The Revolution in Military Affairs and Directed Energy Weapons

by

Matthew Mowthorpe

The current revolution in military affairs (RMA) is based primarily on the impact made by advancing information, sensor, computing, and telecommunications technologies on the modern military. The concept is defined in the DoD's Annual Report to Congress as:

> A Revolution in Military Affairs (RMA) occurs when a nation's military seizes an opportunity to transform its strategy, military doctrine, training, education, organization, equipment, operations, and tactics to achieve decisive military results in fundamentally new ways.[1]

The interplay of advanced technology and new operational concepts occurs in two distinct ways. The first is "requirements pull," where a new critical operational task emerges requiring the development of new technology to accomplish new missions. An example of this is ballistic missile defense (BMD), where the proliferation of ballistic missiles and their associated technologies created the requirement for theater missile defense of forward forces and potentially national ballistic missile defense for the U.S. homeland. The second is "technology push," where a promising new technology spurs the development of a new weapon system or operational concept and enables new, perhaps previously un-thought of, missions. An example of this is the utilization of the global positioning system to navigate precision munitions. It is the combination of requirements pull and technology push that drives the current RMA by maturing advanced technologies and enabling new military missions.

Directed energy weapons (DEW) are a technology area that has been neglected in this RMA. The technologies associated with DEWs have been maturing, while political support and new expenditures from Congress are making deployment of DEW systems in the near future a realistic possibility. The use of DEWs on the modern battlefield would contribute to the current RMA. DEWs will be able to provide defense against short-range artillery shells and theater/intercontinental missiles, as well as anti-satellite capabilities that will contribute to a space control strategy. This article examines advances in DEW technology and the new military missions and roles that will be enabled by these new weapon systems.

Space Based Lasers for Ballistic Missile Defense

Interest in utilizing space-based lasers (SBLs) for ballistic missile defense (BMD) arose when two facts emerged. First, ballistic missiles are relatively fragile and do not resist laser energy and secondly, chemical lasers could project missile killing amounts of energy over 3,000 kilometers. These two facts peaked political interest over the possibility of placing laser weapons in space. SBLs could be used to intercept ballistic missiles in their boost phase, thus dropping disabled missiles on an enemy's own territory.

The Lethality of A Space-Based Laser

Delivering a high-intensity laser beam for a long enough time to disable a target is the objective of a laser weapon. Laser energy can damage missile boosters if the laser has a moderate intensity combined with a sustained dwell time on the booster, the laser will then burn through the missile skin. A 10 meter mirror with a hydrogen fluoride (HF) laser beam would yield a 0.32 micro radian divergence angle and create a laser spot 1.3 meters in diameter at a range of 4,000 meters. The distribution of 20 MW over the laser spot would create an energy flux of 1.5 kilowatts per square centimeter (kW/cm^2). The laser spot would need to dwell on the target for 6.6 seconds to create the nominal lethal energy of 10 kilojoules per square centimeter (kJ/cm^2).[2] At a range of 2,000 meters the destruction of the booster would require 1.7 seconds of illumination.[3]

A solid fuelled booster could probably absorb, without disruption, approximately 10 kJ/cm^2 on its skin,[4] the energy from a 1 second illumination at 10kW/cm^2. The application of an ablative material would probably double or maybe even triple the lethal energy required. It is sometimes argued that the use of a mirrored reflective coating to the booster would deflect the laser, but the abrasion during the boost phase could cause it to lose its reflective capabilities. Another method of countering lasers is spinning the missile, which could raise its hardness by a factor of three[5] by shortening the period that any single spot on the missile is illuminated by the laser. However, it is possible that the uniform heating around the spinning circumference of the missile could introduce a lethal mechanism that could also destroy the booster.

A SBL with a 20 MW HF laser and 10 meter mirrors would have a 2.7 micron wavelength. The beam would be attenuated as it disseminated through the atmosphere with most of the beam reaching down to an altitude of around 10 kilometers.[6] Penetration deeper than this would not be required since the laser would not be in a position to attack missiles in flight until they had reached this altitude. Also, clouds could obscure the booster below a ceiling of 10 kilometers.

Table 1: Requirements for several laser weapons

	ASAT Space	ASAT Ground	Space-based BMD
Laser type	chem (HF)	chem (DF)	chem (HF)
Laser wavelength	2.7:m	3.8:m	2.7:m
Laser location	space	ground	space
Target distance	3,000km	10km	3,000km
Mirror diameter	4m	4m	10m
Laser output	2.5MW	2MW	20MW
Time/shot (at maximum range)	75 secs	75 secs	8 secs
Beam spread	0.8:rad	1.2:rad	0.33:rad

Beam size at target	2.5m	2.5m	1m
Incident energy for kill	$56W/cm^2$	$56W/cm^2$	$20kJ/cm^2$
Atmospheric transmission	100%	50%	100%
Laser efficiency	20%	20%	20%
Fuel energy content	1.4MJ/kg	1.4MJ/kg	1.4MJ/kg
Fuel per shot	720kg	est. 720kg	560kg

Source: Adapted from Dietrich Schroeer, "Directed-Energy Weapons and Strategic Defence: A Primer," Adelphi Papers 221, (IISS: London, Summer 1987)

Characteristics of a SBL

SBLs would be located on satellites placed in low-earth orbit. The type of orbit would depend on the nature of the threat. A satellite's orbital altitude is an important factor since it must place the laser, as frequently as possible, in a position where it can destroy the largest number of missiles in their boost phase. The satellite needs to be at an altitude sufficient to enable it to intercept the farthest boosting missile it can see without focusing the beam in such a way that closer and more vulnerable missiles are missed. The optimal altitude depends upon the height at which the booster's engines stop firing, the capacity of the laser, and the hardness of the missiles. When the Soviet Union's ICBMs were considered the main threat, polar orbits were chosen since they provided good coverage of the northern latitudes. However, polar orbits concentrate SBLs at the poles where there are no ballistic missiles deployed. The optimum configuration would be a number of orbital planes inclined about 70^o to the equator.[7]

It is generally accepted that SBLs would be incapable of lasing a missile re-entry vehicle with a destructive dose of energy during its midcourse and re-entry trajectory. Re-entry vehicles are hardened to survive the launch, midcourse and thermal re-entry phases of missile flight, then successfully detonate and destroy even hard targets.[8] The missile must therefore be targeted during the time when it is above the clouds and atmosphere and before it deploys re-entry vehicles.

DEWs have an advantage over interceptor missiles with high explosive warheads for BMD in that destructive amounts of energy can be transmitted to the target at the speed of light. Consequently, only laser weapons are currently capable of intercepting an intercontinental ballistic missile during the boost phase of its flight. One disadvantage of laser weapons vice conventional interceptors is that the beam must hit the target, which at long range raises serious target acquisition and tracking problems. Whereas, with a conventional warhead a kill could occur if the warhead blast is sufficiently close to the target missile.

History of the SBL Program

Throughout the 1980s the SBL testing and development were conducted under the auspices of the Strategic Defense Initiative. However, in the early 1990s developmental work was not given a high priority within the U.S. defense budget. The Republican take over of the Congress in 1996 saw resumption of high energy laser testing after a two year hold. The Republican controlled Congress added $70 million to the $30 million the Ballistic Missile Defense Organization (BMDO) had requested for SBL activities in 1997.[9]

A half-scale SBL demonstrator, known as Star Lite, was planned to fly as early as 2005. The demonstration test would cost around $1.5 billion.[10] The Star Lite program was born out of the Strategic Defense Initiative's Zenith Star program. Prior to Zenith Star's demise in 1993, due to funding and technical problems, it was going to be a 45,000 kg spacecraft with a primary mirror 8 meters in diameter. The program was restarted in 1995 due to breakthroughs in high-reflectivity coatings and adaptive, uncooled glass optics. In March 1997, TRW and Lockheed Martin completed the first integrated ground test with a 0.5 second long firing of the laser.

In March 1998, Boeing and TRW, together known as "Team SBL" (Table 2), were awarded a six-month contract worth $10 million to define the concepts for a Space-Based Laser Readiness Demonstrator (SBLRD). The SBLRD would prove the technical feasibility of using a SBL to intercept and destroy ballistic missiles in their boost phase. Under the contract, Team SBL defined concepts for several issues of the SBLRD program: a concept for the demonstrator space vehicle, a concept for a SBLRD test program, and a risk-mitigation concept.[11] The contract addressed a fast and normal schedule. The fast schedule envisioned a 2005-6 launch using existing technologies, whereas the slow schedule planned a 2008 launch date examining newer technologies. Several technologies have been demonstrated that will reduce the weight of the SBL by 10%. These include more efficient rocket nozzles for producing HF laser fuel and reducing fuel consumption, lightweight spacecraft buses, die to composite materials, and better structural analysis.[12] In February 1999, the USAF awarded a contract for the SBL Integrated Flight Experiment (SBL-IFX), the new name for SBLRD. SBL-IFX is jointly funded by the USAF and the Ballistic Missile Defense Organization. In 1999, $168 million was allocated for the development.[13]

Table 2: The Team SBL-Integrated Flight Experiment (SBL-IFX) and the companies involved

Company	Areas of Responsibility
Lockheed Martin Missiles & Space Operations	Leading development of the SBL-IFX spacecraft & its payload integration; developing and maturing beam director technologies; leading development of the SBL-IFX ground support segment; & leading operational SBL architectural definition
TRW Space & Electronics Group	Leading definition & development of operational SBL-IFX technologies; leading integration of the SBL-IFX payload, developing and maturing laser payload techniques; & leading development of the test facility

Boeing Space & Communications Group	Leading SBL-IFX systems engineering, integration, and test; developing and maturing SBL-IFX beam control technologies, including those needed for acquisition, tracking and pointing leading optical integration in the SBL-IFX payload segment; & leading the SBL-IFX mission operation segment

Source: Adapted from . R. Wilson, "Putting Space Weapons on the Fast Track", Aerospace America, July 2001.

Current SBL Program

The US fiscal year 2002 (FY02) defense budget request for the SBL-IFX program is $110 million. SBL-IFX may be ready for an initial test in around three years.[14] The chemical HF laser was chosen for the SBL-IFX because it's reactants absorb waste heat as they are used and emit any excess heat into space. The stability and long shelf lives of hydrogen and fluorine are also positive factors.[15] The experimental demonstration vehicle will weigh between 40,000 and 42,000 pounds and will carry a megawatt-class laser and a 2.8 meter beam-directing optical mirror. The actual operational system would be equipped with a multi-megawatt laser and carry an 8-12 meter mirror. The demonstration vehicle is now planned to be in orbit in 2012.[16] The major participants in the $4 billion SBL-IFX are Lockheed Martin, Boeing and TRW.

The operational SBL is to be capable of intercepting ballistic missiles in the upper reaches of the stratosphere (40,000 to 50,000 feet above the earth) and in space. The SBL will consist of a constellation of 20 laser firing satellites and is intended to operate an altitude of 1,300 kilometers and would have a lethal range of 4,000-5,000 kilometers. A single satellite could cover as much as 10 percent of the Earth's surface.[17] The inability of the laser to penetrate beneath the earth's atmosphere, since the HF laser's effects are diminished by water vapor in the earth's atmosphere, is considered to be an advantage politically, i.e. SBL will not have the stigma of being a "death ray weapon" from space to the ground.

The Airborne Laser (ABL)

The Airborne Laser Laboratory (ALL), developed during the late 1970s and out of service by 1983, proved that it was possible for an airborne laser to intercept aerial targets and confirmed that lasers had weapons potential. ALL demonstrated half-megawatt class laser power levels, tens-of-microradian beam jitter levels, and accurate safe beam control using 1970s technology (Table 3).[18] The opportunity for a follow-on program declined with the establishment of the Strategic Defense Initiative Organization in 1983 and its shift in emphasis to research and development potential for SBLs.[19] Nevertheless, the ability of the ALL to shoot down missiles had a profound influence on the U.S. Air Force's decision to move forward with the conception, initial planning, and preliminary development of a second-generation ABL in 1991.[20] The experience gained from the ALL motivated many proponents of an ABL to put their case forward.

Table 3: The Beam time achieved on target by The Airborne Laser Laboratory successful intercepts against an AIM-9B missile

Intercepts Made by Laser	Beam Time on Missile's Nose (in seconds)
1 - May 26, 1983	4.8
2 - May 26, 1983	3.8
3 - May 31, 1983	2.4
4 - June 1st, 1983	3.6
5 - June 1st, 1983	3.1

Source: Adapted from Robert W. Duffner, Airborne Laser: Bullets of Light, (Plenum Press: New York, 1997).

In 1983 the ABL lacked a mission and the support of a user. Iraq's use of the Scud missile as a terror weapon during the Gulf War exposed a potential mission. The U.S. needed a better way to locate and intercept theater ballistic missiles. This led the USAF to propose an ABL weapon system that would be capable of locating, tracking, and destroying such missiles in their boost phase.

The chemical oxygen iodine laser (COIL) was chosen for the ABL for several reasons. COIL differs from other chemical lasers in that it radiates only a single wavelength of light at 1.315 :m.[21] This short wavelength reduces diffraction effects that limit the utility of other lasers within the atmosphere. The COIL also has the advantage that most of its excess heat is liberated in the production of the excited oxygen, significantly reducing the turbulence inside the laser cavity and facilitating the production of high-quality beams.[22] A 1 MW COIL would produce 5 MW of waste heat. Ammonia is used to deal with this heat.

The Airborne Laser in Operation

In operation, the ABL aircraft will patrol just outside of enemy airspace, if an enemy missile launch is detected by a variety of U.S. sensor systems this information will be relayed to the ABL. The aircraft nose is designed to swivel and is fitted with a 1.5 meter mirror which will focus the beam from a megawatt-class COIL onto the missile. The beam is designed to lock onto the target missile from a range of hundreds of kilometers away. The range is determined by the accuracy the primary laser beam, the power density it can deliver, and the structural design of the missile being attacked.[23] If the beam is able to dwell on the target for a sufficient amount of time (Table 4) the metal of the missile case will breach, exposing its guidance system or fuel tank to the laser resulting in destruction of the missile.

Table 4: Engagement parameters of the airborne laser and various missiles

		Missile			Airborne	Laser
Name (country of origin)	Range (km)	Burn time (seconds)	Diameter (metre)	Skin metal & thickness	Range for decisive engagement[a] (km)	Maximum range (km)
Scud-B (USSR)	300	75	0.84	Steel 1mm	240	320
al-Husayn (Iraq)	650	90	0.84	Steel 1mm	320	470
Nodong-1 (North Korea)	1 000[b]	70[b]	1.2[b]	Steel 3mm[b]	185	320
ICBM (SS-18) (USSR)	10 000	324	3	Aluminum 2mm	-	>1000

[a] Decisive engagements require a 45-degree arc of the missile circumference to be heated to the point of rupturing
[b] Estimated

Source: Geoffrey E. Forden, "The Airborne Laser", IEEE Spectrum, September 1997.

Intercept Ranges

The ABL is unable to optically track missiles through dense clouds; subsequently it must wait until a missile has risen above the clouds. Only at this point can tracking algorithms start to lock onto the target. The nominal 12.9 km flying altitude of the ABL is well above the altitude at which clouds occur.

There is some discrepancy between industry and U.S. Defense officials regarding the intercept range of the ABL. U.S. Defense Department officials put the intercept range at around 200km (125 miles) from its standoff position. This is based on the knowledge that high-value aircraft usually remain about 50 miles behind the front lines, which means that the effective missile defense range is reduced to about 70 miles into enemy territory.[24] However, industry officials deny this and identify the Ballistic Missile Defense Organization as the source of such opposition. They claim that the actual projected laser ranges are 400 km (250 miles) or more based on scaled data tests.[25]

The construction of an enemy missile and its surface properties determine the aim point of the ABL. The warhead/nosecone of a missile is structurally very strong and too well thermally insulated to make a good target. The tail section with its internal supports (which are used to transfer the engine's thrust to the rest of the missile) similarly does not make a good target.

However, most Third World countries' missiles consist of fuel tanks without such internal supports. This makes a suitable aim point for the ABL's intercept laser. This target point enables a hole to be punctured in the side of the missile by the internal pressure of the target's fuel tank, thereby shortening its flight. Liquid fuelled missiles maintain a pressure inside the tank of 130-200 kPa. This pressure ensures a constant rate of fuel into the turbopumps that feed the combustion chamber. However, if the missile skin is heated up to its critical temperature, 460°C for steel or 182°C for aluminum the fuel tank will rupture.[26]

Another method to destroy a missile with a laser is to make it collapse from a compressive load along its axis. An axial load has two sources. One is atmospheric drag, which exerts a large force on the missile, particularly as it surpasses the speed of sound. The second is the stress on the missile from its inertial load, which comes from the accelerating mass. An al-Husayn missile passes Mach 1 when it is 30-40 seconds into its flight at an altitude of around 5-7 km and reaches its acceleration maximum of 7 m/s^2 at burn out. At this point if a laser inflicts a sufficient arc on the missile, the missile will collapse.

Team ABL is led by Boeing Defense & Space, which has overall program and management and systems integration responsibilities (Table 5).

Table 5: Team ABL members/responsibilities

Boeing Space & Communications	• Overall programme management and systems integration • Development of ABL battle management system • Modification of 747 aircraft
Lockheed Martin Missiles & Space	• Design, development and production of ABL target acquisition and beam control systems
TRW Space & Electronics Group	• Design, development and production of ABL high-energy laser • Design and development of ground support subsystems

Source: Airborne Laser Website (http://www.airbornelaser.com)

Team ABL's current Program Definition and Risk Reduction (PDRR) contract, worth $1.3 billion, with the Air Force calls for the team to produce, integrate and flight test the first prototype ABL demonstration system. The contract is scheduled to culminate in 2003 with a boost-phase interception of a theater ballistic missile. An engineering, manufacturing and development (EMD) program could begin as early as 2004. The PDRR aircraft will provide the Air Force with a residual operational capability.

The aircraft for the ABL is a Boeing 747-400 freighter aircraft that has undergone modifications such as the installation of the turret in the aircraft's nose where the laser will emerge. Additionally, the aircraft has to be modified to accept the COIL laser, the specialized optics, and the computer equipment to enable it to fulfill its mission. The modified 747 is designated the YAL-A1 Attack Laser. The ABL System Program Office is responsible for producing the YAL-1A.[27] The office was formed in 1993 at Kirtland Air Force Base, New Mexico, and is a major unit of Air Force Space and Missile Systems Center, Los Angeles Air Force Base, California. The initial cost-plus contract was awarded by the Air Force in November 1996 to Boeing Defense Group. Once the modifications are complete the battle management and optical systems will be installed and the aircraft will be put through a series of airworthiness tests. When those are complete, the ABL will be flown to Edwards Air Force Base, California for flight tests.

The assembly of the first 747-400 was completed in 1999. In April 2000 the final critical design review was completed. In July 2001 the first ship-set of six infrared search and track sensors was delivered. The beam control system will begin installation on the airframe in spring, 2002. The PDRR phase will culminate in 2003 with the interception of a missile and the ABL will enter production from 2004 to 2008. The initial operational capability with three aircraft will be achieved by 2005/6 and full operational capability with 7 aircraft by 2007/8.

ABL and Boost-phase Intercept Programs

The boost-phase intercept program represents a small portion of BMDO's total expenditures, although this could increase significantly in the future as the programs proceed from concepts to prototypes. The total FY02 missile defense program budget is $7B with boost phase program representing just less than 10%.[28] The majority of this ($685M) is allocated to the ABL (Table 6). The Pentagon's cancellation of the Navy's wide area ballistic missile defense program means that the ABL is the only near term boost phase intercept program.[29] Those funds are expected to reprogrammed to accelerate the development of the ABL.

Table 6: Boost-Phase intercept fiscal 2002 request

	Fiscal 2002 Request (in Millions)
Air-Based	$410
Space-Based	$190
Sea-Based	$50
Program Operations	$20
System Engineering & Integration	$15

Source: U.S. Department of Defence

Tactical High Energy Laser (THEL)

The Nautilus program was a project to evaluate the effectiveness of lasers for use as a tactical air defense system against short-range rockets. Nautilus was a joint U.S.-Israeli project operated by the U.S. Army Space and Missile Defense Command with support from the Israeli Ministry of Defense Directorate of Defense R&D. In February 1996, the U.S. Army used a laser to intercept and destroy a short-range rocket in flight.

The Mid-Infrared Advanced Chemical Laser (MIRACL) was used for the Nautilus program. MIRACL is a megawatt-class continuous wave, deuterium fluoride (DF), chemical laser built by TRW in 1970s. A small fraction of the MIRACL's power was used for the February 1996 test, corresponding to the power produced by a compact and mobile tactical laser system that could be fielded using existing and demonstrated laser technologies.[30] The Sealite Beam Director built by Hughes Aircraft Company, a high precision pointer-tracker system, enables the tracking and targeting of highly maneuverable tactical targets by the MIRACL. The Sealite and MIRACL together form the THEL (Table 7).

Table 7: The Tactical High Energy Laser (MIRACL) Ground based laser

Name	THEL (Tactical High Energy Laser - MIRACL (Mid-Infrared Advanced Chemical Laser)
Location	White Sands, New Mexico
Mission	Using a Hughes Sealite beam director which is housed on a 5.1 inch gun turret and fast, 350 degree motion, a laser designator lases the target and the chemical laser is fired through a 1.5 meter aperture telescope
Technology	Laser is a Deuterium Fluoride chemical laser, multi-megawatts. Computer controlled tracking and targeting system
Capability	Can attack tactical targets in an area within a minimum of 450 meters to unreleased or undetermined maximum
Tests	White Sands test in February, 1996 destroyed a light, short-range rocket paving the way for further THEL development in conjunction with Israel

Source: Mark Framer & Frank Vizard, "Sabers of Light" Popular Science Magazine, September 1997

United States and Israeli Cooperation in the THEL Program

The requirements for the THEL are driven primarily by Israel, which has an urgent need to protect civilians on its northern borders against terrorist rocket attacks. The Katyusha rockets they face have little or no guidance and are not lethal enough to defeat Israel militarily, but they have been used successfully by terrorist groups such as Hezbollah, operating mainly out of Lebanon to cause terror among the Israeli population. The THEL program stems in part from a commitment from former President Clinton and Secretary of Defense Perry to then Israeli Prime

Minister Shimon Peres in April 1996 to assist Israel in the development of a defensive capability against rocket attacks. The U.S. requirement is for a weapon system capable of protecting soldiers and military assets involved in regional conflicts against short-range rocket attacks.[31] The United States has invested about $170 million into the THEL program, matched by $80 million from Israel, although the development is solely under U.S. control.[32]

A mobile version of the THEL is a follow-on to the THEL system which shot down 23 Katyusha rockets.[33] The mobile THEL is supposed to be 5-10 times smaller than the current system, with the possibility that Israel will opt for a larger system with the U.S. Army opting for a smaller one with less power. The goal is for the Mobile THEL (MTHEL) to be deployable by a C-130 and consist of three vehicles. The current THEL mounted at White Sands Missile Range is 80’ x 80’ on a concrete pad. In the mobile system, the laser would be based on one vehicle, the fire control radar on another, and the laser fuel on a third.[34]

Advanced Tactical Lasers (ATL)

The U.S. Army wants to develop an airborne tactical laser for use by special operations forces. The system is intended to be mounted on a V-22 tilt rotor or CH-47 Chinook helicopter, to be used for covert activities such as setting fires.[35] The ATL would use a COIL, the same technology used on the ABL program. However, the power output by the Army's system would be at levels around 50-75 kW and the maximum range of the system will only be several kilometers,. The system will have a sealed exhaust system. The U.S. Special Operations Command is sponsoring the technology demonstration. Boeing has been advancing the ATL concept, but the Army has yet to make a decision on whether to complete the program.

The Vulnerability of Satellites to Lasers

Satellites are particularly vulnerable to laser attack. The thermal management of satellites is critical in their design. The balance between solar absorption and re-radiation to space is delicately poised between the absorbtivity and emissivity of the surface materials. In order for the solid-state electronics to operate, the internal temperatures have to be managed within a narrow range. Any damage to these surfaces will result in temperatures being severely affected to the satellite's detriment.

Since satellites are not designed to redistribute heat, a laser attack could proceed at a leisurely pace. Antisatellite (ASAT) laser weapons would require a 100 second engagement period, which is the exposure time of a low-earth orbit satellite to a ground station or an airborne weapon. Target irradiances of several to 10 watts/cm^2 would be lethal.[36]

Table 8: Vulnerability of Military Orbits to Laser Attack

		Orbit		
Threat	**Low Earth**	**Semi synchronous**	**Molniya**	**Geo-synchronous**

Ground-based directed energy	Capable of damaging optical sensors	No threat, current or potential	No threat, current or potential	No threat Current or potential
Space-based directed energy	Potential threat	Potential threat	Potential threat	Potential threat

Source: Adapted from Robert B. Giffen, Space Systems Survivability: Strategic Alternatives for the 1990s.

A U.S. Defense Department directive (DOD I 3100.11) is the driving force behind the world's satellites being evaluated for their vulnerability to lasers by the Satellite Assessment Center of the Air Force Research Laboratory's Directed Energy Directorate. The work is being undertaken in response to the new Defense directive that reflects two factors. First, there is an increasing number of satellites in space and second; some of these are particularly vulnerable to laser radiation.[37] The Satellite Assessment Center compiles detailed satellite intelligence coupled with laser effects testing on actual spacecraft components and materials to build high-fidelity computer models of foreign and domestic satellites. Using these models, the safe level of laser illumination for a particular satellite is determined (Table 8).[38]

ASAT Mid-Infrared Chemical Laser Testing

The U.S. Department of Defense conducted a lasing experiment in October 1997 involving the Mid-Infrared Chemical Laser (MIRACL) and the Miniature Sensor Technology Integration (MSTI-3) spacecraft that had been testing new ways of tracking missile launches and had completed its in-orbit mission. Defense Department Officials have been reluctant to provide information regarding what was obtained from the test firing, which included lasings by MIRACL and a low-power chemical laser.[39] The test cost about $2M, with MIRACL operations running about $6,000 per second. Two bursts from the laser struck a sensor array on the MSTI-3 satellite. One burst was an initial one-second firing to calibrate the laser's location on the satellite's body. The second beam was a 10 second burst, which triggered the satellite’s sensors and relayed data back to the ground tracking and monitoring stations.[40]

The Airborne laser as a Potential ASAT Weapon

An airborne ASAT laser weapon has many advantages over a ground-based one. It has the ability to avoid low-altitude turbulence. A small fleet of aircraft fitted with laser weapons could position themselves near the ground track of a target satellite, whereas a fixed ground-based laser could have to wait for an opportunity to target a low altitude satellite. An ABL system can operate in the stratosphere above most cloud cover that could interfere with beam propagation and target tracking of a ground based laser. Although, an aircraft does impose constraints on the size of the laser mirror and the mass of hardware, fuel, and coolant it could carry. Also, the process of tracking and aiming would be a much more complex operation for an airborne ASAT mission.

A latent capability exists in using the ABL as an ASAT weapon. The primary problem in using the ABL as an ASAT weapon arises from the use of infrared technology to track targets and cue the laser.[41] This requires a bright infrared reflection from the target. To use the ABL in an ASAT mission role an active system such as radar would have to be used to detect the satellites. There is also a difference of opinion on whether the deconfliction system in development for the ABL could be incorporated in an ASAT role. The deconfliction process is used to ensure that the long-range radar does not intentionally hit an aircraft or satellite in front of or behind the target.

At present Pentagon officials are not interested in developing the technology required for the ABL to be able to operate as an ASAT weapon. However, Air Force and aerospace industry officials believe that in the future the ABL may be given the task of intercepting satellites within 200 miles of the Earth's surface. It can be assumed that the ABL could destroy most low-Earth orbit satellites given its ability to deploy to a precise location that the satellites must fly over. The ABL is seen as a competitor to the congressionally supported Army program that is developing a ground-based ASAT capability designed upon an advanced kinetic-kill vehicle.[42]

Conclusion

The use of directed energy weapons on the modern battlefield will enable new missions that include theater missile defense and national missile defense. The Airborne Laser is at the forefront of this mission and the recent cancellation of the navy area wide program means that the ABL has been given increased funding priority. The SBL is an area where directed energy weapons could contribute to the national missile defense role, especially in providing boost phase interception.

The jointly developed THEL highlights the use of directed energy weapons on the battlefield, providing protection against short-range artillery shells, such as the Katyusha, and indeed providing population defense against such a threat. The use of directed energy against satellites, which was demonstrated in the U.S. Department of Defense's test against a satellite combined with the defense directive to evaluate the world's satellites, vulnerability to lasers indicates that an ASAT mission for directed energy is seriously being considered. The capability that an ASAT would offer would contribute greatly to the space control mission.

The use of directed energy weapons would contribute to the current RMA. The new missions that laser technology affords will lead to a new strategic environment in the post Soviet-era, in which laser weapons play a significant role. This is truly a Revolution in Military Affairs.

Notes

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