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LASER AND CHARGED PARTICLE BEAM WEAPONS

Introduction:

The idea of a lethal directed beam type of weapon has been a subject of science fiction for at least two generations. For more than five hundred years, warfare has been dominated by the need to produce weapons capable of launching projectiles of an almost countless variety for diminishing the ranks of an adversary. The projectiles have been designed to be lethal in themselves (e.g. bullets) or are designed to explode, producing the desired effect by virtue of high velocity fragments, flame, heat, or blast effects. Even nuclear weapons had to be delivered by sophisticated versions of well understood delivery systems but were capable of producing lethal radiological effects in addition to the more "traditional" blast and heat effects of chemical explosives.[1] Until recently, the dream of a high intensity directed beam weapon has exceeded the grasp of those who would develop it.

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[1] This capsule exposition is not to suggest that there have not been important differences between evolving military technologies. John Keegan's recent book, The Face of Battle (New York: Viking Press, 1976), clearly demonstrates the traumatic impact advances in military technology have had from the long-bow of Agincourt to the carnage wrought by artillery and the machine gun in the Battle of the Somme. The role of the machine gun in changing the character of military history is also well developed in John Ellis' The Social History of the Machine Gun, (New York: Pantheon, 1975).

Advances in physics in the past fifteen years have made it possible for some of the fundamental problems inhibiting the development of directed beam technology to be addressed. The synergistic progress in computer technology, microelectronics, and optics has made it possible to produce laser beams.[1] The engineering community has been quick to exploit these developments where uses could be found. Perhaps their most publicized role has been for the purpose of guiding certain types of weapons to their target. An observer can "illuminate" a target either from the ground or in an aircraft with a laser beam. Then a bomb or an artillery shell with an appropriate device (a "sensor") affixed to it follows the reflected laser beam to the target. Bombs and artillery shells employing laser sensors are a second-generation development of "smart bomb" technology that emerged from the Vietnam war. The first generation devices used in Vietnam were 3,000 pound bombs with a television guidance system rather than the laser-type (although an early version of a laser-guided bomb was employed in 1972). However, the problems of an adversary employing smoke or other countermeasures which would result in inadequate contrast for the TV guidance to work resulted in the employment of laser designators and sensors.[2] Now the employment of non-lethal laser devices has been expanded significantly. They are employed as range-finders on tanks and have early potential applications for communication purposes.

The most significant long-term potential for laser weapons lies in their strategic use as weapons. Unlike nuclear weapons, however, their most appealing use is not as an instrument of mass destruction but as a highly capable defense system against the entire range of airborne threats from aircraft to ballistic missiles.

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[1] "Laser" is an acronym for light amplified by simulated emission of radiation.

[2] The Vietnam conflict was not the first modern conflict to employ "smart" weapons, however. Germany employed radio-guided bombs to sink an Italian cruiser captured by the British Navy in the Mediterranean in World War II. In the Vietnam conflict, very accurate delivery was possible, often 5-10 feet from the target with laser and TV-guided bombs. Even though some of the devices cost as much as $50,000, the ability to destroy a high-value target with a single bomb from a single aircraft was far less costly than multi-aircraft raids. A single bridge in North Vietnam was never successfully destroyed by conventional bombing tactics although more than two dozen aircraft were lost in the attempt. In 1972, the bridge was destroyed by a single 3,000 pound precision-guided bomb.

In this vein, a less well-known but potentially spectacular weaponry with practical applications similar to laser weapons are charged particle beam (CPB) weapons. Such devices would accelerate a subatomic particle so that it would have a very high energy level. The particles so produced would be beamed at or near the speed of light against a target quickly causing destruction of the target. Given their velocity and power, they would thus have the capacity to destroy incoming ICBMs hundreds of miles from their destination.

Laser vs. Charged Particle Beam Weapons:

There are many unanswered problems in the physics and engineering of laser and charged particle beam weapon systems currently under intensive study in the defense establishments of both the United States and the Soviet Union.

The primary advantage of the charged particle beam type of weapon is that its performance is not significantly degraded by passing through the atmosphere as is the case with a laser beam weapon.[1] Thus, a charged particle beam weapon could be employed at a few ground based sites in conjunction with either earth-borne or space-borne radar systems to identify and track incoming ballistic missile warheads. The charged particle beam weapon could be rapidly pointed at the incoming warhead, and an infinite number of "shots" could be fired at the speed of light at the target until it was destroyed. These targets could be destroyed at very long ranges, and thus only a small number of these sites would be necessary. The concept of charged particle beam weapons currently involves very large fixed installations, and therefore they may become vulnerable to sabotage or other forms of attack by an adversary, or the sensor systems(radar or other types) on which the CPB depends to find its targets could be attacked, rendering the system ineffective.

Laser technology is currently in an extremely rapid state of development, particularly high energy lasers of the type that

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1 One commentator, Richard L. Garwin, writing in International Security, (Fall 1976), argues against the cost-effectiveness of laser weapons for anti-aircraft, anti-cruise missile , and anti-ballistic missile employment when ground-based. Laser weapons require so much electrical power to penetrate the atmosphere with enough energy to destroy their target that, according to Garwin, more traditional types of systems would be more effective within the bounds of present laser technology. There is a belief that the pointing accuracy of a particle beam weapon may be influenced by anomalies in the earth's magnetic field, but there is too little evidence available to support any firm conclusions.

could become candidates for space-borne applications. Funding activity for high energy lasers now accounts for two percent of R & D expenditure and may rise to five percent or more in the early 1980s.[1]

Now most of the expenditure is in the "research" rather than development phase. The latter phase became costly because engineering prototypes rather than laboratory experiments must be made to prove concepts. If some of the concepts now being researched in a laboratory environment prove to be effective, prototyping of the concepts would follow quickly.

Because of the inability of laser weapons to be employed efficiently in the atmosphere, the laser weapons will almost certainly have to be based in space or at least in the upper atmosphere. This means that there will be no significant attenuation of the power of the laser beam, and the airborne or spaceborne target it seeks to destroy will be more easily identified and tracked. However, it does pose significant problems of being able to generate sufficient power in space to provide sufficient energy to perform effectively as a weapon. In addition, such a system will have to be capable of being efficiently deployed in space and be able to survive in such an environment in the event that the Soviets develop effective anti-satellite type systems which could be employed against the weapon or develop countermeasures which are effective against laser weapons.[2]

It cannot be forecast whether laser or charged particle beam weapons will become a reality in the near future. Both have serious strengths and weaknesses that interfere with current operational requirements for a directed beam defense weapon. Based upon current defense requirements (i.e., the threat posed by ballistic missile warheads),charged particle beam weapons would probably be preferred by the defense establishments in both the United States and the Soviet Union because the added burden of space basing is not required. However, the development

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1 The future of the Air Force is most directly affected by potential developments in high energy laser weapons. Although the investment of laser R & D in the Army and Navy has been reduced in the FY '78 budget to the level of FY '75, investment in laser research for the Air Force has been increased. See Edgar Ulsamer, "The New Five Year Defense Plan," Air Force Magazine, January 1977, p. 64.

2 Reflective surfaces and evasive maneuvers may impose more stringent requirements for power generation in space which may not be met by a spaceborne laser weapon.

of the Space Shuttle by the United States may make it practical to place very large payloads in orbit cheaply, thus making space-deployed laser systems highly attractive.[1]

Soviet Activities in Laser and CPB Research:

Little is known in the unclassified domain about the extent of Soviet research and development activities in the laser and CPB field. For several years, theoretical work by Soviet scientists was published in the open international scientific literature, but the subject went "underground," presumably in the classified domain, in the Soviet Union when its military application was more widely appreciated in the early 1970s.

Nevertheless, the scale of the Soviet effort appears to be vast. One published account describes the Soviet effort as approximately $1 billion annually in both the laser and CPB fields.[2]

Considerable recent interest has been stimulated by a difficult-to-explain "blinding" of a U.S. observation satellite by what was initially diagnosed as a laser weapon. Subsequent explanations by U.S. officials have attributed the blinding to an intense natural gas pipeline fire in an isolated portion of the Soviet Union.[3] Another explanation may have been associated with

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1 There are some important applications of high energy lasers in space that do not necessarily lend themselves to the antiballistic missile role such as high resolution imaging for space object identification, beamed power transmission or intraspace propulsion. The deployment of any of these capabilities in space would pose serious problems for arms control because spaceborne laser ABM systems are prohibited by treaty. See B. J. Smernoff, "Channeling High Energy Laser Technology Through Arms Control: Some Critical Ambiguities," in International Security (forthcoming).

2 J. W. Canan, The Superwarriors, (New York: Weybright and Talley, 1975), p. 273; and "U.S. and Soviet Reported Trying to Perfect Anti-Missile Beam," N.Y. Times, February 5, 1977.

3 In the testimony of Dr. James Wade of the Department of Defense before the Committee on Armed Services of the House of Representatives, December 15, 1975, Dr. Wade dismissed the ability of lasers to destroy satellites from the ground.

an attempt to employ lasers for the ground-based physical characterization of satellites, a major objective of the U.S. laser program.[1] This would make it possible for the user to identify many of the technical details of a spaceborne vehicle without the time-consuming processing of intercepted electromagnetic radiation from the satellite or related techniques now relied upon to provide information about Soviet space vehicles. Because the wavelength of a laser beam can be measured with extreme precision, it is possible to exploit lasers for very precise measurement at great distances even if they are not otherwise employed for military purposes.

Since the signing of the ABM Treaty by the United States and the Soviet Union in 1972, it is understood that the Soviet Union has a very energetic research and development program in ABM technology including "conventional" ABM involving ground-based radars and interceptor missiles as well as more exotic forms such as laser and CPB weapons. One hypothesis which is consistent with the evidence available but which cannot be proved is that the Soviet Union is satisfied with the restrictions of the ABM Treaty under the existing strictures because they cannot develop an effective ABM technology of the conventional type. Conventional ABM technology depends very heavily on the ability to construct and deploy large-scale computer systems capable of controlling advanced radars and missiles throughout the Soviet Union. "Leap-frogging" to laser or CPB technology would permit them to avoid areas of technology in which they are weakest and concentrate in areas where they have demonstrated considerable strength: optics and nuclear phenomenology. There is a school of thought within the U.S. intelligence community, currently a minority, who believe that the Soviets are far more advanced in laser and CPB technology than most specialists now believe.[2] This is a particularly difficult arena in which to make judgments because U.S. scientific personnel have little experience of their own with which they could compare. Unlike other types of technology where the United States has been the first developer, we are unable

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1 See the testimony of G. Heilmeier, Director of the Advanced Research Projects Agency, Department of Defense, Senate Armed Services Committee, March 9, 1976.

2 For a comprehensive review of what is known and conjectural about Soviet directed energy weapons, see C. A. Robinson in Aviation Week and Space Technology, May 9, 1977.

to know what theory may prove to be practical to produce an effective laser or CPB weapon. Thus, it is virtually impossible to ascertain with high confidence whether or not the Soviet Union is either far ahead or far behind our own efforts. Based upon those efforts which can be observed, it seems clear that the Soviet effort, in terms of resources invested, dwarfs our own; this however is not always a reliable guide to results. Conclusive evidence may only be known after a technological "Pearl Harbor."

Guidelines for Future American Research:

While it is not feasible to predict where important scientific advances will take place, it seems reasonable to anticipate that lasers will have a major role in military forces by the end of this century, and perhaps well before that if important breakthroughs are achieved. Evolutionary development of current laser technology assures a place for lasers in target designation, communication, ranging, and imaging. Plausible future developments of current laser concepts make the application of lasers to propulsion and power transmission and to the ABM role a serious possibility as well.

CPB weaponry is a much more difficult issue to assess. Basic problems in physics and engineering remain to be solved, and it is unlikely that any mere evolutionary development of existing technology will be sufficient to make CPB technology available for weapon purposes, particularly the ABM role.

What is required is, first, an expansion of resources and interest in the pertinent technologies. There is a danger that, because anti-ballistic missile defenses are currently proscribed, policy-makers will be persuaded that research in the field is not worth doing. In fact, over the long term, ABM technology may be the best answer to the problem of nuclear proliferation, and thus may well be brought back into prominence some years hence by Soviet-American agreement. Moreover, an active R & D program is the only means we have of maintaining an understanding of the areas where rapid technological advances are possible so that we may not be caught unaware if the Soviet Union suddenly makes unanticipated progress in the field.

Second, a diversified rather than a centralized research effort must be maintained so that an excessive amount of resources is not devoted to any single approach. There is an inherent danger in government funding that a particular approach may become bureaucratically fashionable to the disadvantage of promising alternative approaches.

Third, a "mobilization base" must be developed to work on the rapid deployment of a laser or CPB weapon system if it can be developed, or an alternative form of ABM defense if it cannot, as a hedge against a Soviet breakthrough in the field. The implications of a Soviet breakthrough, particularly in CPB weapons, are critical because the entire basis for mutual deterrence in the nuclear age could be upset with unmeasurable consequences for our security.

Finally, the tactical technological applications of laser research should be promoted vigorously. The tactical applications particularly of laser weapons are important to almost every area of modern warfare and may lead to breakthroughs affecting strategic warfare more rapidly than if the research focused on strategic warfare alone.