Science In a Social CONText

THE ATOMIC BOMB

John Holman

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ASSOCIATION FOR SCIENCE EDUCATION
BASIL BLACKWELL · PUBLISHER

Acknowledgements

Joan Solomon would like to thank many friends and pupils for their invaluable help and comments, and particularly the many teachers who participated in the SISCON-in-Schools project and tried out these materials in their schools and colleges.

The publishers would like to thank the following for permission to reproduce illustrations on pages: 39 David Austin; 21 Camera Press; 19, 22, 34 Keystone Press; 26 Sidney Harris; 30 Al Johns; 33 The New Statesman; 37 The Observer; 25 Popperfoto.

First published 1983
Basil Blackwell Publisher Limited
108 Cowley Road
Oxford
OX4 1JF
and
The Association for Science Education
College Lane
Hatfield
Hertfordshire
AL10 9AA

ISBN 0 631 91000 X

Typesetting by Oxford Verbatim Limited
Printed in Great Britain

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Introduction

This book tells the story of the atomic bomb, starting from the early discoveries in nuclear physics long before anyone could connect them with weapons or warfare. Gradually, as scientists from many countries pieced together an understanding of nuclear fission, the possibility of a new and powerful explosive emerged at just the same time as the outbreak of the Second World War. The story moves from Europe to wartime Britain and then to the secret city of Los Alamos where the first bombs were made and tested.

From the tragic bombing of Hiroshima and Nagasaki we learn how such decisions were influenced by military and political arguments. Responsibility on personal, national and international scales is illustrated by the stories of the atom spies, the early efforts at the United Nations, and the beginning of the peace protest movements.

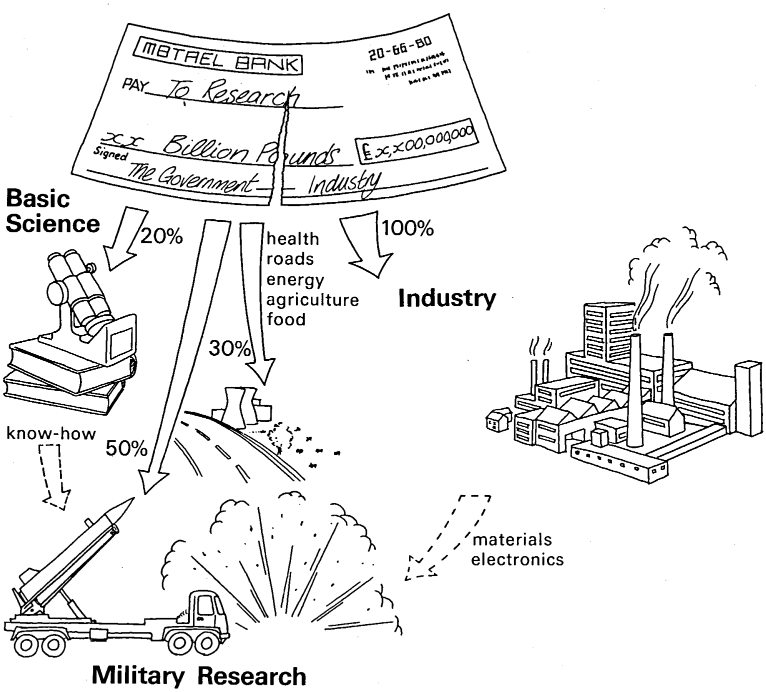
To understand our present problems we also need to know about the sources of bomb materials, how nuclear arms are spreading, war strategies and international treaties. It is a frightening but vitally important subject for us all.

1 Science on the Payroll

WHO PROVIDES THE MONEY?

In the past, the wealth of a country could be judged by the richness of its agricultural land or by its mineral resources. This is no longer the whole story. Nowadays, the scientific and technological inventiveness of a country plays a vital part in its economic status and its political power in the world. Japan is a prime example of a country which owes its economic power to its use of technology. Governments are well aware of this, and are eager to develop their country's science and technology in every possible way. Often they have another motive for supporting scientific research: in the face of a continual threat of war they may feel a need for science and technology in order to develop and maintain their military strength.

Britain backs its science by paying out billions of pounds every year on scientific research. About half of this money comes from industry and is used there to develop new ideas, new processes, and new products



(see *Technology, Invention and Industry* in this series). The other half is paid by the government out of our taxes and is used for a wide variety of purposes.

WHERE THE FUNDS GO

Less than a quarter of the government money is paid out for 'pure' science, which takes place in universities.

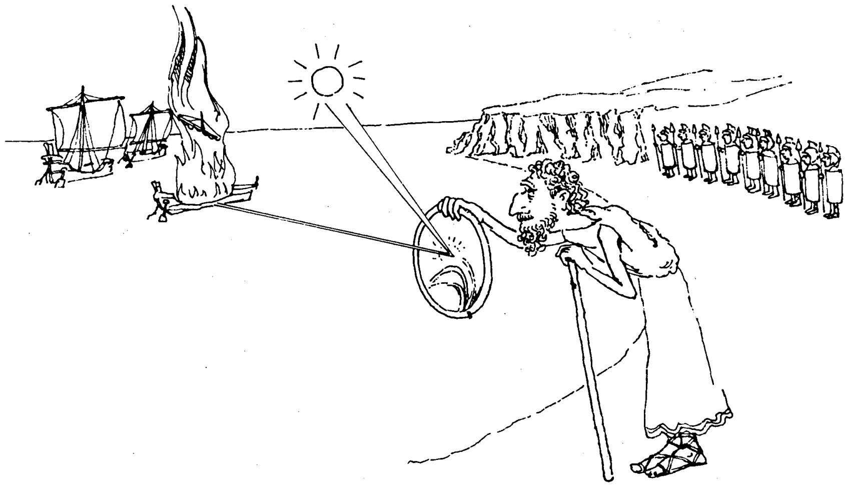
Some of this money is also used for the education of scientists of the future in schools, polytechnics and universities.

A rather larger proportion of government funds goes into special projects in medicine, agriculture, roads and energy. Much of this money will find its way into the research departments of industrial firms which develop the fertilisers, drugs, petroleum products and engineering plants.

About half of the government contribution goes straight into the research budget of the Ministry of Defence. Weapons of every kind – guns, missiles, tanks, ships, aeroplanes – are being developed and improved, including, perhaps, the biological and chemical means of warfare, should the need for these arise. If we take into account the considerable number of private firms which develop new military weapons or the component parts for them, the amount of funds going into military research becomes greater still.

SCIENTISTS WHO WORK FOR WAR

This means that a large part of the nation's scientific manpower – a quarter or more of the whole – is engaged in military research. There is nothing new in scientists contributing to the war effort of their country. Archimedes, who lived in the third century BC, is said to have used concave mirrors to set fire to the invading Roman ships. When Leonardo da Vinci wrote to the Duke of Milan seeking advancement he offered his services as one who would improve that city's fortifications. Alfred Nobel, by whose will the famous Nobel prizes were endowed, was the inventor of dynamite (1862), a weapon so terrible that he believed it might prove the ultimate deterrent to all future wars.



Archimedes protecting Syracuse

Today, the involvement of science in military research has become continuous in peacetime as well as in war. Although every war has used the latest scientific and technological developments, the Second World War and in particular the atomic bomb had a more dramatic effect upon the nature of scientific research than any other. Where before there were comparatively few scientists, all of whom worked and corresponded freely with each other, there are now permanent military research establishments whose workers are bound to secrecy. This is bound to have a considerable effect upon science, upon scientists, and upon how the rest of us think about science.

2 Discovering Atomic Energy

THE THEORY ABOUT MASS AND ENERGY

As early as 1904 Albert Einstein had published his famous Theory of Special Relativity. One of the curious results of this was that mass itself seemed to be a kind of energy and could be converted into the usual kind of energy according to the equation:

$$\text{ENERGY} = \text{MASS} \times (\text{SPEED OF LIGHT})^2$$

Light travels at a colossal speed, about 300 million metres per second, so that if even a small quantity of mass could be converted into the usual forms of energy – heat or movement – then staggering quantities would be released. One gram of matter could give enough energy to run a power station for a year. It seemed amazing and even unlikely at that time since no one knew how to make the transformation happen. Forty-one years later, when the first bomb was dropped on Hiroshima, the power of its explosion was produced by the conversion into energy of *less than one gram of uranium.*

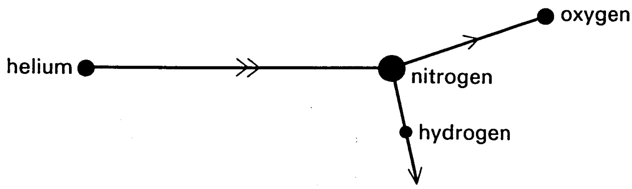
INSIDE THE ATOMS

Early discoveries about radioactivity by Ernest Rutherford had shown that at the heart of every atom there was a small dense nucleus which carried all the mass of the atom. A substance which was radioactive, like radium, contained unstable nuclei which broke up spontaneously, releasing a little energy. This was carried by high-speed nuclear particles, usually the nuclei of helium atoms.

In 1919 Rutherford saw tracks in a cloud chamber which proved to him that one of these high-speed particles had hit a nitrogen atom in the air and split it into two other atoms.

This had happened by chance, but it did show that atoms could be split up. It was also clear that energy was released.

The masses of the different atoms do not increase regularly. Heavy atoms, such as those of uranium, are heavier than would be expected if they were made up only of lighter atoms. They have some hidden extra



An atom of nitrogen split by a chance collision.

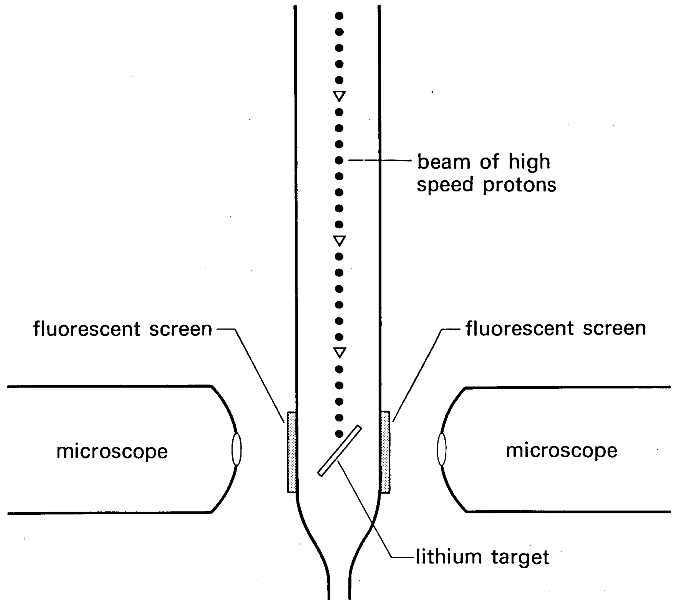
mass. If such atoms could be split in half this extra mass might be expected to turn into pure energy, according to Einstein's mass/energy equation.

In 1928 two physicists, one in Britain and one in America, set out quite independently to devise an experiment to split up atoms in this way. The problem was to accelerate the bombarding particles, hydrogen nuclei, to sufficient speeds so that they could penetrate the nucleus of an atom. Their solutions were different. In Cambridge, John Cockcroft, who was later joined by Ernest Walton, used a large transformer and rectifier which achieved a potential difference of 600,000 volts down a straight tube. In Berkeley, California, Ernest Lawrence built the world's first cyclotron which accelerated particles along a spiral path; machines using this principle are widely used today in physics.

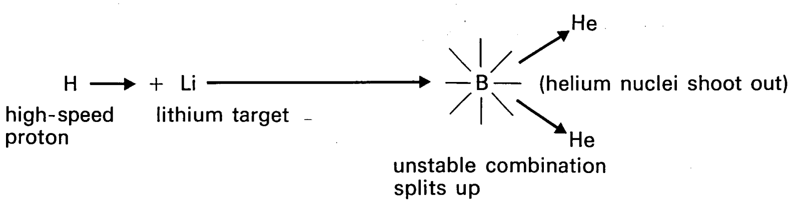
SPLITTING THE ATOM

In Cockcroft and Walton's experiment the hydrogen nuclei (protons) hit a target of the metal lithium. Particles were thrown out sideways and identified as helium nuclei. These caused scintillations on fluorescent screens which were carefully observed and counted through a microscope.

The two helium nuclei together weighed less than the proton and lithium nucleus with which the reaction started. Calculation showed that this loss of mass should be equivalent to about 17 million electron volts of energy, which was almost exactly matched by the energy of the ejected helium nuclei. It was a scientific triumph for which Cockcroft and Walton later received a Nobel prize.



Cockcroft and Walton's atom-splitting experiment.



How an uranium atom undergoes fission.

NEWSPAPER HEADLINES

Never before had a scientific experiment so caught the public eye. The home news was not inspiring; there was continuing economic depression, unemployment and futile disarmament conferences, a mixture not unknown in our own times. Abroad, the Sino-Japanese War had just broken out and the Nazi party was rising to power in Germany in an atmosphere of street violence and racist speeches.

Reaction in the newspapers to the splitting of the atom in 1932.

The scientists were left behind by these reactions. In vain Rutherford and Cockcroft repeated that the experiment had 'purely theoretical' interest. Articles and editorials thundered on about 'man's control of energy', '. . . may blow our planet to pieces . . .', 'More power for industry. . . .' 'Some new horror for the League of Nations to forbid (vainly) in time of war', or simply the prophetic new phrase 'atomic energy'. In 1932 all this may have seemed merely sensational, but who can say now that the journalists were wrong? It was the scientists who still had so much to learn.

FINDING THE NEUTRON

Cockcroft and Walton's experiment released very little energy. It took more energy to accelerate their protons than could be recovered from the high-speed helium nuclei. The problem was that very few of the protons actually hit the tiny nuclei of the lithium atoms. Was there a better bombarding particle that could be used?

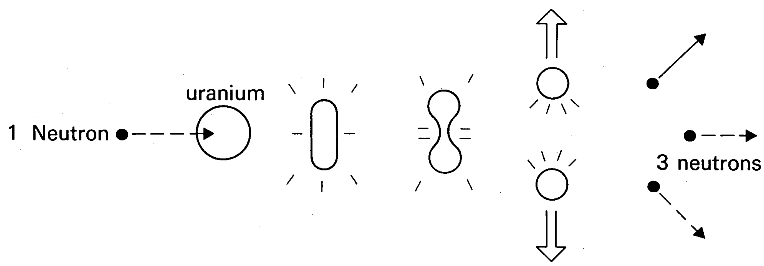
In the same year as the atom was first split (1932) another scientist in Rutherford's laboratory discovered a new nuclear particle. James Chadwick, the scientist, named the particle the 'neutron' because it had no electrical charge. It was to be the atom-smashing bullet of the future.

FISSION AND THE CHAIN REACTION

During the next seven years, despite the mounting threat of war, most scientists continued to work in the way they had always done. Young scientists moved freely from one European university to another studying the latest developments in nuclear physics wherever they could. Research workers published their results in the scientific journals and attended international conferences, considering themselves as a part of the world-wide 'invisible college' of those who shared their interests. Rutherford could still be heard declaring that all talk of utilising atomic energy was 'moonshine'. For several years he had working in his laboratory a brilliant young Russian physicist, Kapitza, who later visited his homeland and was forbidden to return to the West. Rutherford was naturally upset but, believing that science was more important than politics, he had all Kapitza's valuable apparatus packed up and sent after him to Russia so that the work could go on. Even Hitler had not yet realised the political power of science. His persecution had reduced the number of German physicists by twenty-five per cent and when Max Planck remonstrated with him, pointing out the damage that was being done, he is said to have replied 'Then we shall just do without science for a few years', as though science and politics existed in different worlds.

Meanwhile Chadwick's neutrons were proving wonderfully effective for bombarding atoms. In France, Italy, Britain, Germany and America physicists were busy trying out their effect on different nuclei. The neutrons were often captured by the target atoms which then became radioactive, emitting other particles or radiation. Enrico Fermi's team of scientists in Italy used these neutrons on a target of uranium as early as 1934 but somehow missed finding anything specially energetic. They thought that the neutrons had been absorbed, possibly yielding two new elements, neptunium and plutonium, but they were not sure.

It was the Joliot-Curies in Paris who repeated this experiment in 1938 and first realised that something quite new was happening. Then German chemists confirmed that atoms of about half the mass of uranium were to be found in the target material. They communicated with a refugee colleague in Sweden and the new theory of fission (splitting in half) was proposed which involved a huge release of energy.



All over Europe and America physicists rushed into their laboratories to confirm this result. It was astonishing that it had not been discovered sooner.

There was time for one more piece to be added to the puzzle before Europe went to war. The explosive fission of an uranium atom was found to generate yet more neutrons; each of these could then start fission in another uranium atom, and so on. A *chain reaction* might begin which would spread like wildfire through the whole mass of uranium. It was a possible source of great power.

This international research work by scientists, to find out how atoms could be split by fission to release energy, had been begun without any thought of making bombs.

Do you think it should have been stopped?

Can you stop scientific curiosity?

3 The Start of War

SCIENCE GOES SECRET

Inside Germany there was racial persecution and many scientists were dismissed from their posts and had to flee to other countries.

Refugee physicists in Britain and America spread their anxiety about Hitler's intentions and possible nuclear progress. Just how strong were the family ties that bound the international fraternity of scientists? There were some who believed (so they said later) that the transnational bonds of working friendship, together with the power of their exclusive knowledge of the nucleus, could have been used to prevent the exploitation of this new potential explosive.

Hitler had already shown his military aggression and to some this meant that German scientists too must be considered suspect. In February 1939 a prominent American physicist published the following statement:

> I have decided from now on not to show my apparatus or to discuss my experiments with citizens of any totalitarian state.
>
> Bridgeman *Science*

In the same way the custom of publishing every new discovery in the international journals should have been reconsidered. This had always been the triumphant signal of priority and reward for researchers. By 1939 the competition in nuclear physics had become intense and to forgo such recognition would be hard. Leo Szilard, a Hungarian refugee in America, was at the focus of concern about security. As soon as he heard that Joliot-Curie in Paris was working on the problem of the possible chain reaction of uranium fission, Szilard wrote begging him not to publish his results. Joliot-Curie took no notice and mailed them by air (unusual at that time) to the editor of *Nature* in order to obtain the earliest possible recognition of his success. This was in March 1939.

As late as 1941, two years into the war in Europe, when the new fissionable element plutonium was first identified, the news was published openly in an international journal by its American discoverers. Plutonium is the element now used in all nuclear weapons.

In March 1939 Germany invaded Czechoslovakia and seized the richest uranium mines in Europe. Almost at once the export of uranium was banned. To the watching scientists it seemed obvious that the Germans were planning to use uranium fission for warfare.

G. P. Thomson, professor of physics at Imperial College, London, went at once to the Air Ministry, explained the dreadful possibilities of fission power and asked for a ton of pure uranium ore to carry out urgent experiments. The chief scientist at the Air Ministry was Henry Tizard, who was the organiser of our radar warning system and a colleague of Thomson's. His arguments were at once taken seriously and by the following year Tizard had set in being a committee of eminent scientists, including Thomson and Chadwick, to co-ordinate military research into uranium. This committee became known as MAUD.

In April 1940 Germany overran Norway and captured the only plant for making the 'heavy water' that the French were using to generate a uranium chain reaction. June 1940 saw the fall of France and as German troops approached Paris there was a daring evacuation of the physicists and their stock of heavy water to England.

By early 1940 MAUD could report progress to the government's war cabinet on two fronts:

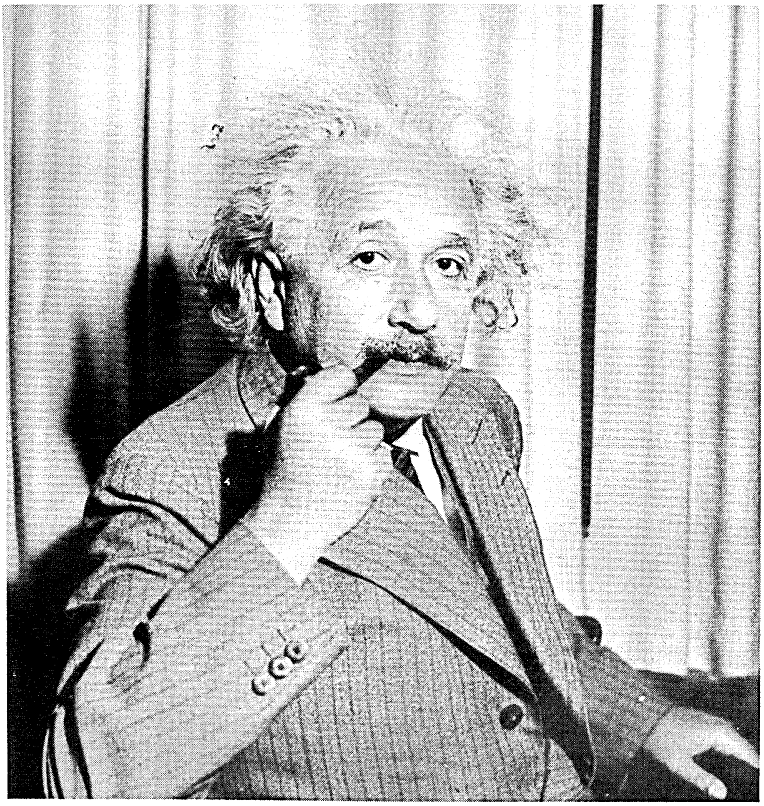
1 Natural uranium consists of two kinds, or isotopes. Less than one per cent is the fissionable isotope U^{235}, so this natural uranium can only have a *slow* chain reaction (with the use of heavy water or graphite). This will not make a bomb, only a nuclear reactor, but the wastes from this contain plutonium which is even more fissionable.
2 To make a bomb either pure U^{235} or pure plutonium would be required. The team had a plan to separate U^{235} from natural uranium but this would be very expensive.

This posed a great problem for Britain whose resources, both in scientists and finance, were fully stretched by the development of radar and manufacture of arms. Churchill and Roosevelt corresponded, British scientists toured the USA to sell their ideas and finally, one day before the bombing of Pearl Harbor and the American entry into the war, an agreement was signed. The Americans would take over the project for building an atomic bomb and the British and French team would move to Canada to build their atomic pile.

AMERICA STARTS PLANNING

In 1939 America seemed far away from war. It was the refugee physicists like Fermi and Szilard, knowing the Nazis at first hand, who tried to warn military authorities. They made little progress. In July Szilard had the idea of reaching President Roosevelt directly, by using the name and reputation of Albert Einstein, himself also a refugee in America. Einstein agreed and signed the now famous letter:

> Sir,
>
> Some recent work by E. Fermi and L. Szilard, which has been communicated to me in manuscript, leads me to expect that the element uranium may be turned into a new and important source of energy in the immediate future. Certain aspects of the situation which has arisen seem to call for watchfulness and, if necessary, quick action on the part of the Administration. I believe therefore that it is my duty to bring to your attention the following facts and recommendations.
>
> This new phenomenon would also lead to the construction of bombs, and it is conceivable – though much less certain – that extremely powerful bombs of a new type may thus be constructed. A single bomb of this type, carried by boat and exploded in a port, might very well destroy the whole port together with some of the surrounding territory. However such bombs might very well prove to be too heavy for transportation by air.
>
> I understand that Germany has actually stopped the sale of uranium from Czechoslovakian mines which she has taken over. That she should have taken such early action might perhaps be understood on the ground that the son of the German Under-Secretary of State, von Weizsacker, is attached to the Kaiser-Wilhelm Institute in Berlin where some of the American work on uranium is now being repeated.
>
> Yours very truly,
> A. Einstein.



Einstein

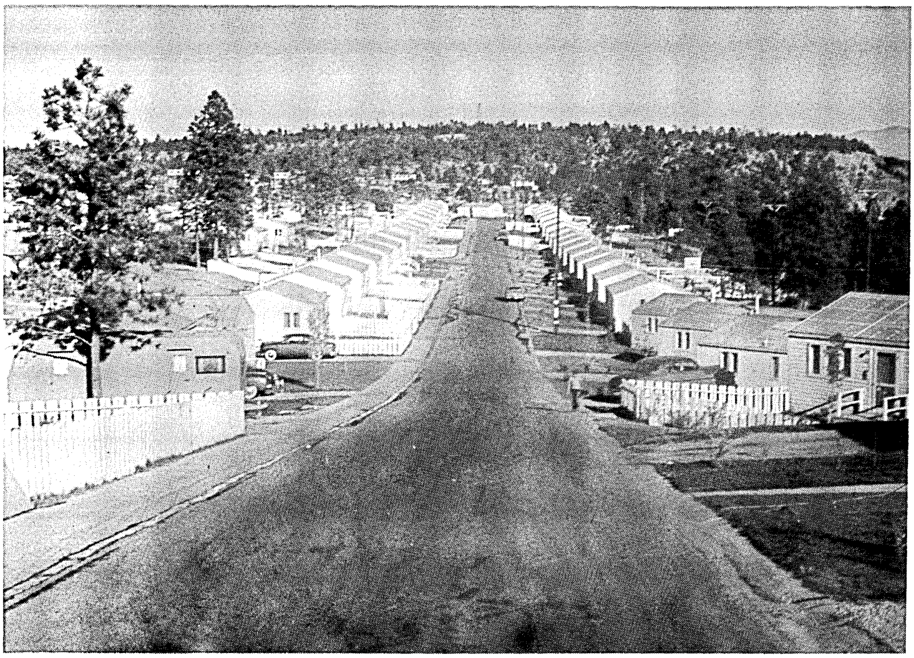
In wartime Britain, Churchill had simply wanted the best possible explosive. Roosevelt saw the bomb as no more than a deterrent against the possibility of the Germans using one. After thirty years of 'cold war' we know that just as fierce an armament race can be based on the deterrent argument as on the needs of actual war.

Within two months of the first decision the army had taken over, and the Manhattan Project came into being. Fermi and his colleagues built a nuclear reactor, huge factories to make the raw materials were constructed and General Groves, who was in charge of the whole project, chose Robert Oppenheimer to lead the section which would produce the bomb.

4 Building the Bombs

THE SECRET COLLEGE AT LOS ALAMOS

When General Groves and Robert Oppenheimer set about selecting a team and a site for making the bombs they had quite different motives. Oppenheimer wanted to build a kind of college where top scientists could pool their ideas, share the experimental data and argue communally over their problems as scientists worldwide had always done. Groves wanted perfect military secrecy. Oppenheimer had always loved the open vistas of near-desert landscape and it was he who showed Groves a remote place in New Mexico where sparse cottonwoods bordered on wild hills and canyons. It suited them both. Here, at Los Alamos, a secret city was built where more than 3,000 scientists and engineers lived while they planned and produced the atomic bombs. It was isolated enough to suit the army organisers, and the concentration of so many eminent scientists gave it a 'hothouse' intellectuality that proved extraordinarily effective.



Los Alamos

Although the military authorities compiled dossiers on the political background of all who worked there (including Oppenheimer whose brother and fiancée had both been communists) this did not slow down the work. Oppenheimer knew that secrecy within the group would stifle the necessary spirit of invention. He was an inspiring leader and those who worked there often looked back on their bomb-making years with nostalgia:

> It was the most exclusive club in the world. At the very start, Oppenheimer killed the idiotic notion that only a few insiders should know what the work was about and that everyone else should follow them blind. I, an almost unknown scientist, came here and found that I was expected to exchange ideas with men I regarded as names in text-books. It was a wonderful thing for me, it opened my eyes. Here at Los Alamos I found a spirit of Athens, of Plato, of an ideal republic.
>
> *James Tuck, a young British scientist at Los Alamos*

What did this scientist consider wonderful?
Do you think they worried about the use of the bomb at this stage?

THE URANIUM BOMB – LITTLE BOY

There were two big problems to be solved. The first was to make a trigger mechanism for setting off the uranium bomb, which came to be known as Little Boy. The bomb was a sphere of almost pure uranium 235 with a hollowed-out core into which the missing part would be fired. It emitted neutrons that caused an explosive chain reaction in the whole mass. Work proceeded fast during 1943 and by 1944 the bomb itself was ready although the uranium 235 to fuel it was not. The separation processes, which took place at another secret establishment in Oak Ridge, proved slow and laborious. It became clear to Oppenheimer that even by his target date – July 20th 1945 – there would be enough material for only one bomb, if that. There would be no chance to test out the uranium bomb.

The first uranium bomb, 'Little Boy'.

THE PLUTONIUM BOMB – FAT BOY

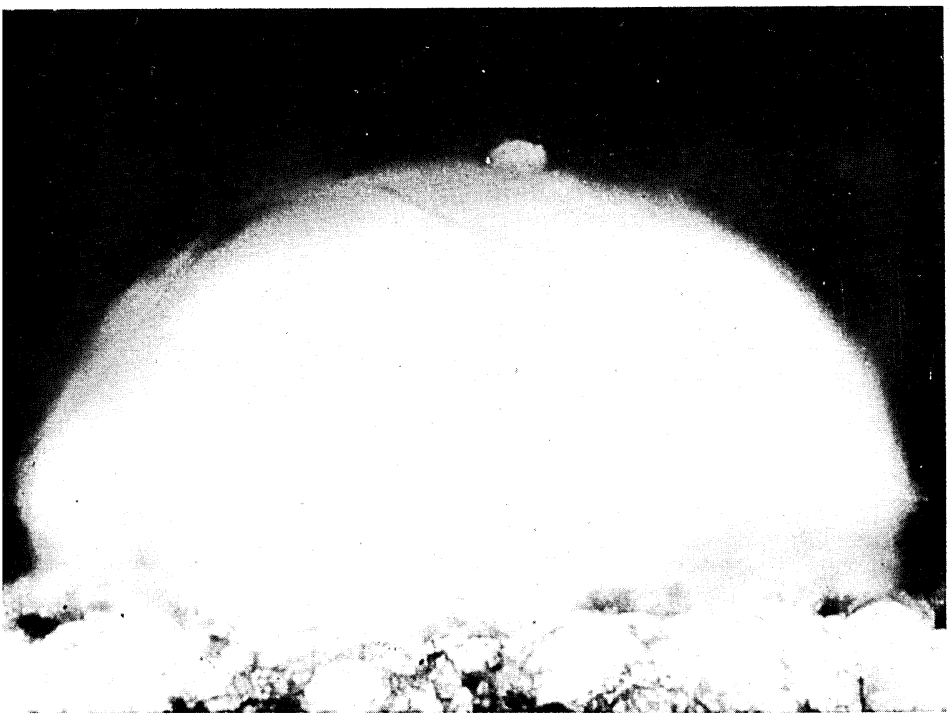
Meanwhile plutonium was being produced in a secret nuclear reactor in greater quantities, but it soon proved to be so 'hot' with radiation that a totally different trigger would be needed – something that would blast the two halves together at unheard-of speed. The solution had to be a kind of inward-driven explosion, whose shock waves were focused simultaneously on the two plutonium components. Problem after problem was examined by new and often dangerous experiments. Slowly the work progressed.

By Feburary 1945 the essential research was completed. Within three months the detonators and shock-wave lens assemblies were ready for a full scale test.

On June 12th two hemispheres of plutonium were delivered to Los Alamos, each about the size of half a grapefruit. The scientist checking them pushed the two parts slowly towards each other while his radiation counters clicked wildly on the table and the air between began to glow blue. Then he packed each piece away separately, ready for the rest of Fat Boy, as the plutonium bomb was nicknamed.

On Sunday July 15th, further south in the desert at Alamagordo, the plutonium bomb stood ready. It was warm and raining, the scientists argued in groups, undecided whether this weather meant that the explosion should be postponed. For the first time in history the expression 'fallout' was used. Would rain bring down radioactive material on the nearest towns? All through the night, Fat Boy hung on a tower of scaffolding, illuminated by occasional flashes of lightning. Eventually the storm cleared and at 5.30 a.m. the bomb was exploded.

The huge fireball was watched with awe from ten or twenty miles away. For the first time since the world began it was flooded by a brilliance beside which the coming dawn would seem pale. There followed the mushroom cloud and a blast of heat and noise that shook the ground a hundred miles away.



The first plutonium bomb, 'Fat Boy', explodes in the Alamagordo desert.

It seems extraordinary that the scientists who actually worked at Los Alamos on the bombs appear to have given so little thought to their final use. When their work began in 1942, Germany had conquered most of Europe and her troops had reached halfway across Russia. Fear of the Nazis and anxiety about a German atomic bomb had been real enough then, but the tide of war had turned while the scientists were researching at Los Alamos.

One eminent physicist, Niels Bohr, did talk to Roosevelt in 1944 about the possibility of a demonstration explosion in some uninhabited region so that the appalling effects of the bomb might be seen by all the warring nations and shock them into an early peace. Soon after this Leo Szilard again visited Einstein to obtain his signature to another letter. This time it was to warn the president against using the bomb, but it arrived too late. When Roosevelt died in April 1945 it was found lying, still unopened, on his desk. His successor, Harry Truman, knew nothing about the bomb and, and on his own admission, hated reading long documents.

Fear of a German atomic bomb had now evaporated. When the first wave of Allied troops invaded Germany they included a small task force whose special job it was to seek out and capture nuclear physicists. They soon found out just how little progress had been made. The first nuclear pile for the military production of plutonium had not gone into action until February 1945 and in April of that year it was captured. One American scientist exclaimed, 'Isn't it wonderful that the Germans have no atomic bomb. Now we won't have to use ours'. The original reason which had been given for making the bomb was shown to be mistaken, but nothing could now stop the scientific and military momentum of the work.

The end of the war in Europe passed without a change of mood at Los Alamos but other scientists were beginning to show anxiety. The bitter conflict with Japan was still going on; was it necessary that the bomb should bring death and destruction to their land? Was there some other way it could be used for peace? Did the scientists themselves not have some responsibility for how the bomb was used?

This questionnaire was drawn up and circulated among the workers at the uranium separation plant in June 1945:

> Which of the following procedures comes closest to your choice as the way in which any new weapon that we might develop should be used in the Japanese war?
>
> 1 Use them in the manner that is from the military point of view most effective in bringing about prompt Japanese surrender at minimum cost to our own armed forces. (15%)
>
> 2 Give a military demonstration in Japan, to be followed by a renewed opportunity for surrender before full use of the weapon. (46%)
>
> 3 Give an experimental demonstration in this country with representatives of Japan present followed by a new opportunity for surrender before full use of the weapons. (26%)
>
> 4 Withold military use of the weapons but make public experimental demonstration of their effectiveness. (11%)
>
> 5 Maintain as secret as possible all developments of our new weapons and refrain from using them in war. (2%)

It is doubtful if this document ever reached the president.

What would you have voted for, if you had been a scientist working at Los Alamos?

THE DECISION IS MADE

Several groups of people, including the scientists, have been singled out for blame, but the issue is not a simple one.

The army chiefs argued strongly for bombing Japan. American casualties during the recent capture of the island of Okinawa had been appalling and far more, perhaps as much as a million dead, were predicted if mainland Japan were invaded.

Four of the top scientists, including Fermi and Oppenheimer, had been consulted on at least three occasions and had agreed to the bombing. After the concerted effort of the whole Manhattan Project the bomb seemed to have acquired a momentum of its own and had to be used to justify its enormous expenditure and to prove that it could work.

It had been agreed that the USSR should enter the war against Japan once Germany was defeated. Peace initiatives by the Japanese may have been held up by the Soviets although American intelligence had intercepted messages admitting defeat. The politicians thought that a prompt and dramatic demonstration of technical power might not only end the war but also prevent future Soviet influence in the Far East.

The scientists had left their protest too late. Only they had been in a position to foresee the destructive power of the bomb, and since they were working for the military it was always a fair assumption that their weapon would be used by the military.

The outcome is well known: on August 6th 1945 the uranium bomb was dropped on Hiroshima, killing about 70,000, mostly civilians. On August 9th, the plutonium bomb was dropped on Nagasaki, killing another 35,000. On August 11th, Japan offered unconditional surrender.

The devastation at Hiroshima after the atom bomb.

The war was over, the scientists' weapon had brought peace but at a great price. The world was horrified by the details of the destruction at Hiroshima; it became a name to haunt the conscience of the West and began an arms race and an age of threat which is with us still.

5 Responsibility and Treachery

THE EFFECT ON WORKING SCIENTISTS

Within a month of the dropping of the bomb many of the scientists left Los Alamos. They were deeply disturbed by the human suffering at Hiroshima for which they felt a measure of responsibility. Oppenheimer himself gave up his post to return to pure research – the study of cosmic rays. Bitter speeches were made in which Oppenheimer predicted, '. . . the time will come when mankind will curse the names of Los Alamos and Hiroshima'. The scientists had had enough of making weapons; many preferred to withdraw into other regions of research where their consciences were untroubled.

These feelings did not always last. When the hydrogen (fusion) bomb was being developed during 1949–52, many of the original scientists went back to Los Alamos. There were new and fascinating problems to investigate which proved an attraction to the researching mind. As Oppenheimer said, 'Whenever a problem looks technically sweet there will always be scientists to work on it'.

The new postwar world of science was heavily financed by governments. Within the universities the armed forces were spending more money on research grants for a wide range of scientific topics; outside,

'Pleasant working conditions, the latest equipment, lots of money – you won't even realize you're working on biological warfare.'

new government research laboratories were springing up. A great deal of the research carried out in Britain today takes place in such military research stations and yet much of it seems reassuringly 'pure'. Scientists can often pursue their favourite topic, a subject which may seem to be theoretical and at a far remove from armaments and weaponry. The authorities provide the funds and simply wait for a useful spin off.

A scientist might, for example, be working in a military laboratory making new materials for better transistors or microchips. He might even be in correspondence with scientists working on the same problems in different countries and be publishing papers on his work in the international journals. Nothing would seem to be secret; he could reassure himself that he was not contributing to the making of nuclear weapons in any way.

However, he would be bound to know that other scientists, perhaps even in the same research laboratories, were making new electronic devices for guiding and exploding missiles. Any discoveries that a scientist makes, which would be useful for this military work, would immediately become secret. There would be no more freedom to publish, and his work would become a part of 'national defence'.

This problem is becoming widespread. At least a quarter of the scientists now working in Britain are in military research establishments.

Would this scientist be to blame if deadly weapons using his inventions were put to use?

THE OFFICIAL SECRETS ACT

All those working in government laboratories in Britain have to sign the Official Secrets Act to show that they understand that no information, even that which they have discovered, may be handed on to others once it has been officially classified as secret. The act, drawn up in 1911 and amended in 1920 declares:

> 1 If any person for any purpose prejudicial to the safety or interests of the State . . . obtains or communicates to any other person any sketch, plan, model, article or note, or other document

or information which is calculated to be or might be or is intended to be directly or indirectly useful to an enemy; he shall be guilty of felony, and shall be liable to penal servitude for a term not less than three years and not exceeding fourteen years. . . .

2 If any person . . .

a communicates the sketch, plan, model, article, note, document or information to any person, other than a person to whom he is authorised to communicate it . . . or

b retains the sketch, plan, model, article, note or document in his possession or control when he has no right to retain it . . . that person shall be guilty of a misdemeanour (Penalty up to two years imprisonment).

All British scientists who worked on wartime atomic development projects, whether in Britain, Canada or the USA, had been given this Official Secrets Act to read and had signed an agreement to abide by it. They all knew the penalties involved and yet at least two such British scientists deliberately chose to break its terms and brave the risks involved.

ATOMIC SPIES

Alan Nunn May was an outstanding experimental physicist and in 1942 he was recruited to work on the uranium project. He had left-wing political views and had once visited Russia, but no one doubted his trustworthiness. He worked in Canada on the heavy water project and had the freedom to visit several of the secret laboratories in the USA. According to his later testimony May believed that it was not in the interests of mankind that America should continue to have a dominating monopoly of atomic expertise, and further that she should share these secrets with Russia who was then her ally in the war against Germany. As a scientist he felt so strong a sense of personal responsibility that he deliberately passed on information and samples of enriched uranium to Soviet secret agents. In 1946 he was arrested and tried at the Old Bailey under the Official Secrets Act. He pleaded guilty and was given a ten-year term of imprisonment of which he served six and a half years. On his release he worked first in Cambridge and then in Ghana.

It may be that Alan Nunn May was an extreme case of conscientious reaction, but as far as Klaus Fuchs was concerned there was a more sinister aspect to the case. He had been forced to flee from Germany in 1933 because he was a committed communist and he continued secretly to give full loyalty to this political party throughout his years in Britain. In 1941 Fuchs became a naturalised British citizen and two years later joined the bomb-making team at Los Alamos. On his own initiative he began at once to pass important secrets about the plutonium bomb to Soviet agents:

> At this time I had complete confidence in Russian policy and I had no hesitation in giving all the information I had. I believed that the Western Allies deliberately allowed Germany and Russia to fight each other to the death.
>
> *K. Fuchs, quoted in* Tongues of Conscience, *R. W. Reid*

In 1946 Fuchs returned to England to take up a post in the new Atomic Energy Research Station at Harwell. He continued to give information to his Soviet contacts. Under examination by the police Fuchs stated that his political belief was more important to him than his oath of allegiance to Britain. Similarly, when a German citizen, he had conspired against the Nazi Brownshirts. The press were quick to call this a case of treachery but, as this country was not at war with the Soviet Union, Fuchs could be tried only under the Official Secrets Act. He received the maximum sentence, served nine years in prison and went to live in East Germany.

A few months before this trial the USSR exploded its own atomic bomb and the Americans were quick to blame this upon Fuchs. Anti-communist feeling mounted and Senator McCarthy launched a campaign against suspected communists. Within two years Robert Oppenheimer himself was effectively put on trial and he lost his right to use secret papers; he was considered a security risk. The American police began a round-up of Fuch's contacts; some turned informer, others escaped with long prison sentences, but for the married couple Ethel and Julius Rosenberg the emotional reaction of the times brought about a tragic end. Both had been members of the communist party but denied forming a part of the espionage chain which had handed over wartime atomic secrets to the Soviets. They were brought to trial and convicted.

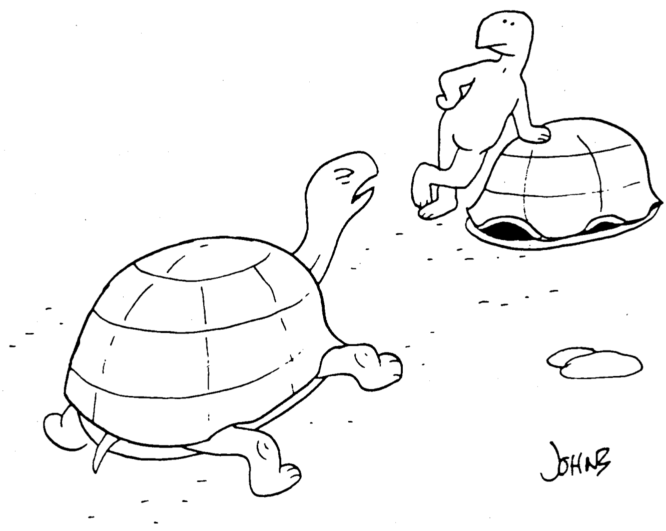
In his summing-up the trial judge said:

> . . . I believe your conduct in putting into the hands of the Russians the A-bomb years before our best scientists predicted Russia would perfect the bomb has already caused, in my opinion, the communist aggression in Korea, with the resultant casualties exceeding fifty thousand, and who knows but that millions more of innocent people may pay the price of your treason.

After several unsuccessful appeals the Rosenbergs were executed in the electric chair in 1953.

WORLD PEACE OR WORLD DESTRUCTION

Every citizen of a democratic country has legal ways open to him by which he may protest against government policy. After the war there were many scientists who were deeply concerned about, even distrustful of, America's position as sole possessor of the atomic bomb. They did not choose, as the atomic spies had done, to act on their own, outside the law. Instead they set out to influence decisions in high places by democratic means. Some toured their own countries giving lectures on the importance of disarmament, others tried to influence the policy of their governments.



'Steve, if this is going to be another one of your lectures on disarmament . . .'

In the immediate postwar years it seemed a matter of world survival. How could international peace be ensured so that a war using these nuclear weapons would not wipe out all human civilisation? The only hope seemed to lie with the newly formed United Nations. At its first session the American delegate rose to present a plan for international control of atomic bombs drawn up by Oppenheimer and others:

> We are here to make a choice between the quick and the dead . . . We must elect World Peace or World Destruction. . . .
>
> The United States proposes the creation of an International Atomic Energy Authority to which should be entrusted all phases of development and use of atomic energy, starting with the raw material and including:
>
> Managerial control or ownership of all atomic energy activities potentially dangerous to world security. . . . (*UN 1946*)

The authority was set up and for two years it argued fruitlessly. The American proposals contained at least two items which the Soviets would not accept:

> An international inspectorate with the power to visit any factory or research station to ensure that no illegal development was going on.
>
> No power of veto within the proposed authority. Its originators hoped to inspire a supra-national loyalty among its members which would do away with the need for such a blocking procedure.

The Soviets, on their part, demanded the immediate destruction of all American bombs. The Americans refused and continued to test out new bombs. The political debate between these two great powers was full of the distrust and blame which we have come to know so well. In the meantime, unknown to the Americans, Russia was making her own atomic bomb. In 1949 the world reverberated to the first Russian atomic explosion. The attempt to abolish national atomic bombs had failed.

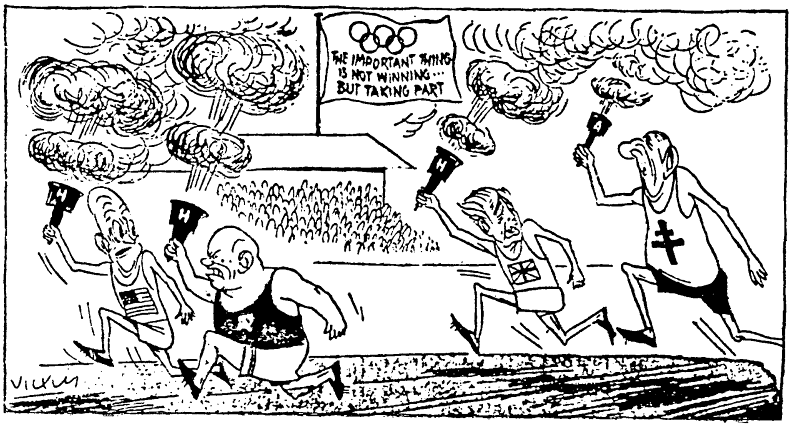
Some scientists have continued to press for nuclear disarmament. In 1945 the *Bulletin of Atomic Scientists* was founded to warn the public against the dangers of nuclear war. Ten years later, after the death of Stalin and when the political climate of the world had softened a little, the scientists formed an international movement which still continues, to unite those who wish to find ways to work for peace through disarmament and control of nuclear tests. This is the Pugwash Movement and includes scientists from both the USSR and the USA.

Can scientists make a special contribution towards peace?
Do you think some stronger sort of United Nations organisation could make war between nations impossible?

6 The Threat of Nuclear War

ATMOSPHERIC TESTS AND NUCLEAR POLLUTION

Many scientists were content to continue with the nuclear arms race that the big powers had decided upon. In 1952 the first American hydrogen bomb (thermonuclear weapon) was exploded on the South Pacific island of Elugelab with such devastating effect that the whole island disappeared. Ten months later the Soviets followed with their own hydrogen bomb. Britain let off her first atomic bomb in 1955 and, five years later, France was testing her atomic bomb while Britain had moved on to hydrogen bombs.



A cartoon showing Macmillan, Prime Minister of Britain; Charles de Gaulle, President of France; Eisenhower, President of the United States; Khrushchev, President of Russia, competing in the nuclear arms race.

One result of this was the further 'proliferation' of nuclear weapons. Another result was the increasing pollution from radiation caused by testing the bombs.

Inevitably there were some tragic accidents. In 1954 the Americans were exploding a bomb on the Bikini atoll when the wind changed slightly. A small Japanese fishing vessel, the *Lucky Dragon*, was caught in the radioactive fallout. One of the fishermen died within the month and the others were all badly affected. The event was widely reported throughout the world. Later it was shown that nearly all the children on one of the neighbouring Marshall Islands had developed cancerous growths on their thyroid glands from drinking water contaminated with radioactive iodine.

Even far away from the weapon-testing grounds the radiation in the atmosphere was increasing at an alarming rate. It was feared that the milk children were drinking was contaminated with radioactive strontium and that it might lodge for life in their bones. Out of this anxiety grew a new movement to 'ban the bomb'.

PUBLIC PROTEST AND THE TEST BAN TREATY

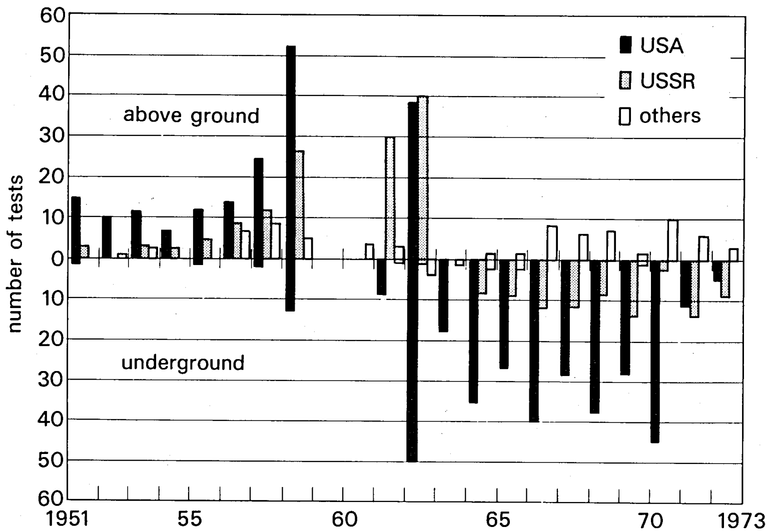
At Easter 1958 the first protest march took place in Britain. The sponsors were a group of scientists, clergymen and politicians who addressed a large crowd of at least 5,000 people from all walks of life in Trafalgar Square, London. They listened to speeches about the dangers of nuclear weapons and radioactive fallout before marching for four days, through some of the coldest and wettest Easter weather within memory, to the barbed-wire perimeter of the nuclear weapons production plant at Aldermaston in Berkshire. This was the beginning of the Campaign for Nuclear Disarmament. The event became an annual pilgrimage with banners saying 'Ban the Bomb' and displaying the now familiar sign.

Michael Foot (centre) Labour Party Member of Parliament, leads a march of the Campaign for Nuclear Disarmament in 1961.

Like all such popular movements these marches gradually changed their character. At first they had been largely composed of parents protesting in the name of their children. By 1961 the numbers had increased to a total nearing 100,000 and also contained a large group of younger people singing protest songs. The movement spread to other countries and is very strong today.

The United Nations reported twice on the levels of radioactivity in the atmosphere, and in 1958 both the USSR and the USA agreed to a one-year ban on the testing of all atomic bombs. The arrangement was then renewed and lasted, with some exceptions, until 1961. Finally, in 1963, the Partial Test Ban Treaty was signed and came into force. The original idea had been to ban all tests but, in the meantime, underground tests had been started and these could be detected only by on-the-spot inspection. Neither of the great powers would agree to this, so the treaty had to be confined to atmospheric tests.

The effect of the Test Ban Treaty was to reduce atmospheric radioactivity but it did not stop either the nuclear arms race or the testing of weapons. Only the USA, the USSR and the UK signed the treaty, so countries which had yet to test their own weapons – France, China and India – felt free to use atmospheric tests.



Effect of the Partial Test Ban Treaty in 1963.

The nuclear arms race between America and the Soviet Union started in earnest after the Russians exploded their first atomic bomb in 1949. To understand how this deadly race keeps going it is not enough to think of the rivalry and hostility between these great powers; we need to enter into their strategic thinking (large-scale war plans).

Nuclear bombs are so horrific in their consequences that both countries base their plans on a policy of deterrence – that is, trying to ensure that the other power will be too frightened to use nuclear weapons because of dreadful and inevitable retaliation. It follows that each side must have plentiful nuclear arms and effective means of delivering them, even if the other side attacks first.

The reason for deterrence is the *defence* of national security but it involves the building up of one's own *attacking* forces in order to cause fear in the potential enemy. If it proves possible to produce reliable means of defence which could neutralise these weapons, then this is seen as a threat to safety because it upsets the 'balance of terror'. This is how it has worked out in practice:

Aeroplanes which carry nuclear bombs are slow and can be detected.

Intercontinental ballistic missiles (ICBMs) with nuclear warheads travel at supersonic speeds.

Anti-ballistic missiles (ABMs) destroy ICBMs.

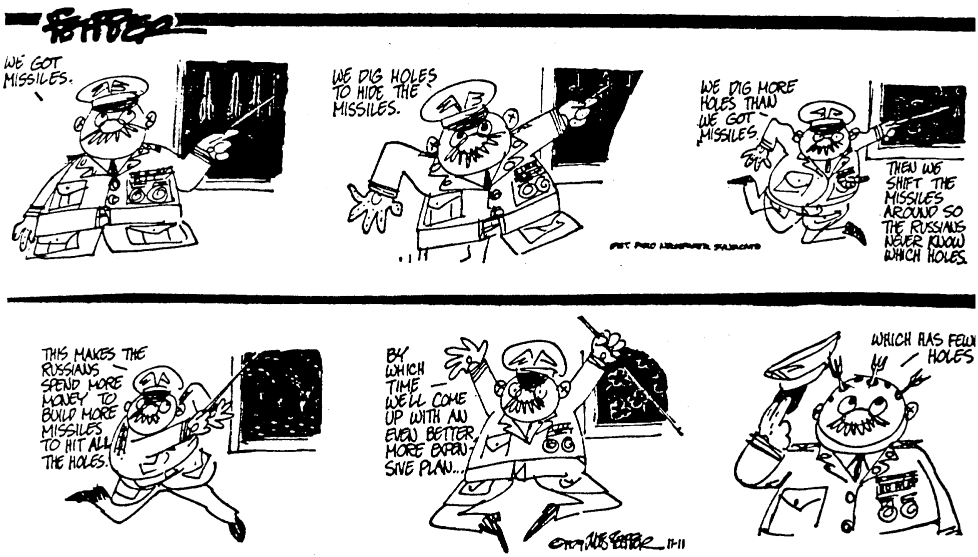
Multiple Independently Targeted Re-entry Vehicles (MIRVs) escape from ABMs by splitting up into several different warheads.

Protection of missile-launching sites from first strike destruction by building underground silos.

Missile-launching submarines which can remain undetected underwater and retaliate after a first strike.

This formed the policy of Mutually Assured Destruction or MAD. Whichever country began a nuclear attack it could be sure that massive retaliation would follow and wipe out a large proportion of its industry and its population. By 1960 it was estimated that the USA had enough missiles to destroy the USSR twice over. The Soviet leader replied to this, 'We're satisfied to finish off the United States first time round. Once is quite enough. What good does it do to annihilate a country twice? We're not a bloodthirsty people'.

In 1972 the two great powers held the first Strategic Arms Limitation Talks (SALT 1). They agreed to limit the numbers of ICBMs and ABMs until 1977. When the next round of SALT was held in 1979 the agreement was never signed because of the Russian invasion of Afghanistan.



TACTICAL NUCLEAR WEAPONS

In the 1960s new technical advances made possible small-scale nuclear weapons which could be directed accurately over short distances. These were designed to be used against enemy troops in a 'limited' nuclear war. The war is expected to be in Europe where NATO (North Atlantic Treaty Organisation) forces oppose those of the Warsaw Pact. In this kind of imagined warfare there cannot be the stability of MAD because the targets are on the battlefield, not in the homelands of the great powers themselves. It has led to a great escalation in weapons as the military-industrial complexes on both sides, which research and manufacture them, produce ever more deadly means of warfare.

This policy of limited nuclear war has raised considerable anxiety in several European countries. There have been attempts to negotiate a reduction of forces, but without success. There has also been a growth of public protest and interest in nuclear disarmament both unilateral (one country only) and multilateral (several countries at the same time).

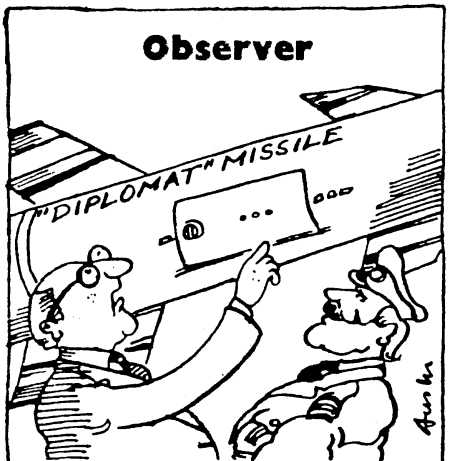
Has MAD been successful in preserving nuclear peace in the last 30 years? (Think of the Korean War, the Cuban Crisis, the conflicts in the Middle East and the Falkland Islands.)
Do you think that Europe could be made into a nuclear-free zone?

PROLIFERATION

Britain and France were quick to make their own nuclear weapons. By the 1970s they had been joined by China, India, and probably Israel, Pakistan and South Africa. This spreading, or proliferation, of nuclear weapons to other countries presents a war danger of a new kind. Minor but bloodthirsty wars between small countries have been common in world history; if nuclear bombs were used when such conflicts break out it would mean not only local devastation but worldwide danger from radioactive pollution and fallout.

The problem of proliferation is connected with the generation of nuclear power, not because nuclear power stations are likely to blow up, but because plutonium, the material for bombs, can be extracted from their nuclear wastes (see *Energy* in this series). To prevent proliferation it may be necessary to think carefully before supplying nuclear power plants to a non-nuclear country. Libya has been trying for several years to obtain either a bomb or a nuclear power station. In 1981 Israel bombed a new Iraqi nuclear plant before it went into action because they believed that it was intended for making plutonium for bombs.

There have been several international treaties designed to prevent proliferation. Antarctica and Outer Space have been declared nuclear-free zones. In 1978 a treaty to exclude nuclear weapons from the countries of Latin America was signed by all except Argentina and the USSR. The biggest international effort was the Non-Proliferation Treaty of 1970. In this the nuclear countries agreed not to supply nuclear weapons or materials, while non-nuclear countries would not try to obtain them. It was not signed by France, China, Cuba, Israel, India, Pakistan, Brazil, Argentina or South Africa. The treaty includes a clause allowing any country to withdraw from its obligations under the treaty, in its own national interests, giving twelve months' notice.



"The onboard computer keeps negotiations going right up until it hits"

Some believe that these international agreements are worth little because they do not contain strict inspection clauses to ensure that countries are conforming to the intention of the treaty. Nations are wary of anything which looks like military spying. Maybe their best feature is that they get political opponents round a table to discuss problems, even if they do not reach a solution. 'Jaw-jaw is better than war-war.'

Some blame the prospect of nuclear war on the inventions of science, some on the economic force of the military-industrial complex, some on nationalistic politicians, and others simply on the human qualities of fear and insecurity.

Consider the importance of each factor at the time of the bombing of Hiroshima, and at the present time.

Suggested Reading

Brighter than a Thousand Suns A. Jungk (Penguin)

A documentary book about the human and scientific aspects of making and testing the bomb.

Tongues of Conscience R. W. Reid (Constable)

Contains fascinating detail about the atom spies. For 16, 17 year olds and older.

Physics in Society Translated from the Dutch (obtainable through SISCON)

Contains an excellent section on nuclear weapons including pictures of missiles and their possible effects in Holland. A text book which contains further physics topics in appendices. For 16, 17 year olds and older.

Hiroshima M. Yass (Wayland)

Simply written in the Documentary History Series. Not too clear in the early scientific part and also rather emotional, but easy to read. For 14 years and older.

Overkill J. Cox (Kestrel)

Goes from the atom bomb to the hydrogen bomb, missiles, anti-missiles, SALT I, non-proliferation, and the British deterrent. A lot of useful material but with a non-nuclear axe to grind. For 15 years and older.

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ISBN 0 631 91000 X