COMMENTARY

# Fermi, Feynman and fission

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*Today's ideas are blueprinted, mocked-up, engineered, electrified, wound-tight and set loose to rev men up or run men down.*

Ray Bradbury[1]

The story of atomic energy attained prominent worldwide public attention with the bombing of Hiroshima and Nagasaki in 1945. Even today, many associate 'nuclear energy' with the World War II attacks on Japan, and the Three Mile Island and Chernobyl disasters. The recent earthquake and tsunami in Japan culminating in the explosion at Fukushima has revived questions on the rationale behind nuclear power. There have been protests worldwide calling for a safer source of energy. Although some countries have put in place a nuclear moratorium and review of existing and proposed nuclear plants, others are going ahead with their nuclear plans. Are the benefits from nuclear power worth the costs and the associated risks?

## From science to strategy

Seven years after the atomic bombings of Hiroshima and Nagasaki on 6 and 9 August 1945, and ten years since the first self-sustaining atomic chain reaction was achieved on 2 December 1942 by Enrico Fermi and his team, Fermi recalls that: 'The sequence of discoveries leading to the atomic chain reaction was part of the search of science for a fuller explanation of nature and the world around us. No one had any idea or intent in the beginning of contributing to a major industrial or military development[2].' He recounts the discoveries that preceded the success of his Chicago pile experiment and how contributions came from many countries (see Box 1).

Fermi also remembers how in 1939, some physicists in the United States, including himself, 'agreed privately to delay further publications of findings in this field[2]' as they were apprehensive that this would help the Nazis in the World War II, that was to start soon. Once the atom bomb project began, secrecy was mandatory. The secrecy was such that Fermi's wife Laura knew about the success of the first self-sustaining chain reaction experiment only two and half years later, after the end of the war!

To obtain a method of using the energy from atoms, the next step was to establish an atomic chain reaction, which Fermi compares to 'the burning of a rubbish pile from spontaneous combustion'. He goes on to explain the process: 'In such a fire, minute parts of the pile start to burn and in turn ignite other tiny fragments. When sufficient numbers of these fractional parts are heated to the kindling points, the entire heap bursts into flames. A similar process takes place in an atomic pile such as was constructed under the West Stands of Stagg Field at the University of Chicago in 1942. The pile itself was constructed of uranium, a material that is embedded in a matrix of graphite. With sufficient uranium in the pile, the few neutrons emitted in a single fission that may accidentally occur strike neighboring atoms, which in turn undergo fission and produce more neutrons. These bombard other atoms and so on at an increasing rate until the atomic "fire" is going full blast. The atomic pile is controlled and prevented from burning itself to complete destruction by cadmium rods which absorb neutrons and stop the bombardment process. The same effect might be achieved by running a pipe of cold water through a rubbish heap; by keeping the temperature low the pipe would prevent the spontaneous burning. The first atomic chain reaction experiment was designed to proceed at a slow rate. In this sense it differed from the atomic bomb, which was designed to proceed at as fast a rate as was possible[2].'

A self-sustaining chain reaction was achieved by Fermi and his team on 2 December 1942 and on 28 December

**Box 1.** Discoveries preceding the first self-sustaining atomic chain reaction.

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| 1896, Paris: | Discovery of radioactive elements by Antoine Henri Becquerel. |
| 1898, Paris: | Discovery of radium by Pierre and Marie Curie. |
| 1905, Zurich: | Declaring his belief that 'mass was equivalent to energy' by Albert Einstein. 'This led to speculation that one could be transformed into the other.' |
| 1912: | Discovery of the nucleus by Ernest Rutherford. 'In ordinary elements this core is stable; in radioactive elements it is unstable.' |
| Shortly after World War I: | Artificial disintegration, for the first time, of the nucleus of the nitrogen atom by Ernest Rutherford. |
| 1932: | 'Walter Bothe in Germany, and Frederic Joliot-Curie in Paris prepared the ground work that led James Chadwick of England to the discovery of the neutron.' |
| 1934, Rome: | Finding that neutrons could disintegrate many atoms, including uranium, by Fermi and others. 'This discovery was to be directly applied in the first atomic chain reaction eight years later.' |
| 1938, Berlin: | Discovery of fission of the uranium atom by Otto Hahn and Fritz Strassman. 'When Hahn achieved fission, it occurred to many scientists that this fact opened the possibility of a form of nuclear (atomic) energy.' |

(Compiled from Fermi's description[2].)

1942, the decision was made by the US Government to build an atomic bomb[2]. These bombs would be dropped on Japan in 1945.

The Manhattan Project to build the first bomb began in 1942. Richard P. Feynman was involved in this project and was the only person who saw the first test atomic blast. He says: 'I am about the only guy that actually looked at the damn thing, the first Trinity Test…The people at six miles couldn't see it because they were all told to lie on the floor with their eyes covered, so nobody saw it. The guys up where I was all had dark glasses. I'm the only guy who saw it with the human eye[3].' Feynman had positioned himself behind a truck windshield through which the ultraviolet rays would not be able to pass and had not worn the protective dark glasses that were handed out.

Feynman[3] recalls his entry into the project. One day when he was working in Princeton University, Robert Wilson informed him of a secret job that he had been funded to do, about the 'problem of separating different isotopes of uranium', of how he had to 'ultimately make a bomb', and a meeting that was to take place regarding this. Feynman had not wanted to be involved in it and told Wilson so. Feynman says: 'So I went back to work on my thesis, for about three minutes. Then I began to pace the floor and think about this thing. The Germans had Hitler and the possibility of developing an atomic bomb was obvious, and the possibility that they would develop it before we did was very much of a fright. So I decided to go to the meeting at three o' clock. By four o' clock I already had a desk in a room and was trying to calculate whether this particular method was limited by the total amount of current that you can get in an ion beam, and so on….'

He narrates an incident that happened when everyone was celebrating the success of the Trinity test. Feynman found Wilson 'moping'. Wilson says: 'It's a terrible thing that we made.' Feynman exclaims: 'But you started it, you got us into it.' Feynman goes on to explain: '…what happened to me, what happened to the rest of us is we *started* for a good reason but then we're working very hard to do something, and to accomplish it, it's a pleasure, it's excitement. And you stop to think, you know, you just stop. So he was the only one who was still thinking about it, at that particular moment.'

In a later interview[3], when Feynman was questioned as to whether he had 'done the right thing or the wrong thing' with his role in making the atomic bomb possible, he answers: 'No, I don't think that I was wrong exactly at the time I made the decision. I thought about it and I think correctly that it was very dangerous if the Nazis got it. There was, however, I think, an error in my thought in that after the Germans were defeated – that was much later, three or four years later – we were working very hard. I didn't stop; I didn't even consider that the motive for originally doing it was no longer there….'

## From strategy to security

Fermi in his account says: '…we all hoped that with the end of the war emphasis would be shifted decidedly from the weapon to the peaceful aspects of atomic energy. We hoped that perhaps the building of power plants, production of radioactive elements for science and medicine would become the paramount objectives. Unfortunately, the end of the war did not bring brotherly love among nations. The fabrication of weapons still is and must be the primary concern of the Atomic Energy Commission. Secrecy that we thought was an unwelcome necessity of the war still appears to be an unwelcome necessity[2].' This was in 1952. During the Nuclear Security Summit on 13 April 2010, the US President Barack Obama is reported to have said: 'Two decades after the end of the Cold War, we face a cruel irony of history – the risk of a nuclear confrontation between nations has gone down, but the risk of nuclear attack has gone up. Terrorist networks such as al Qaeda have tried to acquire the material for a nuclear weapon, and if they ever succeeded, they would surely use it[4].'

In 1946, Fermi[5] discussed the future of atomic energy. He envisioned that in the next 20–30 years, there would be large central installations where electrical energy or steam would be produced for local power consumption. He also predicted that: 'Besides producing directly power, these large units may also produce some amount of plutonium which will be extracted and distributed to small installations in which plutonium and not uranium will be used as the primary fuel.' He talked of other possible applications of atomic power, for example, some of the radioactive materials produced during the fission process could be used for medical applications or as tracers in other fields of study.

Fermi foresaw more political than technical problems associated with the use of atomic power. He says: 'It will require an unusual amount of statesmanship to balance properly the necessity of allaying the international suspicion that arises from withholding technical secrets, against the obvious danger of dumping the details of the procedure for an extremely dangerous new method of warfare on a world that may not yet be prepared to renounce war[5].'

Today, though radioactive elements are being widely used in many applications, the main controversial uses are in the areas of national security (defence) and energy security. These seem to be motivated more by political and economic concerns rather than technological or scientific ones. The case of the disasters at Chernobyl and Fukushima illustrate the risks associated with nuclear power due to faulty designs and human fallibility. The threat of nuclear material falling into the 'wrong hands' also looms large.

Should we stop to think?


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