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DEPARTMENT OF DEFENSE HANDBOOK

RANGE LASER SAFETY

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FOREWORD

1. This handbook is approved for use by all Departments and Agencies of the Department of Defense.

2. This handbook provides uniform guidance for the safe use of military lasers and laser systems on Department of Defense (DoD) ranges. Each military service has previously established normal procedures for approving laser ranges and has 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 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.

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

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

5. This handbook applies to laser systems with optical radiation emission in the wavelength range of 100 nanometers to 1 millimeter, pulsed and continuous wave systems.

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

7. This handbook applies to all hazard categories or hazard classifications defined by ANSI Z136.1, American National Standard for Safe Use of Lasers, and IEC 60825-1, Safety of Laser Products.

8. The intent is for this document to provide sufficient guidance for laser system use on a laser range.

9. Comments, suggestions, or questions on this document should be addressed to Marine Corps Systems Command, 2000 Lester Street, Quantico, VA 22134 ATTN: SIAT-SE-STDS or emailed to USMC_STDZ@usmc.mil. Since contact information can change, you may want to verify the currency of this address information using the ASSIST Online database at https://assist.dla.mil.

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1. SCOPE

1.1 Scope. This handbook contains general and detailed guidance to be followed in evaluating and recommending range laser safety procedures which are intended to serve as a guide to the safe use of laser systems on military operational training and test ranges. The handbook is for guidance only and cannot be cited as a requirement.

1.2 Application. This handbook applies to all ranges where service approved laser systems are employed or research and development lasers are being evaluated. The handbook addresses the roles of several levels of authority including institutional, installation, and unit, and subsequent positions of laser safety responsibility within the services.

This document is applicable to all Department of Defense (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 information and methodologies in accordance with STANAG 3606.

Suggestions for any change, revision, or cancellation of this handbook are to be submitted through the DoD Laser System Safety Working Group.

2. APPLICABLE DOCUMENTS

2.1 General. The documents listed below are not necessarily all of the documents referenced herein, but are those needed to understand the information provided by this handbook.

2.2 Government documents.

2.2.1 Specifications, standards, and handbooks. The following specifications, standards, and handbooks form a part of this document to the extent specified herein.

INTERNATIONAL STANDARDIZATION AGREEMENTS

ARSP-4 - Laser Safety for Military Use

STANAG 3606 - Laser Safety for Military Use

DEPARTMENT OF DEFENSE STANDARDS

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

(Copies of these documents are available online at http://quicksearch.dla.mil/.)

2.2.2 Other Government documents, drawings, and publications. The following other Government documents, drawings, and publications form a part of this document to the extent specified herein.

BUREAU OF MEDICINE AND SURGERY (BUMED)

BUMEDINST 6470.23 - Medical Management of Non-Ionizing Radiation Casualties

(Copies of this document are available online at www.med.navy.mil.)

CODE OF FEDERAL REGULATIONS (CFR)

21 CFR 1040 - Performance Standards for Light-Emitting Products

(Copies of this document are available online at www.ecfr.gov.)

DEPARTMENT OF DEFENSE ISSUANCES

DoDI 6055.15	-	DoD Laser Protection Program

(Copies of this document are available online at www.dtic.mil/whs/directives/.)

DEPARTMENT OF THE NAVY ISSUANCES

OPNAVINST 5100.27/ MCO 5104.1	-	Navy Laser Hazards Control Program
SECNAVINST 5100.14	-	Military Exempt Lasers

(Copies of these documents are available online at http://doni.documentservices.dla.mil/default.aspx.)

FEDERAL AVIATION ADMINISTRATION (FAA)

7930.2	-	Notices to Airmen (NOTAM)

(Copies of this document are available online at www.faa.gov.)

JOINT CHIEFS OF STAFF

Joint Publication (JP) 3-09.3	-	Joint Tactics, Techniques, and Procedures for Close Air Support (CAS)

(Copies of this document are available online at http://www.dtic.mil/docs/citations/ADA429336.)

US AIR FORCE PUBLICATIONS

AFI 13-212VI	-	Range Planning and Operations
AFI 48-139	-	Laser and Optical Radiation Protection Program
AFI 91-401	-	Directed Energy Weapons Safety

(Copies of these documents are available online at http://www.e-publishing.af.mil.)

US ARMY PUBLICATIONS

AR 385-10	-	The Army Safety Program
AR 40-5	-	Preventive Medicine
DA PAM 385-24	-	The Army Radiation Safety Program
DA PAM 385-40	-	Army Accident Investigations and Reporting
DA PAM 385-63	-	Range Safety
TB MED 524	-	Occupational and Environmental Health: Control of Hazards to Health from Laser Radiation

(Copies of these documents are available online at http://www.apd.army.mil.)

US NAVY/MARINE CORPS PUBLICATIONS

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 3570.1	-	Range Safety

(Copies of these documents are available online at https://rtam.tecom.usmc.mil).

2.3 Non-Government publications. The following documents form a part of this document to the extent specified herein.

AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)

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

(Copies of these documents are available online at http://webstore.ansi.org/).

3. DEFINITIONS

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

3.1 Administrative controls. A category of control measures used to eliminate hazards or reduce the degree of risk to personnel and equipment. Administrative controls reduce risks through specific actions. Administrative controls can be implemented by either local or higher authority.

3.2 Atmospheric attenuation. The reduction of energy of a laser beam due to absorption and scattering along its path by atmospheric conditions, such as smoke, haze, fog, or precipitation.

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

3.4 Laser beam divergence. The full angle increase in diameter of the laser beam with distance from the exit aperture of the laser.

3.5 Buffer angle. An angle added to the beam divergence or intended laser projection field in order to ensure a protection zone.

3.6 Buffer zone. The volume of space around a propagating laser beam defined by the buffer angle.

3.7 Controlled area. An area of occupancy or activity, where personnel/equipment are subject to control and supervision for the purpose of protection from radiation hazards.

3.8 Danger zone. An area determined by analysis of weapons characteristics and historical patterns to present risk to personnel or equipment within a designated three-dimensional space.

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

3.10 Engineering controls. A category of control measure used to eliminate hazards or reduce the degree of risk to personnel and equipment. Engineering controls use engineering methods to reduce risks by design, material selection, or substitution.

3.11 Exclusion zone. A designated area which aircraft 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 where the 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.

3.12 Flash blindness. A visual impairment during and following exposure to light of extremely high intensity, caused by blooming (saturation) of the retinal pigment, that may last for a few seconds to a few minutes.

3.13 Fratricide. The employment of friendly weapons with the intent to kill the enemy or destroy his equipment and facilities and which results in unforeseen and unintentional death, injury, or damage to friendly personnel or equipment.

3.14 Installation laser range authority. The organization that provides oversight for range laser activities at the installation level for the Navy, Air Force, and Marines is the Installation Range Laser Safety Officer. For the Army it is the Installation Range Control Officer.

3.15 Institutional laser range authority. The organization that provides oversight to range laser activities at the institutional level is the Institutional Range Laser Safety Specialist.

3.16 Laser. 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.

3.17 Laser footprint. The projection of the laser beam on the ground or target area, to include the buffer angle.

3.18 Laser-guided weapon. A weapon that electro-optically seeks reflected laser from a separate designator source 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, seeks coded laser energy reflected from the target.

3.19 Laser range. A range designated for laser systems use.

3.20 Laser range certification. An approval based on an evaluation process conducted to ensure 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.

3.21 Laser spot size. The area of a laser beams projection on a target. The laser spot size is a function of beam divergence and the distance from the laser designator to the target.

3.22 Laser spot tracker. A type of laser acquisition device, normally mounted on fixed-wing or rotary wing aircraft, used to aid visual acquisition of the target to be engaged by another weapon.

3.23 Laser surface danger zone (LSDZ). Designated area where laser radiation levels may exceed maximum permissible exposure levels, thereby requiring control during laser use. Some organizations use this term interchangeably with Nominal Hazard Zone (NHZ), which includes airspace. To minimize confusion in this document, we will refer to LSDZ generally and use NHZ when not specifically referring to surface dangers. The LSDZ is an area where unauthorized personnel and equipment are not permitted and laser Personal Protective Equipment (PPE) (eye and skin) is required for personnel who may be exposed within this area.

3.24 Laser target designator. A laser used to mark a target or to guide munitions to a target.

3.25 Laser training area (LTA). A training area in which laser systems are used.

3.26 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.

3.27 Milliradian (mrad). Unit of angular measure. One mrad equals one thousandth of a radian. One degree equals 17.45 milliradians.

3.28 Night vision goggles/devices. A nonthermal image intensification device used to enhance night vision.

3.29 Nominal hazard zone (NHZ). Describes the space within which the level of the direct, reflected, or scattered radiation may exceed the applicable MPE during normal operation. Exposure levels outside the NHZ are below the applicable MPE level. The NHZ consists of the target area plus the buffer zones. The NHZ is often confined by the application of backstops. For un-terminated direct viewing this zone would extend to the Nominal Ocular Hazard Distance (NOHD).

3.30 Nominal ocular hazard distance (NOHD). NOHD is the distance from an operating laser to the point where the laser irradiance or radiant exposure is not expected to exceed the appropriate MPE. For the purpose of this document, the term NOHD is used generically such that it does not imply the use of or exclusion of magnifying optics. Terms for the hazard distance specifically associated with viewing lasers with magnifying optics include NOHD-M (magnified) and Extended Nominal Ocular Hazard Distance (ENOHD).

3.31 Ocular interruption (OI) devices. Laser systems that are used to intentionally illuminate the eyes of an individual(s) to provide a warning to them. Fielded as a non-lethal device to be used as part of the escalation of force procedures with vehicle checkpoints, entry control points, perimeter security, and convoys.

3.32 Operator-controlled laser. A laser with sufficiently short NOHD (approximately 100 meters unaided viewing and 700 meters for optically aided viewing) that the operator can effectively mitigate the hazard by controlling the use of the laser without the requirements of other control measures typically associated with higher-classed laser systems. The operator is responsible for monitoring the controlled area.

3.33 Optical density. The amount of laser protection afforded by a particular eye protection for a particular laser wavelength.

3.34 Optically aided viewing. Viewing of lasers using an optical magnifier, such as binoculars or a scope.

3.35 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.

3.36 Scatter. An effect caused by a laser beam reflecting off of particles in the air. Scatter is most pronounced at small distances from the laser source.

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

3.38 Specular reflection. A reflection of a laser beam off of smooth mirror-like surfaces causing the beam to remain coherent upon leaving the surface.

3.39 Spillover. Spillover occurs when part of the laser spot misses the intended target. This can be also termed underspill (in front of target) or overspill (beyond the target).

3.40 Standard operating procedure (SOP). Formal written description of the safety and administrative procedures to be followed in performing a specific task.

3.41 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.

3.42 Unit laser range authority. The organization that provides oversight to range laser activities at the unit level for the Navy, Air Force, and Marines is the Unit Laser Safety Officer. For the Army it is the Laser Range Safety Officer.

3.43 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. Lasers emit light in a narrow, coherent beam of energy. Due to the increased directional intensity of optical radiation generated by a laser, a concentrated optical beam is present at considerable distances which may present a hazard to personnel and equipment.

4.2 Laser system. A laser system is an assembly of electrical, mechanical, optical, and software components which includes a laser. The terms "laser", "laser system", and "laser device" are considered equivalent within this document.

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

4.2.1.1 Class 1. Class 1 laser systems pose no hazard under any normal viewing condition.

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

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

4.2.1.4 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.

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

4.2.1.5.1 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.

4.2.1.5.2 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.

4.2.1.6 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 hazard as well as a possible skin or fire hazard.

4.3 Laser range. 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, target designation, range-finding, fire control, ocular interruption, directed energy weaponry, and 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. 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.

4.4.2 Laser spot tracker. The laser spot tracker identifies the reflected laser energy from a laser designator off the target and displays the target's position on a display panel. Unless this is used with a visual verification an erroneous target could be detected (the laser designator).

4.4.3 Laser-guided weapon. A laser-guided weapon uses a laser to guide the munition to the target by illuminating the target with coded pulses of laser energy that is diffusely reflected from the target. Some laser-guided weapons require laser target designation before launch/release, during the entire time of flight, or only during the terminal portion of flight.

4.4.4 Laser marking. Laser marking involves using a laser 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 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. The laser system should be terminated if exposure distances approach the NOHD of the system (known and briefed prior to use).

4.5 Laser operations. Laser operations involve employment of a laser system to use a weapon, acquire a target for illumination, pointing, target designation, weapon guidance, range-finding, communication, or to provide ocular interruption. These laser systems may be mounted on a platform, a weapon, or they may be hand-held. Laser operations fall into nine different engagement scenarios that are detailed below in table I.

TABLE I. Laser operations engagement scenarios.

Ground to Ground	Air to Ground
Ground to Air	Air to Air
Ground to Surface	Air to Subsurface
Subsurface to Ground	Subsurface to Air
Subsurface to Subsurface	

4.5.1 Force-on-force laser operations. These operations involve combat simulation, target acquisition, illumination, pointing, target designation, weapons guidance, or range-finding against friendly 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, such as light striking a surface will reflect at the same angle that it interacts with the surface.

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

4.6.2 Diffuse reflection. Reflection of a laser beam off of rough surfaces. Examples of diffuse reflectors include dry foliage, rock, camouflage, soil, matte paint, aluminum cans, paper, terrain, roadways, and old ordnance. Diffuse targets reflect light and laser energy in a hemispherical pattern centered at the point of impact (see figure 1). A diffuse surface is one that distorts (or diffuses) 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 surfaces reflect energy in all possible directions including toward the laser. A hazardous diffuse reflection can only be produced by a Class 4 laser system.

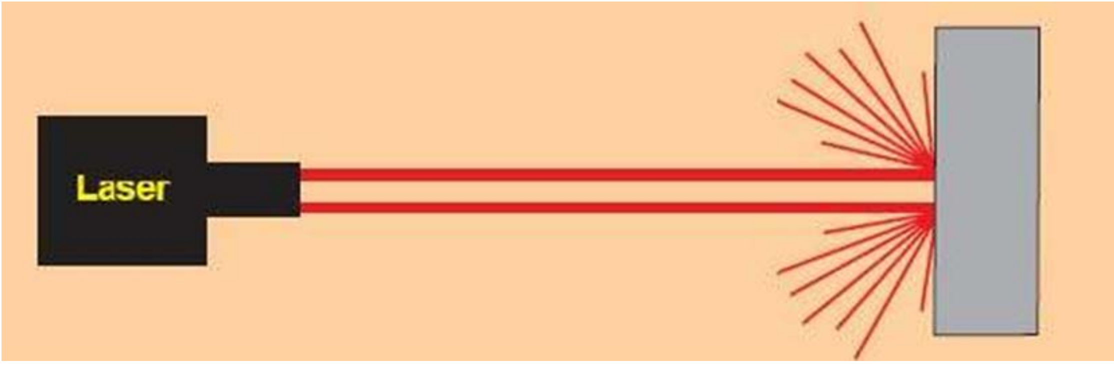


FIGURE 1. Diffuse reflection.

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).

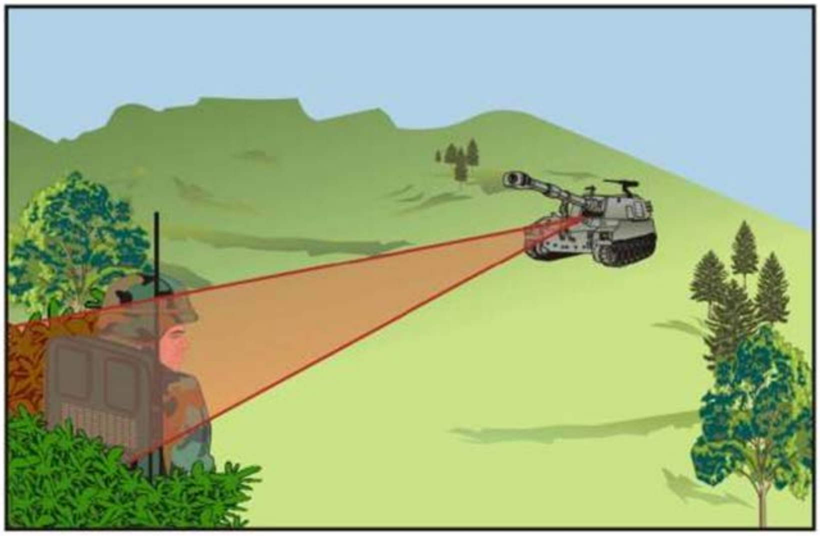


FIGURE 2. Direct intrabeam viewing.

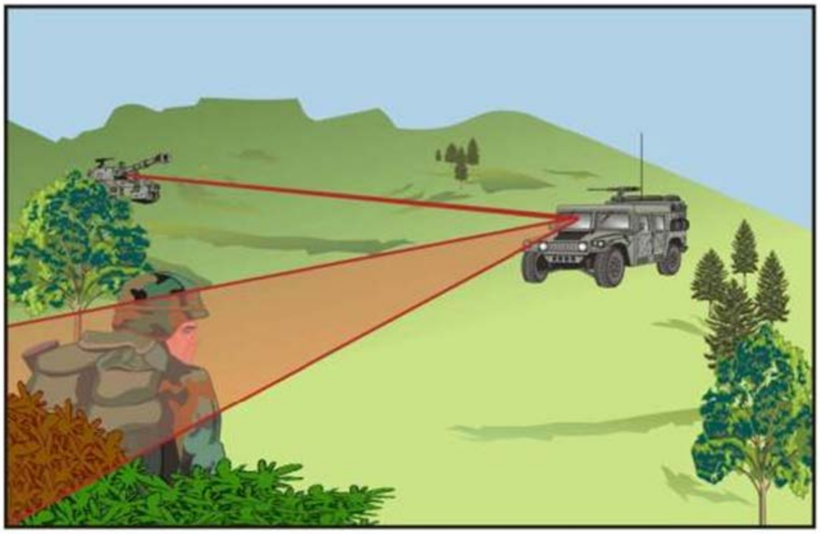


FIGURE 3. Reflected intrabeam viewing.

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

c. Direct intrabeam viewing or 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.

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 impairment during and following exposure to light of extremely high intensity, caused by blooming (saturation) of the retinal pigment, that may last for a few seconds to a few minutes.

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 operations involving laser guided munitions or other laser detectors, the detector may acquire radiation sources within the field of detection other than the target if certain precautions are not taken. If the munitions are misguided, fratricide may occur. Designated areas and tactics should be planned to ensure that scattered laser energy from the designator is not in the field-of-view of the munitions. Misdirected high energy laser beams may also have the potential to cause fratricide.

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 and diffuse reflectivity. In a laser operation involving a laser-guided weapon, the target is designated using a laser. A laser-guided weapon acquires and follows the coded diffuse reflected laser energy to strike the target. This means that the target needs to reflect sufficient laser energy for the laser seeker to lock-on. Certain materials reflect laser energy better than others. For targets with higher reflectivity, the probability of a laser seeker picking up the laser spot is increased. Table II below presents the amount of reflectivity for various types of material.

TABLE II. Amount of reflectivity.

Material	Amount (%) of Reflectivity
Olive Drab Metal (dirty)	2 – 30%
Concrete	10 – 15%
Asphalt	10 – 25%
Unpolished Aluminum	55%
Vegetation	30 – 70%
Brick	55 – 90%

5.2.1 Specular reflection. Approved laser targets should not contain specular reflective (mirror-like) surfaces unless testing or training dictates. Specular reflections can redirect the beam out of the controlled area and can result in eye or skin injury and may also damage equipment. Examples of flat specular reflectors that may be targets include flat glass, flat window, still water, instrument gauge, vehicle rear view mirror, or vision viewblocks.

5.2.1.1 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).

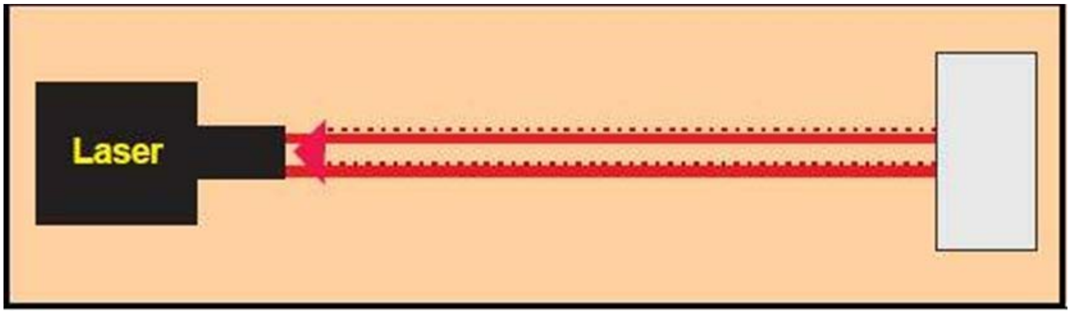


FIGURE 4. Specular (mirror-like) reflection from perpendicular surface.

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).

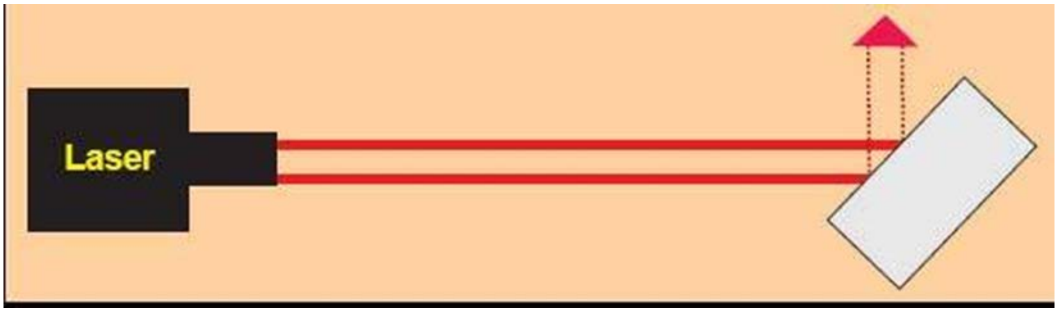


FIGURE 5. Specular (mirror-like) reflection from an angled surface.

Concave reflective surfaces can focus the reflected beam and cause the reflection to be more hazardous than the incident beam (figure 6). 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 optical sights, curved windows, vehicle bumpers, headlight assemblies, or bottles. 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.

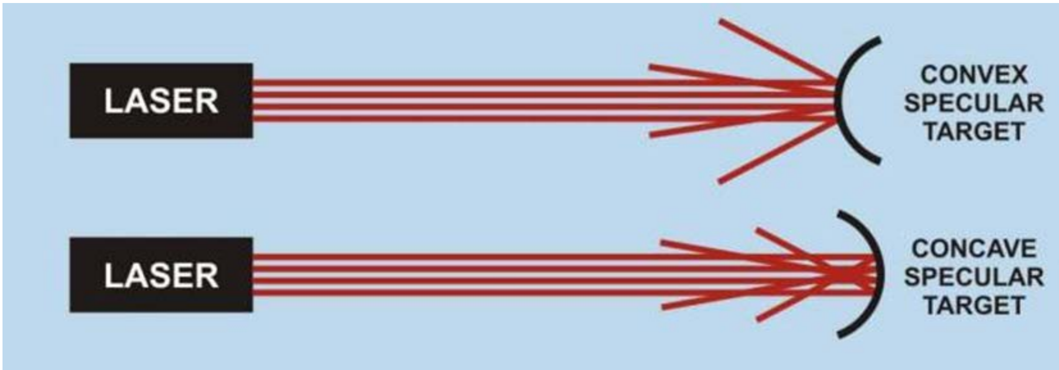


FIGURE 6. Reflection off curved specular surface.

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 meter 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).

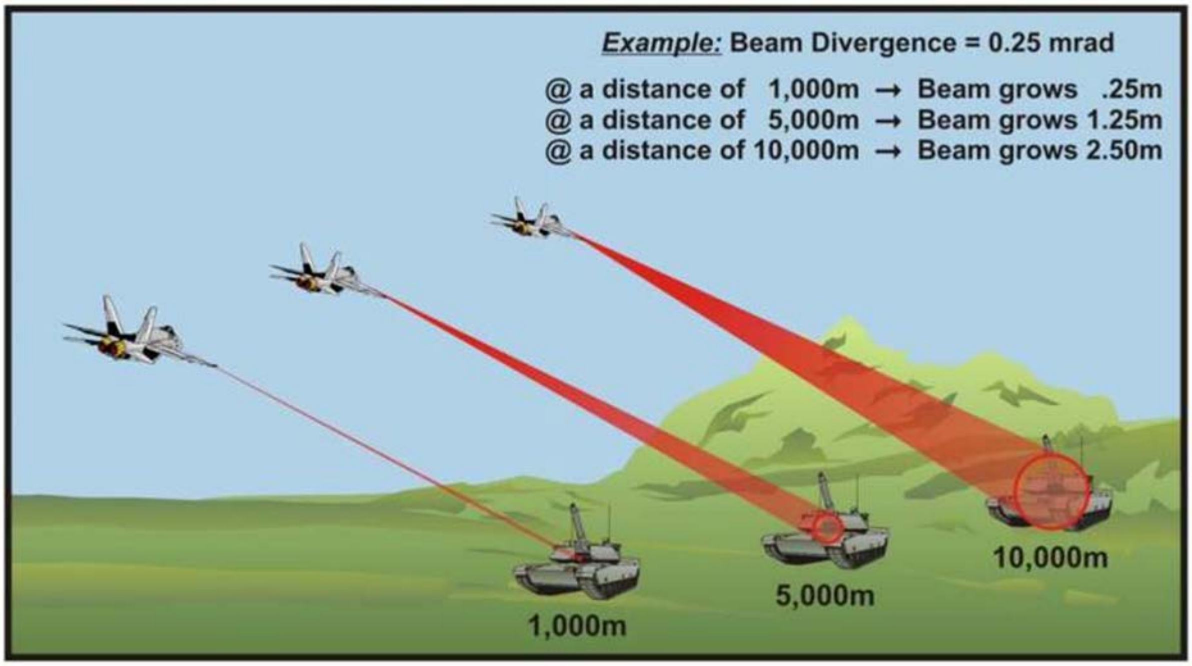


FIGURE 7. Beam divergence.

5.3.3 Spillover. Spillover occurs when some of the laser energy impacts an object other than the intended target that could potentially create 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 spillover can cause a misdirection of the weapon.

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

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

b. Targets should be located 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.

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

5.5 Target maintenance. Specular surfaces should be removed from all targets designated as laser targets prior to placement or if already in place, 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 guidance of 5.5.1 and 5.5.2.

5.5.1 Target condition. Careful attention should be paid to the condition of the target. A specular hazard can present itself upon impacts or explosions which cause target materials to break apart or from high energy laser/material interaction. Weather can deteriorate material as well. Broken or bent specular surfaces can have a flat surface remaining to generate a specular reflection. Target condition should be periodically checked by Installation Laser Range Authority personnel.

a. Specular reflectors should be covered, removed, or rendered diffuse by painting with a matte (non-specular reflecting) paint, sand-blasting, or scuffing up 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. 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. Still 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. Target area condition should be reviewed periodically as determined necessary by the Installation Laser Range Authority to eliminate or mitigate specular hazards.

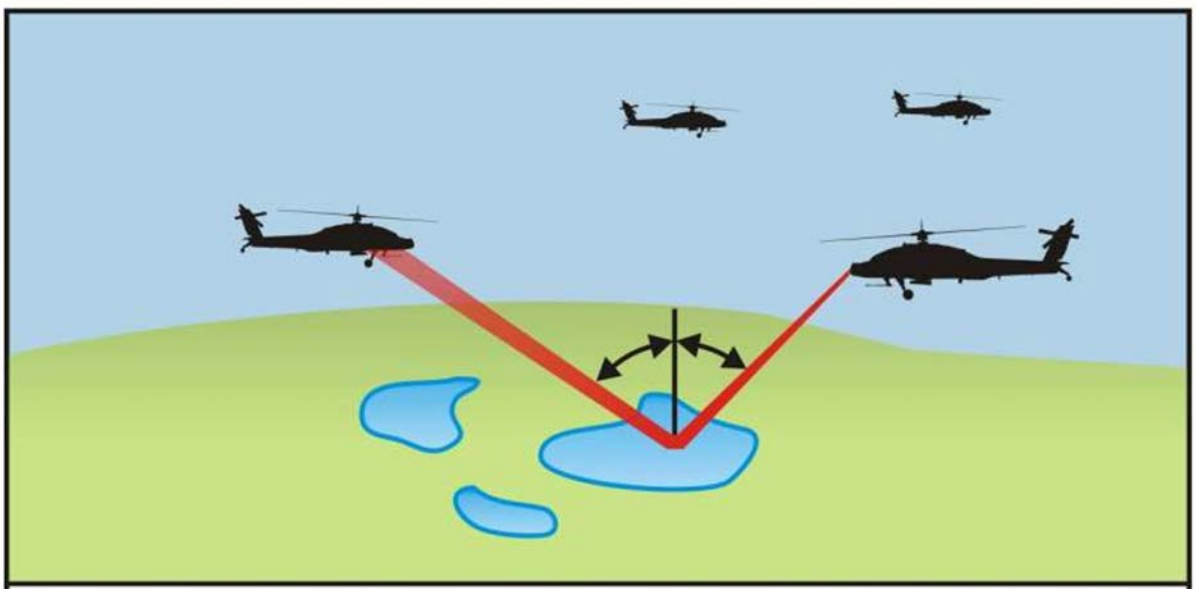


FIGURE 8. Example of airborne laser beam reflection.

a. All specular hazards should be removed or mitigated from the laser training area. If potential reflections have not been considered for the approved target area, ranges will be closed (for example, when still water is present on the ground).

b. Target location should be checked periodically by Installation Laser Range Authority personnel to ensure the location has not changed due to munitions impact. A change in target location or orientation can affect the angle of the laser beam to the target, thereby affecting the LSDZ 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 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. Lasers should be treated as direct-fire weapons. Precautions associated with direct-fire weapons should be applied to all lasers operated on military ranges.

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

c. The use of Class 3B, Class 4, or DoD exempt lasers on test and training ranges should be conducted only at installations that have been certified for the safe use of lasers in accordance with service-specific requirements. Special consideration may be given to ranges using operator-controlled lasers.

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/target areas and only from approved operating positions/areas or on designated headings and altitudes or angles and azimuths.

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 may require coordination with the applicable service airspace representative, the Federal Aviation Administration and Laser Clearinghouse (LCH) if the laser is directed above the horizon.

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

e. Non-laser activities, such as viewing through common optics, can be conducted outside of a laser controlled area by instituting procedures that ensure power to the laser is turned off.

f. When laser systems have both training and combat operating modes, the tactical mode should be employed only when the SOP authorizes.

g. Laser systems should not be employed on a range that is outside the scope of an applicable SOP (see Appendix A).

6.3 Unprotected personnel. Unprotected personnel will not be exposed to laser radiation within the LSDZ of the laser system.

6.4 Protected personnel. Personnel within the LSDZ should wear PPE during laser operations. Eye wear will 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, and rangefinders. 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 with magnifying optics. Optical devices not marked with the level of protection should be assumed to offer no protection unless verified Personnel should not view direct laser radiation with optical instruments within associated NOHD unless such instruments have appropriate laser filters in place.

6.6 Night vision devices (NVD). NVDs may be used to detect lasers. Night vision devices should not be used for laser eye protection (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 (saturated), 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, OPNAVINST 5100.27/MCO 5104.1, DA PAM 385-63/MCO 3570.1, BUMEDINST 6470.23, AFI 13-212, and AFI 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. AIRBORNE 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. Minimum lasing altitudes for the aircraft are to ensure the LSDZs are contained within constraints such as roads, observation points, or range boundaries.

7.1.1 Line of sight. An unrestricted line of sight should exist between the laser system and the target. Since lasers are line of sight, their energy will reflect off 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 such as fog or low clouds could preclude the use of laser systems when a clear line of sight cannot be obtained.

7.1.2 Atmospheric attenuation. 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.

7.1.2.1 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 to a greater degree.

7.1.2.2 How atmospheric attenuation affects laser delivery. Smoke, haze, cloud, precipitation, and fog conditions can cause a laser beam to diffuse 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.

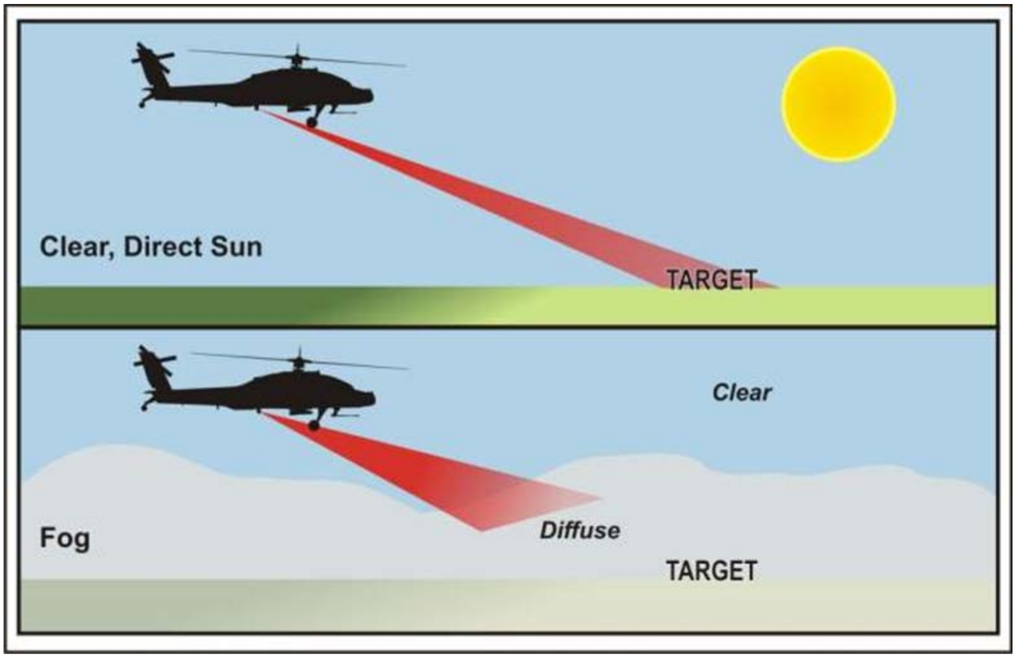


FIGURE 9. Atmospheric attenuation.

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 (see 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. Installation Laser Range Authority and unit range personnel should employ precautions to ensure the safety of personnel and equipment during a laser operation involving laser guided munitions. Consideration should be given to ensure munitions are delivered on target and not directed toward the laser designator.

7.2.1 Seeker. A seeker is a laser acquisition device. It detects laser designated targets so they can be engaged with ground, airborne, or naval weapons. In a laser operation involving a laser-guided weapon, the target is designated using a laser. A seeker acquires diffuse reflected laser energy off the target to direct the munition to that signal. 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 are set to identify the specific laser code (or Pulse Repetition Frequency [PRF]) used by the designator. A seeker can either be part of a laser guided munition or a standalone device such as a laser spot tracker.

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 are matched to the laser guided weapon's sensing system 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 view 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. Exclusion areas and tactics should be planned to ensure the angle between the laser designator line of sight and laser detectors will not mistakenly identify 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 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 will be the same.

7.2.3.2 Line of sight. An unrestricted line of sight needs to exist between designator and the target as well as between target and the seeker (see figure 10). For laser-guided weapons, line of sight is required 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.

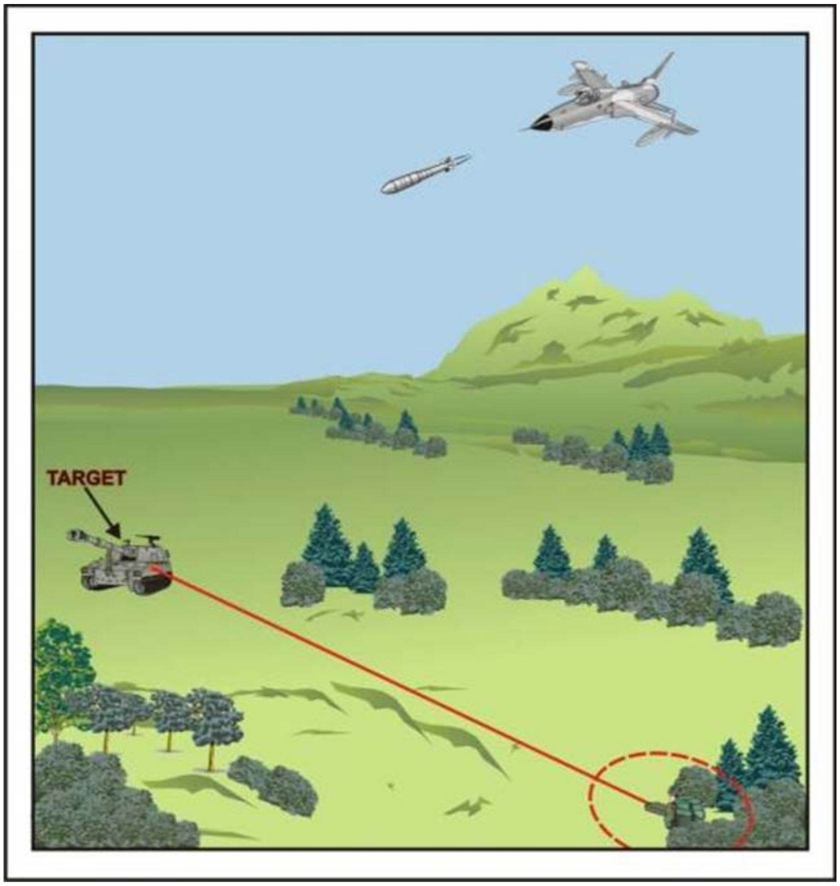


FIGURE 10. Line of sight.

7.2.3.3 Field of view. All seekers have a limited field of view and therefore should 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, preventing sufficient energy reflection from the target thus prohibiting 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. Due to these factors, the laser target designator should be set upwind of targets and the targets should be designated from the farthest downwind to the most upwind.

7.2.4 Laser designation and weapons delivery tactics. Laser-guided munitions delivery tactics may involve the same platform or multiple platforms. The platform delivering the ordnance may not be the same platform 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 allows 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.

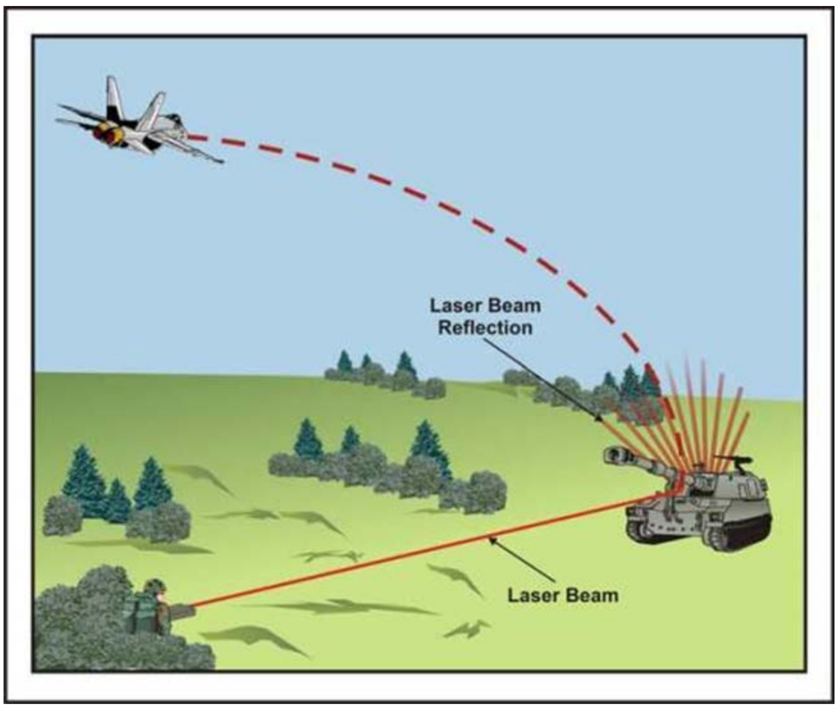


FIGURE 11. Attack heading.

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 correct target acquisition and weapons function.

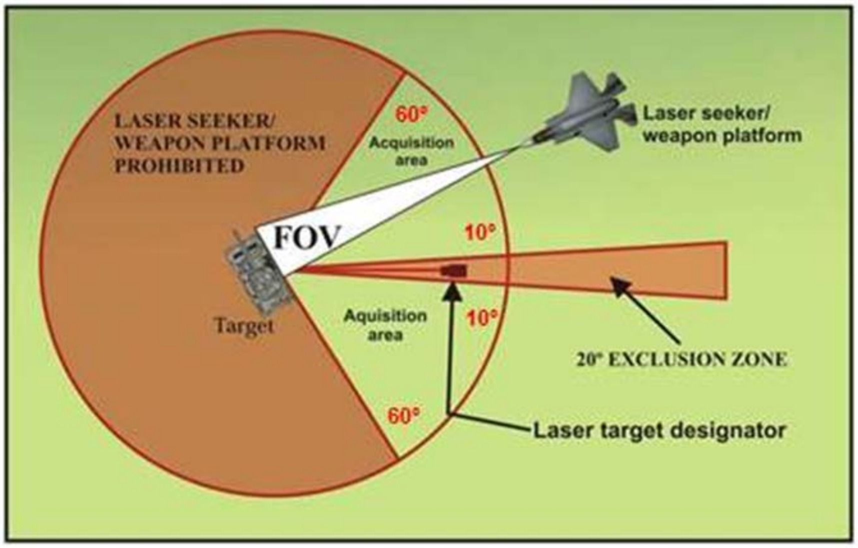


FIGURE 12. Optimal attack zone (top view)

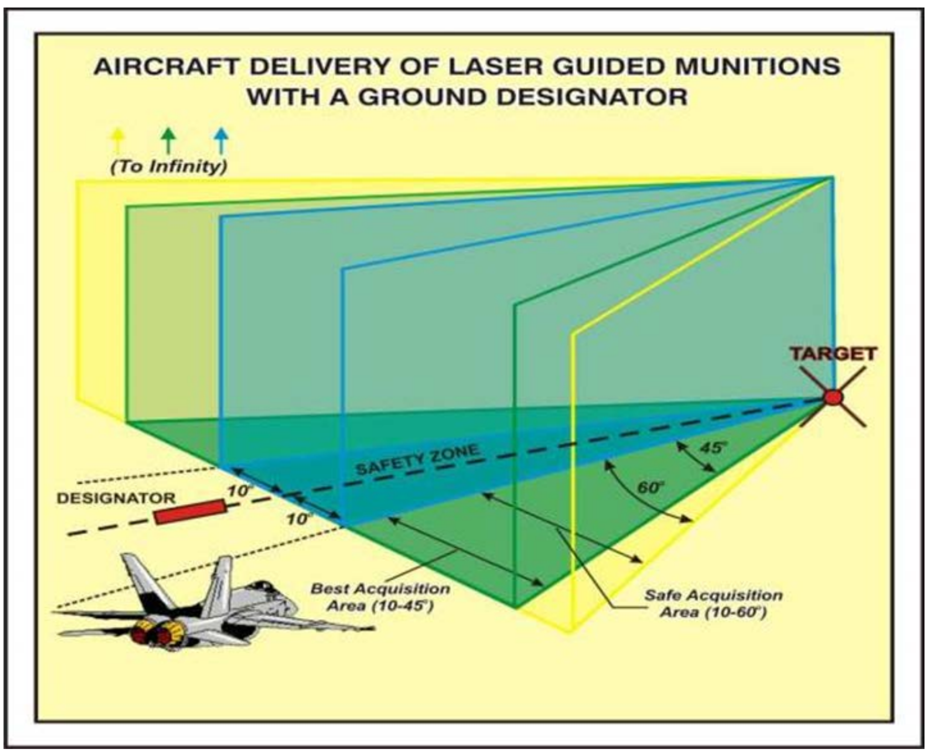


FIGURE 13. Optimal attack zone (side view).

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) on either side of the target-to-laser designator line. This zone extends vertically to infinity and has a horizontal limit of 20 degrees (see figure 14). Weapons release may occur in any area within weapons limits outside the exclusion zone that does not put the designator in jeopardy. Due to 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.

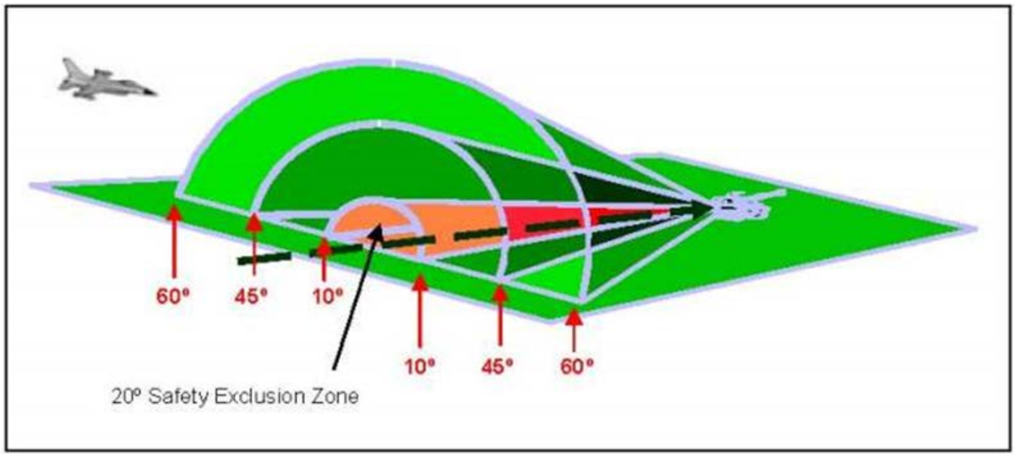


FIGURE 14. Optimal attack zone (vertical perspective).

7.2.4.2.2 Angle of attack. The degree of hazard to ground personnel and equipment 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, 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. 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 has to engage the target at the correct time and for the proper duration. The delivery system releases the weapon within the specific weapon's delivery envelope. 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. To ensure proper target identification, the laser spot cue provided in the cockpit will align with 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 has to correctly lock-on to the laser spot so the target can be accurately engaged. This applies to aerial, ground, and naval launched projectiles. Laser seekers may occasionally lock-on to other reflected energy instead of the target. Under some conditions the seeker may incorrectly lock-on to the laser target designator. 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. The laser target designator and the laser guided weapon should use 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 covers 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 do not follow the laser to the operator rather than the target (see figure 15).

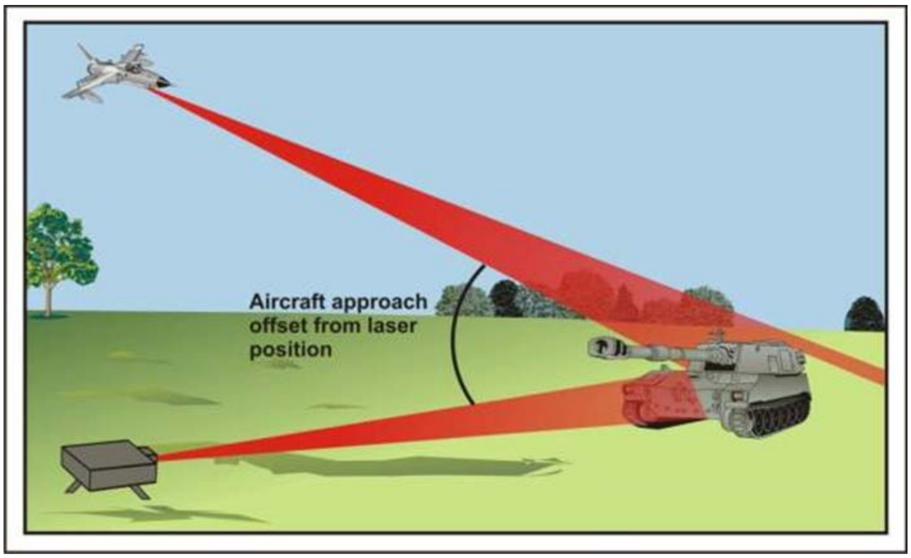


FIGURE 15. Target placement to provide offset.

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–on to 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–on to the obscurant rather than the target (see figure 16).

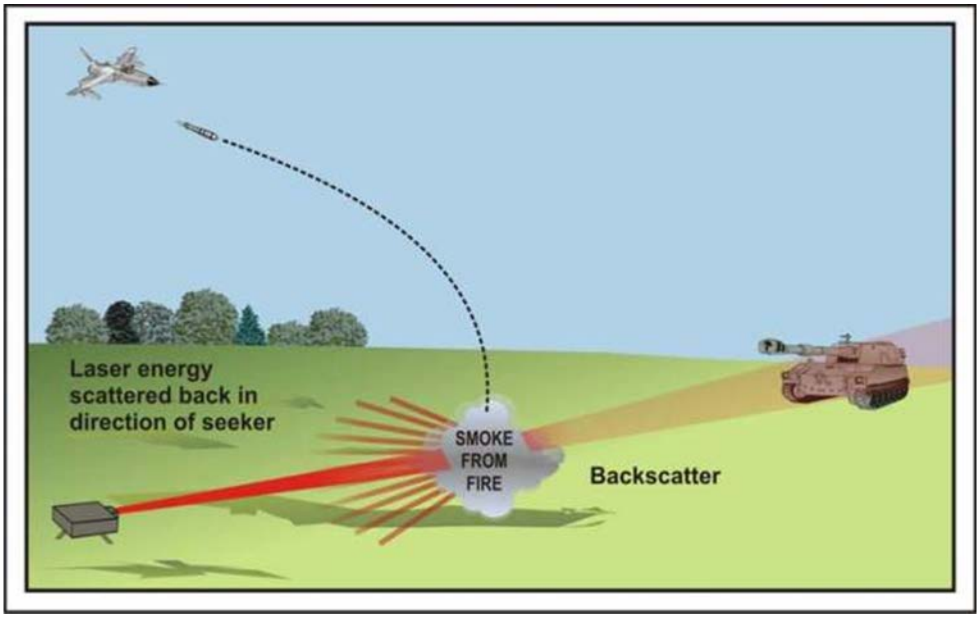


FIGURE 16. Backscatter.

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 17). 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. In general, the closer the designator is to the target the smaller the laser spot. Additionally, for airborne lasing, as the lasing aircraft gets closer to the target, the laser footprint will lessen reducing the spillover.

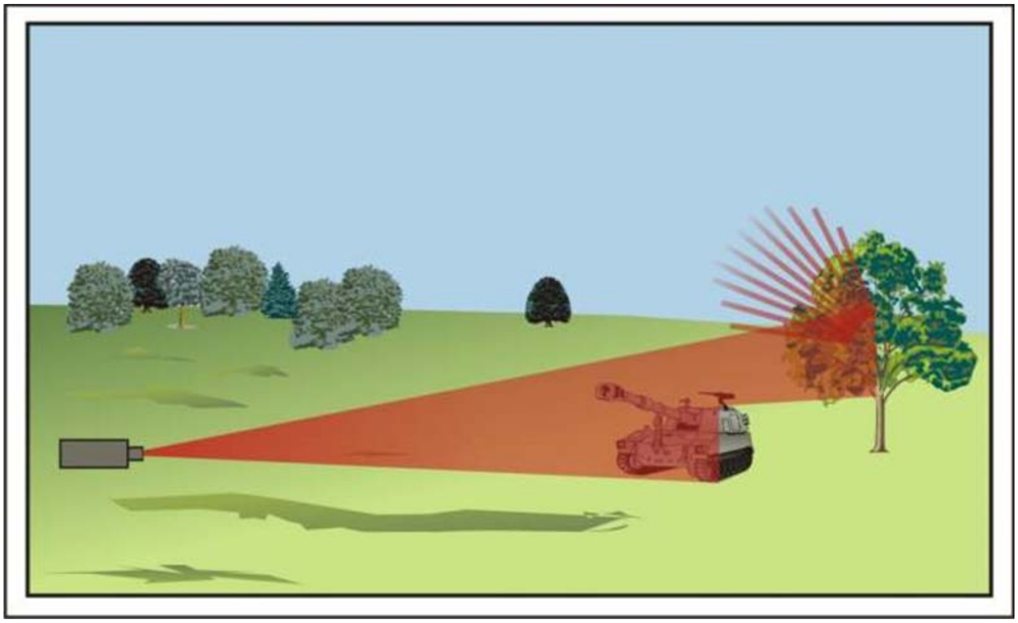


FIGURE 17. Spillover.

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–on to the scattered radiation from 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, the 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 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 phase of the laser-guided weapon profile. If it locks onto the designating aircraft, there is a high probability that it will track and impact 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 manage 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 employ 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 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 Engineering controls associated with the laser system. Control measures built into the design of the laser system are considered engineering controls. These include software, switches, interlocks, protective housing or guards, training filters, key control, beam stop, and software. For example, a training filter can attenuate the radiation level of a laser beam below the MPE limit. Laser systems should not be altered either by removing or modifying these controls (see additional information in MIL–STD–1425 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 can be used to terminate the laser beam. If no backstop is available the laser hazard is required to be controlled out to at least the NOHD and possibly to the distance at which visual interference effects may produce secondary hazards.

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. Ensure all vegetation is trimmed or eliminated to maintain line of sight as environmental policy allows.

8.1.3.2 Mitigation of specular hazards. A maintenance program for the removal of specular reflectors should be established. This can be accomplished via range area cleanup, draining ponds, or painting over targets.

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.

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

c. Targets should be oriented so that specular reflectors are located 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 (see 7.2.4.2) to accommodate the laser designator position so the munitions engage the target rather than the designator.

8.2 Administrative controls. Administrative controls reduce risks through specific documented policies, procedures, and actions and 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.

8.2.4 Warning signs and notices. When possible, warning signs/markers should be posted around the installation laser 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 18). Warning signs/markers should be placed to ensure they are visible to individuals attempting to enter training complex areas at any point around its perimeter. The local SOP should provide for the placement and inspection of laser warning signs at the boundaries of the controlled areas and all 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.

FIGURE 18. Warning sign.

8.2.5 Access control. To limit exposure to a laser hazard, access to an LTA should be controlled. Access controls should prevent unprotected personnel and equipment 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, Local Notice to Mariners, Notices to Airmen, and cameras where the range is unmanned.

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 45 meters 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 being hazardous to nonparticipating aircraft (see figure 19).

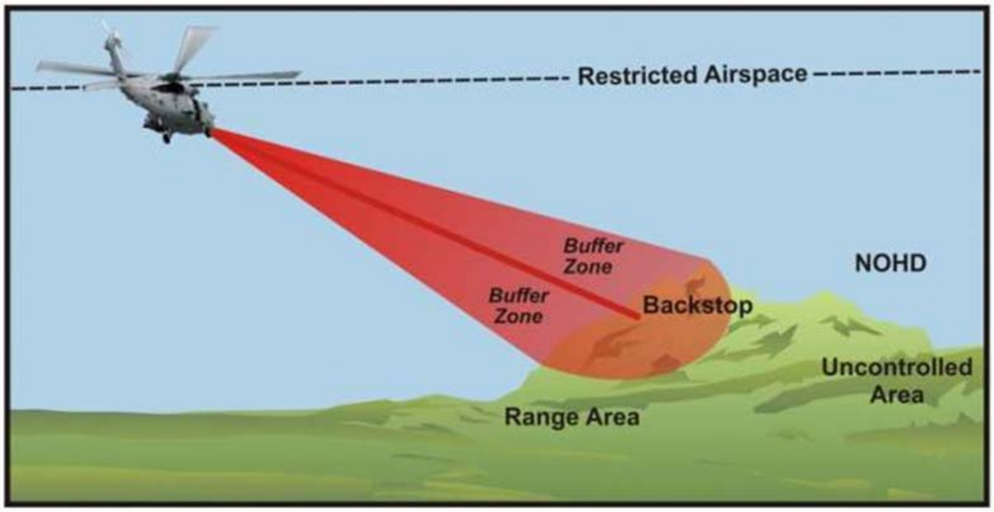


FIGURE 19. Restricted airspace.

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 Personal protective equipment (PPE). 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 PPE required, if any, should be determined for each occupied location.

b. Personnel within the LSDZ should wear LEP and protective clothing, if applicable, during laser operations. LEP will match the required optical density at the 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 provides 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 and laser characteristics combined with historical patterns to define the risk to personnel and equipment within a designated three-dimensional (3D) space. Types of danger zones include LSDZs, Surface Danger Zones (SDZ), and WDZs; for more detail on these see the definitions.

9.2 Laser footprint. A laser footprint is the projection of the laser beam and buffer zone on a surface. A laser footprint serves as the foundation for the worst-case LSDZ calculations. It should be noted that if the laser is not terminated by a surface no footprint exists and the laser hazard will extend to the NOHD.

a. An LSDZ only extends as far as the NOHD. If targets are placed beyond the NOHD, at a distance where the laser no longer exceeds current exposure limits, the laser footprint would indicate target placement is in an area outside the LSDZ. The laser footprint may be part of the LSDZ if the laser footprint lies within the NOHD of the laser.

b. If a laser extends beyond the NOHD, the laser footprint accounts for this area. In the case of visible lasers, when the laser footprint extends beyond the NOHD, this can give an indication of an area that may still be of concern for non-injurious transient effects, such as flash blindness, dazzle, disability glare, and startle.

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, up to which, a person may be exposed without hazardous effect or adverse biological changes in the eye or skin. If possible, laser beams and the associated buffer zone should be terminated by backstops, 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 direct or optically aided viewing by unprotected individuals should be considered in the laser range certification.

9.3.2 Nominal ocular hazard distance (NOHD). NOHD is the distance from an operating laser to the point where the laser irradiance or radiant exposure is not expected to exceed the appropriate MPE. Under normal atmospheric and operational conditions, at distances greater than the NOHD, the laser should be safe for intrabeam viewing. The NOHD for laser systems may be obtained from the Installation/Institutional Laser Range Authority.

9.3.2.1 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 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 9.4.2). The more stable the platform the greater the pointing accuracy; the less stable the platform, the poorer the pointing accuracy.

9.4 LSDZ. The LSDZ consists of a 3D space (volume) extending from the laser system to a backstop, terrain (ground or water), or through NOHD (see figure 20). A LSDZ will always exist if the laser has a NOHD. An LSDZ consists of the following components:

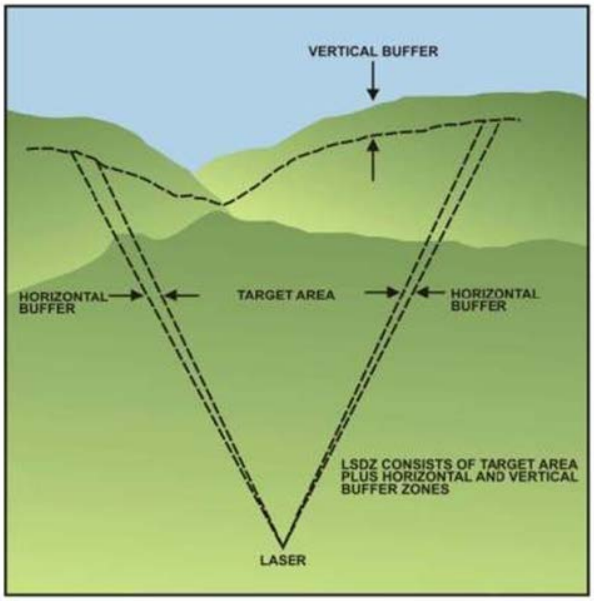


FIGURE 20. Laser surface danger zone (LSDZ).

9.4.1 NOHD and LSDZ. On the ground, the LSDZ normally extends out to the NOHD or beam backstop 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-kilometer NOHD would be increased to 80 kilometers for an individual looking back at the laser from within the beam with 13 power optics (see figure 21). 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.

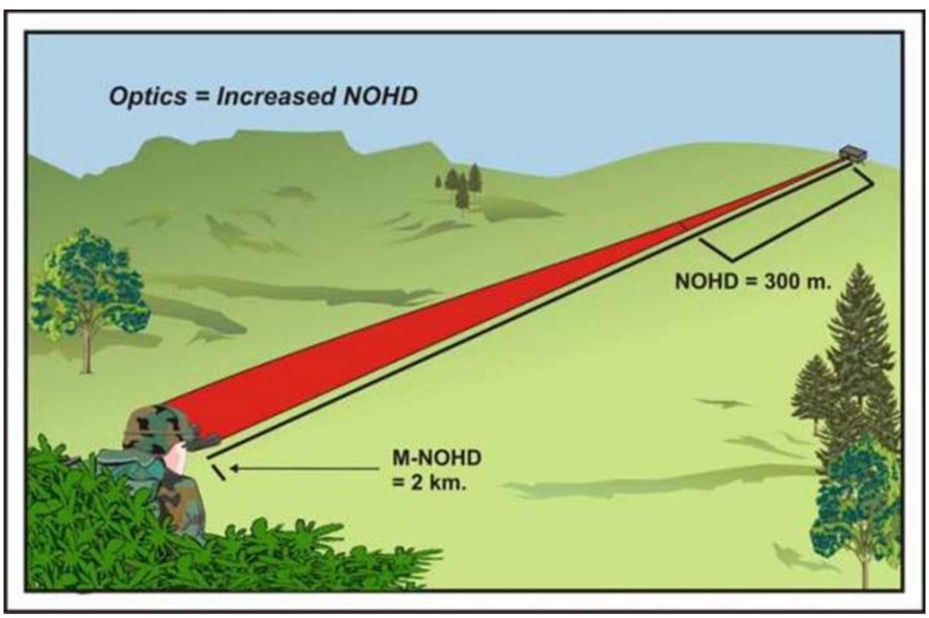


FIGURE 21. NOHD with/without viewing optics.

9.4.1.2 Use of backstop. The use of a natural or man-made backstop affects the size of the LSDZ (see figure 22 and figure 23). 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 a reference value (see figure 22, Beam 1).

b. When a 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 out to the NOHD in the airspace (see figure 22, Beam 2). Laser operations at targets on the horizon are permitted as long as airspace is controlled out to the NOHD. Laser operations at targets above the horizon are permitted as long as the airspace is controlled out to the NOHD and the laser operations are approved by the Laser Clearinghouse.

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

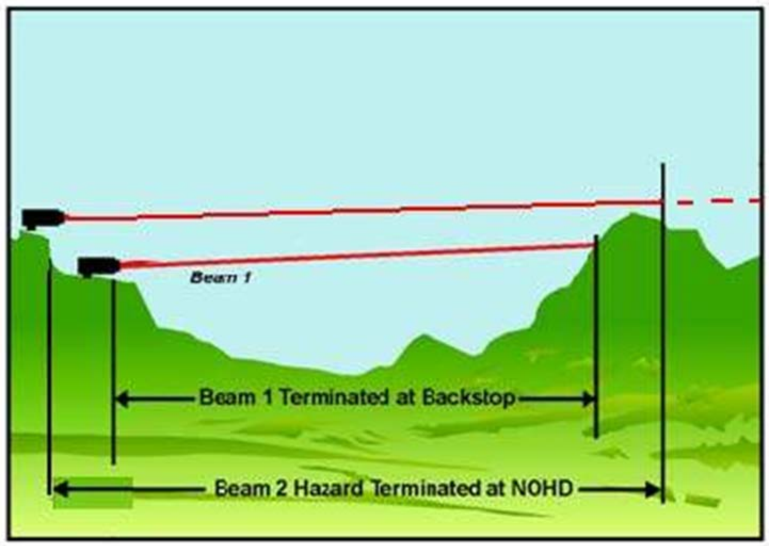


FIGURE 22. Effects of backstops.

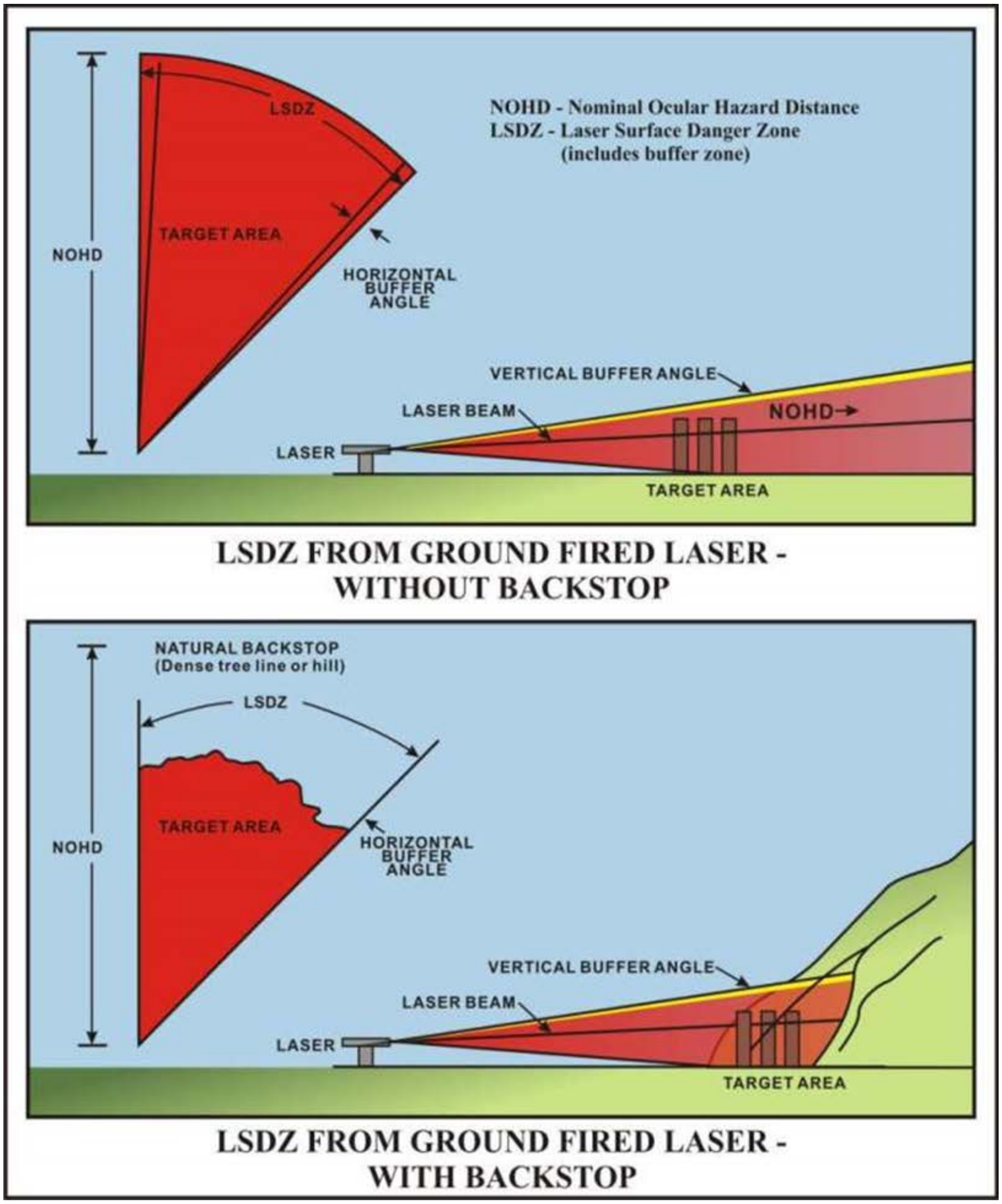


FIGURE 23. LSDZ without and with backstop.

9.4.2 Buffer angle. This is a safety margin added to the beam divergence to establish a laser footprint and is directly proportional to the pointing accuracy of the laser system on its platform. The footprint is then used to assess the viability of potential backstops. Table III lists typical buffer angle values for lasers using an alignment device (optics or sights).

TABLE III. Typical buffer angle values for lasers using an alignment device (optics or sights).

Situation	Buffer Angle	Explanation
Fixed	2 mrad	For targets engaged from a rigid, stationary mounting or a platform where accurate aiming can be guaranteed.
Inertially Stabilized	5 mrad	For targets engaged from a platform using stabilization (gimbal, gyroscope, or accelerometer).
Supported	10 mrad	For targets engaged by hand-held lasers supported on sand bags or other improvised method.
Unsupported	15 mrad	For targets engaged by unsupported hand-held lasers with an aiming or alignment device.
NOTE: 1. For lasers without alignment devices, the aiming accuracy may require significantly larger buffer angles.		

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 angle 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 24) (Note: 17.7 milliradians is equal to one degree).

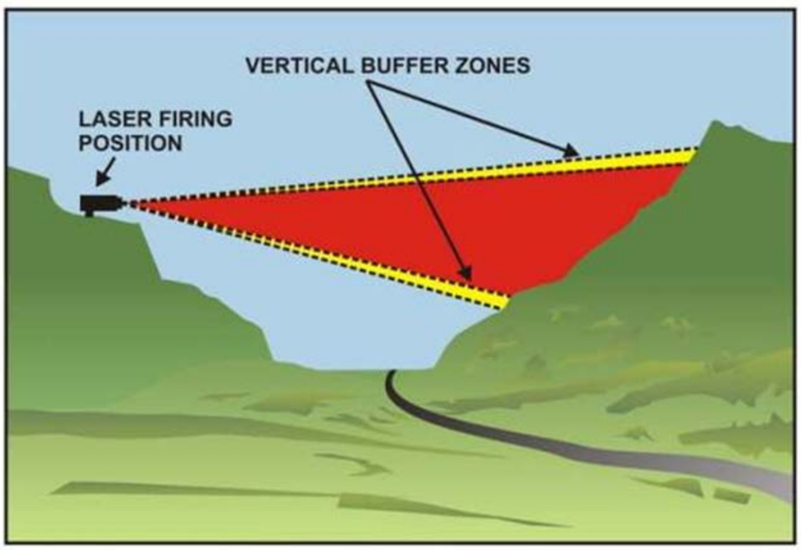


FIGURE 24. Buffer angle.

a. If multiple targets are being lased, the buffer angle is applied 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 the buffer angle is applied to both the initial and final lasing positions for both the left-most and right-most targets/locations.

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.

9.5 Nominal hazard zone (NHZ). Describes the space within which the level of the direct, reflected, or scattered radiation may exceed the applicable MPE during normal operation. Exposure levels outside the NHZ are below the applicable MPE level. The NHZ consists of the target area plus the buffer zones. The NHZ is often confined by the application of backstops. For un-terminated direct viewing, this zone would extend to the NOHD. The size, location (distribution), and type of targets to be lased on a range are of primary importance in determining NHZ.

9.5.1 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.

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

9.6 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. When generating an airborne LSDZ, the prime consideration is the direction of fire of the laser and not the aircraft heading; it is unlikely that aircraft heading will coincide with the laser-to-target bearing. The delivery aircraft could directly approach the target, but may also turn away from the target after weapons release before designating with the laser to guide the weapon to the target.

10. LASER RANGE CERTIFICATION

10.1 Introduction. Prior to any laser range operations, the hazards of laser activities on the range should be identified and incorporated in a laser range certification report. These hazards are identified by a combination of an on-site survey and follow-up analysis of the results. The certification report should include recommendations aimed at mitigating any potential hazards and to provide guidance for safe use of the lasers on the range. Laser range certification reports are valid for a period of time based on DoD service policy. Interim laser certifications may be required if revisions or modifications affecting laser operations occur. The renewal of the laser range certification should be scheduled prior to the expiration of the current certification.

10.1.1 Multiple laser systems. Based on service policy, a laser range certification can be performed for a specific laser system or for a group of lasers with similar characteristics such as Hazard Classes, NOHD, and platform stability. 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.

10.2 Preparation for certification.

10.2.1 Certification questionnaire. The Institutional Laser Range Authority, in conjunction with the Installation Laser Range Authority, assembles materials needed and reviews this information in order to facilitate the certification. The Installation Laser Range Authority should use the applicable service's Laser Range Pre-survey Questionnaire and existing Range Regulations/SOP(s) to provide the Institutional Laser Range Authority with the information necessary to perform the certification. The Appendix B sample questionnaire provides a systematic approach toward preparing for the certification and identifying areas that require additional consideration.

10.2.2 Scheduling. The Installation Laser Range Authority should determine a timeframe for the range evaluation after coordination with the prospective Institutional Laser Range Authority while considering the laser range certification due date. It is suggested that this initial coordination be done a minimum of six months prior to the visit.

10.3 Certification process. A new laser range may be certified for the first time or an existing range may be recertified. Once preliminary data has been gathered and reviewed, the Institutional Laser Range Authority performs the certification. The Institutional Laser Range Authority may document the results of collected data on the Laser Range Certification Questionnaire (see Appendix B). As an example, the certification process may proceed as follows:

a. Contact and Scheduling (see 10.2.2).

b. Gather preliminary data.

c. Preliminary analysis.

d. Perform Survey.

e. Post Survey Analysis.

f. Report.

g. Archiving and Distribution.

10.4 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 or other applicable sources. Preliminary data includes the information in 10.4.1 through 10.4.6.

10.4.1 Range information.

a. Range owner.

b. Name/identification 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 to include installation SOPs.

e. Detailed maps. A range map, National Geospatial Intelligence Agency resources, imagery, and/ an airspace map of the area 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, 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 Geographical Information System (GIS) and GPS data to ensure accuracy. The datum/projection of the GIS data should be 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 United States Geological Survey (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, to include GIS models, are preferred to analyze as opposed to using contour intervals and spot heights on a USGS image if the vertical accuracies are equivalent.

(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 range-specific characteristics, to include possible non-coincident lateral boundaries and minimum and maximum altitudes. 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, additional controls may be necessary, including notification to the FAA and Laser Clearinghouse (LCH).

(5) Recent aerial photos, or commercially available satellite imagery, are reviewed to look at vegetation, backstops, roads, waterways, and other environmental and man-made features.

a. Previous laser range certification should be reviewed, if available.

b. Previously determined LSDZs, if available.

10.4.2 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 (with and without viewing optics) 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 amount 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.

10.4.3 Deconfliction of range activities. A description of weapons authorized to be employed on ranges, surface dangers zones, and weapons danger zones per SOP/Installation Laser Range Authority. Determine which Observations Points (OPs) are used for which ranges, and whether what sites could conflict with lasing operations. This information will be useful for deconfliction/risk mitigation purposes to ensure locations of ground personnel and laser operators are not in conflict with WDZs. Though the laser range certifier is primarily concerned with laser features, hazards, and constraints in the range area, the certifier should understand the effects of changes that the recommendations may make to existing ranges; for example, changing lateral limits to contain laser energy might conflict with other activities that occur on the range. The integration of all the weapon systems and activities occurring on the ranges cannot be overstated.

10.4.4 Training 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 desired training based on the laser platform.

10.4.5 SOPs. Should be comprehensive, up to date, and address all aspects of range safety and operations.

10.4.6 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, or any other areas that may interfere with efficient range operations.

10.5 Perform preliminary data analysis using software/analysis methods. Prior to a site visit, a preliminary analysis of the range area should be performed. The purpose of the preliminary analysis is to identify and define potential problem areas and to maximize effectiveness of on-site survey and allocation of resources. The Institutional Laser Range Authority's preliminary analysis may include such items as LSDZ(s), firing areas, target areas, buffer angles, SOPs, requirement for tree lines and backstops. The preliminary analysis can be accomplished via manually or with software driven methods.

10.5.1 GIS data. GIS software is a common medium when depicting LSDZs during the laser range certification process. During preliminary analysis, comprehensive GIS data mining is essential prior to the survey. The certifier should obtain GIS data that includes feature classes, geodatabases, constraint layers, map projections, lasing/target areas, metadata, map datum, digital elevation model accuracy and currency, and file formats as part of the preliminary data. In addition, the data gathering will assist the certifier to identify data shortfalls that may be filled by the Installation GIS analyst prior to the survey analysis.

10.6 Survey. To perform a laser range certification, it is essential that a thorough range survey be performed. Range facilities are evaluated in terms of location relative to populated areas, military and civilian industrial sites, water/surface/air traffic, and other constraints, and considers specific environmental factors such as wildlife habitat. The range survey is used to verify geometries of the range boundaries with regard to firing and target positions and verify the validity of SOPs. An on-site inspection is performed to verify these geometries and to inspect the areas in question to verify the lack of specular reflectors and other terrain issues. This inspection might require visual access to the entire LTA. The results of this survey provide the certifying authority the conditions for which laser use is acceptable. It also provides recommendations as to what safety control measures should be implemented.

10.6.1 Survey procedures and in-brief. In order to perform the laser range survey, the certifier should schedule an in-brief with the host installation range control. At a minimum, the in-brief discussion should include a review of the last laser range certification, range personnel requirements for supporting the survey, installation range SOPs, range boundaries, airspace restrictions, lateral limits, laser target areas, range points of interest , magnetic declination, hazard clearances, and new ranges that will require certification since last certification report. In addition, any areas of concern by range control should be identified during this time.

10.6.2 Conduct of the survey. During the survey, the certifier should be escorted by an installation range control representative with a comprehensive knowledge of the laser range requirements and the integration of other range activities. During the survey, the certifier will gather data that will be used for the post-survey analysis using mapping-grade accuracy GPS systems, range-finding and azimuth equipment, dispersion-measuring optics (in milliradians), camera(s), and a weather-proof writing tablet for note-taking. At each range the certifier is also looking for man-made and natural backstops, specular reflectors, the presence of laser warning signs, and possible laser hazards. For the laser survey of Infantry Immersion Trainer, Marine Operations Urban Terrain (MOUT) facilities, and shoot houses, many of the same principles, procedures, and observations remain the same with additional attention to specular hazards (such as windows, picture frames, vehicle mirrors), man-made backstops (berms, buildings, walls), and direction of laser fire.

10.6.3 Out brief. Once the survey is complete, an Out Brief should be scheduled between the certifier, range control, and any other representatives identified by the Installation Laser Range Authority. Discussion items should include unsafe laser range activities that require immediate attention (if any), changes/deviations from last laser range certification, requested installation GIS data/information to complete the analysis and report, and approximate target date of written report.

10.7 Survey analysis. Including the analysis performed during the Preliminary Analysis (see 10.5), the laser range certifier conducts and consolidates the Survey Analysis using all laser range data and information to create the LSDZs.

10.7.1 Creating the LSDZs. For the analysis, the certifier will use manual calculations or laser range certification software to create the surface (ground) and aerial LSDZs. Based on the collected survey data, the certifier will input data parameters such as buffer angles, firing points, target points, maneuver areas, azimuths, firing distances, NOHDs, magnetic declination, distances to the target area, lasing altitudes, lateral limits, constraints, tree line size and composition (if required), and target heights (offsets). The LSDZ outputs include a danger zone bounded by firing lines, target lines, lateral limits, the intersection of terrain with the laser energy (or limited by a specific NOHD or a identified constraint), and minimum safe lasing altitudes (for the aerial LSDZs). Once the LSDZ is created, the certifier will verify the LSDZ input parameters for accuracy; once verified, the LSDZ will become part of the laser range certification report.

10.8 Report. Once the LSDZs are completed, the certifier will place the LSDZs in a service-specific layout format and add supporting graphics, data, and text information as required into the report to complete the analysis for a particular range. Including the LSDZ layouts, a report should contain information addressing the date of the survey, range control representative(s) who escorted the laser range certifiers, the date of the last laser range certification, the magnetic declination, date of expiration for new laser range certification, restricted airspace consideration, buffer angles, minimum safe lasing altitudes for aerial ranges, offsets (heights) assigned to the firing and target points, laser systems and associated limitations that may be used on certain ranges depending upon calculated laser range buffers, laser range restrictions, required changes to the installation SOP, and changes from the last laser range certification report. Many of the software tools have report functions that can auto-populate the report template and present information such as firing points, target points, offsets, buffer angles elevation, analysis type, target type, NOHD, ground distances, and minimum safe lasing altitudes. Once the report is complete, it is recommended that the certifier send a draft report to the installation range control that allows a local review to ensure accuracy and completeness.

10.9 Distribution and archiving. Once the report is signed by the Institutional Laser Range Authority, the certifier will distribute the report via an approved distribution list. At a minimum, the report is archived by the Institutional Laser Range Authority. Respective services may use a website to allow access for distribution as approved organizations can download the laser range certification report.

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 and target area/line/points.

d. Verify laser target condition.

e. Verify LSDZs.

f. Determine if safe laser activities can be supported.

g. Ensure the LSDZ is contained within an area of control.

h. Ensure geospatial (GIS) data sets supporting the Certification are in DoD compliant format.

i. Determine encroachment/conflict issues.

j. Review access control measures.

k. Verify compliance SOPs and proposed operations.

l. Validate PPE Program.

11.3 Laser range hazard analysis. The Institutional Laser Range Authority is responsible for conducting laser range hazard analysis and for generating laser danger zones. The Institutional Laser Range Authority is responsible for maintaining its methods and, if necessary, automated software tools 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 GIS data holding of Laser Range Certification features.

j. Summarize hazard analysis findings and recommendations.

For more detailed laser range certification procedures, see section 10.

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 engaging on the laser target designator and wrong targets.

b. Regulations should be developed, or updated as necessary, to account for new laser systems and scenarios. The laser range certification should be used to review and to ensure overall laser 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 range SOPs 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 in the 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 Review Board (LSRB) (service specific approved) laser systems.

(2) Laser range certification criteria.

(3) Range laser operations.

(4) Range laser and target maintenance procedures.

(5) Laser hazard control measures.

(6) Emergency response procedures.

(7) PPE.

(8) Communications.

(9) Notices (Airmen, Mariners, FAA).

(10) Agency Notifications – Memorandums of Agreement (MOAs) or Memorandums of Understanding (MOUs).

(11) Request for authorization for above the horizon lasing from the LCH.

(12) Target maintenance program.

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 reviews the risk management proposal, 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. Laser use is contained within the limits of the LSDZ.

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

d. Hazard area clearance procedures for unprotected personnel and equipment.

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

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

g. 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.

h. PPE requirements to ensure they support the laser.

i. Training mode/filter requirements.

j. Emergency response procedures.

k. Public and agency notifications.

12.2.1 LSDZ. Installation Laser Range Authority personnel may generate LSDZs, as necessary, to support training plans, map data, and information requests. The generated LSDZ will be contained within the certified laser range. This effort considers the laser system data and range data, and performing risk mitigation to ensure the laser training can be safely conducted on a given range.

12.3 Laser systems. The Installation Laser Range Authority is responsible for reviewing laser systems for use on a certified laser range. This includes verifying 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.

12.4 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 need to 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.

12.5 Range laser safety compliance inspection/audit. The Installation Laser Range Authority should perform range laser safety compliance inspection/audits:

a. Confirm laser use is compliant with applicable SOP and laser range safety certification report.

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

c. Inspect targets for serviceable condition and placement/orientation and ensure proper target maintenance.

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

e. Inspect line of sight between laser firing 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.

12.6 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 digital range map.

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

i. Identify Encroachment/conflict issues.

j. Provide Target replacement and maintenance program documentation.

k. Provide PPE/LEP Program details.

12.7 Laser briefings and indoctrination.

12.7.1 Public notices. The Installation Laser Range Authority advises the affected public of the presence of laser operations, where deemed appropriate.

12.7.2 Affected users. 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 avoiding complex scientific data or terminology. 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.

e. Encroachment issue.

f. Address the National Environmental Protection Act concerns.

12.8 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 personnel/equipment locations.

g. Identify range hazard clearing requirements.

h. Identify PPE requirements.

i. Identify communications requirements.

j. Identify emergency response procedures.

k. Present the units laser usage recording practices.

13.2 Conduct of range laser safety 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 and equipment in the area are aware and protected and that equipment does not pose a specular hazard.

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.

j. Control access to the LTA and LSDZ.

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 as applicable.

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 and NOHD as applicable.

h. Control measures to minimize the risk of unauthorized personnel or equipment entering the LSDZ.

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

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

k. Type of PPE to be worn and how it should be worn.

l. Potential hazards posed by the laser system , the target area, maintenance area, types of warning signs to be posted, and specific procedures to avoid these hazards.

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

n. Review the applicable SOP.

13.3 Laser operations. The Unit Laser Range Authority should perform the functions of 13.3.1 through 13.3.5 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 and equipment in the immediate area of the laser firing position are outside the LSDZ while the laser is in use.

b. Ensure LSDZ is clear of all non-essential personnel and equipment.

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 equipment enter the LSDZ.

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 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.

d. Provide information on what happened (who, what, when, where, why, how).

e. Provide information on personnel who may have been exposed to hazardous laser energy.

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 Subject term (key word) listing.

Direct intrabeam viewing

Flash blindness

Laser guided weapon

Laser operation

Range operations

Reflected intrabeam viewing

Scattered radiation

Skin damage

14.3 References. The following references are not listed within the body of this document; however, these documents play an important role in Laser Systems application and Range certification: JP 3-09.3, AFI 91-401, AR 40-5, MCO 3550.9, and MCO P3550.10.

14.4 International standardization agreement implementation. This handbook implements STANAG 3606, Laser Safety for Military Use and ARSP-4, Laser Safety for Military Use. When changes to, revision, or cancellation of this handbook are proposed, the preparing activity must coordinate the action with the U.S. National Point of Contact for the international standardization agreement, as identified in the ASSIST database at https://assist.dla.mil.

14.5 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

A.1.1 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 SOP RESPONSIBILITIES

A.2.1 Laser range SOP. 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. Some concerns to be noted are crater holes, dislodged or moved targets from surveyed location, target debris that exposes specular reflectivity, or appropriate backstop for systems employed to contain all laser activity.

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 adjacent to laser activity 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. PPE maintenance program in place 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. Specify appropriate PPE 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 Laser Injury Hotline).

l. Have provisions for unit laser safety training.

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

n. Target Maintenance Program

A.3 UNIT SOP RESPONSIBILITIES

A.3.1 Unit laser range SOP. Units should have their own laser safety procedures and brief their personnel prior to conducting laser training. Units are responsible for complying with the installation guidance and directives contained within the laser safety SOP. 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 receives 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 LSRB and reviewed by the installation laser range authority 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 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.

g. Confirm no specular reflectors are associated within the Training Areas/LTA/LSDZ 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 unauthorized personnel/equipment enter the LSDZ.

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

k. Ensure personnel forward of the laser are wearing PPE as required; 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 laser activity 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-828 for comprehensive understanding of laser use on outdoor ranges.

r. Ensure 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 per day (1-800-473-3549 Tri-Service Laser Injury Hotline).

EXAMPLE LASER RANGE CERTIFICATION QUESTIONNAIRE

B.1 SCOPE

B.1.1 Scope. This appendix provides an example Laser Range Safety Pre-survey Questionnaire, a Laser Range Certification Survey Questionnaire, and a Laser Range Safety Certification Report. This questionnaire may be used by tailoring or adding items as needed.

B.1.2 Laser range pre-survey questionnaire. The Installation Laser Range Authority should use a Laser Range Pre-survey Questionnaire (see figure B-1) to provide the Institutional Laser Range Authority with the information necessary to perform the laser range safety certification survey.

B.1.3 Laser range certification questionnaire. The Institutional Laser Range Authority annotates the data gathered during the certification survey on the Laser Range Certification Questionnaire (see figure B-2).

B.1.4 Laser range survey report. The Institutional Laser Range Authority compiles the results of the laser range safety certification in a Laser Range Safety Certification Report (see figure B-3).

Laser Range Pre-Survey Questionnaire

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? ______________________

FIGURE B-1. Laser range pre-survey questionnaire.

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: ______________________________

FIGURE B-1. Laser range pre-survey questionnaire – Continued.

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.	

FIGURE B-1. Laser range pre-survey questionnaire – Continued.

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)?

____

____

____

____

FIGURE B-1. Laser range pre-survey questionnaire – Continued.

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?

FIGURE B-1. Laser range pre-survey questionnaire – Continued.

Laser Range Certification Questionnaire

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
____________	____________	____________

FIGURE B-2. Laser range certification questionnaire.

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

FIGURE B-2. Laser range certification questionnaire – Continued.

Personnel Responsibilities			
1. Have all personnel 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 (in accordance with MIL-HDBK-828C) to warn personnel against unauthorized entry?	Yes	No	N/A

FIGURE B-2. Laser range certification questionnaire – Continued.

(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 questionnaires 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

FIGURE B-2. Laser range certification questionnaire – Continued.

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: ______________________________

____

____

____

FIGURE B-3. Laser range safety certification report.

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?

____

____

____

____

____

____

FIGURE B-3. Laser range safety certification report – Continued.

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:

FIGURE B-3. Laser range safety certification report – Continued.

6. Controls for protection from reflected laser beams:

7. Recommended training:

8. Recommended pre-briefs for:
   a. Laser users:

   b. Laser Range Personnel

FIGURE B-3. Laser range safety certification report – Continued.

METHODOLOGY FOR RANGE LASER HAZARD EVALUATION

C.1 SCOPE

C.1.1 Scope. The goal of laser safety evaluations on ranges is to determine what is required to keep the laser beam plus and its associated buffer within the confines of the designated constraint boundary of the range. This appendix provides a methodology for performing range laser hazard evaluations consistent with Chapter 10.

C.2 METHODOLOGY

C.2.1 Methodology. The information provided in this appendix may be used in addition to the service-specific range laser evaluation techniques. The equations are the means to determine minimum laser altitude 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.2.2 Over the horizon lasing. The lack of terrain features to act as a backstop in some environments, when combined with longer NOHDs of some laser systems, causes the curvature of the earth to play a significant role in laser evaluations. Under these circumstances the laser can exit terrestrial constraints and propagate into space. The equations listed in this appendix do not take into account the curvature of the earth and can yield erroneous results for lasers with long NOHDs that are directed near the horizon. The scenario previously described, and systems designed to engage targets above the horizon, require coordination with those responsible for the air space and coordination of satellite space with the LCH.

C.2.3 Hazard evaluation. The goal of airborne laser and ground laser safety evaluations on many ranges is to determine what is required to keep the laser beam, plus its buffer, within the LSDZ.

C.3 FOOTPRINT DEFINITION

C.3.1 Ground laser footprint. The footprint is the projection of the laser beam including its buffer angle on the ground surrounding the intended target. The footprint shape and size are determined by the range from the laser to the target, the angle of the laser beam on the target or range area plane, and the divergence of the laser. 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 elongated shape of the footprint may be of primary concern and changes drastically as a function of the laser's relative elevation and distance to the target.

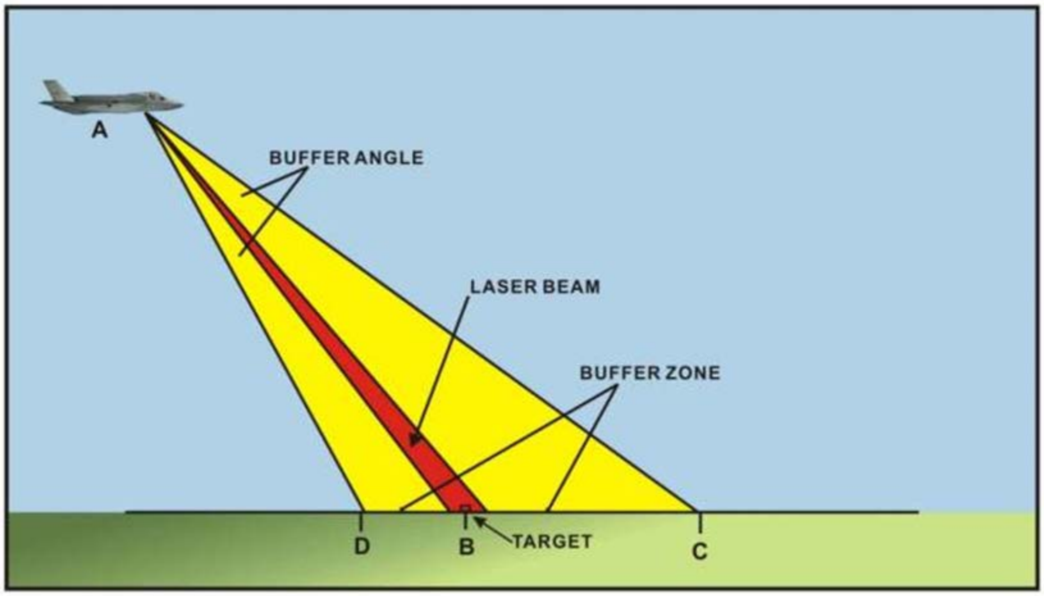


FIGURE C-1. Laser footprint with single target side view.

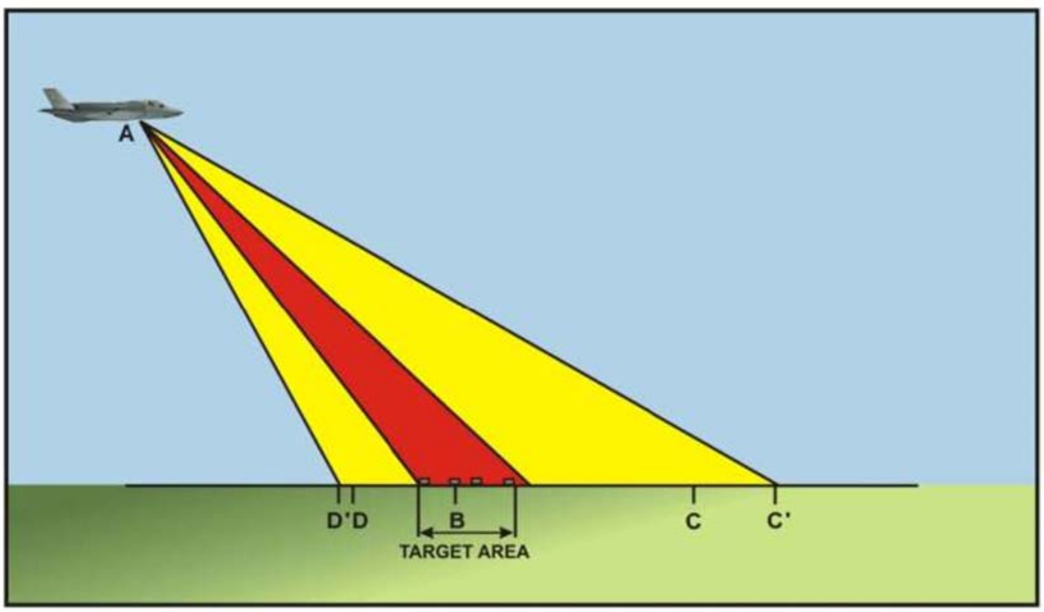


FIGURE C-2. Laser footprint with multiple targets – side view.

C.4 HAZARD EVALUATION WITHOUT SPECULAR REFLECTIONS – AERIAL LASING

This evaluation should be done for each laser heading and should account for any slope of the terrain.

C.4.1 Single laser heading. Provided that the laser target and surrounding area are clear of specular reflectors, the mathematical model used to evaluate range safety assures that the laser beam and its associated buffered footprint fall within the prescribed boundaries of the controlled or restricted ground space. C.4.2 through C.4.3.2 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 view of the footprint is shown in figure C-3.

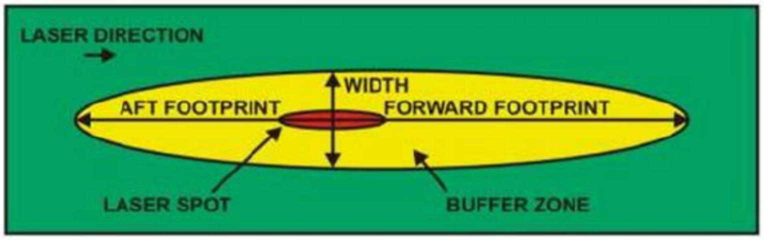


FIGURE C-3. Laser footprint – top view.

C.4.2 Multiple laser headings. If the laser energy will be from several bearings (for example 70 to 110 degrees), the LSDZ will be a summation of all possible buffered footprints as shown in figure C-4. If the bearings are not specified from any direction, 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-5).

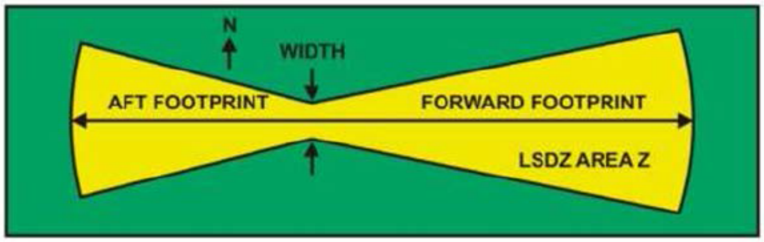


FIGURE C-4. Integrated footprint – bearing 70 to 110 degrees.

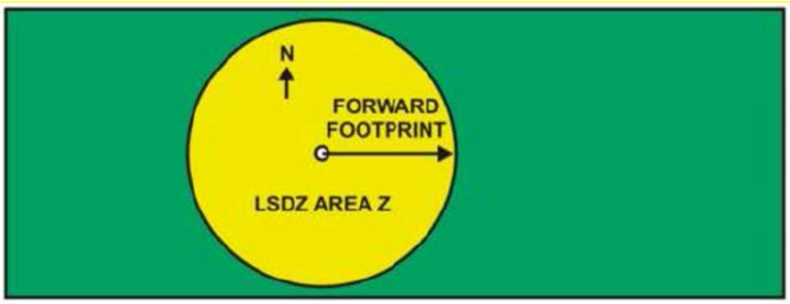


FIGURE C-5. LSDZ – attack from any direction.

C.4.3 Unlevel terrain. Although actual procedures vary on a case-by-case, the following conditions are presented as common.

C.4.3.1 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-6, figure C-7, and figure C-8).

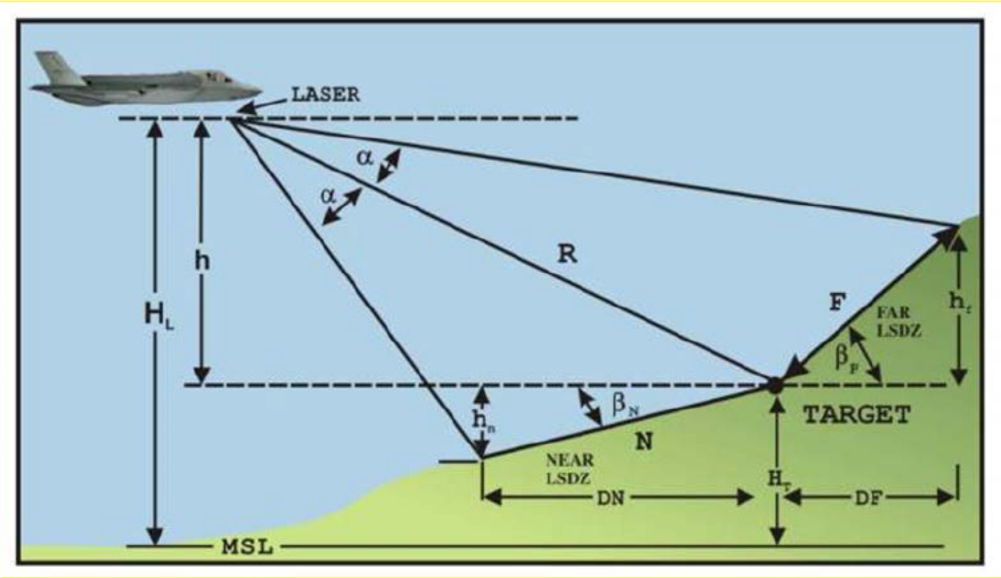


FIGURE C-6. LSDZ with rising terrain.

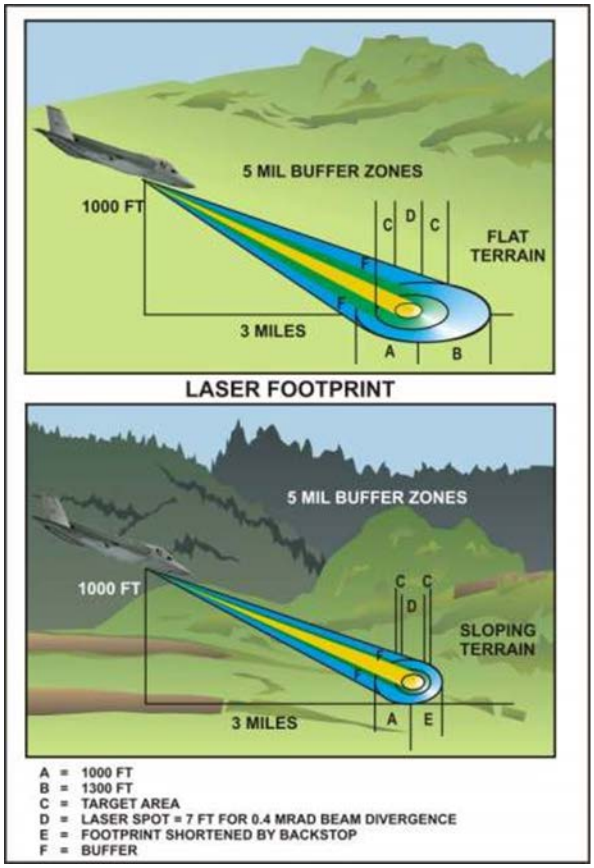


FIGURE C-7. Natural backstops to control laser beam.

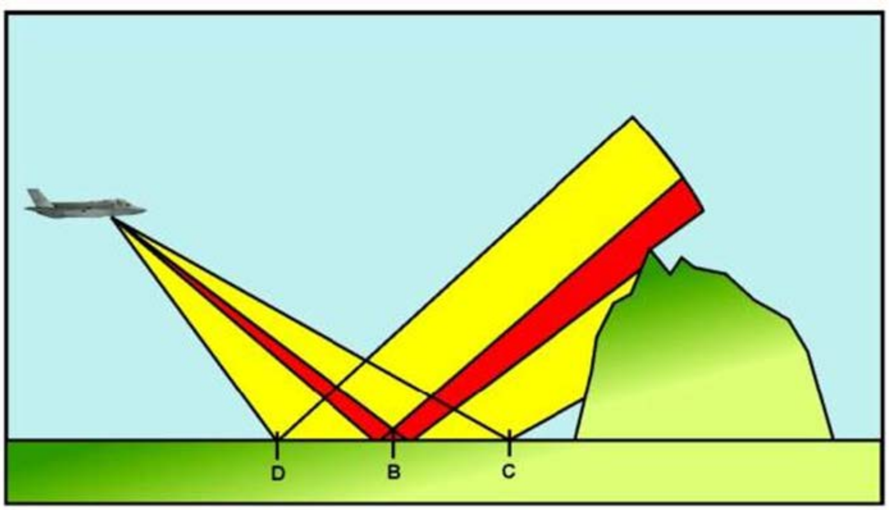


FIGURE C-8. Insufficient backstop to control laser beam.

C.4.3.2 Falling terrain in target area or hills in foreground. This condition will result in longer forward buffered footprints and more restrictive conditions. The height, Mean Sea Level, or Above Ground Level (AGL) of the laser in reference to the target should 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-9 and figure C-10. If flight profiles are not limited, the forward footprint could be as long as the NOHD.

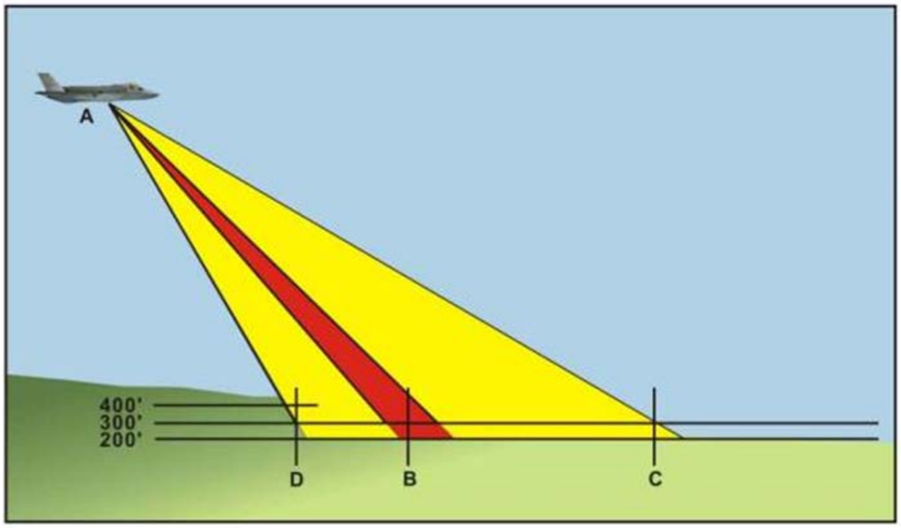


FIGURE C-9. LSDZ with terrain sloping down when range is less than NOHD.

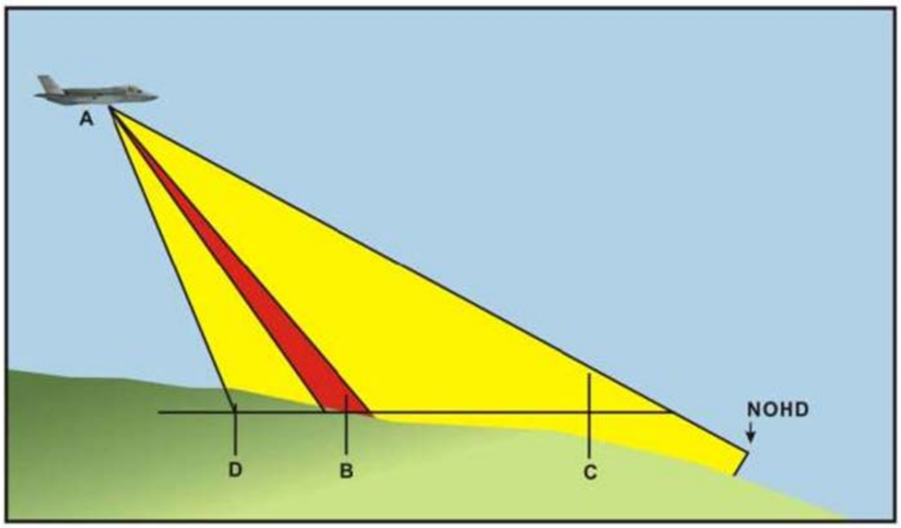


FIGURE C-10. LSDZ with terrain sloping down when range is greater than NOHD.

C.5 SPECULAR REFLECTIONS.

It should be determined 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-11). If this or other specular reflectors appear to be a problem, the flight profiles should be limited, the target should be moved, or more land or airspace should be restricted. 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 will need to be calculated for the specular reflection into the surrounding area or air space. The worst case results should be used.

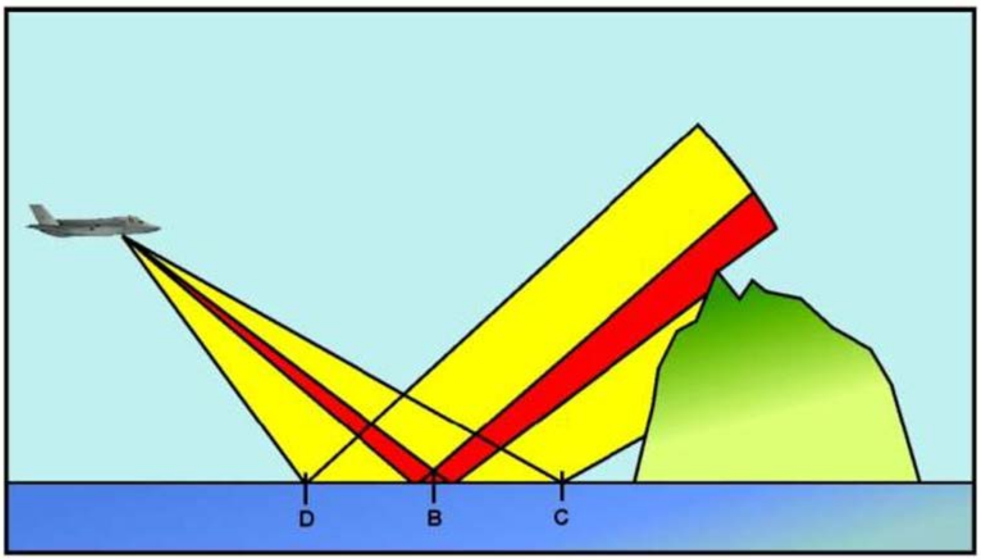


FIGURE C-11. Reflections from still water with LDZ.

C.6 AIRCREW.

Present policy for most services requires aircrews to wear LEP when aircraft may be exposed to hazardous laser radiation. If the target area is not clear of specular surfaces, and the aircrews lase from distances less than ½ the NOHD, aircrews are at risk of eye damage if appropriate LEP is not used. Possible exposure situations to aircrews from specular reflectors are shown in figure C-12 and figure C-13.

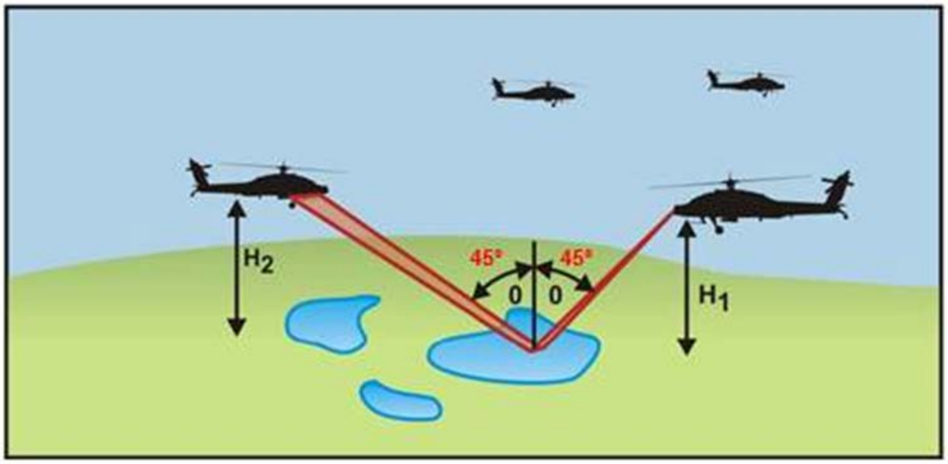


FIGURE C-12. Example of airborne laser beam reflection.

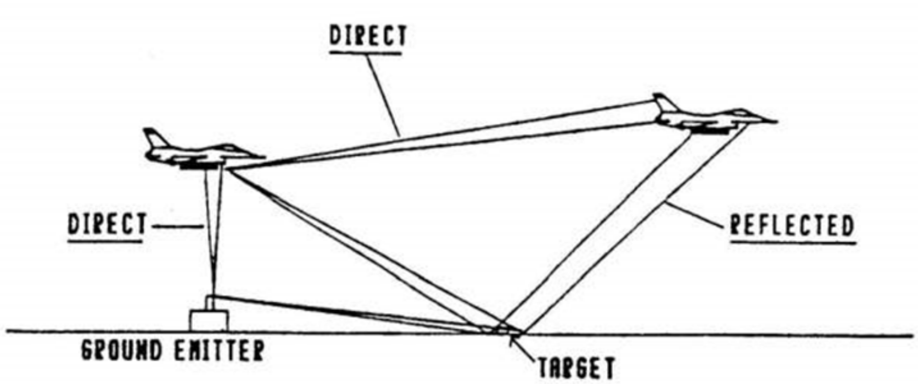


FIGURE C-13. Potential exposure modes.

C.7 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-14 and figure C-15. 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.

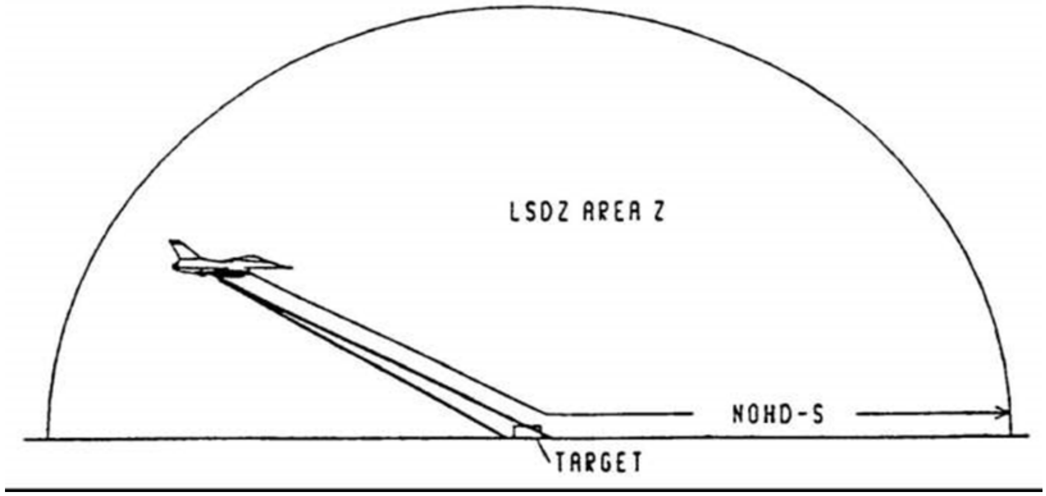


FIGURE C-14. Reflections from flat specular surface – side view.

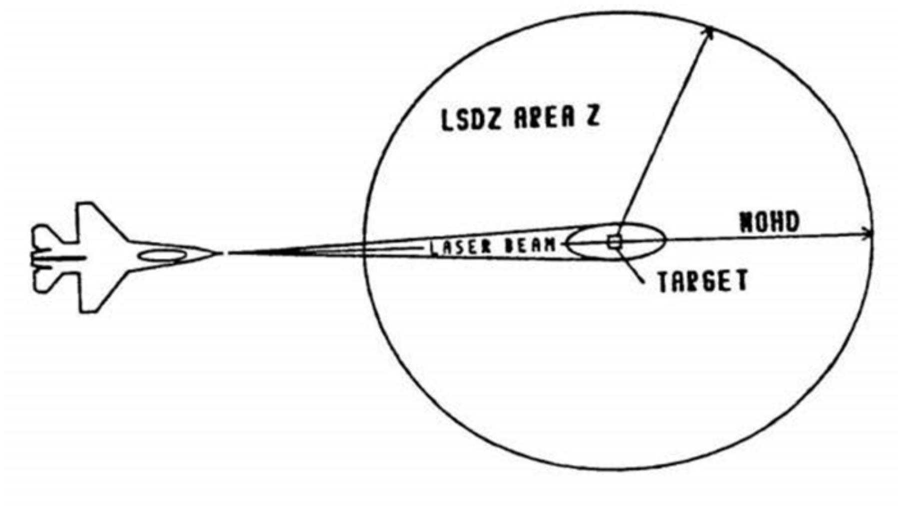


FIGURE C-15. Reflections from flat specular surface – top view.

C.8 FOOTPRINT DETERMINATIONS.

If the range is small and is the controlling factor, the flight profiles should be ascertained 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 calculating 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:

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

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

C.8.1 Ground based lasers. Determine the ability to keep the buffered laser footprint within the restricted boundaries both vertically and horizontally.

C.8.1.1 Vertical buffer far boundary. Addressing the far boundary constraint first, figure C-16 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.

a_1 = altitude of far target.

b_l = altitude of far boundary.

d_l = 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:

$\delta = \arctan((b_1 - h)/(d_1 + A)) + \arctan((h - a_1)/(d_1))$.

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

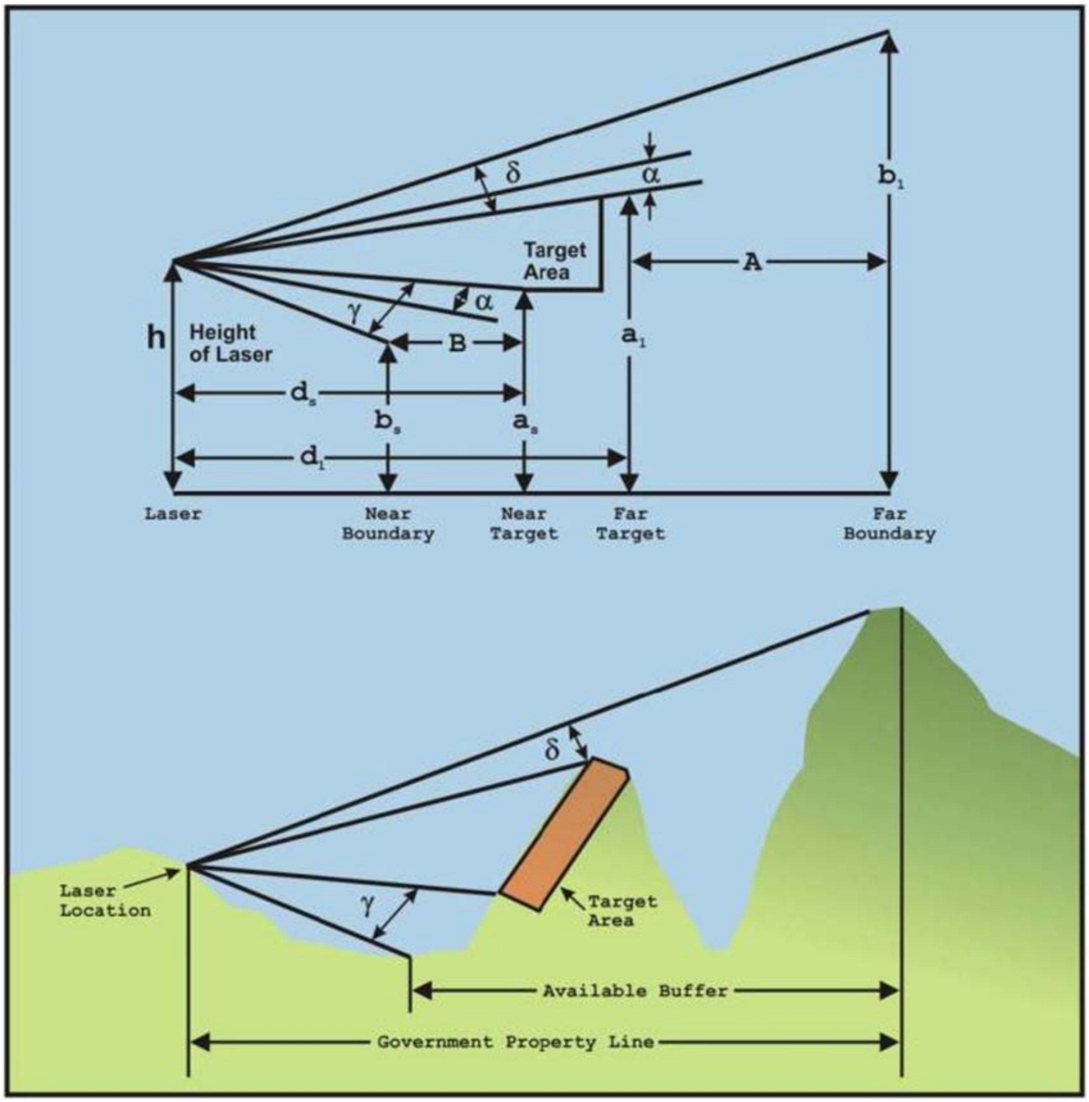


FIGURE C-16. LSDZ geometry and vertical buffer.

C.8.1.2 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.

a_s = altitude of nearest target.

b_s = altitude of near boundary.

d_s = 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:

$\gamma = \arctan((h-b_s)/(d_s-B)) + \arctan((a_s-h)/d_s)$.

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

C.8.1.3 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-17):

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.

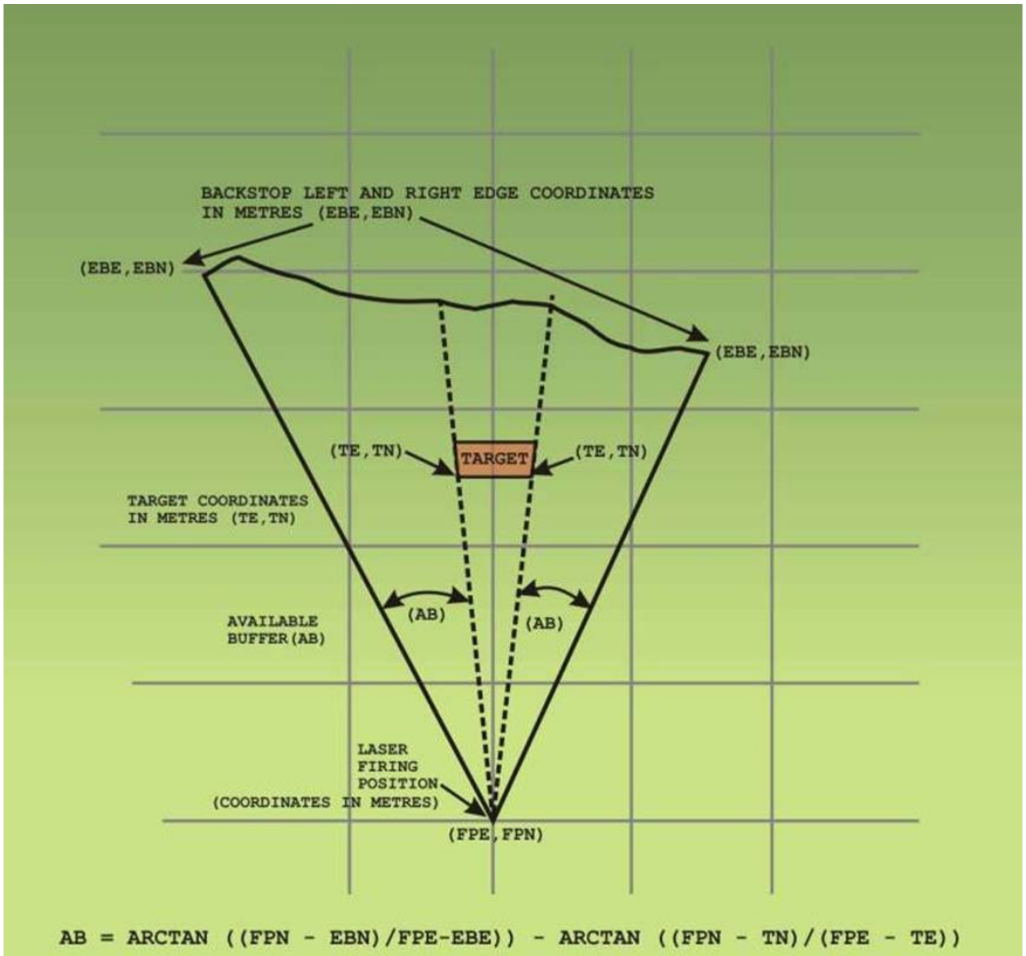


FIGURE C-17. Calculation of available buffer versus allowed buffer.

C.8.1.4 Minimum safe lasing altitude (MSLA). MSLA can be determined from the following equations:

The equations below yield the minimum safe lasing altitude AGL for aircraft lasing. For the derivation of MSLA for the far boundary, the variable H below represents the altitude relative to the top of the target or the far edge of the target area. For the derivation of MSLA for the near boundary, H represents the altitude relative to the ground at the target or the near edge of the target area. In both cases, R represents horizontal (ground) distance from firing (lasing) point to target, not slant range.

The equation for the far boundary does not take into account possible laser backstops between the target and the far boundary. However, the equation may be applied for the backstop locations to possibly reduce the MSLA. Figure C-18 depicts the geometry for the determination of the far boundary and near boundary MSLA for level terrain, figure C-19 depicts the geometry for the determination of the far boundary and near boundary MSLA for rising terrain, and figure C-20 depicts the geometry for the determination of the far boundary and near boundary MSLA for falling terrain.

The MSLA equation for the far boundary is:

$$MSLA_{AGL} = E_T - E_P + T + \frac{P\tan(b) + D_F - \sqrt{(P\tan(b) + D_F)^2 - 4\tan(b)(R^2\tan(b) + RD_F\tan(b) - RP)}}{2\tan(b)}$$

A simpler form is to use the distance from the firing point to far boundary, Q_F:

$$MSLA_{AGL} = E_T - E_P + T + \frac{P\tan(b) + D_F - \sqrt{(P\tan(b) + D_F)^2 - 4\,\mathrm{R}\tan(b)(\mathrm{Q_F}\tan(b) - P)}}{2\tan(b)}$$

For the near boundary, T = 0. The MSLA equation for the near boundary is:

$$MSLA_{AGL} = E_T - E_P + \frac{P\tan(b) + D_N - \sqrt{(P\tan(b) + D_N)^2 - 4\tan(b)(R^2\tan(b) - RD_N\tan(b) + RP)}}{2\tan(b)}$$

A simpler form using the distance from the firing point to the near boundary, Q_N:

$$MSLA_{AGL} = E_T - E_P + \frac{P\tan(b) + D_N - \sqrt{(P\tan(b) + D_N)^2 - 4R\tan(b)(\mathrm{Q_N}\tan(b) + P)}}{2\tan(b)}$$

Diagram notations:

FP = firing point location

EP = elevation of FP

TGT = target location

ET = elevation of target

R = distance from FP to TGT

b = buffer angle

P = elevation of FB or NB minus elevation of TGT

(note P can be positive or negative)

for near, P = EN – ET; for far, P = EF – ET – T

FB = far boundary location

EF = elevation of far boundary location

DF = distance from TGT to FB

QF = distance from FP to FB = R + DF

NB = near boundary location

EN = elevation of near boundary location

DN = distance from TGT to NB

QN = distance from FP to NB = R – DN

T = height of target

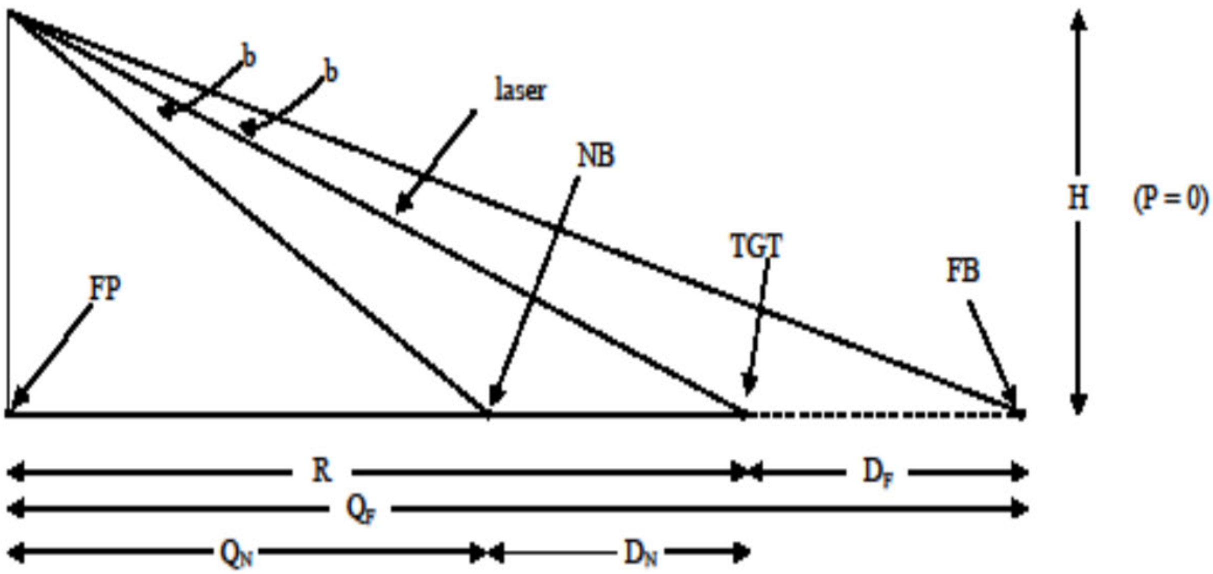


FIGURE C-18. Case 1: FB or NB level with TGT.

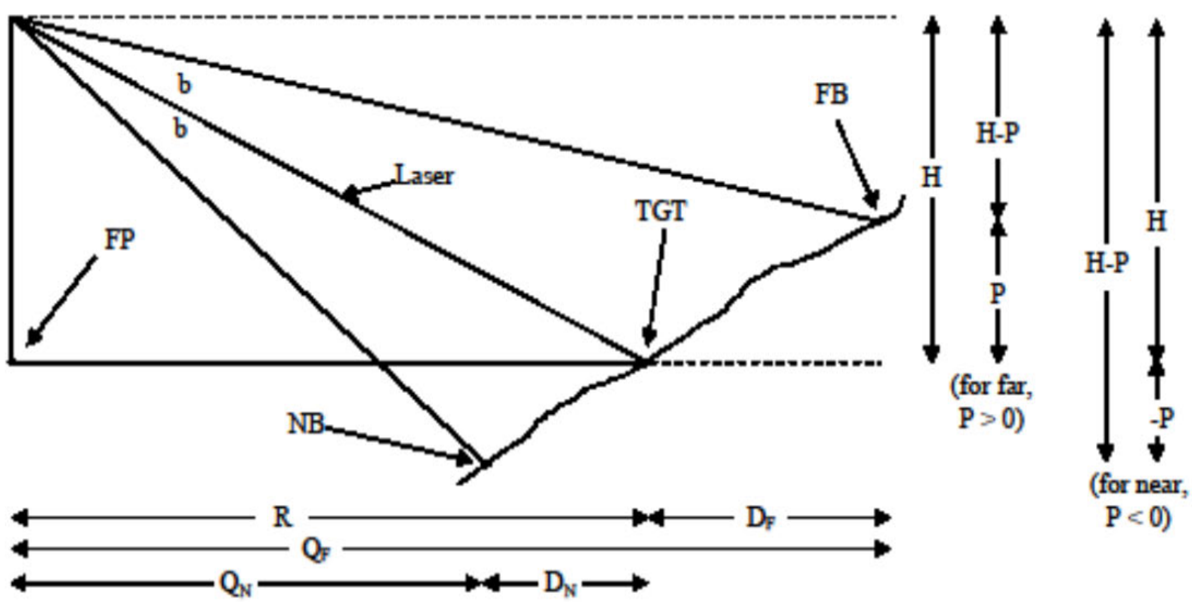


FIGURE C-19. Case 2: Rising terrain.

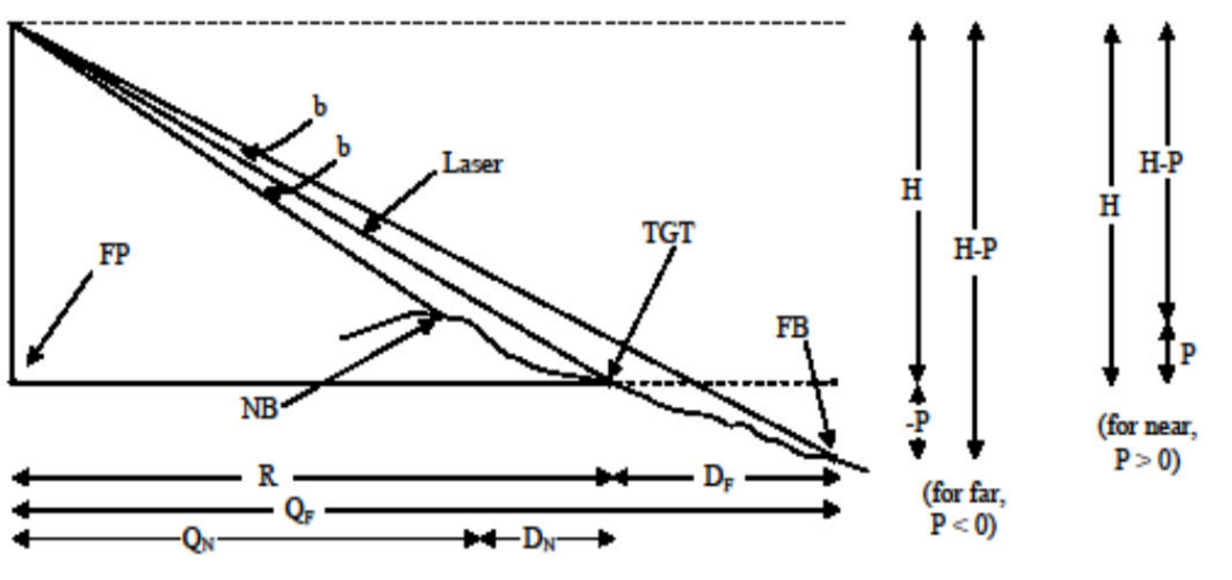


FIGURE C-20. Case 3: Falling terrain.

The point identified as FP is the horizontal location; the vertical location of the firing point is not shown as the elevation of the FP may be higher or lower than the TGT. The point identified as the target represents the near edge of the target area, far edge of the target area, or the top of the target for a single-point three-dimensional target.

C.8.2 Airborne laser with target on level ground. For airborne laser buffer geometry at ground level (see figure C-21).

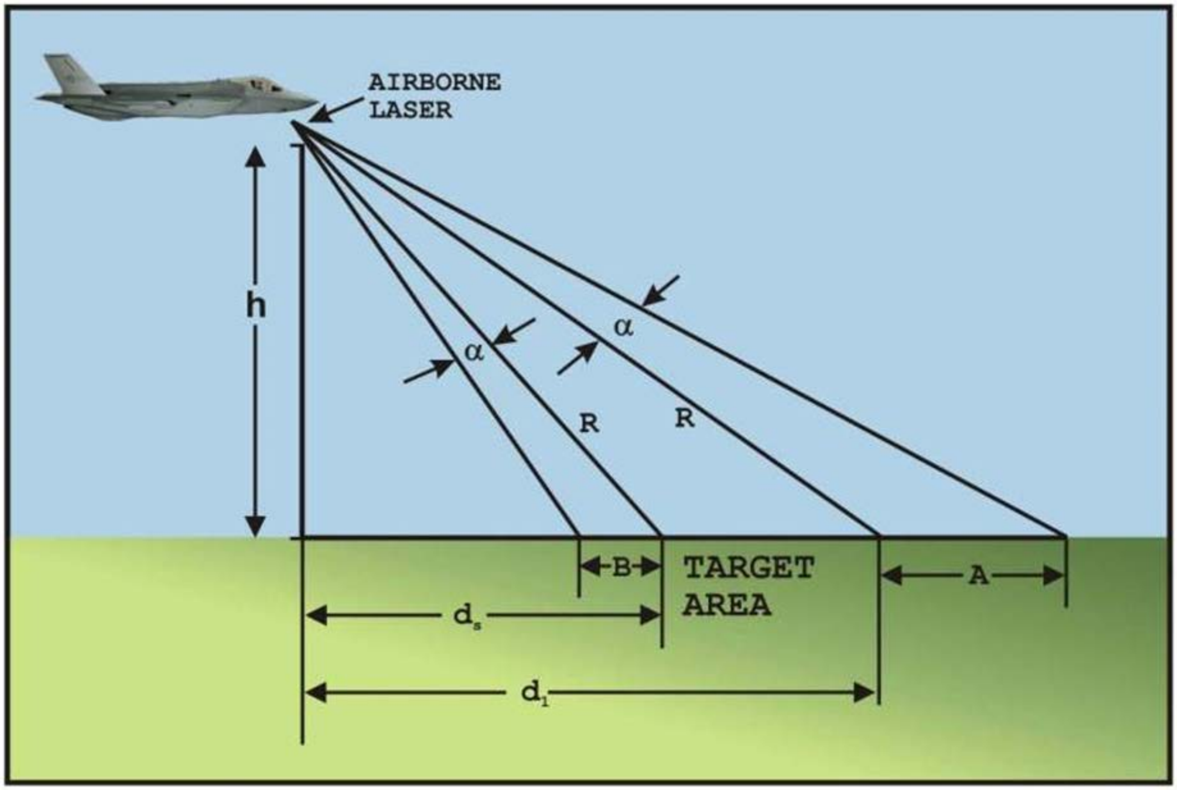


FIGURE C-21. Airborne laser buffer geometry – level ground.

C.8.2.1 Aircraft minimum altitude. The minimum laser altitude (h) relative to the target to keep the 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 the 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.

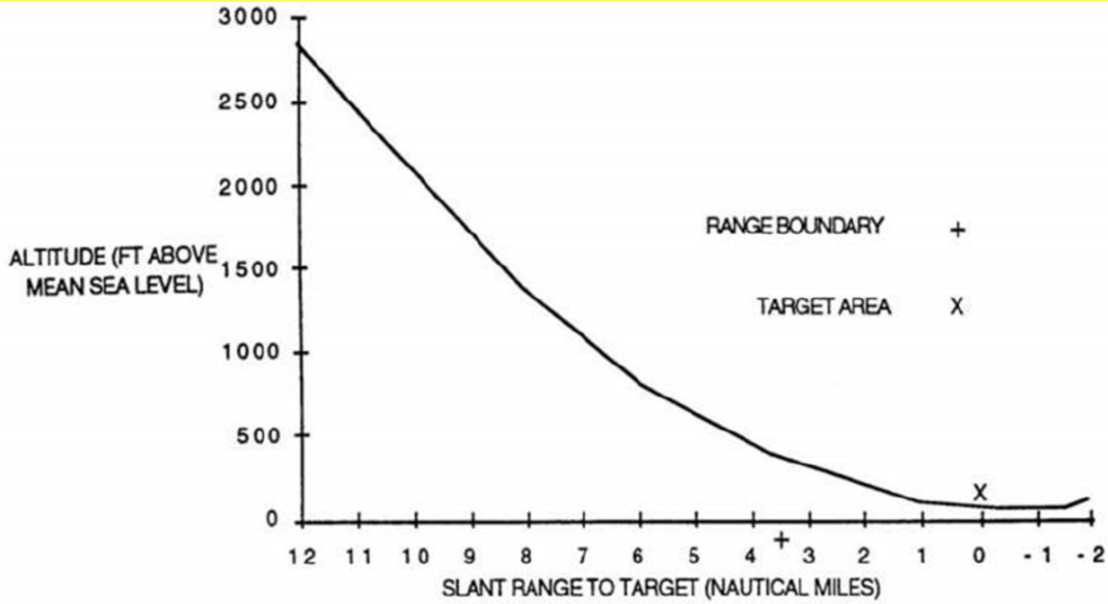
HL = altitude of laser above Mean Sea Level.

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-22.



SLANT RANGE TO TARGET nmi	MINIMUM LASING ALTITUDE ft MSL	SLANT RANGE FROM TARGET nmi	MINIMUM LASING ALTITUDE ft MSL
12	2850	0	10
11	2500	- 1	50
10	2100	- 2	112
9	1750		
8	1400		
7	1100		
6	850		
5	650		
4	450		
3	300		
2	150		
1	100		

FIGURE C-22. Example laser aircraft flight profile.

C.8.2.2 Left and right hand LSDZ. The width of the right hand and left hand LSDZ are calculated as:

$s = R \times \sin(\alpha)$.

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.

Generally, the "small angle approximation" can be utilized for this equation since the buffer angle is usually small. This simplifies the equation to:

$s = R \times \alpha$.

Note: At 15 milliradian, this introduces an error of 0.004 percent. At larger buffer angles the error grows rapidly. If calculations require accuracy greater than this introduced error, do not use this small angle approximation.

C.8.2.3 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-23).

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.

β_F = 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).

β_N = 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).

R = slant range from laser to target.

α = assigned buffer angle plus beam divergence.

For Far Target:

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

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

For Near Target:

$h = R\sin(\arcsin((R/N)\sin(\alpha)) - \beta N - \alpha)$ 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-22.

Left and Right Hand LSDZ. If the buffer angle is small, the width of the right hand and left hand LSDZ can be 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.

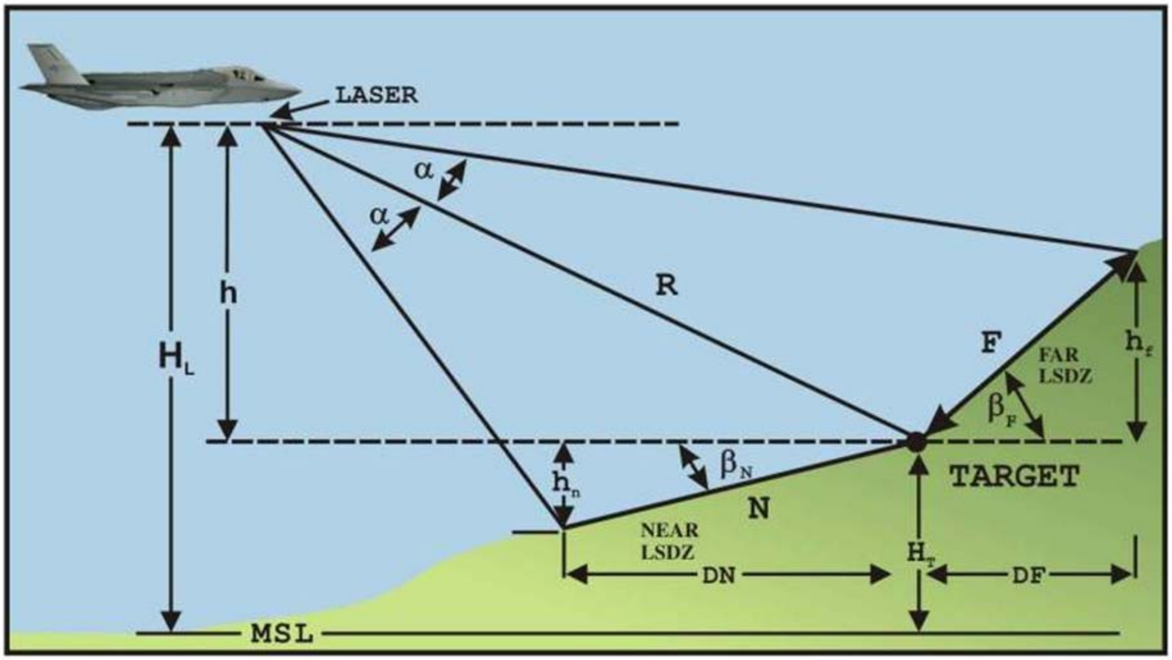


FIGURE C-23. Laser target on sloping terrain.

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Preparing activity:
Navy – MC
(Project SAFT-2014-006)

Review activity:
Navy – EC

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