Director of Central Intelligence

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NOFORN-NOCONTRACT

Soviet Tactical Laser Weapons [redacted]

A Collection Support Brief

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March 1987

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Intelligence

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NOFORN-NOCONTRACT-

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Soviet Tactical Laser Weapons (U)

Preface

Information available as of 19 September 1986 was used in this report.

This Collection Brief is designed as a guide for intelligence collection against tactical laser weapons that the Soviets could deploy during the next five years. The issue of tactical laser weapons has become critically important as the United States and its Allies begin to deploy large numbers of military subsystems that rely heavily on electro-optic sensors. These sensors could be vulnerable to tactical laser weapons. [redacted]

[redacted]

[redacted]

Contents

Overview

Over the past decade, managers for research and development weapons programs for the United States and its Allies have been developing a new class of sensors that will greatly enhance fighting efficiency and effectiveness on the tactical battlefield. These sensors are generally called electro-optic (EO) sensors and include several types. The forward-looking infrared sensor (FLIR) epitomizes this application of electro-optical technology. The FLIR senses long-wavelength infrared radiation (heat) and produces TV-like images of objects viewed by the sensor. FLIR images provide distinct tactical advantages for night vision, for detecting camouflaged equipment, and for automated firepower systems. There currently are many battlefield platforms hosting FLIRs in the US Armed Forces. These platforms include infantry soldiers, tanks, artillery, attack helicopters, and interdiction aircraft. [redacted]

Other electro-optic sensors are being introduced into the military inventory, including sensors for precision-guided munitions and missiles. Integration of these sensors into the battlefield is necessary to counter the large number of conventional forces available to Warsaw Pact nations. [redacted]

All electro-optic sensors, including the human eye, detect low levels of light or infrared energy. These sensors have an inherent susceptibility to bright light or intense infrared energy. This susceptibility can range from temporary masking or blinding to permanent structural damage to the sensor. The laser is an ideal weapon to counter EO sensors. The laser efficiently produces a bright visible or infrared light that, when pointed into a viewing port (aperture) of an EO sensor (or the pupil of the eye), can render the sensors inoperative. [redacted]

[redacted]

[redacted]

[redacted]

Soviet Laser Program Management and RDT&E

Introduction

[redacted]

[redacted]

[redacted]

Soviet Laser and Laser-Related Research Organizations

The design bureaus and research institutes described below are involved in research that is applicable to the development of a tactical battlefield laser weapon. [redacted]

[redacted]

Pages: 4 - 11

Exemptions: (b)(1) (b)(3)

[redacted]

[redacted]

Key Intelligence Questions

1. Where are the production facilities for manufacturing large quantities of laser-associated equipment for military systems (such as laser rangefinders, designators, and, possibly, laser weapons)? [redacted]

[redacted]

Table 2
Lasers Advertised by Mashpriborintorg [a]

Type	Soviet Designators
Helium-neon	OKG-11, LG-32, LG-38, LG-44, LG-52-1, LG-56, LG-79, LG-126-1, GNOM
CO_2	OKG-15, LG-22M, LG-25A, LG-25A-1, LG-43, PM-35
Argon	LG-106M-1, LG-67 (IGLA-2), LG-68 (IGLA-4), MIL-1
Helium-cadmium (cadmium vapor)	LG-31, LG-61, LG-70, LPM-11
Xenon	LG-37-02-01, LGI-40
Neodymium: YAG	LTIPCh-4, LTIPCh-5, LTIPCh-7, LTIPCh-8, LTI-101, LTI-501
Neodymium: glass	GOS-301, GOS-1000
Ruby	GOR-300, OGM-20, OGM-40
Copper vapor	LSHL-504

[a] Mashpriborintorg is a Soviet export-import organization.

[redacted]

Pages: 15-17

Exemptions: (b)(1) (b)(3)

[redacted]

[redacted]

Weapons operator training for laser weapon engagements would be somewhat similar to operator training for laser designators. This type of training would include specialized courses in target recognition, laser safety, and weapon systems operations. This training would probably include development of target recognition criteria for a variety of targets. Training would emphasize reducing the time required to detect and identify a target and reducing the time to position the laser beam on the target's EO sensors. Hands-on field training would be part of an overall training program, and operator firing accuracy could be fully developed at this time. [redacted]

Throughout the operator training period, emphasis would be on operator safety, physical safety devices, and operational safety doctrine. Physical safety measures could include the use of laser safety goggles, fail-safe interlock devices, shrouds, hoods, and baffles. It is likely that all crew members of the laser vehicle would receive first aid training in laser-related accidents. [redacted]

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Exemptions: (b)(1) (b)(3)

Appendix A

Technology Background on Lasers

The importance of the laser lies in the special nature of the light it emits. As a result of this special nature, lasers are designed to emit light that has a very small beam spread as compared to that possible with ordinary sources of light. The light from a laser will normally be of a single color (monochromatic). Finally, it is possible to construct lasers that concentrate a great deal of energy in their narrow beam. The ability to emit a light beam containing a great deal of energy, but with little spread, means that a laser can concentrate its light energy in a small spot at a great distance. Thus, certain lasers can irradiate a target with enough energy per square centimeter to cause damage from distances of at least several kilometers. [redacted]

In order to understand how a laser works and why its output has these properties, we first have to review a few facts about light. A beam of light consists of plane waves. In a single wave the electric and magnetic fields making up the light wave oscillate up and down similar to the motion of waves in an ocean. [redacted]

There are several features that characterize light waves. The first is the *wavelength* (L), which is the distance between successive peaks of the wave. The wavelength determines the color of the light. For lasers, it is common to measure the light's wavelength in terms of micrometers (μm). One micrometer is one-millionth of a meter. Visible light ranges from 0.4 μm (blue) to 0.65 μm (red) in wavelength. Light with wavelengths shorter than 0.4 μm is called ultraviolet (and, for very short wavelengths, X-rays and gamma rays). Light with wavelengths longer than 0.7 μm is called infrared (and, for very long wavelengths, millimeter waves, microwaves, and radio waves). The next feature of the light wave is its *amplitude*, which measures the strength of the electromagnetic fields. The amplitude of a light wave determines its intensity, which is the amount of energy per unit time per unit area that the light wave will deliver to the target. The third feature of the light wave is more subtle, but important. This is called the *phase*. Consider two light waves traveling in the same direction and with exactly the same wavelength and amplitude except that the peak of one wave passes a point before the peak of the other wave. Then these two waves are said to differ in phase. If two waves have the same phase and wavelength, they will add to form a single wave of higher amplitude. Waves that differ in phase will combine to form a single wave of lower, possibly zero, amplitude. [redacted]

The key to the laser is the process called stimulated emission. A collection of atoms can be "pumped" by adding energy to them. This energy will be emitted over a period of time when the atoms radiate light of several specific wavelengths (spontaneous emission). However, when one of the pumped atoms is struck by light at one of these wavelengths, the atom is more likely to radiate additional light of the same wavelength and phase as the incident light. This is the process known as stimulated emission. If a certain percentage of the atoms have been pumped (called a population inversion), the stimulated emission can continue in a chain reaction, greatly amplifying the incident light. As a result of the repeated stimulated emission process, the emitted light will be extremely intense, in phase (coherent), and of the same wavelength (monochromatic). A device that utilizes this principle of stimulated emission to produce intense, coherent monochromatic light is called a laser (*l*ight *a*mplification by *s*timulated *e*mission of *r*adiation). This contrasts with light from ordinary sources (such as light bulbs, which are a mixture of waves with different wavelengths, phases, and amplitudes). [redacted]

For our purposes, the most important result of these features of laser light is that it will have a very small beam spread and will deposit most of its energy in a small area on the surface of a distant target. [redacted]

Generally, in order to get the most light out of a laser, the amplified light has to make several passes through the medium. There may also be several output wavelengths possible, and the right one has to be selected. For these reasons, optical elements such as mirrors have to be provided to tune the laser to the right wavelength and ensure multiple passes. Some lasers amplify light originally produced by random spontaneous emissions. These are called oscillators. Others amplify light fed from another laser and are called amplifiers.[redacted]

Types of Lasers

There are numerous types of lasers and new lasers are being discovered frequently. However, only a few lasers are likely to be useful for battlefield damage weapons. The remainder of this section will concentrate on laser devices and related equipment and methods either identified as having battlefield utility or identified as being of great interest to the Soviets, even if their battlefield potential is not fully understood.[redacted]

There are two generic types of lasers classified by output characteristics. Continuous wave (CW) lasers emit a light consisting of closely spaced spikes for extended periods (seconds more) and are continuously pumped. Pulsed lasers emit short pulses of very high power. They may be repeatedly pulsed at a laser-dependent rate (a few types are strictly one-shot devices).[redacted]

Lasers are most commonly categorized by their working medium (lasant). Solid-state lasers employ glasses, crystals, or semiconductors. Liquid lasers use dyes that are dissolved in a solvent and are now thought to be of weapons interest. There are types of liquid and solid-state lasers that can be tuned to several wavelengths (colors). Gas lasers can be singly pulsed, repetitively pulsed, or CW. In most weapons-class gas lasers, the lasing gas flows through the laser region. These flowing gas lasers can also be open cycle, in which, after lasing, the gases are exhausted or closed cycle where the gases are recycled. Gas lasers can store large amounts of energy per unit weight and can more easily exhaust waste heat than can solid-state lasers. Major disadvantages include the presence of plumbing and low output per unit volume of lasant.[redacted]

There are various schemes by which a laser can be pumped. The choice of pumping scheme depends on the required properties of the lasant; the output; repetition rate; and volume, weight, and packaging. Some common pumping schemes include photo pumping by a bright source (such as a xenon flashlamp or plasma discharge). In chemical lasers, chemical reactions produce the lasant in an excited state. In a chemical transfer laser, an additional gas species is excited and transfers its energy to the lasant. In photodissociation lasers, the pump light acts like a chemical species. These lasers are sometimes referred to as chemical lasers for this reason. Electron beams and/or electric discharges can pump some types of solid-state (semiconductor) or gas lasers. Gas dynamic lasers work by allowing a heated gas to expand through a nozzle.[redacted]

The most common way of designating lasers is by lasant type.[redacted]

For each of the following laser types we give the typical output wavelengths, chief pumping schemes, typical output characteristics, and appropriate comments.[redacted]

Solid-State Lasers

1. Nd:YAG Lasers

Lasant: Neodymium-doped yttrium aluminum garnet crystal

Wavelength: 1.064 μm

Output: Pulsed (nanoseconds) up to 1 J/pulse, 100 Hz pulsed repetition frequency (PRF); CW up to 100 watts (W)

Pumping: Photopumped in the ultraviolet

Comments: Moderate output laser with good-beam-quality thermal properties and high gain. High gain and crystal growth problems limit energy output. Used in many rangefinders, target designators, and laboratory work (other crystal hosts or lasants possible).

2. Nd:glass Lasers

Lasant: Neodymium-doped silicate or phosphate glass
Wavelength: 1.059 μm (varies depending on formulation of glass)
Output: Pulsed with potential for tens or hundreds of kJ per laser rod or slab per pulse. Low PRF, pulses about 10 milliseconds long unless shortened
Pumping: Photopumped in ultraviolet
Comments: Problems of thermal response and beam quality. Phosphate glasses and certain new technologies could give potential for very large pulse with good beam quality several times per second.

3. Frequency-Doubled Nd Lasers

Comments: As in the uses listed for 1 and 2 above, crystal or gas nonlinear material tuned to second harmonic of Nd frequency, 0.53 μm (in green visible). Conversion efficiencies with some extra beam spread can be on the order of 50 percent for lower power devices.

4. Nd:Cr:GSGG

Lasant: Doubly doped gadolinium strontium gallium garnet ($Gd_3Sc_2Ga_3O_{12}$)
Wavelength: 1.064 μm
Output: Three to five times more efficient than Nd:YAG
Pumping: Photopumped
Comments: More efficient crystal for rangefinders and designators.

5. Cr:GSGG

Lasant: Chromium-doped gadolinium strontium gallium garnet ($Gd_3Sc_2Ga_3O_{12}$)
Wavelength: Tunable over 0.71 to 0.83 μm
Pumping: Photopumped
Comment: Relatively efficient, high-power laser that is tunable in the visible wavelengths.

6. Ruby Lasers

Lasant: Ruby crystals (chromium atoms)
Wavelength: 0.694 μm
Output: Pulsed up to several watts average power, up to 100 Hz PRF
Pumping: Photopumped
Comments: It lases in the red portion of the visible spectrum and is useful in laser rangefinders.

7. Semiconductor Lasers

Lasants: Various; a common one is gallium arsenide (GaAs)
Wavelengths: Various, 0.840 μm (GaAs)—often tunable
Output: Almost CW (continuous wave)—several watts or more
Pumping: Photopumped—election beam
Comments: Compact, versatile, with some tunability.

Gas Lasers

1. Carbon Dioxide Lasers

Lasant: CO_2
Wavelength: 10.6 μm, but operation possible in other lines; for example, 14 to 16 μm range
Output: 50-microsecond or shorter pulses with up to hundreds of Hz PRF; or CW. Believed scalable to megawatt class average powers. Miniature CO_2 lasers may be tunable with wave guide cavities.
Pumping: Electric discharge, electron beam, gas dynamic. Combinations of above also chemical and chemical transfer.
Comments: Requires gas handling; can be open cycle, venting exhaust gases into environment, or closed cycle. Major weaponization potential. Other uses include controlled fusion drivers (with shortened pulses), welding, isotope separation (14 to 16 μm wavelength). Relatively low atmospheric breakdown threshold and some propagation problems for high-energy devices. In-band for some FLIRs.

2. Carbon Monoxide Lasers

Lasant: CO
Wavelengths: Various lines. 5 μm important because of propagation advantage over longer wavelengths.
Output and Pumping: As for CO_2

Comments: At 5-μm wavelengths, better propagation and less beam divergence than CO_2. Toxic effluents.

3. Chemical Lasers

Lasants: HF (hydrogen fluoride), DF (deuterium fluoride)
Wavelengths: 2.7 μm (HF), 3.8 μm (DF)
Output: Microsecond pulses with high PRF; or CW. Potential for scaling to high outputs in megawatt class.
Pumping: Chemical, chemical transfer E-beam
Comments: HF strongly absorbed in atmosphere—DF good propagation wavelength. For chemical lasers, low weight and nonelectrical energy source are attractive features. Toxic effluents.

4. Helium-Neon Lasers

Lasant: Neon
Wavelength: 1.15 μm, also 6.3 μm
Pumping: Electric discharge, microwave
Output: Usually CW several watts; possibly can be pulsed.
Comments: Some scalability may be possible.

5. Argon Lasers

Lasant: Ar^+ (Argon Ion)
Wavelength: 0.476 um (principal)
Pumping: Electric discharge
Output: Usually CW up to hundreds of watts
Comments: Blue-green light, some scalability, low output per unit volume could lead to size problems.

6. Atomic Iodine Lasers

Lasant: I_2
Wavelength: 1.315 μm
Pumping: Photo dissociation, chemical transfer
Output: Up to several kiloJoules, with tens of millisecond pulses by photopumping. Up to several kW, CW by chemical transfer.
Comments: Good propagation, short wavelength, scaling potential. Potential for important military and fusion applications.

7. Excimer Lasers

Lasants: Rare gas monohalides (and others), such as XeF, KrF, XeCl
Wavelengths: Various, typically near UV, about 0.350 μm (XeF)
Pumping: Electric beam, optical discharge
Output: Nanosecond pulses-Joules, high PRFs reported but with loss of pulse energy. Up to tens of watts average power.
Comments: Good potential for great increase in output if high-power ultraviolet radiation can be handled by optics. Good potential for military use.

8. Metal Vapor Lasers

Lasants: Various, especially copper
Wavelengths: Various, often visible
Pumping: Usually E-beam or electric discharge
Output: Train of nanosecond pulses, possibly scalable to high-average outputs
Comments: May be available at low- to medium-average power in a few years.

9. Free Electron Lasers

Lasant: Free electrons in undulating magnetic field
Wavelength: Adjustable, tunable
Output: Short pulses
Comments: Requires source of magnetic field and/or microwave. Resembles microwave generator at optical frequencies. [redacted]

The above list is, of course, not complete and other devices of interest may exist. The descriptions of each laser give the most common characteristics and can be used as a guide to the relationships between laser-type output and pumping sources. This does not mean that other associations may not be developed and found useful. [redacted]

Of course, a laser weapon is more than just a laser. Power supplies, optics, and pointing systems are needed. For battlefield lasers, the optics are likely to have diameters on the order of tens of centimeters to about a meter. An important requirement for high-energy laser optics is that they withstand laser fluences that are intended to damage a target. In particular, special glasses are available to withstand large pulses. These glasses are not as necessary for CW or quasi-CW use.

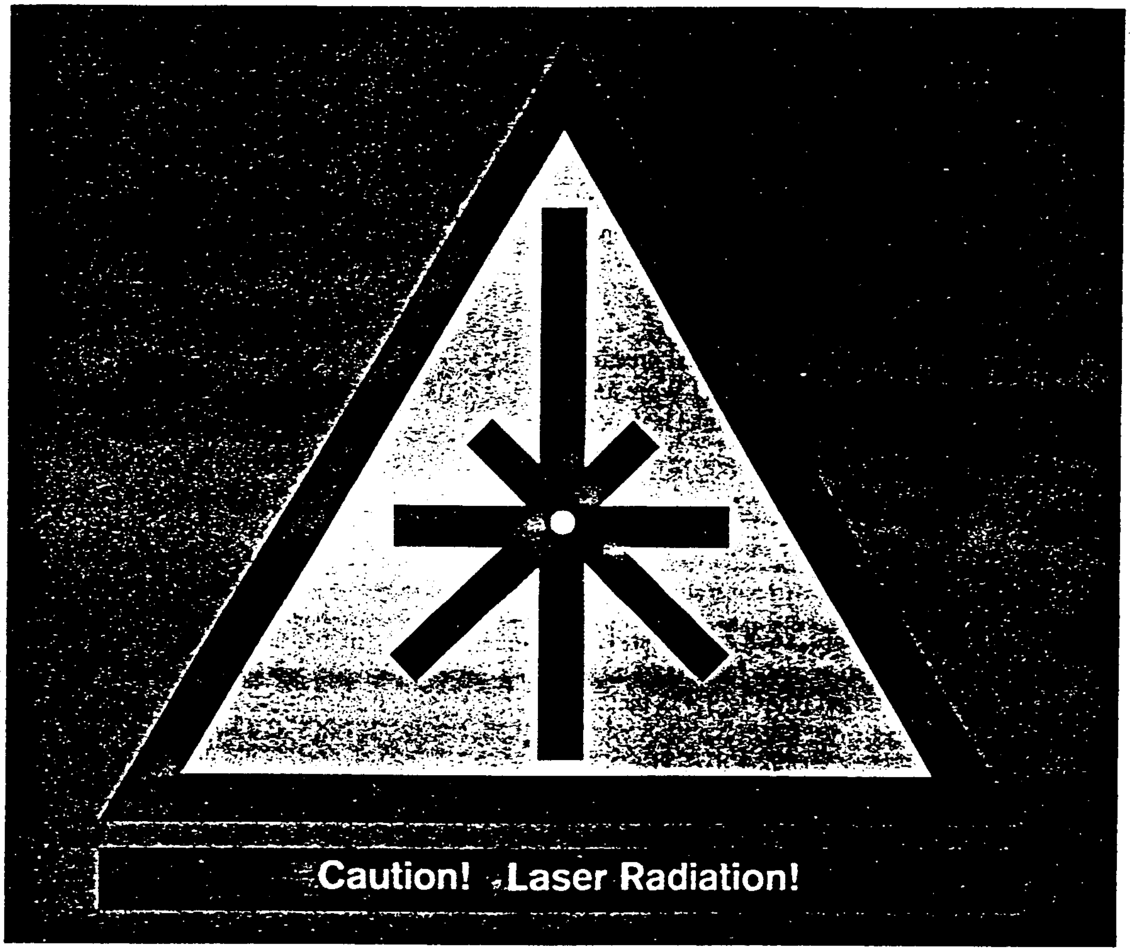
[redacted]

Power supplies include energy storage and pulse-forming networks required for pulsed electrically pumped lasers. Compact high-power energy sources will also be required. These include high-energy storage batteries, flywheels where energy is stored as rotational kinetic energy, and possibly magnetohydrodynamic (MHD) generators. In MHD, when an ionized gas flows across a magnetic field, the positively charged ions will deflect one way and the negatively charged ions the other way. A voltage difference will then appear across the flow that can be used to drive a power supply.[redacted]

Appendix B

[redacted]

Figure B-1
Soviet Laser Hazard Sign



Opasno! Lazernoe Izlucheniye!

[redacted]

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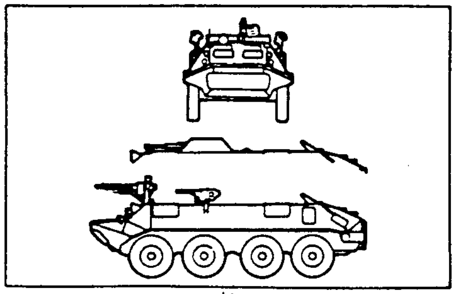
Exemptions: (b)(1) (b)(3)

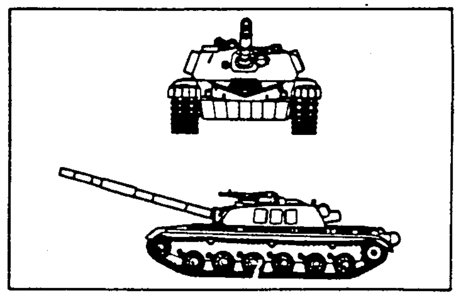
Figure D-1

BTR-60P



T-72

T-80
(Not Shown)



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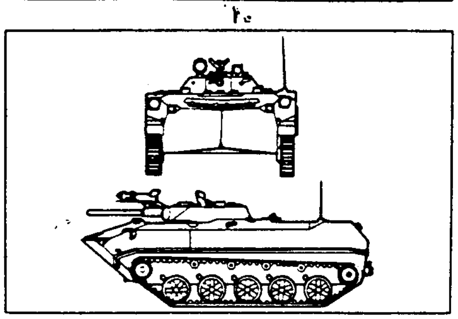

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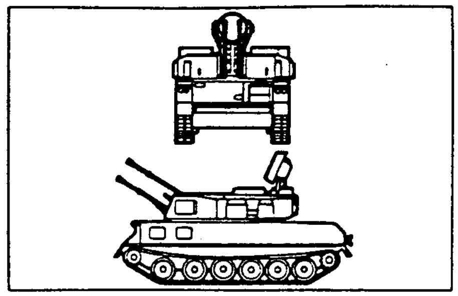

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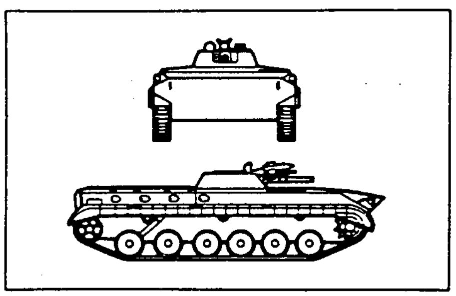

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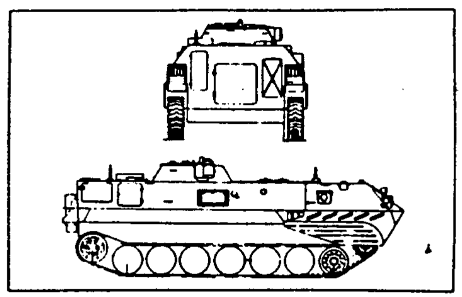
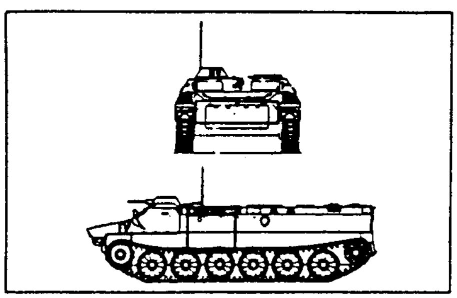


MTLB



[redacted]

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Appendix E

Glossary of Acronyms and Terms

ACRV	Armored command and reconnaissance vehicle [redacted]
ASM	Air-to-surface missile—a missile launched from an aircraft and striking a target on the ground. [redacted]
ATGM	Antitank guided missile—a missile guided to strike a tank. [redacted]
BMD	*Boyevaya mashina desantnika* (combat vehicle, airborne) [redacted]
BMP	*Boyevaya mashina perhoty* (combat vehicle, airborne) [redacted]
BTR	*Bronetransporter* (armored transporter) [redacted]
BW/CW	Biological warfare/chemical warfare [redacted]
CO	Carbon monoxide [redacted]
CO_2	Carbon dioxide [redacted]
CW	Continuous wave *(nepreryvnogo deystviya)*—laser waveform that is made up of a long-train millisecond or more of radiation. [redacted]
Designator	*Illyuminator*—a device that designates or specifies a target for a weapon so that the weapon can strike the target. [redacted]
DF	Deuterium fluoride [redacted]
EO	Electro-optical (*elektro-opticheskiy*)—used to describe a class of optical devices that contain electrically powered device like a detector. [redacted]
FEBA	Forward edge of the battle area [redacted]
Fluence	The energy per unit area falling on a surface. Typical units are joules/cm^2. [redacted]
Flux	The rate per unit area at which beam energy crosses a surface or beam power per unit area. Units: watts/cm^2 [redacted]
HELW	High-energy laser weapons—lasers whose average power is greater than about 100 kW. [redacted]
HF	Hydrogen fluoride [redacted]
Holography	A technique used to store three-dimensional images on a two-dimensional surface. [redacted]
Hz	Hertz—number of cycles per second. [redacted]
I_2	Iodine [redacted]

IOC	Initial operating capability [redacted]
IR	Infrared (*infrakrasnyy*)—a portion of the electromagnetic spectrum just above the one visible in wavelength. [redacted]
J	Joule—a unit of energy. [redacted]
k	Kilo—1,000. For example, 1 kJ = 1,000 joules. [redacted]
[redacted]	[redacted]
Laser	Lazer or OKG (*opticheskiy kvantovyy generator*). [redacted]
LBR	Laser beam rider—a missile that is able to stay within a laser beam all the way to its target. [redacted]
LELW	Low-energy laser weapon—lasers whose average power is less than about 100 kW. [redacted]
LSAH	Laser semiactive homing—a method used to improve the accuracy of a weapon; the laser illuminates the target, and the weapon senses the laser radiation reflected from the target in order to home on the target. [redacted]
m	Milli—one-thousandth. For example, 1 mJ = 0.001 Joule. [redacted]
MDP	Ministry of Defense Industry [redacted]
MTLB	*Mashina transportnaya legkaya boyevaya* (vehicle, transport, light, combat) [redacted]
Nd	Neodymium [redacted]
NIIs	Scientific research institutes [redacted]
Nonlinear optics	A branch of optics in which the optical properties of a material change with the intensity of the light. [redacted]
NPO	Scientific production association (*nauchno-proizvodstvennoe obyedineniye*)—a new type of Soviet organization designed to expedite production. [redacted]
PRF	Pulse-repetition frequency (*chastota povtoreniya impul'sov*)—number of pulses per second. [redacted]
rad.	Radian—a measure of arc. One radian equals 57.3 degrees. [redacted]
Rangefinder	Dal'nomer (*lazernyy*)—a device that determines the range or distance to an object. [redacted]

RDT&E	Research, development, test, and evaluation [redacted]
Spectroscopy	A technique used to determine characteristics of a material from the spectrum of radiation given off by the material. [redacted]
μm	Micrometers—that is, one-millionth of a meter. [redacted]
W	Watts—1 joule/second—a unit of power. [redacted]
WP	Warsaw Pact [redacted]