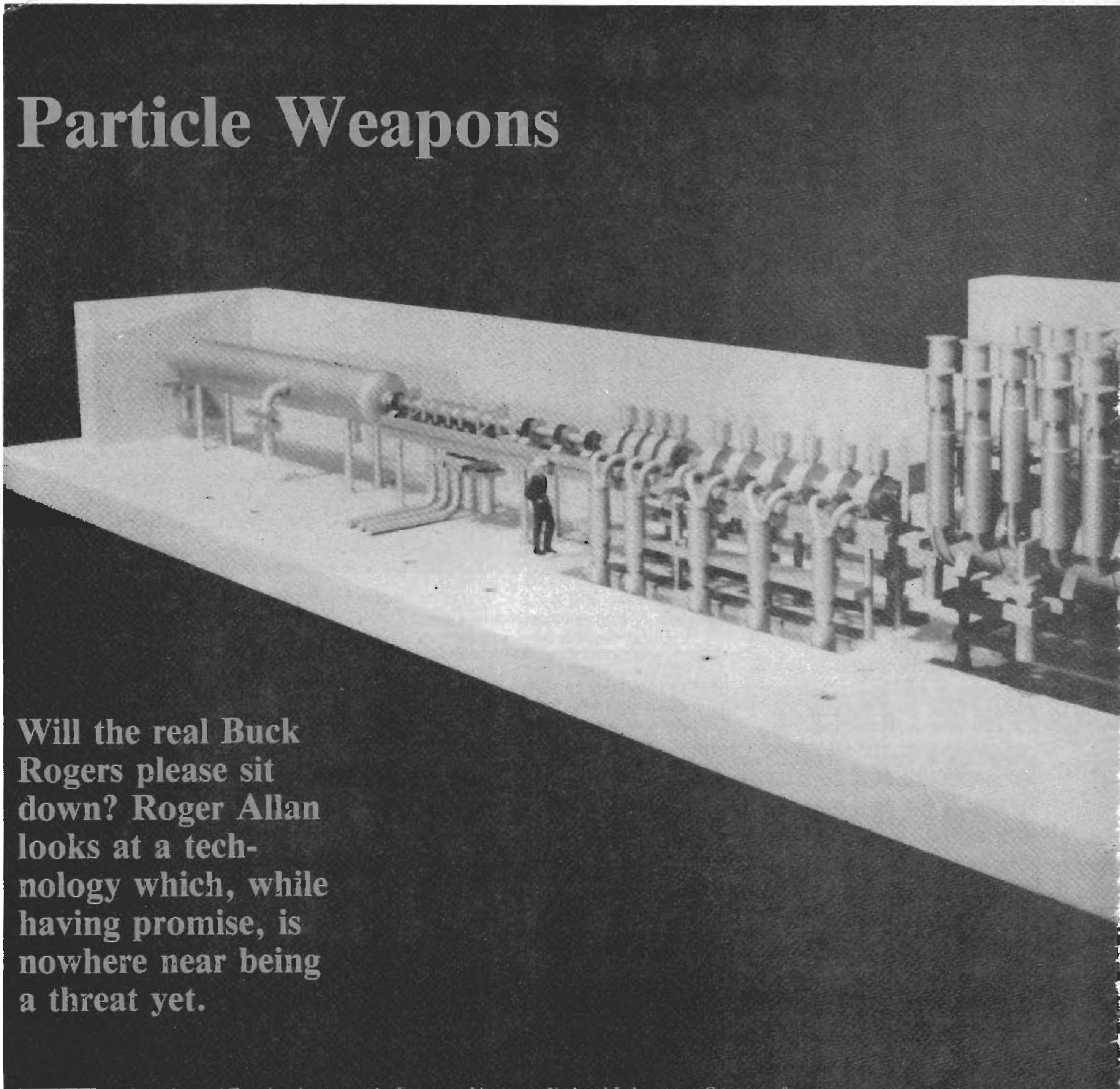
Particle Weapons

Will the real Buck Rogers please sit down? Roger Allan looks at a technology which, while having promise, is nowhere near being a threat yet.

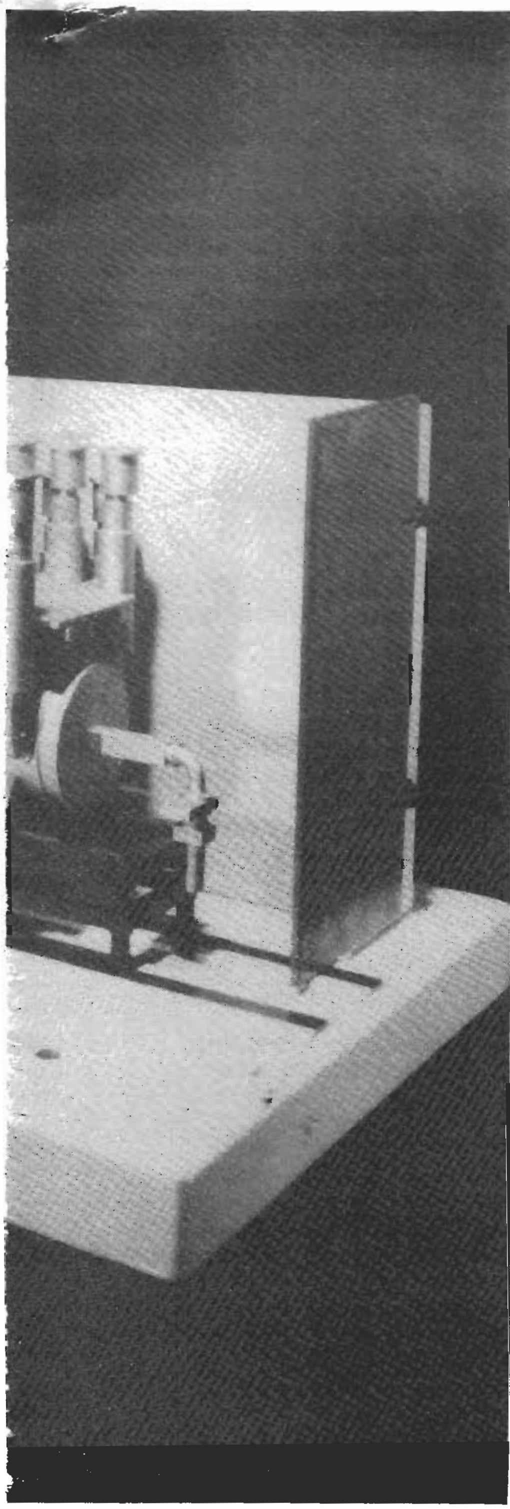


A model of the Experimental Test Accelerator at the Lawrence Livermore National Laboratory. Courtesy of U.S. Department of Defence.

A PARTICLE BEAM is a stream of highly energetic atomic or subatomic size particles such as electrons, protons, hydrogen atoms or ions. By comparison, laser beams are composed of radiant energy photons. Presently, aside from potential applications as weapons, particle beam machines have potential for use in inertial confinement fusion for energy generation, nuclear weapons effects simulation, heating and welding, high intensity microwave generation, geophysical investigations, energy transmission, medical treatment, and basic physics experiments.

Consideration of the use of particle beams as weapons actually dates back to World War II, but the technology of the times could not support such a concept. The early U.S. Department of Defense efforts on particle beams were started by the Defense Advanced Research Projects Agency (DARPA) in 1958 under a program codenamed SEESAW.

The initial potential "mission" was ground-based strategic defense against ballistic missiles (ABM), with work centered at the Lawrence Livermore National Laboratory (LLNL) which dealt with electrons as the particles used to form the beams. SEESAW was terminated in 1972 due to the projected high costs associated with implementation as well as the formidable technical problems associated with propagating a beam through very long ranges in the atmosphere. One of the major difficulties in beam propagation is the bending of the ray. Sub-atomic particles, no matter how small, have substance or mass, and as such are affected by gravity and magnetism. As such, at long ranges, one cannot shoot a bolt in a direct line, but rather has to take into account the earth's magnetic field, which



bends the rays. As the earth's magnetic field is in a constant state of flux, aiming the weapon is extremely difficult.

Department of Defense interest was reinstated in 1974 when the United States Navy initiated the Chair Heritage program, again involving an electron beam development program. The Navy perceived an application to defense of ships against all forms of attack by aircraft and missiles. The Chair Heritage program differed in two ways from the DARPA program, which effectively increased its probability of success. First, the required range of the electron beam would be significantly shorter than for the SEESAW mission. Second, the beam was intended for point defense rather than for defense of large land areas, and the asciated costs would therefore be lower. In 1977, the Chair Heritage program was shifted from a weapons to a technology base program due to a realization that major technological uncertainties still remain. In 1979, at the urging of Congress, the Chair Heritage program was transferred to DARPA.

In 1979 the United States Army initiated a second distinctly different path by starting the exoatmospheric, neutral beam program which is directed toward producing beams of electrically neutral hydrogen atoms. The Army also began a seperate program to demonstrate "proof of principle" of a collective accelerator concept for producing high current ion beams. In fiscal year 1981 these programs were transferred to DARPA.

For several years the United States Air Force has been funding basic research on particle beam technology directed to several topics, including collective acceleration, propagation modelling and target effects. The Air Force has also been involved in developing new accelerator technology and propagation analysis for atmospheric applications, as well as initiating studies in areas that may be important for space applications: ion sources, beam control and power. The Air Force intelligence activities have also provided key information on Soviet technology efforts in particle beam development.

Beginning in fiscal year 1981, and continuing to the present day, DARPA has total responsibility for assuring technical compatibility of all United States military efforts. Due to the extremely high cost of any work in this area, and due to the poverty of funding for the programs ($49.6 million for 1984 — absolute peanuts in any military budget) two realities of this area of study become clear: that DARPA is essentially the only organization involved in this work in North America; and secondly, that that they are getting nowhere very, very, quickly due to lack of funding, with no weapon system even at the concept stage, much less on the horizon.

However, President Reagan has made public pronouncements on the use of "space age technology" as a nuclear deterrent, and so one is obligated to consider what he might mean, even if it is only hypothesis.

Beaming Particles

There are three key components of a hypothetical particle beam weapon system: the source of the beam — the beam generator — consisting of a particle acclerator and its associated supply of electrical power, energy storage and conditioning. The accelerators are similar to those used in research in elementary particle physics except that currents in the beam are much higher. The elementary particle research devices such as the two mile long Stanford Linear Accelerator have been widely publicized as "atom smashers." Second, there is a beam control subsystem to aim the beam at the target and determine that the beam has hit the target. Lastly, the particle beam weapon must have a fire control subsystem which acquires all the targets that need to be engaged, selects the one to engage, and tells the beam control subsystem where to look to find it. Then the fire control system decides when the target has been destroyed and designates the next target. These fire control functions do not differ materially from those of fire control subsystems for other more familiar weapons.

An appreciation of the damaging effect of highly energetic particles striking an object can be seen in many ways. The most easily visualized is the damage lightning can do when it strikes a tree or a house. In high energy physics, experimenters have long been aware of the ability of the highly energetic particles produced by atom smashers to penetrate into materials. As the beam penetrates, it transfers some of its kinetic energy from the particles to the material and, in addition, generates secondary radiation in the material which can also disable the target. If there are enough particles in the beam hitting the target, the rapid transfer of energy to the material cannot be dissipated by the material. Thus, the beam can cause a hole to be burned or melted into the material, or a fracture from thermal stresses as a result of the rapid deposition of energy. A third example of effects can be taken from discoveries in the early days of space flight. Energetic charged particles generated largely by the sun are trapped in the earth's magnetic field thereby forming the "Van Allen" belts. These natural particle beams require spacecraft designers to build shielded and resistant satellites if flights in or through these belts are to occur without damage to such "soft" components as computers or electronics.

As such, one can envision a weapon based on a stream of highly energetic particles that travel at or near the speed of light. This stream of particles would penetrate the metal skin of the target, transferring a large fraction of the energy in the beam to the target. Initially, as the beam enters the target it would damage electronic components and as the beam continues to deliver energy to the target, ignite fuels and explosives and/or create holes in the target ripping it apart.

In warfare, therefore, the theoretical beam weapon shares several "attractive" attributes with other forms of beam weapons (eg. high energy lasers. See "Military Lasers," ETI, November, 1983) in handling target tactics and scenarios that stress the capabilities of missiles and guns. For example:

— near speed of light delivery of destructive energy on line providing the earth's magnetic field is compensated for.

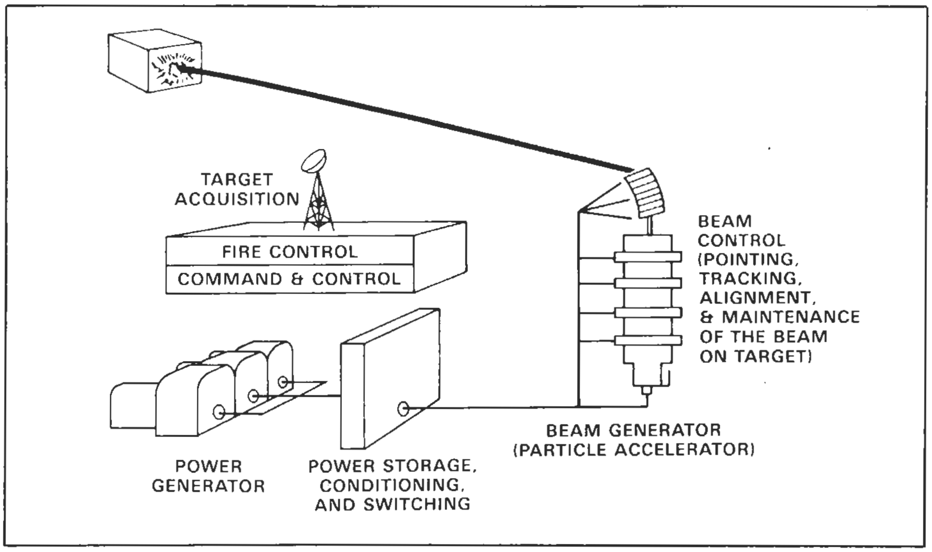
— potentially large numbers of engagements before exhausting the available "magazine" as the "bullets" of a particle beam are, in effect, generated by the electrical power input to the beam generator.

— instant penetration through the skin of the target to destroy or disable key internal components or to ignite fuels and explosives.

If particle beam weapons are feasible, their use of energetic particles as the "bullets" offer two characteristics that reinforce those attributed to beam weapons in general, specifically:

— Since the particles can pass into the target and damage internal components without first burning a hole in the skin, the dwell time of the beam on the target could be quite short, even on targets that are hard to penetrate using other beam types. Keeping dwell times short allows the weapon to defeat the tactic of closely spacing the targets to saturate the weapon system.

— unlike laser weapons, the particle beam weapons can penetrate clouds and rain, giving the potential for an all weather weapon.



The basic layout of a particle beam weapons system.

Raygunomics

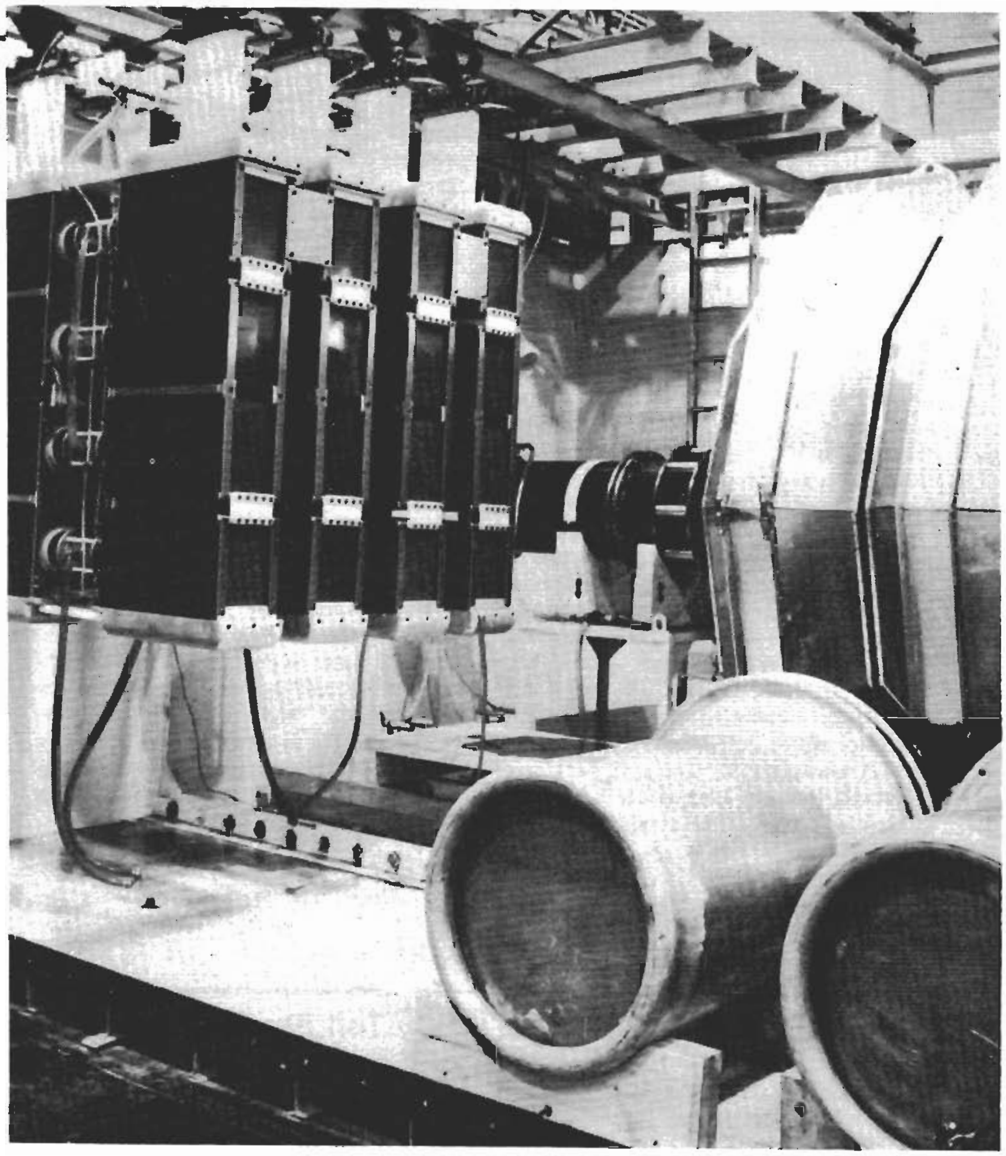
It is recognized by all and sundry, with the possible exception of President Reagan, that particle beam technology is in the very early research and exploratory development phase, with fundamental issues of feasibility still to be resolved. How this is to be done, bearing in mind the high cost of experimentation and the low funding levels, is not explained. There is an enormous gulf between the technology required for fulfillment of the conceptual payoffs and the state-of-the-art. At this stage of development, DARPA has only defined generic "missions" to use as a basis for setting the technology goals. The key variables in these generic missions are range required, particle types used in the beam, and whether the deployment is in the atmosphere or outside of it. Conceptually, defensive applications (eg. defense against attack by ballistic missiles, other types of guided missiles, and aircraft) are the logical underpinnings of their current research. This research is divided into a number of distinct sub-sections:

Beam Generators: The beam generator produces the intense, high energy beam of particles that represent the "bullets" of the particle beam weapon. Broadly speaking, charged particles are injected into an electric potential or voltage which gives the particles a "push" and accelerates them to high speeds. Kinetic energy is added to the particles by an amount equal to the product of the charge on the particle and the potential drop. Kinetic energy is proportional to the mass of the particle and increases with the velocity. Since the mass of the particles is small, their velocity is near the speed of light. The power of an accelerator beam is the product of the current in the beam and the potential drop. For example, an electron or proton has a charge of 1.6×10^{-19} coulomb. A potential drop of a million volts will provide it with an added 1.6×10^{-19} joules or one million electron volts (MeV) of energy. One ampere of current (6.8×10^{18} particles per second) falling through a potential drop of a billion volts has a power of a billion watts. Finally, if the billion watt system is pulsed for a millionth of a second, the pulse energy is 1000 joules or the approximate energy equivalent of raising a 750 pound weight one foot.

U.S. Department of Defense efforts can be broken down into two major thrusts: charged particle beam accelerators suitable for use only within the atmosphere, and accelerator systems capable of producing energetic neutral atomic beams for use only outside the atmosphere.

DARPA efforts are currently being placed on the development of high-current, moderate energy charged particle accelerators which are suitable for propagation experiments. A major part of the funds applied to the particle beam effort during the funding years 1983-84 is devoted to accelerator development. The main efforts in this line is the Experimental Test Accelerator (ETA) and the Advanced Test Accelerator (ATA) which are experimental electron accelerators.

The ETA program was completed in 1981. Since then it has been used as a testbed for ATA technology. It is currently being used to examine techniques for modifying the risetime and radial profile of electron beams to improve their propagation stability. The current program, ATA, produces 50 MeV electrons with a current of 10 kiloamps. It was completed in 1981 and is now used regularly, though only at low power. After the electron beam from ATA has been diagnosed, sometime late this year, it will be used for beam propagation experiments. These experiments, DARPA hopes, will provide the necessary information to show that electron beams can propagate stably for useful distances in the atmosphere.



RADLAC I as it appeared in 1981. Photo courtesy of U.S. Department of Defence.

A smaller effort is being pursued under the Neutral Particle Beam Program ("White Horse") at the Los Alamos National Laboratory to develop the accelerator technology required to accelerate negatively charged ions to high energies. Once high energy is achieved the excess electron is removed, thereby forming a neutral beam which can be directed over long distances in the vacuum of space. Experimental demonstration of the feasibility of generating low-divergence neutral particle beams forms the major element in this program.

The balance of this element in the DARPA program is directed toward investigation of various exploratory accelerator concepts that could have significant impact on the feasibility of this weapon system. The object of these investigations is to take advantage of new technologies which might become available for accelerator construction. An example is the Radial Line Accelerator program at the Air Force Weapons Laboratory, co-funded with the Department of Energy. The radial line accelerator concept proved feasible with the successful completion of RADLAC I in mid-1980. Presently, efforts are underway to examine a new class of transmission line accelerators in RADLAC II, scheduled for completion later this year. The RADLAC program is complementary to the DARPA ETA program in terms of the intended program physics experiments.

Beam Control/Point Tracking: Beam control subsystems for charged and neutral particle beams present technology requirements that are beyond the present state-of-the-art in all cases and without a technology basis in some cases. All are being addressed with a nominal development effort. The Air Force is principally responsible for neutral beam control and tracking. Efforts include design of a system that can sense the beam and provide the necessary extraction and pointing.

Prime Power and Conditioning: Efforts in prime power and conditioning are primarily associated with high repetition rate switching which is capable of handling the high currents used in accelerators suitable for charged particle beam weapon applications. Other efforts involve high voltage pulse forming networks, experimental capacitors and dielectrics, and new materials for high density storage systems.

Propagation of Charged Particle Beams: A major goal in the program is to provide experimental proof that charged particle beams can propagate through the atmosphere with sufficient power, arriving at the target at the ranges needed for weapon system applications. The major part of this effort is being performed by DARPA with emphasis on experiments with the ETA and ATA accelerators. The joint Air Force — Sandia National Laboratory RADLAC accelerator is used in this program.

Material Interaction, Damage and Effects: To understand what it takes to make a particle beam an effective weapon, research and experimentation is required to determine the interaction of particle beams with materials and components, the damage that results and the effects on target capabilities. The goals of the program for material interactions are to provide early assurance, as yet unforthcoming, that the beam can do lethal target damage. Should this element in the program succeed, the data generated will also define the beam power levels needed to assist in defining the R and D objectives in accelerator and pulsed power technology.

Star Wars

In summary, the objectives of the particle beam technology program are to determine feasibility and to develop the critical technologies required once feasibility has been demonstrated. The great majority of the available funds in the next few years will be devoted to building accelerators that can generate the high-current, high-power beams essential to verifying existing theory, theory that, according to DARPA, predicts that beam propogation will be adequate for weapon feasibility.

As for the Soviets, their efforts are judged to be larger than that of the United States, particularly in the area of accelerators for fusion applications, and to have been in progress much longer. However, according to Department of Defense sources, there is no direct correlation between Soviet particle beam work and weapons related work.

Putting it all together, one therefore finds that there are half a dozen major problems to be solved, that some of the problems do not even have a theoretical basis for solution, and that funding for the research is strictly nickels and dimes. Perhaps President Reagan should have had a chat with his military advisors before embarking on a "Star Wars" scenario.

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