Science in Industry and War in the 20th Century

International Trends and National Rivalries

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History of Modern Physical Sciences

Technological Systems

Early 20th century technology was characterized by the development of large scale systems of production and distribution.

- Exploitation of resources
- Production of parts
- Distribution
- Production of goods
- Consumption
- Systems of control for all of the above

Every aspect of these technological systems requires elaborate distribution of resources, energy, information, and so on.

The real presence of these systems was first felt by non-experts in war times when the systems were disrupted by blockades, sanctions, and so on.

Physics in Industry

At the turn of the century, physics began to enter industrial labs in the same way that chemistry had decades earlier.

Physicists began to argue that industrial production was actually a key component of the social value and esteem placed in the science.

Warburg, 1891

"As far as physics is concerned, the so-called rise of the natural sciences, which characterizes modern times, lies not in the number and discoveries of principles of research. It is due much more to greatly increased effect which this science exerts on civil life and on the branches of technology dependent on it. And, as we must add, to the counter-effects which result thereby."

National and Industrial Labs

Siemens to the Prussian government, 1887

"In the competition between nations, presently waged so actively, that country which first sets foot on new paths and first develops them into established branches of industry has a decisive upper hand."

The Physikalisch-Technische Reichsanstalt (1887, Prussia), the National Physics Laboratory (1898, England), the National Bureau of Standards (1901, US), the Institute of Physical and Chemical Research, RIKEN (1917, Japan), are some examples of the new national laboratories.

At the beginning of the century, the development of private labs was most advanced in the US, then Germany. In 1910, 2% of the research papers in physics were from industry; in 1915 it was 14%; by 1920, 22%. The leaders were General Electric (GE) and the American Telephone and Telegraph Company (AT&T).

War-Time Production Surge

During the Great War (1914–1918), production in private laboratories and factories skyrocketed. For example, in 1917, the total production of vacuum tubes in the US was 400/week; by the end of the war it was 80,000/week. This did not entirely abate in the post-war period.

In 1925, papers in *Physical Review*, the top US research journal in physics, were distributed as follows: 27 from GE, 29 Bell Labs (AT&T), 25 Columbia U, 21 Yale U, 75 CalTech.

Between the wars, Bell Labs was the biggest and wealthiest institution for research physics: 3,400 technical staff, 600 PhD scientists.

Science and Technology in War

When the Great War broke out, chemists and physicists offered suggestions to the military about ways in which they could contribute to the war effort. At first, they were ignored or treated with skepticism. Military officers were reluctant to acknowledge any role for civilian scientists.

- In Germany and Austria, young scientists were simply sent to the front to die in the trenches.

Gradually a number of wartime offices were established.

The Artillerie-Prüfungs-Kommission (Germany) organized physicists to study ranging techniques for artillery: optical, acoustic, seismometric and electromagnetic. The Department for Scientific and Industrial Research (England) promoted, funded and coordinated scientific research for military applications.

- Rutherford developed new techniques for tracking German submarines. Curie develop radiology units. De Broglie worked on radio transmission from the Eiffel tower.

The "Chemists' War"

The Great War has sometimes been called the "Chemists' War." In this conflict, there were hardly any of the internationalist sentiments of the 18th and early 19th century among scientists – they almost all devoted themselves to national interests.

Chemists developed a number of important wartime technologies. They developed:

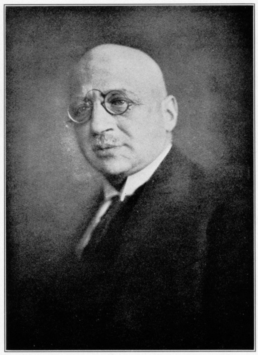
- high-explosive shells that detonated on impact,
- production technologies that would secure manufacturing capability without trade relations with their enemies,
- reorganized production of drugs for medicine and combat, and
- *chemical weapons*.

The stalemate of long-term trench warfare may help account for the resort to poison gases.

Gas Warfare

Fritz Harber (1868–1934) established connections between the war ministry and the Kaiser Wilhelm Institute for Physical Chemistry. They developed a series of poison gases that could be used in explosives – tear gas (1914, first by the French), chlorine gas or "Disinfection" (1915), mustard gas (1917). The French and British responded with their own gasses.

There were over a million gas casualties.



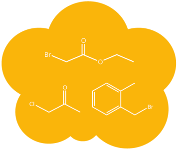
F. Harber

Gattefossé

"The war of tomorrow will surpass the horror that preceded it; without any doubt, the perfection of aviation and chemical warfare will allow entire regions to be rendered uninhabitable."

CHEMICAL WARFARE WORLD WAR 1

WORLD WAR ONE IS SEEN AS THE DAWN OF MODERN CHEMICAL WARFARE, WITH A VARIETY OF DIFFERENT CHEMICAL AGENTS BEING EMPLOYED ON A LARGE SCALE, RESULTING IN APPROXIMATELY 1,240,000 NON-FATAL CASUALTIES, AND 91,000 FATALITIES. A VARIETY OF POISONOUS GASES WERE USED THROUGHOUT THE CONFLICT, WITH EACH HAVING DIFFERING EFFECTS UPON VICTIMS.



TEAR GASES

(ethyl bromoacetate, chloroacetone & xylyl bromide)

SMELL & APPEARANCE

Both ethyl bromoacetate and chloroacetone are colourless to light yellow liquids with fruity, pungent odours. Xylyl bromide is a colourless liquid with a pleasant, aromatic odour.

EFFECTS

Tear gases are what is known as 'lachrymatory agents' - they irritate mucous membranes in the eyes, mouth, throat & lungs, leading to crying, coughing, breathing difficulties, and temporary blindness.

FIRST USED

1914 In August 1914, the French forces used tear gas grenades against the German army, to little effect.

ESTIMATED CASUALTIES

0 fatal

These gases were used to incapacitate enemies rather than to kill; symptoms commonly resolved within 30 minutes of leaving the affected area.

CHLORINE

SMELL & APPEARANCE

Chlorine is a yellow-green gas with a strong, bleach-like odour. Soldiers described its smell as 'a distinct mix of pepper and pineapple'.

EFFECTS

Chlorine reacts with water in the lungs, forming hydrochloric acid. It can cause coughing, vomiting, and irritation to the eyes at low concentrations, and rapid death at concentrations of 1000 parts per million.

FIRST USED

1915 Used by German forces at Ypres in April 1915. British forces used it for the first time at Loos in September.

ESTIMATED CASUALTIES

5,000 number of fatalities in first use of chlorine at Ypres

Chlorine was devastating as troops were initially unequipped to deal with it. Later, gas masks limited its effectiveness.

PHOSGENE

(carbonyl dichloride)

SMELL & APPEARANCE

Phosgene is a colourless gas with a musty odour comparable to that of newly mown hay or grass. If the odour is detectable, it indicates a hazardous level of phosgene. Its density is four times that of air.

EFFECTS

Reacts with proteins in lung alveoli, causing suffocation. Causes coughing, difficulty breathing and irritation to the throat & eyes. Can cause delayed effects, not evident for 48hrs, including fluid in the lungs & death.

FIRST USED

1915 In December 1915, the German forces used phosgene against the British at Ypres.

ESTIMATED CASUALTIES

85% of all gas-related fatalities

It's estimated 85% of all gas-related fatalities in World War 1 resulted from phosgene. It was often used in combination with chlorine.

MUSTARD GAS

(bis(2-chloroethyl) sulfide)

SMELL & APPEARANCE

When pure, mustard gas is a colourless and odourless liquid, but it's used as a chemical agent in impure form. These are yellow-brown in colour and have an odour resembling garlic or horseradish.

EFFECTS

Powerful irritant and vesicant (blistering agent) that can damage the eyes, skin, & respiratory tract. Causes chemical burns on contact with skin. Forms intermediates that react with DNA leading to cell death.

FIRST USED

1917 On 12th July 1917, German forces used mustard gas against the British at Ypres.

ESTIMATED CASUALTIES

2-3% mortality rate of mustard gas casualties

The mortality rate of mustard gas casualties was low - but its effects were debilitating, and patients required elaborate care.

Gas casualties in Britain’s 55th Division 1918

Australian infantrymen with respirators in a trench at Ypres, 1917

German soldiers and military dogs wearing protective gas masks

A soldier exposed to mustard gas

The Outbreak of the Great War

Rutherford and Moseley were at the BAAS meeting in Brisbane. Rutherford proceeded home via Montreal and New York. Moseley joined the army, and was killed at the front. Bohr was at a conference in Germany; he took the last train back to Denmark.

Albin Haller (1849–1925), a leading organic chemist and an Alsatian by birth, became chief counsel on explosives to the French government.

In the early weeks of the war, formerly collegial men degenerated into nationalistic polemic – writing jingoistic editorials and renouncing their international colleagues.

When Britain declared war on Germany, a number of German scientists renounced their honorary degrees from English institutions.

A Mixed Reaction

While many scientists supported this sort of nationalistic fervor, there were some who did not.

P. Ehrenfest, letter to H. Lorentz, 1914

"The typical newspaper report that Haeckel… has rejected his English academic honorary degrees has left me very depressed. Whatever one may think of Haeckel as a scientist… he is at all events a man who is really true to his own conscience, or so it seems to me. Then how could he do such a thing? Now he should also throw away Darwin's books... as another gesture… I don't doubt for an instant that a large fraction of the scientists in all these countries know that the distinctive element of Haeckel's action (treating an honorary degree from Cambridge as if it were a military decoration) is completely irrational and perverse."

Ramsey's Reaction

William Ramsay was a Scottish chemist who had been trained in Germany.

Ramsey, letter to the editor, *Nature*, 1914

"German ideals are infinitely removed from the conception of the true man of science... The greatest advances in scientific thought have not been made by members of the German race... So far as we can see at present, the restriction of the Teutons will relieve the world from a deluge of mediocrity... The motto of the Allies must be 'Never again.' Not merely must the dangerous and insufferable despotism which has eaten like a cancer into the morals of the German nation be annihilated, but all possibility of its resuscitation must be made hopeless. The nation, in the elegant words of one of its distinguished representatives, must be 'bled white.'"

Ramsey's Personal Thoughts

Ramsey was conflicted in his outright denunciation of the "Teutonic race," and tried to come up with some sort of naturalistic explanation for why all of this could be happening.

Ramsey, letter to Remen

"Our friends, the Germans, are very different from what we knew then. I have found out why. Before the war, our Govt. appointed a commission of which the president is one of my old medical colleagues... to investigate syphilis... He told me that in Britain less than 1/2% of the population is syphilitic, in France, about 1-1/2%; in Germany 8.5%! ... While syphilitics often keep going, & retain energy, they appear almost always to have a mental twist; they become abnormal in one way or another. So it comes to this: this is a war against syphilis."

Krieg der Geister – War of the Learned

The Allied press was alarmed that Germany attacked neutral Belgium and there were reports that the troops were destroying treasures of art and science. In response to this, 93 prominent German intellectuals responded to this with the “Appeal to the Cultured People of the world.” It was distributed in 10 languages in all the major German papers. It was followed a few weeks later by a shorter manifesto signed by 3,016 German professors. (Only four, including Einstein, signed a dissenting manifesto.)

They declared themselves, the German leaders of art and science, to be at one with the Prussian army. They repudiated the claims of atrocities as malicious lies, and anyway impossible for good, well-educated German boys to commit. They ended by claiming that they were waging a “civilized war” because after all they were the country which had produced “a Goethe,” “a Beethoven” and “a Kant.”

An die Kulturwelt!

The Shorter Manifesto

"We instructors at Germany's universities… serve scholarship and carry forth a work of peace. But it fills us with dismay that the enemies of Germany, England at the head, wishes – ostensibly for our benefit – to polarize the spirit of German scholarship from what they call Prussian militarism. In the German army, there is no other spirit than in the German people, for both are one, and we are also a part of it. Our army also nurtures scholarship and can attribute its accomplishments in no small part to it… For the army educates them to sacrificial faithfulness to duty and lends them the self confidence and sense of honor of the truly free man who submits himself willingly to the whole… Our belief is that salvation for the very culture of Europe depends on the victory that German 'militarism' will gain: manly virtue, faithfulness, the will to sacrifice found in the united, free German people."

The French Response

The Académie, in Paris, revoked the foreign memberships of all who had signed. A number of French scholars claimed that although the Germans were good organizers, they appropriated all their ideas from elsewhere.

According to P. Duhem (1861–1916), a French physicist and historian of science, in his book *La science allemande*, German science was distinctly marked by the German races' "deplorable" moral and mental characteristics.

One of his prime examples of this was the theory of relativity – developed most intensively by one of the few Germans who had not signed the manifesto, as well as Dutch, British and French physicists – with its "absurd" postulate of the velocity of light as the upper limit of all velocity.

A Popular French Response

The general French public also reacted by condemning the new theories that were coming out of Germany.

A French newspaper editorial, 1916

"The principle of relativity is the basis of a scientific evolution which can best be compared with futurism and cubism in the arts… We find a good example of this mathematical-metaphysical delirium in the theory of quanta of Max Planck, a professor of physics in Berlin and one of the 93 intellectuals on the other side of the Rhine. Planck… introduces… atoms of heat, light, mechanical energy [!], indeed of energy in general; as a result of the theory of relativity these atoms even posses a mass endowed with inertia [!]."

Although this passage shows a number of misunderstandings of the theory – marked by [!] – the general sense of derision is at least clear.

Post-War Tension

With the Treatise of Versailles signed, the Swedish Academy announced the recipients of the Nobel Prize in Physics for 1918 and 1919: M. Planck, J. Stark and F. Harber – All Germans. The French scientists refused to attend the awards ceremony.

No Germans or Austrians were invited to attend a major international conference in chemistry, Solvay, 1922.

At the Solvay physics conferences, E. Schrödinger (Austrian) was the only German to attend until 1927. Einstein was invited but declined in solidarity with his German colleagues.

Einstein

"In my opinion it is not right to bring politics into scientific matters, nor should individuals be held responsible for the government of the country to which they happen to belong."

Rising Anti-Semitism in Germany

In 1920, Paul Weyland (1888–1972) organized a mass meeting at which he gave a lecture slandering Einstein's theories because the latter was a Jew, a pacifist, a publicity-seeker and a "scientific Dadaist."

When Einstein received the Nobel Prize in 1921, Paul Lenard (1862–1947) complained to the Swedish academy that it "had not been able to bring to bear a sufficiently Germanic spirit to avoid perpetrating such a fraud."

When Einstein was invited to give a talk to the Society of German Physicists and Physicians in 1922, he received death threats.

Johannes Stark (1874–1957) began a campaign against "Jewish theoretical physics."

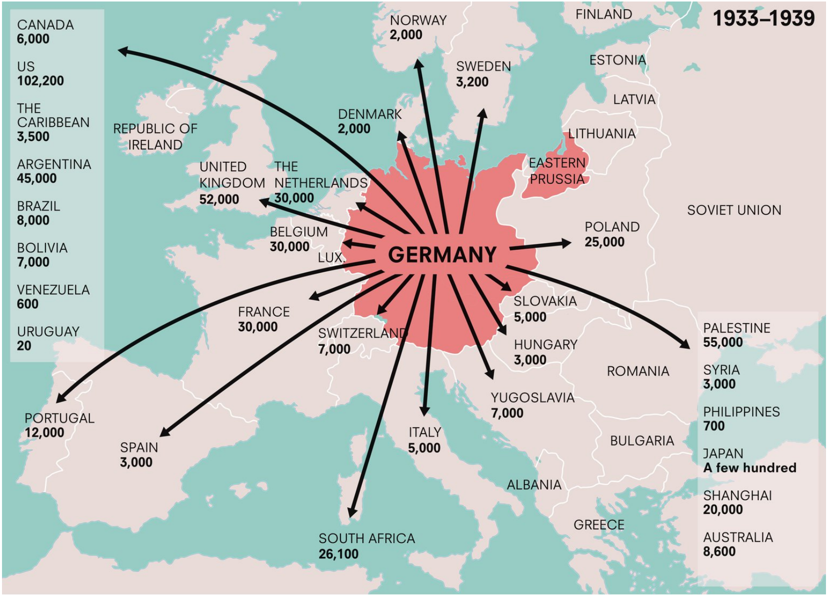
Anti-Semitic Laws

In 1933, A. Hitler gave his acceptance speech as the new leader of Germany. Lise Meitner (1978–1968) described the speech in letter to her colleague Otto Hahn (1879–1968) as moderate and tactful. She said, “hopefully things will continue in this vein… Everything now depends on rational moderation.”

The Nazi party soon declared the country a dictatorship and began to issue a series of progressively more severe anti-Semitic laws.

1933 Civil Service Law: This law stated that civil servants – which included professors – who were not of “Aryan” descent were to be retired, with a few exceptions for veterans of the Great War and their decendents.

1935 Nuremberg Laws: These laws forbade marriage and sexual relationships between Jews and ”citizens of German or kindred blood,” and restricted both citizenship and rights and protections under the law to people of “German or kindred blood.”



Jewish emigration from Nazi Germany

The Great Brain Drain

The dismissals of 1933 included over 1,000 university teachers and over 300 full professors. Some German professors resigned in protest. These individuals began to leave Germany, and to seek employment abroad.

An American reporter, by letter

"Most people don't give a darn; a large proportion is rather glad it happened. Those extremely few who are upset by it are disinclined to say anything publicly or even privately."

Although the majority of emigrants were Jews, among intellectuals and artists a much smaller number of other Germans and central Europeans also left.

These included many highly respected and accomplished individuals in a wide range of intellectual fields, and cultural activities.

The Destinations

In terms of intellectuals and university professors, many of the emigrants initially moved to nearby countries; Denmark, Switzerland, the Netherlands, and France. As the war progressed, however, they often had to move on, and the largest numbers settled in Britain and, especially, the US.

The US was still dealing with the effects of the depression and a strong, but disorganized, anti-science movement. Nevertheless, the US science infrastructure, and its university system, was now the largest in the world and these institutions were best able to absorb the emigrants.

The integration of eminent scientist in the US was as varied as the individuals. Jewish scientists had to cope with American anti-Semitism, especially in the South. They had to cope with large cultural differences. Many returned to Europe after the war, but many more stayed.

The Emigrant Intellectuals

Those who stayed had a profound and lasting impact on the intellectual history of North America. Often they came from great centers of European culture and did not want to go to the US.

Martin Schwarzschild, astronomer

"I did not want to spend my life [there] … I had a simplified picture, to exaggerate a little, that the United States consisted of Indians, gangsters, and Mount Wilson."

Many of them began to publish in English, and this had an effect on their thinking and scholarship.

Erwin Panofsky, art historian

"There are more words in our [German] philosophy than are dreamt of in heaven and earth," noting that in English "even an art historian must more or less know what he means and what he says."

The Emigrant Physicists

In the early 1930s, Germany lost about 25% of its physicists – but this was a critical mass of talent, experience and originality that could not be replaced. In general, the more theoretical the institute, the more dismissals.

Göttingen was the hardest hit – both the mathematics and the physics departments were destroyed.

John von Neumann, by letter

"We have been three days in Göttingen and the rest in Berlin, and had time to see and appreciate the effects of the present German madness. It is simply horrible. In Göttingen, in the first place, it is quite obvious that if these boys continue for only two more years, they will ruin German science for a generation – at least."

The international physics community began to respond to this by isolating Germany – canceling subscriptions to journals and memberships in societies, and not traveling to Germany.

The International Community

The German dismissals gave the scientific community the chance to test the ideals of its international commitment. Scientists reacted swiftly and efficiently.

Private foundations were established, funded by individual donations, and private corporations set up relief funds. Many scientists, and other scholars, pledged 1–3% of their salary to these funds.

- Imperial Chemical Industries, Britain, gave out 2–3 year grants.
- The Emergency Society for German Scientists Abroad was established and gave out temporary grants.
- Academic Assistance Council, England, was set up to collect donations and distribute grants.
- The Emergency Committee in Aid of Displaced German Scholars, US, collected private donations and funded emigrants.

A number of German scientists attempted to take control of the direction of German science by promoting people who supported Nazi ideology, and also by arguing that there was something essentially unsound about the new theories that were being put forward.

B.J. Thüring, 1936

"The ancient magnanimity of soul of the Germanic man, directed away from the world and all external appearance, posed the first world-encompassing question about nature and thus became the mother of natural science."

He claimed that Kepler, Newton, Galileo, Guericke, Faraday, Gauss, Maxwell, and Robert Mayer all had the proper "Germanic spirit" to do real science, but that "it is altogether different with the Jew Einstein." (Notice that four of these individuals were not German.)

The Theory of Deutsche Physik – Germanic Physics

B.J. Thüring, 1936

"There have been repeated attempts in lectures and books to present the theory of relativity as the grand capstone of centuries of progressive scientific development, which began with Copernicus and Galileo and led, via Kepler and Newton, to Einstein. No! Copernicus, Galileo, Kepler, and Newton are not Einstein's predecessors and pathfinders, but his antipodes. Einstein is not the pupil of these men, but their determined opponent; his theory is not the keystone of a development, but a declaration of total war, waged with the purpose of destroying what lies at the basis of this development, namely, the worldview of Germanic man."

Racist Views of Scientific Productivity

J. Stark, a racist theory of science, 1934

"The slogan has been coined, and has been spread particularly by the Jews, that science is international… No, science is not international; it is just as national as art. This can be shown by the example of Germans and Jews in the natural sciences… Natural science is overwhelmingly a creation of the Nordic-Germanic blood component of the Aryan peoples… It is true, however, that the Jewish spirit, thanks to the flexibility of its intellect, is capable, through imitation of Germanic examples, of producing noteworthy accomplishments, but it is not able to rise to authentic creative work, to great discoveries in the natural sciences. In recent times the Jews have frequently invoked the name of Heinrich Hertz as a counter-argument to this thesis. True, Heinrich Hertz made the great discovery of electromagnetic waves, but he was not a full-blooded Jew. He had a German mother, from whose side his spiritual endowment may well have been conditioned."

The German Physics Community Reacts

German physicists and science administrators tried to convince their government that the policies were bad for Germany – and to defray the damage of the new Nazi polices of "Aryan Science."

C.W. Ramsauer (1879–1955) produced a report for the government on the state of German physics in 1942. He pointed out that American citations in *Annalen der Physik* were rising, while German citations in *Physical Review*, "the internationally acknowledged leading physics journal," were declining. In discussing nuclear physics, he stated that

Ramsauer, governmental report on German physics 1942

"The number of German papers in this most modern and promising field has thus risen 3.5-fold, whereas the number of papers written in English has risen 13.5-fold. Yet, as every nuclear physicist will confirm, the quality of American papers is at the very least equivalent to that of the German papers."

The Mainstream Reaction

The Nazi scientists were actually a small minority of the German scientists but they had a strong power base in the 1930s – they were able to fill many of the university positions vacated by dismissed scholars with their own members.

The clear danger that this sort of approach to the sciences posed to intellectual life became a rallying point for more mainstream German scientists, even many of those who politically supported the Nazis.

Prominent physicists, such as M. Planck and W. Heisenberg, took it as their imperative to fight this threat. We just saw the report written by Ramsauer, which attempted to move the Nazi government away from this type of cronyism.

By 1942–1943, the racist scientists had lost much of their following and the movement began to fall apart.

Einstein's Reaction

In 1933, when Nazi Germany passed the racist and antisemitic civil service laws, Einstein was at CalTech, Pasadena, and stated that he would not return to Germany, since the country no longer enjoyed "civil liberty, tolerance, and equality." The Berlin Academy of Science issued a statement that this was an insult to the fatherland. Einstein resigned his membership in the Academy and his German citizenship – for the second time.

Einstein renounced his previous pacifism and internationalism. When asked to support two conscientious objectors in Belgium, he wrote the following:

Einstein, letter to conscientious objectors, 1933

"What I shall tell you will greatly surprise you… Imagine Belgium occupied by present day Germany. Things would be far worse than in 1914… Hence I must tell you candidly: Were I a Belgian, I would not, in the present circumstances, refuse military service."

The Manhattan Project

The Manhattan District, or Development of Substitute Materials, was the name of the US project to build atomic bombs, which was implemented in 1939, and absorbed the previous British project, known as Tube Alloys.

The project was carried out under the direction of General Leslie Groves (1896–1970), with the physicist Robert Oppenheimer (1904–1967) directing the scientific and technical aspects. It employed some 130,000 people and cost around US$2B (US$35B adjusted). There were three primary sites – Hanford, Washington (plutonium production); Oak Ridge, Tennessee (uranium enrichment); Los Alamos, New Mexico (research and design).

Security was a major issue, so almost everyone was kept ignorant of the full scope of the project. Although Germany and Japan were not informed of the project, or its progress, the Soviets were kept aware of the technical details, especially by the German-émigré physicist Klaus Fuchs (1911–1988), who was a spy.

Political Will

Technical work on the ideas behind the bomb began in Britain, by Rudolph Peierls (1907–1995) and Otto Frisch (1904–1979), both German emigrants under a project codenamed MAUD, and then Tube Alloys.

In the US, the motivation for starting the project was the fear that Nazi Germany would start work in a similar vein, which was acutely felt by the emigrant scientists. The famous letter that convinced President Roosevelt to start the project on a small scale was written by L. Sizlárd, E. Teller, and E. Wigner, and signed by Einstein – all emigrants. The fear was that Germany was already working on such a project.

In fact, during the war, Germany, Russia and Japan also had programs for developing atomic weapons – but these were on a much smaller scale and they had no success.

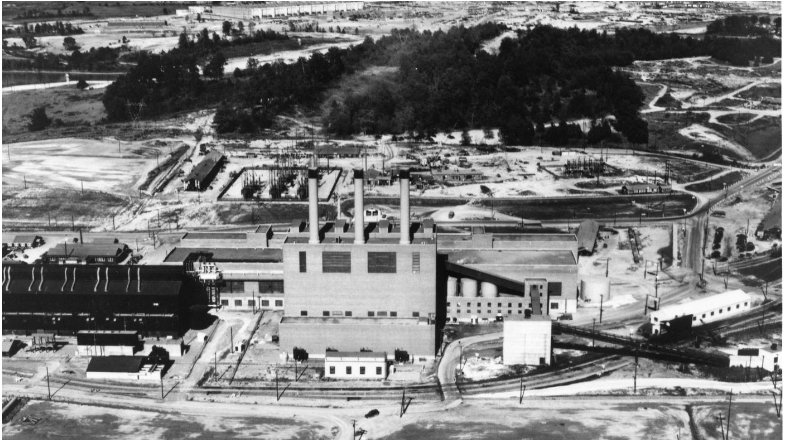
Scientific and Technical Development

The Manhattan Project had five technical divisions: Theory, Experimental physics, Chemistry (later Chemistry and metallurgy), Ordnance and engineering, and Administration. There was a rigid hierarchy of communication and responsibility – something that scientists were not familiar with.

The plan was to build two different types of "gadgets" – one from uranium-235, and one from plutonium-239. For the uranium bomb, a mechanical gun would fire one sub-critical mass of uranium into another at such a velocity that they would become super-critical in a short enough time to explode. For the plutonium bomb, the idea was to implode a spherical sub-critical mass into itself so that the compression would cause super-criticality. Because this design involved a heavy amount of theoretical work – and much calculation, carried out by teams of high-school student "computers" – it was decided that a test would be necessary to determine if it would actually work.

Domestic life at the Los Alamos facility, New Mexico

A declassified photograph of the Hanford B Reactor, Washington



Constructing the Oak Ridge facility, Tennessee

Women on their way to work, Oak Ridge facility, Tennessee

Trinity

The Trinity test was conducted on July 16, 1945, in the Jornada del Muerto desert, about 55km east of Socorro, New Mexico, in order to test the design of the plutonium bomb. The observers included prominent scientists and science administrators – such as V. Bush, J. Chadwick, E. Fermi, R. Feynman, J.R. Oppenheimer, and so on – as well as military commanders and enlisted men.

The site was selected because it was remote, and in a largely unpopulated area. The land had been acquired by the government, and local residents were evacuated. The work was carried out by a group known as the E-9 (Explosives Development) Group, in seven subdivisions: Services, Shock and Blast, Measurements, Meteorology, Spectrographic and Photographic, Airborne Measurements, and Medical. Each was headed by a prominent scientist.

Because of the intensity of the light, locals were told that a stock of ammunition had detonated.

An official photograph of the trinity test

Eyewitnesses of the Trinity Test

Edwin M. McMillan

"The whole spectacle was so tremendous and one might almost say fantastic that the immediate reaction of the watchers was one of awe rather than excitement. After some minutes of silence, a few people made remarks like, 'Well, it worked,' and then conversation and discussion became general. I am sure that all who witnessed this test went away with a profound feeling that they had seen one of the great events of history."

Maurice Shapiro

"The shock wave from the explosion arrived about one and a half minutes after the flash of light, and I heard it as a sharp report. Although I had expected it, the intensity of the blast startled me. My impression at the time was that an enemy observer stationed about 20 miles (30km) from the scene of delivery would be deeply impressed, to say the least."

Deployment

Although, the project was begun with the Germans in mind, by the time the bombs were complete the Germans had already surrendered. A few scientists – including Leó Szilárd – argued that the bombs should not be used – but no one listened, and it was out of their hands anyway.

The US military had intentionally left certain Japanese cities alone so that they would have "virgin targets" upon which the effects of the new weapons would be clearly seen. Flight teams had been preparing for months for the new bombs.

- Hiroshima, Aug. 6, 1945 (uranium, 90-160K casualties).
- Nagasaki, Aug. 9, 1945 (plutonium, 60-80K casualties).

A third bomb had been prepared, but the Japanese government – through the announcement of the Showa Emperor – surrendered.

Eyewitness Accounts

Eyewitness accounts described both the intensity of the explosion:

Michiko Yamaoka, 15yo

"There was no sound. I felt something strong. It was terribly intense. I felt colors. It wasn't heat. You can't call it yellow, and it wasn't blue."

And the human suffering:

An anonymous high school girl

"[I saw] three high school girls who looked as though they were from our school; their faces and everything were completely burned and they held their arms out in front of their chests like kangaroos with only their hands pointing downwards; from their whole bodies something thin like paper was dangling – their peeled off skin which hung there, and trailing behind them the unburned remnants of their puttees. They staggered just like sleepwalkers."

A photograph of the devastation at Nagasaki

Big Science in the Wars

The expression “Big Science” has been used to describe the type of scientific project that developed in the 20th century, and was particularly expanded by the great wars. Big science has a number of characteristics – (a) goal-directed and highly technological research, (b) strong links between military, industrial and university labs and personnel, with a central role for industry, (c) highly specialized, but interdisciplinary, research teams, and (d) military- or corporate-style organizational structures.

- **The Great War:** synthetic rubber production, sonar, wireless communications, x-ray and radiology research, and so on.
- **The Second World War:** radar, jet fuel, penicillin production, code writing and breaking, digital and electronic computers, v-2 rockets, the atomic bomb, and so on.

In both wars, national organizations were established to mobilize and coordinate technical work, which continued in various forms as governmental peacetime institutions.

Big Science in the Post-War Period

Some scientist have criticized Big Science as being an extension of the American mentality of building bigger and bigger machines and seeing what would happen. A. Weinberg, director of Oak Ridge National Laboratories, wrote a paper arguing that Big Science was ruining science, ruining the economy, and that the US should divert more funding to projects that would immediately concern human well-being.

Nevertheless, many of the discoveries of the post-war period could not have been made without the sorts of funding structure and organization made possible by this style of science.

- NASA, ESA, JSA, and so on; high energy physics laboratories (CERN, SLA, and so on), the Human Genome Project, the Hubble and James Webb Space Telescopes, the Atacama Large Millimeter Array (radio telescope); and many more.

Indeed, whole disciplines such as high energy physics, modern astronomy, cosmology, and so on, would be impossible without the Big Science infrastructure.

Overview

- In the 20th century, science and technology moved into a central role in the political, military and economic arenas.
- Scientists and technocrats became socially and politically interconnected with industrialists and politicians.
- It became clear that science and technology were a necessary component of military and economic strength.
- It became clear that science and technology made it possible to commit atrocities on a massive scale.
- As a result of this, the public's image of scientists was changed.