nature 18 January 1979

The next generation of weapons

In the late 1960s there was widespread debate in the United States on the advisability of installing defences against intercontinental ballistic missiles (ICBMs). At that time the intentions were to install radars around sites to be defended and to fire nuclear-armed rockets at any incoming missile. A defending rocket would not necessarily have to score a direct hit on an attacker—a nuclear explosion in its vicinity would suffice.

Such an anti-ballistic missile, or ABM system would have cost an immense amount and could have hardly guaranteed 100% protection. Further, its very existence would have been an encouragement to the nuclear superpowers to find means of rendering it ineffective. On the other hand, even a partial defence of a major constituent of a nation's deterrent was not to be lightly dismissed. In the event, after long and highly-informed public technical discussions, it became clear that neither superpower was strongly committed to ABM, and a bilateral treaty was signed in 1972 severely restricting deployment.

Military technology has not stood still, however, and new ways of attacking targets such as ICBMs have recently been the subject of a growing amount of interest. Are lasers or particle beam weapons a serious option? Research is being carried out in the United States and almost certainly in the Soviet Union to try and answer this question, and recently debate has moved into the public arena, notably with Richard Garwin's article on beam weapons in the October 1978 issue of the *Bulletin of the Atomic Scientists*, and with a series of articles in *Aviation Week*, also in October, on beam weapons research.

A report has recently been issued by MIT's Program in Science and Technology for International Security (*Particle Beam Weapons*, obtainable from the Department of Physics, MIT). In it, a study group reports in technical terms on the pros and cons of beam weapons in the environments both of space and on the ground.

A beam weapon damages its target by cracking its outer shell, by damaging the electronics or by exploding the warhead's trigger. Typically, to do any or all of these things with a beam of area one square metre, of the order of 100 megajoules would have to be delivered. This is not impossible. On the ground jet engines could be used; in space 60 kilograms of high explosive detonated per second would provide the necessary energy per pulse.

Propagation is more problematical. In space, charged particles are of no use. They leave an opposite charge on the generator which attracts them back towards the gun; it is estimated that a 1GeV, 1,000 amp electron beam with a 1-cm radius would get only a metre beyond the accelerator's exit port. Even if a charged particle beam could propagate, it would be degraded over thousands of kilometres by Coulomb repulsion, and deflected by the geomagnetic field which is imperfectly known in space.

Neutral beams don't suffer the same problems, but even so, gamma-rays and neutrons are not easily concentrated to square-metre cross-sections at thousands of kilometres. Hydrogen atoms look more promising. They can be accelerated in a linear accelerator to several hundred MeV as hydrogen with a second electron in the 2s state, or H^-. The beam can then be aimed with a magnetic lens and the electrons stripped by passage through gas. The divergence introduced by stripping leads to a less than ideally concentrated beam, but even so the components of a hydrogen-beam system appear, in the words of the report 'physically feasible'.

Within the atmosphere, charged beams ionise air and this ionisation makes propagation possible. On the other hand the beam is degraded both in energy and cross-section by scattering. What can happen, however, is that a beam of, say, electrons depositing energy along a path through the atmosphere heats that channel, and within a small fraction of a second air density has dropped to a tenth, or even less of normal. In effect, a hole can be bored through the atmosphere, and for perhaps one-tenth of a second can permit pulses of electrons to travel relatively unimpeded. Many questions remain to be answered, but the possibility of an electron beam of a few thousand amps, consisting of ten thousand or more 100-nsec pulses, being able to damage an incoming missile 'cannot be excluded'. Nor, the group find, is there any compelling reason to conclude that exoatmospheric accelerators for H^- atoms or ground-based electron accelerators could not be built at some time in the future.

Even if the system can be made to work, however, it has to do so in conditions of war. In space a hydrogen beam might be used either against satellites or to attack ICBMs. At ground level an electron beam might be used as a terminal defence against ICBMs or, at sea, to protect a ship against cruise missiles. In all instances a direct hit is called for (which means accuracies from radars of up to a few parts in a million), and even after such a hit there may be no immediate indication of success. And if the beam misses, it seems near to impossible to determine by how much. Further, the system is open to all the jamming measures that were once discussed in the ABM debate and if the accelerator were in orbit and receiving instructions from the ground that link would be particularly vulnerable. What is more a hydrogen beam would be completely disrupted by the slightest amount of air in space, so a defensive measure could be to fire an explosion in the upper atmosphere, lifting air into space.

The ABM debate is being replayed. An immensely difficult and expensive technical mission, with serious questions at every turn, will be ventured into for fear that the other side just possibly might secure an advantage. There are powerful forces to move the programme forward and spend a lot of money; and for all we know there could be success at the end of the road. There is an arms-control means of stopping development, however. The 1972 treaty noted that if ABM systems 'based on other physical principles' emerged, discussions would be held on limiting such systems. Beam weapons clearly fall into this category. Talks should start soon, even if at present there are no plans for deployment. □