plant was not supposed to begin before late 1978.

The role of the breeder steering committee turned out to be pro forma only. The committee finished its work on the evening of 6 April, and Carter announced his breeder policy the next morning. The committee's membership was heavily weighted with nuclear industry representatives and breeder program officials, but in the end it did not make much difference. Two conflicting reports were drawn up by two segments of the committee,* one stressing that the breeder would be needed in the next few decades because of the limited supply of uranium, the other recommending cancellation of breeder demonstration plans, saying that the country could safely rely on "proliferation resistant uranium-conserving reactors over the next century." The minority report used ERDA's uranium estimate (3.7 million tons), and characterized its finding as insensitive to the growth rate of nuclear power through the year 2000, so long as the nuclear generating capacity leveled off early in the next century.

The policy that came out of the White House was remarkably similar to that recommended in the Ford Foundation–MITRE Corporation report, *Nuclear Power, Issues and Choices*, which stressed the diseconomy of reprocessing and breeders. But when representatives of the Ford-MITRE group—largely Washington insiders—briefed the steering committee, they were met with accusations of being dovishly aligned with the Arms Control and Disarmament Association (ACDA) and being incapable of judging the breeder program plan because no member had "hands on" nuclear experience. The acrimonious tone of the 3-hour briefing prompted Hans Landsberg, of Resources for the Future, to write to Thorne that it is "unfortunate" that the advocates of nuclear power seem to think "one must either buy the whole package—reprocessing, the breeder, and all—or else be considered an antagonist." Although the Ford-MITRE report was widely hailed as a sensible approach to the problems of plutonium and nuclear power, inside government circles the trend toward considering proliferation as a major component in nuclear policy was started more than a year ago by an ACDA report, "Moving toward life in a nuclear armed crowd?"

In spite of the firm announcement about plutonium and the unequivocal rejection of reprocessing, the Carter breeder policy leaves the program, and the Clinch River project in particular, in an ambiguous position. The only thing that seems sure at this point is that extra delay will be introduced into a project that has been delayed for most of its existence.

Some observers think Carter is planning to study the Clinch River project until it slowly dies, even though that would mean writing off $500 million that has already been spent on design and equipment. But the leading alternatives would apparently allow the project to go ahead in a form that would look remarkably like the original plan to anyone but a nuclear engineer—and, perhaps more importantly, could be readapted to the original plan at a later time.

While the new plutonium policy was designed to send abroad a strong signal that the United States has changed its nuclear intentions, a close reading of the policy with respect to the government's biggest nuclear energy project indicates that so far very little has changed.

—WILLIAM D. METZ

Particle Beams as ABM Weapons: General and Physicists Differ

The Soviet Union is successfully developing a proton beam as an antiballistic missile device, whereas the American effort to weaponize a charged particle beam was abandoned because it was staked on electrons.

So said Major General George J. Keegan, former head of Air Force Intelligence, in an elaboration to *Science* of a recent press briefing at the American Security Council in which he warned that the Soviet Union is "20 years ahead of the United States in its development of a technology which they believe will soon neutralize the ballistic missile weapon as a threat to the Soviet Union."

Keegan, who retired from the Air Force this January, has a reputation as a worst case analyst who sees Soviet military developments in the most threatening light. Other military analysts believe his views on the Soviet lead with the particle beam are overstated. Keegan himself says his aim is "to provoke and make enough people angry" about the situation.

Physicists knowledgeable about military affairs say that even if the beam weapon were possible, it would have all the same problems of conventional ABM systems, such as vulnerable radars and huge cost. "Keegan has put together a story from all kinds of odds and ends gathered together. He is trying to explain some facts and facilities for which there is no known purpose, but there are other explanations besides his. Even if what he is pointing to is a particle beam program, it takes a long time between demonstrating something in the lab and deploying it in the field. We could be there in 2 years, wherever that is," says a physicist involved in defense matters.

Accounts in the national press within the last 2 months have quoted unnamed military intelligence sources as saying that the Soviet Union has devoted an effort on the scale of the Manhattan project to developing the charged particle beam as an antimissile device.

Physicists who work at particle accelerators know that if the beam is discharged into a brick, the brick will absorb the energy and explode. In accelerators, however, the beams are propagated in a vacuum. Firing a beam through the atmosphere is a different proposition. But should it be feasible, a beam might deliver more energy than would a laser, say, on an incoming missile during the few seconds it was within range.

In his American Security Council briefing, published in the 28 March issue of *Aviation Week*, Keegan states that the Soviets "have every expectation that well before 1980, if they don't blow themselves up—and they may—[they] will perceive that they have technically and scientifically solved the problem of the ballistic missile threat."

In an interview with *Science* Keegan confirmed that the weapon he referred to was the charged particle beam. He said the Russians were working with a proton beam accelerated by an "explosive power generator." High power, in his view, is the solution to all the problems in

beam technology, such as getting the beam to propagate through the atmosphere, keeping it focused, and achieving burn-through. But American scientists have disbelieved his assessments of what the Soviets are doing, and in their own efforts to develop beams "have simply failed to deal with the power levels which would have solved the problem of beam propagation—all their calculations were wrong," Keegan avers.

He used part of his own budget to fund research on the problem and achieved "several major pioneering breakthroughs. I went to young geniuses under 29 who weren't slaves to the conventional wisdom." As a result of his efforts there is now a "massive new interest" in particle beams, but the program, directed at alternative power sources, is underfunded, the general says.

Keegan adds that the concept of using particle beams as weapons was first invented by British scientists in 1944 to 1945, but "they kept the thing from the United States on the direction of the Prime Minister. They abandoned the project because they could not get enough power. The failure in the United States is that for some reason we experimented with electrons." The electron beam experiment, known as Project Seesaw, was closed down 4 years ago.

The villains of the piece, in Keegan's view, are those who didn't believe his warnings, chiefly the CIA and scientific advisers. "One hundred percent of the effort has been devoted to disproving my hypotheses. The CIA has played the dominant role in that." As for technical reviewers, "I am absolutely contemptuous of the American scientist in this kind of business—he is worse than an ostrich," Keegan opines.

Keegan's account is difficult to verify, but on those points which can be checked, others tend to hold different opinions. The issue of Russian progress with particle beams, for example, was discussed at a hearing held on 16 March before the Senate arms control subcommittee. Jeremy Stone, director of the Federation of American Scientists, told the committee that the idea of using particle beams as weapons "has been invented and reinvented almost every year since there were these particle accelerators," and that it would be surprising if there were not ten Russian scientists thinking about the problem at any given time. Lieutenant General Daniel O. Graham, former head of the Defense Intelligence Agency, said that the Soviet Union had a "very strong effort" directed at the perfection of energy beam weapons of one sort or another. But,

Maj. Gen. George J. Keegan, Jr.

Graham added, presumably in reference to Keegan's statements, "I think the case as to where they stand now can be and has been overstated. I don't think . . . that they have perfected a weapon that can in any way interfere with the strategic balance at this juncture."

As to the history of American interest in charged particle beams, the CIA refused comment on Keegan's criticisms. A source in a position to have an opinion said he did not agree with the charge that scientists had given Keegan's ideas unfair review: "Any quasi-exotic military application gets a rather detailed scrutiny, and people who become enthusiasts for one scheme or another frequently feel stymied when they fall into the kind of grilling that scientists are accustomed to give new ideas."

As to the technical feasibility of using particle beams as weapons, none of several physicists consulted said the concept was possible but none dismissed it out of hand. "It doesn't violate the second law of thermodynamics," observed a scientist knowledgeable about military interest in the particle beam concept. "Just getting the beam to propagate over the long distances has been thought of as the principal difficulty. You have high current beams of relativistic particles. No matter how you slice it this means very large powers. Also the design of a suitable accelerator is rather problematical."

The same scientist remarks that interest in particle beams "has been a cyclical thing over the years. It is probably fair to say that the cycle at present is on the upswing as far as interest goes." Asked if some new technical development was the cause of the upswing, he noted that Keegan had been advocating the same views in private about Soviet particle beam technology for some time before he started discussing them in public.

The "explosive beam generator" referred to by Keegan involves the use of high explosive to move metal through a magnetic field. The device produces high power for a short instant. One of the originators of the concept was Soviet nuclear physicist A. D. Sakharov. But it has not been ignored in the United States. "We have had explosive power generators and we know how to make them," says a physicist.

Scientists knowledgeable about military matters see the particle beam issue in a wider context than does Keegan. A West Coast physicist says that "In principle it could be possible but even if it were, I would seriously question if it would be worth doing. You would need radar systems and a very large accelerator and I doubt if it would be cheaper than a conventional ABM system."

The same objections are voiced by an East Coast physicist who says the only new system advantage offered by particle beams over conventional interceptors is the possibility of putting the beam system on a satellite and directing it at missiles shortly after their launch. The advantage of a "boost-phase ABM system" is that the target is a large rocket, not a cloud of Mirvs and decoys.

But there are severe problems with this system too. If the satellites are in high orbit they are very visible and vulnerable; if in low orbit, most are in the wrong place at any one time to be brought into play.

As for the beam, if the particles are charged they are liable to be deflected by natural variations in the earth's magnetic field, which in any case can be "wiggled" for defense. If they are neutral, as a stream of hydrogen atoms would be, a simple countermeasure would be to heat the top of the atmosphere with a near-space explosion, which would bring up tons of air and dissipate the beam.

"The trouble is that systems problems with any kind of ABM system are very severe," this physicist concludes. Particle beams have been considered for other military uses but are just not competitive. For ship defense, homing missiles do the job better. For airborne defense, the problem is that high-flying aircraft are very vulnerable to missiles and low-flying aircraft would require sensors in conjunction with the beam, a situation in which missiles are again more competitive.

Keegan has his own reasons for believing the Russians have found a way to use particle beams as weapons, but the view of at least some physicists seems to be that particle beams are most useful inside accelerators.—NICHOLAS WADE