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A crash program for developing beam-weapons defense systems

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Within the next few years a technology could be developed which would, in the words of President Reagan, "render nuclear weapons impotent and obsolete." Most experts now agree that by using the most advanced beam and laser technologies combined with "conventional" anti-ballistic missile (ABM) designs based on anti-missile missiles, an effective ABM system could have its first military applications in two to three years and be fully deployed for defense against ballistic missiles in five years. *These experts emphasize that the present ABM research program in the United States is limited by funding and not by technical or scientific difficulties.*

The remaining problems in beam weapon development fall into three areas, all of which are immediately amenable to a crash engineering effort:

1) **The development of high-power lasers.** There are two most promising types of laser under development, both of which are far enough advanced to be rapidly accelerated with large amounts of funds and manpower. The first of these, the chemical gas dynamic laser (hydrogen-fluoride, krypton-fluoride, or carbon dioxide) has already produced large power outputs in prototype devices and must now address problems of repetition rates, reliability, and lifetimes. The second, a much newer and more advanced device called an x-ray laser, is for technical reasons well-suited to a large-scale engineering program.

2) **The perfection of guidance, optical, and space technologies.** The tolerances in pointing, tracking, resolution, target acquisition, and battle management required for ballistic missile defense have been realized in current scientific and military systems. The completion of these technologies and their integration into a functioning command and control system for an ABM system is entirely dependent on funding and manpower levels.

3) **The implementation of launching and maintenance capabilities.** The large increase in space-engineering capabilities demanded by deployment of a spaced-based beam component of an ABM system is a formidable task, but one entirely solvable by an Apollo-style space engineering effort.

With the solution of these three engineering problems, a first-generation ABM system could be fielded in prototype form in the next two to three years, with full deployment in the next five.

The structure of a crash program

The efficient achievement of this goal requires the Department of Defense at the level of the Joint Chiefs of Staff to establish an aggressive research, development, and demonstration program for perfection of anti-ballistic missile systems. The objectives of the program are:

- to begin deployment of all available conventional ABM technologies for near-term protection against nuclear bombardment;
- to proceed immediately with the work necessary to deploy high-energy beam systems within the next five years based on x-ray/EMP (electro-magnetic pulse) and microwave technologies, complemenary with the conventional ABM system, that could provide a defensive capability against a small number of nuclear armed intercontinental ballistic missiles;
- to accelerate research and development of short-wavelength laser and particle-beam programs, with the goal of determining the optimum research and development path for succeeding generations of beam weapons designed to provide complete protection of the United States in case of nuclear war, and of putting this system in place within a decade;
- to coordinate with the National Aeronautics and Space Administration (NASA) the construction of a large, near-Earth-orbit space station and the space engineering capabilities required for such a station;
- to provide for the rapid civilian industrial proliferation and implementation of as many of the advanced plasma, laser and automation technologies as possible, as they arise in the development of beam weapons;
- to take appropriate measures, modeled on the National Defense Education Act as originally adopted, to ensure the provision of adequate scientific and engineering manpower for the development of these weapons systems and their civilian applications.

We concentrate here on the first two of these tasks.

The status of ABM technologies

Two types of currently available technologies can be used for near-term ABM system development. "Conventional" technologies (anti-ballistic missile missiles, for example) can be immediately developed for ABM missions. Second, the first generation of directed-energy beam systems (using chemical lasers, EMP bursts, and high-intensity microwaves) can be developed and deployed on approximately the same time scale. This second type of system provides not only near-term defense capabilities, but also a natural continuum to the most advanced x-ray laser and free-electron laser capabilities.

Conventional Systems: The United States is currently capable of accelerated development and deployment of three conventional (non-beam) ABM systems:

1) **The F-15 fired anti-satellite (ASAT) missile.** This missile is currently being flight tested. The system utilizes simple vehicle collision intercept to destroy low orbit satellites. With a slight upgrading, such as the addition of a very small nuclear warhead, this system would make a deployable terminal point defense against incoming warheads. Current public projections state that only a few score of these ASAT missiles will be deployed by 1985. A slightly increased program realizes hundreds by sometime in 1984. The system would only provide a limited ballistic missile defense (BMD) capability, but could prove crucial in the near future in defending hard military targets such as missile fields.

2) **Low Altitude Defense System (LOads).** LOads consists of a series of conventional terminal point BMD systems. These range from environmental defense—where buried nuclear bombs explode when incoming warheads approach hardened targets, throwing dirt and rocks in their path and thus destroying them before they can detonate near their targets—to conventional short-range intercept with missiles, and defensive basing modes for offensive weapons themselves. Many of these systems could be deployed to provide point defense for hardened military targets within one to two years.

3) **Homing Overlay Experiment (HOE).** HOE is based on matching conventional ABM intercept with advanced infrared target diagnostics and compact computer chip control. HOE consists of a multi-stage rocket which pops into space an interceptor which is guided by long wavelength infrared telescopes and other diagnostics to collide with an ICBM or its bus or warhead. Before colliding with the target, HOE deploys as a large net. The high relative velocities, tens of kilometers per second, lead to certain destruction once a collision course is achieved. HOE is capable of both point and area defense roles. Because of its long range and rapid pop-up deployment mode, HOE is particularly useful against accidental or third party launches in the near future. A crash program could realize the deployment of hundreds of HOE units over the next two years.

First-generation beam-based systems: There are three bands of the electromagnetic spectrum usable—with present technologies—for ABM systems.

1) **The chemical laser.** Producing energy in the infrared band chemical lasers can be used to burn up ballistic missiles as they are launched. The power density of the infrared light is low enough that these lasers would not be effective against re-entry vehicles but would be very effective against missiles in the boost phase, satellites, and other soft targets.

2) **X-ray/EMP devices.** Using high-intensity, bomb-produced bursts of x-rays, this precursor to the more advanced x-ray laser can be used to generate electromagnetic pulses to destroy missiles and reentry vehicles.

3) **Microwaves.** High-intensity relativistic electron beams can be used to generate microwave beams of sufficient intensity to destroy missiles after the last ("bus") stage is released, or to attack the warheads themselves after they are ejected from the bus.

The use of chemical lasers for beam defense is the basis of the existing U.S. research and development program. The so-called Triad program, involving experiments on laser development, large optics for control of the laser beam, and point and tracking, has been limited in funding since its inception. A crash program for ABM development must upgrade this program significantly. Projections are that a space-based demonstration of these chemical laser technologies could be made in the next three years in a "hybrid" basing mode in which the laser itself is on the Earth and the large mirror and control systems in orbit around the Earth.

These chemical laser systems are, according to most estimates, too large and vulnerable to function as a defensive system in real wartime conditions. However, they are a critical part of a crash program for two reasons: First, they provide a near-term, long-range capability for destruction of a small number of missiles that might be launched by accident or by a third power. Second, the very stringent pointing and tracking requirements of such a device provide an engineering test laboratory for similar requirements for accurate target acquisition and aiming demanded by second and third generation, short-wavelength systems.

Less well-known than the chemical laser beam system is a device that generates high-power pulses of electromagnetic radiation in the x-ray band and then uses this radiation either in a form which directly interacts with the target (called system-generated EMP) or with the environment around the target (usually called EMP).

System generated-electromagnetic pulse occurs as the result of generation of large, non-uniform current pulses in the exterior of the target due to x-ray deposition. This leads to the irradiation of the interior of the target with a large EMP generated by these currents.

The generation of electromagnetic wave pulses over large areas can be directly accomplished from high-altitude nuclear explosions, generating an EMP which covers millions of square miles. Through a complex plasma process the small fraction of one percent of the bomb energy, released in the form of high-energy gamma rays, ionizes and energizes the resulting free electrons through Compton scattering. The Earth's magnetic field traps these high-energy Compton electrons, creating a time-varying current flow, which in turn leads to the generation of EMP perpendicular to the direction of the current flow.

These intense currents can be used to provide a lethal means of intercepting launch boosters, jets, cruise missiles, buses, and even reentry vehicles. By making use of shaped charges using nuclear explosives and the deployment of materials for ionisphere modification, it is possible to greatly concentrate and amplify EMP pulse generation. This would provide the means for destroying even hardened targets. EMP offers a near-term, wide-area—albeit leaky—missile defense system.

Intense microwave beams can also be used to destroy incoming nuclear-armed missiles. Microwave technologies, at the opposite, long-wavelength end of the electromagnetic spectrum from x-rays, have in the past several years made major advances in the production of very high-intensity sources using plasma and electron beam processes rather than the conventional vacuum tube processes.

In the earliest of these devices, called plasma masers (microwave amplification through spontaneous emission of radiation), a plasma medium is used to create the same kind of coherent, monochromatic radiation that a laser does at shorter wavelengths. Utilizing lower energy electron orbitals for achieving inverted populations in atoms and molecules, new plasma masers are under development which can convert several percent of a thermonuclear explosive's energy into a coherent beam of microwaves.

Other possibilities exist in which plasma jets are utilized to generate, through explosive flux compression or magnetohydrodyamics (MHD), large electrical currents which in turn can be utilized to generate large relativistic electron beams. These beams can then be used to generate microwaves.

The power densities achieved in laboratory devices are already enormous. Reports of power densities exceeding one gigawatt per square centimenter are published in the open literature. These devices can in many cases be scaled up several million-fold to energies that would be provided by a nuclear energy source (pump). For example a laboratory megajoule pulsed power system will generate 100,000-joule microwave bursts. A kiloton nuclear detonation will generate 100-billion-joule bursts.

Microwaves only interact with conductors and specific molecular vibrational modes, in particular those found with oxygen-hydrogen bonds in water and organic molecules. Because of this, microwaves propagate with little loss through the atmosphere at fairly large power densities. While assured kills with microwaves will only be achieved with soft targets, it is quite possible that system-generated electromagnetic pulses could lead to killing of hard targets. Microwave beam weapons provide a very cost effective, easily deployed, and efficient extensive defensive screen for the full range of targets.

Second generation beam systems: As these three first-generation beam systems are developed and deployed, a crash program must be pursued in parallel research on more advanced systems. The most important of these are the eximer laser (closely related to current chemical lasers), the x-ray laser (the successor to the x-ray/EMP device), the free-electron laser (the successor to the high-power microwave devices), and particle beams.

1) **Eximer Lasers.** A large program already exists for the development of relativistic electron-beam-driven eximer lasers. Los Alamos Scientific Laboratory has built and demonstrated the optimal scale amplifier for this system in the KrF mode. Combined aperature multiplexing has been theoretically demonstrated for laser pulse compression and is being experimentally explored. The eximer laser combines shorter wavelength (out of the infrared, which is strongly absorbed by the atmosphere) with dramatically lower costs (in the range of $100 per joule). This system would be based on higher elevations since the short wavelengths it generates do not propogate through the atmosphere efficiently. It would be combined with both pop-up and deployed orbiting mirrors for interdiction of all types of targets. The system could be utilized for both target acquisition and kill.

2) **X-ray lasers.** Current information indicates that the United States is months to a few years away from perfecting the bomb-pumped x-ray laser to a sufficient level for pop-up deployment against launch vehicles. The x-ray laser energy density deposition on launch vehicles should achieve kills using between 10 and 100 joules per square centimeter in pulse lengths of several nanoseconds. Given that the pop-up deployment of these systems takes place from bases and submarines located near the borders and projected trajectories of enemy ICBMs, kill distances would range from several hundred to several thousand kilometers. The predictable and necessary trajectory of launch vehicles guarantees that pop-up systems can be deployed in time to achieve these types of 1,000 kilometer range intercepts.

Rather straightforward considerations of the physical principles of x-ray lasers indicate that they can achieve total energy per beam pulse output approaching several hundred billion joules. At the 10 joules per square centimeter lower limit, a beam with a diameter approaching one kilometer at the indicated beam pulse energy would achieve a kill of a launch vehicle. This means that the beam divergence and pointing accuracy are of the order of .001 radians. The human eye is sufficient to attain these accuracies and the existing early warning/spy satellite systems are far better. Therefore this first generation version of x-ray laser defense might be deployed as soon as underground testing proves successful. As x-ray lasers are improved, these systems will utilize higher-energy density kills against harder targets at longer ranges.

3) **Free-electron lasers.** Free Electron Lasers (FELs) will first be combined as efficient amplifiers (10 to 25 percent efficiency) with eximer laser inputs. It should be noted that Betatrons are the most likely candidates for providing FELs with their pump electron beams. Development and deployment could be achieved within three to five years. The com-

bination of eximer and FEL is done primarily to attain higher system energy efficiencies. By the end of the decade fully tunable pure FEL with efficiencies ranging up to 50 percent are attainable. The high efficiencies and variable wavelength make the FEL one of the most important candidates for more advanced applications of beam weapons, including submarine detection and destruction.

4) **Particle beams.** Particle beams are distinguished by the mass of the particle being accelerated, ranging from the lighter of the subatomic particles (electrons and muons), to neutral atoms (so-called neutral beams), to small assemblages of plasma (called plasmoids), up to macroscopic particles. Each of these technologies must be pursued for the realization of a high-energy particle beam capable of destroying the hardest of targets, the reentry vehicle.

The major current U.S. research program in particle beam weapons is concentrated on two accelerators, the Experimental Test Accelerator (which is operational) and the Advanced Test Accelerator (soon to be completed). These devices generate multi-megavolt beams of extremely large current (multi-megamp). The results made public from experiments on these devices give very optimistic scaling laws for larger devices.

More advanced particle accelerators, with energies higher by several orders of magnitude but with much smaller currents, can be used as the driver for a second or third generation system. Multi-terravolt muon beams offer the prospect of achieving the most efficient form of tuned kill of nuclear warheads with a long-range terminal defense system. The generator for the multi-TeV muon beam would be a 40 TeV proton beam. When the proton beam hits a target, measons are generated which decay into muons. High-energy muons interact anomalously with heavy nuclei. Beam propagation through the atmosphere is extremely efficient. This means that a few thousand joules of muons could incapacitate a warhead. The accelerator needed for generating TeV muons would be up to 100 kilometers in diameter and take three to five years to build. Ongoing muon interaction tests could be completed before the prototype accelerator is completed. Three to five accelerators, each with an effective range of several thousand kilometers, could give most of the United States an ideal terminal defense.

Tremendous interest has centered in the past year on the possibility of using high-density, self-structured plasmas as projectiles to generate a plasmoid beam weapon. High-velocity plasmoids, if they can be made to efficiently propogate either through the atmosphere or space, will provide the capability of achieving extremely efficient target destruction. The elemental and physical structure of the plasmoid can be designed such that on impact it will generate intense forms of energy (gamma rays, x-rays, EMP and particle beams) which are capable of achieving a tuned kill. These systems are under active theoretical study but no large experimental program yet exists.