Scientists with a secret

While the Nazi war machine was gearing up, a few physicists realized that a fission chain reaction was feasible—would they be able to get all groups to agree to hold back publication?

Spencer R. Weart

What are physicists to do if they make a discovery that promises to transform industry but also threatens to revolutionize warfare? Should they investigate the phenomenon within their traditions of free and open inquiry or keep the deadly secret to themselves? This is the dilemma that was faced by several groups of physicists who studied uranium fission in 1939 and 1940. In the spring of 1939 one group, foreseeing the unprecedented power of nuclear weapons, made a concerted attempt to restrict knowledge of chain reactions. But it was not until over a year later that censorship—imposed by the community of physicists on itself—became fairly complete.

Any attempt to keep a secret must by its very nature follow a course that is difficult to observe, creating confusion and misunderstanding. But this course, which the participants could not see clearly at the time, can now be pieced together from collections of papers made available to researchers, supplemented by oral history interviews conducted by the Center for History of Physics of the American Institute of Physics.

Fears of disaster

The first arguments over nuclear secrecy revolved around the unlikely figure of Leo Szilard. A short, round, exuberant Hungarian, Szilard in 1939 had neither a job nor a home. But he was uniquely qualified to face the issues of nuclear energy and secrecy because for over five years he—and he alone—had been concentrating on these problems.

Since 1933 Szilard, then recently arrived in England to escape the Nazi persecution of Jews, had wondered if there was a way to release the energy that physicists knew to be bound up in nuclei.[1] The answer came with his realization that if one could bombard some element with a particle (say, a neutron) and make it radioactive in such a way that it emitted two particles, a chain reaction of awesome power might be induced. The possibility seemed much closer the next year, when Frédéric Joliot and his wife Irène Curie, working at the Radium Institute in Paris, discovered that, with alpha particles, one could indeed make nuclei radioactive artificially. Szilard decided to devote himself to nuclear physics and set out to search for some type of nucleus in which a chain reaction might be sustained.

From the start Szilard feared the consequences of his work. He attempted to gain some control by the only means then available to a scientist who wanted to restrict the use made of his work: He took out a patent on his ideas. Furthermore, he persuaded the British government to declare the patent secret; there was a small but real possibility, he warned them, of constructing "explosive bodies ... very many thousand times more powerful than ordinary bombs."[2] Meanwhile Szilard brashly tried to alert his colleagues in Britain. His ideas, he told one professor in 1935, could cause an industrial revolution but might cause a disaster first. It would be necessary to bring about something like a conspiracy of the scientists working in the general field. In a letter to F. A. Lindemann, the head of physics at Oxford, he offered a mechanism to ensure secrecy—an agreement to make experimental results in the dangerous zone available only to those working in nuclear physics in England, America and perhaps one or two other countries, while otherwise keeping quiet.[3]

Szilard foresaw only too well the likely reaction to his efforts: "Unfortunately it will appear to many people premature to take some action until it will be too late to take any action."[3] And indeed the leading physicists in Britain were cool to Szilard's obstreperous advice. They thought his proposed chain reaction entirely unworkable (as was in fact the case for the mechanisms Szilard was then considering). They were suspicious when he sought to patent his ideas, suspecting that he was seeking pecuniary return, a motive incompatible with British traditions of disinterested science. Finally, they found the idea of scientific secrecy entirely alien. Even those scientists who felt most keenly the responsibility of scientists for the consequences of their discoveries traditionally felt that secrecy is abhorrent and that interference with the normal process of open criticism would not only impede scientific progress but pervert it.[4,5]

Spencer R. Weart is the director of the Center for History of Physics, American Institute of Physics, New York.

Szilard went on to study various elements for a possible chain-reaction mechanism; he had not quite reached uranium when he learned that Otto Hahn, Fritz Strassmann, Otto Frisch and Lise Meitner had discovered uranium fission. When Szilard heard of this in January 1939 in New York, where he had moved to escape the war that appeared ever more imminent in Europe, he discussed his concern with scientists at Columbia University.

Private messages

The leading nuclear physicist there was Enrico Fermi, who had fled Italy because Fascist race laws affected his Jewish wife, and who had arrived in New York scarcely three weeks ahead of the news of the discovery of fission. Like Szilard and other physicists, Fermi quickly recognized the possibilities this discovery opened. According to one account, he made a rough calculation of the size of the hole a kilogram of uranium would make in Manhattan Island if it underwent an explosive chain reaction.[6] However, he soon concluded that this would never happen: When a uranium nucleus was struck by a neutron and split in two, it seemed unlikely that it would release enough neutrons to sustain a chain reaction. When Szilard approached Fermi about the need to keep fission work secret, Fermi's response was direct: "Nuts!"

> From the very beginning [*Szilard recalled*] the line was drawn; the difference between Fermi's position throughout this and mine was marked on the first day we talked about it. We both wanted to be conservative, but Fermi thought that the conservative thing was to play down the possibility that this [chain reaction] might happen, and I thought the conservative thing was to assume that it would happen and take all the necessary precautions.[1]

Rebuffed by Fermi, Szilard remained alert for a way to control events. At about this time, late January, a telegram arrived at Columbia, addressed from Hans Halban, a physicist in Paris, to his colleague George Placzek. As Szilard recalled it long after, the telegram was opened by a secretary by mistake, and Szilard learned the contents: "JOLIOT'S EXPERIMENTS SECRET." Placzek had just come from a visit in Paris, and Szilard assumed that Placzek had learned of an experiment Joliot was doing; apparently Joliot had now decided to keep the experiment quiet for the time being. Szilard had little doubt what experiment would be so important as to require secrecy.

What Szilard felt was involved here was the sort of secrecy that had been traditional in science for centuries—the caution of the scientist who holds back his results until he is ready to publish them, so they will not be broadcast in a distorted form and so that others will not take advantage of a hint to beat him to the next result. This was quite different from the sort of secrecy Szilard had in mind. There was some misunderstanding here, for Joliot did not actually begin fission experiments until late January, after Placzek had left Paris, and it is not clear what Halban and Placzek were corresponding about. But Szilard now believed (correctly as it happened) that Joliot's group was working on fission, and decided to send him a letter.

The only reason he was writing, Szilard said, was that there was a remote possibility that he would be sending a cable after some weeks, and the letter was to explain what his cable would be about. Some scientists in New York were concerned about the possibility that neutrons would be liberated in fission. Obviously, if more than one neutron would be liberated, a sort of chain reaction would be possible. In certain circumstances this might then lead to the construction of bombs which would be extremely dangerous in general and particularly in the hands of certain governments. Perhaps steps should be taken to prevent anything on this subject from being published. No definite conclusions had been reached, but if and when any steps were agreed on, Szilard would cable Joliot. Meanwhile Fermi was doing experiments to see whether the danger was real, and these would perhaps be the first to give reliable results. But if Joliot got definite results sooner, Szilard would be glad to have the uncertainty ended. Also, if Joliot felt that secrecy should be imposed, his opinions would be given very serious consideration.[3]

Neither Joliot nor his close collaborators Halban and Lew Kowarski responded. The letter was obviously a purely personal venture, and this impression must have been reinforced by a letter Fermi sent Joliot two days later. On 4 February 1939 Fermi wrote that he was then engaged in trying to understand what was going on in uranium fission—as was, he thought, every nuclear physics laboratory. After thus informing Joliot's team that they had competition, Fermi went on to ask help for another Italian refugee scientist and closed without saying a word about keeping secrets.[7] There was every reason to believe that Fermi would publish first if the French held back their own results.

Even as a personal request Szilard's letter made little impression on the French, for it stated that it was only meant to help them understand a cable that might follow. Weeks passed, no cable appeared, and the French, as Kowarski recalled, "considered that probably the whole idea was abandoned. We simply published."[8]

This publication, the first result of the joint efforts of Halban, Joliot and Kowarski, contained important news: Neutrons were indeed liberated when a uranium nucleus fissioned.[9] The experiment was of a kind that would only have been done in a few places, requiring ingenuity, a powerful source of radioactivity and an interest in chain reactions. It had not been easy to detect the few neutrons produced in fission amidst the flood of neutrons that had been required to provoke some fissions in the first place, nor had it been obvious that these neutrons were important. Although the French, like Fermi, believed scientists everywhere were

The many "secrets" of the atomic bomb

There was no single discovery that showed how atomic bombs could be built, but a combination of discoveries made at various times. Here is a partial list:

Published discoveries

1934 Artificial radioactivity can be produced with alpha particles (Joliot and Curie, *France*) or neutrons (Fermi, *Italy*).

December 1938 Neutrons can cause uranium to fission (Hahn and Strassmann, *Germany*, Frisch, *Denmark* and Meitner, *Sweden*).

March 1939
- Neutrons are produced during fission (Anderson, Fermi and Hanstein, *US;* Szilard and Zinn, *US;* Halban, Joliot and Kowarski, *France*).
- Two or three neutrons are emitted per fission (same groups).
- U^{235} is the fissionable isotope of uranium (Bohr and Wheeler, *US*).

Unpublished discoveries

June 1939–February 1940 A self-sustaining nuclear reactor can be built if a suitable moderator can be found (Szilard, *US;* Halban, Joliot, Kowarski and Perrin, *France;* Heisenberg, *Germany;* various groups, *USSR*).

Spring 1940
- Carbon is a suitable moderator for a nuclear reactor (Anderson and Fermi, *US*).
- Nuclear reactors can be used to produce a fissionable element, plutonium (Turner, *US*)—from this resulted the bomb that devastated Nagasaki.
- It is possible to isolate sufficient U^{235} to make an explosive critical mass (Frisch and Peierls, *UK*)—from this resulted the bomb that devastated Hiroshima.

hard at work on the question, there was in fact only one other group then carrying on a similar experiment—the group at Columbia.

Chain reaction—and invasion

By mid-March Fermi and Szilard, working with Herbert Anderson, Walter Zinn and others, had done their own experiments and independently learned the distressing news that neutrons were produced in fission. This was still far from proving that a chain reaction was possible, for that would depend on the precise number of neutrons emitted in each fission, a thing still more difficult to measure. The group estimated that there were about two neutrons per fission, which made it appear only barely possible that a chain reaction could be sustained (the true value is about 2.5 neutrons per fission).

On 15 March, as the Columbia physicists finished writing up their experiments for publication, German troops invaded the remnant of Czechoslovakia that had survived the Munich agreement. With this action, many felt, Hitler crossed his Rubicon, subjecting for the first time a non-German people and giving a clear signal that world war was inevitable. Despite their concern over this, the physicists sent their papers to the *Physical Review* the next day.

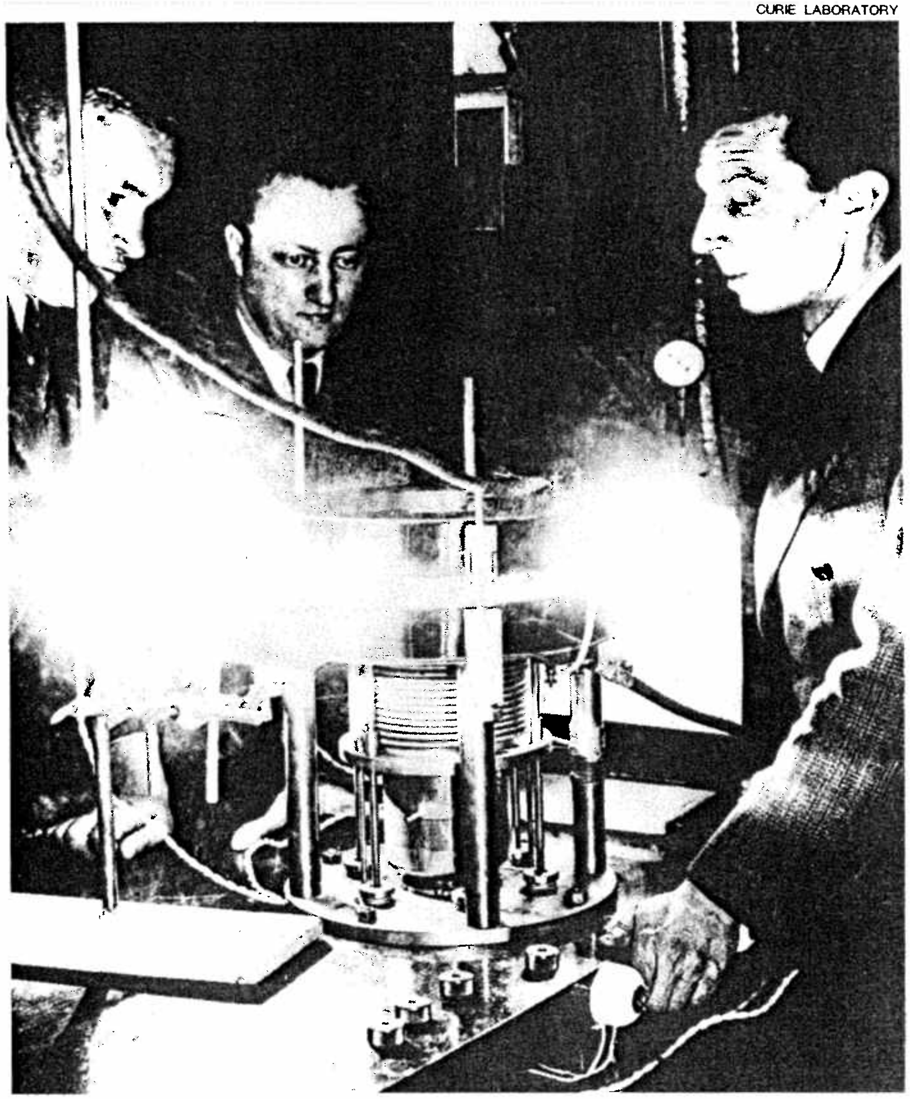
Szilard was not satisfied, and three days later he met with Fermi and with another Hungarian refugee physicist, Edward Teller. As Szilard recalled the meeting, he and Teller pressed for keeping their work secret, but Fermi was repelled by this idea, holding that publication was basic to scientific morality. "But after a long discussion, Fermi took the position that after all this is a democracy; if the majority was against publication he would abide by the wish of the majority . . ."[1] Fermi therefore arranged to ask the *Physical Review* to delay the publication indefinitely.

Szilard was now on the point of cabling Joliot, but before he did so he heard of the French team's note, just published in *Nature*, which revealed that some neutrons are emitted in fission. Fermi felt that there was now no secret to keep, so that there was no longer any sense in refusing to publish. Szilard denied this (the crucial number of neutrons emitted per fission was not yet published), and argued that "If we persisted in not publishing, Joliot would have to come around; otherwise, he would be at a disadvantage, because we could know his results and he would not know our results." Fermi was not convinced but, determined to be fair, he reluctantly agreed to put the matter before George Pegram, administrative patron of the Columbia group and a respected physicist. Pegram delayed his

WIDE WORLD

SZILARD

CURIE LABORATORY



KOWARSKI, HALBAN AND JOLIOT

decision for some time. Szilard's arguments were forceful, but others at Columbia replied that an attempt to restrict publication was both futile and an undesirable breach of scientific custom.[1,3]

Warnings

While Pegram deliberated, Szilard and his friends were determined to waste no time. Several of them talked the matter over, among them Victor Weisskopf, an emigré Austrian physicist. "We were very much afraid of the Nazis," Weisskopf recalled. "We knew this was a hopeless thing but we thought we had to try . . . And then the question was . . . how do we get to Joliot." As Weisskopf said in a recent interview, he had met Joliot's collaborator Halban years earlier and the two had become close personal friends, so Szilard and Weisskopf drafted a telegram to Halban, which Weisskopf signed. The telegram asked Halban to advise Joliot that papers on neutron emission had already been sent to *the Physical Review,* but that the authors had agreed to delay publication for the reasons indicated in Szilard's letter to Joliot of 2 February. The telegram continued:

> NEWS FROM JOLIOT WHETHER HE IS WILLING SIMILARLY TO DELAY PUBLICATION OF RESULTS UNTIL FURTHER NOTICE WOULD BE WELCOME STOP IT IS SUGGESTED THAT PAPERS BE SENT TO PERIODICALS AS USUAL BUT PRINTING BE DELAYED UNTIL IT IS CERTAIN THAT NO HARMFUL CONSEQUENCES TO BE FEARED STOP RESULTS WOULD BE COMMUNICATED IN MANUSCRIPTS TO COOPERATING LABORATORIES IN AMERICA ENGLAND FRANCE AND DENMARK . . .[7]

The proposed scheme was similar to the one Szilard had conceived in 1935, with the additional idea that papers should be sent to journals, not for publication but to certify priority of discovery.

At the same time Weisskopf also cabled P.M.S. Blackett, a leading British physicist, asking whether it would be possible for *Nature* and the Royal Society's *Proceedings* to cooperate in delaying publication of fission research. Meanwhile another of Szilard's Hungarian physicist friends, Eugene Wigner, wrote P.A.M. Dirac and asked him to support Blackett. The matter was rather urgent, Wigner said; although American scientists were willing to cooperate, they realized that their interests might be prejudiced if scientists in other nations published results and they did not.[3,10] Blackett and another prominent physicist, John Cockcroft, promptly replied that they would support the secrecy plan. *Nature* and the Royal Society were expected to cooperate.[3]

NATIONAL ARCHIVES

FERMI

Szilard, Teller, Weisskopf and Wigner also talked the problem over with Niels Bohr, who was visiting the United States. Bohr doubted very much that fission could be used to cause a devastating explosion. And he thought that at any rate it would be difficult if not impossible to keep truly important results secret from military experts—the matter was already public. Nevertheless he agreed to go along with the attempt and drafted a letter to his Institute in Denmark (which apparently he did not immediately mail):

> The Columbia group is busy organizing cooperation among all the physics laboratories outside the dictatorship countries, to keep possible results from being used in a catastrophic way in a war situation, and I must therefore ask you, if work along these lines is going on in Copenhagen, to wait before you publish anything until you have cabled me about the results and received an answer.[11]

But the conspirators still had to win the agreement of other American laboratories.

The most immediate problem was a group headed by Richard Roberts working under Merle Tuve at the Carnegie Institution in Washington, DC. They too had recently seen some neutrons released from uranium. But the neutrons they saw were emitted over a period of some seconds after fission occurred: These were not the true fission neutrons, but occasional neutrons produced as a side effect of the radioactivity of the fission fragments.[12,13] The development was announced in a news release of Science Service dated 24 February, written by Robert D. Potter, a science writer who kept in touch with the Columbia physicists and was infected with their excitement over chain reactions. Potter headlined the possibility of an explosive chain reaction propagated by neutrons. He carefully noted that Roberts's delayed neutrons might not be enough to sustain a chain reaction—in fact they are not—but he quoted Fermi as saying that the possibility of a chain reaction was certainly present.[14]

Szilard and his friends quickly approached the Washington group, who promised to cooperate in withholding future publications. The proposal was spread further within the United States by word of mouth and letter. Maurice Goldhaber of the University of Illinois was included and Ernest Lawrence of Berkeley was probably informed of the matter when he visited New York on 3 April.[15] John Tate, editor of the *Physical Review,* was brought in, for nearly all important physics papers in the United States passed through Tate's office; anyone else who showed an interest in fission neutrons could thus be put in touch with the conspirators. The attempt to restrict the circulation of information to physicists outside the dictatorships was well begun. It lacked chiefly the acquiescence of the French.

The French reply

The French knew what Weisskopf's telegram implied, for they were as alarmed as he by Hitler's march towards world war. However, like Bohr and Fermi, the French believed an atomic bomb was not likely to be built for many years, if ever. In this they were entirely correct, so far as atomic bombs were then conceived—masses of tons of natural uranium. Nobody had yet seriously considered the likelihood of isolating a substantial quantity of the rare fissionable isotope U^{235}, still less of the undiscovered element plutonium; and these two substances are the only ones that could in fact be used for a nuclear weapon. Unaware of these possibilities, Joliot and his collaborators thought that industrial nuclear power from nuclear reactors was a much more immediate prospect than weaponry.

It was up to Joliot, as head of the team, to answer Weisskopf's telegram, but he discussed it at length with his colleagues. Thinking back, they recalled a number of factors that entered their decision.[8,16] For one thing, Joliot believed strongly in the international fellowship of scientists, and in principle had little sympathy with secrecy.[17] For another, if he and his colleagues failed to publish, they might well be eclipsed by those who did. For they could scarcely believe that everyone would adhere to an unprecedented pact, a pact pushed forward, so far as they knew, only by two Central European refugees on the outskirts of the Columbia scientific community. (Had Fermi, Bohr or a leading American scientist written them about the scheme, the French might have found it more plausible.) And if they failed to be first to publish discoveries, the French might have trouble getting the money they would need to pursue the development of industrial nuclear energy. Finally, even if all the laboratories joined and stuck by the agreement, there would remain a powerful objection, the same one noted by Fermi and Bohr. It was scarcely likely that copies of papers circulated privately around America, France, Britain and Denmark could be kept out of

BREIT

Germany and the Soviet Union; moreover, German and Soviet scientists were surely aware of the importance of fission chain reactions.

Ideas of fission power and weapons had begun to show up in the popular press. The French were aware of at least some of the sensational news stories that emanated from the United States. The French were not in close touch with what was happening there, but it is very likely that they had seen a copy of a Science Service news release of 16 March, which summarized their own report, published in *Nature* on that date, of neutrons resulting from fission. Presumably they were not pleased to read that they had apparently been beaten to the discovery: Their result, the release said, "is comparable with, and a confirmation of, the announcement (Science Service, 24 February 1939) that scientists at the Carnegie Institution . . . had been able to observe the same important reaction in atomic transmutation."[18] This was an error, but it made it seem that the most important facts were already leaking out in America.

For all these reasons, the team cabled Weisskopf a discouraging reply around 5 April.

> SZILARD LETTER RECEIVED BUT NOT PROMISED CABLE STOP PROPOSITION OF MARCH 31 VERY REASONABLE BUT COMES TOO LATE STOP LEARNED LAST WEEK THAT SCIENCE SERVICE HAD INFORMED AMERICAN PRESS FEBRUARY 24 ABOUT ROBERTS WORK STOP LETTER FOLLOWS
>
> JOLIOT HALBAN KOWARSKI[3]

Szilard was well informed on the work of Roberts's group through their publications and through letters from Teller, who had visited them various times, and on the next day, Weisskopf having left New York, Szilard answered on his behalf. Roberts's paper, he noted, concerned delayed neutron emission, which was harmless. But the group had been approached and had promised to cooperate. The American group had delayed publishing papers; were the French inclined to delay their papers too, or did they think everything should be published?

That same day the French sent their final answer:

> QUESTION STUDIED MY OPINION IS TO PUBLISH NOW REGARDS JOLIOT.[3]

The scheme fails

This reply, along with the preceding French publication of the fact that fission does produce some neutrons, doomed the attempt to restrict publication. Pegram, who was not aware how much progress Szilard and his friends had made aside from the French, after some days of deliberation decided that any attempt to impose secrecy was hopeless. Szilard was forced to give in. The Columbia scientists asked the *Physical Review* to print their papers.[19]

On April 7, the day of the final exchange of cables with Szilard, the French sent *Nature* the results of experiments and calculations that estimated the number of neutrons emitted per fission at between three and four. The report was duly published on 22 April 1939. This note convinced many physicists that uranium chain reactions were a real possibility. In Britain, George P. Thomson decided to warn his government of the dangerous prospects and meanwhile to begin experimenting with uranium.[20] In Germany, Georg Joos wrote a letter to the Reich Ministry of Education; independently and simultaneously, Paul Harteck and Wilhelm Groth wrote a joint letter to the War Office.[21] News of the French work may also have played a role in the start-up of Soviet nuclear energy research, perhaps provoking the letters on uranium which I.V. Kurchatov and others sent the Soviet Academy of Sciences about this time.[22] Thus in Britain, Germany and perhaps the Soviet Union, publication of the French results precipitated offically-supported programs of research into nuclear energy. The effort of Szilard and his friends, after coming within an inch of success, had failed disastrously.

Nevertheless, by the end of 1939 a blanket of secrecy had settled over fission research in certain countries. After war broke out in September, scientists in France, Germany and Britain withheld publication on fission and any other subject remotely of military interest. But in the United States, the Soviet Union and other neutral countries, publication was scarcely impeded.

US government: Do it yourself

Szilard continued to work on the problem. With Albert Einstein he set in motion a chain of events that led to the formation of an official government committee, under Lyman J. Briggs, which was supposed to support and coordinate fission work.[23] From the beginning Szilard hoped that the committee would also do something about secrecy. When he took up the matter with Briggs he added another element to his by now increasingly well developed scheme. Presumably to counter objections he had faced from younger men at Columbia, he wrote:

> For a physicist, who has not yet made a name for himself, refraining from publication means a sacrifice which he should not be asked to make without being offered some compensation. Some addition to the salary which he is normally drawing from the university might therefore be desirable and might require the creation of some special fund.[3]

But the Briggs committee remained all but inactive, leaving everything up to the physicists. As late as 27 April 1940, when the committee held one of its rare meetings, the only response Szilard could get was a suggestion from Admiral Harold Bowen, present as an observer, that the scientists working on uranium might get together and impose upon themselves whatever censorship they felt necessary. The government itself would do nothing.[3]

Szilard had already taken the single step that was entirely within his power: He withheld from publication a paper of his own. This paper, completed in February 1940, contained elaborate calculations of the characteristics of a nuclear reactor and concluded that there was a strong possibility of making one work. Had the article been published, it surely would have been a great stimulus to nuclear reactor work in various countries. But when Szilard sent it to the *Physical Review* he requested that printing be delayed until further notice.[2] For a second specimen of a withheld paper, in late April Szilard persuaded Herbert Anderson, a graduate student who had worked closely with Fermi on fission from the beginning, to hold back his doctoral thesis on neutron absorption in uranium, which was then already in proof.[24,25]

Anderson and Fermi had meanwhile been measuring the neutron-absorption cross section of carbon. This difficult-to-determine quantity was central to the question of whether or not a nuclear reactor could be built, for carbon seemed the only feasible moderator, and even carbon could be used only if it absorbed virtually no neutrons. This turned out to be the case: The cross section was extremely small. Szilard now approached Fermi and suggested that the value for the cross section should not be published. "At this point," Szilard recalled, "Fermi really lost his temper; he really thought that this was absurd." But while Fermi stuck by his principles, Pegram had second thoughts and finally asked Fermi to keep his work secret.[1]

This decision came late, but still in time: If the value for the carbon cross section had been published, the course of World War II might conceivably have been changed. For German scientists, using experiments they carried out later in 1940, wrongly concluded that carbon had a substantial neutron-absorption cross section. From that point on they abandoned carbon as a moderator and attempted to use the extremely rare isotope deuterium, which they never managed to get enough of.[21,26] Soviet scientists too at first did not seriously consider carbon as a moderator.[27] The French scientists were also committed to deuterium. They escaped to England when France fell to the Germans, and thereafter the British followed their lead in matters of reactors, regarding carbon as an unlikely choice. Anderson and Fermi's work could have put all these groups on a different track.


PHYSICS

Exploding Uranium Atoms May Set Off Others in Chain

Explanation Suggested at Physics Meeting Believed By Prof. Fermi To Be One of Several Possibilities

EXPLODING atoms of uranium may [illegible] each other off in a chain like stick [illegible] laid in a row. New poss[illegible] [illegible]sive rupture [illegible] of the th[illegible] it A [illegible] hit another uranium atom and break it, too.

Prior work on uranium splitting has indicated that for a single neutron striking a single uranium atom the process [illegible]. But it was also found [illegible]expenditures

SCIENCE NEWS LETTER, for April 1, 1939

PHYSICS

Confirm Release of Neutrons From Splitting Uranium Atoms

FRENCH scientists have confirmed the American discovery that splitting uranium atoms, releasing their enormous amount of atomic energy, also give off neutrons in the reaction.

This liberation of neutrons from uranium atoms split by impact with other neutrons, is most important because it provides a mechanism [illegible] theoretically [illegible]

These American scientists, Drs. Richard B. Roberts, R. C. Meyer and P. Wang, found that the secondary neutron emission from the uranium splitting was delayed by some seconds. There is no indication whether the experiments [illegible]

Two history-making releases from Science Service, as reprinted in *Science News Letter*. After reading an erroneous statement in the later (lower) article, which said that their results had already been published in America, the French team rejected Szilard's request for secrecy.

Prescription for a bomb

This was not the only hole in the dike that had to be plugged. In late May, Louis Turner at Princeton sent Szilard a copy of a paper on "Atomic Energy from U^{238}." In this paper Turner pointed out that if U^{238} were bombarded by neutrons, as would happen in a nuclear reactor, a series of steps would give rise to a new element. This he predicted to be fissionable—it was the element later named plutonium. Although Turner had not realized it, he had written the prescription for the easiest route to building an atomic bomb.

Szilard wrote back at once to say that his own paper was secret, implying that there was an official move underway to withhold papers. He persuaded Turner to write the *Physical Review* and delay publication.[3] It was well he did so: Turner's paper could have been an essential clue for the Germans and others. Meanwhile Szilard approached Harold Urey and asked him to try to set up a committee to regulate fission publications.

Before much progress had been made, the 15 June issue of the *Physical Review* appeared, containing a letter from Edwin McMillan and Philip Abelson at Berkeley. They had observed the production of neptunium when uranium was bombarded with neutrons. This was the first and most essential step of the process that Turner had predicted should lead to plutonium. But Abelson and McMillan had simply failed to see the connection between their work on transuranic elements and the fission problem.[15,28]

This publication brought down a flurry of protest, which helped to settle the secrecy issue. From as far as Britain, scientists interested in fission protested the publication of such revealing information. But the most important news came from Gregory Breit at the University of Wisconsin. Breit had known Szilard and Wigner for years, and was awakened to the secrecy problem through long conversations with them. Around the beginning of June Breit found a way to circumvent the problems Szilard and others were running into. Recently named to the National Academy of Sciences, he had been put in the Division of Physical Sciences of the Academy's National Research Council. At a committee meeting he spoke up in favor of censorship. There was some skepticism, Breit later recalled, but a committee on publications was appointed to consider the problem. Breit was made chairman of a subcommittee concerned specifically with uranium. Acting on his own initiative, he immediately began writing letters to journal editors, proposing a voluntary plan under which papers relating to fission would be submitted to his committee before publication. Sensitive papers would be circulated only to a limited number of workers. Breit added that he expected ultimately to publish the papers in book form or otherwise, with a statement of the original date of the paper and with a suitable acknowledgment of the public spirit of the authors.[15]

There were some raised eyebrows, but the editors of scientific journals and other leading scientists agreed to the plan. "As recently as six months ago," Lawrence wrote Breit, "I should have been opposed to any such procedure, but I feel now that we are in many respects essentially on a war basis."[15] German troops were pursuing the remnants of the defeated French army, and none could doubt that the international situation was desperate.

Better than never

Within a few weeks Breit, who swiftly set up close communications with Fermi, Urey, Wigner and others involved in parallel efforts at secrecy, had imposed total censorship on American fission research. After passing the papers around by mail for comment, Breit's committee let some through as innocuous; other they withheld from publication.[25] Because of this procedure, carried out entirely by physicists with no government participation, long before the United States went to war it was keeping vital scientific information within its own borders.

The extraordinary coincidence that history's most dangerous scientific secret appeared at the moment history's greatest war began made possible this unique case of scientific self-censorship. It was imposed against the grain—even some of the conspirators, like Szilard and Teller, would later argue strongly for the advantages of open publication. But it is worth noting that if self-censorship is difficult, under sufficiently deadly circumstances it can be achieved, and that if it may seem to come late, late may be far better than never.

* * *

I wish to thank first of all Gertrud Weiss Szilard, who kindly gave me permission to use the Szilard Papers and to publish the excerpts above. Thanks are also due to Hélène Langevin, who kindly made available the Joliot-Curie Papers; to Monique Bordry, who gave invaluable assistance in their use; to Gregory Breit, Otto Frisch, Victor Weisskopf, and particularly Lew Kowarski, who answered the questions I posed them, and to Charles Weiner, who assembled interviews and other materials at the Center for History of Physics of the American Institute of Physics. Further details and documentation on the subject of this article will be published in Volume 2 of The Collected Works of Leo Szilard (reference 1 below) and in a book I am preparing on French scientists and nuclear energy. All translations are my own except for the Bohr letter, for assistance with which (and for much else) I thank John Heilbron.

References

1. L. Szilard, "Reminiscences," *The Intellectual Migration, Europe and America, 1930–1960* (D. Fleming and B. Bailyn, eds.) Harvard U. P., Cambridge, Mass. A revised and expanded version will be in *The Collected Works of Leo Szilard*, volume 2 (G. W. Szilard, H. Hawkins, S. Weart, eds.), MIT Press, to be published.
2. *The Collected Works of Leo Szilard, Volume 1, Scientific Papers* (B. T. Feld, G. W. Szilard, eds.), MIT Press, Cambridge, Mass. (1972).
3. Szilard papers, La Jolla, Calif.
4. Bainbridge collection, American Institute of Physics, New York.
5. J. D. Bernal, *The Social Function of Science*, Routledge & Kegan Paul, London (1939), pages 150, 182.
6. Pegram collection, Columbia Univ. Library.
7. Joliot-Curie papers, Radium Institute, Paris.
8. Testimony of L. Kowarski before the US Atomic Energy Commission's Patent Compensation Board, Docket 18, 16 March 1967, Energy Research and Development Administration, Germantown, Md.
9. H. von Halban, F. Joliot, L. Kowarski, Nature **143,** 470 (1939); *The Discovery of Nuclear Fission: A Documentary History* (H. Graetzer, L. Anderson, eds.), Van Nostrand Reinhold, N. Y. (1971).
10. Copies are in ref. 3; the original is in Dirac papers, Churchill College, Cambridge, UK.
11. Bohr Scientific Correspondence (copies are held at the American Institute of Physics, New York; American Philosophical Society Library, Philadelphia; Bancroft Library, Berkeley, and Niels Bohr Institute, Copenhagen).
12. R. B. Roberts, R. C. Meyer, P. Wang, Phys. Rev. **55,** 510 (1939).
13. R. Roberts, L. R. Hafsted, R. C. Meyer, P. Wang, Phys. Rev. **55,** 664 (1939).
14. Science Service, 24 Feb. 1939; reprinted in Science News Letter, 11 March 1939, page 140.
15. Lawrence papers, Bancroft Library, Berkeley, Calif.
16. R. Clark, *The Birth of the Bomb: The Untold Story of Britain's Part in the Weapon that Changed the World*, Horizon, New York (1961); B. Goldschmidt, *Les Rivalités Atomiques 1939–1966*, Fayard, Paris (1967), page 27; interview of Kowarski by Weiner, American Institute of Physics.
17. F. Joliot-Curie, *Textes Choisis*, Editions sociales, Paris (1959), page 154.
18. Science Service, 16 March 1939; reprinted in Science News Letter, 1 April 1939, page 196.
19. R. B. Anderson, E. Fermi, H. B. Hanstein, Phys. Rev. **55,** 797 (1939); L. Szilard, W. H. Zinn, Phys. Rev. **55,** 799 (1939).
20. M. Gowing, *Britain and Atomic Energy, 1939–1945*, St. Martin's Press, New York (1964), page 34.
21. D. Irving, *The Virus House: Germany's Atomic Research and Allied Counter-Measures*, William Kimber, London (1967), page 32.
22. I. N. Golovin, *I. V. Kurchatov: A Socialist-Realist Biography of the Soviet Nuclear Scientist* (H. Dougherty, transl.), Selbstverlag Press, Bloomington, Ind. (1968), page 31.
23. R. G. Hewlett, O. E. Anderson Jr, *The New World: A History of the United States Atomic Energy Commission, volume 1: 1939–1946*, Pennsylvania State U. P., University Park, Pa. (1962), page 16; Briggs Committee correspondence, Atomic Energy Papers, Office of Scientific Research and Development, National Archives, Washington, DC.
24. E. Fermi, *Collected Papers, volume 2: United States 1939–1954*, (E. Segrè *et al*, eds.) University of Chicago Press, Chicago (1965), page 31.
25. Samuel A. Goudsmit collection, Library of Congress, Washington, DC.
26. W. Bothe, P. Jensen, "Die Absorption thermischer Neutronen in Elektrographit," 20 Jan. 1941, captured German report G-71, Technical Information Service.
27. Bulletin de l'Académie des Sciences de l'URSS, Ser. Phys. **5,** 555 (1941); a translation by E. Rabinowitch, Report CP-3021, is available from Technical Information Service, Oak Ridge, Tenn.
28. E. McMillan, P. H. Abelson, Phys. Rev. **57,** 1185 (1940). □