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MILITARY HANDBOOK

LASER RANGE SAFETY

AMSC/NA

FSC 4240

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MIL-HDBK-828

DEPARTMENT OF DEFENSE

LASER RANGE SAFETY

1. This standardization handbook was developed by the Department of Defense Laser System Safety Working Group. The working group had representatives from the Departments of the U.S. Army, U.S. Air Force, U.S. Navy and U.S. Marine Corps.

2. This document supplements departmental manuals, directives, military standards, and other related documents, to assist in standardizing basic information on laser range safety.

3. Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to: Commander, Space and Naval Warfare Systems Command, SPAWAR OOF, 2451 Crystal Drive, Arlington, VA 22245-5200.

FOREWORD

This Military Handbook is approved for use by all Departments and Agencies of the Department of Defense.

Copies of this document may be obtained through DOD publication channels.

Available from: Standardization Documents Order Desk
Bldg 4D
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To place an order by touch tone telephone, obtain a customer number (for urgent requests, a customer number may be obtained by calling (215) 697-2179) and access the telephone order entry system by dialing (215) 697-1187 (replace the letter “Q” with “7" and “Z” with “9”) .

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1. SCOPE

1.1 Purpose. The purpose of this handbook is to provide uniform guidance in evaluations for the safe use of military lasers and laser systems on DoD military reservations or military-controlled areas worldwide. Each military Service has previously established normal procedures for approving laser ranges. This guidance is intended to supplement these procedures. It does not replace those procedures or release individuals from compliance with the requirements of their particular Service.

1.2 Application This handbook applies to:

a. All DoD ranges or operational test facilities where lasers are used and all DoD laser operations conducted on non-DoD controlled ranges or test facilities.

b. Laser systems that have been evaluated by the health and safety specialists as designated below for your respective Service:

(1) US Army Environmental Hygiene Agency
ATTN : HSHB-MR-LL
Aberdeen Proving Ground, MD 21010-5422
DSN 584-39.32/2331, Commercial (410) 671-3932

(2) Space and Naval Warfare Systems Command
Code 00F
Washington, DC 20363-5700
DSN 332-7235/73, Commercial (703) 602-7235

(3) Armstrong Laboratory
Bioenvirormental Engineering Division
Radiation Services Branch
Brooks AFB, TX 78235-5501
DSN 240-3486, Commercial (210) 536-3622/4784
WATS 1-800-531-7235

c. Outdoor laser use.

d. single-sided laser exercises.

e. Fixed and rotary wing airborne laser platforms, as well as ground- and ship-mounted laser systems.

1.2.1 Exclusions. This handbook does not apply to:

a. Indoor use; e.g., laboratory laser repair depots or industrial laser facilities due to the unique control measures required.

b. Industrial and construction lasers such as those used for surveying.

c. New technology laser applications.

1.2.2 High energgv laser systems. High energy laser systems (lasers capable of cutting material or burning standard target material) require unique control measures. Use of these lasers must be approved by the local Laser Safety Officer (LSO) in coordination with the specialists in 1.2b.

1.2.3 Broad beam lasers. Lasers with broad beam or autonomous scanning systems that are not directly under the operator's control may require additional evaluation assistance from the organizations listed in 1.2b.

1.2.4 Force on force exercises. Force on force exercises using lasers and laser devices (except training lasers such as the Multiple Integrated Laser Engagement System (MILES) which is addressed elsewhere in this Manual) are special cases requiring additional controls. They must be addressed on an individual basis by the local LSO with assistance from the Service component safety and health specialist listed in 1.2b.

1.3 Content This handbook contains sections that give the general and detailed policies to be followed in evaluating and recommending laser range safety procedures. Appendix A provides safety hazard control data for specific laser systems evaluated by each of the service safety specialists. Appendix B provides safety information on lasers used for scoring tactical exercises. Appendix C summarizes safety data for gunnery training systems and simulators. Appendix D is a sample Laser Safety Standard Operating Procedure (SOP) . Appendix E describes the equations utilized to determine Laser Surface Danger Zones (LSDZ)/Nominal Hazard Zones (NHZ). Appendix F contains checklists to be used for the laser safety pre-survey, the site survey, and the laser range safety evaluation reports. Appendix G discusses methods of evaluating hazards from specular reflections of the laser beam. Appendix H provides safety policy for at-sea operations against ships towed targets and separate targets (SEPTAR) .

2. REFERENCED DOCUMENTS

2* APPLICABLE DOCUMENTS

2.1 Government documents.

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

STANDARDS

MILITARY

MIL-STD-1425 Safety Design Requirements For Military Lasers And Associated Support Equipment

NATO STANDARDIZATION AGREEMENTS

STANAG 3606 Evaluation And Control Of Laser Hazards

2.1.2 Other Government publications. The following other Government publications form a part of this handbook. This handbook supplements and does not supersede the regulations for each service. All offices responsible for laser safety will have a copy of the references applicable to their Service.

DEPARTMENT OF DEFENSE

DoD Instruction 6050.6, "Exemption for Military Laser products," June 17, 1986.

DoD Directive 3200.22, "operation on National Ranges and Test Facilities,"

DoD RCC Document 316-91, "Laser Range Safety, Range Safety Group, DoD Range Commanders Council."

Us. ARMY

TB MED 524, "Control of Hazards to Health from Laser Radiation. "

DAPM 385-63/MCO P3570.1, "Policies and procedures for Firing Ammunition for Training, Target Practice and Combat.

AR 40-46, "Control of Health Hazards from Lasers and Other High Intensity Light Sources."

AR 385-30, "Safety Color Code Markings and Signs."

AMCR 385-29, "Safety-Laser Safety."

AR 40-5 "Preventive Medicine."

U.S. AIR FORCE

AFOSH Standard 161-10, “Health Hazards Control for Laser Radiation”.
USAFOEHL Report AL-TR-1991-0112, “Base-Level Management of Laser Radiation Protection Program”
USAFOEHL Report 87-091RCO111GLA ‘Laser Range Evaluation Guide For Bioenviromental Engineers”

U.S. NAVY

BUMED Instruction 6470.2A, “Laser Radiation Health Hazards.”
SECNAV Instruction 5100.14B, “Exemption of Military Laser Products.
SPAWAR Instruction 5100.I2A, ‘Navy Laser Hazards Prevention Program.”
EO410-BA-GYD-O10 , “Technical Manual, Laser Safety, “
MCO P3570.1, “Policies and Procedures for Firing Ammunition for Training, Target Practice and Combat.”

CODE OF FEDERAL REGULATIONS (CFR)

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

OCCUPATIONAL SAFETY AND HEALTH ADMINISTRATION (OSHA)

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

FEDERAL AVIATION ADMINISTRATION (FAA)

FAA 7930.2B Notices To Airmen (NOTAM)

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

2.2 Other publications. The following document forms a part of this handbook to the extent specified herein. Unless otherwise specified, the issues of the documents which are DoD adopted shall be those listed in the issue of the DoDISS specified in the solicitation. Unless otherwise specified, the issues of documents not listed in the DoDISS shall be the issue of the nongovernment documents which is current on the date of the solicitation.

AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)

ANSI 2136.1 Safe Use of Lasers

(Copies of this document may be obtained through DOD publication channels for government activities. For all others, application for copies should be addressed to American National Standards Institute (ANSI), 11 West 42nd Street, New York, NY 10036 or to the publisher, Laser Institute of America, 12424 Research Parkway, Suite 125, Orlando, FL 32826)

2.3 Order of precedence. In the event of a conflict between the text of this handbook and the references cited herein, the conflict will be referred to the military service specialists in paragraph 1.2b of this handbook who have jurisdiction of the laser range. Nothing in this handbook, however, shall supersede applicable laws and regulations unless a specific exemption has been obtained.

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3. DEFINITIONS

3.1 Terms and Units. The following definitions are used in this manual. (For other definitions, refer to ANSI 2136.1.

3.1.1 Aircraft Exclusion Zone. A cone around the laser line-of-sight that is 20 times the buffer angle. Laser Operations must stop when another aircraft enters this zone.

3.1.2 Aperture. Any opening in the protective housing, shielding or other enclosure of a laser product through which laser or collateral radiation is emitted, thereby allowing human access to such radiation.

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

3.1.4 Buffer Angle. The angle about the laser's line-of-sight with apex at the laser aperture that is used to determine the buffer zone. It is typically set, as a minimum, to five times the demonstrated pointing accuracy of the system plus the beam divergence. Buffer angles for several lasers are assigned in Table A-I.

3.1.5 Buffer Zone. A conical volume centered on the laser's line-of-sight with its apex at the aperture of the laser, within which the beam will be contained with a high degree of certainty.

3.1.6 Laser Footprint. The projection of the laser beam and buffer zone on the ground or target area. The laser footprint may be part of the laser surface danger zone if that footprint lies within the nominal ocular hazard distance of the laser.

3.1.7 Closed Installation. Any location where laser systems and products are used that will be closed or opaque to unprotected personnel during laser operations.

3.1.8 Collateral Radiation. Extraneous radiation (such as secondary beams from optics, flash lamp light, radio frequency radiation, x-rays, etc.) that is not the intended laser beam as a result of the operation of the product or any of its components. System indicator lights would not normally be considered sources of collateral radiation.

3.1.9 Continuous Wave (CW) . The output of a laser that provides a steady or continuous output power rather than a pulsed output. A laser emitting with a continuous output for a period in excess of or equal to 0.25 seconds is a CW laser.

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

3.1.11 Diffuse Reflection. Reflection from a surface in which the beam is scattered in all directions e.g., a reflection from a rough surface. An ideal diffuse surface in which reflected brightness is independent of the viewing angle is called a Lambertian surface.

3.1.12 Electromagnetic Radiation. The propagation of energy consisting of alternating electric and magnetic fields that travels through space at the velocity of light and includes light, radio frequency radiation and microwaves.

3.1.13 Exempted Lasers. Military lasers exempted" from 21 CFR 1040, 'Performance Standards for Light-Emitting Products", when compliance would hinder mission fulfillment during actual combat or combat training operations or when the laser product is classified in the interest of national security. These lasers must comply with MIL-STD-1425, 'Safety Design Requirements for Military Lasers and Associated Support Equipment." See DODI 6050.6.

3.1.14 High Energy Laser. All class 4 lasers with power of at least 20 kilowatts for more than 1.5 seconds or energy of at least 30 kilojoules for less than 1.5 seconds.

3.1.15 Infrared Radiation (IR) Electromagnetic radiation with wavelengths within the range of"700 nanometers (rim) to 1,000 micrometers (μm). This region is often divided into three spectral bands by wavelength: IR-A (700 to 1400 nm) , IR-B (1400 to 3000 m), and IR-C (3 to 1000 μm). IR-A is sometimes called near-infrared.

3.1.16 Irradiance (E) . Measure of radiant power in watts per square centimeter.

3.1.17 Joule. A unit of energy, used principally for pulsed lasers, equal to 1 watt-second or 0.239 calories (cal) .

3.1.18 Laser. Any device that can produce or amplify optical radiation primarily by the process of controlled stimulated emission. A laser may emit electromagnetic radiation from the ultraviolet portion of the spectrum through the infrared portion. Also, an acronym for "Light Amplification by Stimulated Emission of Radiation".

3.1.19 Laser Controlled Area. Any area that contains one or more lasers where the activity of personnel is subject to *control* and supervision for the protection from radiation hazards associated with laser operation.

3.1.20 Laser Radiation Coherent electromagnetic radiation produced as a result of-controlled stimulated emission within the **spectral range of 200 nm to 1000 µm.**

3.1.21 Laser Safety Officer (LSO) /Laser System Safety Officer (LSSO). An individual trained in laser safety, who is appointed by the commander to be responsible for control of laser hazards at a particular installation. The term Laser System Safety Officer is used by the Navy to differentiate the LSSO from the Landing Signal Officer (LSO). Each Service's regulations will stipulate training requirements for LSOS and/or LSSOS.

3.1.22 Laser Surface Danger Zone (LSDZ), Nominal Hazard Zone (NHZ) . Designated region where laser radiation levels may exceed the maximum permissible exposure level.

3.1.23 Maintenance. Performance of those adjustments or procedures to be performed by the user for ensuring the intended performance of the product. It does not include operation or servicing. This definition is equivalent to the DoD concepts of operator-performed maintenance and/or organizational maintenance. This organizational maintenance could include firing the laser.

3.1.24 Maximum Permissible Exposure. Laser radiation exposure levels published in ANSI 2136.1, and established for the protection of personnel. These are levels of laser radiation to which a person may be exposed without known hazardous effects or adverse biological changes in the eye or skin. The MPEs contained in ANSI 2136.1 are used in this handbook and agree with STANAG 3606.

3.1.25 Milliradian (mrad) . Unit of angular measure. one mrad equals one thousandth of a radian. One degree equals 17.5 milliradians.

3.1.26 Micrometer (um) Formerly termed 'micron", a measure of . length equal to 0.000001 meter (10^{-6} meter) .

3.1.27 Nanometer (nm) A measure of length equal to .000000001 meter (10^{-9} meter) . Formerly, and sometimes still, termed millimicron.

3.1.28 Nominal Hazard Zone. See Laser Surface Danger Zone.

3.1.29 Nominal Ocular Hazard Distance (NOHD) The distance along the axis of the laser beam beyond which-the irradiance (W/cm^2) or radiant exposure (J/cm^2) is not expected to exceed the appropriate MPE; that is, the safe distance from the laser. The NOHD-O is the NOHD when viewing with optical aids.

3.1.30 Optical Density (OD) The following logarithmic expression for the attenuation produced by a filter such as an eye protection filter: -

$$OD = \log_{10} (I_o/I_t)$$

Where I_0 is the power incident upon the filter and I_t is the power transmitted through the filter at a specific wavelength.

3.1.31 Optical Radiation. Electromagnetic radiation with wavelengths that lie within the range of 200 nm to 1060 nm. This radiation is often divided into three spectral regions by wavelength: ultraviolet radiation (200-400 nm) , visible radiation (400-700 nm), and infrared radiation (700 nm - 1060 nm) .

3.1.32 Pulse Duration The time increment measured between the half-peak- power points on the leading and the trailing edges of a pulse.

3.1.33 Pulsed Laser. A laser that delivers its energy in discontinuous bursts; i.e., there are time gaps during which no energy is emitted. For the purpose of this handbook, a laser that emits a pulse for less than 0.25 second.

3.1.34 Radian (rad). A unit of angular measure equal to 57.3 degrees.

3.1.35 Radiance (L). The radiant energy per unit solid angle emitted by a source.

3.1.36 Radiant Energy (Q). Energy in the form of electromagnetic waves, usually expressed in units of joules. Commonly used to describe the output of pulsed lasers.

3.1.37 Radiant Exposure (H) The radiant energy per unit area incident upon a given surface. It is used to express exposure dose to pulsed laser radiation and is commonly expressed in joules per square centimeter or joules per square centimeter per pulse.

3.1.38 "Radiant Flux or Power (Φ). The time rate of flow of radiant energy given in units of watts. Commonly used to describe the output power of CW lasers or the average output power of repetitively pulsed lasers.

3.1.39 Reflectance or Reflectivity [Pi . The ratio of total reflected energy to total incident energy.

3.1.40 Repetitively Pulsed Laser. A pulsed laser with a sequentially recurring pulsed output.

3.1.41 Service. The performance of those procedures or adjustments described in the manufacturer's service instructions that may affect any aspect of the product's performance for which this handbook has applicable requirements. It does not include maintenance or operation as defined in this section. This definition is equivalent to DoD concepts of maintenance above the organizational level.

3.1.42 Solid Angle (Ω) The ratio of the area on the surface of a sphere to the square if the radius of that sphere. It is expressed in steradians.

3.1.43 Steradian (sr) . The unit of measure for a solid angle. There are 4 pi steradians in a sphere.

3.1.44 Support Equipment. Devices or enclosures procured specifically for, or modified for, laser test, calibration maintenance, or other support not part of the laser primary mission.

3.1.45 Transmittance or Transmissivity (t) The ratio of total transmitted radiant power to total incident radiant power.

3.1.46 Ultraviolett Radiation Electromagnetic radiation with wavelengths between soft X-rays and visible radiation. This region is often divided into three spectral bands by wavelength: W-A (315 - 400 rim), W-B (280 - 315 rim), and UV=-C (200 - 280 nm) .

3.1.47 Visible Radiation (light). Electromagnetic radiation that can be detected by the human eye. It is commonly used to describe wavelengths that lie in the range between 400 nm and 700 nm.

3.1.48 Watt (W). The unit of power or radiant flux equal to one joule per second. Used principally with CW lasers.

3.1.49 Wavelength (λ) The distance between two points in a periodic wave that have the same phase is termed one wavelength. The velocity of light in centimeters per second divided by frequency (in Hz) equals the wavelength (in cm).

4. GENERAL RANGE CONTROL PHILOSOPHY

4.1 General Policy. The underlying concept of laser range safety is to prevent injury to personnel from laser radiation. The objective of performing laser safety evaluations of DOD laser ranges is to ensure that no unprotected personnel are exposed to laser radiation above the protection standards specified in ANSI 2136.1 without placing unnecessary restrictions on laser system use. This shall be accomplished as follows (See Figures 4-1 and 4-2):

a. Locate target areas where no line-of-sight exists between lasers and uncontrolled, potentially occupied areas.

b. Remove specular surfaces from targets and target areas. Do not use a laser to designate or range still water, flat glass, mirrors, glazed ice, plexiglass, or other specular reflectors.

c. Laser beams and their associated buffer zone must be terminated or the radiation level attenuated below the Maximum Permissible Exposure (MPE) limit within the controlled range or test facility or in controlled airspace. If energy below the MPE is allowed to leave the range, the possibility of optically aided viewing by unprotected individuals must be considered in the safety evaluation.

d. Lasers should be of the lowest emission level consistent with mission requirements.

e. On most ranges, some personnel and moving targets are required to be on the range during laser operations for instrumentation operations, munitions impact spotting, and other required activities. The locations of all occupied areas must be determined and evaluated relative to the laser hazard area. The type of laser protective devices required, if any, must then be determined for each occupied location.

f. Safety evaluations and degree of restrictions shall consider:

1. Extent of range boundaries.
2. Required warning signs.
3. Number and location of specular reflectors.
4. Ease of public access to the range.
5. Airspace restrictions.

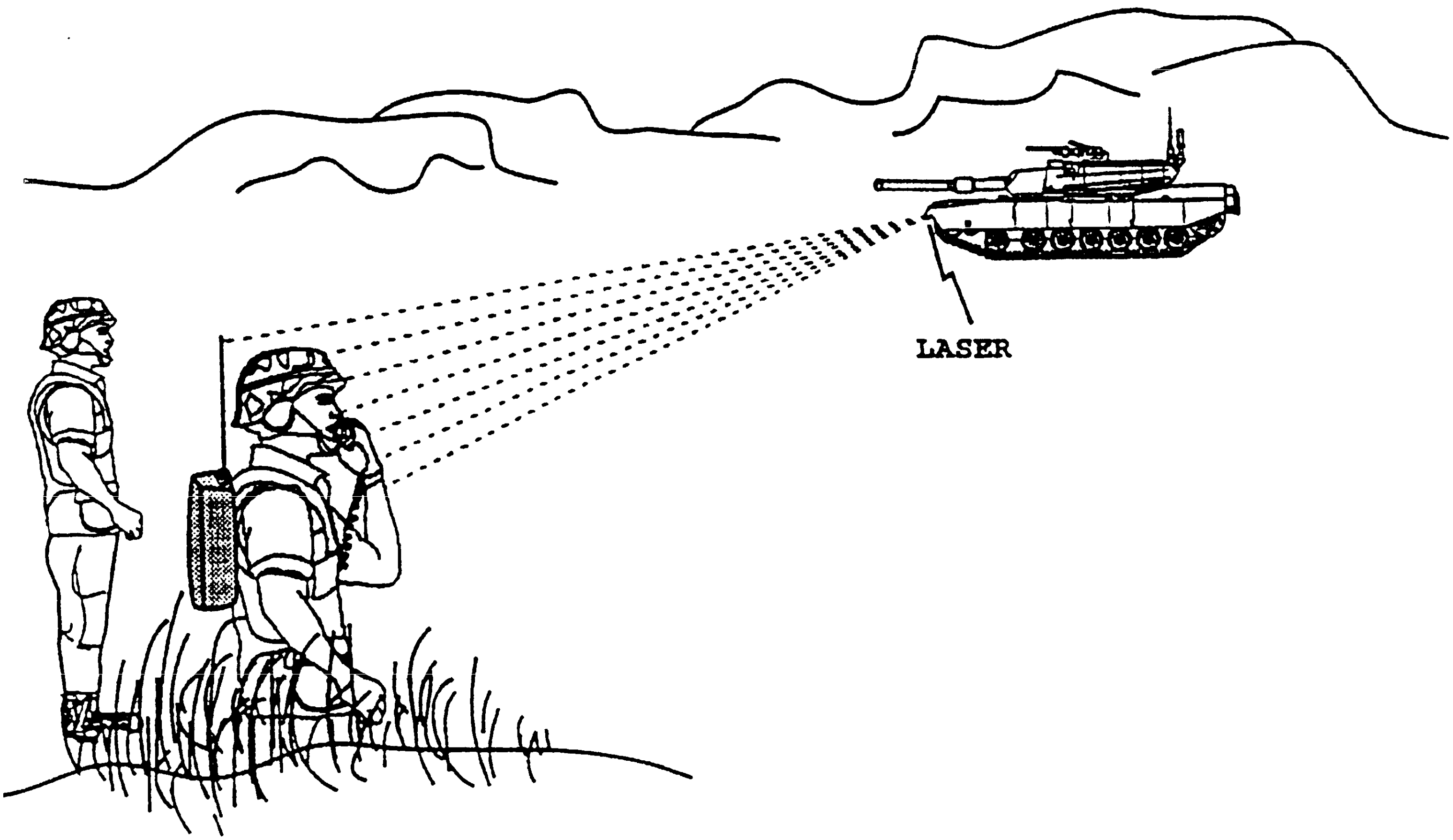

Figure 4-1. Direct Intrabeam Viewing

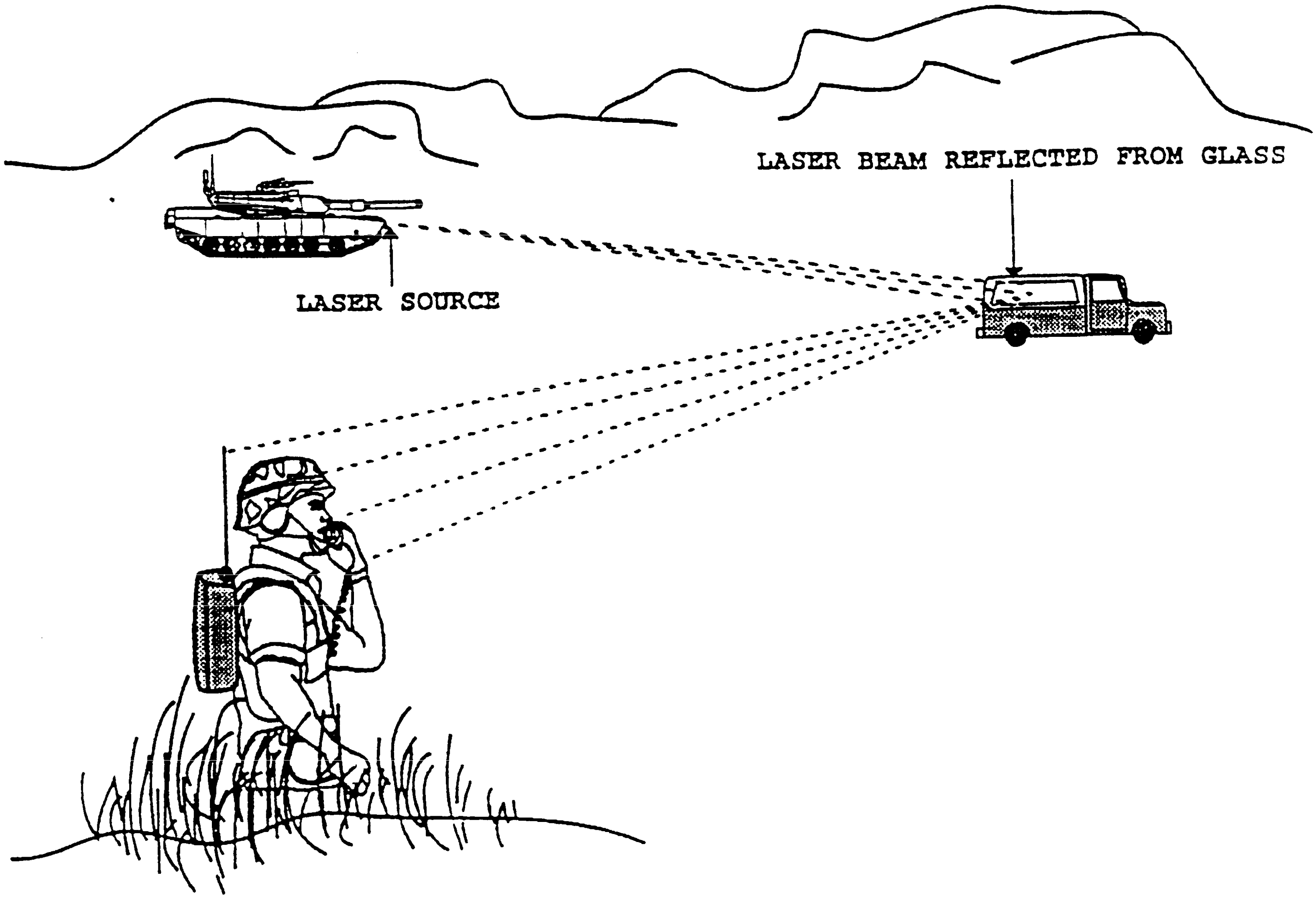

Figure 4-2. Reflected Intrabeam Viewing

6. Local operating procedures.

7. Environmental conditions.

g. In joint laser exercises, all parties shall be informed of the intended laser operations prior to scheduling, including the:

1. Range Control Office.

2. Range Safety Office.

3. LSO/LSSO/Radiation Protection Office (RPO).

4. Liaison Office for the Services involved.

In coordinating with these offices ensure that Notice to Airmen (NOTAM) and Notice to Mariners (NOTMAR) are prepared and issued per FAA, USCG and DMA regulations where required. Also ensure that use of class 3 or class 4 lasers above the horizon is approved by NORAD (Laser Clearing Housing) DSN 834-1211 extension 3290.

4.2 Recommended Targets. Recommended target areas are those without specular (mirror-like) surfaces. Glossy foliage, raindrops, fog, snow and most other natural objects are not considered to be specular surfaces that would create ocular hazards. All reflectors posing a specular reflectance hazard shall be removed from the Laser Surface Danger Zone (LSDZ) . Calm, smooth water and clean ice can reflect laser beams, especially at low angles of incidence. Consider these potential reflections when establishing target areas. If these potential reflections were not considered for the approved target area, ranges shall be closed when water begins pending on either ground, snow or ice.

4.3 Beam Control. If target areas have no flat specular surfaces, then range control measures can be limited to the control of the beam path between laser and backstop.

4.4 Specular Reflectors. Specular surfaces within distance "s" (see Appendix A, Table A-I and Appendix B) of the laser target visible to unprotected personnel, through binoculars or magnifying optics will be removed, covered, painted or destroyed. For lasers used from fixed wing aircraft, the entire buffered laser footprint area shall be cleared of specular reflectors. (See Appendix E).

4.5 Hazards

a. Laser devices, such as those listed in Appendix A, Table

A-I, can seriously injure the unprotected eyes of individuals within the hazard zone of the laser beam. Intrabeam viewing of either the direct beam or a beam reflected from a flat mirror-like surface may expose unprotected eyes to a potential injury and must be avoided.

b. Every diffuse reflecting object that the laser beam strikes will reflect some energy back in all directions and toward the laser. This diffusely reflected energy will not be hazardous if the laser is located greater than a distance "t" from the target. (See Table A-I.) Similarly, to avoid hazardous specular reflections, the area around the target must be cleared of specular (mirror-like) reflectors. The hazard of exposure to the skin is small compared to the eye; however, personnel should also avoid direct laser beam exposure to the skin within distance "t" from the laser.

c* A less severe hazard exists for the devices listed in the Tables of Appendices C and D, but intrabeam viewing of the laser bean at distances less than that specified with the unprotected eye should be avoided.

d. Dazzle and momentary flashblindness can occur from visible laser exposures below MPEs. Laser eye protection may not attenuate the radiation sufficiently to eliminate these effects. Appropriate precautions *must* be taken if personnel performing critical tasks, such as flying aircraft, may be exposed to laser radiation levels that may cause dazzle or momentary flashblindness.

4.6 Unprotected Personnel. Unprotected personnel must not be exposed to laser radiation in excess of the MPE from either the direct or reflected beam.

4.7 Warning Signs. Evaluation of each anticipated operating condition must include development of procedures for ensuring proper placement of warning signs. Local SOPS should provide for the placement of temporary signs during operation. Signs should be in accordance with AR 385-30, SPAWARINST 5100.12A or AFOSH Std 161-10. See Figure 4-3.

4.8 Personnel Protection. Individuals within the horizontal or vertical LSDZ, such as moving target operators, support personnel, and aircrew members, should wear laser protective eyewear with curved protective lenses during laser firing. The curved lenses are necessary if there is a probability that laser eye protection will specularly reflect the beam into an uncontrolled area. Eye protection with side shields may be required if the laser beam can get behind the lens. Eyewear must be approved for the wavelength of the laser device being fired. A laser filter designed to protect against one wavelength of

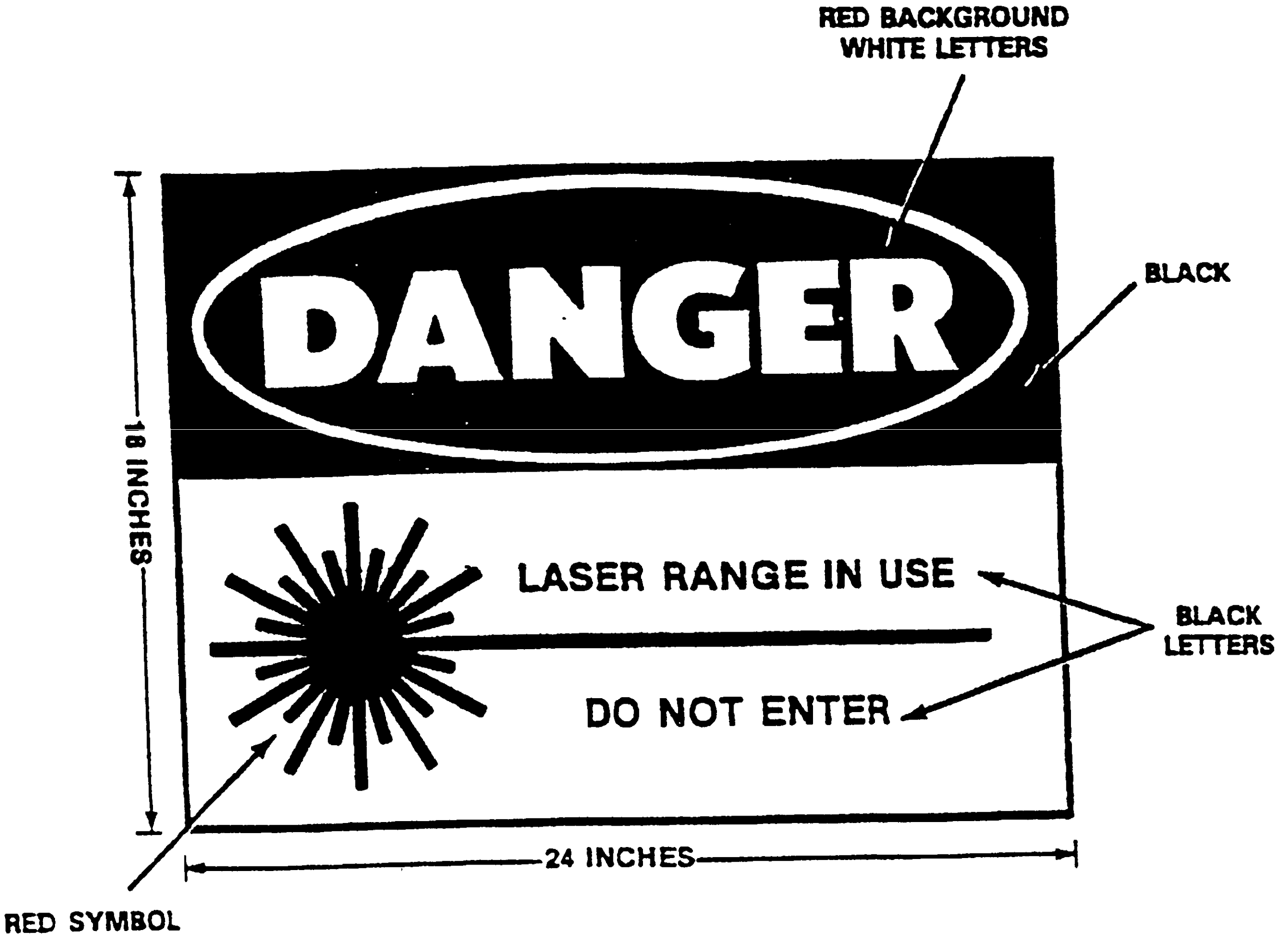

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Figure 4-3. Example Warning Sign

laser may not protect against harm from another. See Table A-II for the wavelength and optical density required for the current fielded devices. If more than one type of device is used, protective measures must cover all devices. For devices of the same wavelength, the highest required optical density will be used.

4.9 Magnifying Optics. The use of magnifying daylight optical devices to observe the target during laser operation is permitted if flat mirror-like surfaces have been removed from the target area. Mirror-like targets can be observed only if appropriate laser safety filters are placed in the optical train of the magnifying optics. Protected optics such as sights must be so marked.

4.10 Specific Guidelines. The following specific guidelines are provided as a minimum to ensure proper control of hazardous laser energy:

a. Keep a log showing the date, time, and appropriate laser operations information for each laser operation.

b. Post the range boundaries to advise the public of the presence of laser operations. These signs shall be in accordance with MIL-STD-1425. See Figure 4-3.

c. Fire lasers only at authorized targets.

d. Do not fire the laser at still water, flat glass, mirrors, glazed ice, plexiglass, or any other specular reflectors unless specifically authorized by the Laser Safety Officer.

e. Do not fire the laser at aircraft unless specifically authorized by the Laser Safety Officer.

f. Before operating fire control lasers or rangefinders, be certain that the target is positively identified under the crosshairs of the scope or on the operator's monitor or in accordance with specific safety procedures approved by the Laser Safety Officer.

g" Cease laser operations if the operator or range control is dissatisfied with target tracking.

h. Cease laser operations if unprotected and/or unauthorized personnel enter the laser hazard area.

i. Clear the range using range personnel or by a flyover of the range to ensure that no unprotected and/or authorized personnel are in the laser hazard area. This includes fishing boats where island or shoreline ranges are involved.

j. For air operations, cease laser firing if unprotected and/or unauthorized aircraft enter the operations area or a restricted zone between the aircraft carrying the laser and the target. The restricted zone for most fire control lasers is defined as twenty times the assigned buffer zone. For example, when using a laser with an assigned buffer zone of five milliradians, the restricted zone around the laser beam out to the NOHD for other aircraft with unprotected personnel would be a one hundred milliradian or five degree (half angle) cone surrounding the laser line-of-sight to the target with the aircraft carrying the laser at the apex.

k. Maintain two-way communication between the laser system operators and all affected range personnel.

1. Establish a laser operator training program.

HA. Provide a "Pre-mission Brief" to all laser operators and affected personnel prior to laser operations. The brief shall include as a minimum:

1. Maps depicting the targets and/or target areas and their laser hazard area.

2. Drawings or photographs of the target/targets to be used.

3. Run-in headings and flight profiles to be used for airborne laser operations and permissible firing fans for ground-based laser operations.

n. Do not direct class 3 and 4 lasers above the horizon unless coordinated with NORAD (Laser Clearing House) DSN 834-1211, Ext. 3290 and with the regional FAA office for laser radiation above the MPE outside restricted airspace.

Ensure ground-based lasers are at the approved operating position or firing points and always pointed down range toward the target.

p. For ground based lasers, ensure all unprotected personnel in the immediate area of the laser firing position are outside the laser surface danger zone or behind the laser operator while the laser is in use. Laser eye protection is not required for laser operators or observation personnel viewing a target area from which specular reflectors have been cleared, even when binoculars are used. However, personnel must never wander into the LSDZ without appropriate eye protection.

q. Immediately report any suspected injury or defective equipment (e.g. , misalignment of the laser beam with the pointing optics) to the cognizant supervisor so the appropriate action can be taken.

r. Do not operate the laser or use it experimentally outside the range area without such operation being specifically authorized by the local Laser Safety Officer.

4.11 <u>Laser Pre-firing and Post Firing Restrictions</u>. When lasers are not in use, hazardous laser output shall be prevented by use of such devices as output covers, or rotating the laser into the stow position, unless otherwise specifically authorized by the local Laser Safety Officer.

a. Any maintenance performed in a range environment must be in accordance with operating procedures approved by the local Laser Safety Officer.

b. Prefire checks that require operation of the laser may be made in a controlled area with the laser beam terminated by an opaque backstop. Prefire checks that do not require operation of the laser, but require use of the optics, may also be safely made in a controlled area. To operate the optics without firing the laser, institute operating procedures to ensure power to the laser is turned off in accordance with local ‘lock-out/tag-out” procedures.

c. Non-laser operations (such as viewing through common optics) can be conducted in a non-laser controlled area with the laser exit port cover removed. This is done by instituting procedures that ensure power to the laser is turned off.

d. The laser exit port must be covered, or laser otherwise stowed and turned off, when transiting the range and:

1. Not engaged in non-laser operations conducted in a controlled environment.

2. Traveling on public highways or in uncontrolled air space or shipping lanes.

5. PLANNING REQUIREMENTS

5.1 Range Evaluation Planning

5.1.1 Background. Before any laser range operations, the hazards of using the system on the range must be fully evaluated. Both the laser user and the range control personnel must mutually agree on the conditions for laser operations. A sample checklist is provided in Appendix F for this data collection.

5.1.2 Laser User. The laser user shall provide:

a. Technical Orders, Technical Manuals, and/or reports on the laser system and associated hazards as requested by the range evaluator.

b. NOHD's and sources of evaluations or the parameters required to perform the safety evaluations.

c. Standard operating procedures on the laser.

d. Intended operational environment for laser use to include types of targets and position, laser firing locations, run-in headings, maximum and minimum firing altitudes and ranges, direction of laser operations, and any other special considerations.

e. Laser systems parameters.

f. Hazardous failure modes (i.e., those that affect laser parameters or beam steering, secondary beams, inadvertent firing and other potential system problems) .

5.1.3 Range Operator. The range operator shall provide:

a. Local instructions that outline general range operating and safety requirements.

b. Detailed range maps showing laser location, target location, restricted airspace or artificial backstops, flight path, and range boundaries, populated areas, public roads, “no lase” areas, etc.

5.1.4 Range Evaluator. The range evaluator will review laser system data, maps, targets, instructions, SOP’s and other information provided by the laser user and range operator to determine which existing requirements impact the safety of laser operations on the range such as:

a. Limitations on allowable laser locations and run-in headings for aircraft.

headings for aircraft.

b. Minimum and maximum flight altitudes (airborne platforms only) .

c. Airspace surveillance.

d. Flyover requirements to ensure range security.

e. Locations of control towers and other manned areas.

f* Locations of non-controlled personnel access to the areas surrounding the target area. See sample diagram in figure 5-1.

9* Specific information on maintenance, boresighting or other-activities on the range.

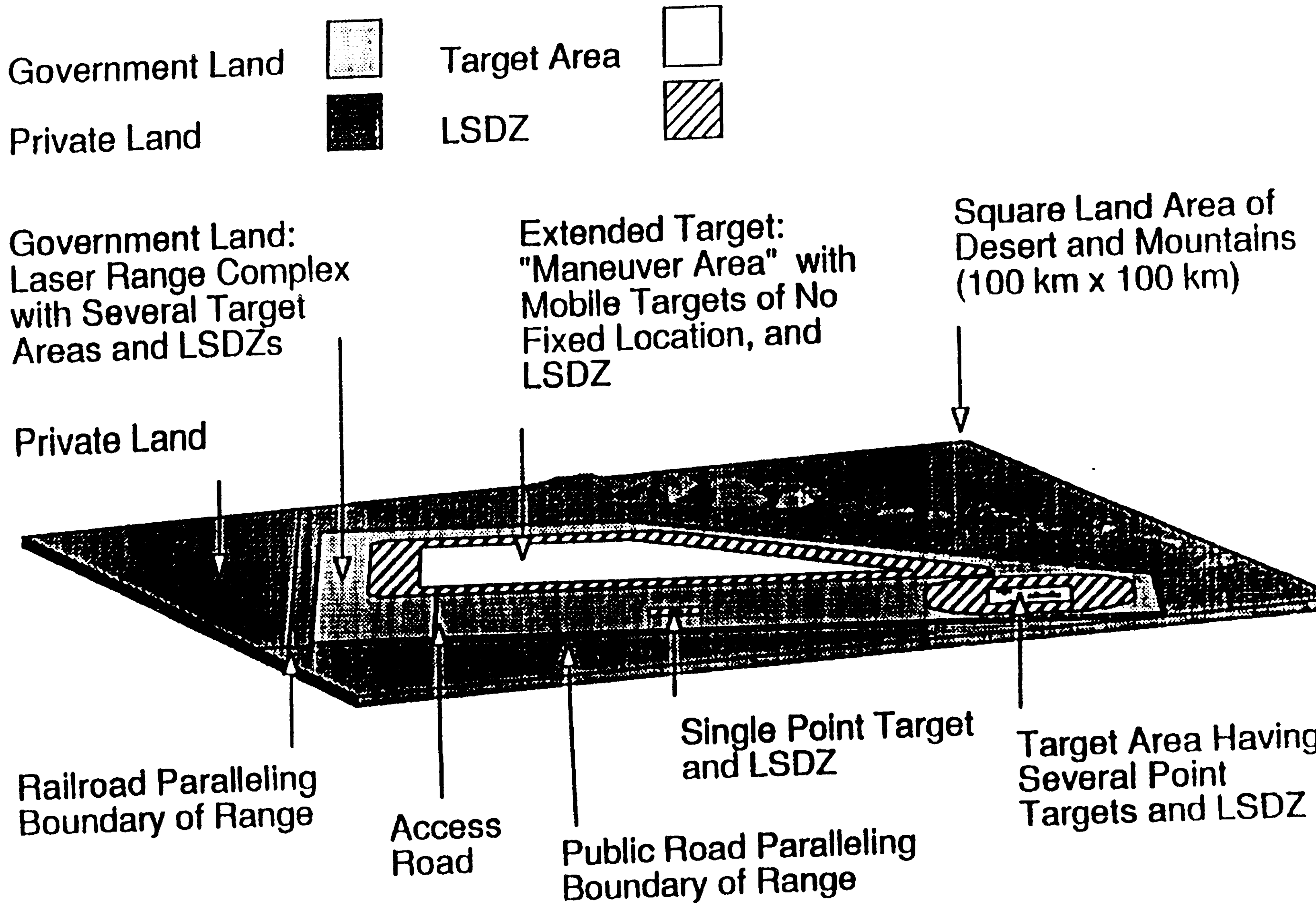


Figure 5-1. Laser Range Complex with Multiple Target Areas

6. EVALUATION REQUIREMENTS

6.1 Range Evaluation procedure

6.1.1 Evaluation Sequence. A laser range evaluation can be performed for a specific laser system or for a group of similar lasers. An evaluation of a group of similar lasers is recommended if available land permits and the *mission* is not severely impacted. To perform this general evaluation, the worst case conditions of all possible systems and missions are used. If these conditions are too restrictive, separate evaluations for each system must be performed. The evaluation should be conducted on-site at the laser range, including a flyover, drive-through and walk-through inspection. To simplify the range evaluation procedure, it may be divided into five steps: The laser; the range; the target; “the mission; and the laser surface danger zone.

a. The Laser. To evaluate a laser for use on a range, it is necessary to determine the hazard potential of the system by determining the following:

1. Maximum Permissible Exposure (MPE) Limits Determine the applicable MPE for the laser being evaluated. MPE's *are* given in ANSI Z136.1.

2. Laser Classification Classify the laser using procedures in MIL-STD 1425, "Saftey Design Requirements for Military Lasers and Associated Support Equipment", to determine what laser control procedures are required (interlocks, warning labels, etc.).

3. Nominal Ocular Hazard Distance (NOHD). Determine the distance from an operating laser to the point where it is no longer an eye hazard using procedures designated by the specialists of 1.2.b, or, use the values given in Appendices A and C.

4. Reflections. Determine if the laser is capable of producing hazardous reflections under established conditions using procedures designated by specialists in 1.2.b or Appendices A and C.

A. Specular Reflections. Determine what kinds of surfaces will act as specular reflectors at the laser wavelength. See Figure 6-1, Table 6-1 and Appendix G.

TABLE 6-I. TYPICAL REFLECTIVE SURFACES
(See figure 6-1 for illustration)

Diffuse Reflectors	Flat Specular Reflectors	Curved Specular[2] Reflectors
dry foliage	flat glass[1]	wet foliage
rocks	vision viewblocks	beer bottle
camouflage	calm water*	turbulent water
soil	vehicle rear view mirror	glossy paint
matte paint	instrument gauges	optical sights
aluminum cans	flat windows*	curved windows
old ordnance	detector windows	automobile bumpers

[1] See Table G-I for reflectivity at various angles of incidence.
[2] Generally not a hazard beyond a few meters.

B. Diffuse Reflections- Determine if the laser is capable of producing hazardous diffuse reflections. Lasers that can produce hazardous diffuse reflections are classified as Class 4 and have a diffuse reflection hazard distance (t) associated with it. It is unusual for field type lasers to produce diffuse hazards (presently, only the M60 Tank, the M551Al Sheridan Vehicle and the OV-1OD Night Observation System produce hazardous diffuse reflections). Normally for a diffuse hazard, the beam path out to the distance "t" as shown in Table A-I, is a denied occupancy area and no objects are permitted in the beam path out to this distance.

5. Optical Density (OD). The degree of protection required to reduce the incident laser energy to safe eye and skin levels must be determined. These are also available in Appendices A and B and from the designated specialists of 1.2.b.

6. Optical Viewinq Consider the possibility of personnel directly viewing the beam (intrabeam viewing), or reflections of the beam, through optical instruments such as binoculars. The light-gathering ability of the optics can significantly increase the degree of hazard for the eyes (increase OD and NOHD). Procedures to evaluate this are in AFOSH Standard 161-10, ANSI 2136.1 and TB MED 524. Some evaluation results are included in Appendices A and B.

7. Atmospheric Attenuation. Atmospheric attenuation can be quite high for infrared lasers operating over distances of 10 kilometers or greater. It can reduce the NOHD considerably and should therefore be included in the laser evaluation.

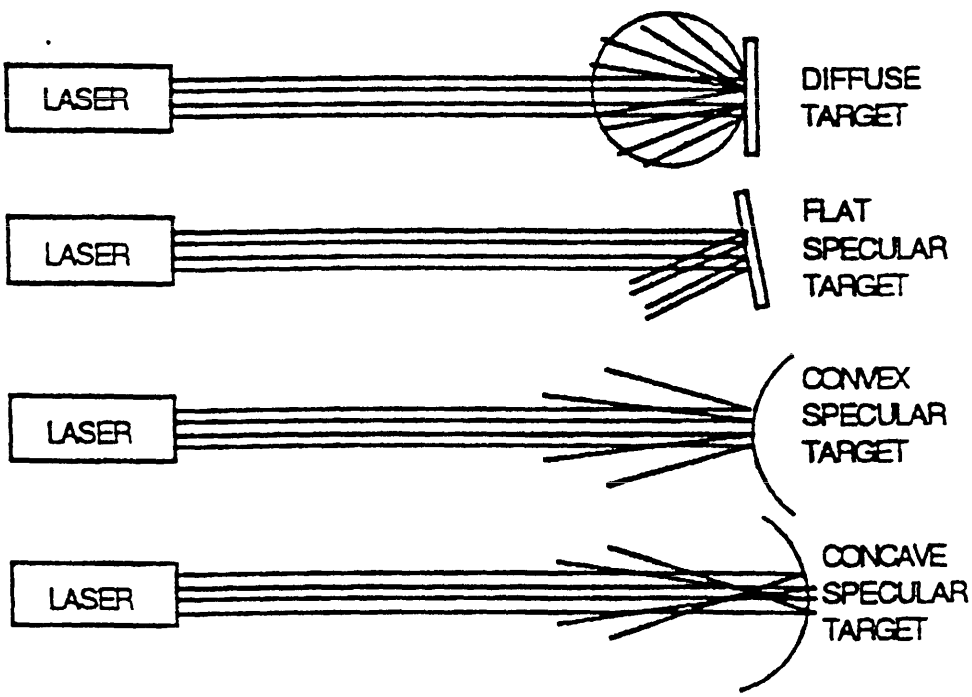


Figure 6-1. **Diffuse Reflection and Specular** Reflection

8. Laser Platform Stability. The stability of the laser platform must be evaluated to determine pointing accuracy of the laser system. The pointing accuracy will determine the size of the buffer angle. The typical buffer angle for airborne (aircraft), ground based, or shipboard stable platforms (tripods) is 5 milliradians, while hand-held lasers normally require 10 milliradians. Paragraphs later in this chapter further discuss the buffer angle.

b. The Range. A range map, a topographic map and an air space map of the area are needed for the laser range evaluation.

1. Range Map. The range map is essential to establish accurate distances from target area to range boundaries. The range map should have the boundaries and include geographic items such as towers, buildings, etc., which should also be on the map. Boundaries of special purpose areas such as an airstrip and the location of the targets are also required.

2. Topographic Map. The topographic map is important because it enables the evaluator to determine the elevation of the target area relative to the surrounding terrain. It is important that no portion of the beam that exceeds the MPE limits extend beyond the controlled area. The beam can be controlled by using natural geographic backstops such as hills. A topographic map is very helpful in identifying these backstops and in repositioning targets if necessary.

3. Airspace Map ‘Controlled airspace” is that airspace associated with the range having specific, possibly non-coincident lateral boundaries and a specific minimum and maximum altitude. It is important that this controlled airspace and any other special conditions are made known. Laser operations are not normally authorized outside the controlled airspace or when other aircraft are between the laser and the target. Also, if the beam is directed up, or if hazardous reflections could exceed the height of the controlled airspace, additional controls may be necessary.

c. The Target and Target Area. The size, location, and type of targets to be fired at on a range are of primary importance in determining the hazard zone.

1. Optimum Target. The optimum target from a safety point of view is a nonreflective surface. Flat specular surfaces must be removed or covered because reflections from them can retain high collimation. A flat specular surface is one in which you can see a relatively undistorted image. Examples of specular surfaces are windows, Army tank vision blocks, search light cover glass, plastic sheets, glossy painted surfaces, still water, clean ice, flat chrome, and mirrors. Snow is not a specular

surface, but if thawed and refrozen, hazardous reflections can be found, especially at low angles of incidence.

Glossy foliage, raindrops, and other natural objects are not hazardous targets since their curved reflective surfaces as well as other tuned reflective surfaces cause the beam to spread and the reflected irradiance (energy per unit area) decreases quickly with distance. The only exception to this is concave reflective surfaces. These can focus the reflected beam and cause the reflection to be more hazardous than the incident beam. Practically, these reflections are of little concern since it is improbable that the surface is perfectly concave (focuses the beam to a single point) or perfectly reflective. Additionally, the focal point(s) of concave reflectors would probably be very close to the object (small radius of curvature) and be of little concern since people don't normally put their head close to objects *and* if they did, they would probably block the incident beam. Concave surfaces with a large radius of curvature which could focus at longer distances would appear nearly flat and must be removed or covered.

Although curved surface reflection may not be hazardous at typical laser to target engagement ranges, large shiny curved surfaces should be removed. An example of such a surface is a curved automobile bumper. Lastly, a diffuse surface is one *that* totally distorts (or diffuses) the beam shape, normally resulting in a safe to view reflection from outside the target area. Table 6-I lists some common items found in a typical range area and their type classification for reflection. Appendix G provides additional information.

2. *Size* and Location. The number and location of targets (distribution) will affect the size of the hazard zone. On ranges with limited space, it is important that all targets be as close together as tactically feasible.

3. See Appendix H for Navy separate target (SEPTAR) operations.

d. The Mission An evaluation must be accomplished for each type of laser used on the range. The laser operating mode; e.g., air-to-ground, ground-to-ground, ship-to-target, etc., must be determined. At the present time, air-to-ground, ground-to-ground, and ship-to-target are the normal modes used by tactical forces. In the near future, training exercises and tests will include the ground-to-air mode as more state-of-the-art airfield and ground force air defense systems are developed. The air-to-air mode is used for R&D projects and then only with special permission. Required information is listed below for each case:

1. Air-to-Ground. Determine desired flight profiles. Flight information necessary to perform an evaluation are: altitudes, ranges, and directions of the aircraft relative to the target during laser operations. Various terms are used to describe the aircraft direction during ordnance delivery; they include: approach track, attack heading, and run-in heading. These headings can be on a single bearing, a range of bearings, and unrestricted approach (360 degrees) .

Typical mission profiles are:

A. Toss Delivery, General Profile:

Slant Range:l,800-70,000 feet
Altitude:200-2,600 feet

B. Toss Delivery, Mode A:

Slant range:20,000-70,000 feet
Altitude:200-320 feet

C. Toss Delivery, Mode B:

Slant range: 10,000-25,000 feet
Altitude: 1,000-3,400 feet

D. Straight and Level Delivery:

Slant range: l,800-30,000 feet
Altitude: l,500-3,300 feet

E. Dive Delivery

Slant range: 8,500-14,000 feet
Altitude: 4,000-7,600 feet

2. Ground-to-Ground. Determine possible laser locations and direction of laser operations.

3. Ship-to-Target. Determine the possible laser locations, direction of laser operations, and ship headings.

e. LSDZ. Laser surface danger zone (also called buffered laser footprint for airborne/elevated lasers) must be determined using the procedures in 6.1.3, 6.1.5, 6.1.7, 6.1.8, and 6.1.9.

6.1.2 Target and/or Target Area Condition

Careful attention must be paid to the condition of the target and surrounding laser hazard area. Any specular reflectors on or around the laser targets must be either removed or rendered diffuse. Specular reflectors may be rendered diffuse by painting with a flat (non-specularly reflecting) paint. Merely *covering* a specular reflector is not adequate, since the covering material is usually susceptible to damage by ordnance. The position and orientation of any specular reflectors, that cannot be removed or rendered diffuse must be noted so that they can be considered during the laser safety evaluation. Generally, specular reflectors larger than one half inch in diameter must be removed from the LSDZ. If this is too restrictive, individual LSOs may refer to the specialists in 1.2.b. Target area conditions should be reviewed periodically as determined necessary by local safety authority.

6.1.3 System Performance

To meet mission requirements, the stability, pointing accuracy and boresight retention capabilities of a laser rangefinder and/or designator system must exceed those required for range safety.

a. Buffer Zones. In establishing the laser safety buffer zone for a particular system, a factor of at least five times the demonstrated accuracy of the system is used. This factor has been used to compensate for such factors as untrained operators, adverse environmental factors, and use of the system at the limits of its capability. These buffer zones for specific systems are addressed in Appendix A, Table A-I.

b. Variety of Lasers. If a variety of laser systems with similar capabilities is to be used on the same range, only the worst-case parameters are used in the laser safety evaluation of the range. As an example, The A-6E Target Recognition Attack Multisensor (TRAM), the OV-1OD Night Observation System (NOS), and the F-ill Pave Tack systems have similar performance capabilities and may be considered for use on the same range facility. The NOHD'S of the systems, as measured in the far field, are 8.1 nautical miles (NMI), 6.1 NMI, and 8.6 NMI, respectively. All three systems have been assigned a safety buffer zone of 5 mrad. A range safety evaluation based on an NOHD of 8.6 nmi and a 5-mrad buffer zone would, therefore, allow safe use of any one of the three systems on the range without the confusion of three different sets of restrictions. The system parameters are also adequately similar so that the least hazardous systems *are* not unduly restricted.

6.1.4 Laser Surface Danger Zone (LSDZ) The LSDZ consists of the target area plus the horizontal and vertical buffer zones. (See Figure 6-2). It considers both direct hazards (main beam) and indirect hazards (reflections) . The boundaries of the LSDZ depend on which of the two overlapping zones, direct hazard zone or the indirect hazard zone, are larger. If there are no specular reflectors on the range and the laser is not a diffuse reflection hazard, there will not be an indirect hazard zone. The direct hazard zone will always exist if laser to target distance is less than the NOHD. The LSDZ includes the laser beam plus a buffer zone around the beam to account for laser platform instability. There are three types of LSDZs:

a. The total hazard zone is LSDZ area Z or simply the LSDZ. It extends out to the NOHD/NOHD-O or beam backstop and the edges of the laser beam buffer zone.

b. The area that must be cleared of specular surfaces is LSDZ area S. For ground based lasers that do not project a well defined footprint on the ground around the target (beam and buffer footprint are contained on target), LSDZ area S is usually defined by a circle of radius s (as specified in Appendix A, Table A-I) around the target. For airborne laser operations, area S is the same as LSDZ area Z. For ground based laser operations from elevated platforms where the laser projects a well defined buffer footprint, area S should equal LSDZ area Z. Backstop areas where the energy of the incident beam is capable of producing a specular reflection hazard are considered LSDZ area S.

c. The diffuse reflection hazard zone is LSDZ area T. It extends to distance t, the diffuse reflection hazard distance, and will only be present for lasers capable of producing a hazardous diffuse reflection (these have a distance t associated with them) . LSDZ area T is considered an exclusion zone, no one is allowed in it, and firing of lasers at any materials located within this diffuse reflection hazard area must be prohibited. Although a skin hazard can also exist in this area, it is a minor concern compared to the diffuse reflection hazard (See figure 6-3).

6.1.4.1 <u>LSDZ DIMENSIONS</u>. The tables in Appendices A, B, and C list the applicable dimensions of the hazard distances for current laser devices. Figure 6-4 provides an example of an LSDZ or laser range danger fan (LRDF) for a training situation. The following paragraphs describe the LSDZ limits:

a. <u>Existing Surface Danger Zones</u>. Existing munitions surface danger zones for direct fire weapons are usually large enough to provide the required horizontal and vertical buffer zones for ground-to-ground laser operations provided the beam is terminated in the impact area (see Figures 6-5 and 6-6).

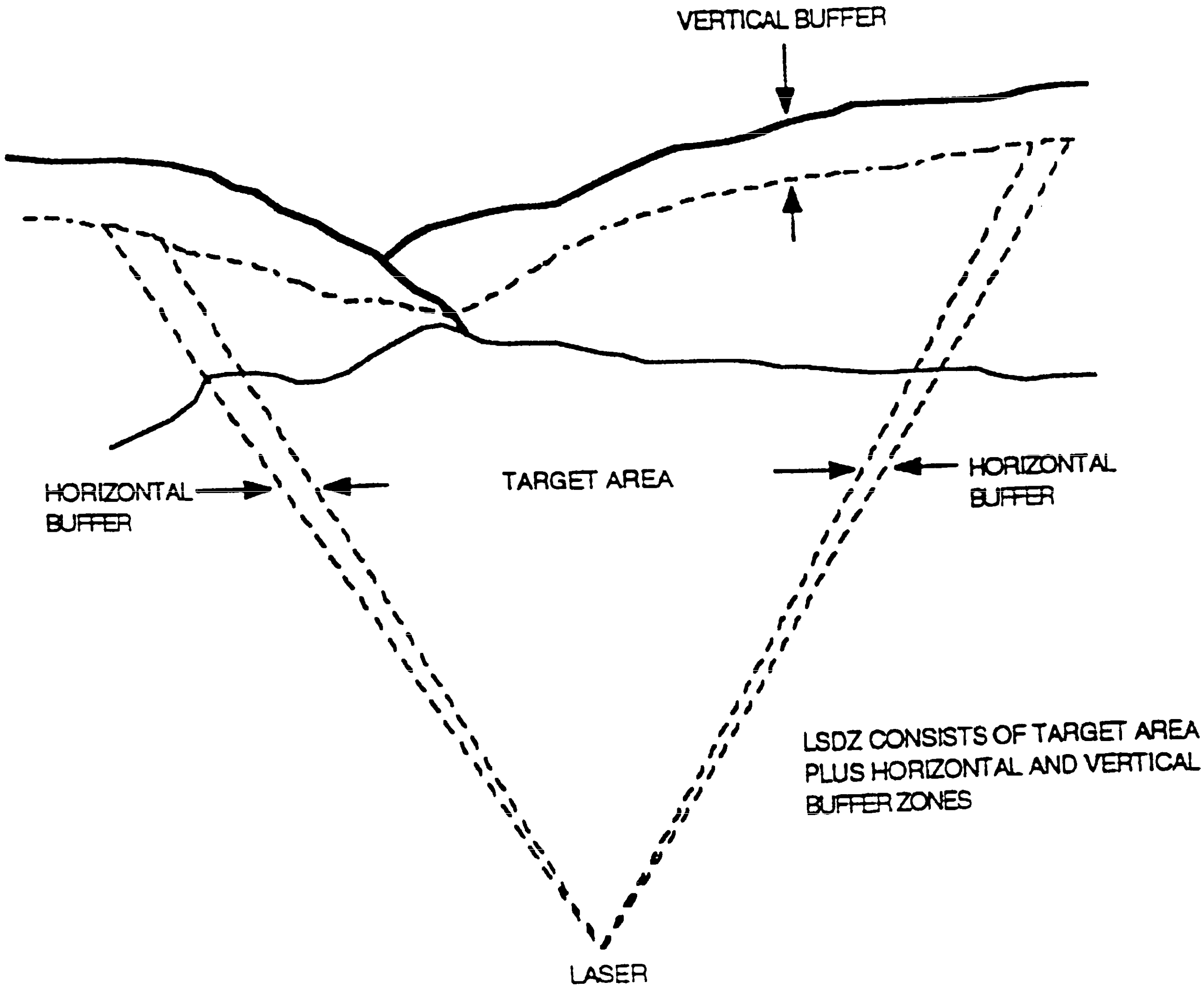


Figure 6-2. Laser Surface Danger Zone (LSDZ)

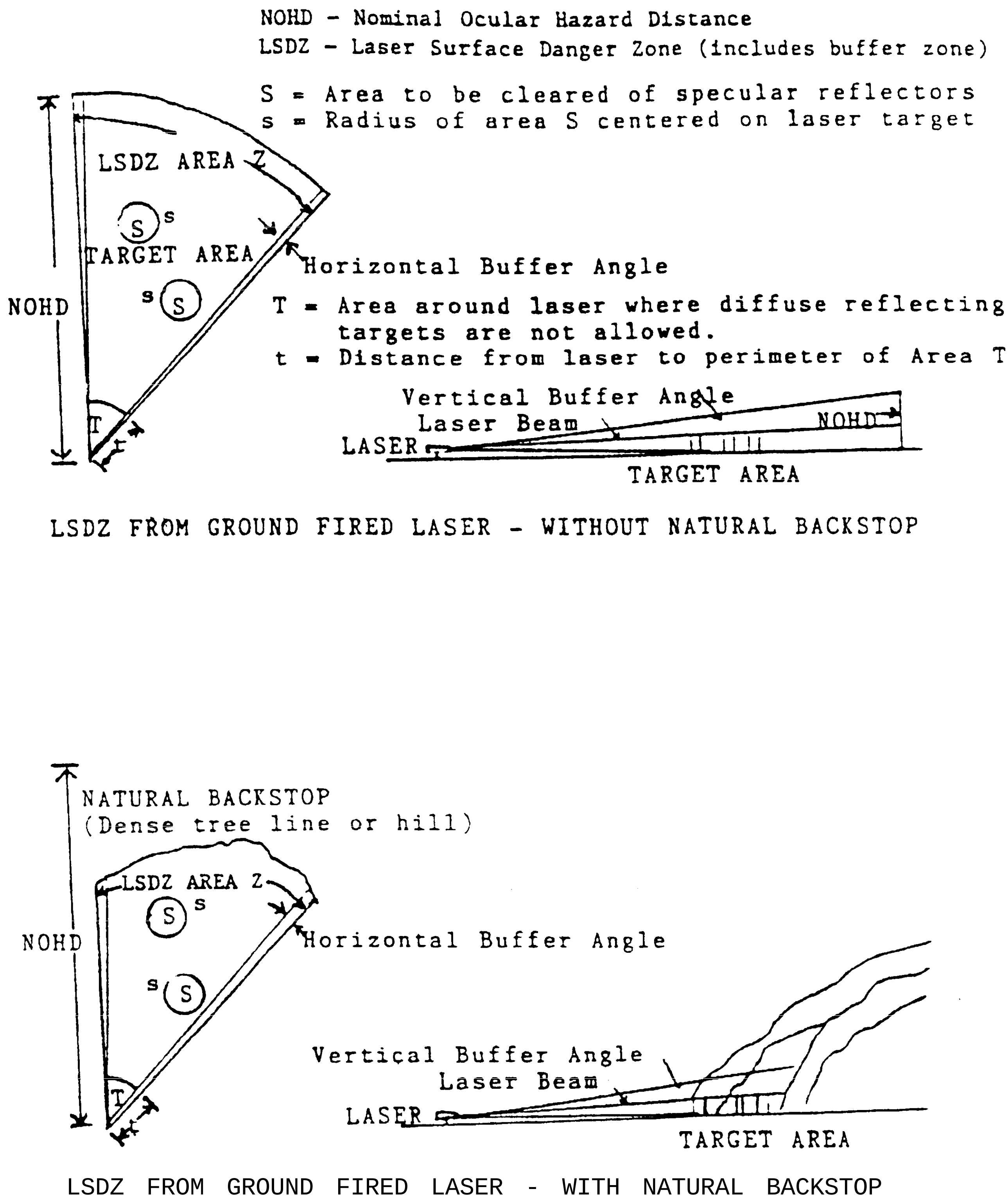
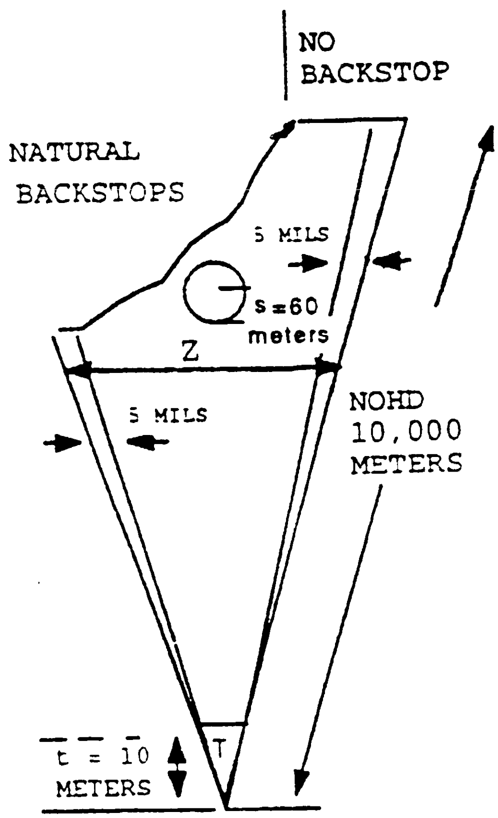
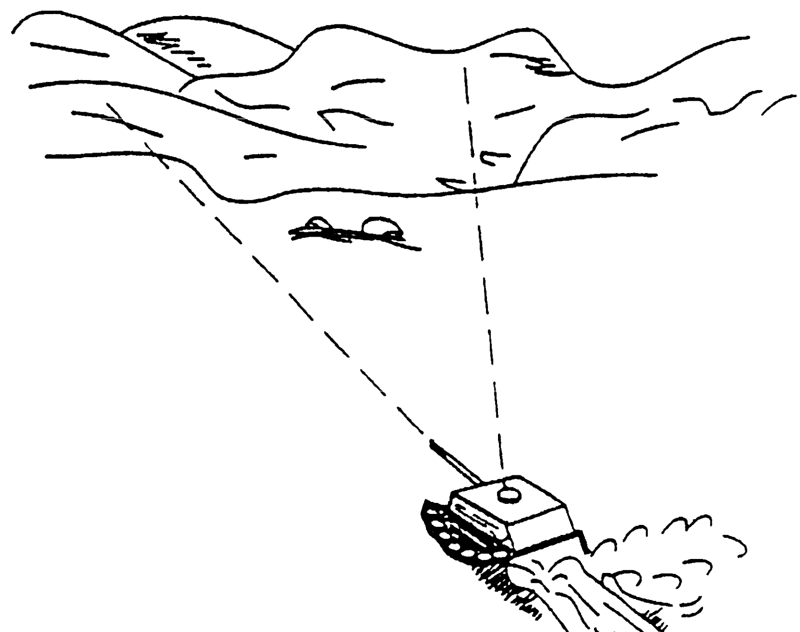


Figure 6-3. LSDZ with and without natural backstop

EXAMPLE

M60A3 WITH STABILIZATION AND LASER RANGEFINDER FIRING THE MAIN GUN WHILE MOVING. IN THE COMMANDER'S JUDGEMENT, THE POSSIBILITY OF AN OBSERVER WITH MAGNIFYING OPTICS OBSERVING THE OPERATING LASER ON THE TANK FROM A DISTANT GROUND POSITION BEYOND THE NOHD IS VERY REMOTE. THE AIRSPACE DOWNRANGE IS RESTRICTED OUT TO 10 KILOMETERS.





CALCULATION OF THE LASER RANGE DANGER FAN (LDRF), ALSO CALLED LASER SURFACE DANGER ZONE (LSDZ):

1. Determine t, s, & NOHD from Table A-1. (t= 10 m, s= 60 m, NOHD = 10,000m)

2. Determine the buffer zone from Table A-1. for the moving tank. (Buffer zone = 5 mils)

3. Draw a Laser Range Danger Fan incorporating the natural backstops on the left and the target area

Figure 6-4. Example Laser Range Danger Fan/Laser Surface Danger Zone

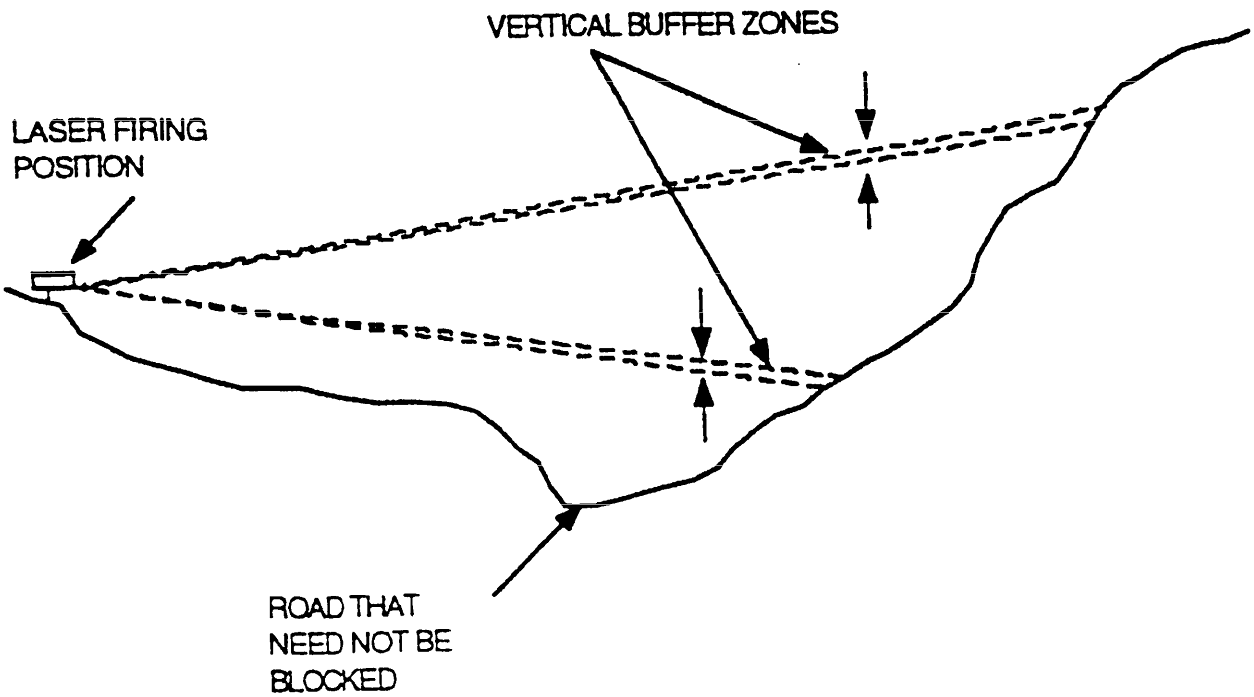


Figure 6-5. Vertical Buffer Zone

b. Distance of the Laser Surface Danger Zone.

The following combination of NOHD and terrain features must be considered in controlling laser hazards:

1. When viewing the collimated beam with a telescope, the hazardous range is greatly increased. For example, a 10 km NOHD would be increased to 80 km for an individual looking back at the laser from within the beam with 13 power optics. such large amounts of real estate are difficult to control. The solution is to use a backstop behind the target.

2. On the ground, this area normally extends to an adequate backstop or the NOHD. Laser operations at targets on the horizon is permitted as long as air space is controlled to the NOHD. In this case, the LSDZ extends downrange to the NOHD in the air space and to the skyline on the ground as seen from the laser position (see Figure 6-6). Operators and crews will conduct laser operations only at approved targets. Usually, when there are no natural backstops available (e.g., mountains), the magnified NOHD-O (O indicates optics) may extend out to extremely long ranges (e.g., 80 km for tank-mounted laser rangefinder (LRF)). This extreme situation would only create ocular hazards if:

A. There was a direct line-of-sight to an observer on the ground, and

B. There is a possibility that the observer could be engaged in direct intrabeam viewing with unfiltered magnifying optics.

3. Unless the NOHD or NOHD-O has been exceeded, the hazard distance of the laser device is the distance to the back-stop. This hazard distance must be controlled. The terrain profile from the laser device's field of-view plays a very important role since the laser presents only a line-of-sight hazard. The optimal use of natural backstops is the obvious key of minimizing laser range control problems.

c. Buffer Zones. The extent of horizontal and vertical buffer zones around the target area, as viewed from the firing area, depends on the aiming accuracy and stability of the laser device. The laser horizontal buffer zones could partially or completely be included in lateral safety or ricochet areas on ranges where the laser is used with live fire weapons. Appendix A, Table A-I, lists buffer zone values for currently fielded equipment.

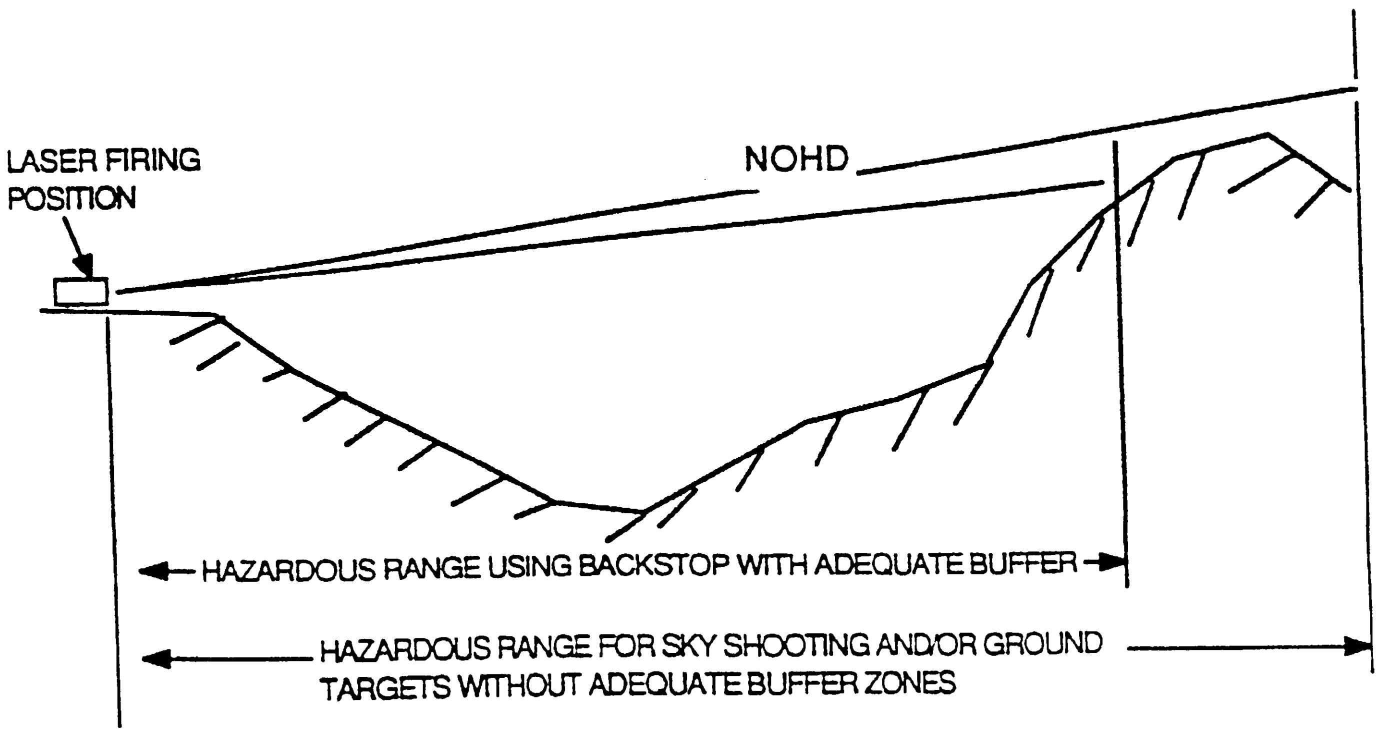


Figure 6-6. Effects of Backstops

6.1.5 Range Facilities Evaluation

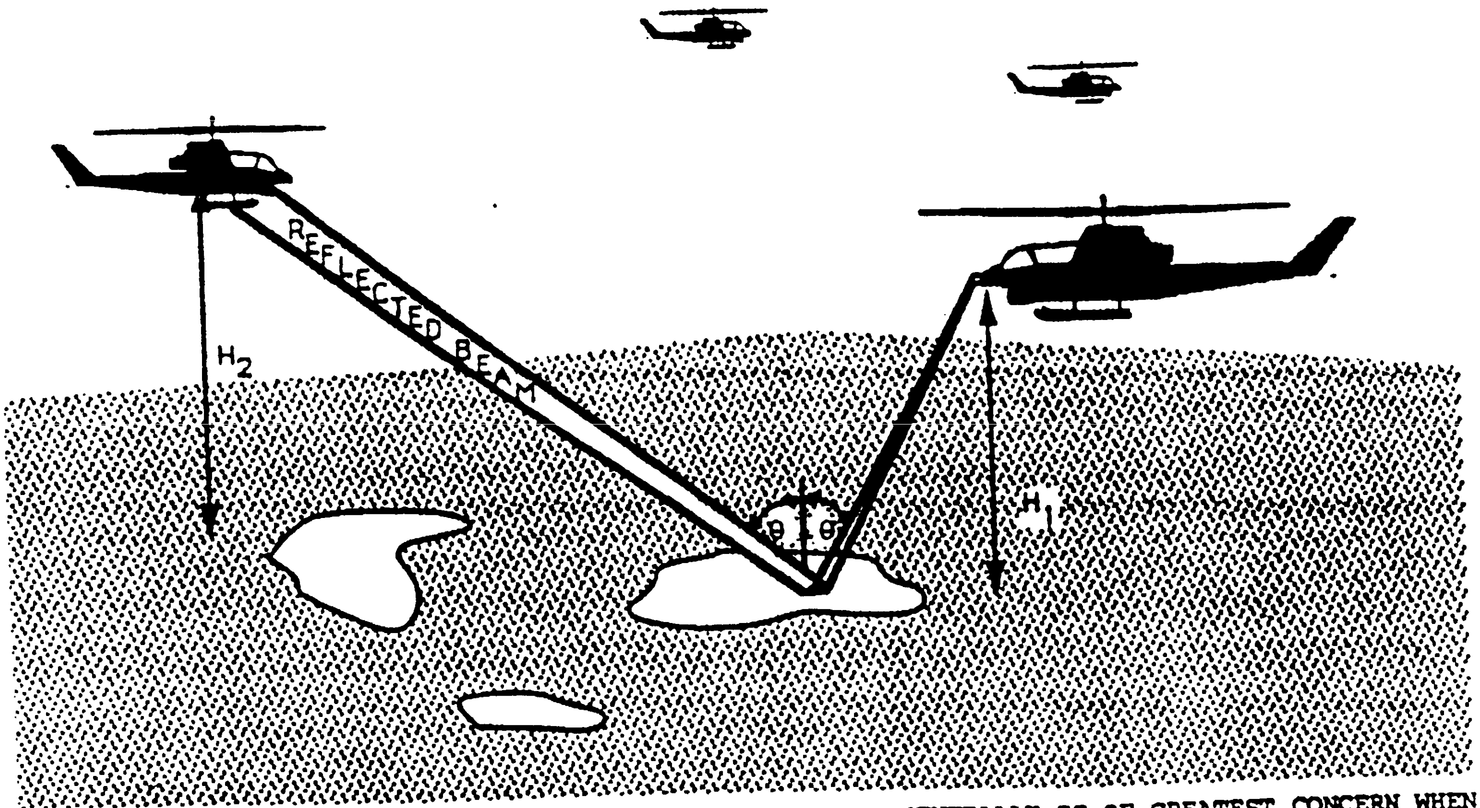
a. Range Location and Access. The range facilities are evaluated in terms of location relative to populated areas, military and civilian industrial sites, and water surface traffic. The methods used to control access to the potential laser hazard area (i.e., fences, warning signs, airspace restrictions, water surface danger areas, etc.) must be evaluated for adequacy. The locations of all occupied areas on the range, such as control towers, must be determined, as well as specific environmental factors; i.e. , the habitat of any endangered wildlife in the range area.

b. Types of Targets. Target areas are evaluated for types of targets currently in position. Vehicular targets, in particular, could have chrome bumpers, windshields, or other flat glass or chrome surfaces. Presence of these types of surfaces could generate a specular reflection when optical radiation is incident to the target. This hazard could even exist if the surface were bent or broken due to previous ordnance impact or explosion. Broken or bent specular surfaces could still have an adequately large flat surface remaining to generate a specular reflection. Unexploded ordnance areas in or surrounding the proposed target area could have an impact on the advisability of policing or masking existing specular surfaces.

c. Terrain Features. Terrain features on and surrounding the range are evaluated for impact on laser safety. Useable terrain and vegetation backstops are identified and located on maps of the range area. Any mountain peaks outside the range are examined to verify that such obstructions as radio or television towers or park service observation towers do not extend into the laser buffer zone between the laser and the target. This consideration should only affect airborne laser systems when active target illumination commences before the aircraft enters the range boundaries.

d. Access Control. Roads or other access points to the range area should be evaluated to determine the probabilities of non-controlled personnel entering the target area or controlled range areas. Roadblocks should be established and posted at the area where access could occur.

e. Operations Over Water. See Figure 6-7. Since water can become a flat specular reflector when it is calm, additional precautions *are required* when firing the laser over water. While in most applications, the reflectors contained in Table 6-I can be either covered or removed, water cannot always be avoided. Therefore, additional precautions are required when firing over water as discussed in Appendix G.



THE SPECULARLY REFLECTED BEAM FROM AN AIRBORNE LASER GENERALLY IS OF GREATEST CONCERN WHEN ORGINATING FROM STILL WATER. THE REFLECTED BEAM IS REDIRECTED UPWARD AT THE SAME ANGLE (θ) AS THE INCIDENT BEAM.

Figure 6-7. Example of Airborne Laser Beam Reflection

6.1.6 Visual Survey A visual survey of the range area is often very useful. The survey should be conducted from actual firing locations and target locations. If the target is used for aerial operations, the range evaluator should whenever possible perform an aerial fly-over on the proposed or approved laser run-in headings. A pair of binoculars with an angular calibrated graticule can be used to scan the terrain features to estimate the natural buffer area. Suitable areas should be marked on a current map. Do not *rely* entirely upon the contour lines on the range map, since they may result in an erroneous estimation of the buffer area. Actual targets should be visually inspected for specular reflectors before their insertion onto the range to ensure that these surfaces are removed. Conversion of an impact area to a laser range area may require over-flights to obsene any glints of sunlight reflecting from broken bits of glass *or* other reflectors laying on the ground.

6.1.7 Laser Parameters

Laser system parameters may vary greatly with laser location, look angle, support structure and laser characteristics. The effects of these parameters are described in the following paragraphs.

a. Knowledge of the specific laser system, in addition to knowing the geometry of the range environment, is essential. Perhaps the most important aspect to laser range safety is the assurance that the laser beam is terminated within a controlled area. When the distance to the backstop is less than the NOHD, the backstop determines the absolute hazard distance and the NOHD is of academic value. The buffer zone requirements are based on the pointing accuracy and stability of the system and therefore are dependent upon the laser system mounting; i.e. , a hand-held laser system has a larger buffer zone than a tripod mounted system. Some laser systems are designed to be used from a variety of mounting configurations. Appendix A, Table A-I, contains the minimum buffer zone requirements for currently fielded laser systems under their intended mounting configurations.

b. A controlled area is an area where the occupancy and activity of those within the area are subject to control and supervision for the purpose of protection from laser radiation hazards. The hazard zone or footprint will be the beam itself plus a buffer zone. This footprint is normally an ellipse. The minor axis depends on the laser to target range and the buffer zone angle for that particular laser. The major axis depends upon the altitude of the laser above the target in addition to the requirements for the minor axis. Therefore, the amount of and surface area required to be controlled depends upon the elevation of the laser, range to target, and the specific laser system. When necessary, any of these factors can be changed to ensure that the laser beam is terminated within the controlled range boundary; i.e., the footprint can be reduced in size by elevating the laser. Thus, we can have either a fairly large area to control that might extend out to the NOHD, or we can select target or laser locations which provide the required backstop.

6.1.8 Laser Footprint Calculate the size of the beam which irradiates the ground & ground-based, sea-based, or airborne target (footprint). Normally, laser beams are circular, diverge equally in all directions, and produce cone shaped beams. The size of the beam depends on the initial beam diameter, divergence, and distance (slant range) from the source. The size of the footprint is the size of the beam plus a buffer zone (see figure 6-8). For scanning systems, the size of the beam would include all positions in the scan. The shape of the footprint depends on the angle of the beam that intersects the ground (slant angle is determined from the range and altitude). The footprint is determined by the following:

a. Determine the buffer angle: If the assigned laser buffer angle is 5 milliradians and the beam divergence is less than 0.5 milliradians, *use* 5 milliradians for the buffered footprint angular width and ignore the beam divergence. This approach will only introduce an error of less than 5%. If this evaluation is overly restrictive (requires too much land), a system specific evaluation can be made for each laser system. The appropriate buffer angles for most systems are listed in Appendix A. To calculate a buffered footprint for other systems, perform the following: When the beam divergence is equal to or greater than 1.0 milliradian, the footprint will be the buffer angle plus the beam divergence. When the beam divergence is less than 1.0 milliradian, the following will apply:

1. If the aiming accuracy for a stabilized laser is unknown, buffered footprint angular width will be five milliradians either side of the beam.

2. If the aiming accuracy is known, the buffered footprint angular width will be five milliradians, or the absolute value of the aiming uncertainty (in milliradians) plus five times the beam divergence at the I/e (.3679) point, whichever is less, either side of the laser beam. Aiming accuracy should be contained in the system specifications.

b. Determine Footprint Size. There are at least two approaches used to determine the size of the footprint. If the

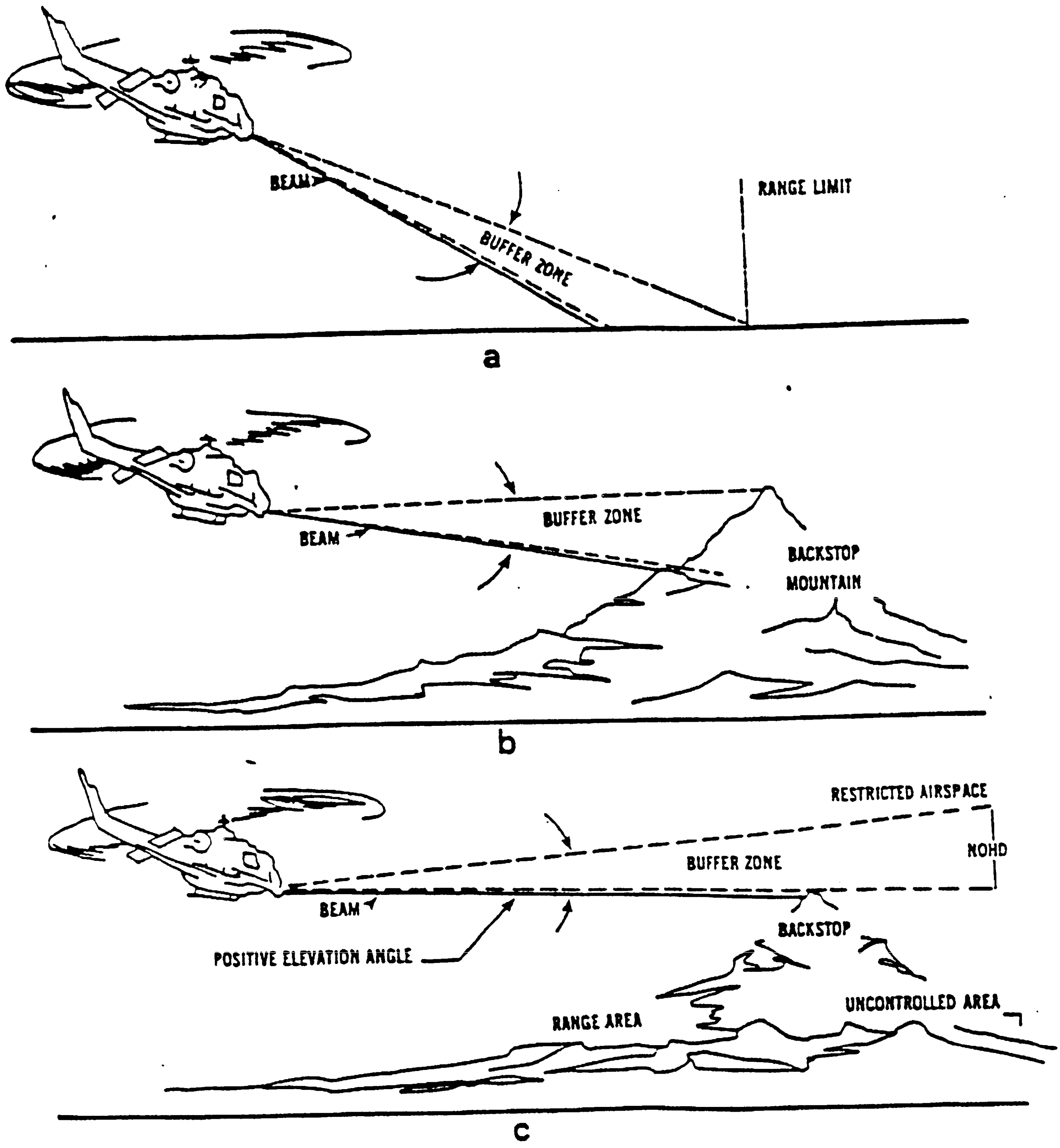


Figure 6-8. Examples of the Use of Natural Backstops, Buffer Zones and Restricted Air Space.

desired flight profiles are known, then the size of the footprint can be determined from these flight profiles. If the size of the range is the limiting factor, the boundaries of flight profiles can be determined which would keep the footprint within the range. These two approaches can be used independently or, typically, used together to maximize land use and minimize mission impact. The procedures for these two approaches are detailed in Appendix E.

6.1.9 Other Considerations.

a. Moving Targets or Lasers. A moving target or laser will affect the size of the LSDZ and may indicate that the single pulse NOHD is more applicable than the multiple pulse NOHD, especially when evaluating specular reflections. This must be decided on a case by case basis. A common application of this includes evaluating reflection hazards when the angle of laser operations is rapidly changing, and therefore the probability of a multiple pulse exposure is small.

b. Operating Outside of Controlled Area. Targets should never be positioned outside the controlled area (including airspace) . Airborne lasers should not be operated outside the controlled airspace if the potential for the beam striking an object outside the controlled area exists. If this risk is minimal, consider permitting laser operations from uncontrolled areas under controlled conditions. Ensure the regional Flight Service Center for the Federal Aviation Administration *(FAA)* and Coast Guard are notified before starting this operation so they can publish a Notice to Airmen and Mariners. The FAA regulation governing this is 7930.2B, Notices to Airmen (NOTAM) . Ground laser systems should never be operated outside the controlled area.

6.1.10 Range Control procedures and Recommendations

a. Objective. The underlying concept of laser range safety is to prevent exposure of unprotected personnel from laser radiation in excess of the MPE. This is accomplished by determining where the laser radiation is expected to be, restricting access of unprotected personnel, and removing reflective surfaces from this area.

b. Target Areas. Recommended target areas are those without specular (mirror-like) surfaces. Glossy foliage, raindrops, snow, and other natural objects are not considered to be specular surfaces that would create ocular hazards. Although snow is not considered to be a specular surface, if thawed and refrozen, hazardous reflections can be found, especially at low angles of incidence.

c. Sanitized Ranges. If the target areas have no flat specular surfaces, range control measures can be limited to the control of the area where the laser beam hits directly.

d. Laser Operation. Laser devices shall only be directed at safety approved targets and only from approved operating positions or on designated headings and altitudes.

e. Unprotected Personnel. Unprotected personnel must not be exposed to laser radiation greater than the MPE.

f. Signs. Local procedures should provide for the placement of laser warning signs at the boundaries of the controlled *areas* and the access points. This is normally a coordinated process between bioenvironmental engineers/industrial hygienists and/or laser safety officers, ground safety and/or ship's safety officer, and the range officer. These signs should be constructed per MIL-STD-1425. They are also available in the federal stock system (see figure 4-3). If the hazard zone is within a designated range, access controls must be established.

g. Eye Wear Personnel within the LSDZ shall wear laser protective eye wear during laser operations. Eye wear must be approved for the wavelength of the laser system being used and must provide sufficient protection (See Table A-I). If more than one type of laser is used, protective eye wear must provide adequate protection for all wavelenghts involved (OD greater or equal to the largest minimum OD required for each wavelength) .

h. Optical Devices. Magnifying daylight optical devices, without attenuation, may be used to view the target only if flat specular surfaces have been removed from the target area. Specular surfaces can be viewed only if appropriate laser safety filters are placed in the optical train of the magnifying optics.

i. Range Access Restrictions. Access restrictions to the laser range should include consideration of road blocks or gates especially where the range is unmanned.

j. Laser Demonstrations. Personnel may safely view a diffuse reflection of an otherwise hazardous laser beam from a protected setting as shown in Figure 6-9. The laser-to-target distance is great enough to preclude a hazardous reflection from a dry diffuse target. Infrared viewers or night vision goggles are necessary to view the diffuse reflections from near-infrared lasers. Visible diffuse reflections can be seen with the unaided eye.

LASER TRAINING RANGE

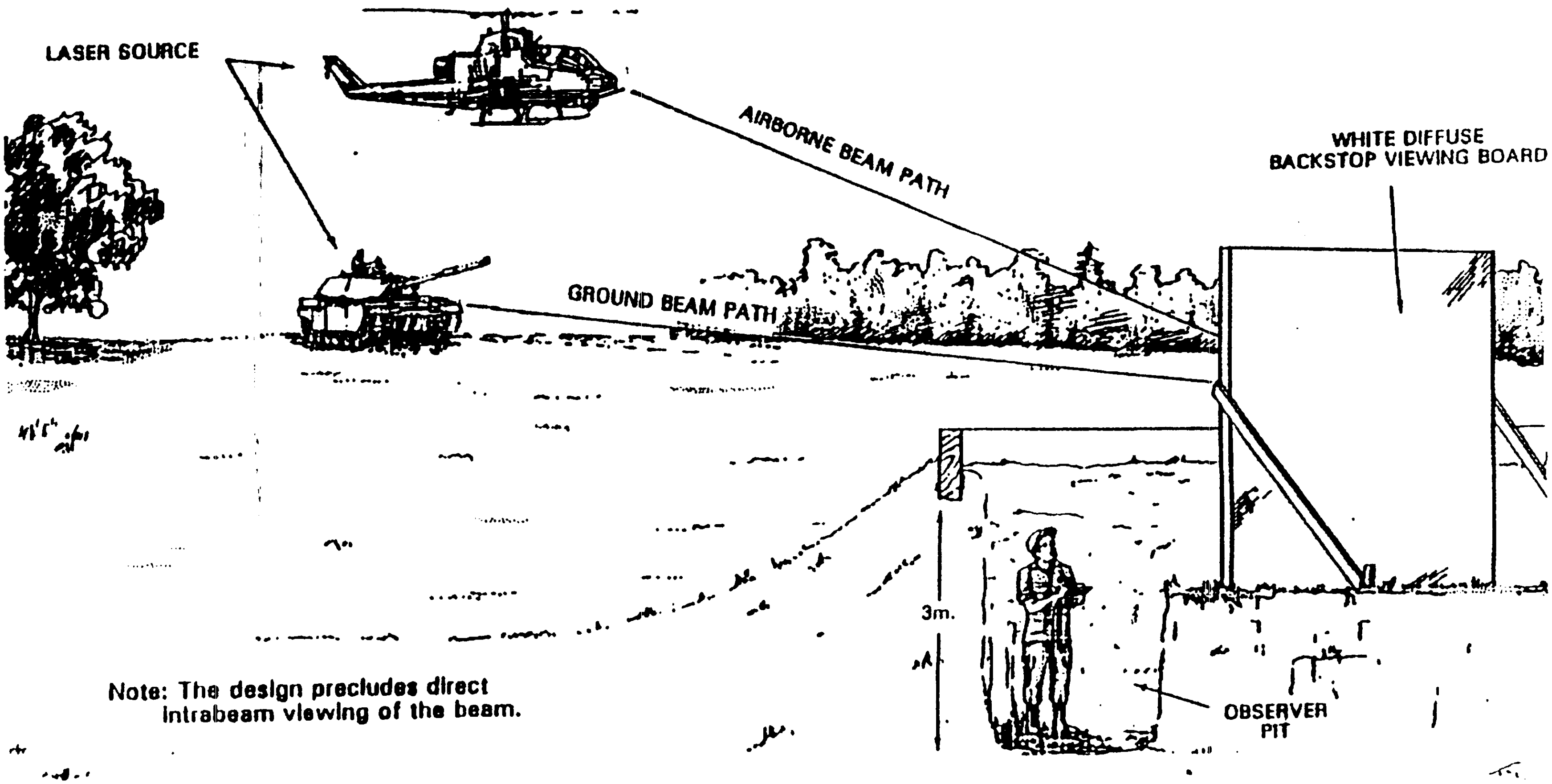


Figure 6-9. SUPERVISED LASER DEMONSTRATION FOR MILITARY TRAINING. (MODIFIED FROM FIGURE 2D, ANSI Z136.1)

7. REQUIREMENTS FOR USER LEVEL LASER INSTRUCTIONS

7.1 User-Level Laser Instructions

7.1.1 Instruction. Utilizing the laser range safety evaluation, the *range* planner/laser safety officer will determine the necessary information to:

a. Prepare or modify range laser-safety directives.

b. Develop Standard Operating Procedures (SOP) for laser operations.

c. Brief personnel involved in laser operations to provide an understanding of the hazards of specific devices, and allay unfounded fears.

d. Prescribe the personal protective equipment to be used.

7.1.2 Directives. The laser range safety evaluation should be utilized to review and ensure that overall range safety regulations are current. Regulations should be developed or updated as necessary to take into account new laser systems, operating areas and targets.

7.1.3 SOP. SOPS for specific laser devices should be prepared to inform laser users of the potential hazards from the laser devices under their control during the laser operation. Checklists for evaluating SOPS are contained in Appendix F. Also an SOP should be prepared concerning procedures for a pre-sweep of the range before laser operation to ensure that unprotected personnel are not in the target area and to maintain radio communications, etc.

7.1.4 Safety Briefing. In addition to instructions on particular devices or simulators, training material required for class room instructors and range personnel should include:

a. principles of reflection or refraction of light.

b. Hazards of laser beams to humans and misconceptions about laser effects.

c. Safety standards or operational control procedures.

d. Preparation of range areas for laser use (e.g., ensure that personnel have been alerted to the laser hazard and covered, removed, or avoided firing at specular surfaces) .

7.1.5 Protective Equipment. Eye protection requirements are listed in Appendix A, Table A-II.

7.2 Systems Briefings. Laser indoctrination should have been provided at the same time as the basic weapons systems instruction to students taking advanced individual training and to officers taking basic courses. The classroom instructors must be knowledgeable in operator and crew aspects of laser safety. Reference publications on subject lasers should be readily available. The instruction presented should be at the user level. (Complex scientific data or terminology should be avoided). A training film, if available, should be included in the instruction program. Hazard data for lasers as incorporated into the TM on the related weapon system or on the laser component should be stressed. Proper channels for obtaining professional safety and medical assistance should be addressed during indoctrination.

8. NOTES

(This section contains information of a general or explanatory nature that my be helpful, but is not mandatory”)

8.1 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.

8.2 International standardization agreement. Certain provisions of this handbook are the subject of international standardization agreement (STANAG 3606) . When amendment, revision, or cancellation of this handbook is proposed which are inconsistent with the international agreement concerned, the preparing activity will take appropriate action through international standardization channels including departmental standardization offices to change the agreement or make other appropriate accommodations.

SUMMARY OF LASER SAFETY INFORMATION FOR FIRE CONTROL LASER SYSTEMS

10. SCOPE

10.1 Scope. This appendix provides safety information for currently fielded laser fire control systems.

20. APPLICABLE DOCUMENTS

l Information in this section was obtained from documents referenced in Chapter 2 and from informal documents provided by each of the Service's safety specialists in Chapter 1.

30. FIRE CONTROL LASER SAFETY FEATURES

30.1 Fire control laser systems. Fire control laser systems are laser rangefinders (LRFs) and laser designators (LDs). These laser systems can be far more harmful to the eye than laser training devices such as the MILES and Air to Ground Engagement System/Air Defense (AGES/AD) laser simulators. Consequently, fire control lasers require control measures to prevent permanent blindness to an unprotected individual viewing the laser system from within the laser beam. A sample list of control measures for operators of the control lasers is provided in Appendix H.

30.2 Current laser safety summary. Tables A-X and A-II on the following pages summarize current laser safety information pertaining to the most common fire control laser systems likely to be encountered. The Nominal Ocular Hazard Distances for unaided viewing (NOHD) and while viewing the beam through an optical instrument such as a pair of binoculars (NOHD-0) are listed in Table A-I. The importance of NOHD is often over-valued since the laser beam is normally required to be terminated in a controlled area and the distance to the backstop defines the absolute hazard distance.

30.3 Ruby LRFs. The ruby LRFs on the tanks are the most hazardous lasers to the eye at close range. These lasers not only pose a hazard while viewing the laser from within the direct beam, but also from viewing the diffusely reflected laser radiation. The distance "t" is the distance from the laser within the laser beam path in which there is both a skin hazard and diffuse reflection hazard. Distance "t" represents the range to be cleared in front of the tank.

30.4 Distance "s". The distance "s" was established to prevent specular or collimated reflections from flat glass and other flat and smooth surfaces. These reflections might leave the controlled range area. This is the radial distance away from targets out to which flat specular reflectors must be cleared- For fixed wing aircraft, the entire buffered laser footprint must be cleared of specular reflectors. A specular reflector is one that is so smooth that one can observe one's image by it. A curved specular reflector does not create a significant risk to individuals at typical training distances from a target.

30.5 Buffer Zones. Each buffer zone in Table A-I gives the minimum angular size of backstop behind the target which is used to terminate the beam. By ensuring that adequate backstop is present, laser energy is prevented from leaving the controlled area. Thus , if a moving target approaches the skyline within the buffer zone, laser operation should cease unless adequate airspace is controlled.

30.6 Eve Protection. Table A-II summarizes the eye protection optical density requirements for worse-case exposure at the laser output (unaided) or when collected with an optical instrument (total). The stated optical densities must be at the laser wavelength, otherwise they may offer very little protection. At longer distances away from the laser, the beam begins to spread out and become less harmful. Thus, less optical density would be required at a distance away from the laser.

30.7 Description of Fielded Laser Systems

a. AN/VVS-l Laser Range Finder mounted on the M60A2 tank.

b. AN/VVG-l Laser Range Finder mounted on the M551A.1 Sheridan Vehicles.

c. AN/VVG-2 Laser Range Finder mounted on the M60A3 tank. Used with two filters, the green Eye Safe Simulated Laser Range Finder (ESSLJ2) filter and the red ESSLR filter. The green ESSLR is eye safe, the red ESSLR is less hazardous than the system without filters (see Appendix C) .

d. AN/VVG-3 Ml tank laser rangefinder used with one eyesafe filter.

AN/GVS-5 Laser Range Finder Infrared Observation Set (Handheld).

f. AN/PAQ-l (LTD) Laser Target Designator. This is a lightweight, handheld, battery operated laser device. Forward observers use it to designate targets.

g. AN\TVQ-2 (G\VLLD) Ground/Vehicle Laser Locator Designator. This is a principal ranging and laser designating device used by Army artillery forward observers with laser energy homing munitions. It is capable of designating stationary or moving vehicular targets and may be used in a stationary, vehicle mounted, or tripod supported dismounted mode. The primary vehicle mount is the Fire Support Team Vehicle (FISTV).

h. AN/PAQ-3 (MULE) Modular Universal Laser Equipment. This is a Marine Corps laser designator used with laser energy homing munitions. The MULE is man portable and is used only in a dismounted mode.

i. Laser Augmented Airborne TOW (LAAT) mounted in the AH-1S COBRA Helicopter. The LAAT system consists of a laser range finder and receiver that is incorporated into the M65 tube launched, optically tracked, wire guided (TOW) telescopic sight unit.

j. Target Acquisition and Designation System with Pilot Night Vision Sight (TADS/PNVS) mounted in the Apache Advanced Attack Helicopter.

k. Mast Mounted Sight on the OH-58D that, in addition to thermal and optical sensors and imaging instrumentation, incorporates a laser rangefinder and/or designator.

1. AN/AAS-37 , Laser Range Finder *Designator* mounted on the Marine Corps OV-10 observation Aircraft.

m. M55, *Laser Tank* Gunnery Trainer.

n. Air to Ground Engagement System/Air Defense (AGES/AD) is an extension of MILES to air defense simulation.

o. AN/AAS-33A, Target Recognition Attack Multisensory (TRAM) laser system. This system is mounted on the A6-E Aircraft and has a laser target designator and forward looking infrared (FLIR) l

p. Multiple Integrated Laser Engagement System (MILES). The MILES system uses low risk lasers and does not require service members to wear protective eyewear during the conduct of training with the MILES system.

q. LANTIRN System, Low Altitude Navigation and Targeting Infrared System for Night. A two pod system containing a terrain following radar (TFR), forward looking infrared (FLIR), laser designation, and later, a target recognition system. This system is designed *to* be flown on the F-15, F-16 and A-10. The laser operate; at 1064 nm and may have a training modification to operate at 1540 nm which will be eye safe.

r. SHILLELAGH Conduct of Fire Trainer (SCOFT) .

s. PAVE PENNY (AN/AAS-35): Laser tracker pod used on the A-10 and A-7 aircraft. Does not contain a laser.

t. PAVE SPECTRE (AN/AVQ-19): Laser tracking and designator used on C-130 gunships.

u. PAVE SPIKE (AN/AVQ-12): Laser tracking and designator pod fitted on F-4 and F-111 aircraft.

v. PAVE TACK (AN/AVQ-26): Advanced optronics pod containing stabilized turret with FLIR, laser designator and tracker used on the F-4, RF-4, and F-lllF aircraft.

w. COMPACT LASER DESIGNATOR (CLD): A small, lightweight laser designator and/or rangefinder used by the Navy for target designation.

x. MINI LASER RANGEFINDER (MLRF): A lightweight, handheld Neodymium YAG laser rangefinder. The RCA MLRF listed in table A-1 is given the designation of AN/PVS-X to distinguish it from future MLRF’s, which should not have off-axis radiation that would cause it to have such large buffer zone requirements as the AN/PVS-X.

y. TD-100 : A day/night aiming laser. For daytime use this device uses a class 2 helium neon visible laser and for night time it uses a class 3b infra-red laser diode. Night vision goggles will provide adequate night time protection for any one viewing the infrared laser.

z. AIM-1 : A class 3b infra-red diode aiming laser for use with night vision goggles. The AIM/MLR is mounted on Marine Corps 50 caliber helicopter gun mounts. The AIM/EXL version is hard mounted on the AH-1 turret. Night vision goggles provide adequate protection against these lasers.

aa. LPL-30: A class 3b infra-red diode aiming laser used by command to indicate targets of choice to attacking forces equipped with the night vision goggles. Night vision goggles also provide adequate protection against these lasers.

ab. AN/PEQ-l SOFLAM: Special Operating Forces Laser Marker.

ac. AN/GAQ-Tl LDSS: Laser Designator Simulator System.

30.8 <u>Description of Inactive Lasers and Associated systems</u>. The following systems are not in the active inventory but are included for background:

a. PAVE ARROW (AN/AVQ-14): This was a laser tracker pod developed for use in conjunction with the PAVE SPOT laser designator used on O-2A FAC spotter planes, C-123, and was planned for use on the F-100. It was eventually merged with the PAVE SWORD program.

b. PAVE BLIND BAT: The PAVE BLIND BAT consisted of a laser target designator to illuminate targets for the PAVE WAY guided bombs. It bad an effective range of 18,000 ft and was developed in part for *use* by AC-130 gunships to aid supporting fighter aircraft.

c. PAVE FIRE: Development of laser scanner in 1969-70 to aid F-4 Phantoms in securing proper target bearing.

d. PAVE GAT: Development of a laser range finder for use on the B-52G.

e. PAVE KNIFE (AN/ALQ-10): The original laser designator pod developed by Aeronutronic-Ford and use in combat in Vietnam 1971-73.

f. PAVE LANCE: Developmental effort to replace the PAVE KNIFE by improving night capability with the addition of a forward looking infrared (FLIR) in place *of the* low light television (LLTV). Superseded by PAVE TACK.

g* PAVE LIGHT (AN/AVQ-9): Stabilized laser designator developed for the F-4 Phantom.

h. PAVE MACK: Development of laser seeker head for air to ground rockets. Project was also called LARS (Laser Aided Rocket System) and rockets were to be used in conjunction with FAC (Forward Air Controller) mounted PAVE SPOT designator.

i. PAVE NAIL (AN/AVQ-13): Modification of 18 OV-10 FAC aircraft with stabilized periscopic night sight and laser designator. Program coordinated with PAVE PHANTOM and PAVE SPOT.

j. PAVE PHANTOM: Addition of an ARN-92 Loran and computer to the F-4D allowing aircraft to store targeting information for eight separate positions illuminated by OV-10 PAVE NAIL.

k. PAVE POINTED: Palletized gun direction system consisting of a laser designator and/or rangefinder and low light TV employed on a C-123 and forerunner of subsequent gunship fire control stems.

1. PAVE PRISM: Aerodyne Research effort to develop IR and active laser seekers for use on the ASRAAM air-to-air missile.

m. PAVE PRONTO: Modification of AC-130 gunships for night attack including an LTV Electro systems night observation camera, AAD-4, or AAD-6 FLIR and AVQ-17 illuminator.

PAVE SCOPE: Target acquisition aids for jet fighter aircraft such as the Eagle Eye (LAD) AN/AVG-8, and TISEO.

o. PAVE SHIELD: Classified project undertaken by Aeronautical Research Associates.

p" PAVE SPOT (AN/AVQ-12): Stabilized periscopic night vision sight developed by Varo for use on *the* O-2A FAC. The system was fitted with a Korad laser designator (ND:YAG) and first went into service in 1970 over Vietnam.

q. PAVE STRIKE: A related group of air-to-ground strike programs include PAVE TACK and IR guided bombs.

r. PAVE SWORD (AN/AVQ-11): Laser tracker designed to pick up energy from targets illuminated by O-2A spotter planes. Used on F-4, and bore sighted with its radar set.

s. PAVE WAY: Code name for a wide variety of guided bomb projects, also refers to AN/AVQ-9 laser designator developed by Martin Marietta in the late 1960s for use on the F-4 Phantom.

TABLE A-I. NOMINAL OCULAR HAZARD DISTANCES AND RANGE SAFETY INFORMATION FOR FIELDED MILITARY LASER SYSTEMS.

Device/Mounting	NOHD (Kilometers)		NOHD-O (Kilometers)			REFLECTOR CLEARANCE (Meters)		Buffer Zones (Buffer Angle) (Each side) (Milliradians)	
	Multi-Pulse	Single Pulse	7X50 Binoc.	8 cm Optics	12 cm Optics	t[1] Diffuse	s[2] Specular	Static	Moving
******TANK MOUNTED******									
AN/VVG-1(M551A1)	9	9	32	47	67	10	60	2	Not allowed
AN/VVS-1(M60A2)	9	9	32	36	44	10	100	5	10
AN/VVG-2(M60A3)	8	8	30	40	47	10	60	2	5
red ESSLR(29dB)	0.3	0.3	1.8			0	Target	2	5
green ESSLR(55dB)	0	0	0	0	0	0	0	NA	NA
AN/VVG-3(M1Tank)	7	7	25	35	44	0	60	2	5
SLR	0	0	0	0	0	0	0	NA	NA
***********MAN PORTABLE************									
AN/TVQ-2 GVLLD (Tripod)									
Designator	25	17	63	80	87	0	60	2	NA
Rangefinder	8	8	28.5	40	-	0	60	2	NA
Rangefinder with 8.5dB yell.filter	3.1	3.1	15	23	-	0	100	2	NA
AN/PAQ-3 MULE (Tripod)									
Designator-Day	20	12	53	64	78	0	60	2	NA
Designator-Night	20	12	53	64	78	0	150	5	NA
Rangefinder-Day	12	12	37	47	-	0	60	2	NA
Rangefinder-Night	12	12	37	47	-	0	150	5	NA
Rangefinder with 12dB filter	3.3	3.3	16	-	-	0	60	2	NA
AN/PAQ-3 MULE (Handheld)									
Designator-Day	20	12	53	64	78	0	200	10	NA
Designator-Night	20	12	53	64	78	0	300	15	NA
Rangefinder-Day	12	12	37	47	-	0	200	10	NA
Rangefinder-Night	12	12	37	47	-	0	300	15	NA

l. t = distance from the laser in the laser beam path in which there is both a skin hazard and diffuse reflection hazard. Represents the range to be cleared in front of the k.

s. distance around the target out to which specular reflectors must be cleared when laser is level or nearly level with target.

TABLE A-I. NOMINAL OCULAR HAZARD DISTANCES AND RANGE SAFETY INFORMATION FOR FIELDED MILITARY LASER SYSTEMS.

Device/Mounting	NOHD (Kilometers)		NOHD-O (Kilometers)			REFLECTOR CLEARANCE (Meters)		Buffer Zones (Buffer Angle) (Each Side) Milliradians	
	Multi-Pulse	Single Pulse	7X50 Binoc.	8 cm Optics	12 cm Optics	t[1] Diffuse	s[2] Specular	Static	Moving
MAN PORTABLE									
AN/GVS-5(Handheld)	2.7	2.7	13	21	27	0	200	10	NA
19dB red filter	0.29	0.29	1.8	1.8	-	0	200	10	NA
29dB yell. filt	0.056	0.056	0.55	0.55	-	0	200	10	NA
AN/PAQ-1 (Handheld LTD)	7	3.5	15	33	-	0	200	10	NA
LLTD	7	-	15	38	-	0	200	10	NA
AN/GAQ-T1(LD82LB LDSS)	12.5	-	-	43	52	0	200	5	NA
CLD(Compact Laser Designator)	9.7	-	38	48	58	0	200	10	NA
AN/PEQ-1 (SOFLAM)	9.6	-	35	45	54	0	200	10	NA
AN/PVS-X MLRF Mini-Laser Rangefinder	-	3	16	29	-	0	200	90degrees[3]	
TD-100	0.1	-	-	-	-	0	30	10	10
LPL-30	0.085	-	0.68	1.1	1.6	0	20	10	10
M-931	0.011	-	0.16	0.28	0.4	0	0	10	10
HAVIS M16 Aiming Light	0.012	-	0.1	0.17	0.25	0	0	10	10

1. t = distance from the laser in the laser beam path in which there is both a skin hazard and diffuse reflection hazard. Range to be cleared in front of the laser.
2. s = distance around the target out to which specular reflectors must be cleared when laser is level or nearly level with target.
3. 90 degree buffer zone required for RCA version AN/PVS-X with secondary beams. 10 degree buffer zone required for Brunswick version.

TABLE A-I. NOMINAL OCULAR HAZARD DISTANCES AND RANGE SAFETY INFORMATION FOR FIELDED MILITARY LASER SYSTEMS.

Device/Mounting	NOHD (Kilometers)		NOHD-O (Kilometers)			REFLECTOR CLEARANCE (Meters)		Buffer Zones (Buffer Angle) (Each Side) Milliradians	
	Multi-Pulse	Single Pulse	7X50 Binoc.	8 cm Optics	12 cm Optics	t[1] Diffuse	s[2] Specular	Static	Moving
***************AIRCRAFT MOUNTED LASERS**************									
LAAT (AH1S MC)	5	3.4	15	30	36	0	100	5	5
TADS (Apache)	26	16	45	68	-	0	100	5	5
MMS (OH-58D)	35	23	56	-	-	0	100	5	5
NITE EAGLE (UH-1N)	15	11	45	55	65	0	100	5	5
AN/ASQ-153(F-4E PAVE SPIKE)	10	6.8	-	48	58	0	N/A	N/A	5
AN/AVQ-25(F-111F PAVE TACK)	16	8.8	-	52	70	0	N/A	N/A	5
AN/AAS-33A(A-6E TRAM)	14.6	9	-	58	67	0	N/A	N/A	5
AN/AAS-37(OV-10D NOS)	11.2	7.1	45	56	59	35	N/A	N/A	5
AN/AAS-38A (F/A-18)	17		50	63	73	0	N/A	N/A	5
AIM-1/MLR	0.085	-	0.68	1.1	1.6	0	20	10	10
AIM-1/EXL	0.085	-	0.68	1.1	1.6	0	20	10	10
LANTIRN									
(Combat mode)	22.7	11.6	157	-	-	0	N/A	N/A	5[3]
(Training mode)	0	0	0	-	-	0	0	N/A	N/A
(Secondary Beam)	Maintain 2000 ft separation from other aircraft.								
F-117	18.5	9.5	130	-	-	0	N/A	N/A	TBD
PAVE SPECTRE	8.9	5	63	-	-	0	N/A	N/A	5

1. t = distance from the laser in the laser beam path in which there is both a skin hazard and diffuse reflection hazard. Range to be cleared in front of the laser.
2. s = distance around the target out to which specular reflectors must be cleared when laser is level or nearly level with target.
3. Air Force assigned buffer zone is 2 milliradians for LANTIRN. It is general policy for this is manual that aircraft be assigned a minimum buffer zone of 5 milliradians.

TABLE A-II. EYE PROTECTION REQUIREMENTS FOR FIELDED LASERS.

Device/Mounting	Wavelength (Nanometers)	Built-in Safety Filter (OD)*	Required Eye Protection (Optical Density (OD)) Unaided	Aided	Other Aircraft
TANK MOUNTED					
AN/VVG-1(M551a1)	694.3	clip-on 5	5.8	5.8	
AN/VVS-1(M60A2)	694.3	clip-on 5	5.8	5.8	
AN/VVG-2(M60A3)	694.3	clip-on 5	5.8	5.8	
AN/VVG-3(M1)	1064	5	4.7	4.7	
MAN PORTABLE					
AN/GVS-5	1064	5	3.7	4.4	
AN/PAQ-1(LTD)	1064	4	4.2	5.8	
AN/TVQ-2(GVLLD)	1064	YES	3.8	5.5	
AN/PAQ-3(MULE)	1064	5	3.9	5.6	
AN/GAQ-T1(LD82LB)	1064	YES	4.6	5.5	
CLD(Compact Laser Designator)	1064	5	4.5	5.4	
AN/PEQ-1 (SOFLAM)	1064	5	4.0	5.3	
LLTD	1064		4.0	4.9	
M-931	850		0.7	0.8	
LPL-30	800-850		1.7	1.7	
MLRF(Mini-Laser Rangefinder)	1064	YES	3.7	3.7	
HAVIS M16 Aiming Light	850		1.1	1.1	
TD-100	850		1.1	1.1	
	632.8		0.3	0.3	
TD-100A	850		1.1	1.1	
	670		0.6	0.6	
AIRCRAFT MOUNTED					
LAAT(AH-1S(MC))	1064	YES	3.5	4.8	
TADS/PNVS(APACHE AAH)	1064	YES	4.0	5.5	
MMS(OH-58D)	1064		4.1	5.3	
NITE EAGLE (UH-1N)	1064		4.1	5.2	3.7
AIM-1/(MLR and EXL)	800-850		1.7	1.7	
AN/ASQ-153 (F-4E PAVE SPIKE)	1064		4.2	5.6	
AN/AVQ-25 (F-111F PAVE TACK)	1064		4.3	5.8	
AN/AAS-33A(A-6E TRAM)	1064		4.6	5.8	3.0
AN/AAS-37 (OV-10D NOS)	1064		5.2	5.6	3.0
AN/AAS-38A (F/A-18)	1064		4.3	5.4	3.0
LANTIRN					
(Combat Mode)	1064	N/A	4.2	5.8	
(Training Mode)	1540	N/A	0	0	
F-117	1064	N/A	4.5	6	
PAVE SPECTRE	1064	N/A	3.7	5.4	

* Assume that built-in safety filter only protects against the wavelength of the laser in which it is installed and that it does not always protect against other laser wavelengths

APPENDIX B

MILES OPTICAL SAFETY SUMMARY

10 SCOPE

10.1 Scope. This hazard information applies to MILES exercises.

20 APPLICABLE DOCUMENTS

Information in this section was obtained from documents referenced in Chapter 2 and from informal documents provided by each of the Service's safety specialists in Chapter 1.

30 OPTICAL SAFETY

30.1 MILES. The MILES is an ingenious system for scoring tactical exercises. This is accomplished through an infrared beam emitted from each weapon and detected by a target that can be a man or vehicle. These devices do not present a hazard during normal field exercises. However, the beam is quite concentrated as it leaves the transmitter and cautionary measures are advised at extremely close engagement ranges. Table B-I provides distances within which the weapons should not be pointed at the face of another person. Since optical aids; i.e. , binoculars, tend to concentrate this energy, these distances may be extended when unfiltered optical aids are used. In most cases, greater hazards than from the infrared energy exist during training exercises. In the case of the M-16 rifle, a person would be more likely to receive an eye injury from the impact of the blank fired at close range than from the infrared energy.

TABLE B-I
NOHD FOR MILES AND OTHER TRAINING LASERS

Device	NOHD (m)	NOHD-O(m)[1]
MILES Large Gun Simulators	12	75
MILES Small Arms Transmitters[2]	0	0
M55(pulsed mode)	0	0
M55(continuous mode)[3]	0	0
SCOFT	13	160

1 Nominal Ocular Hazard Distance with optics
2 The pre-1986 rifle and machine gun simulators are not hazardous during blank fire, but have an NOHD of 7 m during dry fire.
3 The M55 Tank Gunnery Trainer is not a hazard for momentary (0.25 s) viewing at any range.

APPENDIX C

AGES/AD, LATAGS, PGTS AND AN/GVT-l SAFETY SUMMARY

10. Scope. This appendix provides hazard information on gunnery training systems.

20. APPLICABLE DOCUMENTS

Information in this section was obtained from documents referenced in Chapter 2 and from informal documents provided by each of the Service's safety specialists in Chapter 1.

30. SAFETY SUMMARY

The Air to Ground Engagement System/Air Defense (AGES/AD) , Laser Air to Air Gunnery Systems (LATAGS) and Precision Gunnery Training System (PGTS) for TOW and Dragon missiles are an extension of and are similar to the Multiple Integrated Laser Engagement System (MILES). The AGES/AD, LATAGS and PGTS systems emit infrared laser beams to simulate various air defense, airborne and ground weapons systems to improve realism during training. The AN/GVT-l is a simulator of a target illuminated by a laser; it consists of an infrared laser emitter covered by a diffuser. Table C-I lists cautionary viewing distance for an eye exposed from within the infrared laser beam for various versions of the AGES/AD, LATAGS and PGTS and AN/GVT-l simulators. Since these systems are either airborne, pointed toward the sky, aimed at a retroreflector mounted on a target in a restricted area or contained *within* a diffuser, no optical radiation hazard exists during normal field exercises. Other potential hazards such as posed by the blast simulators must also be considered.

TABLE C-I. CAUTIONARY DISTANCES FOR EYE EXPOSURE TO THE AGES/AD AND LATAGS PGTS AND AN/GVT-1 LASERS

Device/Simulator	Unaided Viewing	Optically Aided Viewing (7 x 50 Binoculars)
TOW	12 m	75 m
Chaparral	0 m	110 m
Vulcan	12 m	75 m
2.75" Rocket	12 m	75 m
20 mm Gun	12 m	75 m
Stinger	12 m	75 m
AN/ASQ-193 LATAGS	0 m	438 m
PGTS	0 m	154 m
AN/GVT-1 Simulated Laser Target		
With Diffuser	0 m	0 m
Without Diffuser	2760 m	15,000 m

APPENDIX D

SAMPLE CONTENT FOR LASER SAFETY SOP FOR TWINING WITH PORTABLE FIRE CONTROL LASERS

WARNING

Laser rangefinders and designators can cause irreparable blindness if used improperly. Exposure of the eye to either the direct beam or a beam reflected from a flat mirror-like surface can cause an eye injury at a great distance. These lasers will not pose a skin or diffuse reflection viewing hazard. The following control measures will prevent such an exposure when training operators with portable fire control lasers in one-sided exercises:

a. Laser operators shall periodically read and always follow this safety SOP.

b. Never point the laser at any unprotected personnel or flat mirror-like surfaces such as glass.

c. Operate only on laser-approved ranges established in accordance with this manual

d. The laser will not be operated or experimented with outside the range area unless it is specifically authorized. The laser exit port will be covered by an opaque dust cover and the laser disabled by removal of the battery when the laser is located outside the range area.

e. Positively identify the target and buffer areas before laser operations.

f. Since the target area must be clear of specular reflectors, laser eye protection is not required for laser operators even when viewing the target area with binoculars. However, personnel should never enter the laser hazard area during lasing operations without appropriate laser eye protection. Such eye protection shall have curved lenses.

9“ No special precautions are necessary for firing during rain, fog, or snowfall. Certain ranges may be closed for operation if water begins pending either on the ground or on snow.

h. Report immediately to your supervisor any suspected injury or defective equipment (such as misalignment of the laser beam with the pointing telescope) so that appropriate action may be taken.

i. The SOP must also include general information such as responsibilities, emergency procedures, and the meaning of operational and warning signals.

EQUATIONS FOR LASER HAZARD EVALUATION

10 SCOPE

10.1 Scope. This appendix contains equations for laser hazard evaluation to conform to range safety constraints.

20 APPLICABLE DOCUMENTS

The references from which these equations were derived are given in Chapter 2 of this handbook.

30 APPLICATION OF EQUATIONS

30.1 Introduction

The information provided in this Appendix may be used in addition to the Service-specific laser evaluation techniques.

The equations in this section provide the means to determine minimum laser altitude above Mean Sea Level (MSL) that 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 also provided to determine positions of ground based lasers that will satisfy the safety constraints on a given range.

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

The use of these equations in the case of shipboard laser systems would provide pessimistic results. The lack of terrain features to act as a backstop in an open ocean environment, when combined with the longer NOHD of a more powerful shipboard laser system, causes the curvature of the earth to play a significant role in shipboard laser evaluations. The optical horizon from an elevation of 80-ft MSL is approximately 9.5 nmi. Since at a range of 19 nmi (the approximate NOHD for unaided viewing of some proposed shipboard laser systems), the propagated beam could not possibly be below 80-ft MSL, the *use* of optical aids aboard other surface vessels would not increase the probability of exposure. It would increase the extent of damage should an exposure occur. It would also require coordination with those responsible for the air space and coordination of satellite space with Space Command, Cheyenne Mountain, Colorado.

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

30.2 Hazard Evaluation

a. Buffered Footprint Definition. The buffered footprint is the projection of the laser beam and its associated buffer zone on the ground surrounding the intended target. The footprint configuration and size are determined by the range from the laser aperture to the target, the incidence angle of the laser beam line-of-sight on the target or range area plane and the assigned buffer angle.

Figures E-1 and E-2 illustrate the geometry of the buffered footprint. The footprint of this laser is an ellipse whose width is typically quite small and a simple function of the distance to the target. The spreading of the beam along the ground in the direction of the laser line-of-sight is of primary concern and changes drastically as a function of the aircraft's height above and distance to the target.

b. Hazard Evaluation Without Specular Reflections. This evaluation should be done for each aircraft heading and account for slope of the terrain.

1. Single Laser Aircraft Heading Provided that the laser target and surrounding area are clear of* specular reflectors, the mathematical model used to evaluate range safety must assure that the laser beam and its associated buffered footprint fall within the prescribed boundaries of the controlled and restricted ground space. The following paragraphs describe the equations used for this model. Figure E-1 illustrates an aircraft laser illuminating a small target area with the associated buffer zones fore and aft. Figure E-2 shows an airborne laser illuminating a large target area with near and far buffer zones assigned as if the laser were always aimed at the nearest and farthest targets. The plan views of these buffered foot prints are given in figures E-3 and E-4. When using tables E-I through E-V to determine buffered footprint widths and lengths, refer to the rectangle in figure E-4 to visualize dimensions in the footprint tables which are listed as forward, aft, and width.

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

3. Examples (Level Ground). The following examples are

provided as an application of the conditions described above.

A. EXAMPLE 1 (Level ground): Referring to table E-I, for a PAVE SPIKE laser fired from 200 - 1000 feet above ground level (AGL) at ranges from 1 to 4 miles, the longest buffered footprint dimensions on level ground are 8500 feet forward, 5960 feet aft and 130 feet wide. The areas within these distances of target must be restricted as the LSDZ.

B. EXAMPLE 2 (Level ground) : Referring to table E-V, for any PAVE SPIKE or PAVE TACK laser fired from 200 - 1000 feet above ground level at ranges from 1 to 4 miles, the longest buffered footprint dimensions on level ground are 37600 feet forward, 9190 feet aft and 243 feet wide. The areas within these distances of the target must be restricted as the LSDZ.

4. Terrain Not Level.

Actual procedures vary case by case but the following are presented as common conditions:

A. 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 figures E-7, E-8 and E-9 .

B. Falling terrain in target area or hills in foreground This condition will result in longer forward buffered footprints and more restrictive conditions.

(1) Foreground distances. The height, mean sea level (MSL) or above ground level (AGL) of the laser in reference to the target must be determined for all distances between the laser and target.

(2) Distance beyond target. The downward sloping ground beyond the target can greatly extend the forward footprint as illustrated in figures E-10 and E-11. If flight profiles are not limited, the forward footprint could be as long as the NOHD.

C. Specular Reflections

1. Still Water and Other Flat Specular Surfaces

Determine if the reflection from still water can enter uncontrolled air space, or hit a hill or ship's structure within

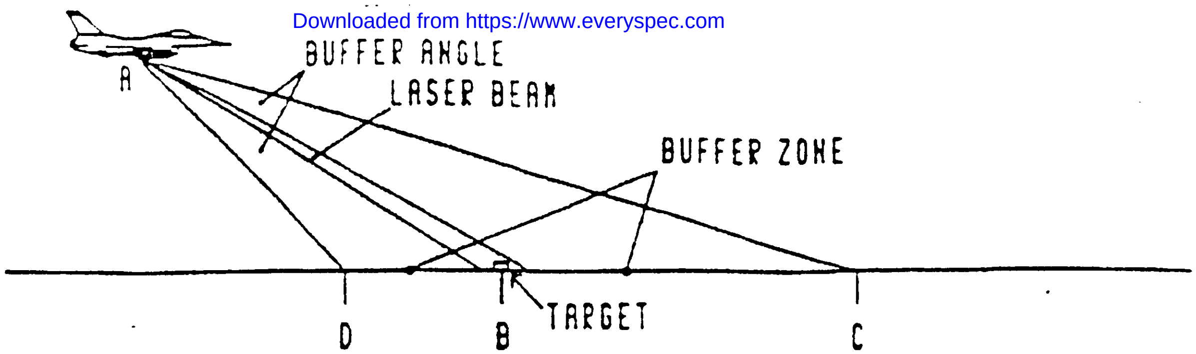


Figure E-1. Laser Footprint with Single Target - Side View

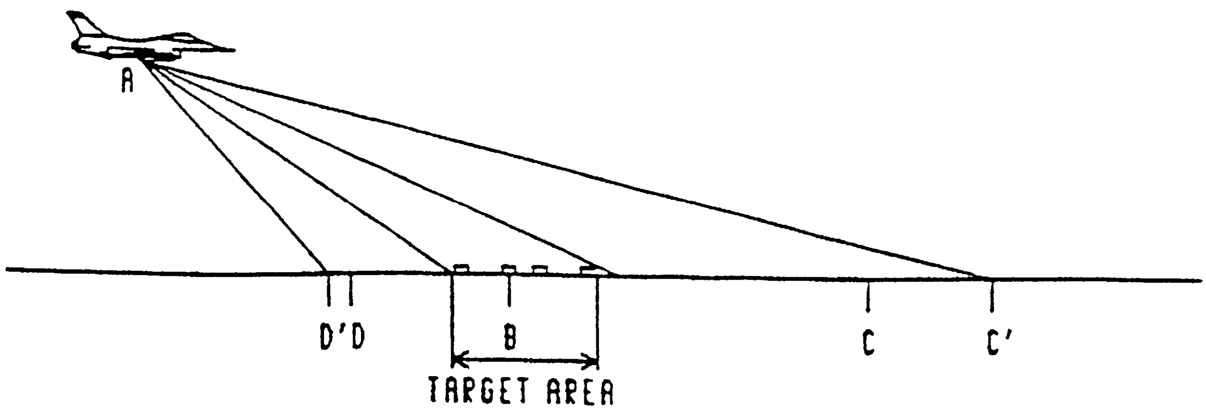


Figure E-2. Laser Footprint with Multiple Targets - Side View

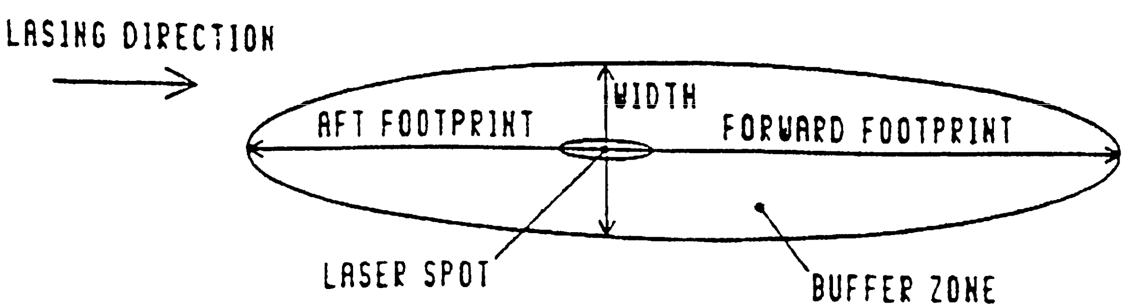


Figure E-3. Laser Footprint - Top View

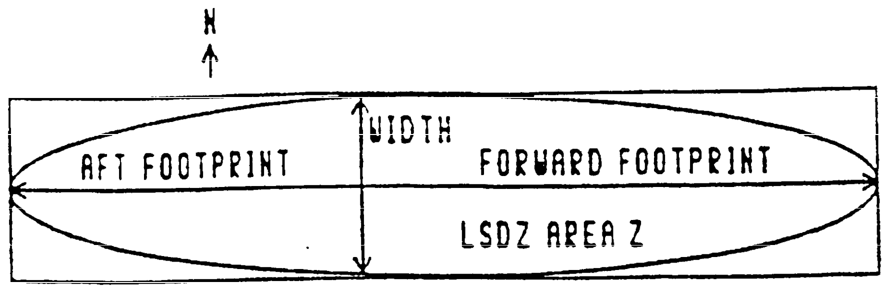


Figure E-4. LSDZ - Attack Bearing 90 Degrees

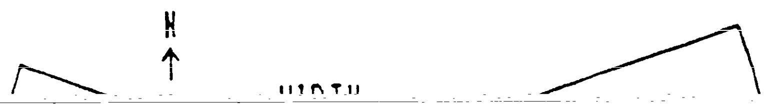


Table E-I. LASER FOOTPRINT TABLE for: PAVE SPIKE (USING VACUUM NOHD)
Table based on: Flat terrain, Buffer = 2.5 , mrad, Divergence = .35 mrad
NOHD= 10000 meters (32900 feet or 5.4 nautical miles)

Table values are FOOTPRINT dimensions(feet and meters)

ALTITUDE (feet)	FOOTPRINT	SLANT RANGE (nautical miles, feet, and meters)								
		1.0 NM 6080 ft 1850 m	2.0 NM 12200 ft 3700 m	3.0 NM 18200 ft 5560 m	4.0 NM 24300 ft 7410 m	5.0 NM 30400 ft 9260 m	6.0 NM 36500 ft 11100 m	7.0 NM 42500 ft 13000 m	8.0 NM 48600 ft 14800 m	9.0 NM 54700 ft 16700 m
100	FORWARD	1180 ft 359 m	5850 ft 1780 m	14600 ft 4440 m	8500 ft 2590 m	2420 ft 737 m	0 ft 0 m	0 ft 0 m	0 ft 0 m	0 ft 0 m
	AFT	850 ft 259 m	2980 ft 909 m	5970 ft 1820 m	9580 ft 2920 m	13600 ft 4150 m	18000 ft 5490 m	22500 ft 6900 m	27500 ft 8380 m	32500 ft 9900 m
200	FORWARD	537 ft 164 m	2360 ft 719 m	5880 ft 1790 m	8500 ft 2590 m	2420 ft 731 m	0 ft 0 m	0 ft 0 m	0 ft 0 m	0 ft 0 m
	AFT	457 ft 139 m	1,700 ft 518 m	3570 ft 1090 m	5960 ft 1820 m	8780 ft 2680 m	11900 ft 3640 m	15400 ft 4700 m	19200 ft 5840 m	23100 ft 7040 m
300	FORWARD	348 ft 106 m	1480 ft 450 m	3540 ft 1080 m	6720 ft 2050 m	2420 ft 737 m	0 ft 0 m	0 ft 0 m	0 ft 0 m	0 ft 0 m
	AFT	312 ft 95 m	1190 ft 362 m	2550 ft 777 m	4330 ft 1320 m	6480 ft 1970 m	8940 ft 2730 m	11700 ft 3560 m	0 ft 0 m	0 ft 0 m
400	FORWARD	257 ft 78 m	1070 ft 328 m	2530 ft 171 m	4720 ft 1440 m	2420 ft 737 m	0 ft 0 m	0 ft 0 m	0 ft 0 m	0 ft 0 m
	AFT	237 ft 72 m	913 ft 278 m	1980 ft 604 m	3400 ft 1040 m	5130 ft 1560 m	7150 ft 2180 m	0 ft 0 m	0 ft 0 m	0 ft 0 m
500	FORWARD	204 ft 62 m	845 ft 258 m	1970 ft 600 m	3630 ft 1110 m	2420 ft 738 m	0 ft 0 m	0 ft 0 m	0 ft 0 m	0 ft 0 m
	AFT	191 ft 58 m	742 ft 226 m	1620 ft 494 m	2800 ft 852 m	4250 ft 1290 m	5950 ft 1810 m	0 ft 0 m	0 ft 0 m	0 ft 0 m
600	FORWARD	169 ft 52 m	696 ft 212 m	1610 ft 491 m	2950 ft 900 m	2420 ft 738 m	0 ft 0 m	0 ft 0 m	0 ft 0 m	0 ft 0 m
	AFT	160 ft 49 m	625 ft 190 m	1370 ft 418 m	2380 ft 724 m	3620 ft 1100 m	5100 ft 1550 m	0 ft 0 m	0 ft 0 m	0 ft 0 m
700	FORWARD	144 ft 44 m	592 ft 180 m	1360 ft 416 m	2490 ft 758 m	2420 ft 738 m	0 ft 0 m	0 ft 0 m	0 ft 0 m	0 ft 0 m
	AFT	138 ft 42 m	539 ft 164 m	1190 ft 362 m	2070 ft 630 m	3160 ft 963 m	4450 ft 1360 m	0 ft 0 m	0 ft 0 m	0 ft 0 m
800	FORWARD	126 ft 38 m	515 ft 157 m	1180 ft 361 m	2150 ft 655 m	2420 ft 738 m	0 ft 0 m	0 ft 0 m	0 ft 0 m	0 ft 0 m
	AFT	121 ft 37 m	475 ft 145 m	1050 ft 319 m	1830 ft 557 m	2800 ft 854 m	3960 ft 1210 m	0 ft 0 m	0 ft 0 m	0 ft 0 m
	WIDTH	33 ft 10 m	65 ft 20 m	98 ft 30 m	130 ft 40 m	163 ft 50 m	195 ft 59 m	228 ft 69 m	260 ft 79 m	293 ft 89 m

FOOTPRINT FORWARD - distance beyond target
FOOTPRINT AFT - distance from target toward aircraft.
FOOTPRINT WIDTH - total width at target.
NOTE: -99 Indicates an impossible alt./range combination.

Table E-II
LASER FOOTPRINT TABLE for: PAVE SPIKE (INCLUDING ATMOSPHERIC ATTENUATION FOR LASING FROM ALTITUDES BELOW 1 km MSL ONLY)
Table based on: Flat terrain, Buffer = 2.5 mrad, Divergence = .35 mrad
NOHD= 8200 meters (26896 feet or 4.4 nautical miles)

Table values are FOOTPRINT dimensions(feet and meters)

ALTITUDE (feet)	FOOTPRINT	SLANT RANGE (nautical miles, feet, and meters) 1.0 NM 6080 ft 1850 m	2.0 NM 12200 ft 3700 m	3.0 NM 18200 ft 5560 m	4.0 NM 24300 ft 7410 m	5.0 NM 30400 ft 9260 m	6.0 NM 36500 ft 11100 m	7.0 NM 42500 ft 13000 m	8.0 NM 48600 ft 14800 m	9.0 NM 54700 ft 16700 m
100	FORWARD	1180 ft	5050 ft	8670 ft	2590 ft	0 ft	0 ft	0 ft	0 ft	0 ft
		359 m	1780 m	2640 m	790 m	0 m	0 m	0 m	0 m	0 m
	AFT	850 ft	2980 ft	5970 ft	9580 ft	13600 ft	18000 ft	22600 ft	27500 ft	32500 ft
		259 m	909 m	1820 m	2920 m	4150 m	5490 m	6900 m	8380 m	9900 m
200	FORWARD	537 ft	2360 ft	5880 ft	2590 ft	0 ft	0 ft	0 ft	0 ft	0 ft
		164 m	719 m	1790 m	790 m	0 m	0 m	0 m	0 m	0 m
	AFT	457 ft	1700 ft	3570 ft	5960 ft	8780 ft	11900 ft	0 ft	0 ft	0 ft
		139 m	518 m	1090 m	1820 m	2680 m	3640 m	0 m	0 m	0 m
300	FORWARD	348 ft	1480 ft	3540 ft	2590 ft	0 ft	0 ft	0 ft	0 ft	0 ft
		106 m	450 m	1080 m	790 m	0 m	0 m	0 m	0 m	0 m
	AFT	312 ft	1190 ft	2550 ft	4330 ft	6480 ft	0 ft	0 ft	0 ft	0 ft
		95 m	362 m	777 m	1320 m	1970 m	0 m	0 m	0 m	0 m
400	FORWARD	257 ft	1070 ft	2530 ft	2590 ft	0 ft	0 ft	0 ft	0 ft	0 ft
		78 m	328 m	771 m	790 m	0 m	0 m	0 m	0 m	0 m
	AFT	237 ft	913 ft	1980 ft	3400 ft	5130 ft	0 ft	0 ft	0 ft	0 ft
		72 m	278 m	604 m	1040 m	1560 m	0 m	0 m	0 m	0 m
500	FORWARD	204 ft	845 ft	1970 ft	2590 ft	0 ft	0 ft	0 ft	0 ft	0 ft
		62 m	258 m	600 m	790 m	0 m	0 m	0 m	0 m	0 m
	AFT	191 ft	742 ft	1620 ft	2800 ft	4250 ft	0 ft	0 ft	0 ft	0 ft
		58 m	226 m	494 m	852 m	1290 m	0 m	0 m	0 m	0 m
600	FORWARD	169 ft	696 ft	1610 ft	2590 ft	0 ft	0 ft	0 ft	0 ft	0 ft
		52 m	212 m	491 m	790 m	0 m	0 m	0 m	0 m	0 m
	AFT	160 ft	625 ft	1370 ft	2380 ft	3620 ft	0 ft	0 ft	0 ft	0 ft
		49 m	190 m	418 m	724 m	1100 m	0 m	0 m	0 m	0 m
700	FORWARD	144 ft	592 ft	1360 ft	2490 ft	0 ft	0 ft	0 ft	0 ft	0 ft
		44 m	180 m	416 m	758 m	0 m	0 m	0 m	0 m	0 m
	AFT	138 ft	539 ft	1190 ft	2070 ft	0 ft	0 ft	0 ft	0 ft	0 ft
		42 m	164 m	362 m	630 m	0 m	0 m	0 m	0 m	0 m
800	FORWARD	126 ft	515 ft	1180 ft	2150 ft	0 ft	0 ft	0 ft	0 ft	0 ft
		38 m	157 m	361 m	655 m	0 m	0 m	0 m	0 m	0 m
	AFT	121 ft	475 ft	1050 ft	1830 ft	0 ft	0 ft	0 ft	0 ft	0 ft
		37 m	145 m	319 m	557 m	0 m	0 m	0 m	0 m	0 m
	WIDTH	33 ft	65 ft	98 ft	130 ft	163 ft	195 ft	228 ft	260 ft	293 ft
		10 m	20 m	30 m	40 m	50 m	59 m	69 m	79 m	89 m

FOOTPRINT FORWARD - distance beyond target.
FOOTPRINT AFT - distance from target toward aircraft.
FOOTPRINT WIDTH - total width at target.
NOTE: -99 indicates an impossible alt./range combination.

Table E-III
LASER FOOTPRINT TABLE for: PAVE TACK (USING VACUUM NOHD)
Table based on: Flat terrain, Buffer = 2 mrad, Divergence = 0 mrad
NOHD= 16000 meters (52480 feet or 8.6 nautical miles)

Table values are FOOTPRINT dimensions(feet and meters)

ALTITUDE (feet)	FOOTPRINT	SLANT RANGE (nautical miles, feet, and meters) 1.0 NM 6080 ft 1850 m	2.0 NM 12200 ft 3700 m	3.0 NM 18200 ft 5560 m	4.0 NM 24300 ft 7410 m	5.0 NM 30400 ft 9260 m	6.0 NM 36500 ft 11100 m	7.0 NM 42500 ft 13000 m	8.0 NM 48600 ft 14800 m	9.0 NM 54700 ft 16700 m
100	FORWARD	841 ft	3900 ft	10500 ft	23000 ft	22100 ft	16000 ft	9950 ft	3870 ft	0 ft
		256 m	1190 m	3190 m	7010 m	6740 m	4880 m	3030 m	1180 m	0 m
	AFT	658 ft	2380 ft	4870 ft	7950 ft	11500 ft	15400 ft	19600 ft	24000 ft	28600 ft
		201 m	724 m	1480 m	2420 m	3500 m	4690 m	5960 m	7300 m	8710 m
200	FORWARD	393 ft	1680 ft	4060 ft	7800 ft	13300 ft	16000 ft	9950 ft	3870 ft	0 ft
		120 m	512 m	1240 m	2380 m	4040 m	4880 m	3030 m	1180 m	0 m
	AFT	348 ft	1320 ft	2810 ft	4750 ft	7080 ft	9740 ft	12700 ft	15900 ft	19300 ft
		106 m	401 m	857 m	1450 m	2160 m	2970 m	3870 m	4850 m	5890 m
300	FORWARD	257 ft	1070 ft	2520 ft	4700 ft	7720 ft	11700 ft	9950 ft	3870 ft	0 ft
		78 m	327 m	769 m	1430 m	2350 m	3570 m	3030 m	1180 m	0 m
	AFT	237 ft	911 ft	1980 ft	3390 ft	5120 ft	7130 ft	9400 ft	11900 ft	14600 ft
		72 m	278 m	602 m	1030 m	1560 m	2170 m	2860 m	3630 m	4450 m
400	FORWARD	190 ft	786 ft	1830 ft	3360 ft	5440 ft	8130 ft	9950 ft	3870 ft	0 ft
		58 m	240 m	557 m	1020 m	1660 m	2480 m	3030 m	1180 m	0 m
	AFT	179 ft	696 ft	1520 ft	2630 ft	4010 ft	5620 ft	7460 ft	9500 ft	11700 ft
		55 m	212 m	464 m	803 m	1220 m	1710 m	2270 m	2900 m	3580 m
500	FORWARD	151 ft	621 ft	1430 ft	2620 ft	4200 ft	6220 ft	8720 ft	3870 ft	0 ft
		46 m	189 m	437 m	798 m	1280 m	1900 m	2660 m	1180 m	0 m
	AFT	144 ft	563 ft	1240 ft	2150 ft	3290 ft	4640 ft	6180 ft	7910 ft	9810 ft
		44 m	172 m	378 m	656 m	1000 m	1410 m	1880 m	2410 m	2990 m
600	FORWARD	126 ft	513 ft	1180 ft	2140 ft	3420 ft	5040 ft	7030 ft	3870 ft	0 ft
		33 m	156 m	359 m	653 m	1040 m	1540 m	2140 m	1180 m	0 m
	AFT	121 ft	473 ft	1040 ft	1820 ft	2790 ft	3950 ft	5280 ft	6780 ft	8430 ft
		37 m	144 m	318 m	555 m	852 m	1200 m	1610 m	2070 m	2570 m
700	FORWARD	107 ft	437 ft	1000 ft	1810 ft	2890 ft	4240 ft	5880 ft	3870 ft	0 ft
		33 m	133 m	305 m	553 m	880 m	1290 m	1790 m	1180 m	0 m
	AFT	104 ft	408 ft	902 ft	1580 ft	2430 ft	3440 ft	4610 ft	5930 ft	7390 ft
		32 m	124 m	275 m	481 m	740 m	1050 m	1400 m	1810 m	2250 m
800	FORWARD	94 ft	381 ft	870 ft	1570 ft	2500 ft	3660 ft	5060 ft	3870 ft	0 ft
		29 m	116 m	265 m	479 m	761 m	1110 m	1540 m	1180 m	0 m
	AFT	91 ft	358 ft	795 ft	1390 ft	2140 ft	3050 ft	4090 ft	5270 ft	6580 ft
		28 m	109 m	242 m	424 m	654 m	928 m	1250 m	1610 m	2000 m
	WIDTH	24 ft	49 ft	73 ft	97 ft	122 ft	146 ft	170 ft	194 ft	219 ft
		7 m	15 m	22 m	30 m	37 m	44 m	52 m	59 m	67 m

FOOTPRINT FORWARD - distance beyond target.
FOOTPRINT AFT - distance from target toward aircraft.
FOOTPRINT WIDTH - total width at target.
NOTE: -99 indicates an impossible alt./range combination.

Table E-IV
LASER FOOTPRINT TABLE for: PAVE TACK (INCLUDING ATMOSPHERIC ATTENUATION FOR LASING FROM ALTITUDES BELOW 1 km MSL ONLY)
Table based on: Flat terrain, Buffer = 2 mrad, Divergence = 0 mrad
NOHD= 12000 meters (39360 feet or 6.5 nautical miles)

Table values are FOOTPRINT dimensions (feet and meters)

ALTITUDE (feet)	FOOTPRINT	SLANT RANGE (nautical miles, feet, and meters)								
		1.0 NM 6080 ft 1850 m	2.0 NM 12200 ft 3700 m	3.0 NM 18200 ft 5560 m	4.0 NM 24300 ft 7410 m	5.0 NM 30400 ft 9260 m	6.0 NM 36500 ft 11100 m	7.0 NM 42500 ft 13000 m	8.0 NM 48600 ft 14800 m	9.0 NM 64700 ft 16700 m
100	FORWARD	841 ft	3900 ft	10500 ft	15100 ft	8980 ft	2900 ft	0 ft	0 ft	0 ft
		256 m	1190 m	3190 m	4590 m	2740 m	885 m	0 m	0 m	0 m
	AFT	658 ft	2380 ft	4870 ft	7950 ft	11500 ft	15400 ft	19600 ft	24000 ft	28600 ft
		201 m	724 m	1480 m	2420 m	3500 m	4690 m	5960 m	7300 m	8710 m
200	FORWARD	393 ft	1680 ft	4060 ft	7800 ft	8980 ft	2900 ft	0 ft	0 ft	0 ft
		120 m	512 m	1240 m	2380 m	2740 m	885 m	0 m	0 m	0 m
	AFT	348 ft	1320 ft	2810 ft	4750 ft	7080 ft	9740 ft	12700 ft	15900 ft	19300 ft
		106 m	401 m	857 m	1450 m	2160 m	2970 m	3870 m	4850 m	5890 m
300	FORWARD	257 ft	1070 ft	2520 ft	4700 ft	7720 ft	2900 ft	0 ft	0 ft	0 ft
		78 m	327 m	769 m	1430 m	2350 m	885 m	0 m	0 m	0 m
	AFT	237 ft	911 ft	1980 ft	3390 ft	5120 ft	7130 ft	9400 ft	11900 ft	0 ft
		72 m	278 m	602 m	1030 m	1560 m	2170 m	2860 m	3630 m	0 m
400	FORWARD	190 ft	786 ft	1830 ft	3360 ft	5440 ft	2900 ft	0 ft	0 ft	0 ft
		58 m	240 m	557 m	1020 m	1660 m	885 m	0 m	0 m	0 m
	AFT	179 ft	69 ft	1520 ft	2630 ft	4010 ft	5620 ft	7460 ft	9500 ft	0 ft
		55 m	212 m	464 m	803 m	1220 m	1710 m	2270 m	2900 m	0 m
500	FORWARD	151 ft	621 ft	1430 ft	2620 ft	4200 ft	2900 ft	0 ft	0 ft	0 ft
		46 m	189 m	437 m	798 m	1280 m	885 m	0 m	0 m	0 m
	AFT	144 ft	563 ft	1240 ft	2150 ft	3290 ft	4640 ft	6180 ft	0 ft	0 ft
		44 m	172 m	378 m	656 m	1000 m	1410 m	1880 m	0 m	0 m
600	FORWARD	126 ft	513 ft	1180 ft	2140 ft	3420 ft	2900 ft	0 ft	0 ft	0 ft
		38 m	156 m	359 m	653 m	1040 m	885 m	0 m	0 m	0 m
	AFT	121 ft	473 ft	1040 ft	1820 ft	2790 ft	3950 ft	5280 ft	0 ft	0 ft
		37 m	144 m	318 m	555 m	852 m	1200 m	1610 m	0 m	0 m
700	FORWARD	107 ft	437 ft	1000 ft	1810 ft	2890 ft	2900 ft	0 ft	0 ft	0 ft
		33 m	133 m	305 m	553 m	880 m	885 m	0 m	0 m	0 m
	AFT	104 ft	408 ft	902 ft	1580 ft	2430 ft	3440 ft	4610 ft	0 ft	0 ft
		32 m	124 m	275 m	481 m	740 m	1050 m	1400 m	0 m	0 m
800	FORWARD	94 ft	381 ft	870 ft	1570 ft	2500 ft	2900 ft	0 ft	0 ft	0 ft
		29 m	116 m	265 m	479 m	761 m	885 m	0 m	0 m	0 m
	AFT	91 ft	358 ft	795 ft	1390 ft	2140 ft	3050 ft	4090 ft	0 ft	0 ft
		28 m	109 m	242 m	424 m	654 m	928 m	1250 m	0 m	0 m
	WIDTH	24 ft	49 ft	73 ft	97 ft	122 ft	146 ft	170 ft	194 ft	219 ft
		7 m	15 m	22 m	30 m	37 m	44 m	52 m	59 m	67 m

FOOTPRINT FORWARD - distance beyond target.
FOOTPRINT AFT - distance from target toward aircraft.
FOOTPRINT WIDTH = total width at target.
NOTE: -99 indicates an impossible alt./range combination

Table E-V
LASER FOOTPRINT TABLE for: ANY LASER SYSTEM WITH BEAM DIVERGENCE < 0.5 mrad
Table based on: Flat terrain. Buffer = 5 mrad, Divergence = 0 mrad
NOHD= 100000 meters (328000 feet or 54.0 nautical miles)

Table values are FOOTPRINT dimensions (feet and meters)

ALTITUDE (feet)	FOOTPRINT	SLANT RANGE (nautical miles, feet, and meters) 1.0 NM 6080 ft 1850 m	2.0 NM 12200 ft 3700 m	3.0 NM 18200 ft 5560 m	4.0 NM 24300 ft 7410 m	5.0 NM 30400 ft 9260 m	6.0 NM 36500 ft 11100 m	7.0 NM 42500 ft 13000 m	8.0 NM 48600 ft 14800 m	9.0 NM 54700 ft 16700 m
100	FORWARD	2650 ft	18800 ft	188000 ft	304000 ft	298000 ft	292000 ft	285000 ft	279000 ft	273000 ft
		808 m	5740 m	57200 m	92600 m	90700 m	88900 m	87000 m	85200 m	83300 m
	AFT	1420 ft	4590 ft	8690 ft	13300 ft	18300 ft	23500 ft	28900 ft	34400 ft	40000 ft
		432 m	1400 m	2650 m	4060 m	5580 m	7180 m	8820 m	10500 m	12200 m
200	FORWARD	1090 ft	5300 ft	15300 ft	37600 ft	95900 ft	292000 ft	285000 ft	279000 ft	273000 ft
		332 m	1620 m	4650 m	11500 m	29200 m	88900 m	87000 m	85200 m	83300 m
	AFT	801 ft	2830 ft	5710 ft	9190 ft	13100 ft	17400 ft	21900 ft	26700 ft	31600 ft
		244 m	863 m	1740 m	2800 m	4000 m	5300 m	6680 m	8130 m	9630 m
300	FORWARD	685 ft	3090 ft	7950 ft	16500 ft	31200 ft	56500 ft	104000 ft	207000 ft	273000 ft
		209 m	941 m	2420 m	5040 m	9500 m	17200 m	31500 m	63200 m	83300 m
	AFT	559 ft	2050 ft	4250 ft	7010 ft	10200 ft	13800 ft	17600 ft	21800 ft	26100 ft
		170 m	624 m	1290 m	2140 m	3110 m	4200 m	5380 m	6630 m	7950 m
400	FORWARD	499 ft	2180 ft	5380 ft	10600 ft	18600 ft	30500 ft	48300 ft	75300 ft	118000 ft
		152 m	663 m	1640 m	3230 m	5670 m	9300 m	14700 m	22900 m	36000 m
	AFT	429 ft	1600 ft	3380 ft	5660 ft	8360 ft	11400 ft	14800 ft	18400 ft	22200 ft
		131 m	488 m	1030 m	1730 m	2550 m	3480 m	4500 m	5600 m	6770 m
500	FORWARD	393 ft	1680 ft	4060 ft	7800 ft	13300 ft	20900 ft	31500 ft	46000 ft	66000 ft
		120 m	512 m	1240 m	2380 m	4040 m	6380 m	9590 m	14000 m	20100 m
	AFT	348 ft	1320 ft	2810 ft	4750 ft	7080 ft	9740 ft	12700 ft	15900 ft	19300 ft
		106 m	401 m	857 m	1450 m	2160 m	2970 m	3870 m	4850 m	5890 m
600	FORWARD	324 ft	1370 ft	3260 ft	6170 ft	10300 ft	15900 ft	23400 ft	33100 ft	45800 ft
		99 m	417 m	995 m	1880 m	3140 m	4850 m	7120 m	10100 m	14000 m
	AFT	293 ft	1120 ft	2400 ft	4090 ft	6140 ft	8500 ft	11100 ft	14000 ft	17100 ft
		89 m	341 m	733 m	1250 m	1870 m	2590 m	3390 m	4270 m	5220 m
700	FORWARD	276 ft	1150 ft	2730 ft	5110 ft	8420 ft	12800 ft	18500 ft	25900 ft	35100 ft
		84 m	352 m	832 m	1560 m	2570 m	3910 m	5660 m	7880 m	10700 m
	AFT	253 ft	971 ft	2100 ft	3600 ft	5420 ft	7530 ft	9910 ft	12500 ft	15400 ft
		77 m	296 m	640 m	1100 m	1650 m	2300 m	3020 m	3820 m	4880 m
800	FORWARD	240 ft	999 ft	2340 ft	4350 ft	7120 ft	10800 ft	15400 ft	21200 ft	28400 ft
		73 m	304 m	714 m	1330 m	2170 m	3280 m	4690 m	6470 m	8650 m
	AFT	222 ft	858 ft	1860 ft	3210 ft	4850 ft	6770 ft	8930 ft	11300 ft	13900 ft
		68 m	262 m	568 m	977 m	1480 m	2060 m	2720 m	3450 m	4250 m
	WIDTH	61 ft	122 ft	182 ft	243 ft	304 ft	365 ft	425 ft	486 ft	547 ft
		19 m	37 m	56 m	74 m	93 m	111 m	130 m	148 m	167 m

FOOTPRINT FORWARD - distance beyond target.
FOOTPRINT AFT - distance from target toward aircraft.
FOOTPRINT WIDTH - total width at target.
NOTE: -99 indicates an impossible alt./range combination.

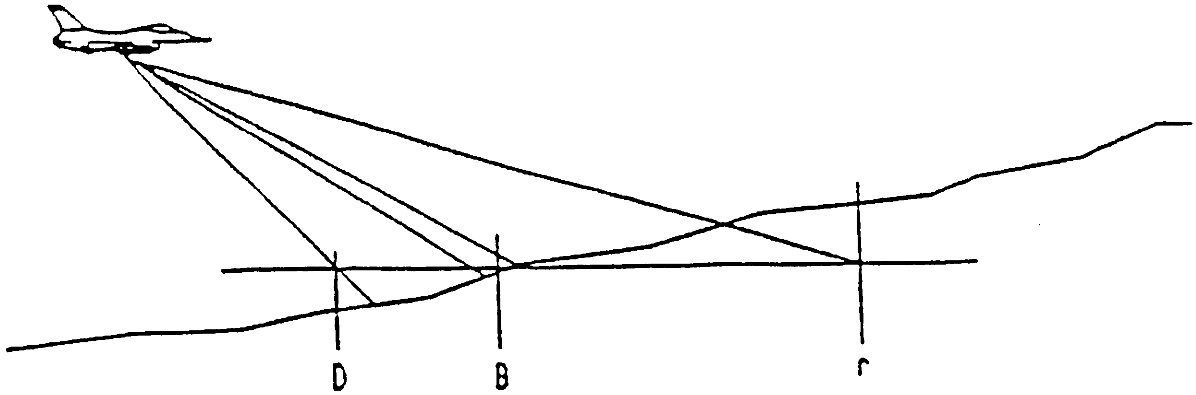


Figure E-7. LSDZ with rising terrain

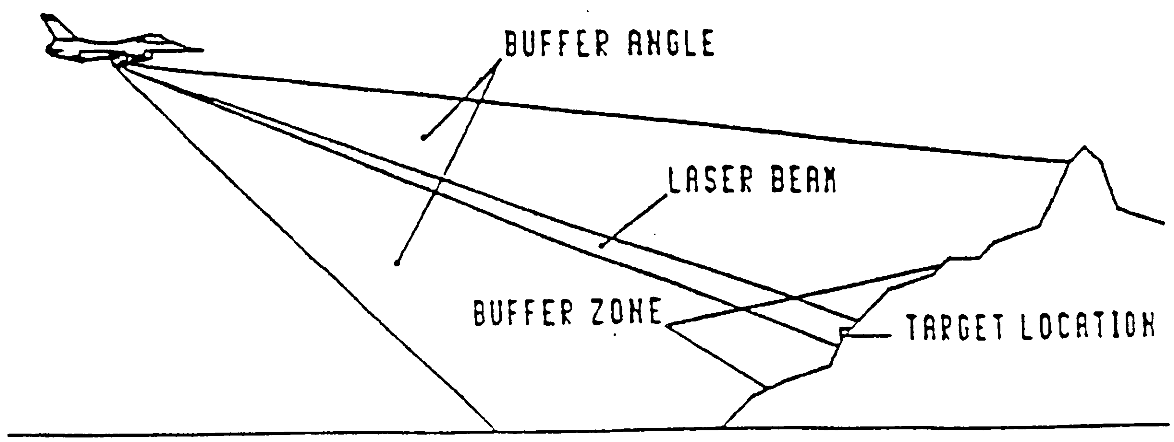


Figure E-8. Use of Natural Backstops to control laser beam

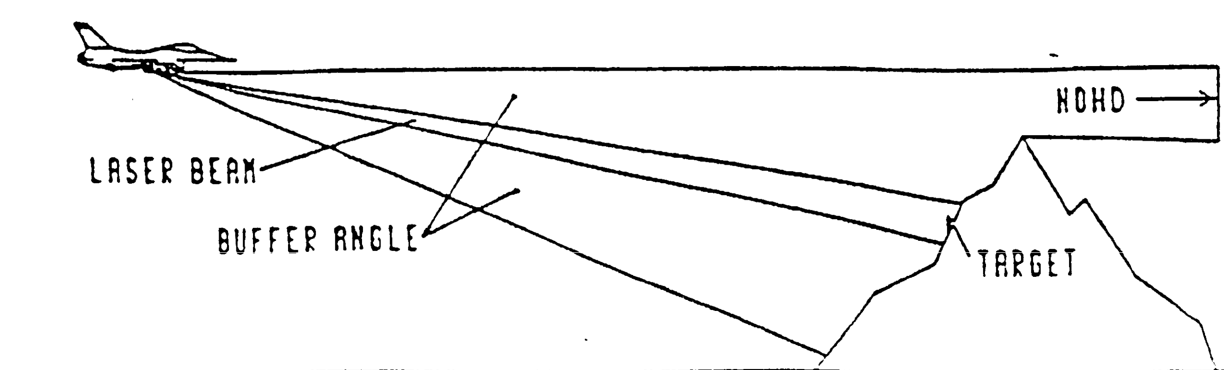


Figure E-9. Insufficient Backstop to control laser beam

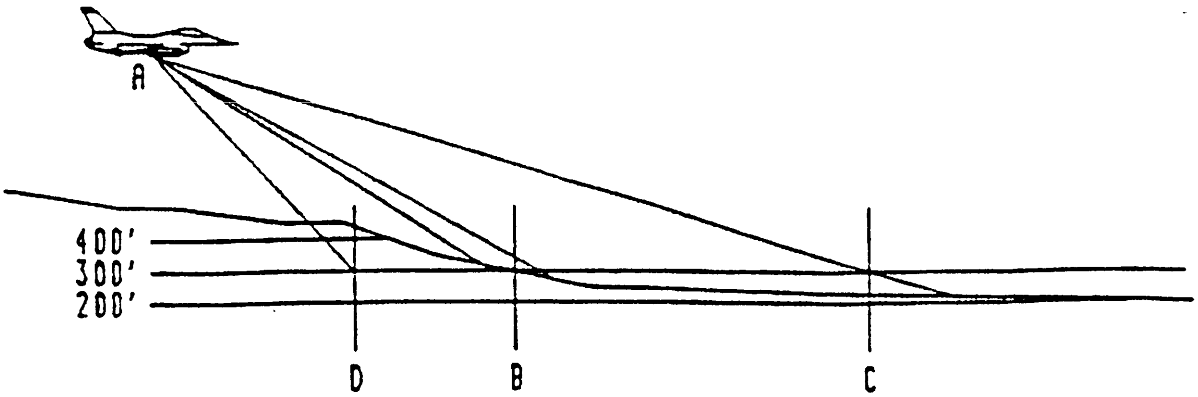


Figure E-10. LSDZ with Terrain sloping down. Range less than NOHD, target at 300ft. MSL

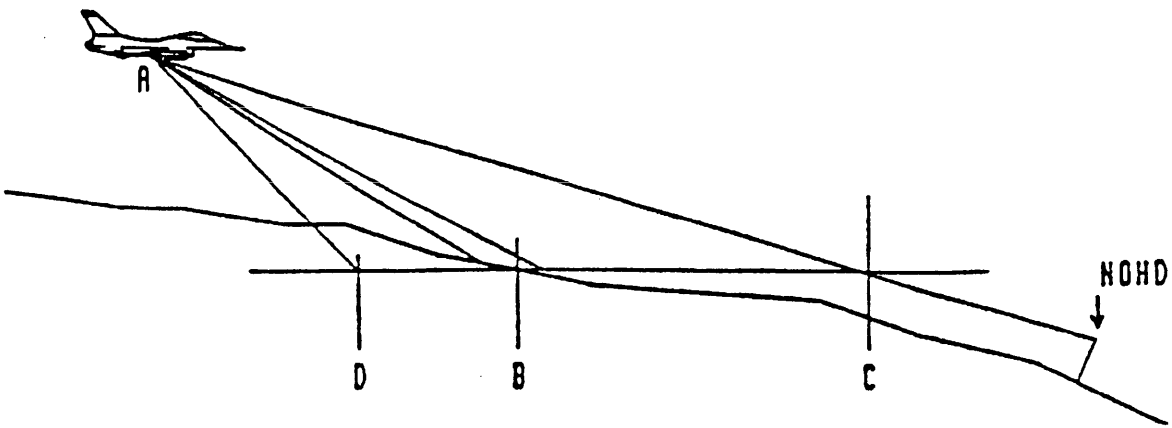


Figure E-11. LSDZ with Terrain sloping down. Range greater than NOHD.

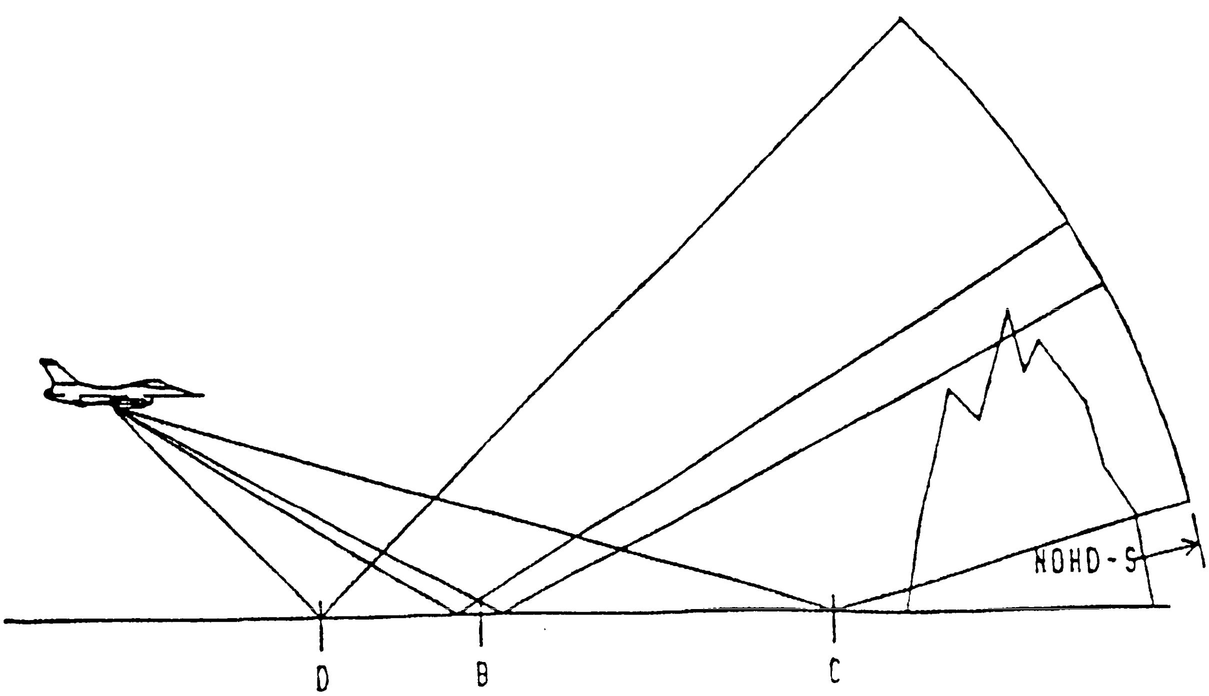


Figure E-12. Reflections from still water within LSDZ the NOHD and beyond the restricted boundaries. This is illustrated in figure E-12. If this or other specular reflectors appear to be a Problem, limit the flight profiles, move the target, or restrict more land or airspace.

If still water cannot be avoided or flat specular reflecting surfaces in the area of the foot print cannot be removed, then the aircrew, personnel in other aircraft, ground and shipboard personnel and the surrounding community need to be considered for this condition. 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. See Appendix G for some reflection coefficients.

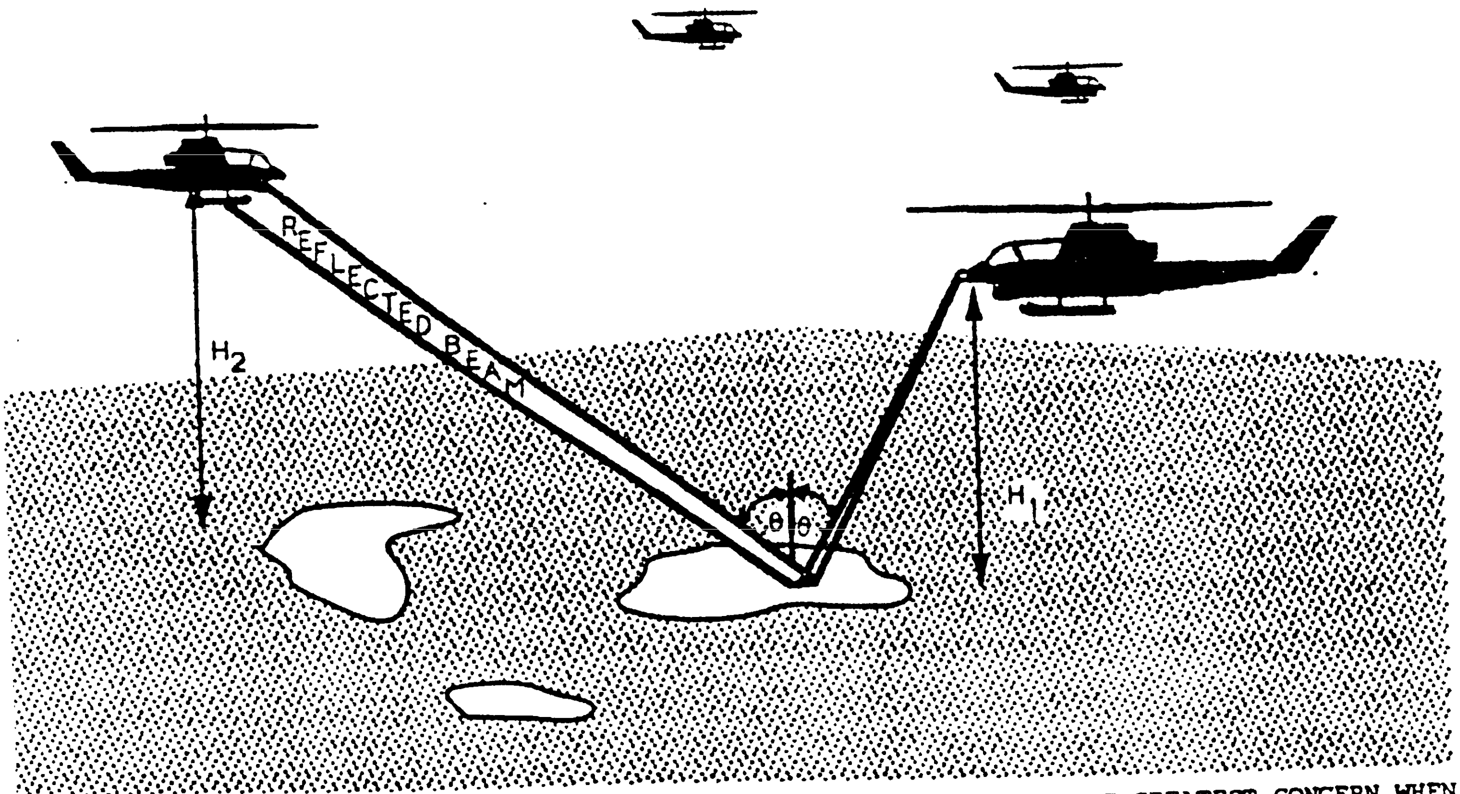
For each altitude of the aircraft and distance from the specular reflector a new sphere or linear distance must be calculated for the specular reflection into the surrounding area or air space. Use the worst case results.

d. Aircrew. Present policy for most services requires aircrews to wear laser protective eye wear when: flying in multiple ship formations, targets are not clear of specular surfaces or ground based lasers are used against aircraft. If the target area is not clear of specular surfaces, and the aircrews lase from distances less than one half the NOHD, aircrews are at risk of eye damage if laser protective eye wear is not used.

Possible exposure situations to aircrews from specular reflectors are shown in figures E-13 and E-14.

e. 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 figures E-15 and E-16. The LSDZ should then be extended to a hemisphere or portion of a hemisphere with a distance from the specular reflector equal to the NOHD minus the minimum lasing distance from the laser to specular reflector. As with the cases described above, natural backstops and terrain may alter the shape of this area. Additionally, airspace over the range or personnel on ships superstructure or land based high structures may be at an unacceptable risk.

f. Hazard Distances from various reflective surfaces. This can be calculated from the information in Appendix G.



THE SPECULARLY REFLECTED BEAM FROM AN AIRBORNE LASER GENERALLY IS OF GREATEST CONCERN WHEN ORGINATING FROM STILL WATER. THE REFLECTED BEAM IS REDIRECTED UPWARD AT THE SAME ANGLE (θ) AS THE INCIDENT BEAM.

Figure E-13. Example of Airborne Laser Beam Reflection

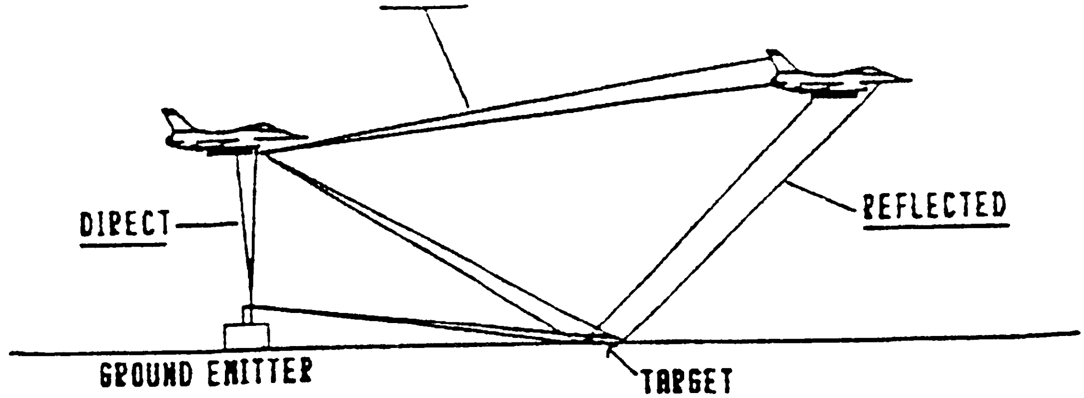


Figure E-14. Potential Exposure Modes

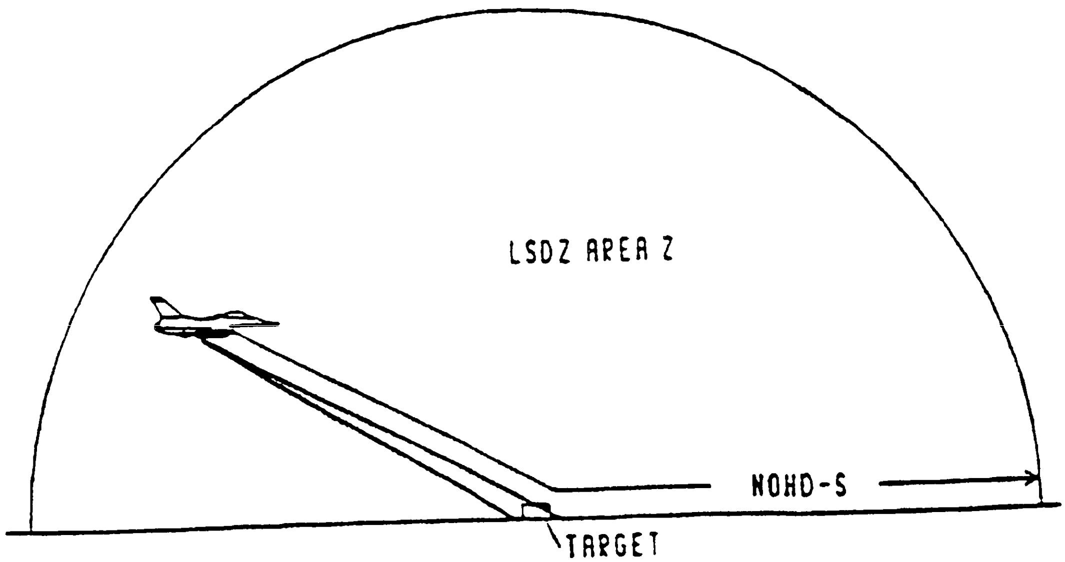


Figure E-15. Reflections from flat specular surface - side view

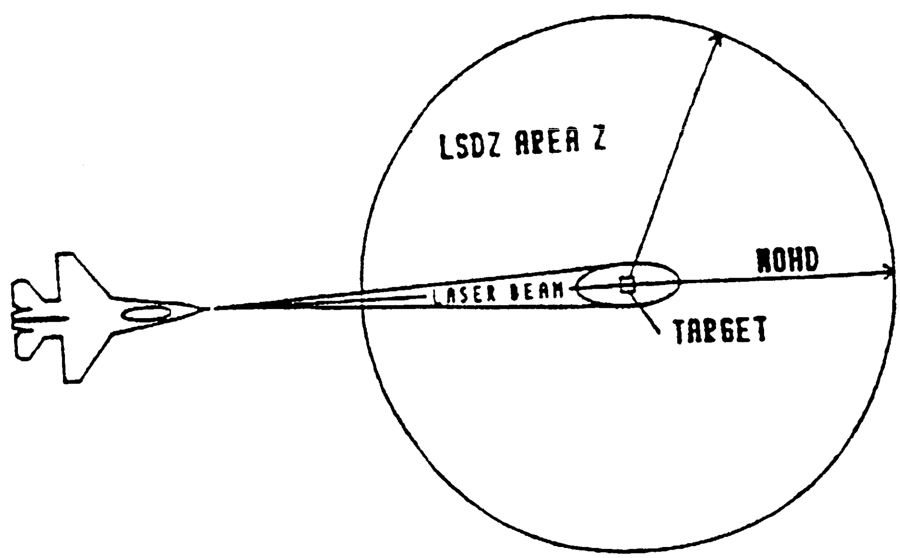


Figure E-16. Reflections from flat specular surface - top view

30.3 Footprint Determinations If the range is small and therefore is the controlling factor, we usually determine the flight profiles from the land size as follows:

Determine desired target location.

Draw outline of controllable restricted range area.

Measure distance from target to range boundaries.

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

For both ground based lasers and airborne lasers, the problem can be broken into two constraints, the first being that the buffered footprint does not exceed-the available controlled area between the target and the laser (near boundary). Likewise, the second constraint is that the buffered footprint does not exceed the available controlled area beyond the target (far boundary).

a. Ground Based Lasers

Determine the ability to keep the buffered laser footprint vertically and horizontally within the restricted boundaries.

1. Vertical Buffer Far Boundarv. Addressing the far boundary constraint first, figure E-17 illustrates the geometry of the problem.

First, determine the available buffer above and below the target out to the edge of the backstop.

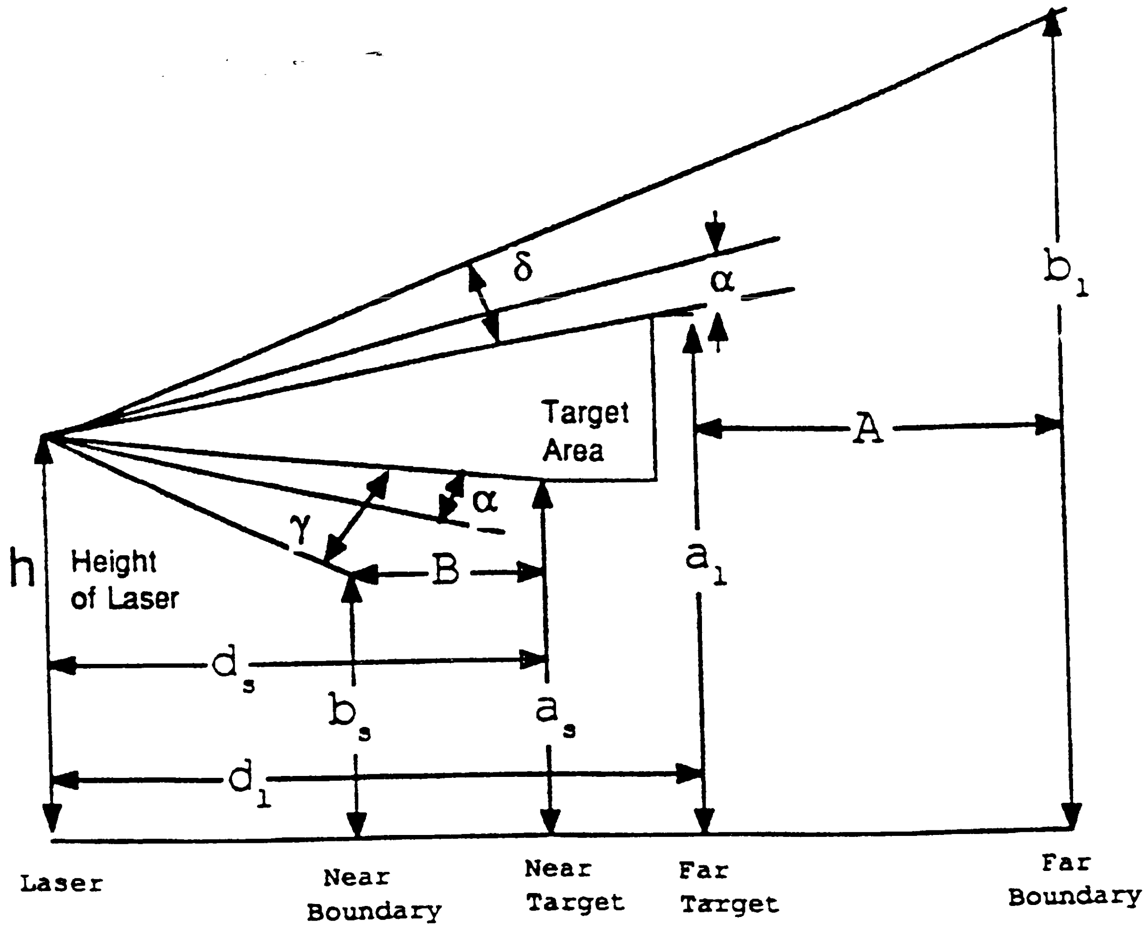
α = buffer angle plus beam divergence either side of laser line-of-sight. For systems listed in table A-I, the beam divergence is extremely small compared to the buffer angle and hence the beam divergence may be ignored.

δ = Available vertical buffer angle between laser line-of-sight to target and laser line-of-sight to backstop.

h = altitude of laser
al = altitude of far target
bl = altitude of far boundary
dl = horizontal distance on surface from laser to furthest target
A = distance from target to far boundary of LSDZ (backstop)

The angle δ may be calculated from the following equation.

$$\delta = \arctan(\,bl - h)/(dl + A)) + \arctan((h - al)/(dl))$$



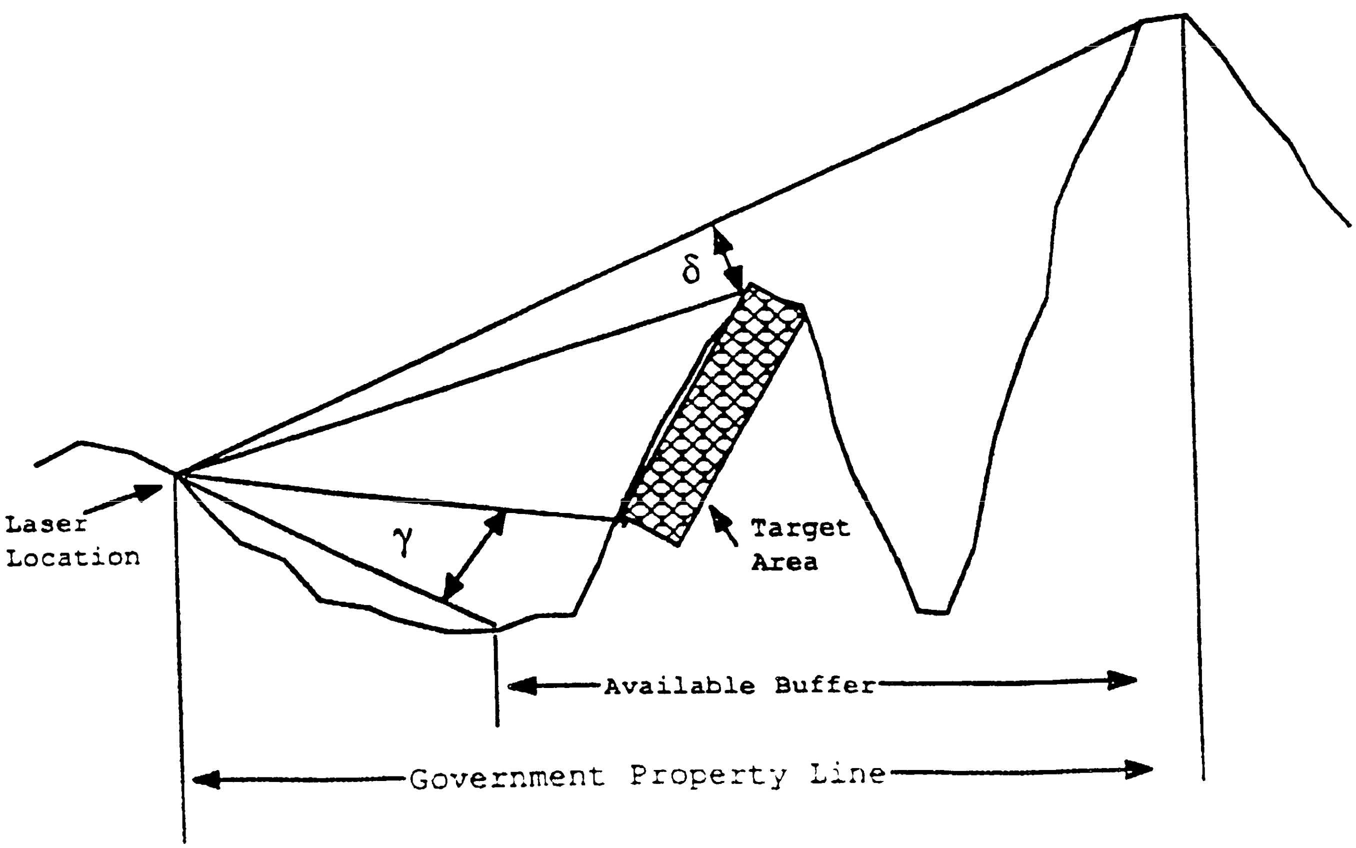


Figure E-17. Vertical Buffer and LSDZ Geometry

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

2. Vertical Buffer Near Boundarv

Similarly for the near boundary:

a = buffer angle plus beam divergence either side of laser line-of-sight. For systems listed in table A-I, the beam divergence is extremely small compared to the buffer angle and hence the beam divergence may be ignored.

γ = vertical angle from either side of laser line-of-sight to near edge of LSDZ (backstop) between the laser and the target.
h = altitude of laser
as = altitude of nearest target
bs = altitude of near boundary
ds = horizontal distance on surface from laser to nearest target
B = distance from target to near boundary of LSDZ (backstop)

The vertical angle γ may be calculated from the following equation.

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

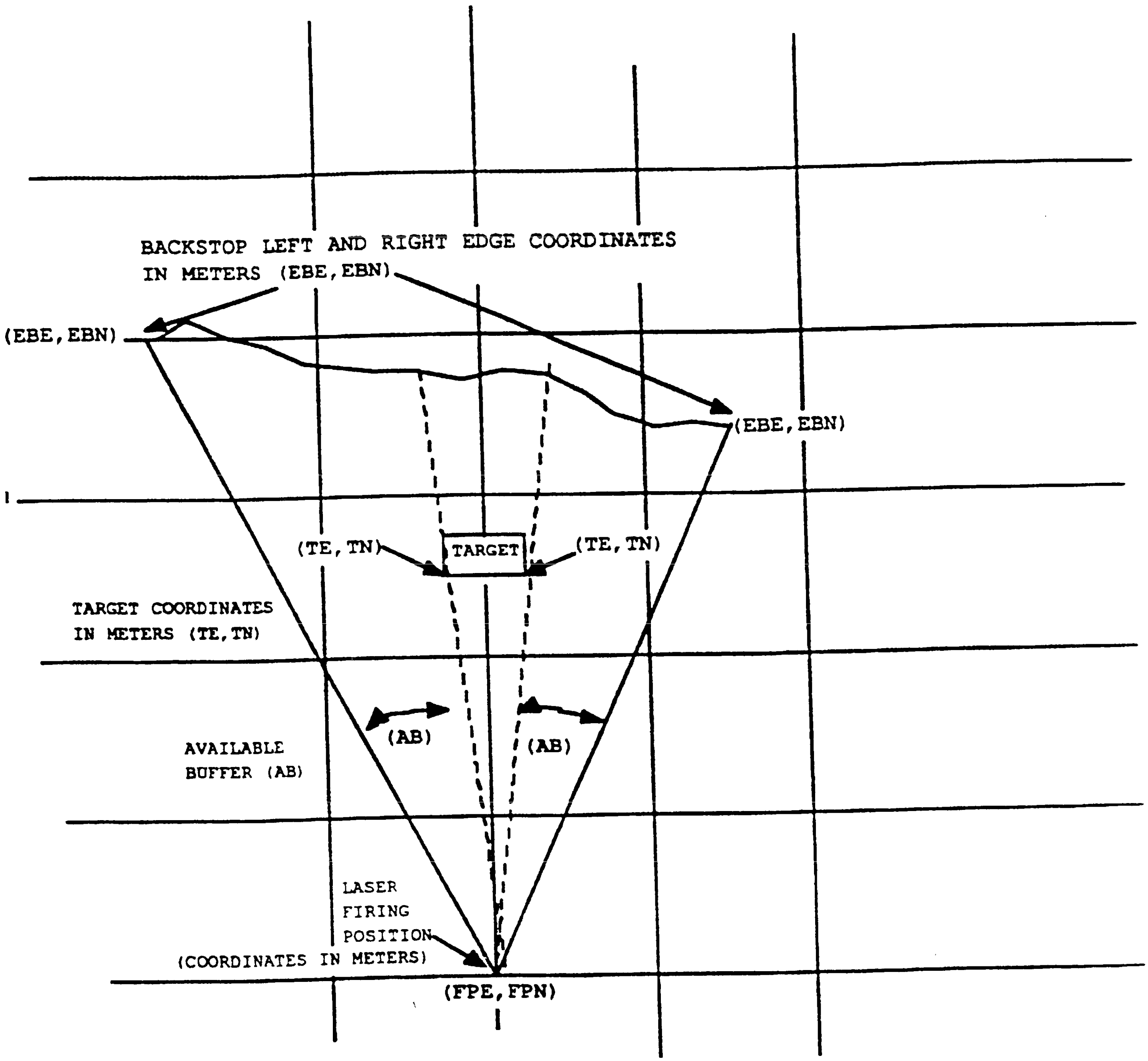
As long as the angle γ remains greater than angle α, the beam is safely contained vertically within the designated LSDZ.

3. Horizontal Buffer. See figure E-18. Available buffer to the left and right of the target out to the backstop may be calculated as follows:

$$AB = \arctan((FPN-EBN)/(FPE-EBE)) - \arctan((FPN-TN)/(FPE-TE))$$

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.



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

To safely contain the laser beam, the available buffer must be larger than the allowed buffer for the laser in use (see Table A-1 for allowed buffer zones for specific lasers.).

Figure E-18. Calculation of Available Buffer versus Allowed Buffer.

b. Airborne Laser with Target on Level Ground

a. Aircraft minimum altitude to keep buffered footprint within far and near boundaries of LSDZ

See figure E-19.

Minimum laser altitude (h) relative to target to keep buffered laser footprint within the far boundary when at slant range (R) from target is

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

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

$$h = R\sin(\arcsin((R/B)\sin(a)) - a)$$

Where:

R = slant range from laser to target

a = buffer angle plus beam divergence either side of laser line-of-sight. For systems listed in table A-I 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 E-20.

b. Left and Right Hand LSDZ. The width of the right hand and left hand LSDZ width (See figure E-3) are calculated as follows:

$$s = R \times a$$

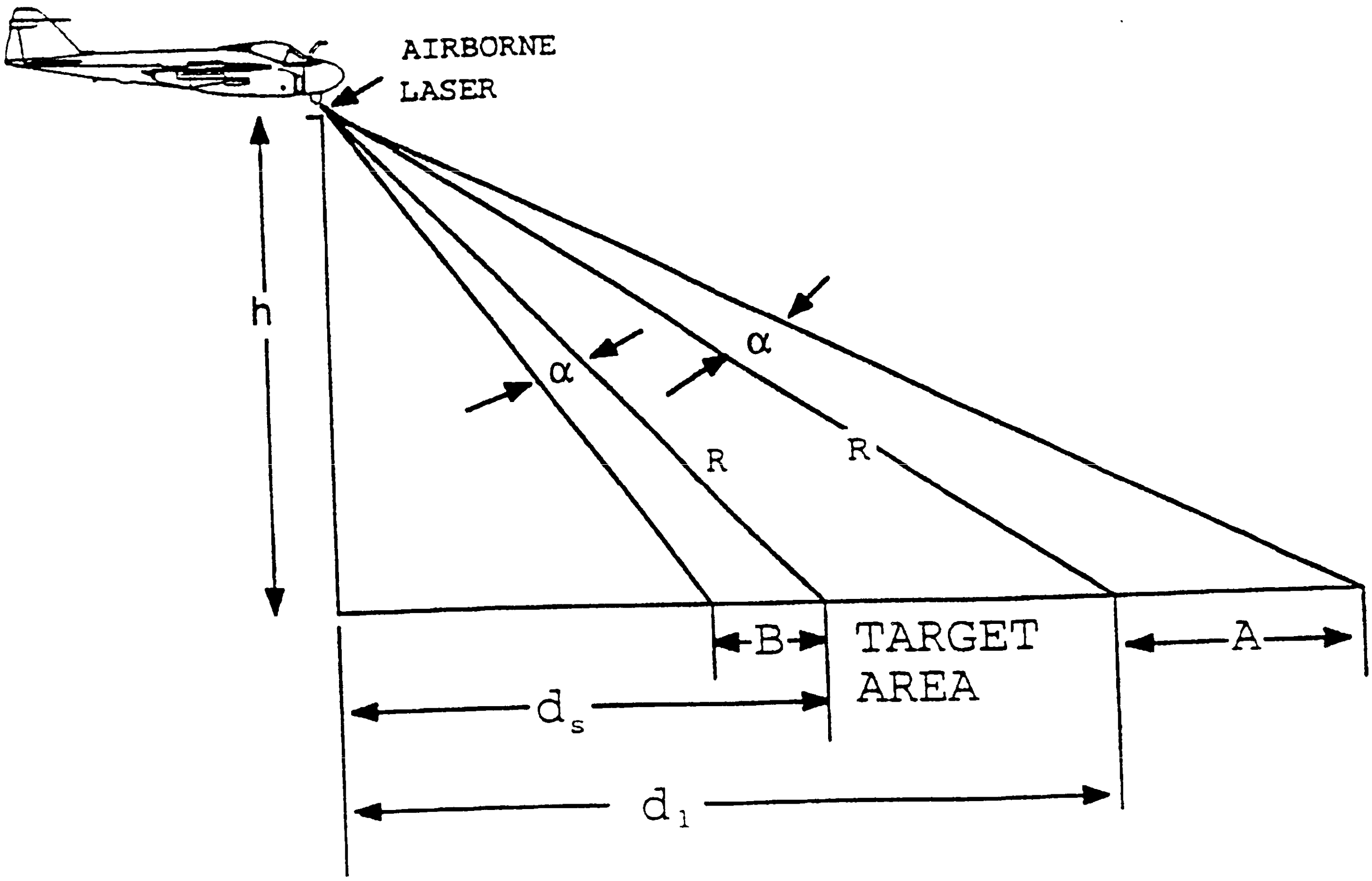
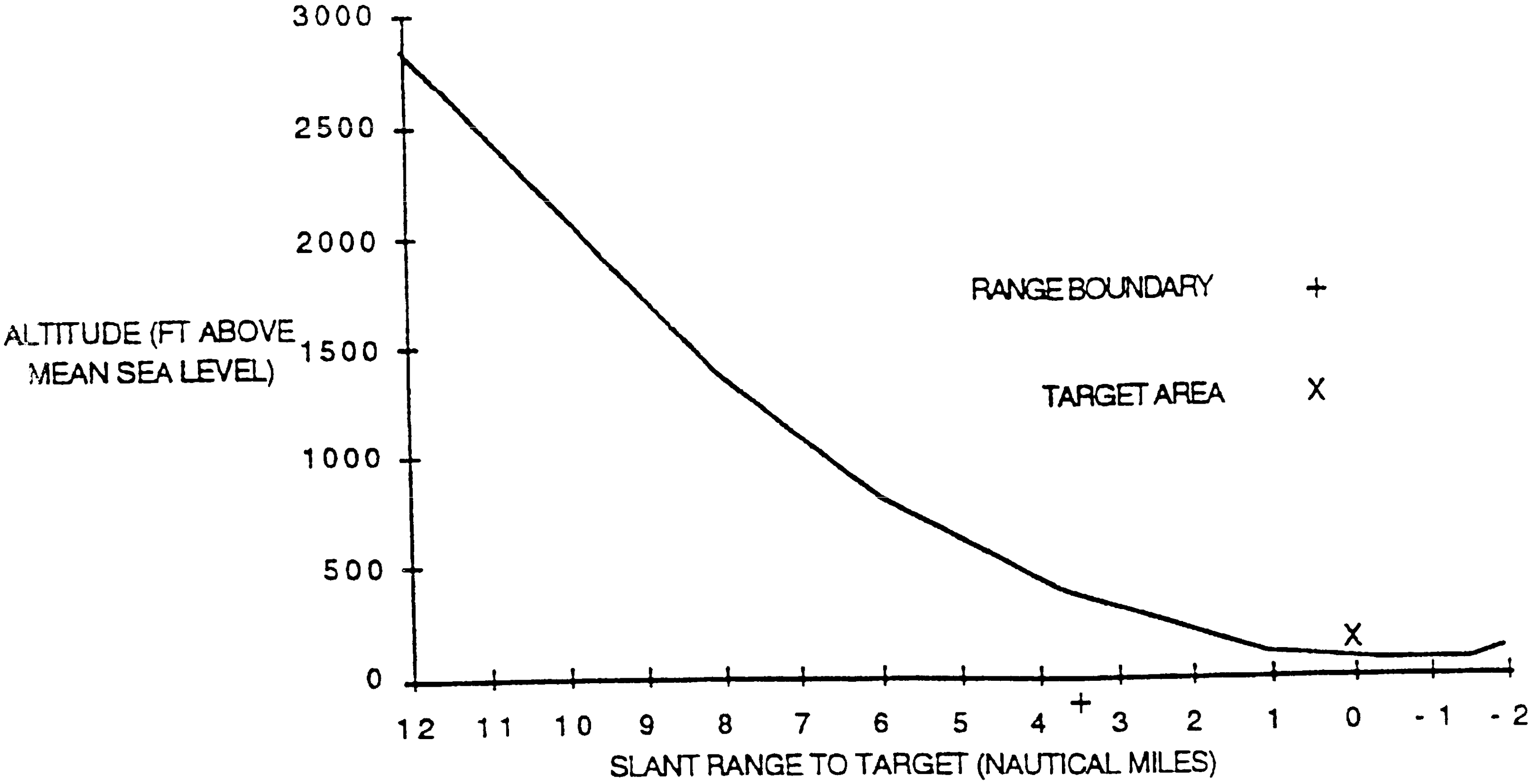


Figure E-19. Airborne Laser Buffer Geometry - Level Ground



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

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

Figure E-20. Example Laser Aircraft Flight Profile

s = left hand LSDZ width or right hand LSDZ width
R = slant range from laser to target
α = assigned buffer angle plus beam divergence either side of the laser line-of-sight. For systems listed in table A-I the beam divergence is small compared to the buffer angle and may be ignored.

c. <u>Airborne Laser with Target on Sloping Ground</u>

Altitudes to keep buffered laser footprint within near or far boundary LSDZ can be calculated as follows:

1. <u>Buffered Footprint.</u> See figure E-21.

HT = altitude of target above” mean sea level
h = altitude of laser above target
HL = altitude of laser above mean sea level = h + HT
hn = height of near boundary above or below target
hf = height of far boundary above or below target
DN = horizontal distance from target to near boundary
DF = horizontal distance from target to far boundary
N = slant range distance from near edge of near target to edge of near boundary = square root of the sum of the squares of hn and DN
F = slant range distance from far edge of far target to edge Of far boundary = square root of the sum of the squares of hf and DF
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
a = assigned buffer angle plus beam divergence. For systems listed in table A-I the beam divergence is small compared to the buffer angle and hence may be ignored.

2. <u>For far target:</u>

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

and

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

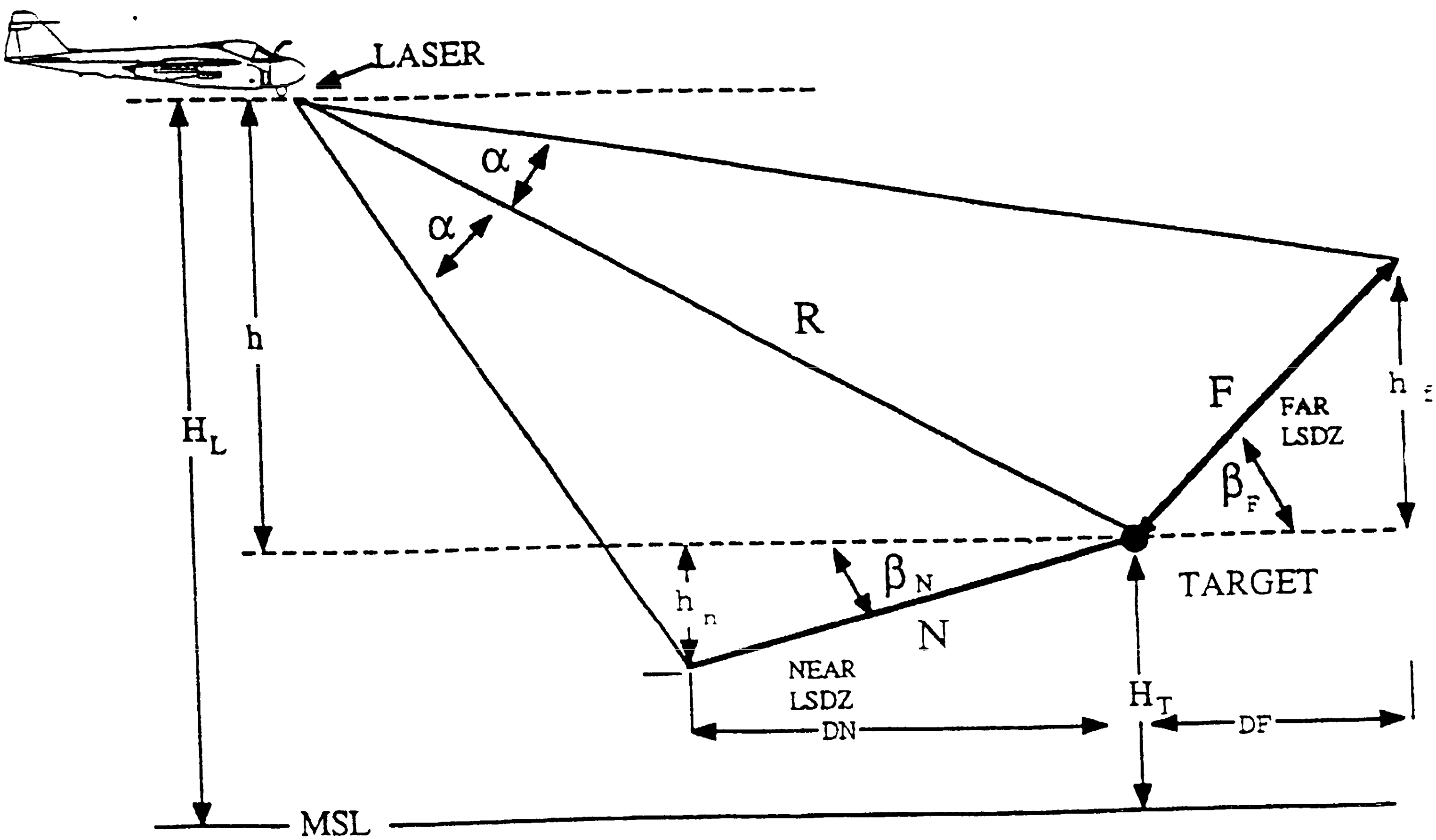


Figure E-21. Laser Target on Sloping Terrain

3. 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 in figure E-20.

4. Left and Right Hand LSDZ

The width of the right hand and left hand LSDZ are calculated as follows:

$$s = R \times a$$

s = left hand LSDZ width or right hand LSDZ width
R = slant range from laser to target
a = assigned buffer angle plus beam divergence either side of the laser line-of-sight. For systems listed in table A-I, the beam divergence is small compared to the buffer angle and may be ignored.

DOD LASER RANGE SURVEY CHECKLISTS

10 SCOPE

10.1 Scope. This appendix provides presurvey, survey and survey report checklist examples that may be used by tailorlng or adding items as needed for local situations such as training operations, research, developement or testing.

20 APPLICABLE DOCUMENTS

This section is not applicable to this appendix.

30 CHECKLISTS.

Sample checklists are enclosed.

30.1 LASER RANGE PRESURVEY CHECKLIST

RANGE/AREA NAME: ____________________
DATE: ______________________________
LOCATION (GRID COORDINATES) ____________________________
ADDRESS: ________________________ PLANNED SURVEY
DATE: ______________________
________________________________ LAST SURVEY DATE: _______________
PHONE: (A/V) ______________________ PERFORMED BY: ____________________
(COMM) _____________________ RANGE POC: _______________________
USER POC'S: ____
____

DATA COLLECTION

DOCUMENTS
- RANGE SOP ________________
- RANGE LASER DIRECTIVES ________________
- OLD SURVEY REPORT ________________________

MAPS OF
- RANGE BOUNDARIES _______ TOPOGRAPHY _____
- RESTRICTED AIR SPACE _____ TGT LOCATIONS _____
- LASER OPERATING LOCATIONS _____

TYPES OF LASER OPERATIONS
- AIRBORNE LASER OPERATIONS _____
- GROUND BASED LASER OPERATIONS _____
- SHIP MOUNTED LASER OPERATIONS _____

SYSTEMS TO BE USED ON RANGE

TRAM _____	LTD _____	MULE _____	LANTIRN _____	NOS _____
LD-82 _____	GVLLD ___	M60A2 ___	PAVE TACK ___	GVS-5 _____
M60A3 ___	M1A1 ____	M551A1 ___	PAVE SPIKE ___	MILES _____
TADS ___	LAAT ____	CLD ___	PAVE KNIFE ___	F/A-18 _____

MMS __________ OTHERS (LIST)
____

TARGET NAME	GRID COORDINATES
1. ____________________	______________________________
2. ____________________	______________________________
3. ____________________	______________________________
4. ____________________	______________________________
5. ____________________	______________________________
6. ____________________	______________________________
7. ____________________	______________________________
8. ____________________	______________________________
9. ____________________	______________________________
10. ____________________	______________________________

LASER OPERATOR/FIRING POSITIONS FOR TARGET #?	GRID COORDINATES
1. ________	________
2. ________	________
3. ________	________
4. ________	________
5. ________	________
6. ________	________
7. ________	________
8. ________	________
9. ________	________
10. ________	________

FORWARD OBSERVER POSITIONS FOR TARGET #?/LASER #?	GRID COORDINATES
1. ________	________
2. ________	________
3. ________	________
4. ________	________
5. ________	________
6. ________	________
7. ________	________
8. ________	________
9. ________	________
10. ________	________

A. Does the range have established run in headings for aircraft?

Yes _____ No _____
If Yes, what are they?

____
____
____

B. Will more targets be added? Yes _____ No _____
If yes, where? grid coordinates

____
____

Are there manned positions on the range? Yes _____ No _____
If so, where? grid coordinates

____
____
____
____

D. Are there any conditions off the range that need to be addressed?
Yes _____ No _____
If yes, what? ____

____
____
____
____
____

E. Any other changes ____

____
____
____
____

F. Comments ____

____
____
____
____
____

REVIEW OF RANGE SOP and/or LASER SAFETY INSTRUCTION

Does SOP or Laser Safety Instruction specify:

(a) Permissible aircraft flight profiles and run-in headings for specified targets or target areas. Yes__ No__

(b) Permissible ships headings and safe firing zones for specified targets or target areas. Yes__ No__

(c) Permissible ground based laser operating positions and/or areas for specified targets or target areas. Yes__ No__

(d) Hazard areas to be cleared of non-operating personnel (road blocks if required). Yes__ No__

(e) Operating personnel locations (indicating those requiring eye protection) . Yes__ No__

(f) Types of surveillance to be used to ensue a clear range. Yes__ No__

(g) Radio freqencies for communication where appropriate.
____

(h) Firing log/schedule is kept by the range officer in accordance with DOD safety and health record keeping regulations.
Yes__ No__

(i) Laser systems will not be activated until the target has been positively identified. Yes__ No__

(j) All class 3 and 4 lasers shall not be directed above the horizon unless coordinated with all DOD components including NORAD (DSN 834-1211 Ext 3290) and regional service rep to FAA when lasing outside restricted air space. Has coordination been completed?
Yes__ No__

(k) For ground based lasers, all unprotected personnel must remain behind the laser operator. Are these instructions in place? __Yes
No__

z(1) Requirement that personnel in other aircraft in the restricted cone around the laser line of sight have eye protection of the proper wavelength and Optical density as specified in Appendix A of the DoD Laser Range Safety Manual for the specific system or as approved by the laser safety specialists for that DOD component.
Yes__ No__

30.2 LASER RANGE SITE SURVEY

1. Laser Safety Officer ____________________

Address ____________________

Phone (A/V) ____________________

2. Is there a Laser Safety Officer on range during laser operations ?
Yes _____ No _____

3. Have all of the range personnel involved with laser operations had laser safety training? Yes _____ No _____

4. Is there a medical surveillance program in place? Yes _____ No _____

5. *Have* all of the lasers being used on the range been evaluated by the specific service agency in Chapt 1 para Ala? Yes _____ No _____

6. Is the range adequately fenced to prevent unauthorized entry?
Yes _____ No _____

7. Are laser warning signs posted at the range boundaries and at the entrance? Yes _____ No _____

8. Are there barricades with laser warning signs?
Yes _____ No _____

9. If necessary, are the laser warning signs multilingual?
Yes _____ No _____

10. Are the targets made of a non-reflecting material for the laser wavelengths being used on the ranges? Yes _____ No _____

11. *Are* the target and target areas free of specular reflectors?
Yes _____ No _____

12. Is there a protective eyewear training, inspection and replacement program in place? Yes _____ No _____

13. *Are* all of the personnel who must be on the range during laser operations equipped with the proper eye protection?
Yes _____ No _____

14. Is a laser operations log or schedule containing the date, time and heading of all laser operations being kept?
Yes ____ No ____

15• Is there two-way communication between the range laser safety officer, laser system operators and range personnel? Yes _ No ____

16. Describe the surveillance of the range

____

30.3 RANGE SURVEY REPORT

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

RANGE/AREA NAME:

SURVEY SUMMARY

Date Survey was completed ____________

Applicable Regulations ____________________

Range Controlled by ____

Survey completed by (Name/Organization)

____

Dates of operations for which survey is valid _________________

Other Pertinent Information ____

SURVEY RESULTS

1. Degree of Compliance with applicable regulations

____

____

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

RECOMMENDED ACTIONS

1. Corrective actions for existing deficiencies

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

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

4. Recommended operating procedures/range regulations.

5. Recommended Laser Eye Protection.

6. Controls for protection from reflected laser beams.

7. Recommended Training

8. Recommended prebriefs for

(1) laser users

(2) laser range personnel

SPECULAR REFLECTION

10 SCOPE

10.1 Scope. This appendix provides information on specular reflection hazards for guidance.

20 APPLICABLE DOCUMENTS ,

Willem P. Van De Merwe and Wesley J. Marshall, "Hazardous Ranges of Laser Beams and Their Reflections from Targets'*, Applied Optics, vol. 25, No.5, 1 March 1986.

30 SPECULAR REFLECTION CHARACTERISTICS

30.1 Intreduction. The amount of laser energy reflected from a specular surface and the divergence of the reflected laser beam are dependent on:

a. Reflectivity and/or index of refraction of the material at the laser wavelength.

b. Polarization of the laser beam.

c. Angle of incidence of the laser beam.

d. Size of the specular reflector relative to the size of the laser spot on the reflector. A specular reflector cross section that is smaller than the cross section of the incident laser beam will only reflect a proportional amount of the laser energy. With small size reflectors, diffraction effects may also be present, resulting in a larger divergence of the laser beam.

e. Number of reflective surfaces. Normally a pane of glass will reflect from both the front and back surface. However the reflected beams are seldom co-linear.

f. Curvature of the reflecting surface. Curved specular reflectors (See table 6-I) will diverge most laser beams so they generally present no hazard beyond a few meters from the reflector. For this reason, personnel in laser restricted areas should wear laser eye protection with curved lenses.

30.2 Flat Reflectors. A flat specular surface is one that retains a collimated reflected beam. Examples are:

a. Standing water.

b. Flat glass.

c. Flat plexiglass.

d. Imaging optical systems.

e. Corner cube reflectors.

f. Flat mirror-like chrome bumpers.

30.3 Hazardous Ranges of Reflected Laser Beam. The amount of reflected laser energy and the resultant hazard distance from a specular reflector are dependent on the factors described in 30.1.

a. Reflection from Reflector Larger Than Cross Section of Incident Laser Beam. Figures 6-7 and G-1 illustrate possible laser reflection hazards from standing water. Figure G-2 depicts the possible laser reflection hazard from specularly reflecting objects in random orientations. Shown in figure G-3 is a worst case example of reflectance from both the front and back surfaces of a flat glass plate. Figures G-4 and G-5 provide values of reflectance for fresh and salt water surfaces. In ascertaining the hazardous range of the reflective laser energy, the second surface reflections are usually ignored for distances beyond a few meters from the reflector. Neglecting second surface reflections, the following equation may be used to determine the hazardous range of reflected laser energy in situations similar to figure 6-7.

$$NOHR = H2/\cos(\theta) = NOHD \times (\%P \times R_{||} + \%N \times R_{\perp})^{1/2} - H1/\cos(\theta)$$

$$= NOHD \times [\%P(\tan^2(\theta-\theta'))/(\tan^2(\theta+\theta')) + \%N(\sin^2(\theta-\theta'))/(\sin^2(\theta+\theta'))]^{1/2} - H1/\cos(\theta)$$

where:

NOHR = Nominal Ocular Hazard Distance from Reflector

H1 = altitude of laser

H2 = altitude of observer viewing reflected laser beam

θ = angle incident and reflected laser beam makes with a line perpendicular to the reflecting surface (angle of incidence) = arctan(D1/H1) for a flat reflector on flat ground.

D1 = horizontal distance from laser to reflector

θ' = angle of refracted beam in a reflecting media = arcsin(θ/n)

n = index of refraction of reflecting media

%P = fraction of laser beam polarized parallel to the plane of incidence

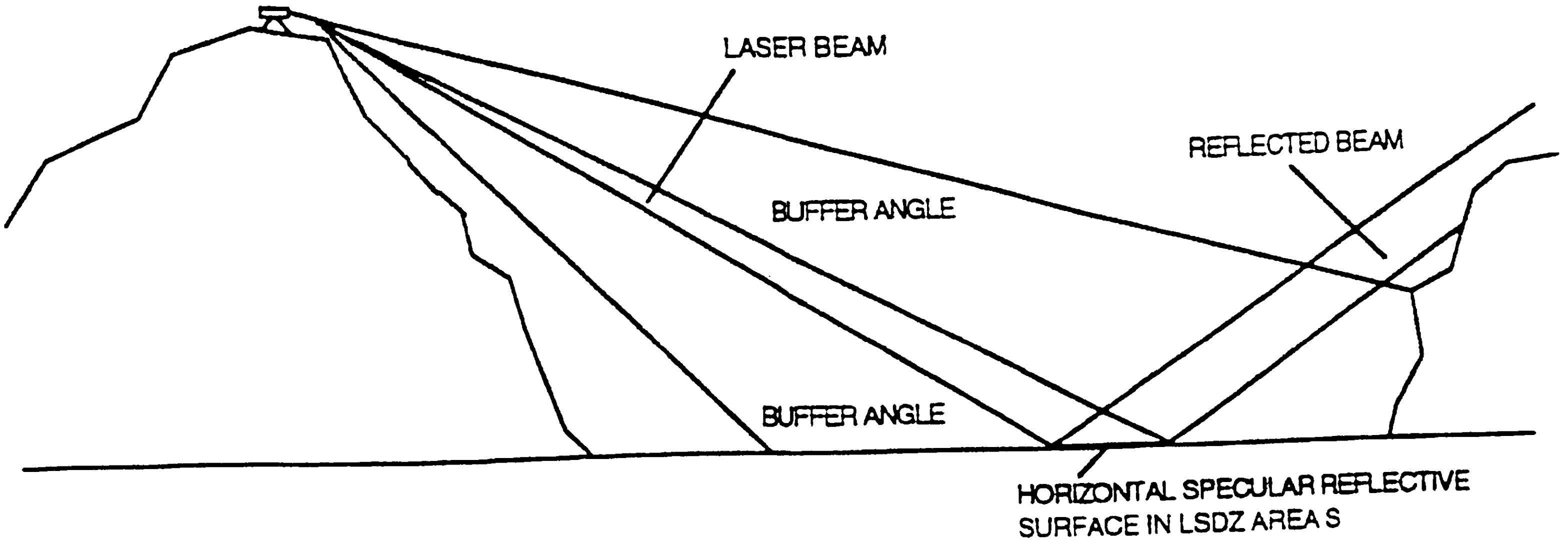


Figure G-1. LSDZ WITH SPECULAR REFLECTIONS FROM STANDING STILL WATER

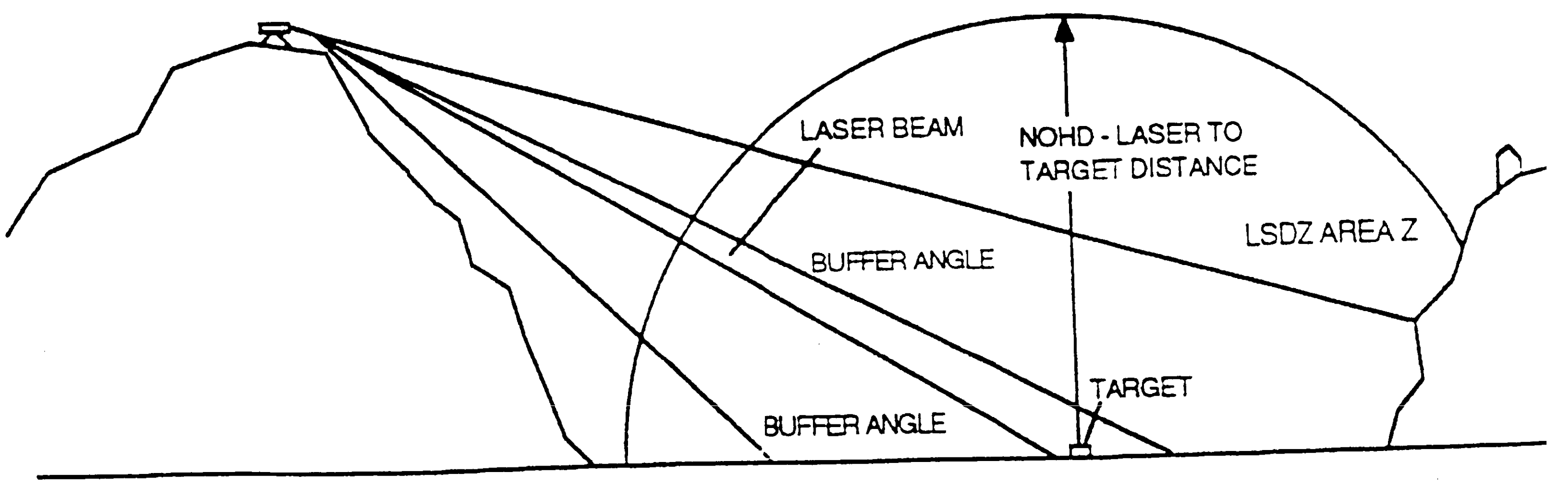


Figure G-2. LSDZ WITH SPECULAR REFLECTIVE TARGET - SIDE VIEW

Figure G-3. Specular reflectance from both surfaces of plate glass (index of refraction = 1.5)

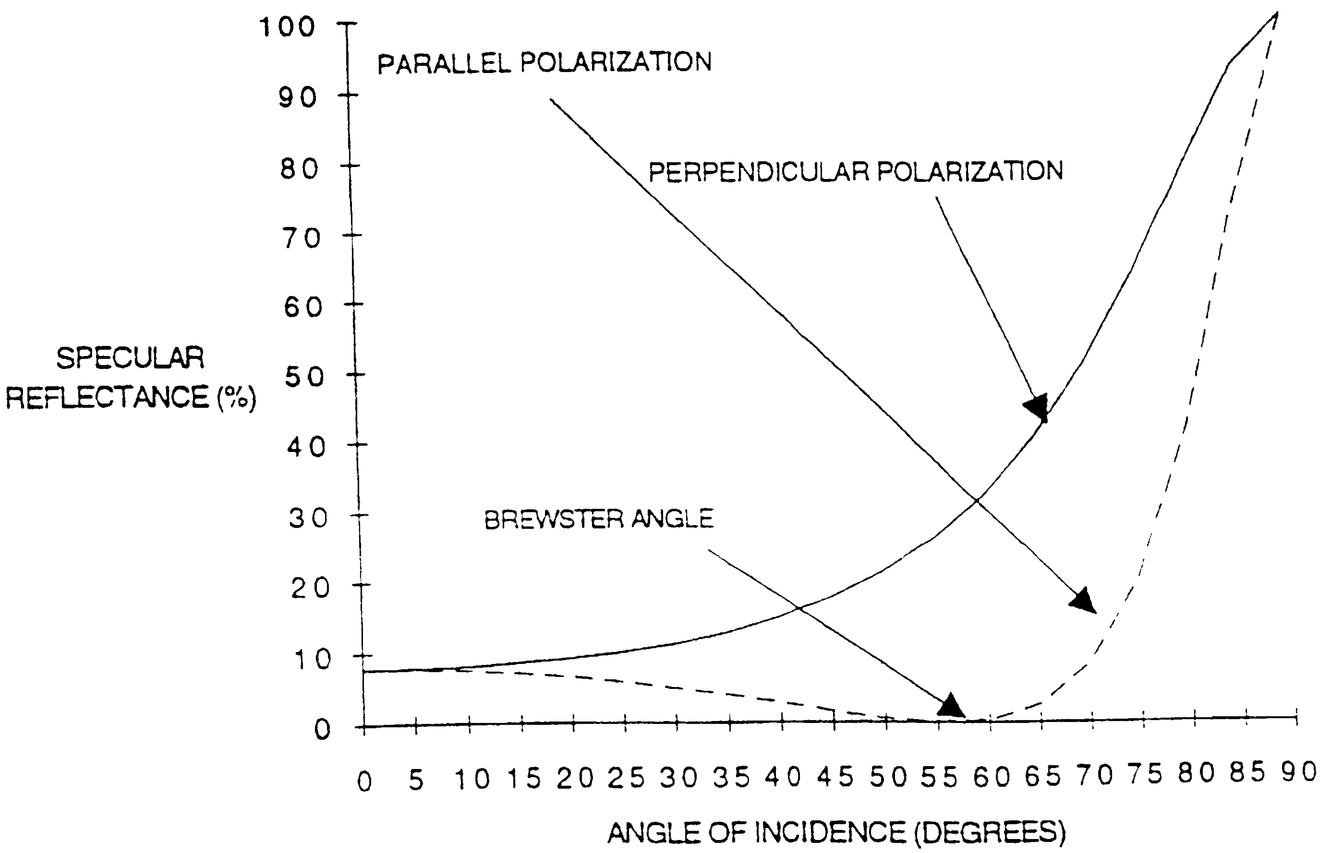


Figure G-4. Reflectance of sea water (index of refraction = 1.378)

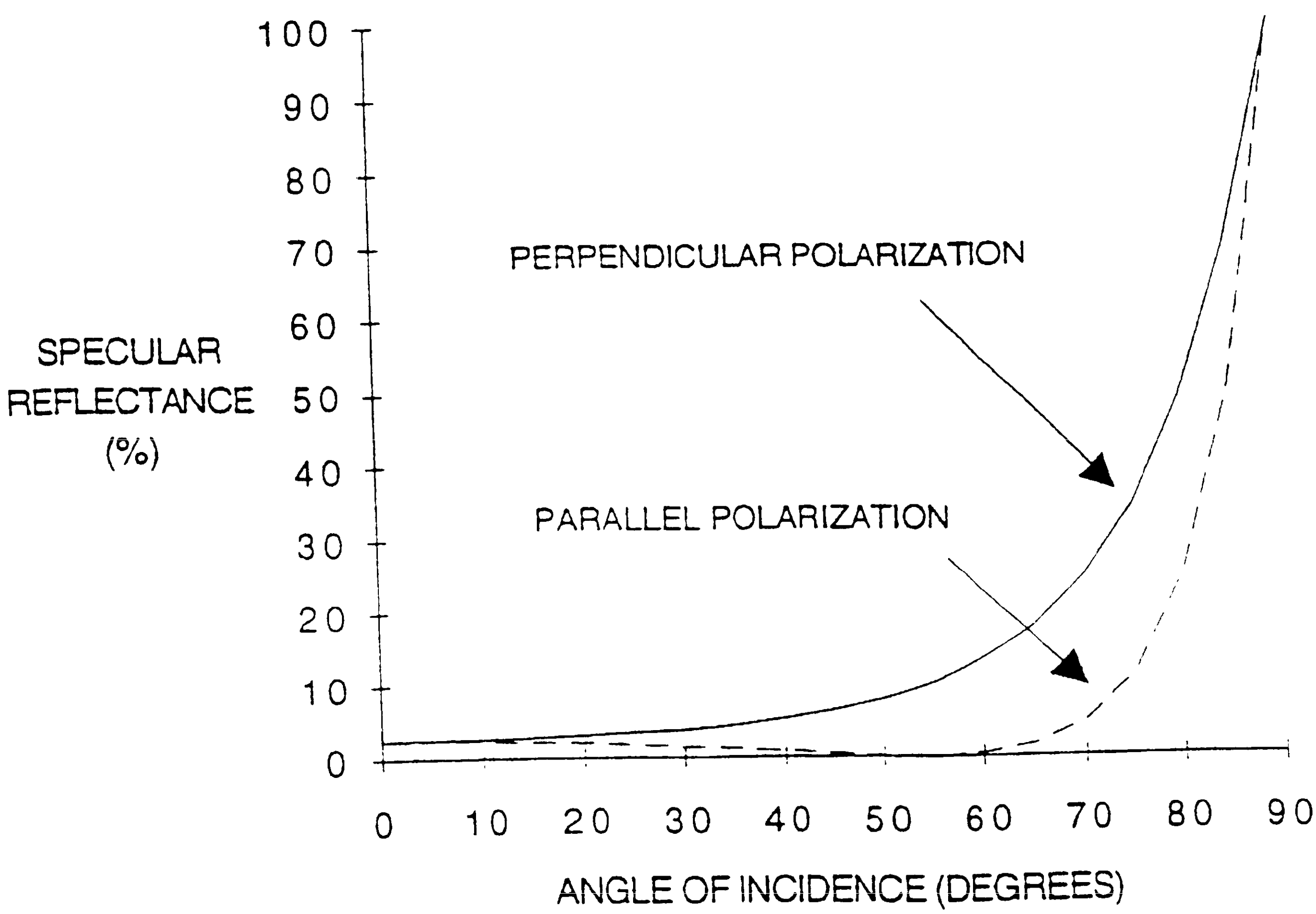
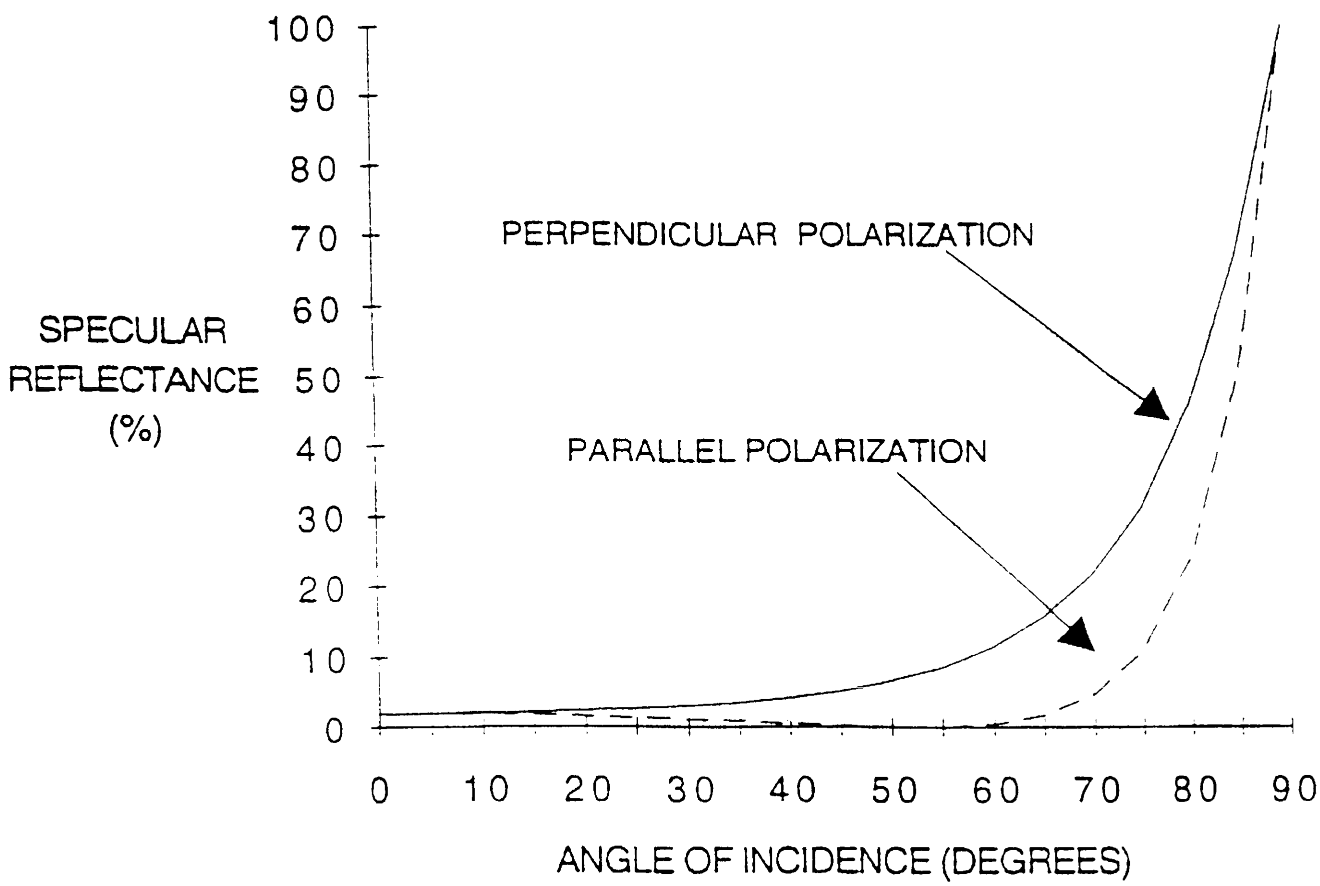


FIGURE G-5. Reflectance of fresh water (index of refraction = 1.33)



%N = fraction of laser beam polarized perpendicular to plane of incidence

NOHD = Nominal Ocular Hazard Distance (See Table A-I for typical distances)

$R_{||}$ = Parallel polarization reflection

coefficient = $(\tan^2(\theta-\theta'))/(\tan^2(\theta+\theta')$

$R_{\perp}$ = Perpendicular polarization reflection
coefficient = $(\sin^2(\theta-\theta'))/(\sin^2(\theta+\theta'))$

If the fractions of the laser beam polarizations are not known, choose the highest reflectivity for the given angle of incidence. Typical values are given in tables G-I through G-III. Calculate the value of NOHR for various values of D1 and θ. Choose the worst case NOHR to restrict airspace, ships, vehicles or projecting land masses.

b. Reflection from Reflector Smaller than Incident Laser Beam Cross Section. Reflective objects that are smaller in cross section than the incident laser beam will pose less of a reflection hazard since only a proportional amount of laser radiation will be reflected. Small reflectors will also cause diffraction effects. For a detailed explanation of this, see references in the applicable documents section of this appendix. Ignoring diffraction effects and second surface reflection, the hazard distance from reflectors smaller than the incident laser beam cross section is given by the following equation:

$$NOHR = H2/\cos(\theta) = NOHD \times (\%P \times R_{||} + \%N \times R_{\perp})^{1/2}(RA/LA)^{1/2} - H1/\cos(\theta)$$

$$= NOHD \times [\%P(\tan^2(\theta-\theta'))/(\tan^2(\theta+\theta'))+\%N(\sin^2(\theta-\theta'))/(\sin^2(\theta+\theta'))]^{1/2} \times (RA/LA)^{1/2} - H1/\cos(\theta)$$

Where:

RA = cross sectional area of the reflector

LA = cross sectional area of the incident laser beam

NOHR = Nominal Ocular Hazard Distance from Reflector

H1 = altitude of laser

H2 = altitude of observer viewing reflected laser beam

e = angle incident and reflected laser beam makes with a *line* perpendicular to the reflecting surface (angle of incidence)= arctan(D1/Hl) for a flat reflector on flat ground.

D1 = horizontal distance from laser to reflector

θ' = angle of refracted beam in a reflecting media = arcsin(θ/n)

n = index of refraction of reflecting media

%P = fraction of laser beam polarized parallel to plane of incidence

%N = fraction of laser beam polarized perpendicular to plane of incidence

NOHD = Nominal Ocular Hazard Distance (See Table A-I for typical distances)

$R_{\parallel}$ = Parallel polarization reflection

coefficient = $(\tan^2(\theta-\theta'))/(\tan^2(\theta+\theta'))$

$R_{\perp}$ = Perpendicular polarization reflection coefficient = $(\sin^2(\theta-\theta'))/(\sin^2(\theta+\theta'))$

If the fractions of the laser beam polarizations are not known, choose the highest reflectivity for the given angle of incidence. Typical values are given in table G-1 through G-III. Calculate the value of NOHR for various values of D1 and θ. Choose the worst case NOHR to restrict airspace, ships, vehicles or projecting land masses. Table G-IV gives the reflectivity of shiny metal.

MATERIAL - GLASS
APPROX. INDEX OF REFRACTION AT WAVELENGTHS .3 TO 2 MICRONS = 1.55

ANGLE OF INCIDENCE (DEGREES)	REFLECTIVITY PERPENDICULAR POLARIZATION	REFLECTIVITY PARALLEL POLARIZATION
0	0.0465	0.0465
10	0.0484	0.0447
20	0.0545	0.0391
30	0.0664	0.0299
40	0.0877	0.0175
50	0.1254	0.0046
60	0.1935	0.0012
70	0.3199	0.0400
80	0.5574	0.2334
90	1.0	1.0

Table G-I. Reflectivity of Glass at Various Angles of Incidence

MATERIAL - FRESH WATER
APPROX. INDEX OF REFRACTION AT WAVELENGTHS .3 TO 2 MICRONS = 1.33

ANGLE OF INCIDENCE (DEGREES)	REFLECTIVITY PERPENDICULAR POLARIZATION	REFLECTIVITY PARALLEL POLARIZATION
0	0.0201	0.0201
10	0.0210	0.0191
20	0.0241	0.0164
30	0.0305	0.0117
40	0.0426	0.0057
50	0.0660	0.0006
60	0.1139	0.0044
70	0.2180	0.0473
80	0.4552	0.2387
90	1.0	1.0

Table G-II. Reflectivity of Fresh Water at Various Angles of Incidence

MATERIAL - SEA WATER
APPROX. INDEX OF REFRACTION AT WAVELENGTHS .3 TO 2 MICRONS= 1.378

ANGLE OF INCIDENCE (DEGREES)	REFLECTIVITY PERPENDICULAR POLARIZATION	REFLECTIVITY PARALLEL POLARIZATION
0	0.0253	0.0253
10	0.0264	0.0241
20	0.0302	0.0207
30	0.0378	0.0151
40	0.0521	0.0078
50	0.0790	0.0010
60	0.1324	0.0037
70	0.2433	0.0467
80	0.4826	0.2403
90	1.0	1.0

Table G-III. Reflectivity of Sea Water at Various Angles of Incidence

MATERIAL - SHINY METAL (SILVER) AT ALL ANGLES OF INCIDENCE

WAVELENGTH (Microns)	REFLECTIVITY
.45	.88
.50	.90
.55	.915
.60	.927
.65	.935
.70	.941
.80	.951
.90	.96
1.0	.965
2.0.	.979

Table G-IV. Reflectivity of Shiny Metal

APPENDIX H

SEPARATE TARGET (SEPTAR) AND SHIP'S TOWED TARGET OPERATIONS

10 SCOPE

10.1 Scope. This appendix provides safety guidance on SEPTAR and ship towed target operations.

20 APPLICABLE DOCUMENTS

U.S. Navy
E0410-BA-GYD-010, Technical Manual Laser Safety

NATO
STANAG 3606, Evaluation and Control of Laser Hazards

30 GUIDANCE

30.1 Septar Operations. SEPTARS may be used for A-6E TRAM, OV-1OD NOS, F-lllF PAVE TACK, and PAVE SPIKE laser operations in open restricted areas provided that:

a. A two nautical mile (nmi) SEPTAR operating area is established with a 1-, 2-, 3-, 4-, or 5-nmi buffer zone around the operating area (See Figure H-1) as appropriate for the flight profiles in tables H-I through H-V.

b. No laser operations within 10 nmi of land are allowed when the laser line of sight (LLOS) is directed toward land.

c. All specular reflectors on the SEPTAR must be removed or covered prior to laser operations.

d. Every person required to be within the operations areas or buffer zone must wear laser protective goggles of adequate protection at 1.06 micron wavelength during laser operations.

e. The target must be positively identified on the operator's monitor before to lasing.

f. Laser operations shall cease if either the pilot or system operator is dissatisfied with target tracking.

g. Lasing shall cease if unprotected or unauthorized aircraft enter the operations area or buffer zone from O to 1800 feet above mean sea level (MSL) or between the lasing aircraft and the target.

h. Lasing shall cease if unprotected or unauthorized surface craft enter the operations area or buffer zone.

i. The aircraft must be at or above the flight profiles in Tables

H-I through H-V for the assigned buffer zone.

j. A log of the date and time of all laser firings must be kept.

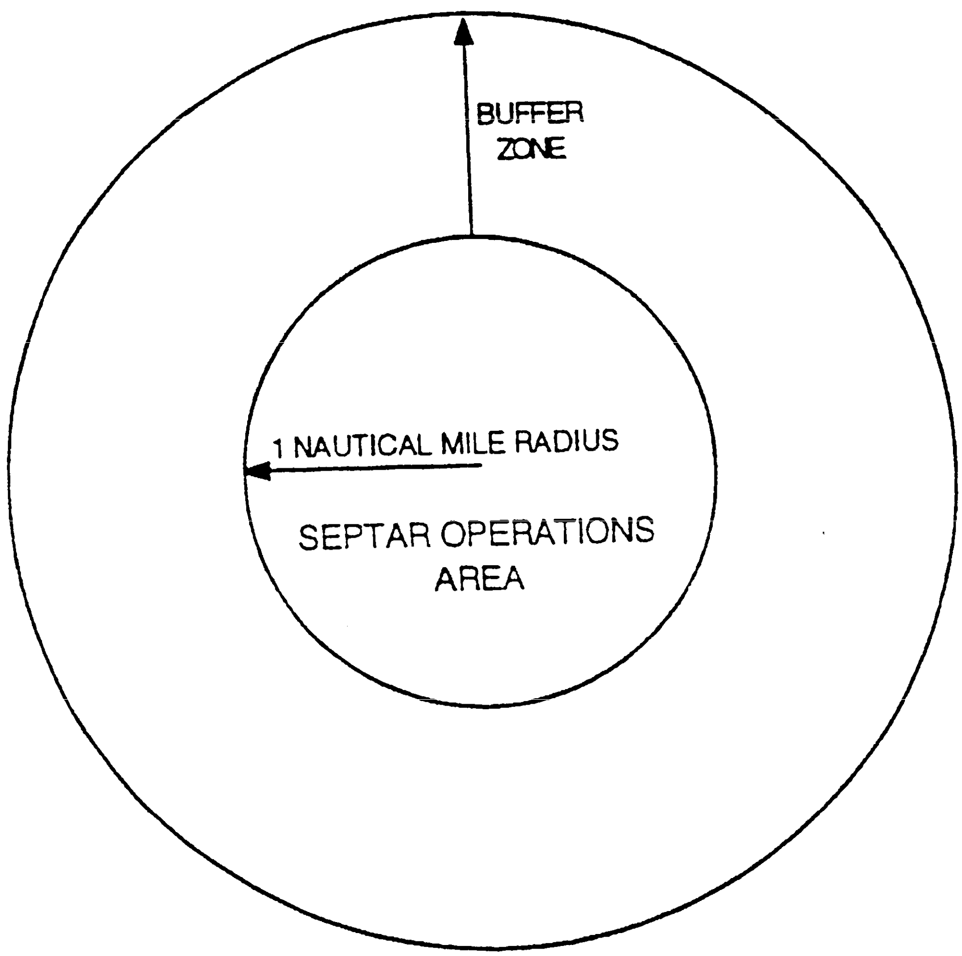
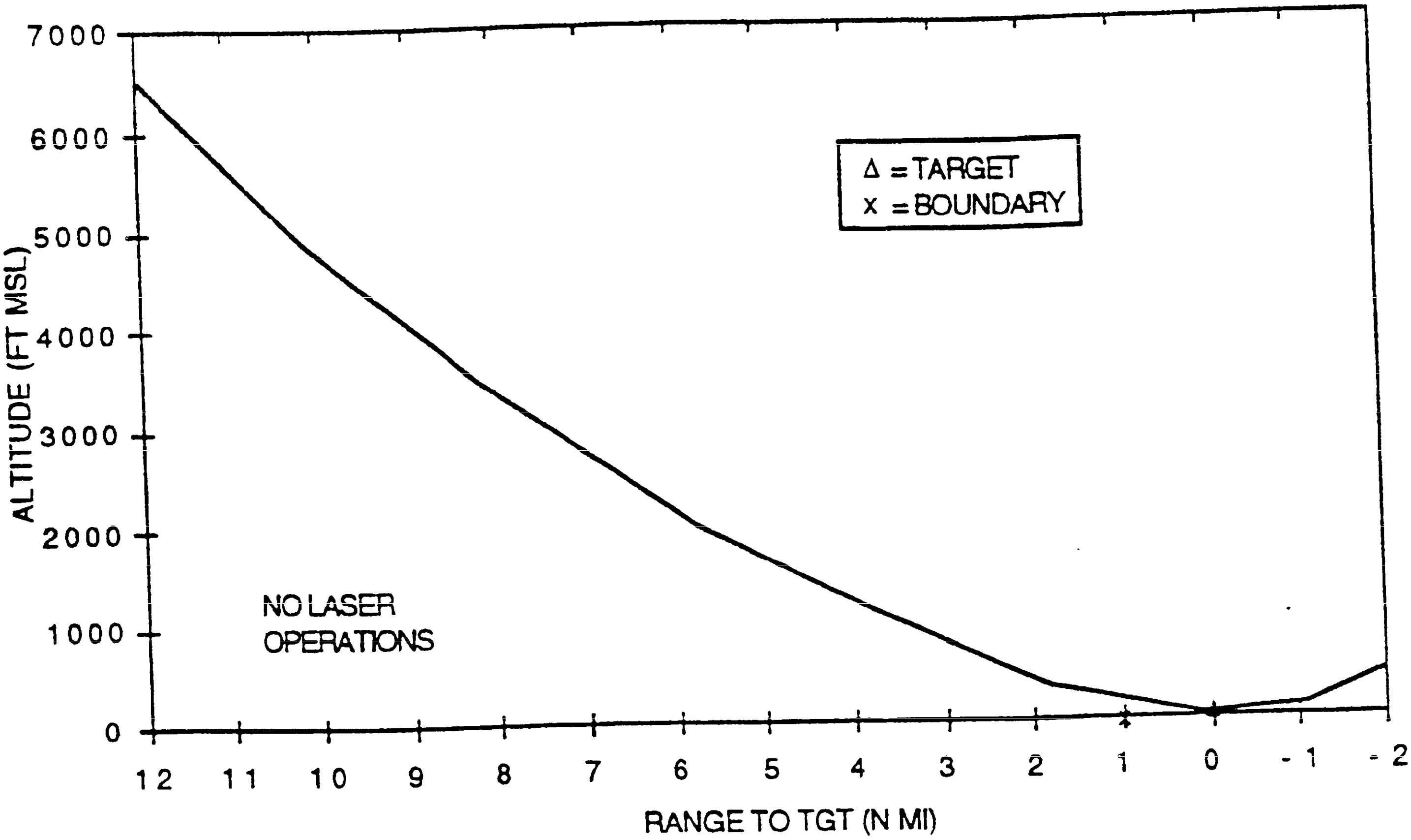
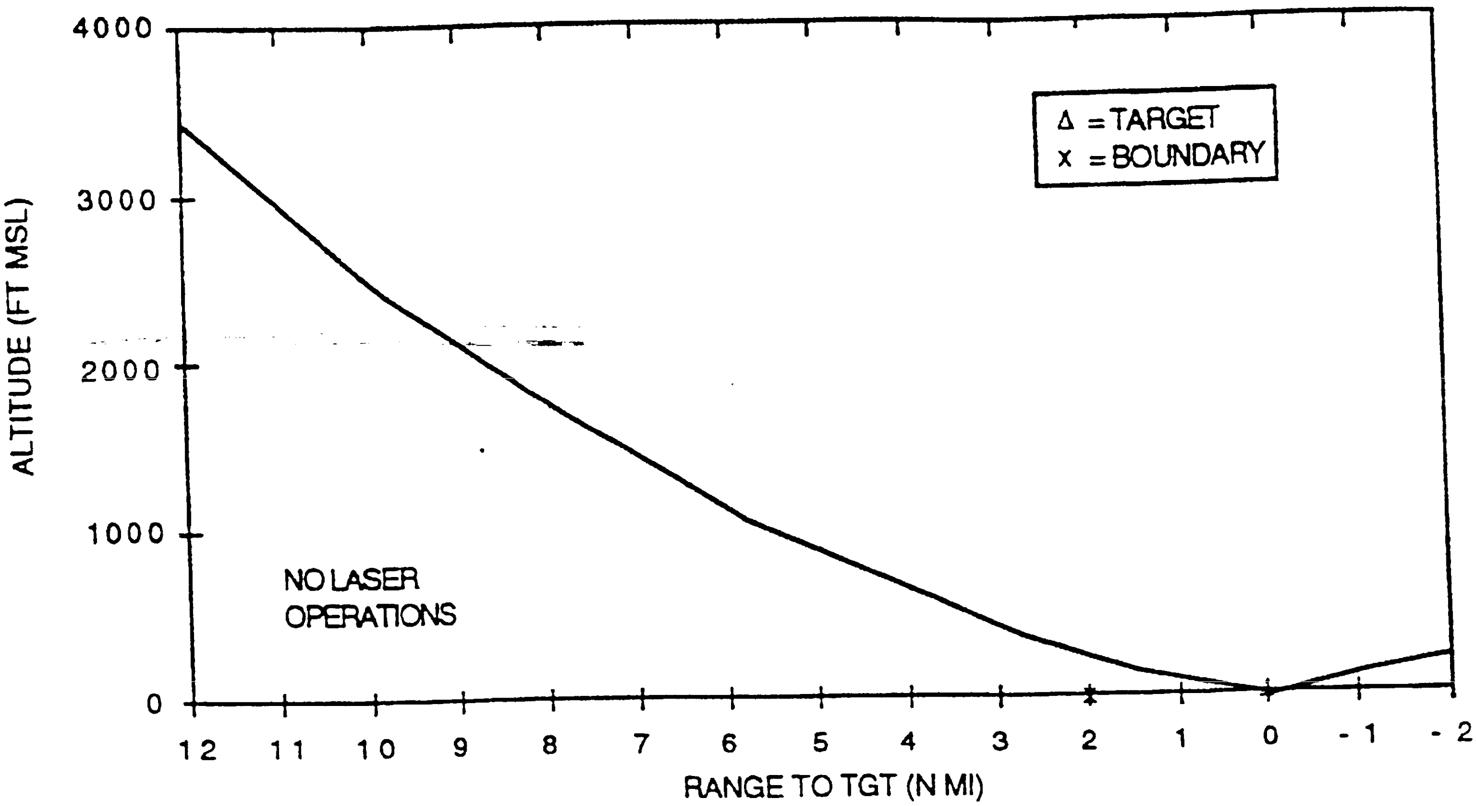


Figure H-1. SEPTAR Operations Area and Buffer Zone



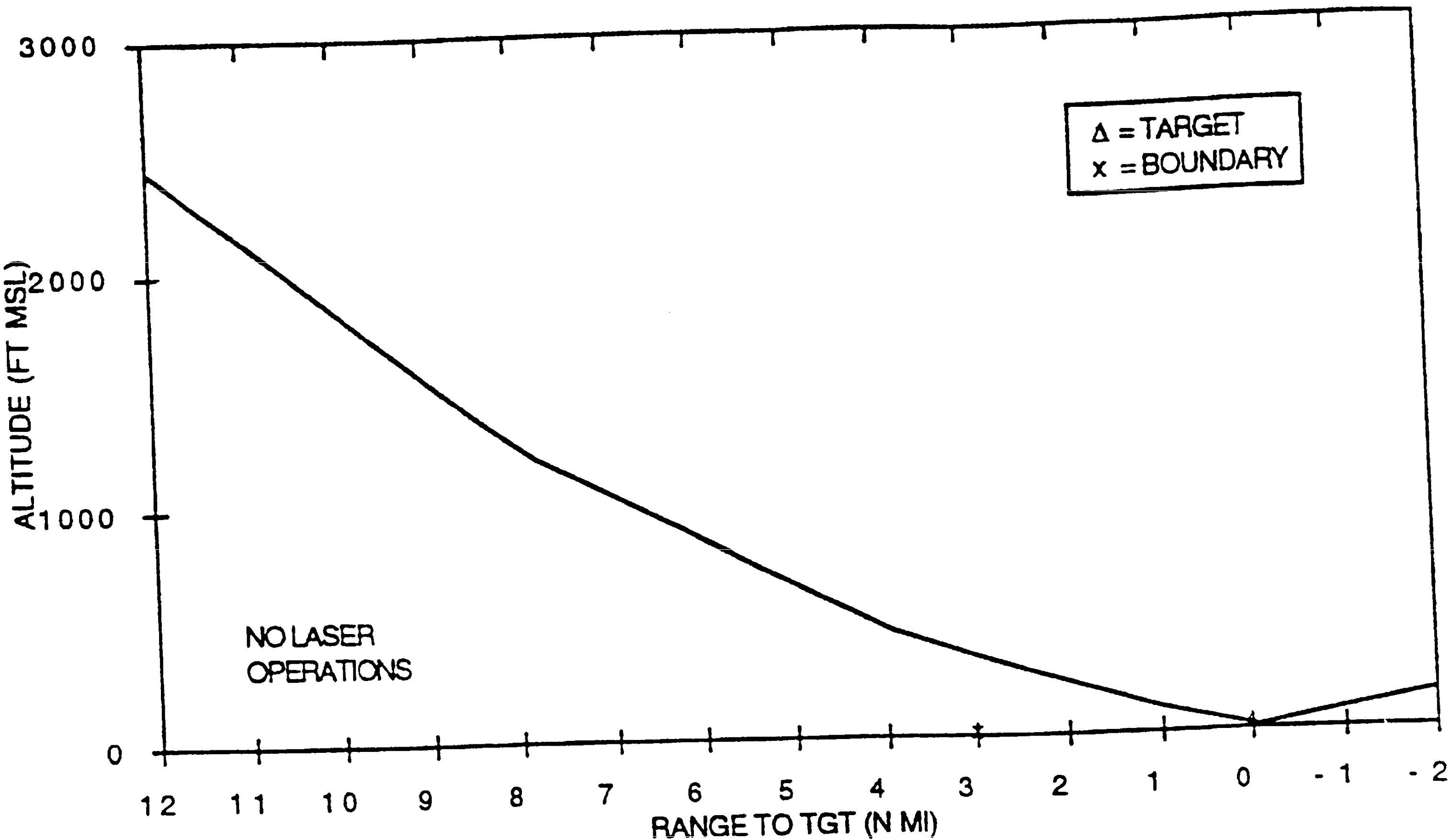
RANGE TO TARGET (N MI)	MINIMUM ALTITUDE (FT)	RANGE TO TARGET (N MI)	MINIMUM ALTITUDE (FT)
12	6550	0	50
11	5650	1	150
10	4850	2	450
9	4050		
8	3350		
7	2750		
6	2150		
5	1650		
4	1250		
3	850		
2	450		
1	250		

TABLE H-I. Septar 1-nmi Buffer Zone 0 to 360-Degrees



RANGE TO TARGET (N MI)	MINIMUM ALTITUDE (FT)	RANGE TO TARGET (N MI)	MINIMUM ALTITUDE (FT)
12	3450	0	50
11	3050	1	150
10	2550	2	250
9	2150		
8	1850		
7	1450		
6	1150		
5	950		
4	650		
3	450		
2	250		
1	150		

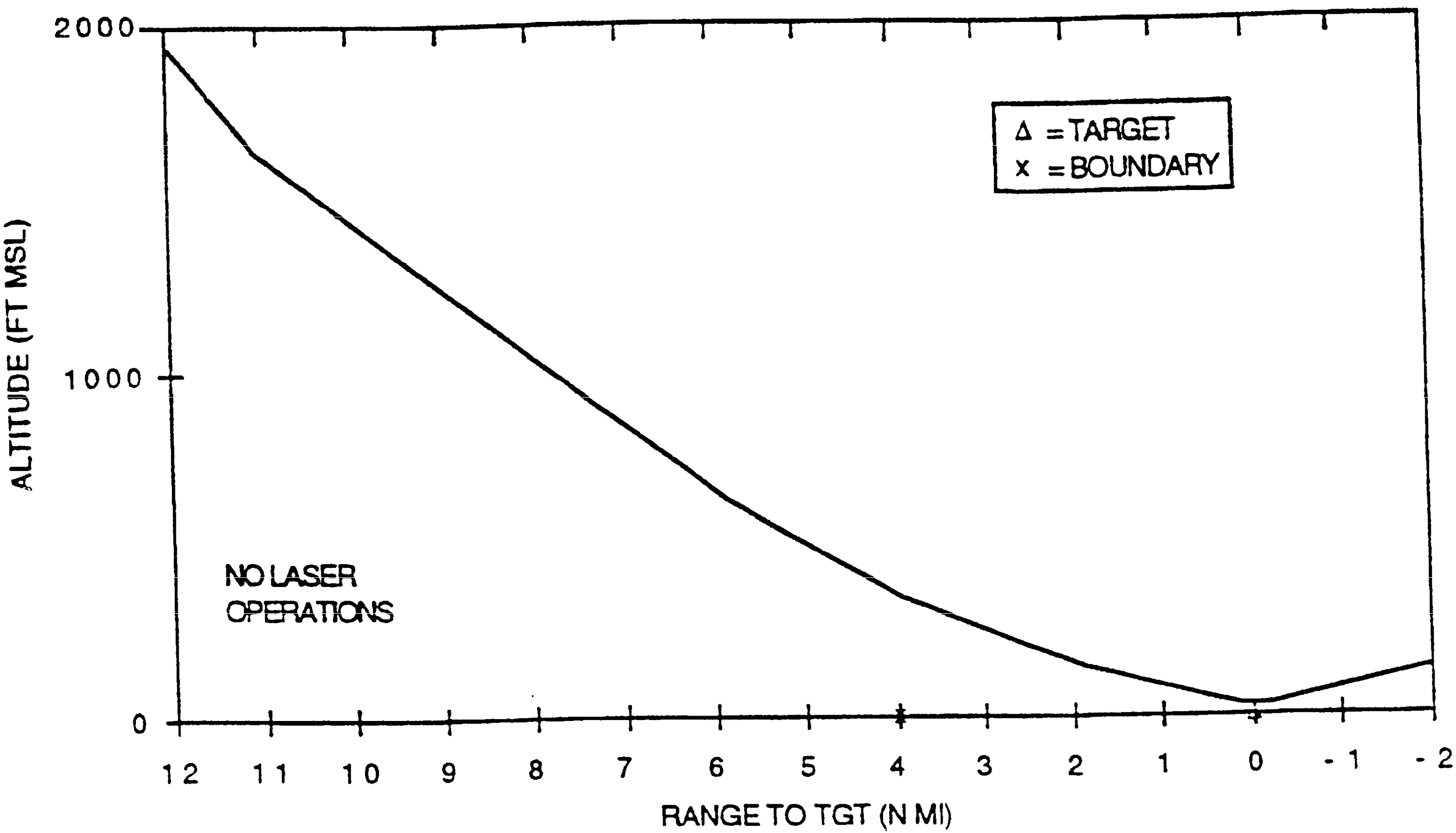
TABLE H-II Septar 2-nmi Buffer Zone 0 to 360-Degrees



RANGE TO TARGET (N MI)	MINIMUM ALTITUDE (FT)
12	2450
11	2150
10	1850
9	1550
8	1250
7	1050
6	850
5	650
4	450
3	350
2	250
1	100

RANGE TO TARGET (N MI)	MINIMUM ALTITUDE (FT)
0	50
1	100
2	150

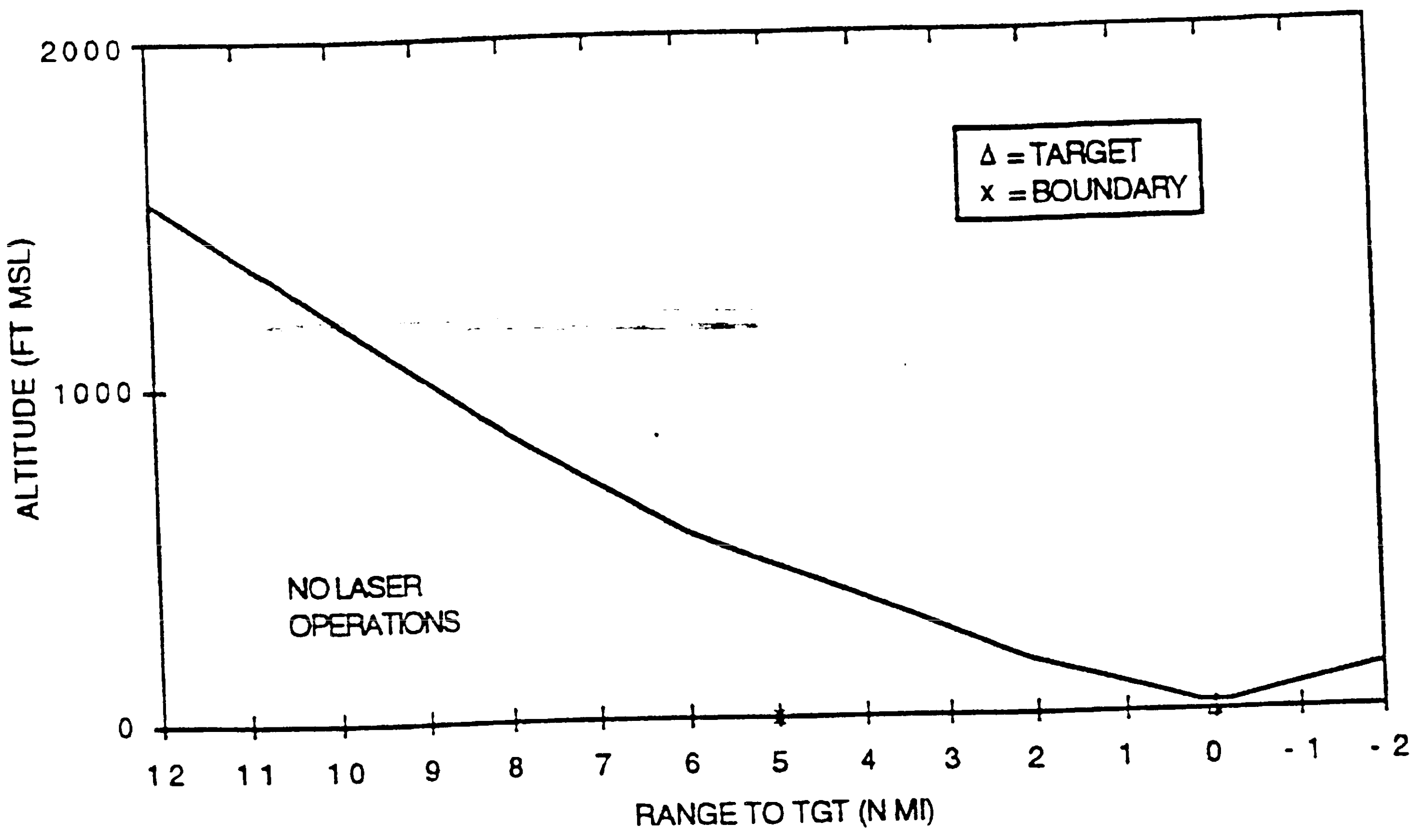
TABLE H-III Septar 3-nmi Buffer Zone 0 to 360-Degrees



RANGE TO TARGET (N MI)	MINIMUM ALTITUDE (FT)
12	1950
11	1650
10	1450
9	1250
8	1050
7	850
6	650
5	550
4	350
3	250
2	150
1	100

RANGE TO TARGET (N MI)	MINIMUM ALTITUDE (FT)
0	50
1	100
2	150

TABLE H-IV Septar 4-nmi Buffer Zone 0 to 360-Degrees



RANGE TO TARGET (N MI)	MINIMUM ALTITUDE (FT)
12	1550
11	1350
10	1250
9	1050
8	850
7	750
6	550
5	450
4	350
3	250
2	150
1	100

RANGE TO TARGET (N MI)	MINIMUM ALTITUDE (FT)
0	50
1	100
2	150

TABLE H-V. Septar 5-nmi Buffer Zone 0 to 360-Degrees

30.2 <u>Ship's Towed Target Operations</u>. Ship's towed target operations as shown in figure H-2 shall abide by the following:

a. The target shall be towed no closer than one thousand feet from the towing ship.

b. All laser operations shall be conducted on incoming headings of 60 to 90 degrees and 260 to 300 degrees relative to towing ship's heading. If lasing back at the target is required, after passing over it, the outgoing heading shall be in the zones specified above for the incoming headings (See figure H-2).

c. Laser operation shall not be initiated until the laser operator has identified the target under the reticle on the display, and the pilot has identified the target through the optical gun sight.

d. Laser operation must cease if the system is not properly tracking the target.

e. Laser operation shall cease immediately after weapon release for conventional ordnance or immediately after weapon impact for laser-guided ordnance.

f. Laser operation shall cease whenever friendly ships are within 48,000 feet of the target along the LLOS and + 700 feet either side of the LLOS, unless the use of laser protective eyewear by onboard personnel is assured.

g. Laser operations shall cease whenever friendly aircraft operating below 6,000 feet altitude are within 31,000 feet of the target along the LLOS and +700 feet either side of the LLOS, unless the use of laser protective eyewear by onboard personnel is assured.

h. Optical aids used to view the target during laser operations must be equipped with proper protective filters when the viewer is within the boundaries cited and along the LLOS out to the optical aids nominal ocular hazard distance for the specific laser and specific optical aid.

i. Viewing of the target with optical aids from the towing ship, or from other ships and aircraft outside of the laser beam hazard control zone described above is permitted.

j. Targets shall be non-specular.

k. A log of the date, time, and heading of all laser firings must be kept.

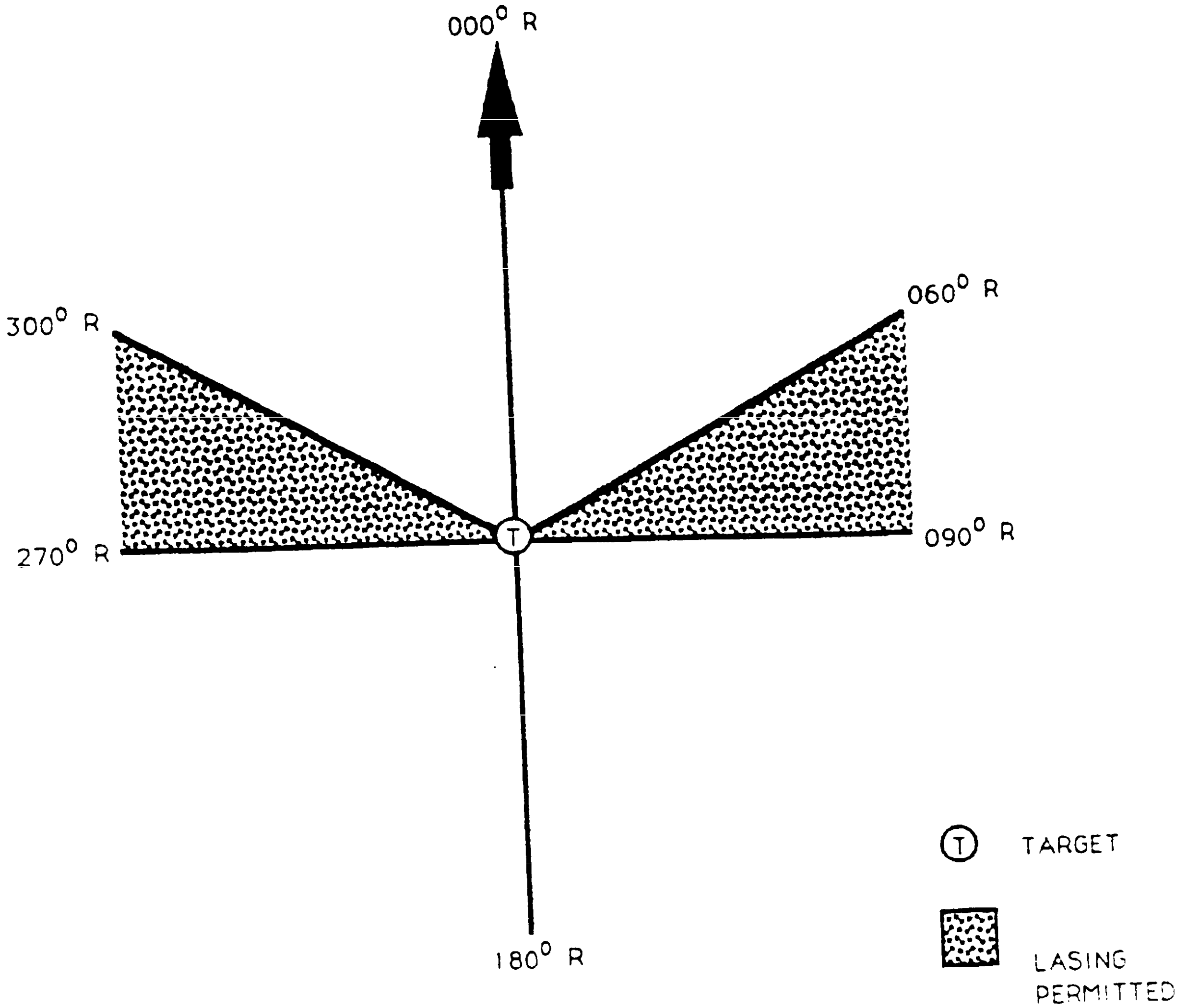


Figure H-2. Zones Relative to Towing Ship's Heading in Which Laser Operations are Permitted for A-6E TRAM, OV-10D NOS, F111-PAVETACK and PAVESPIKE

CONCLUDING MATERIAL

Lead Standardization Activity:

Army - EA

Preparing Activity:

Navy - EC
Project No. 4240-0585

Custodians:

Navy - EC
Army - EA
Air Force - 10

STANDARDIZATION DOCUMENT IMPROVEMENT PROPOSAL

INSTRUCTIONS

1. The preparing activity must complete blocks 1, 2, 3, and 8. In block 1, both the document number and revision letter should be given.
2. The submitter of this form must complete blocks 4, 5, 6, and 7.
3. The preparing activity must provide a reply within 30 days from receipt of the form.

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I RECOMMEND A CHANGE:	1. DOCUMENT NUMBER MIL-HDBK-828	2. DOCUMENT DATE (YYMMDD) 93-04-15

3. DOCUMENT TITLE
LASER RANGE SAFETY

4. NATURE OF CHANGE *(Identify paragraph number and include proposed rewrite, if possible. Attach extra sheets as needed.)*

5. REASON FOR RECOMMENDATION

6. SUBMITTER

a. NAME (Last, First, Middle Initial)	b. ORGANIZATION	
c. ADDRESS (Include Zip Code)	d. TELEPHONE (Include Area Code) (1) Commercial (2) AUTOVON (If applicable)	7. DATE SUBMITTED (YYMMDD)

8. PREPARING ACTIVITY

a. NAME Technical Point of Contact (TPOC): Anthony F. Sliwa (SPAWAR 00F)	b. TELEPHONE (Include Area Code) (1) Commercial (703) 602-7235 (2) AUTOVON 332-7235
c. ADDRESS (Include Zip Code) Commander Space and Naval Warfare Systems Command 2451 Crystal Drive Arlington, VA 22245-5200	IF YOU DO NOT RECEIVE A REPLY WITHIN 45 DAYS, CONTACT Defense Quality and Standardization Office 5203 Leesburg Pike, Suite 1403, Falls Church, VA 22041-3466 Telephone (703) 756-2340 AUTOVON 289-2340

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