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HIGH ENERGY LASER WEAPONS

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by Carlo Kopp

Editor's Note 2005: This technical primer and analysis predates Star Wars by half a decade, and predates the AL-1A ABL by two decades. Adaptive mirror technology, the key enabler for HEL weapons, did not materialise until well after the ALL program completed.

If we examine physical weapons, whether a club or an ICBM, we'll find they have one very important factor in common - they damage their target by the release of stored energy: in the first instance, kinetic, in the second, the nuclear binding energy of several kilograms of plutonium. In the absolute sense, a weapon destroys its target by transferring a quantity of energy which the target cannot absorb without damaging itself.

Air to air weaponry, and by the same development surface to air weaponry, can be divided into two main categories - unguided and guided projectiles. Unguided rockets disappeared with the F-96C (neglecting the AIR-2 Genie - it's gyro stabilised). The current representatives of unguided weapons being cannon shells and machine gun bullets. Machine gun bullets damage by releasing their kinetic energy, cannon shells add to that the stored chemical energy of their explosive charge. High kill probabilities are basically achieved by spraying the target with a large number of projectiles (an M-61A1 gatling can fire 100 rounds per second), the spread, cancelling pointing and gunnery inaccuracies, is favourable, as only several rounds are usually necessary for the destruction of the intended target.

A guided missile achieves a high kill probability by altering its flight path so as to come within a certain range of the target, the range given by the effectiveness of the warhead. Accurate guidance and high manoeuvrability result in target kills s with usually, one or two missiles. Guns have the advantage of simplicity, but their range is severely limited and they are only as accurate as the aiming system they employ. Missiles have the advantage of superior range and effectiveness under non-visual conditions. On the other hand, their guidance may be jammed or deceived. However, the range of the best of either categories, longer ranged missiles, is still limited order of a hundred nautical miles.

Whatever their respective advantages or disadvantages both categories of weapon have one great drawback in common, a drawback inherent in their nature. They transfer energy to the target via a physical object, a projectile, and bearing in mind the medium they operate in, this projectile must traverse a certain distance, taking a certain time. Ideally this time would be short as possible, but here is where the problem arises as practical considerations limit the projectile's velocity, therefore always placing a restraint on the shortest time possible - further restraint on the combined use is given by the aircraft's payload - it may carry a lot of ammunition for the gun, but the gun is useless against distant targets and equally useless against small, fast moving targets, e.g. missiles, which are too small to aim at visually and too fast to track with an aircraft, not speak of their cross section. Missiles may be capable of hitting distant and small fast moving targets, but the launch aircraft may carry only a limited number, usually restricted by payload. Gun ammunition is expensive, while the price of a good missile would keep the average citizen going for some while.

Projectile weapons simply suffer limitations given by their nature, limitations that can never really be engineered out though one may get close (researchers in the US are working on the ultimate projectile weapon - the railgun. Employing plasma driven by a magnetic field to accelerate the projectile, energies great enough to cause thermal fusion on impact or provide escape velocity have been projected. As of yet, a lot of development to go).

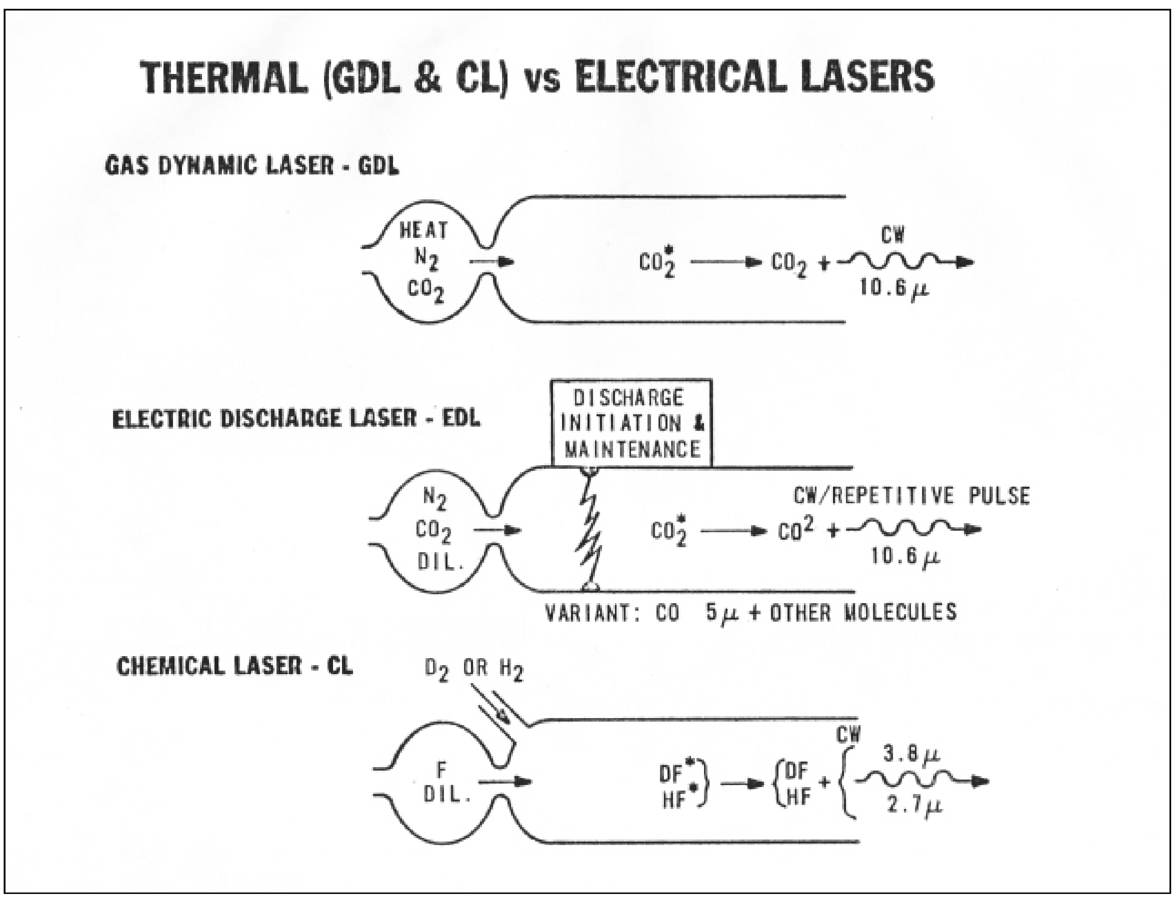
A new class of weapon is on the horizon - a weapon which will, once deployed on a massive scale, revolutionise warfare and render more than one "unbeatable" weapon system obsolete. It may, eventually, lead to changes in the world's current power structure. The weapon is the high energy laser, a device which the unaware may mentally shelve among Star Wars, Buck Rogers and Flash Gordon, something for the kiddies and sci-fi fanatics.

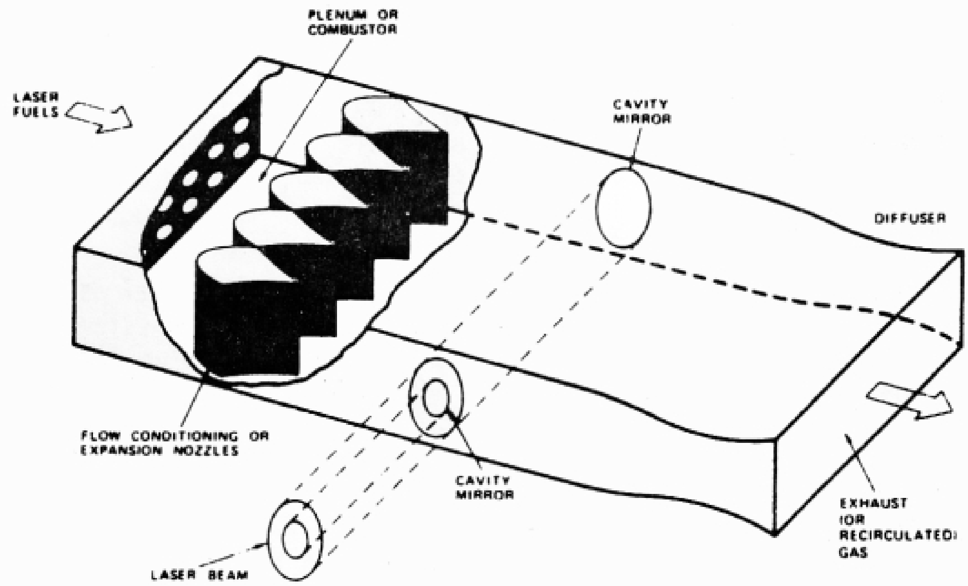
Both the United States and the Soviet Union are spending significant amounts on research, with some very convincing results, where publicised (to illustrate the restrictions involved, when the author was acquiring material for this article, three separate departments involved in this project supplied identical information sheets. Even very general information on the project is severely restricted). Though neither side claims to be involved in a technology race in laser weapons, there is no doubt that the side first to deploy on a large scale would have a significant tactical and strategic advantage until its opponent catches up, if it ever has the opportunity. The device which has enabled the development of operationally feasible laser weapons is the gasdynamic laser, or GDL. Since the first lasers were constructed in the early sixties, researchers were trying to increase power outputs, as the implications of high power lasers were obvious.

At the time, population inversions (see Laser Guided Weapons - Sept 1980 AADR) were being generated either optically or electrically. Optical pumping of the laser medium is very inefficient, only part of the light used enters the material and only part of that serves to excite the energy levels required for the laser to operate. Electrical pumping offered more promise, as the energy was being directly supplied into the laser medium. The idea of a beam with a cross sectional area of the order of tens of square centimetres transmitting tens or hundreds of kilowatts of power was enough to drive researchers on. The discovery of laser action in carbon dioxide-nitrogen-helium/water mixtures was a significant breakthrough, as reasonably high efficiencies were predicted, but building a device which could deliver the required power output was a big problem. In order for the laser to operate, a population inversion (a state where atoms/molecules of the laser medium are excited to a particular energy level above the ground (unexcited state) must exist and be maintained). The side effects of the electrical discharge used to excite the lasing medium, heating and ionisation, were upsetting the required population inversion. In order for the laser to operate efficiently, it was necessary to remove the gas mixture and replenish it at a high rate. The resulting devices required vacuum pumps, as the laser would only operate at pressures of the order of a thousandth of atmospheric pressure. As the number of photons released by stimulated emission is proportional to the length of their path in the medium, the devices had to be lengthy. The results were hardly adequate - efficiencies of a few percent and large devices, eg, a 200 ft - long laser tube delivering a mere 9 kW.

USAF ALL. Note the 60 cm aperture of the telescope. The forward fuselage houses a 10.6 um carbon dioxide gasdynamic laser. The hump aft of the telescope conceals an acquisition and tracking radar system.

It was quite obvious this was not the right path of development, but another path existed. In the early sixties a number of physicists suggested it may be possible to generate a population inversion in a molecular gas by rapid heating or cooling, a further suggestion was that this cooling could be achieved through the expansion of heated gas through a supersonic nozzle. In 1966, a team of physicists and engineers working for Avco Everett constructed and operated the world's first gasdynamic laser, operating on a mixture of $C0_2$, N_2 and H_20. By 1970, continuous power outputs of 60 kW were being generated and a 1973 pulsed GDL delivered 400 kW for 4 milliseconds. These results clearly opened the way for high energy laser weapons.





SCHEMATIC DIAGRAM OF A HIGH POWER LASER

The Gasdynamic Laser (GDL)

The design of a GDL demands the extensive application of fields as diverse as quantum mechanics and aerodynamics, success in design is given by the amount of close teamwork involved.

A GDL (see diagram) is comprised of four main components - a combuster, a bank of expansion nozzles, an extraction cavity and an exhaust diffuser. The combustor is where the fuels for the laser action are injected and combusted. In order for the laser to operate, the fuels must be carefully chosen - on combustion they must yield as much energy as possible and the combustion products must contain $C0_2$, N_2 and H_20 in exactly the right proportions for the laser effect to occur later on. Because the temperature and pressure requirements must be met very closely, early GDLs burned carbon monoxide (CO) in oxygen-nitrogen and water being added. However, this arrangement isn't practical for operationally deployable systems, for a number of reasons, so different fuel combinations have been examined. CO burning in N_20 and benzene (C_6H_6) burning N_20 are both applicable, though the former has the disadvantage of toxicity.

The combination products are heated by the released energy (1000 to 2000 deg C -- depending on the laser), reaching high pressures, they then enter the expansion nozzles. At a molecular level, the thermal energy of a gas actually becomes kinetic, rotational and vibrational energy of individual molecules. When the combustion products pass through the nozzles, two things occur - the rapid expansion creates a population inversion in one of the vibrational mode energy levels of $C0_2$, assisted by collisions with energised N_2 molecules and flow conditions are created, which will enable the extraction of laser energy. The flowing laser medium then passes through the extraction cavity. The laser radiation, at 10.6 micrometres (IR), must be extracted, preferably as early as possible in the flow, as collisions among the molecules upset the population inversion. The extraction takes place in an optical resonator formed by two cavity mirrors, concave to increase the stability of the standing wave pattern between them. The mirrors must be capable of withstanding high temperatures, as a loss of 1 per cent of energy in the mirror, in a 100 kW laser amounts to 1000 Watts of power being dissipated in the mirror itself. Another technique available is the use of an aerodynamic window, where an aerodynamic shock wave effect creates an interface, transparent to the radiation, but separating the flow (-0.1 atm) from the atmosphere.

Once the energy is extracted, the gas is exhausted via a diffuser, which helps maintain the required flow conditions. The result is a 10.6 micron beam of electromagnetic radiation, delivering powers of tens to hundreds of kilowatts on continuous operation (further reading - *Anderson: Gasdynamic Lasers, An Introduction - 1976*). The GDL is the device which delivers the raw energy for a laser weapon, but that is by no means adequate for a weapon, on its own.

A laser weapon system must first acquire a target, at a substantial range, to make its use worthwhile, track the target, fine track the target, fire the laser beam, assess whether the target is destroyed and, if necessary, re-attack. In order to understand the problems involved in an operationally feasible system, we must examine the aspects of the beam's propagation through the atmosphere, its effects on targets and the problems involved in tracking a target and pointing the beam.

Beam Propagation

Light waves propagate through free space at 3.10^8 metres/sec, when propagating through a medium like the atmosphere the velocity, on an average differs little from that figure. However, a number of phenomena occur, which can effect both the coherence of the beam and its intensity, both lowering the final concentration of power in the beam, with obvious effects. The three principal effects in question are absorption, scattering and turbulence.

Absorption is a quantum physical effect, which occurs when an atom or molecule absorbs a photon of light. Thought this photon may be emitted after a short period of time, it need not be in the same direction it was travelling initially, therefore it is lost. Absorption losses are proportional to the length of the beam's path and the number of molecules in the beam's path, which may absorb photons, likewise they are proportional to the beam's intensity. At high altitudes, where the atmosphere is less dense, this effect would not be as important as at low altitudes. Fortunately, for the user of the $C0_2$ GDL, there does happen to be a "window" in atmospheric absorption, between 10 and 13 microns, the laser's 10.6 microns fitting in very nicely. An ultraviolet laser would be heavily absorbed by atmospheric nitrogen. Absorption losses are greatly increased by the presence of water vapour, but here is where the effect of scattering comes into play. Any particles in the path of the beam, such as water droplets, dust particles or molecules may scatter the radiation. A photon impinging on the surface of a particle will either be absorbed or reflected, and the reflection is the cause of scattering. Rain, fog and snow will have obvious effects on beam transmission.

The 10.6 micron laser experiences a relatively low amount of scattering, under normal conditions, as compared to shorter wavelength lasers, but it will experience some absorption, mainly due to $C0_2$ and water in the atmosphere, the effect of water vapour diminishing with altitude.

Another effect which can affect the beam's propagation is turbulence. The basic mechanisms of atmospheric currents responsible are wind shear and heating. Under turbulent conditions, the flow is broken up into vortices and eddies, each of these possessing a slightly different temperature. This results in the volume of the eddy possessing a slightly different refractive index. If we pass a beam of light through an interface between two substances with different refractive indices, it will change its direction (shine a torch into an aquarium). The slight differences in the refractive index may not amount to much beam deflection individually, but the cumulative effects after passing a beam through several kilometres of atmosphere do, resulting in blooming of the focussed spot and random jitter.

Another cumulative effect will become important with the use of high power lasers and high beam intensities, namely, the beam's effects on the atmosphere it's passing through. The energy which has been absorbed by the atmosphere in the beam's path will cause heating. The heating will, in turn, increase turbulence, which will increase overall beam losses. The result is that increasing beam power will actually result in decreasing the amount of power reaching the actual target! In summary, the atmosphere affects the beam in two ways - it decreases the intensity of the beam and it defocuses the beam, in a manner fluctuating with time. All of these effects are far greater at sea level than at an altitude, and are aggravated by the presence of water vapour and haze, increasing the effects in adverse weather. All effects tends to decrease with altitude and, due to their nature, are entirely absent in space. (Reading - *Bertollotti - Effects of Atmosphere on Propagation of Laser Beams.*) Assuming we can deliver power to the target, we must now find how much energy we require to damage or destroy the target.

Effects of Laser Beams on Materials

In the simplest of terms, a laser affects a material by delivering large amounts of power to a small area, as the energy (heat) can escape the area only by conduction or radiation, both slow processes, the temperature will shoot up and the material will vapourise at the affected spot.

The power density required for this to occur depends on several factors, the most important being the material's surface reflectivity and thermal conductivity.

When a laser beam hits the surface of a material. two things happen - part of the energy is reflected and part absorbed in the surface layer. The surface layer vapourises and the vapours leave the surface, forming a layer above the heated area. This layer absorbs far more energy than the surface beneath it and its temperature rapidly rises, assisting the burning of the hole. The reflectivity of surfaces depends on the type of material and its surface finish. A polished surface will obviously reflect more energy than a roughened one. Here is where, though, a snag appears for the airborne use of lasers. The reflectivity of polished aluminium to the 10.6 micron radiation of a C02 laser is about 97 per cent. Only three per cent of the energy transmitted is absorbed initially and that clearly indicates how much more power is required. On the other hand, there is another factor which may be of assistance. Virtually all current combat aircraft are painted with low reflectivity paints. The vapourising of the paint layer would help 'trap' the initial amount of energy required to vapourise the surface of the aluminium (the author points out that this is speculation, as there is little available information on this subject).

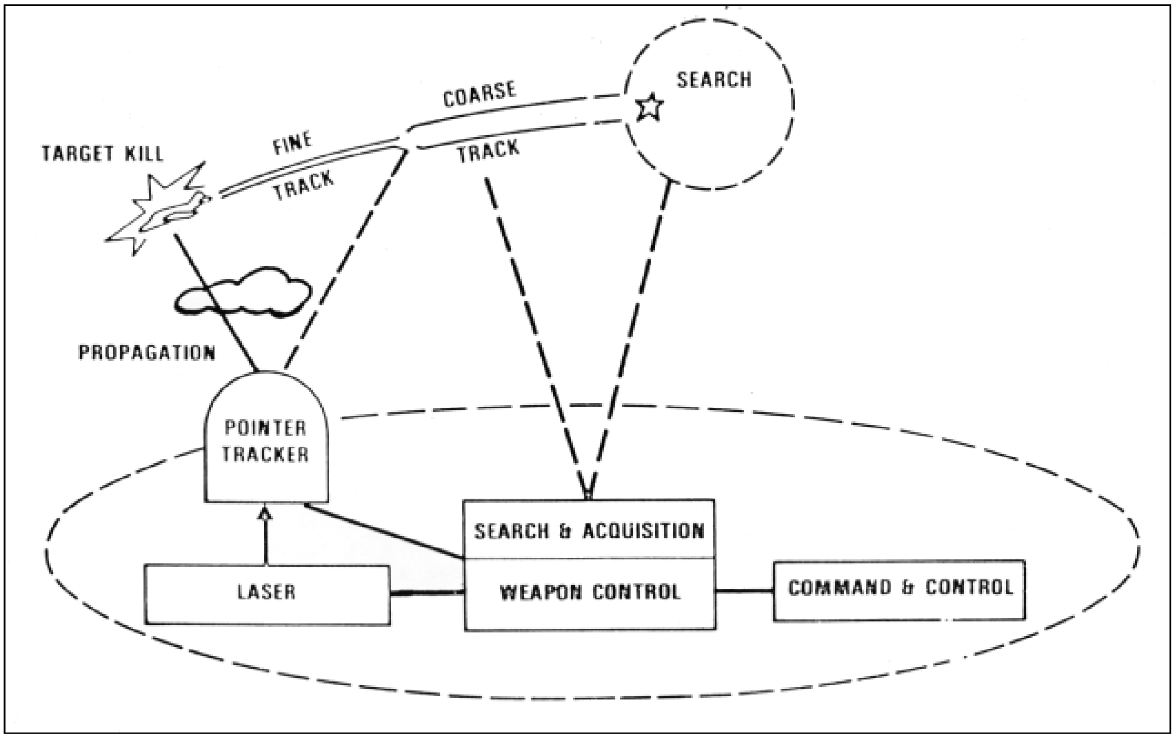
Heat conduction is an effect which slows the whole burning process. However, in materials such as plastics, composites or thin aluminium alloys being subjected to very high power densities, its effects are substantially lower than those of reflectance.

Some idea of the destructive potential of concentrated laser energy may be received from the surface melting times of aluminium and titanium subjected to a beam density of 10,000 W/cm2. Aluminium reaches its melting temperature in 0.042 sec, titanium in 0.015 sec. Beam densities of operational HEL weapons would hardly reach those levels, for the propagation losses and irregularities in illumination. A HEL weapon's beam would have to 'dwell' on the surface of the target for a time in the order of a second or seconds, until the surface melts through. This fact is probably the source of most of the difficulties encountered in the development of a HEL weapon system, as it demands an increase in aiming accuracy of about two orders.

Once, however, a laser weapon can burn a hole through the skin of its target, success is practically assured. Aircraft with wet wings are doomed, similarly fuel cells not protected by substantial amounts of airframe structure. Missiles with solid propellant engines and warheads are also left with little potential to survive. The damage that can be done to guidance or control systems is also vast.

The C02 laser isn't the only option open to HEL weapons. The USN has been researching chemical lasers, employing hydrogen/deuterium-fluorine systems, operating at 3.8 and 2.7 microns. The key to an efficient high power laser weapon is finding a laser which will operate at a wavelength that doesn't suffer much atmospheric absorption and has a low reflectance for materials like Al or Ti, which are extensively used for aviation.

Currently laser weapons are in their infancy, a lot of research will have to be done before the HEL reaches the level of development projectile weapons have reached.



Tracking and Pointing Systems

The atmospheric and surface reflection losses will cause a substantial decrease in the effective power density of the incident beam. This means the beam must spend a lot of time on a single spot before it can inflict any reasonable amount of damage. The big task is developing a system capable of aiming a beam at a point tens of kilometres away (or hundreds, in space) and tracking exactly that point, in spite of its motion and the motion of the platform carrying the laser. Current missile and cannon guidance / aiming systems have accuracies ranging from tens of metres down to a metre, at ranges of several kilometres. The target area of a HEL weapon has a size of tens to hundreds of square centimetres (3x3 to 10sx10s of cm) and must be tracked exactly for several seconds, as there is little point in scorching the paint.

Several problems arise in systems configured for a task of this magnitude. Conventional radar systems 'see' the target as a return, the size and exact position of this return given by the shape and relative attitude of target with respect to the radar. That means that the 'centre' of the target may drift as the aircraft changes its attitude. Advanced signal processors may be capable of extracting a lot of information as to the shape/attitude of the target, by looking at the amplitude/phase variations in the return, but one could only speculate as to how accurate that could be. A far more likely approach would be the use of a radar of this kind to point a fine tracking radar, operating on a substantially shorter wavelength, or perhaps a low power laser device. The fine tracking radar would employ a beamwidth smaller than the target and it would scan over it, later perhaps even identify the most vulnerable spot, then finding a particular point and locking on to it. This system could probably also use small Doppler shifts to detect vibration or fine motion of the target.

Some idea of the order of magnitude required in the accuracy of a system of this kind can be given by comparing the range to the permissible drift of the spot. 10 km vs 10 cm yields 100,000. That implies an angle of 10^-5 radians or about 0.0005 degrees. As one can see, it is quite demanding.

Another factor worth serious consideration is the nature of the platform the HEL weapon is mounted on. Ground based weapons should not really suffer any problems associated with vibration or buffeting, but an aircraft, on the other hand, cannot avoid them. Beam jitter due to atmospheric effects is serious enough a problem to deal with, without the beam being thrown metres or more off target by minor airframe vibrations. The result is a requirement for an extremely well stabilised pointing system, at least one to two orders better than systems currently in use on air-air radar.

Providing all requirements are met for generating a beam and accurately pointing it, the seemingly lesser problem of fire control can be approached. The basic requirement is a radar/computer combination with the ability to track a number of targets, identify them and decide on which to have the highest priority for destruction. Targets scheduled for destruction would be handed over to the tracking and/or fine tracking systems, which would then enable the HEL to down the target.

The question arises of what are the possible defensive measures. Ablative paints or coatings would be hardly effective, delaying the inevitable by perhaps half a second. The only real solution seems to be either terrain masking, not always possible, or effective ECM to confuse the fine tracking radar. A small error or fluctuating error signal would suffice to put the beam off target or spread its energy enough to degrade its effects to a 'safe' level.

Another question is the deployment of the weapon. Due to its size and rather more defensive nature, it would perfectly fit the role of protecting aircraft like bombers, tankers, transports and AEW/AWACS, which all have the size and payload to accommodate the system and are relatively stable platforms, in comparison with interdiction and fighter aircraft. The weapon's greater effectiveness at altitudes, as compared to sea level, also points to larger aircraft. (A nasty bit of speculation - how about replacing the tailguns of a B-52 with a HEL system, SAM and fighter proof?)

The deployment of HEL weapons in space would have a far greater impact on the strategic situation, in comparison with the tactical consequences of atmospheric HEL weapons. Ultimately, the HEL could mean the demise of the ICBM and the SLBM. Beam propagation in free space is virtually unaffected by distance, providing the beam is adequately collimated. Therefore, ranges to thousands of kilometres are quite realistic, providing the pointing is accurate enough [Editor's Note 2005: prophetic words given that the subsequent Star Wars program envisaged exactly this, and the current AL-1A ABL hundreds of kilometres].

HEL equipped satellites, together with booster stages, could be carried by the Space Shuttle to low orbits, from which they would climb, using their own boosters, to a stationary orbit. Once positioned, they could be activated and would destroy any unauthorised vehicle entering a restricted area. ICBMs would be detected in the upward part of their trajectories and destroyed at the top of the trajectory. Reconnaissance satellites could be destroyed or disabled, likewise manned vehicles. Orbiting HEL satellites at lower altitudes could function as killer satellites or even as offensive ICBM killers, hitting the missiles as they leave the atmosphere. The potential is enormous. Compared to the other alternative for space warfare, the particle beam (a stream of particles, eg, hydrogen ions, accelerated to velocities close to light), the HEL is far simpler, not requiring an enormous energy source, and is unaffected by the earth's magnetic field. It is, in fact, doubtful whether an operationally feasible particle beam weapon can be produced at all.

The HEL is the ideal weapon for space warfare and future developments are very likely to confirm this. The establishment of a HEL satellite defence network will require considerable resources, unlikely to fit in the budget of current air forces and this may lead to the establishment of a further type of service -a space force or space command. The USAF is spending substantial amounts on a project code-named Talon Gold - the development of a tracking and aiming system for an orbital beam weapon.

If either side would succeed in deploying a system of this kind before its opponent, it is very likely that side would gain a virtual first strike capability, having nothing to fear from the other side's ICBMs. The resulting destabilisation could trigger on all-out conflict, either by enabling the side with the upper hand to crush its enemy or by provoking the non-equipped side during the deployment of the system. Whatever the case, the deployment of the HEL in space would cause more damage to the USSR, as the US does possess the cruise missile and would, therefore, retain some effective strike capability.

The United States' DoD High Energy Laser Program

The United States' DoD has been researching HEL systems since the late sixties, although a lot of work hasn't been publicised. The main objective of the program is not the development of a HEL weapon system, but the demonstration of the feasibility of a HEL in an operational environment. A secondary objective is the investigation of HEL effects on targets, in order to develop necessary technologies for hardening future systems against HEL weapons. If the program yields positive results, the DoD would, in the mid-eighties, authorise the development of several prototype HEL weapon systems. Probably the best illustration of the program's results, up to date, are a number of target kills, achieved with HEL devices.

The first was in 1973, the USAF downing, at their Sandia Optical Range, New Mexico, a winged drone, using a moderately powered GDL and gimballed telescope. In 1976 the US Army, employing a lower power electrically pumped HEL, destroyed a number of winged and helicopter drones at the Redstone Arsenal, Alabama. The USN, in March 1978, engaged and destroyed an Army TOW missile in flight, using a moderately powered chemical laser developed by DARPA/USN and a pointer-tracker developed by the USN. These tests were carried out at San Juan Capistrano near Camp Pendleton, California, as part of the Unified Navy Field Test Program.

The US Army is currently examining the feasibility of the HEL as a battlefield air defence weapon, having completed tests with its Mobile Test Unit, an early laser device mounted on an LVTP-7 tracked armoured vehicle. The US Navy is currently preparing for another series of tests in the mid-eighties, at the DoD's HEL National Test Range, under development at the White Sands Missile Range, New Mexico. DARPA is focussing its attention on the development of orbital HEL systems. The USAF Systems Command is testing HEL devices in an air-air environment, using the Airborne Laser Laboratory.

The USAF Airborne Laser Laboratory Flight Test Program

The Airborne Laser Lab (ALL), a modified NKC-135A aircraft, is the USAF's test platform for airborne HEL research (see photo, cutaway). The ALL test program serves three primary purposes. The demonstration of operation and integration of a HEL weapon system in an air-air environment, the demonstration of the HEL's effectiveness as an air-air weapon and the provision of a technology base for further HEL systems.

ALL carries its laser and pointing/tracking systems in the forward fuselage, the test crew of twelve and their instrumentation occupy the fuselage aft of the wing. The HEL employed is a high power $C0_2$GDL, the aircraft also carries a number of low power lasers for alignment and diagnostic purposes.

The 10.6 micron GDL, power output classified, is powered by fuel provided from tanks situated in the laser compartment. The laser energy delivered by the GDL is fed into an stabilised telescope assembly, which focusses the beam on the target. The output aperture of the telescope is 60 centimetres in diameter, the beam focussed onto a much smaller area on the target itself. The large diameter of the beam initially would serve to lower the beam's intensity through part of its path. cutting losses. It may also serve to cancel part of the spreading/blooming due to turbulence. The hump aft of the telescope houses the acquisition and tracking radar system (no particular information released). The systems fitted to ALL are basically configured for air-air engagements of drones or air/surface-air missiles. Tests are carried out at the White Sands Missile Range. ALL is operated by a detachment of the USAFSC's 4950th Test Wing, from Kirtland AFB. New Mexico.

As of yet, little has been released on the results of the ALL test program, which began in early 1981. One report. about mid-year, appeared in the daily press, apparently leaked from USAF sources. According to USAF sources, the report stated, ALL failed to down an AIM-9 Sidewinder missile in flight, the test crew supposedly not knowing what went wrong. If the report is correct, it hardly points to anything significant - the AIM-9 is a relatively fast AAM with a fairly small size and radar cross section. Attempting to down it at a range, from a moving platform, does require a capable system. Were it a subsonic drone, then one could really say 'what went wrong?' The USAF will probably release a report at the end of the program, so all that one can really do is sit back and wait for the outcome.

The USAF's 1981 budget for the program involved $60 million. A comment by the Secretary of the Air Force, Hans Marks, in February this year, while observing ALL ground tests at Kirtland AFB, seems to indicate a growing interest in HEL weapons.

"We can now think about shooting down the other fellow's missiles without using nuclear warheads. I don't see any technical problems that are in the way. We know the Russians are doing a lot of work on lasers. But, as far as I know, they do not have a laser like this on an aeroplane. We're way ahead of them on this . . . In the next decade or so, I believe lasers in space will become an important part of this country's strategic arsenal."

It sounds as if the race is already on, in spite of all the DoD's information sheet assurances that the US is not engaged in a technology race with the USSR. There is no doubt that the Russians possess the physics; engineering expertise to develop a GDL or other HEL device, though they apparently show great interest in Western manufactured components, eg, high power 10.6 micron mirrors, but is is doubtful whether they would have the ability to develop the tracking system, as they are behind in electronics and their radar technology approaches early seventies Western technology.

As it seems, the US will be first to deploy HEL weapons, but one can only speculate when. 1995?

We are standing at a technological threshold, probably as significant as the time the first gun was invented. The door is open for a whole new sphere in warfare, the implications are staggering, one can only wait and see.

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