MARS/A. Moore

Will the towns and villages of West Germany be the nuclear battlefield of the future?

Armour defuses the neutron bomb

The neutron bomb gave the designers of nuclear weapons their most exciting technical challenge. The proposals to deploy it in Europe provoked unprecedented political conflict within NATO. The weapon itself has no military value

John Harris and André Gsponer

ON 23 OCTOBER last year, the French government exploded a nuclear weapon at its test site on Mururoa atoll in the Pacific. The test was almost an anticlimax, following as it did the scandal created by the bombing of Greenpeace's flagship and the death of a photographer on board. It is widely believed that the French exploded a neutron bomb at Mururoa. The neutron bomb—or the enhanced radiation weapon, as it is technically known—has been the subject of controversy ever since Edward Teller first proposed it 30 years ago.

On the morning of 19 August 1959, President Eisenhower's scientific adviser, the physicist George B. Kistiakowsky, had a visitor. His journal for the day noted: "10.30-11.30. Teller here. The meeting started with a mild mutual strain . . . Teller then went into a long discourse on the tremendous military importance of the 'pure radiation' small tactical nuclear weapons. I wasn't fully convinced, although they might be useful in some circumstances, but they certainly wouldn't be available for quite a few years."

Kistiakowsky's judgment was correct. No one has ever developed a weapon that releases pure radiation—a fusion warhead without a fission trigger. The next best thing, the enhanced radiation warhead, took 20 years to move from a physicist's back-of-the-envelope calculation to a tested weapon ready for the battlefield. Whether neutron bombs are useful is still in doubt.

The development of the neutron bomb posed several difficult technical problems. An acrimonious debate broke out over its deployment in Europe. The technical problems concerned the behaviour of the weapon's components during the microsecond or so that it takes for the fission trigger to initiate fusion reactions. The X-ray optics within the weapon also posed difficult problems. However, after testing a device at the test site in Nevada in 1963, designers knew that the concept was workable. But it was late in the 1970s before a weapon was ready for deployment.

The neutron bomb's political problems were equally serious. Ultimately, the issue strained the NATO alliance and contributed to Jimmy Carter's reputation as an irresolute leader. In the end, members of NATO reached a compromise: if the US produced the weapons, it would not stockpile them in Europe. This compromise has since been somewhat eroded. Currently, the US *does* stockpile the weapons in Europe, but the capsules of lithium deuteride and tritide that are the fusion fuel will remain in the US until the weapons are ready to be used. It is a distinction without a difference; in the event that the Warsaw Pact attacks western Europe, neutron bombs will be among the first nuclear weapons used to stop the attack.

The US has already produced several hundred W-79 warheads for its 8-inch howitzer, a gun that is nearly obsolete. The Americans are also starting production of 500 W-82 warheads for the 155-mm gun, the standard NATO field piece. Sources in Washington suggest that NATO's defence ministers gave secret support for the deployment of the weapons in Europe at their meeting last year in Montebello. The test at Mururoa may be the final stage in readying France's own neutron bomb for production.

The main justification for deploying these weapons is that they are especially effective against tanks. This argument is wrong. It is based on erroneous assumptions about how well modern tank armour can shield the crew of a tank from radiation. Neutron bombs are no more effective against tanks with modern armour than were fission weapons against tanks of the 1960s.

J. Robert Oppenheimer advocated small tactical weapons for the defence of Europe as early as 1951. Advocating what we would now call a war-fighting strategy, he wrote of weapons that would "give combat forces help that they would otherwise lack . . . only when the atomic bomb is recognised as being useful . . . will it really be much help in fighting a war . . .". But the first NATO exercise that simulated the large-scale use of nuclear weapons in the defence of Europe, Operation Carte Blanche in 1955, provoked a political storm when people realised that had the weapons been real they would have killed millions of West German civilians. The weapons' designers, continuing their search for a weapon that, as Oppenheimer put it, "could be recognised as being useful", began to focus on a weapon which would kill primarily by prompt radiation, and minimise the damage to civilian targets from blast, heat and radioactive fallout.

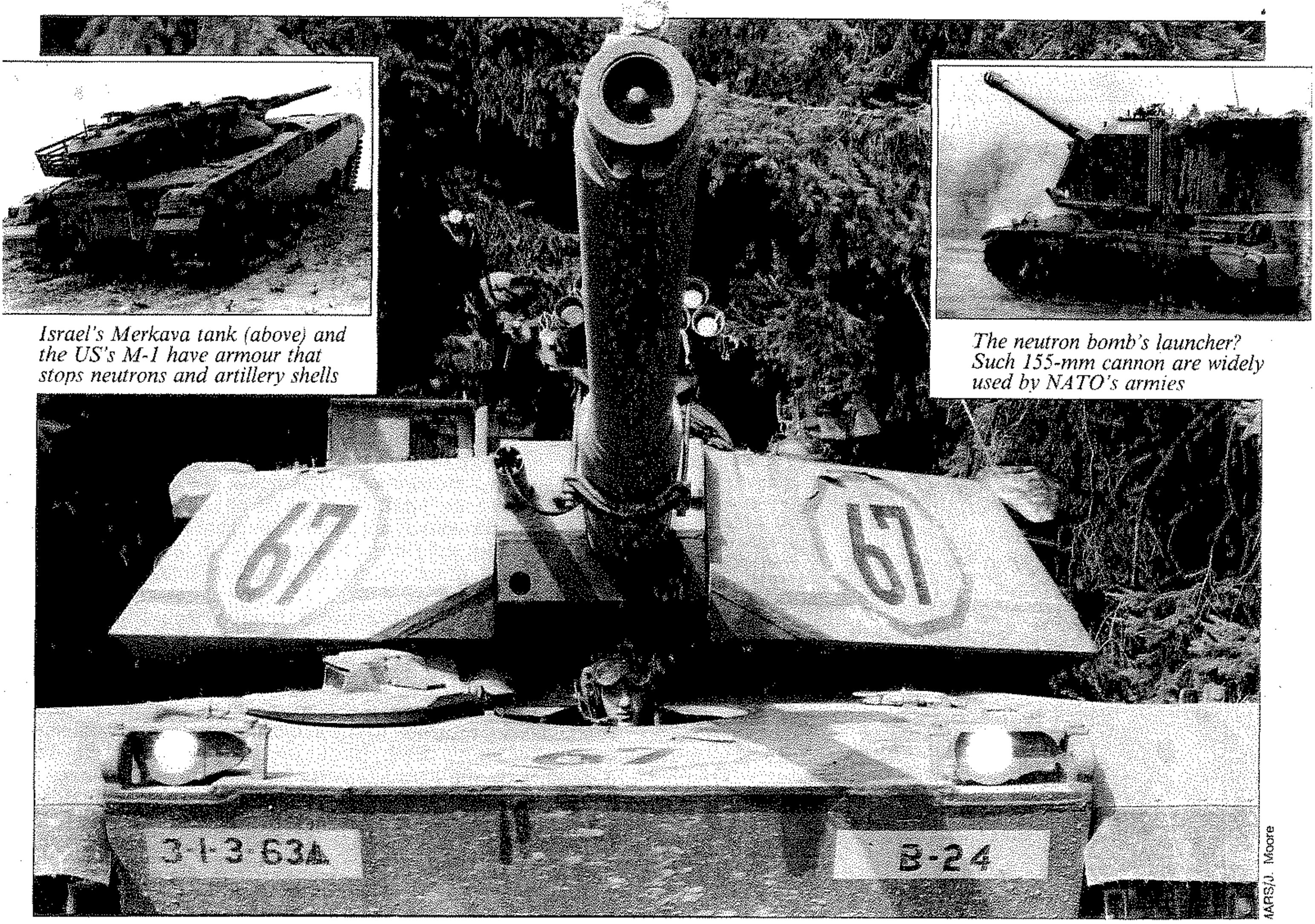
Thomas E. Murray, then a commissioner of the US Atomic Energy Commission, described the proposed weapon in a letter to the two presidential candidates, Richard Nixon and John F. Kennedy, in 1960: "It is primarily antipersonnel in destination and effect. Hence it is apt for properly military uses . . . and it need not create suicidal hazards for the country that employs it."

The argument that the proposed weapons would do less damage to buildings did little to solve the political difficulties with the European countries. West German leaders pointed out that, as their villages and towns are only a kilometre or two apart, the weapons would still kill many West German civilians. The knowledge that, as people died a slow death from radiation sickness, their barns and churches remained standing would do little to comfort them.

The main lobbyist for the new weapon was Samuel T. Cohen, a physicist at the US Air Force's main think-tank, the Rand Corporation. He became excited by the new weapon after a visit in 1959 to the recently organised Lawrence Livermore weapons laboratory. His enthusiasm was to lead to virtually a full-time career seeking support for the neutron bomb over the next ten years. That he became so deeply involved is more than a little surprising, because the Rand Corporation was set up by the US Air Force's Strategic Air Command (SAC), which had no interest in small nuclear weapons. Its one and only plan of war at the time was to deliver in one go the entire American stockpile of nuclear weapons to targets in the USSR, China and Eastern Europe.

For a time, the SAC's commander, Curtis LeMay, prohibited Cohen from giving his briefing on the neutron bomb outside the air force. Despite this, Cohen built a small group of supporters among the staff of the Atomic Energy Commission and in Congress. Some embraced the idea of the new weapons with almost a religious fervour. Atomic Energy Commissioner Murray wrote that unless the US moved ahead and developed the neutron bomb it would be "vulnerable to a wholly new kind of threat . . . nuclear blackmail assumes a new meaning".

The argument that the neutron bomb is specially valuable because it kills people without damaging property is, in the first instance, only a matter of degree. A 1-kiloton neutron bomb will destroy all but the strongest buildings within a radius of a kilometre or so. Nonetheless, critics began to dub



Israel's Merkava tank (above) and the US's M-1 have armour that stops neutrons and artillery shells

The neutron bomb's launcher? Such 155-mm cannon are widely used by NATO's armies

MARS/J. Moore

The technical challenge of designing the neutron bomb

ALL NUCLEAR weapons derive their explosive energy from the fission of nuclei of very heavy atoms, or from the fusion of nuclei of very light elements, or from a combination of both. When they explode, nuclear weapons release an intense pulse of heat, a blast wave, and a mixture of neutrons and X-rays. The development of the enhanced radiation weapon or neutron bomb presented two technical challenges.

The first problem that its engineers faced was to reduce the proportion of the explosive power that went into blast and heat and instead ensure that the weapon released most of its energy in the form of neutron radiation. As the bomb is intended for use on the battlefield, it has to be in a handy form for the front-line soldiers to use. The designers have been so successful in this second task, that it is actually a misnomer to refer to the weapon as a "bomb". All the complexity of the enhanced radiation weapon has been packed inside the casing of a standard 155-mm artillery shell.

Although the design of the neutron bomb is a closely guarded secret, the basic principles of nuclear weapons are now well known. Only three elements are capable of setting off the uncontrolled chain reaction from which a fission weapon gets its explosive yield. If enough of this fissile material is present to make a "critical mass", the neutrons released by each fission will strike other nuclei, splitting them and causing them to emit neutrons in their turn. This process, the chain reaction, proceeds exponentially, releasing enormous quantities of energy.

To set off a nuclear explosion, you have to convert a subcritical mass of fissile material into a critical mass in the shortest possible time. In most designs, the explosion is set off by the implosion technique. Such weapons consist of concentric spheres of material. At the centre lies a hollow sphere of fissile material that is just less than a critical mass. This is surrounded by a concentric spherical charge of chemical high explosive.

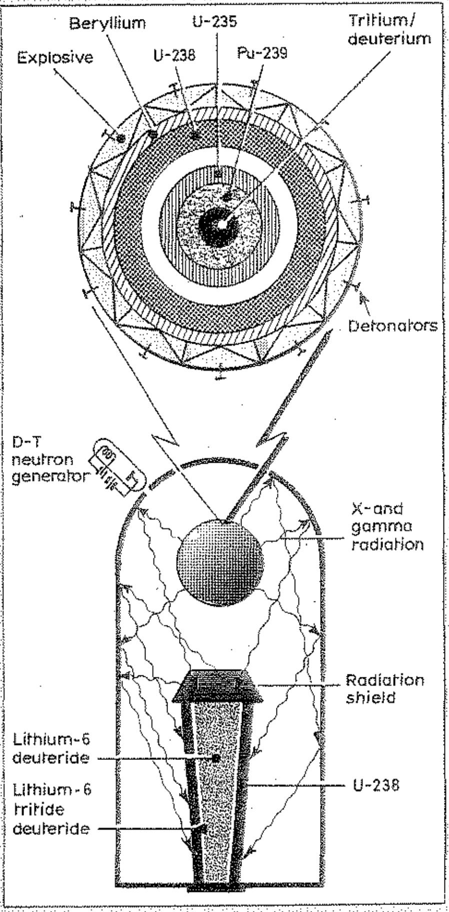
When a bomb explodes, the chemical high explosive is detonated uniformly to create a pressure wave that compresses the fissile material and makes the previously subcritical mass turn supercritical. In less than half a microsecond, the chain reaction will fission more than 10^{23} nuclei, yielding an explosion equivalent to a thousand tonnes of TNT.

A second design of fission device uses the gun technique whereby a subcritical mass is shot down a tube on to another subcritical mass. The bomb that destroyed Hiroshima was of this type.

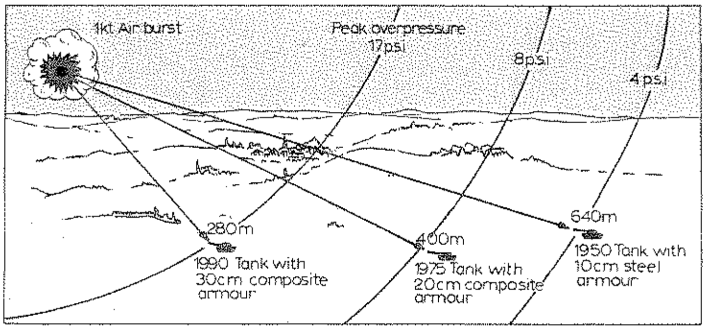
Fusion weapons depend upon deuterium, an isotope of hydrogen. This type of weapon forces the nuclei together rather than splitting them. Because the atoms involved in fusion are so light, between three and four times as much energy is released per unit weight from the fusion "fuel" as from the plutonium or uranium that "fuels" a fission weapon.

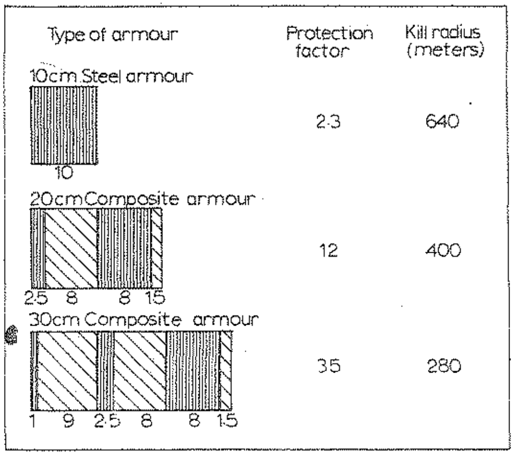
If fusion is to happen, then the fuel must be simultaneously compressed and heated to about 100 million° C. The only way of achieving these conditions simultaneously is by using a fission bomb as the detonator of the fusion explosion.

Tom Wilkie



Radiation from a fission explosion can trigger a fusion weapon





Type of armour	Protection factor	Kill radius (meters)
10cm Steel armour	2.3	640
20cm Composite armour	12	400
30cm Composite armour	35	280

The armour of a modern tank protects its crew so well that they would be destroyed by blast rather than radiation

it "the ultimate capitalist weapon". The need for the new weapon was recast in terms of the balance of forces in Europe and the penetrating power of the 14-megaelectronvolt (MeV) neutrons that nuclear fusion produces.

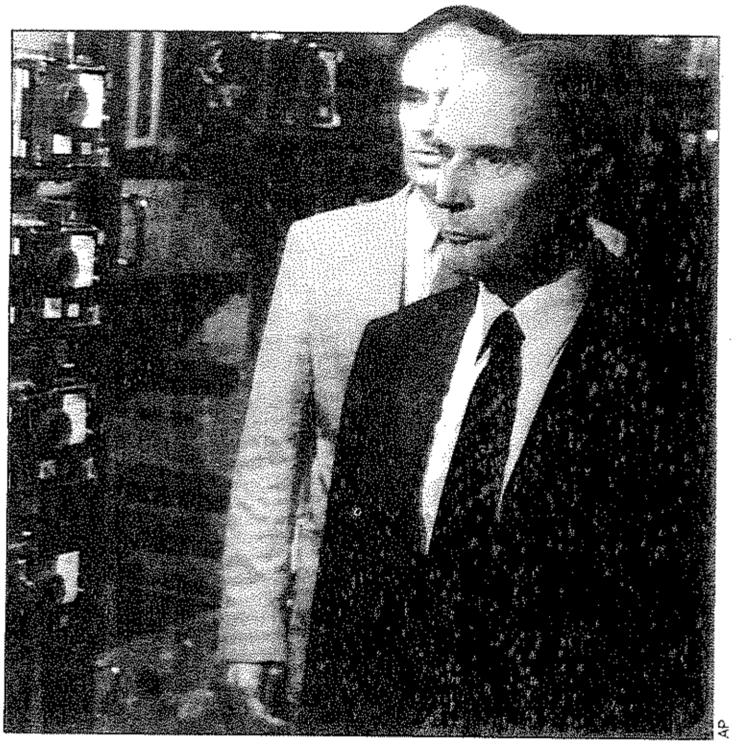
The need rested on the claim that the Warsaw Pact had substantially more tanks than NATO. War games had begun to focus on a scenario which has, over the years, become almost a convention. According to this scenario, the forces of the Warsaw Pact would "punch through" NATO's defences with a massed tank attack in north Germany. In the early 1960s, tank armour was made of standard steel, 10 centimetres thick, which does not substantially absorb 14-MeV neutrons. At a distance of 600 metres from a 1-kiloton neutron bomb, a tank crew would at once receive a dose of radiation of between 5000 and 10 000 rads. This dose would almost immediately incapacitate the crew. A fission weapon, however, emits most of its energy in the form of X-rays. To irradiate a tank crew to the same extent, a fission weapon would have to have almost 10 times the explosive yield. It would, therefore, create a much wider area of damage due to blast and heat.

The argument that neutron bombs would cause less damage but still deliver enough radiation to tank crews to put them out of action had considerable merit when strategists proposed it in the 1960s. Even in recent years, few commentators have questioned the technical facts. Kistiakowsky returned to the subject in an article, published shortly before his death, in the journal *Technology Review*, published by the Massachusetts Institute of Technology. In the article, he pointed out that one can enhance the shielding effect of tank armour by a factor of five or so, simply by adding about 10 centimetres of hydrogenous material. Others have since pointed out that by adding small quantities of boron to the hydrogenous material, one would further increase the effectiveness of the shielding against neutrons by another factor of between two and five.

Few people fully realise, however, that tank armour has undergone many changes since the neutron bomb was developed. The need to protect from attack by conventional armour-piercing shells has driven many changes in the design of tank armour. These changes have also dramatically increased the effectiveness of the armour in shielding the crew against radiation. The details of tank armour are closely held military secrets, but enough information is openly available to allow us to study the implications of such changes for the neutron bomb.

They won't stop tanks

By the end of the Second World War, it was clear that new developments in projectiles were beginning to overwhelm armour. A single layer of steel armour was no longer proof against small-diameter rounds possessing high kinetic energy. One such was the so-called "sabot round", which achieves maximum acceleration in the barrel of the gun because it is relatively light; it then reduces its air resistance by throwing off much of its bulk on leaving the muzzle. Other projectiles cut through armour by projecting a very hot plasma. By the 1960s, both types of shell had progressed to the point where they could penetrate almost a metre of steel. Clearly, no tank could carry armour this thick. The solution, developed by the British Army, was the so-called Chobham armour. This armour is made up of many layers of materials that have markedly different physical properties. Some layers are of relatively light but yielding material that breaks up shock waves. Others might be ceramic, to resist the high-temperature plasma lance.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Mitterrand is developing a French neutron bomb

Another necessary change to tank armour stems from the use of helicopters from which to launch guided antitank weapons. Before the advent of helicopters, everyone assumed that an attack on a tank would come from the front. Consequently, only a limited area at the front and sides of the tank was protected by armour of the full thickness. But a helicopter might come from any angle, even directly overhead.

These two changes have led to dramatic improvements in the effectiveness of tank armour as a radiation shield. Tank designers have also consciously tried to design armour that would serve as a better radiation shield. In Europe, a study on the design of NATO's main battle tank, issued in 1975, showed that careful placement of the armour could attenuate the radiation to one-twentieth of its strength. This study did not take into account the shielding effect of the equipment and contents of the tank. This is not negligible, since both fuel and ammunition are effective shields against neutrons. The Israeli Merkava tank and the Swedish S-1 tank—the forerunners of the main battle tank of the future—both have fuel tanks between layers of armour.

The study on NATO's main battle tank contributed to the design of both the German Leopard II tank and the American M1 Abrams tank. At the White Sands Missile Range, the US Army tested a full-scale engineering mock-up of the M1 tank to assess how well both crew and equipment could withstand radiation from a nuclear explosion. The design criteria for this tank specified that the crew and equipment should be able to "carry out a designated mission within a specified time after a nuclear event".

One of us, André Gsponer working with Sumer Sahin, now at the King Saud University, Riyadh, has studied how the effectiveness of the shielding varies with different configurations of armour. We took as examples the steel slab, 10 centimetres thick, typical of tanks in the 1950s; the multilayer armour, 20 centimetres thick, typical of the 1980s, and finally the many-layered armour, 30 centimetres thick, expected for the most modern main battle tanks of the 1990s. We found that the protection factor increases from about 2·3 for the earliest armour up to about 35 for the most modern armour. We assumed that the thickness of armour was the same all over the tank. This assumption would overestimate the effectiveness of the shielding, were it not for the fact that the internal and external equipment of the tank adds considerably to the shielding effect. Our assumption and the programs to calculate the neutron transport (the depths to which neutrons penetrate different materials) are typical of calculations made by the two American nuclear weapons laboratories.

Because of this modernisation, the radius within which a 1-kiloton neutron bomb will promptly incapacitate a tank crew shrinks from 640 metres to less than 300 metres. This is approximately the radius at which blast and heat will disable the tank. The neutron bomb's special effectiveness against the Warsaw Pact's tanks is illusory.

Nuclear weapons for use on the European battlefield grew out of the hope of men like Oppenheimer, Cohen and strategist Bernard Brodie that they could avoid the all-out "Sunday punch" that the Strategic Air Command was poised to deliver. Daniel Ellsberg, then a colleague of Sam Cohen's at the Rand Corporation, characterised the policy of the 1950s when he said: "We all agreed that we must be willing to blow up the world if the Russians crossed the borders of Germany."

Sam Cohen, partly as a result of his concerns about such a policy became, as he said, "obsessed with tactical nuclear weapons". When he took up the cause of the neutron bomb in the early 1950s, he became a useful ally of those who used the need to develop the new weapons as a pretext to delay the test-ban treaty. Although Cohen accepted the title "father of the neutron bomb", he was, he says, a "captive salesman. I had been picked by a group." It appears that military need and technical rationality had little to do with the decision to develop the weapon. If the neutron bomb is deployed, it will be in spite of the knowledge that it will be ineffective. ☐

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