degree of protection required in PPE to reduce the incident laser energy to safe eye levels for a particular laser.

g. Technical orders, technical manuals, SOPs, and reports on the laser system and associated hazards to include laser systems parameters and hazardous failure modes that affect laser parameters or beam steering, secondary beams, inadvertent firing, and other potential system problems.

10.5.3. Weapons Data. A description of weapons authorized to be employed on ranges and weapons danger zones per SOP/Installation Laser Range Authority. This information is necessary for deconfliction/risk mitigation purposes (e.g., locations of ground personnel and laser operators are not in conflict with weapons danger zones).

10.5.4. Exercise Information

a. Intended operational environment for laser use including types of targets and position, laser firing locations, run-in headings, maximum and minimum firing altitudes and ranges, aircraft positioning and profiles, direction of laser operations, and any other special considerations.

b. The desired buffer angle for the range based on the desired exercises and laser platform.

10.5.5. SOPs. Sources of information (SOP, publications, orders, regulations, etc.). The SOPs should be comprehensive and address all aspects of range safety and operations. SOP shows how the range is being used, how lasers/weapons are employed, etc.

10.5.6. Areas of Concern. Any areas of concern either by the range manager or the installation commander need to be addressed such as changes to targets, target areas, backstops, environmental changes, encroachment issues, etc.

10.6. <u>Perform Preliminary Data Analysis Using Software/Analysis Methods.</u> Prior to a site visit, an analysis of the range area should be completed using a laser range management tool to generate an LSDZ using the preliminary data gathered. The Institutional Laser Range Authority should generate LSDZ(s) if one does not exist or verify the accuracy and currency of LSDZ(s) that do exist. The LSDZ(s) will contain firing areas, target areas, buffer angles while considering effects of munitions to be used on range. The tool will generate LSDZ(s) to include the following elements:

a. Potential firing point (s), line, area.

b. Potential target (s), line, area.

c. NOHD.

d. Buffer angle.

e. Target/area alignment (crossfire, lateral limits).

f. Magnetic declination.

g. Far and near bounding points and offsets (aerial only).

10.7. <u>Conduct Range Survey.</u> Range facilities are evaluated in terms of location relative to populated areas, military and civilian industrial sites, and water surface traffic. The locations of all occupied areas on the range such as observation points or control towers should be determined as well as specific environmental factors (e.g., habitat of any endangered wildlife in the range area).

10.7.1. <u>Site Visit.</u> A site visit should be conducted to analyze the range. The range survey/site visit should include the following actions:

a. Verify range boundaries using GPS and map data.

b. Verify laser firing area/line/points using GPS and map data.

c. Verify laser target location using GPS and map data.

d. Verify through visual inspection that target materials will not provide specular reflectors. Targets and target areas should be inspected to ensure they are not capable of producing hazardous reflections. The evaluator should ensure specular reflections are removed or rendered diffuse.

e. Verify the terrain can support safe laser training; i.e., no specular reflections, clear line of sight between the laser firing point and the target, and backstop in good condition. Terrain features on and surrounding the range are evaluated for impact on laser safety. Usable terrain and vegetation backstops are identified and located on maps of the range area. Any mountain peaks outside the range are examined to verify that such obstructions as radio or television towers or park service observation towers do not extend into the laser buffer zone between the laser and the target.

f. Verify elevation of lasing position, target, and backstop, e.g., erosion will change the angle of the beam to backstop and the backstop may no longer contain the beam.

g. Ensure the LSDZ is contained within the boundary of the range.

h. Verify the LSDZ requirements including buffer angles and aircraft headings.

i. Verify the danger zones associated with laser training events are supportable.

j. Verify the roads or other access points to the range area will be controlled as is done for conventional weapons training. Determine the probabilities of non-controlled personnel entering the target area or controlled range areas. The methods used to control access to the potential laser hazard area such as fences, gates, warning signs, airspace restrictions, and water surface danger areas, should be evaluated for adequacy.

k. Verify appropriate PPE is available, if required.

l. Verify processes are in place for communication/notification of laser activities.

10.7.2. Visual Survey. A visual survey of the range area is required. The range evaluator may perform an aerial fly-over on the proposed or approved targets and laser run-in headings. A visual survey from the air can observe any glints of sunlight reflecting from broken bits of glass or other reflectors lying on the ground. Cameras or other surveillance may be used to assist in the visual survey. A pair of binoculars can be used to scan the terrain features to estimate the natural buffer area.

10.8. Analyze Data and Recommend Risk Mitigation Actions. The Institutional Laser Range Authority should review laser system data, maps, targets, instructions, SOPs, and other information provided by the laser user and range operator to determine which existing requirements impact the safety of laser operations on the range. Appendix B provides a checklist for range certification that includes risk mitigation factors that should be analyzed and addressed in the certification.

10.9. Compile and Report Results. The Institutional Laser Range Authority may compile certification results on the sample laser range certification checklists contained in Appendix B.

11. INSTITUTIONAL LASER RANGE AUTHORITY ROLES AND RESPONSIBILITIES

Institutional laser range roles and responsibilities in support of range laser operations are as follows.

11.1. Institutional Guidance Regarding Range Laser Safety. The Institutional Laser Range Authority provides institutional guidance to installations via service-specific regulations. The Institutional Laser Range Authority is responsible for maintaining publications relating to laser use on ranges and establishing or recommending the requirements for training programs. If there are questions regarding range laser safety and certification, they should be directed to the Institutional Laser Range Authority.

11.2. Laser Range Certification. When empowered, the Institutional Laser Range Authority is responsible for certifying laser ranges. A laser range certification provides recommendations for the safe use of specific lasers and laser activities. The Institutional Laser Range Authority should:

a. Review the laser systems to be employed.

b. Verify range boundaries.

c. Verify laser firing area/line/points.

d. Verify laser target location and material.

e. Verify LSDZ requirements.

f. Determine that the terrain can support safe laser activities.

g. Ensure the LSDZ is contained within the boundary.

h. Determine whether the range meets certification requirements.

11.3. Laser Range Hazard Analysis. The Institutional Laser Range Authority is responsible for conducting laser range hazard analysis for ground and aerial operations either manually or by using a laser range management tool. The Institutional Laser Range Authority is responsible for maintaining its methods and, if necessary, automated tools such as a laser range management tool for generating danger zones. The Institutional Laser Range Authority should:

a. Determine buffer angle.

b. Validate laser firing area/line/points.

c. Validate laser target area/line/points/area offset.

d. Validate location of laser target area/line/points.

e. Validate magnetic declination.

f. Generate calculations for LSDZ.

g. Generate flight profiles, if applicable.

h. Capture area with digital pictures/video record for report.

i. Create data store of Laser Range Certification features.

j. Summarize hazard analysis findings.

12. INSTALLATION LASER RANGE AUTHORITY ROLES AND RESPONSIBILITIES

12.1. Operating Procedures. The Installation Laser Range Authority is responsible for maintaining operating procedures pertaining to installation range laser safety. To ensure proper control of hazardous laser radiation, the Installation Laser Range Authority should institute the following:

a. Publish and enforce safety instructions for the safe use of lasers at their range(s). Ensure that written procedures exist to minimize laser radiation hazards and other laser related range hazards such as homing on the laser target designator and wrong targets.

b. Regulations should be developed or updated as necessary to account for new laser systems, operating areas, and targets. The laser range certification should be used to review and to ensure overall range safety regulations are current.

c. Ensure operating procedures for specific laser systems inform laser users of the potential hazards from the laser systems under their control during laser operation. Checklists for evaluating SOPs are provided in Appendix B. The Installation Laser Range Authority should require users to adhere to the range SOP for all range training operations.

d. Keep records of the date, start and stop time for lasing periods, and type of laser or other appropriate information for each laser operation (i.e., laser firing log).

e. Ensure a range Laser Safety Officer is assigned to be responsible for ensuring appropriate safety control measures are followed.

f. Through proper management of operating procedures, the Installation Laser Range Authority should ensure the following are acknowledged to ensure currency and to mitigate risk:

1. Range-approved laser systems

2. Laser range certification criteria

3. Range laser operations

4. Range laser maintenance procedures

5. Laser hazard control measures

6. Emergency response procedures

7. PPE

8. Notices (Airmen, Mariners)

9. Agency Notifications (MOAs, MOUs)

12.2. Laser Training Plan. The Installation Laser Range Authority reviews laser training plans as part of the approval process. This focus is on verifying the information to ensure the range supports execution of the training plan in a safe manner. In addition, the Installation Laser Range Authority performs risk mitigation, as necessary, and identifies revisions to the training plan to ensure compliance with safety and operational procedures/policies. The Installation Laser Range Authority should assist units, as necessary, in helping them to develop a plan that will meet training objectives. As part of this review, the Installation Laser Range Authority should review/determine the following data points within the laser training plan. Note that service-specific guidance will dictate whether the Installation Laser Range Authority ‘reviews’ or ‘determines’ the following data points:

a. Laser system(s) is approved.

b. Limits of the LSDZ.

c. Ground personnel locations to ensure those requiring PPE are identified.

d. Hazard area clearance procedures for unprotected personnel.

e. Control measures for ensuring personnel remain clear of the LSDZ.

f. Laser mode/tactic to be employed to ensure it supports the laser system, range, training plan, and weapon delivery.

g. Laser output power to ensure it is in compliance with local SOP.

h. Targets, laser firing area/line/points, orbit points, and laser to target orientation to ensure they can be supported by the laser system and the range.

i. PPE requirements to ensure they support the laser and weapon systems.

j. Training mode/filter requirements.

k. Emergency response procedures.

l. Public and agency notifications.

12.3. LSDZ. Installation Laser Range Authority personnel generate LSDZs either manually or by using a laser range management tool, as necessary, to support training plans, map data, information requests, etc. This is done only on a previously certified laser range. This effort includes inputting the laser system data and range data (e.g., firing points, targets) and performing risk mitigation to ensure the laser training can be safely conducted on a given range.

12.4. Laser Systems. The Installation Laser Range Authority is responsible for reviewing laser systems for use on a certified laser range. This includes performing a verification to ensure the system falls within the current certification for that range. The Installation Laser Range Authority should:

a. Review range specifications and certification.

b. Review training plan including tactics, laser firing area/line/points, laser surface danger zone, and laser target area.

c. Review laser specifications.

d. Compare characteristics of laser systems already authorized for use on the range with the new laser system.

e. Compare laser specifications with maximum supportable buffer angles on the range.

f. Compare NOHD of the laser with range specifications and intended training activities.

g. Determine if the laser system exceeds or falls within current range certification.

h. Recommend approval or disapproval of the use of the laser system on the range.

12.5. Laser Range Design. When new ranges requiring laser operations are considered, the Installation Laser Range Authority provides input to the design of the range with regard to technical requirements. The Installation Laser Range Authority should review training requirements and tactics and should:

a. Conduct site analysis to determine range design requirements.

b. Recommend whether an existing range can be modified or a new range must be established to meet the training/testing requirement.

c. Perform risk assessment to determine potential hazards.

d. Provide technical guidance on range design to support safety, mission, and environmental requirements.

e. Provide technical guidance on construction requirements.

f. Consult the Institutional Laser Range Authority.

12.6. Range Laser Safety Compliance Inspection/Audit. The Institutional Laser Range Authority should perform range laser safety compliance inspection/audits:

a. Verify LSDZ boundaries.

b. Verify the existence and placement of range boundary warning signs.

c. Inspect targets for serviceable condition and placement/orientation.

d. Verify accessibility, condition, height, and coordinates of ground laser system firing area/line/points.

e. Inspect line of sight between laser designator position and targets.

f. Verify the condition and height of the backstop as applicable.

g. Verify there are no specular reflectors in the LTA.

h. Inspect the range for state of maintenance.

i. Provide inspection/audit results to the range laser certifying authority

j. Verify authorized laser system listing is indicative of actual systems used and is current.

12.7. Laser Range Certification. The Installation Laser Range Authority accepts the responsibility for the laser range certification as performed by the Institutional Laser Range Authority. The Installation Laser Range Authority assists the range certifying authority in performing range certification for the safe use of lasers. Certifications should consider, but not be limited to, the extent of range boundaries, required warning signs, number and location of non-removable specular reflectors, access control, airspace restrictions, local operating procedures, and environmental conditions/restrictions. The Installation Laser Range Authority should:

a. Review the laser systems to be employed.

b. Identify range boundaries.

c. Identify airspace restrictions.

d. Identify laser firing area/line/points.

e. Identify laser target area/line/points.

f. Identify LSDZ limitations.

g. Provide a range map.

h. Identify points of interest (towers, structures, roadways, etc.).

12.8. Laser Briefings and Indoctrination. The Installation Laser Range Authority advises the affected public of the presence of laser operations, where deemed appropriate. The Installation Laser Range Authority provides laser briefings and indoctrinations in accordance with service-specific guidance. Laser indoctrination should be provided at the same time as the basic weapons systems instruction. The indoctrination should be at the user level (i.e., complex scientific data or terminology should be avoided). Proper channels for obtaining professional safety and medical assistance should be addressed during indoctrination. In addition to instructions on particular devices, indoctrination should include:

a. Principles of laser reflection.

b. Laser hazards.

c. Safety standards or operational control procedures of laser systems.

d. Range laser operations.

12.9. Laser Incident Investigations. The Installation Laser Range Authority should participate in laser incident investigations to include:

a. Review incident in accordance with local SOP and training plan.

b. Provide technical advice on laser capabilities and laser hazard effects.

c. Gather information about the incident.

d. Prepare and submit data for the investigation report.

13. UNIT LASER RANGE AUTHORITY ROLES AND RESPONSIBILITIES

13.1. Laser Training Plan. The Unit Laser Range Authority is responsible for preparing a laser training plan to submit to the Installation Laser Range Authority for approval to perform laser activities on a specific LTA. As part of preparing a laser training plan, the Unit Laser Range Authority should:

a. Determine laser operations in support of training requirements.

b. Review training to be accomplished against local operating procedures.

c. Select a range whose laser range certification supports the laser system(s) to be used and training exercise to be accomplished.

d. Review laser mode/tactic to be employed to ensure it supports the laser system and range.

e. Identify targets, laser firing area/line/points, laser to target orientation, and orbit points that can be supported by the laser surface danger zone.

f. Identify ground personnel locations.

g. Identify range hazard clearing requirements.

h. Identify PPE requirements.

i. Identify communications requirements.

j. Identify emergency response procedures.

13.2. Range Laser Safety Inspection. Conduct of Inspection. The Unit Laser Range Authority should conduct a laser safety inspection of the range and its operations prior to its use:

a. Ensure laser warning signs have been posted.

b. Check range conditions (targets/backstop, range boundaries, laser firing area/line/point(s))

c. Ensure the area is clear of specular reflectors.

d. Ensure the LTA is clear of non-essential personnel and equipment.

e. Ensure that essential personnel in the area are aware and protected.

f. Ensure laser system(s) are authorized per the training plan.

g. Ensure training filters/modes are used, as applicable.

h. Ensure communication and terminology is agreed upon.

i. Correct any discrepancies if possible.

13.2.1. Safety Brief/Pre-mission Brief. The Unit Laser Range Authority should provide safety briefs/pre-mission briefs to laser range users and observers. Provide a pre-mission brief to all laser operators and affected personnel prior to laser operations. The brief should include all potential hazards such as radiation and weapons misguidance, control measures specific to the lasers employed, and the range upon which they are used. As a minimum, the brief should include:

a. Laser systems to be used.

b. Authorized tactics, laser firing positions, laser to target orientation, weapons release points, and weapon performance.

c. Drawings, photographs, descriptions or grid points of authorized targets.

d. Communication procedures that include specific frequencies (or channels), controlling authorities, and standardized terminology.

e. Acquisition, identification, and tracking procedures for targets.

f. Missile/ordnance mode of operation.

g. Requirements for beam termination.

h. Control measures to minimize the risk of unauthorized personnel or aircraft entering the range area.

i. Run-in headings and flight profiles to be used for airborne laser operations or permissible LSDZ for ground- and naval-based laser operations.

j. Review of mission profiles to prevent misdirection of laser guided weapons.

k. Type of eye protection to be worn and how it should be worn.

l. Potential hazards posed by the laser system (e.g. backscatter), the target area, maintenance area, etc., types of warning signs to be posted, and specific procedures to avoid these hazards (as appropriate).

m. Risk considerations for location of personnel within the WDZ for observing/lasing the target area to weapons impact.

n. A review of applicable SOP information.

13.3. Laser Operations. The Unit Laser Range Authority should perform the following functions in support of supervising laser operations:

13.3.1. Laser Systems/Targets.

a. Ensure only service-approved lasers are employed on the range.

b. Ensure laser systems are at the approved operating position or firing points and always pointed toward the target; verify laser firing area/line/points and laser to target orientation.

c. Ensure that laser systems are only fired at authorized targets.

d. Ensure that the target is positively identified in accordance with appropriate safety procedures before operation of a laser system.

13.3.2. LSDZ.

a. Ensure all unprotected personnel in the immediate area of the laser firing position are outside the LSDZ while the laser is in use.

b. Ensure LTA is clear of all non-essential personnel.

13.3.3. Pre-fire Checks. Supervise pre-fire checks. Pre-fire checks that require operation of the laser system may be made in a controlled area with the laser beam terminated by an approved backstop. Pre-fire checks that do not require operation of the laser, but require use of the optics, may be safely made in any area. To operate the optics without firing the laser, follow SOP to ensure power to the laser is turned off.

13.3.4. Cease Fire Operations. Ensure laser operations are ceased when any unsafe condition is observed. Cease laser operations if:

a. A specular reflection is presented in the target area.

b. Poor target tracking is observed.

c. Non-essential personnel and/or traffic enter the LTA.

13.3.5. General Supervision

a. Maintain communication with the laser system operators, the Installation Laser Range Authority, and all affected range personnel.

b. Ensure that lasers do not exceed the NOHD outside the restricted airspace without proper coordination.

c. Ensure personnel follow safety procedures in accordance with local SOP.

d. Ensure training filters/modes are used, as required.

e. Ensure PPE are being used, as required.

f. Ensure the approved training plan is followed.

g. Coordinate emergency response, as necessary.

13.4 Laser Incident Investigations. The Unit Laser Range Authority should participate in laser incident investigations that occur during their training. The Unit Laser Range Authority should:

a. Ensure the laser system involved is quarantined.

b. Report the incident to the Installation Laser Range Authority.

c. Provide information on training activity/exercise, as necessary.

d. Provide information on what happened, where, when, how, etc.

e. Provide information on personnel who may have been exposed to a laser hazard.

14. NOTES

14.1. Intended use. The contents of this handbook are intended to serve as a guide to the safe use of lasers and laser systems used on military reservations and in military controlled areas.

14.2. Supersession data. This handbook supersedes MIL-HDBK-828A dated 31 December 1996.

14.3. Subject term (key word) listing. Safety, range operations, laser operation, direct and reflected intrabeam viewing, flash blindness, skin damage, scattered radiation, laser guided weapon.

14.4. Changes from previous issue. Marginal notations are not used in this revision to identify changes with respect to the previous issue due to the extent of the changes.

LASER SAFETY SOP

A.1. SCOPE. This appendix provides information that should be contained within a laser safety SOP and unit responsibilities for compliance with laser safety SOPs

A.2. INSTALLATION LASER RANGE AUTHORITY RESPONSIBILITIES. The following items should be addressed in a laser safety SOP. Installations should prioritize these and other items according to their local requirements and situation. This list is not intended to be all-encompassing, but should meet the mandates of service orders and directives. Additional or more restrictive conditions may be appropriate. The laser safety SOP should:

a. Provide a schedule for checking target location and environment (e.g., crater holes, dislodged or moved targets from surveyed location, target debris that exposes specular reflectivity, appropriate backstop for systems employed to contain all laser activity, etc.).

b. Delineate Installation Laser Range Authority responsibilities and those of the unit.

c. Provide communication frequencies for training units and cease lasing operations if communications are lost.

d. Coordinate laser codes for multiple users to ensure deconfliction.

e. Require briefings for the unit laser range authorities, including the range description, approved laser systems, targets, firing points or movement boxes (ground, airborne, or naval).

f. Have provisions for ensuring personnel surrounding laser activity on the same range are aware of the laser activities.

g. Have provisions for ensuring all ranges are marked with appropriate signage with particular attention paid to all access points/areas.

h. Have provisions for designating an assembly/marshaling area that is clear of the laser training area during laser events.

i. Detail the procedures for scheduling laser activity through the common range scheduling system and log all events within it.

j. Provide PPE/eyewear requirements appropriate for the laser systems being employed.

k. Detail emergency response actions for laser injuries, including medical response and 24 hour hotline (1-800-473-3549 Tri-service Injury Hotline).

l. Have provisions for unit laser safety training.

m. Reflect any other laser guidance specific to your installation.

A.3. UNIT RESPONSIBILITIES. Units should have their own laser safety program and training and should brief their units prior to engaging training. Units are responsible for complying with the installation guidance and directives contained within the laser safety SOP. Unit responsibilities include the following:

a. All units conducting laser training should provide to the Installation Laser Range Authority an assigned laser range safety officer in writing to direct the safe use of lasers, ensure range regulations, the range SOP, and Installation Laser Range Authority directives are complied with. This appointment letter should be provided to Installation Laser Range Authority prior to any laser training.

b. The Unit Laser Range Authority must receive a Range Laser Safety Brief by the Installation Laser Range Authority prior to conducting laser operations on the range. This briefing should review laser operations from entry on the range until exit, with specific detail for any installation concerns or lessons learned.

c. Ensure only systems approved by the Laser Systems Review Board (LSRB) and reviewed by the installation are authorized for use.

d. Ensure the laser system(s) employed meet the specifications of the range certification, including allowable buffer angle, NOHD, MPE, and platform constraints, activated only from the specified location at the specified target.

e. Provide a log for the laser operations to the Installation Laser Range Authority to be recorded on the common range scheduling system schedule and retained for reference.

f. Conduct a thorough air, ground, and/or water inspection of the range prior to training to ensure the range is clear of equipment and nonessential personnel, and that those present are informed of the laser operations and possess appropriate PPE/eyewear.

g. Confirm no specular reflectors are associated with their assigned targets prior to use.

h. Ensure unit assembly/marshaling areas remain clear of the laser training area while lasers are in use.

i. Cease lasing immediately if personnel/aircraft enter the laser range.

j. When lasing, always point the laser down range toward the target/impact area.

k. Ensure personnel forward of the laser are wearing protective eyewear; ensure unprotected personnel remain behind the laser operator.

l. Ensure lasers are not activated until the target has been positively identified by the laser operator.

m. Ensure all personnel involved with laser operations know and understand LSDZ and range boundaries.

n. Ensure all safety mechanisms, switches, and covers are used until the laser operator is prepared to engage the target and activate the laser.

o. Cease lasing if communications are lost to the Installation Laser Range Authority, or with any person involved with the laser operations. Ensure lasing does not resume until communications are re-established.

p. Ensure all lasers are safe prior to departing the laser training area using all available measures that could allow the laser to be activated accidentally.

q. Review MIL-HDBK-828B for comprehensive understanding of laser use on outdoor ranges.

r. Ensure aircrew personnel are knowledgeable of all laser range restrictions and laser operations on the range.

s. Ensure personnel are briefed on emergency response actions for lasers, including the emergency response hotline 24 hours/day (1-800-473-3549 Tri-service Injury Hotline).

LASER RANGE CERTIFICATION CHECKLISTS

B.1. SCOPE. This appendix provides a Laser Range Safety Presurvey Checklist, a Laser Range Certification Checklist, and a Range Survey Report. These checklists may be used by tailoring or adding items as needed for local situations.

B.1.1. Laser Range Pre-survey Checklist The Installation Laser Range Authority should use the Laser Range Presurvey Checklist to provide the Institutional Laser Range Authority with the information necessary to perform the laser range certification.

B.1.2. Laser Range Certification Checklist The Institutional Laser Range Authority annotates the data gathered during the certification on the Laser Range Certification Checklist.

B.1.3. Laser Range Survey Report. The Institutional Laser Range Authority annotates the results of the laser range certification on a Laser Range Survey Report.

Laser Range Pre-Survey Checklist

Range/Area Name: ______________________ Date: __________

Location (Grid Coordinates): ______________________

Address: ______________________

Range owner: ______________________

Planned Survey Date: ______________________

Last Survey Date:: ______________________

Phone (DSN) ______________ Performed by: ______________

Comm: ______________ Range POC: ______________

User POCs ______________________

____

Description

What is the restricted airspace? ______________________

____

____

What are the range boundaries? ______________________

____

____

What are the range’s laser target areas? ______________________

____

____

What are the range’s firing points? ______________________

____

____

What are the range’s firing lines? ______________________

____

____

What are the range’s firing areas? ______________________

____

What are the range's target lines? ______________________________

What are the range's point targets? ______________________________

What are the ranges points of interest? ______________________________

What is the buffer angle desired by the range? ______________________________

What platforms are approved for ground operations? ______________________________

Data Collection

Documents:
- Range SOP: ______________________________
- Range Laser Directives: ______________________________
- Old Survey Report: ______________________________

Maps:
- Range Boundaries: ______________________________
- Topography: ______________________________
- Restricted Air Space: ______________________________
- Target Locations: ______________________________
- Laser Operating Locations: ______________________________

Types of Laser Operations:

Airborne: ______________________________

Ground-based: ______________________________

Restricted Air Space: ______________________________

Laser Systems to be used on the range:

____
____
____
____
____
____
____
____
____

Target name	Grid Coordinates
1.	
2.	
3.	
4.	
5.	
6.	
7.	
8.	
9.	
10.	

Laser operator firing positions for Target #	Grid coordinates
1.	
2.	
3.	
4.	
5.	
6.	
7.	
8.	
9.	
10.	

Forward Observer positions for Target # Laser #	Grid coordinates
1.	
2.	
3.	
4.	
5.	
6.	
7.	
8.	
9.	
10.	

1. Does the range have established run-in headings for aircraft? Yes _____ No _____

If yes, what are they?

2. Will more targets be added? Yes _____ No _____

If yes, where (grid coordinates)?

3. Are there manned positions on the range? Yes _____ No _____

If yes, where (grid coordinates)?

4. Describe the surveillance of the range.

5. Are there any conditions off the range that need to be addressed? Yes _____ No _____

If yes, what are they?

6. Any other changes?

7. Comments?

Laser Range Certification Checklist

References: a) ______________________________
b) ______________________________

Location (Installation): ______________________________

Facility: (Official Range Name): ______________________________

Type of range: ______________________________

Range owner: ______________________________

Date of next onsite survey: ______________________________

Date next onsite survey is due: ______________________________

Inspected by:

Last name and initials	Command (Code):	Phone number:
______________	______________	______________

Format of data collected (e.g., WGS 84, NAD 27): ______________________________
____

Declination angle: ______________________________

Documents referenced for this survey: ______________________________
____
____

Laser range safety officer:

Name	Address	Phone
______________	______________	______________

Standard Operating Procedure (SOP)

1. Is there a current, signed SOP for the range? Yes ______ No ______ N/A _______

2. Are emergency procedures outlined in the SOP pertaining to personnel injury? Yes ______ No ______ N/A _______

3. Are there procedures outlined in the SOP for the clearing and inspecting of lasers prior to departing the range?	Yes ______	No ______	N/A _______
4. Does the SOP indicate coordinated laser codes for designators and seekers?	Yes ______	No ______	N/A _______
5. Does the SOP indicate permissible aircraft flight profiles and run-in headings for specified targets or target areas?	Yes ______	No ______	N/A _______
6. Does the SOP indicate permissible ship headings and safe firing zones for specified targets or target areas?	Yes ______	No ______	N/A _______
7. Does the SOP indicate permissible ground-based laser operating positions and/or areas for specified targets or target areas?	Yes ______	No ______	N/A _______
8. Does the SOP indicate hazard areas to be cleared of non-operating personnel (road blocks, if required)?	Yes ______	No ______	N/A _______
9. Does the SOP indicate operating personnel locations (including those requiring eye protection)?	Yes ______	No ______	N/A _______
10. Are surveillance procedures delineated in the SOP to ensure a clear range?	Yes ______	No ______	N/A _______
11. Does the SOP indicate radio frequencies for communication?	Yes ______	No ______	N/A _______
12. Does the SOP indicate that laser systems will not be activated until the target has been positively identified?	Yes ______	No ______	N/A _______
13. Does the SOP indicate that Class 3 and 4 lasers shall not be directed above the horizon unless coordination has been completed with DOD components?	Yes ______	No ______	N/A _______
14. Does the SOP indicate that for ground-based lasers, all unprotected personnel must remain behind the laser safety zone?	Yes ______	No ______	N/A _______

Personnel Responsibilities			
1. Have all personnel been authorized to check out a range or training area received the Unit Laser Range Authority class from the Installation Laser Range Authority?	Yes ______	No ______	N/A _______
2. Has the Installation Laser Range Authority maintained records of qualified Unit Laser Range Authority?	Yes ______	No ______	N/A _______
3. Are there measures in place to ensure the Unit Laser Range Authority is qualified/certified and knowledgeable of the lasers being fired on the range?	Yes ______	No ______	N/A _______
4. Is the Unit Laser Range Authority appointed in writing by the commanding officer?	Yes ______	No ______	N/A _______
5. Does the Installation Laser Range Authority supply the Unit Laser Range Authority with specific check-in and check-out procedures for each range?	Yes ______	No ______	N/A _______
6. Is it routine policy for the Unit Laser Range Authority to conduct a reading of the range safety rules in detail prior to the range exercise?	Yes ______	No ______	N/A _______
7. Are there procedures in place to ensure the Unit Laser Range Authority is briefed on changes to policies and procedures since they attended installation laser training?	Yes ______	No ______	N/A _______
8. Does the Installation Laser Range Authority review all waiver/special event requests that do not comply with installation regulations?	Yes ______	No ______	N/A _______
9. Are all of the personnel who must be on the range during laser operations equipped with the proper eye protection?	Yes ______	No ______	N/A _______
10. Have all of the range personnel involved with laser operations had laser safety training?	Yes ______	No ______	N/A _______

Administrative	
1. Are laser warning signs posted along the perimeter of the LSDZ (IAW MIL-HDBK-828B) to warn personnel against unauthorized entry?	Yes ______ No ______ N/A _______

(Date) _______________

Laser Range Certification

1. __________________ (range/range training facility) and attendant laser hazard analysis have been designated to accommodate the following, under the supervision of a qualified laser range officer in charge and laser range safety officer, per the range SOP:

   a. The use of ________________________ laser(s).

   b. The use of lasers with the following NOHD:

   ____

   c. The use of lasers with the buffer angles:

   ____

   d. Appropriate ____________________ wavelength PPE:

2. A risk assessment of all “no” answers on certification checklists has been completed and steps taken to mitigate the risk. A summary of that risk assessment and risk mitigation steps is enclosed.

3. ______________________ (range/range training facility) meets the criteria established in service directives and is certified effective as of the date of this letter.

Signature: _____________________________________

Copy to: Institutional Laser Range Authority
Service Range Safety Authority
Installation Laser Range Authority

Laser Range Survey Report

Note: This report may require sign-off by the Service Laser Safety Authority.

Range Area/Name: ______________________________

Survey Summary

Date of onsite survey: ______________________________

Date when next on-site survey is due: ______________________________

Applicable Regulations: ______________________________

____

____

Range controlled by: ______________________________

Range owner: ______________________________

Survey completed by (Name/Organization): ______________________________

____

Date of operations for which survey is valid: ______________________________

Format of data collected (e.g., WGS 84, NAD 27): ______________________________

Declination angle: ______________________________

Documents referenced for this survey: ______________________________

____

____

____

____

Other pertinent information: ______________________________

____

____

____

Survey

Who performed this survey? ______________________________

What are their titles? ______________________________

Who else was involved in this survey? ______________________________

____

Any adverse conditions?: ______________________________

____

____

Evaluation

What is the buffer angle desired by the range? ______________________________

____

Survey Results

1. Degree of compliance with applicable regulations:

____

____

____

____

____

____

2. Safety deficiencies that must be corrected before approving range for laser use:

____

____

____

____

____

____

3. What are the range's desired run-in headings for aircraft?

____

____

____

____

____

____

Recommended Actions

1. Corrective actions for existing deficiencies:

2. Ground Laser Restrictions - Description of Laser Surface Danger Zones (LSDZ):

3. Aircraft Mounted Lasers - Description of Laser Surface Danger Zones (LSDZ):

4. Recommended operating procedures/range regulations:

5. Recommended laser eye protection:

6. Controls for protection from reflected laser beams:

7. Recommended training:

8. Recommended prebriefs for:
   a. Laser users:

   b. Laser Range Personnel

EQUATIONS FOR LASER HAZARD EVALUATION

C.1. SCOPE This appendix contains equations for laser hazard evaluation to conform to range safety constraints.

C.2. APPLICABLE DOCUMENTS. The references from which these equations were derived are given in Chapter 2.

C.3. EQUATION APPLICATIONS. The information provided in this appendix may be used in addition to the service-specific laser evaluation techniques. The equations are the means to determine minimum laser altitude above mean sea level (msl) which will satisfy the safety constraints for use of an airborne laser system on a particular range and at a specified distance from the target. Equations are provided to determine positions of ground based lasers that will satisfy the safety constraints on a given range.

C.3.1. Sloping ranges. Many ranges have a sloping terrain which yields a laser footprint plus buffer zone resembling an ellipse. This footprint will be a more elongated ellipse for airborne lasers illuminating a downward sloping terrain and a truncated ellipse for lasers illuminating an upward sloping terrain.

C.3.2. Shipboard Laser System. The use of these equations in the case of shipboard laser systems would provide pessimistic results. The lack of terrain features to act as a backstop in an open ocean environment, when combined with the longer NOHD of a more powerful shipboard laser system, causes the curvature of the earth to play a significant role in shipboard laser evaluations. The optical horizon from an elevation of 80-feet msl is approximately 9.5 nmi.

Because at a range of l9 nmi (the approximate NOHD for unaided viewing of some proposed shipboard laser systems) the propagated beam could not possibly be below 80-feet msl, the use of optical aids aboard other surface vessels would not increase the probability of exposure. It would increase the extent of damage should an exposure occur. It would also require coordination with those responsible for the air space and coordination of satellite space with Space Command, Cheyenne Mountain, Colorado.

C.3.3. Hazard Evaluation. The goal of airborne laser and ground laser safety evaluations on many ranges is to determine the aircraft flight profile required to keep the laser beam plus its buffer within the confines of the target restricted area, that is, the LSDZ.

C.4. BUFFERED FOOTPRINT DEFINITION. The buffered footprint is the projection of the laser beam and its associated buffer zone on the ground surrounding the intended target. The footprint configuration and size are determined by the range from the laser aperture to the target, the incidence angle of the laser beam LOS on the target or range area plane and the assigned buffer angle. FIGURE C-1 and FIGURE C-2 show the geometry of the buffered footprint. The footprint of this laser is an ellipse whose width is typically quite small and a simple function of the distance to the target. The spreading of the beam along the ground in the direction of the laser LOS is of primary concern and changes drastically as a function of the aircraft's height above and distance to the target.

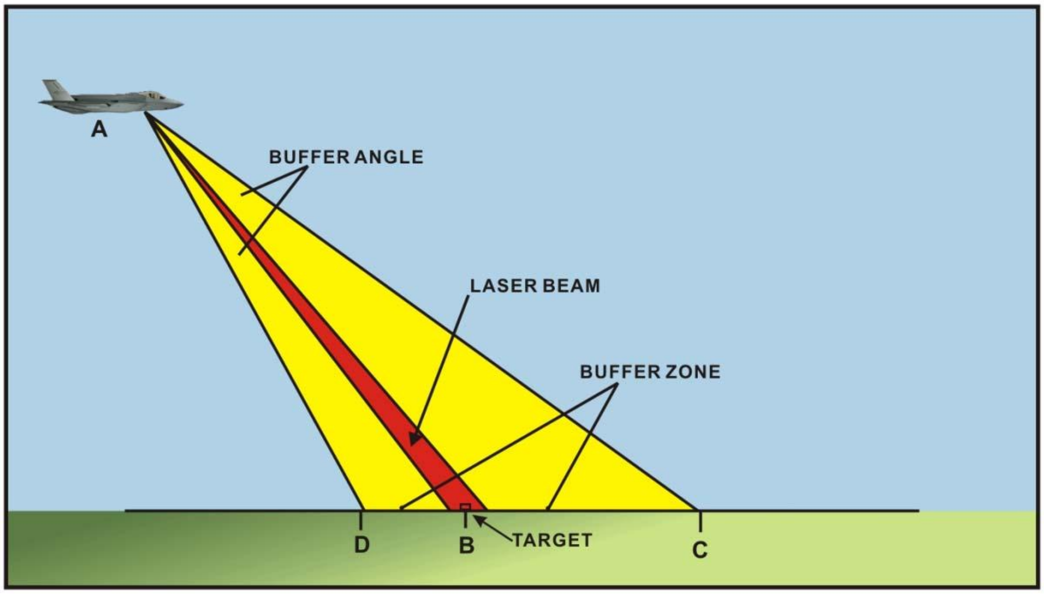


FIGURE C-1. Laser footprint with single target side view.

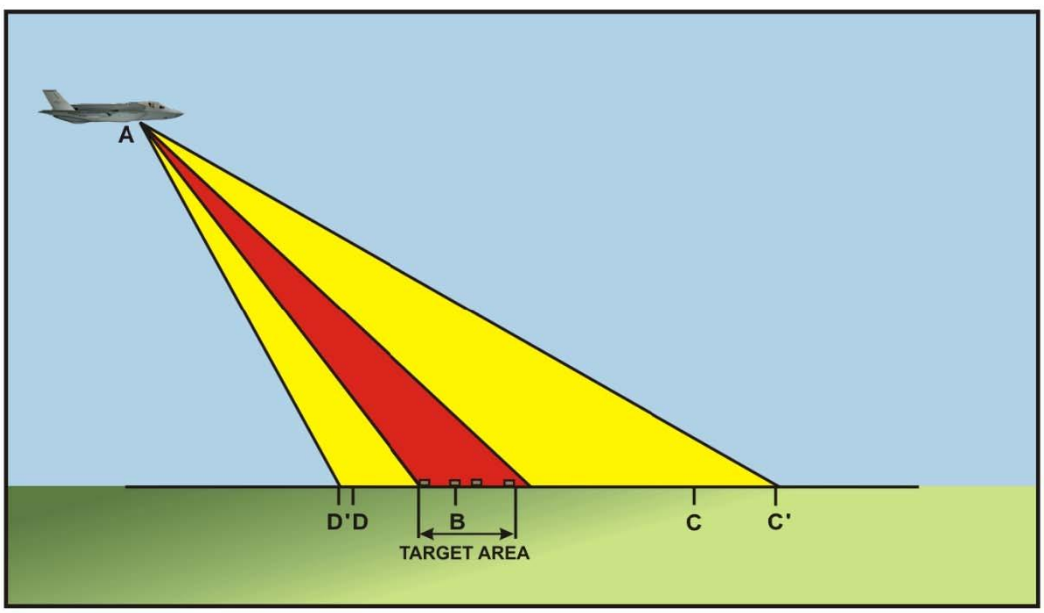


FIGURE C-2. Laser footprint with multiple targets – side view.

C.5. HAZARD EVALUATION WITHOUT SPECULAR REFLECTIONS. This evaluation should be done for each aircraft heading and should account for slope of the terrain.

C.5.1. Single Laser Aircraft Heading. Provided that the laser target and surrounding area are clear of specular reflectors, the mathematical model used to evaluate range safety must assure that the laser beam and its associated buffered footprint fall within the prescribed boundaries of the controlled and restricted ground space. The following paragraphs describe the equations used for this model. FIGURE C-1 shows an aircraft laser illuminating a small target area with the associated buffer zones fore and aft. FIGURE C-2 shows an airborne laser illuminating a large target area with near and far buffer zones assigned as if the laser were always aimed at the nearest and farthest targets. The plan views of these buffered footprints are shown in FIGURE C-3 and FIGURE C-4.

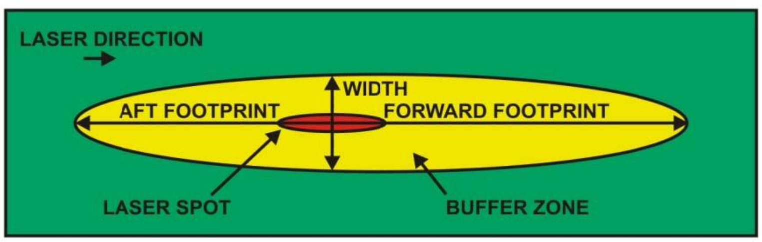


FIGURE C-3 Laser footprint – top view.

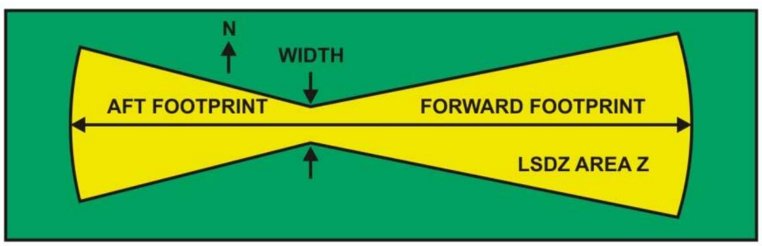


FIGURE C-4. LSDZ – attack bearing 90º.

C.5.2. Multiple Laser Aircraft Headings. If the laser attack will be from several bearings (for example 45º to 135º), the LSDZ will be a summation of all possible buffered footprints as shown in FIGURE C-5. If the attack bearings are not specified or attack from any direction is desired, the LSDZ will be a circle with a radius equal to the longest forward or aft buffered footprint dimension for the possible altitudes or slant ranges (see FIGURE C-6).

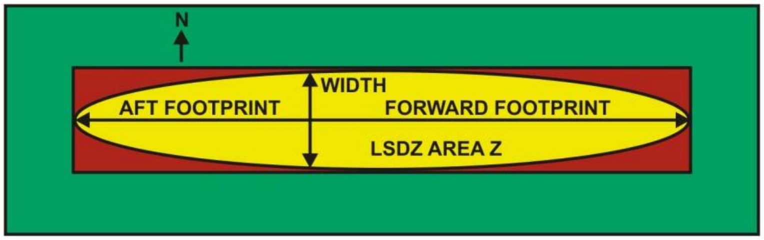


FIGURE C-5 LSDZ – attack bearing 70 to 110º.

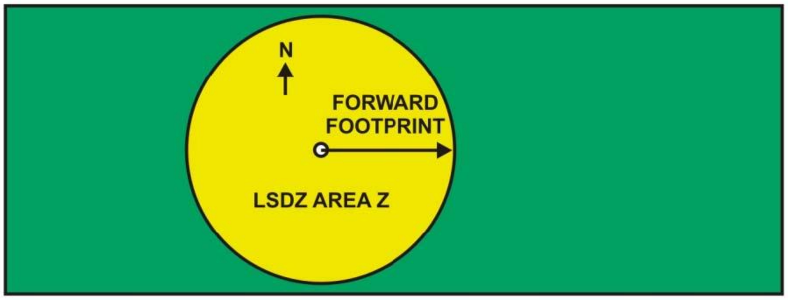


FIGURE C-6. LSDZ – attack from any direction.

C.5.3. Level Ground Examples. The following examples are provided as an application of the conditions described previously.

C.5.3.1. Example 1 (Level Ground). For a PAVE SPIKE laser fired from 200 to 1000 feet above ground level (AGL) at ranges from 1 to 4 miles, the longest buffered footprint dimensions on level ground are 8500 feet forward, 5960 feet aft, and 130 feet wide. The areas within these target distances must be restricted as the LSDZ.

C.5.3.2. Example 2 (Level Ground). For any PAVE SPIKE or PAVE TACK laser fired from 200 feet to 1000 feet above ground level at ranges from 1 to 4 miles, the longest buffered footprint dimensions on level ground are 37,600 feet forward, 9190 feet aft, and 243 feet wide. The areas within these target distances must be restricted as the LSDZ.

C.5.4. Unlevel Terrain. Although actual procedures vary on a case-by-case, the following conditions are presented as common.

C.5.4.1. Target on Rising Terrain Or Hills Behind Target (Natural Backstop). The condition of targets on rising terrain sometimes lengthens the near boundary and makes the far boundary less restrictive than the level ground condition. Hills behind the targets can act as natural backstops and reduce the size of the forward footprint as rising terrain did (see FIGURE C-7, FIGURE C-8, and FIGURE C-9).

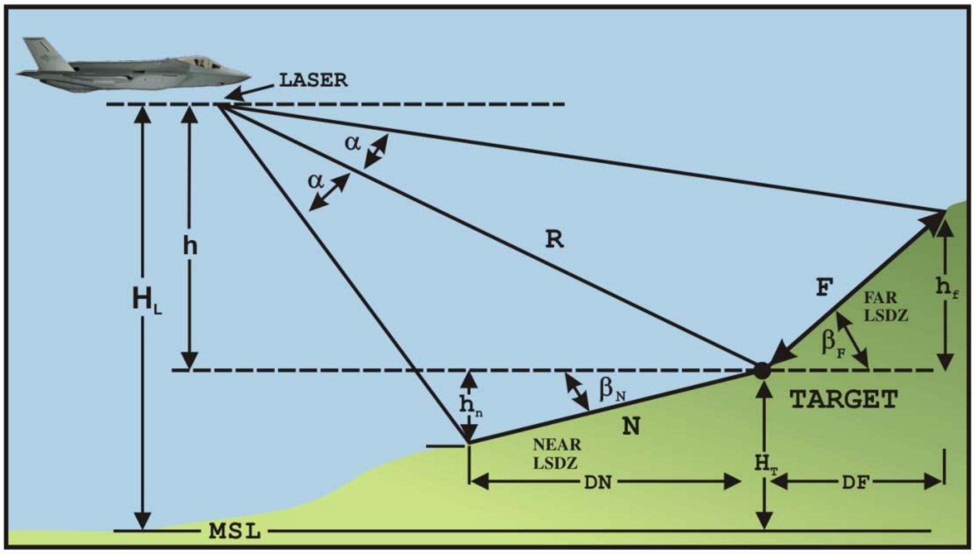


FIGURE C-7. LSDZ with rising terrain.

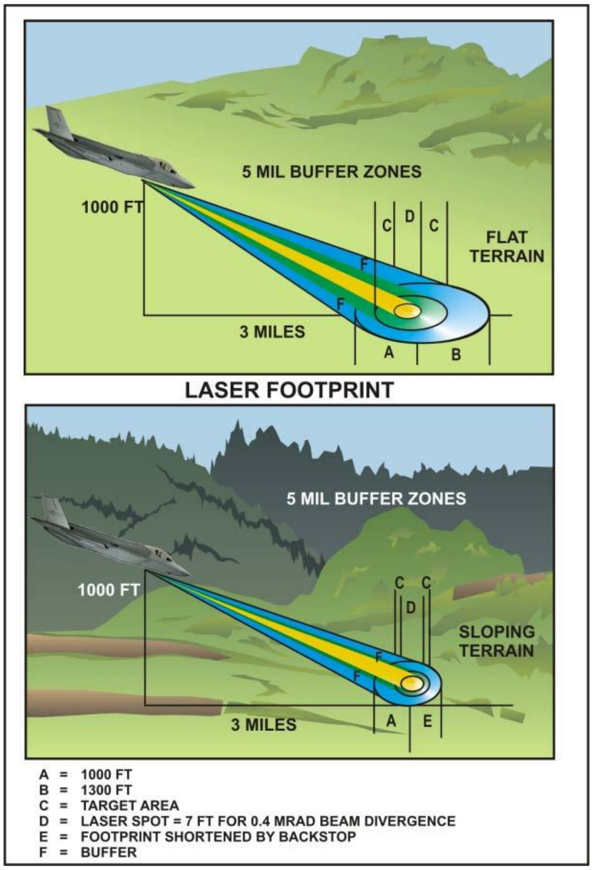


FIGURE C-8. Natural backstops to control laser beam.

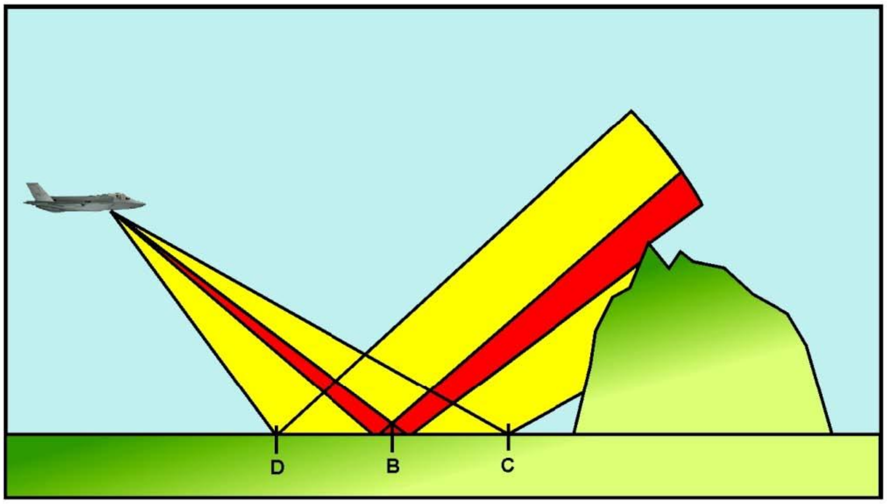


FIGURE C-9. Insufficient backstop to control laser beam.

C.5.4.2. Falling Terrain in Target Area or Hills in Foreground. This condition will result in longer forward buffered footprints and more restrictive conditions. The height, MSL, or above ground level (AGL) of the laser in reference to the target must be determined for all distances between the laser and target. The downward sloping ground beyond the target can greatly extend the forward footprint as shown in FIGURE C-10 and FIGURE C-11. If flight profiles are not limited, the forward footprint could be as long as the NOHD.

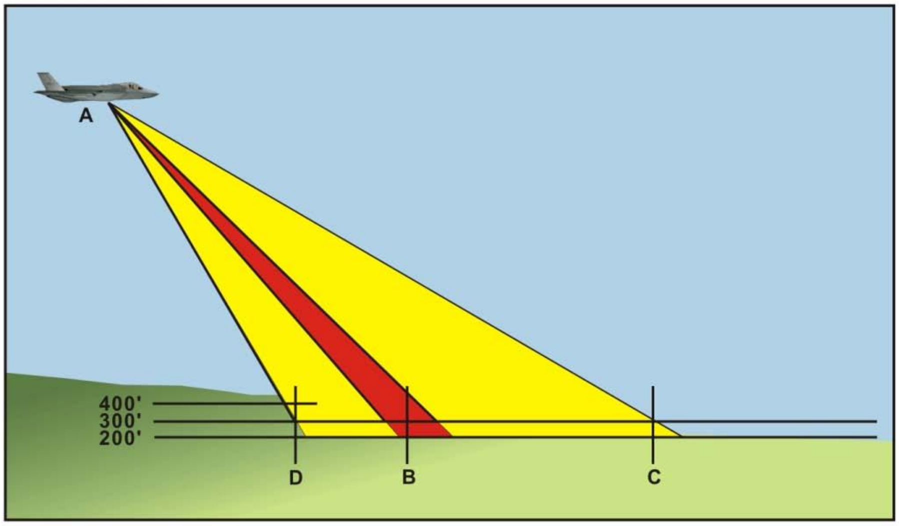


FIGURE C-10. LSDZ with terrain sloping down. Range is less than NOHD.

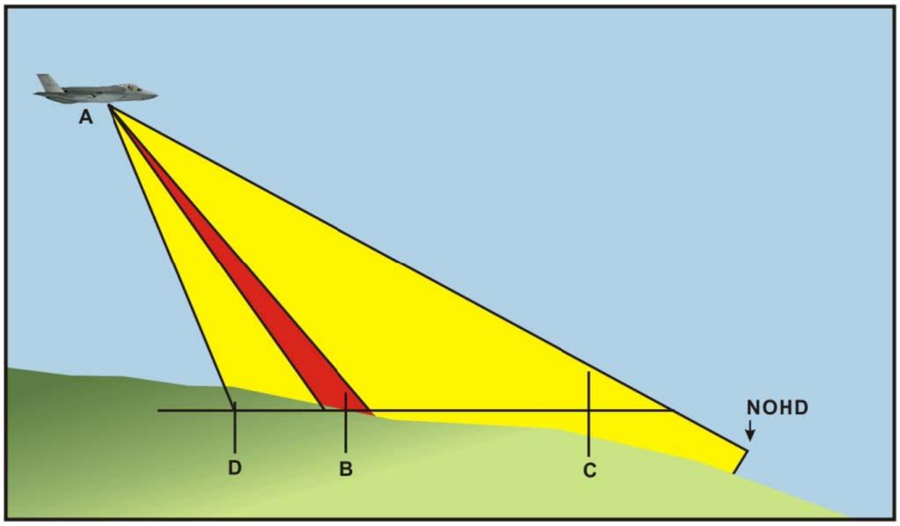


FIGURE C-11. LSDZ with Terrain sloping down. Range is greater than NOHD.

C.6. SPECULAR REFLECTIONS. Determine if the reflection from still water can enter uncontrolled air space or hit a hill or ship's structure within the NOHD and beyond the restricted boundaries (see FIGURE C-12. Reflections from still water with LDZ.). If this or other specular reflectors appear to be a problem, limit the flight profiles, move the target, or restrict more land or airspace. If still water cannot be avoided or flat specular reflecting surfaces in the area of the footprint cannot be removed, then the aircrew, personnel in other aircraft, ground and shipboard personnel, and the surrounding community need to be considered.

If the reflectivity of the specular surface is known, the effective NOHD (distance from laser to reflector plus distance of reflected beam to end of hazard zone) can be reduced by (approximately) the square root of the reflection coefficient. For each altitude of the aircraft and distance from the specular reflector, a new sphere or linear distance must be calculated for the specular reflection into the surrounding area or air space. Use the worst case results.

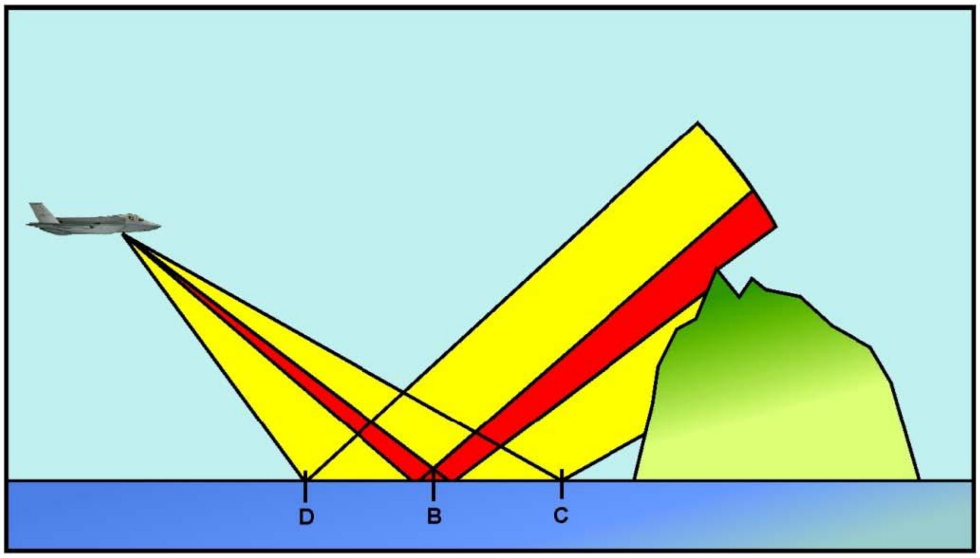


FIGURE C-12. Reflections from still water with LDZ.

C.7. AIRCREW. Present policy for most services requires aircrews to wear laser protective eye wear when aircraft are flying in multiple ship formations, targets are not clear of specular surfaces, or ground based lasers are used against aircraft. If the target area is not clear of specular surfaces, and the aircrews lase from distances less than one half the NOHD, aircrews are at risk of eye damage if laser protective eyewear is not used. Possible exposure situations to aircrews from specular reflectors are shown in FIGURE C-13 and FIGURE C-14.

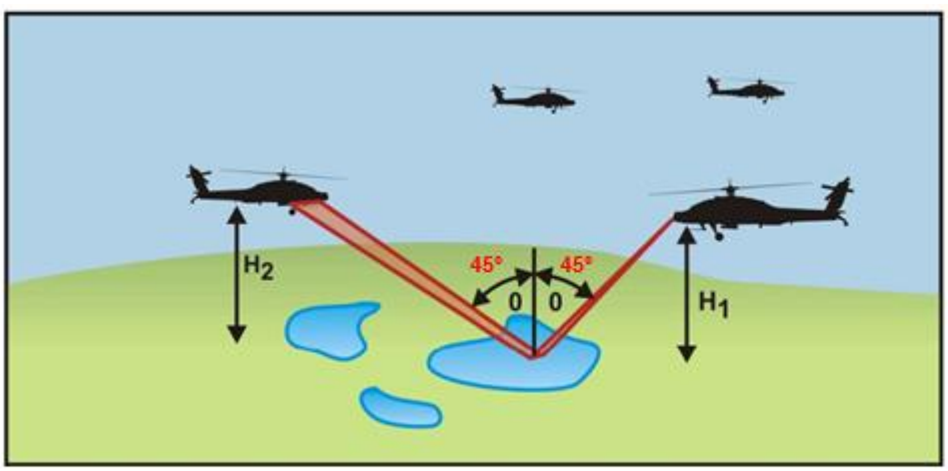


FIGURE C-13. Example of airborne laser beam reflection.

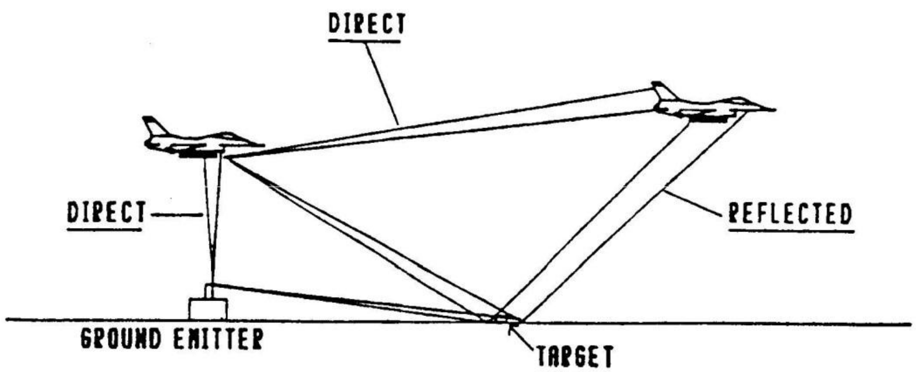


FIGURE C-14. Potential exposure modes.

C.8. GROUND PERSONNEL, SHIPBOARD PERSONNEL, OTHER AIRCRAFT, AND SURROUNDING COMMUNITY. If flat specular surfaces are near the target, the laser beam can be redirected in any direction as shown in FIGURE C-15 and FIGURE C-16. The LSDZ should then be extended to a hemisphere or portion of a hemisphere with a distance from the specular reflector equal to the NOHD minus the minimum lasing distance from the laser to specular reflector. As with the cases described previously, natural backstops and terrain may alter the shape of this area. Airspace over the range, personnel on ships superstructure, or land based high structures may be at an unacceptable risk.

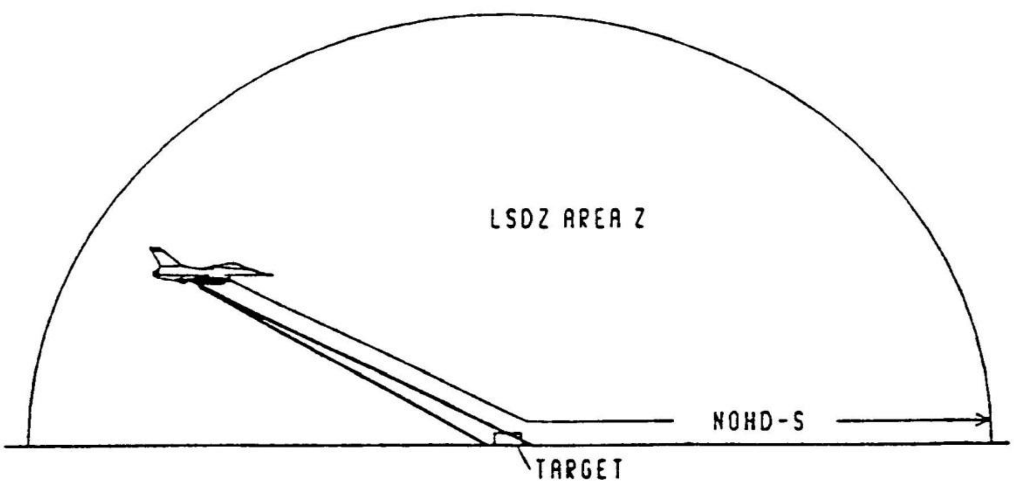


FIGURE C-15. Reflections from flat specular surface – side view.

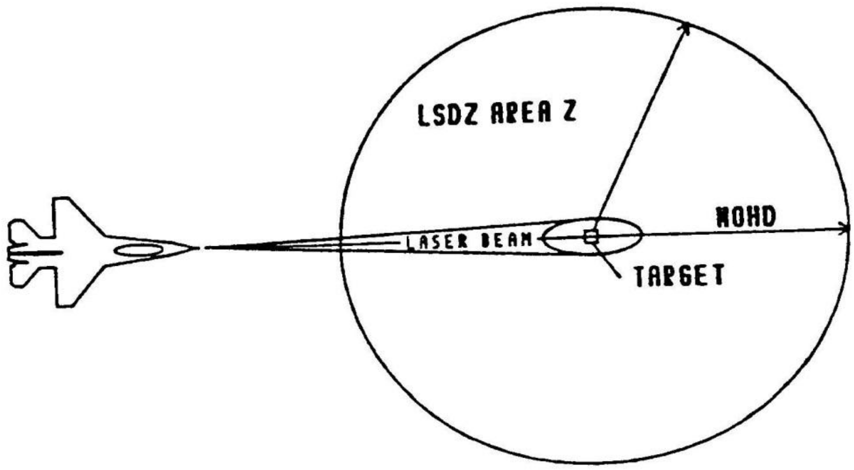


FIGURE C-16. Reflections from flat specular surface – top view.

C.9. FOOTPRINT DETERMINATIONS. If the range is small and is the controlling factor, ascertain the flight profiles from the land size by:

a. Determining the desired target location,

b. Outlining the controllable restricted range area,

c. Measuring distance from target to range boundaries, and

d. Using footprint tables or calculate flight profiles which would not cause the LSDZ to exceed the range boundaries.

For both ground based lasers and airborne lasers, the problem can be broken into two constraints:

a. The buffered footprint does not exceed the available controlled area between the target and the laser (near boundary)

b. The buffered footprint does not exceed the available controlled area beyond the target (far boundary).

C.9.1. Ground Based Lasers. Determine the ability to keep the buffered laser footprint vertically and horizontally within the restricted boundaries.

C.9.1.1. Vertical Buffer Far Boundary. Addressing the far boundary constraint first, FIGURE C-17 illustrates the geometry of the problem. First determine the available buffer above and below the target out to the edge of the backstop, where:

α = buffer angle plus beam divergence on either side of the laser line of sight (LOS). The beam divergence is extremely small compared to the buffer angle, so the beam divergence may be ignored.

δ = available vertical buffer angle between laser LOS to target and laser LOS to backstop.

h = altitude of laser

a1 = altitude of far target

bl = altitude of far boundary

dl = horizontal distance on surface from laser to furthest target

A = distance from target to far boundary of LSDZ (backstop)

The angle δ may be calculated from

$$\delta = \arctan((b1 - h)/(d1 + A)) + \arctan((h - a1)/(d1))$$

As long as the angle δ remains greater than angle α, the beam is safely contained vertically within the designated LSDZ.

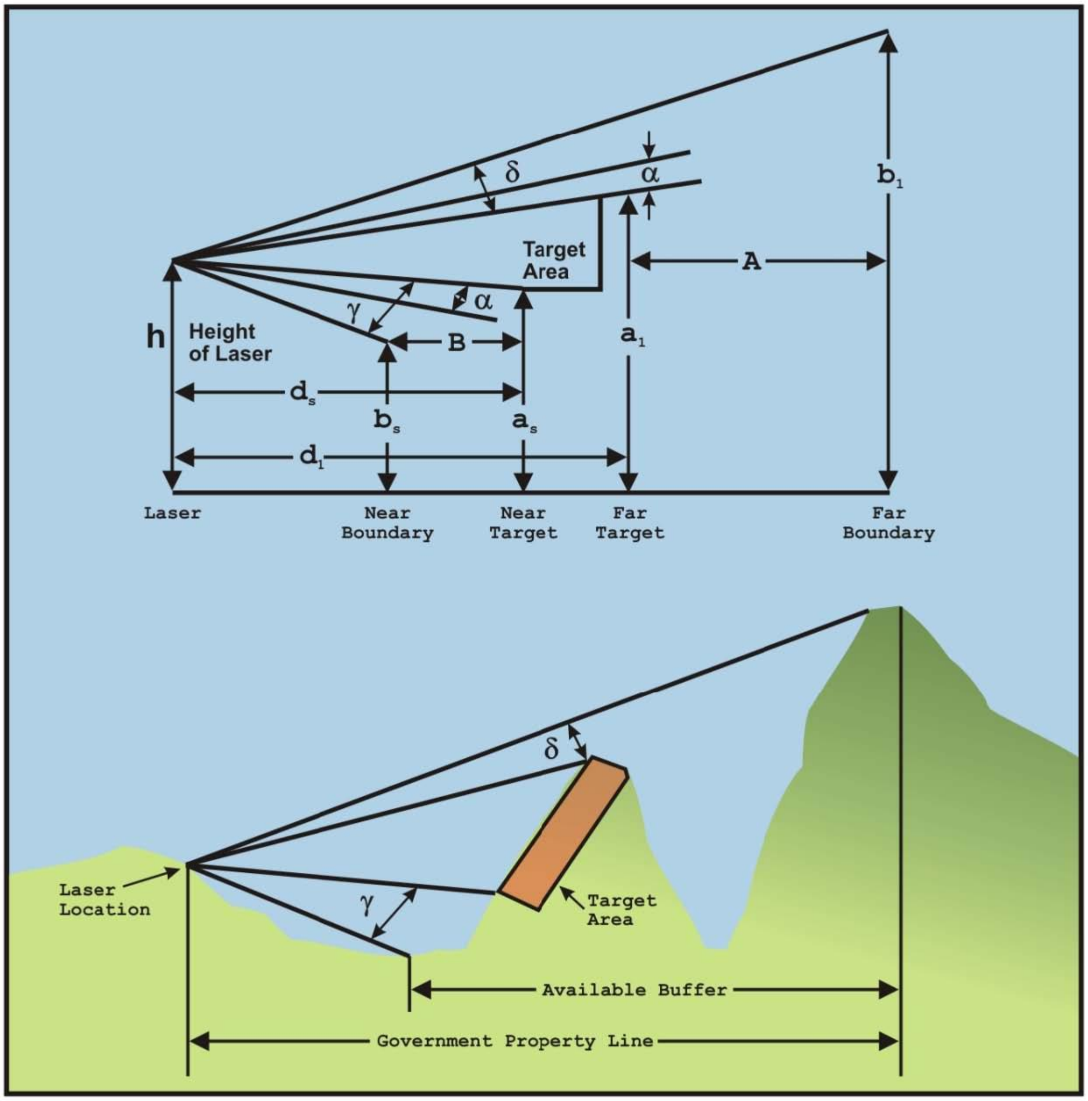


FIGURE C-17. LSDZ geometry and vertical buffer.

C.9.1.2. Vertical Buffer Near Boundary. Similarly for the near boundary:

α = buffer angle plus beam divergence on either side of the laser LOS. The beam divergence is extremely small compared to the buffer angle, so the beam divergence may be ignored.

γ = vertical angle from either side of the laser, LOS to the near edge of LSDZ (backstop) between the laser and the target.

h = altitude of laser.

as = altitude of nearest target.

bs = altitude of near boundary.

ds = horizontal distance on surface from laser to nearest target.

B = distance from target to near boundary of LSDZ (backstop).

The vertical angle γ may be calculated from

$$\gamma = \arctan((h-bs)/(ds-B)) + \arctan((as-h)/ds))$$

As long as the angle γ remains greater than the angle α, the beam is safely contained vertically within the designated LSDZ.

C.9.1.3. Horizontal Buffer. Available buffer to the left and the right of the target out to the backstop may be calculated as follows: (See FIGURE C-18.)

AB = arctan((FPN-EBN)/(FPE-EBE)) - arctan((FPN-TN)/(FPE-TE)) where:

AB = available buffer angle in radians left and right of target out to the backstop.

FPN = laser firing position north coordinate in meters

EBN = edge of backstop north coordinate in meters

FPE = laser firing position east coordinate in meters

EBE = edge of backstop east coordinate in meters

TN = edge of target north coordinate in meters

TE = edge of target east coordinate in meters

As long as the angle AB is greater than angle α and is negative for the right edge of the backstop and positive for the left edge of the backstop, the beam is safely contained horizontally within the designated LSDZ.

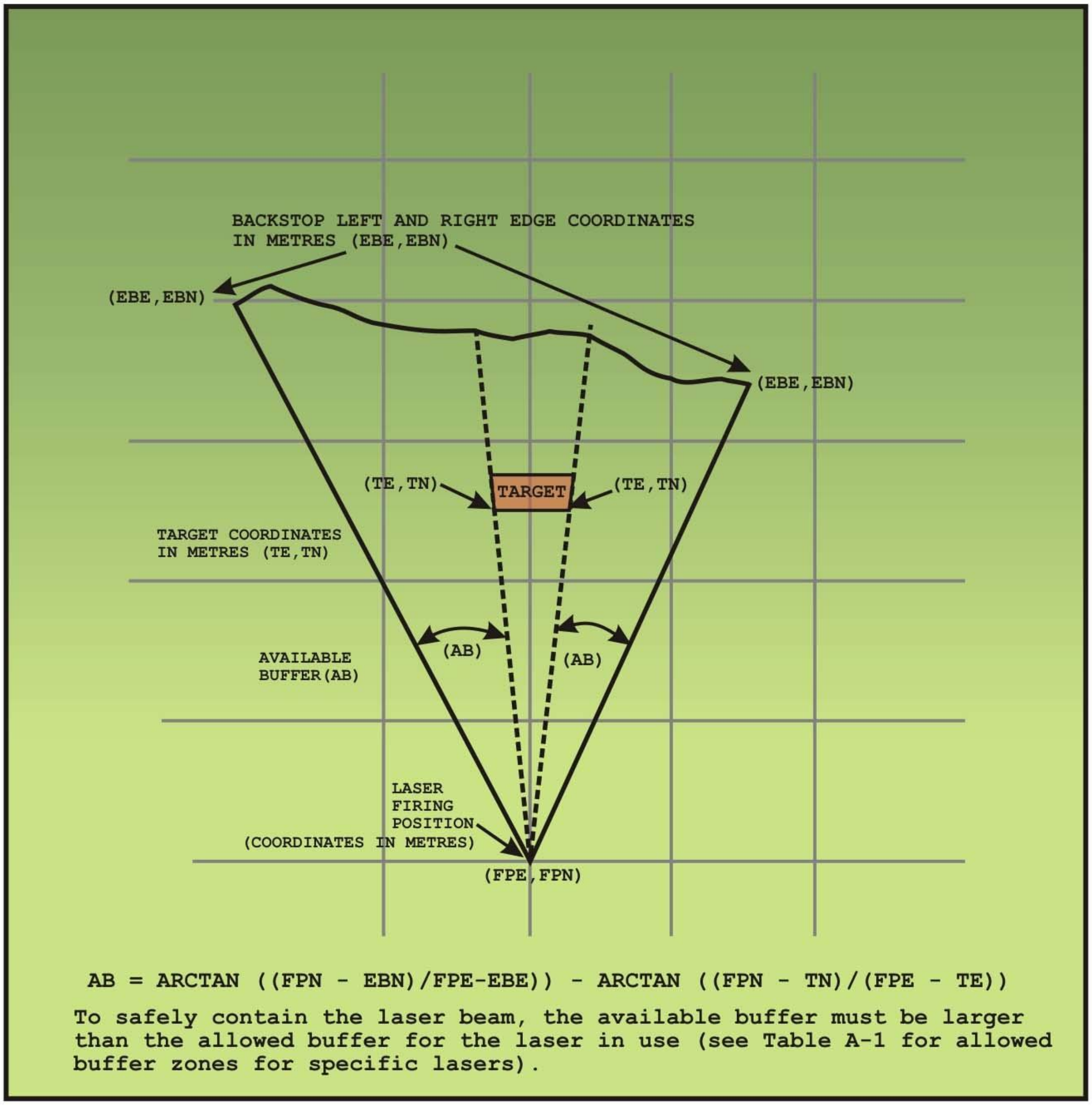


FIGURE C-18. Calculation of available buffer versus allowed buffer.

C.9.2. Airborne Laser with Target on Level Ground. For airborne laser buffer geometry at ground level, see FIGURE C-19.

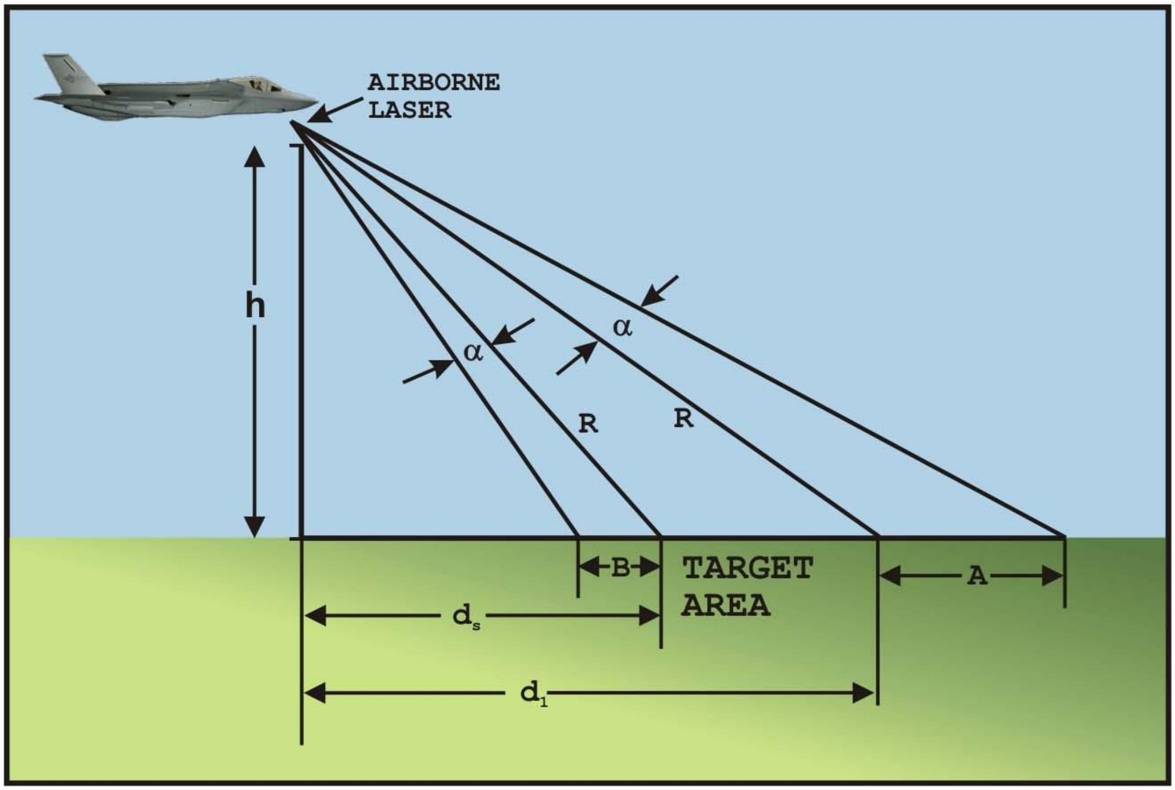


FIGURE C-19. Airborne laser buffer geometry – level ground.

C.9.2.1. Aircraft Minimum Altitude. The minimum laser altitude (h) relative to the target to keep buffered laser footprint within the far boundary when at slant range (R) from target is:

$$h = R\sin(\arcsin((R/A)\sin(\alpha)) + \alpha)$$

The minimum altitude relative to target to keep buffered laser footprint within the near boundary when at slant range R from target is:

$$h = R\sin(\arcsin((R/B)\sin(\alpha)) - \alpha)$$ where:

R = slant range from laser to target

α = buffer angle plus beam divergence either side of laser LOS. The beam divergence is extremely small compared to the buffer angle and hence the beam divergence may be ignored.

A = distance from target to far boundary of LSDZ

B = distance from target to near boundary of LSDZ

h = altitude of laser relative to target surface

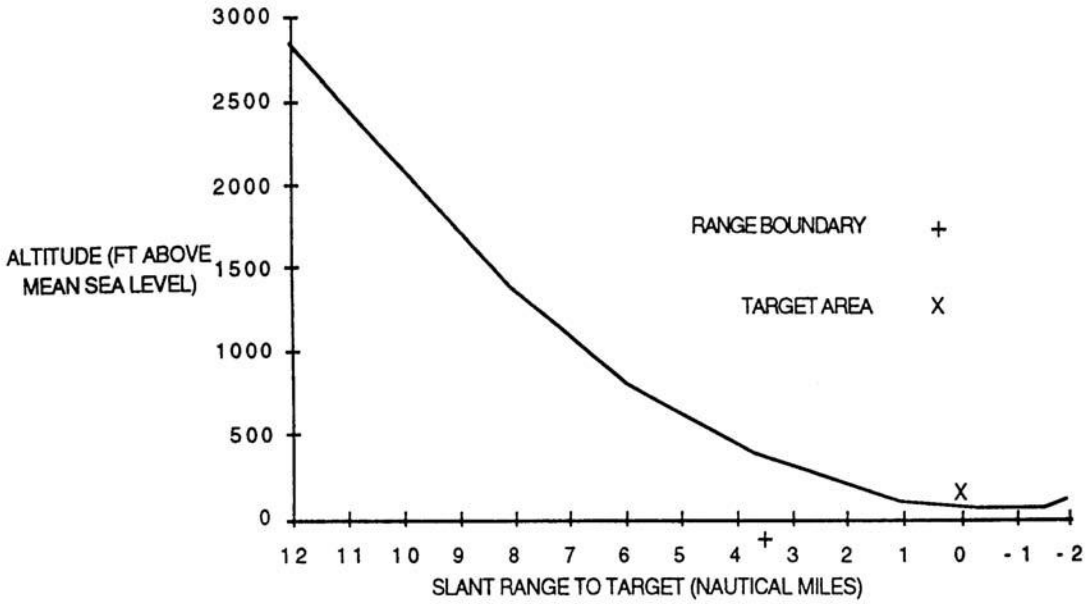
HL = altitude of laser above Mean Sea Level

HT = height of target above Mean Sea Level

Choose whichever h is the higher number and assign it as the safe altitude for lasing at range R. If altitude is altitude above mean sea level then the required laser altitude is:

HL = h + HT

Repeat this calculation for every nautical mile (or fraction of a mile depending on the risk) starting at about 12 nautical miles up to and beyond the target. Then plot the results. Remember as you pass over the target that the far and near boundary definitions reverse. A typical flight profile is plotted in FIGURE C-20.



SLANT RANGE TO TARGET nmi	MINIMUM LASING ALTITUDE ft MSL
12	2850
11	2500
10	2100
9	1750
8	1400
7	1100
6	850
5	650
4	450
3	300
2	150
1	100

SLANT RANGE FROM TARGET nmi	MINIMUM LASING ALTITUDE ft MSL
0	10
- 1	50
- 2	112

FIGURE C-20. Example laser aircraft flight profile.

C.9.2.2. Left and Right Hand LSDZ. The width of the right hand and left hand LSDZ width (see Figure C-3) are calculated as:

$s = R \times \alpha$

s = left hand LSDZ width or right hand LSDZ width

R = slant range from laser to target

α = assigned buffer angle plus beam divergence on either side of the laser LOS. The beam divergence is small compared to the buffer angle and may be ignored.

C.9.2.3. Airborne Laser with Target on Sloping Ground. Altitudes to keep buffered laser footprint within near or far boundary LSDZ can be calculated as:

Buffered Footprint. See FIGURE C-21.

HT = altitude of target above mean sea level

h = altitude of laser above target

HL = altitude of laser above mean sea level = h + HT

hn = height of near boundary above or below target

hf = height of far boundary above or below target

DN = horizontal distance from target to near boundary

DF = horizontal distance from target to far boundary

N = slant range distance from near edge of near target to edge of near boundary = square root of the sum of the squares of hn and DN

F = slant range distance from far edge of far target to edge of far boundary = square root of the sum of the squares of hf and DF

βF = declination or elevation angle from horizontal between edge of far target and edge of far boundary = arctan(hf/DF) (positive number for far boundary higher than the target and negative number for far boundary lower than target)

βN = declination or elevation angle from horizontal between edge of near target and edge of near boundary = arctan(hn/DN) (positive number for near boundary lower than target and negative number for near boundary higher than target)

hn = height of near boundary above or below target

R = slant range from laser to target

α = assigned buffer angle plus beam divergence.

For Far Target

$$h = R\sin(\arcsin((R/F)\sin(\alpha)) - \beta F + \alpha) \text{ and}$$

$$HL = R\sin(\arcsin((R/F)\sin(\alpha)) - \beta F + \alpha) + HT$$

For Near Target

$$h = R\sin(\arcsin((R/N)\sin(\alpha)) - \beta N - \alpha) \text{ and}$$

$$HL = R\sin(\arcsin((R/N)\sin(\alpha)) - \beta N - \alpha) + HT$$

Choose whichever h is the higher number and assign it as the safe altitude for lasing at range R. Repeat this calculation for every nautical mile (or fraction of a mile depending on the risk) starting at about 12 nautical miles up to and beyond the target. Then plot the results. Remember as you pass over the target that the far and near boundary definitions reverse. A typical flight profile is plotted on FIGURE C-20.

Left and Right Hand LSDZ. The width of the right hand and left hand LSDZ are calculated as:

$s = R \times \alpha$

s = left hand LSDZ width or right hand LSDZ width

R = slant range from laser to target

α = assigned buffer angle plus beam divergence on either side of the laser LOS. The beam divergence is small compared to the buffer angle and may be ignored.

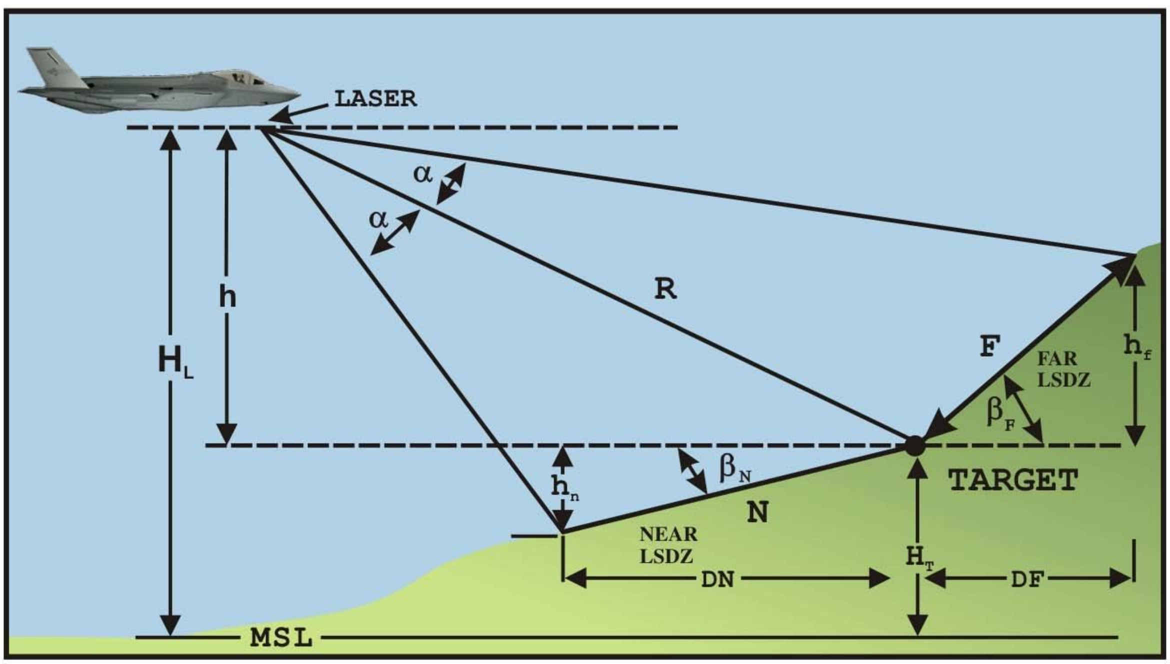


FIGURE C-21. Laser target on sloping terrain.

CONCLUDING MATERIAL.

Custodians:
Army – AR
Navy – EC
Air Force – 10

Preparing Activity:
Navy – EC
SAFT-2011-004

Reviewer:
Marine Corps – MC

Civil Agencies:
FAA

Industry Associations
AIA, ASTM, EIA, SAE

The activities listed above were interested in this document as of the date of this document. Since organizations and responsibilities can change, you should verify the currency of the information above using the ASSIST Online database at https://assist.daps.dla.mil."