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PARTICLE BEAM WEAPONS : *A need for re-assessment*

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Recently a number of articles have been published in various scientific, technical and military journals on the possible use of high energy particle beams as weapons[1]. One of the most recent was a review article published in *Nature* early this year[2]. Although one of the few objective articles written on the subject, it contained a number of technical errors. Since the consequences of such weapons, should they become a reality, are so far reaching, an accurate as well as an objective analysis of the state of the technology and its future prospects is very important. In this letter, therefore, we wish to point out some errors and omissions made in the *Nature* article so that any future studies on the subject do not suffer from possible, if only slight, loss in credebility.

For instance, the beam dispersion calculations are done using formulas outside of their range of validity; the conclusion on endoatmospheric proton beam propagation can be misleading; the heating of the air in the region of the beam comes mostly from ionisation losses, even in case of electrons the bremsstrahlung's contribution is negligible; and the figure used for the atomic density of air at STP is incorrect so that errors are introduced in several numerical calculations.

The article also suffers from a lack of adequate discussion on the endoatmospheric use of particle beams (i.e. for point defense against cruise-missiles or incoming re-entry vehicles) and their target damage capabilities.

The problems of beam propagation in the atmosphere are complex and different particles (e.g. electrons, protons and ions) of similar kinetic energies behave differently with different propagation ranges so that they have to be treated separately. In the relative vacuum of the outer space, propagation is mainly affected by the Earth's magnetic field and, therefore, discussion in this case are confined only to neutral particles (i.e. hydrogen atoms).

As for the propagation of high energy particles in the atmosphere, contrary to the suggestion made in the *Nature* article, a proton beam, in principle, has better atmospheric propagation properties than an electron beam. We have numerically integrated the full equation of the beam expansion theory developed by Lee and Cooper[3], taking beam energy loss and beam intensity loss into account. According to our estimates, a proton beam pulse with an intensity of 10 kA and a kinetic energy of 1000 MeV would propagate in air at standard temperature and pressure up to 350 m. After this distance the beam breaks up. Under the same conditions, a similar pulse of an electron beam or an alpha ion beam would propagate up to about 150 m. For 10 kA and 10'000 MeV beam pulses, we find ranges of 200, 500 and 600 m, respectively for electron, alpha ion and proton beams.

In the same *Nature* article, little consideration is given to the intense electromagnetic (or nuclear) cascade that is generated by a beam of electrons (or protons) as it propagates through the atmosphere or interacts with the target. In the case of an electron beam, the electromagnetic shower produced by a 100 ns long, 10 kA, 1000 MeV beam would result in a radiation dose of about 2000 Rem per pulse within a diameter of 10 m around the beam axis and over a distance of about 400 m. A few such pulses would thus direct towards the target a narrow radiation beam of an intensity sufficiant to upset the electronics or to kill people, without the beam having to score a direct hit.

Moreover, contrary to laser or heavy ion beams, which interact with the target only at its surface, electron, proton, or light ion beams can penetrate the target and thus inflict potentially more severe damage. This is particularly important as it renders shielding against such beams more difficult. Furthermore, a beam of protons in the 1000 MeV energy range on hitting a heavy target would generate a nuclear cascade with a substantial flux of spallation and evaporation neutrons[4]. If the target contains a nuclear warhead, the neutrons could enter the fissile material causing the atoms to fission and so generate large amounts of heat.

All these various aspects show the complex nature of such weapons and point to the fact that apart from the long range strategic applications discussed in the *Nature* article, short range tactical applications of these weapons should also be considered. This is particularly needed because in this mode particle beam weapons may be less prone to countermeasures. Also, a proton or light ion beam has some potential as an ABM system and may compare favorably with other fast and short range ABM systems.

The use of particle beams as weapons is an old idea, probably going back to World War II [5]. Even at this time it was realized that one of the major problems was the question of beam stability. Very extensive theoretical studies were therefore conducted in the 1960's on this question by many prominent US physicists working in collaboration with the JASON division of the Institute of Defence Analysis[6]. It was found that the propagation of charged particle beams through ionized gases may be hindered by many possible instabilities. It was not until the construction of powerfull high current accelerators that these theories were put to test experimentaly. It was discovered in 1967 [7] that stable propagation of short but intense pulses of charged particles were possible through air, but at a reduced density corresponding to a pressure of a few torr. Similar propagation experiments were subsequently performed in the USSR, investigating the stability question at atmospheric pressure as well[8].

These results, together with the considerable development of the accelerator technology led to renewed speculations on the military potential of particle beams, and triggered an extensive coverage of the subject[1,15]. It may be prematured to draw any final conclusion on the feasability of particle beam weapons, but the rather pessimistic conclusions drawn in the *Nature* article do not seem to be supported by the large amount of effort been put at present into the research and development on such weapons and related subjects.

Research directly related to particle beam weapons includes further testing of high intensity beam propagation in air at various pressures at the Naval Research Laboratory[9], the study of reduced pressure gas channel formation by pulsed laser[10], the development of new accelerators such as the 50 MeV, 10 kA induction linac at the Lawrence Livermore Laboratory[11], or the autoresonnant accelerator (suported by the US Army Balistic Missile Defense Advanced Technology Center)[12] which is expected to accelerate protons to an energy of 1000 MeV in a few tens of meters[13]. For fiscal year 1981, approximately $35 million is budgeted for particle-beam technology by the Department of Defense. The major objective of this programme is to demonstrate the feasibility of stable exo- and endo-atmospheric propagation of high power beams[14]. Probably similar efforts are being made in the USSR also[15].

Research indirectly related to particle beam weapons includes of course that devoted to laser beam weapons and the considerable resources being poured into the development of inertial confinement fusion devices triggered by high energy lasers and various particles beams. Similarly, the construction of large and powerfull accelerators for both military and civilian purposes will slowly but surely help to solve many technical challenges implied in the construction of accelerators suitable for beam weapons applications.

Finaly, it is worth noting that the current proliferation of accelerator technology has serious implications on several other arms control issues. The development of particle beam weapons, particularly their tactical use on Earth and their long range use in outer space by technologically advanced nations will certainly add a new dimension to the arms race. It is thus very important to properly reasses the beam weapons question, especially in view of the clear need of international agreements to prevent the misuse of the modern particle accelerator technology.

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