# The History of the Twentieth Century
## Episode 337
## "The Tizard Mission"
### Transcript

[music: Fanfare]

When the Second World War began, British scientists were investigating a number of new technologies that could potentially change the course of the war. But when Britain was left to fight the Germans alone, British industry was stretched to the limit just to keep up.

What was the solution? How about turning to the nation that was a world leader in mass production?

Welcome to *The History of the Twentieth Century*.

[music: Opening War Theme]

Episode 337. The Tizard Mission.

All the way back in episode 301, I told you about the German physicists Otto Hahn and Fritz Strassmann, who were the first to split the uranium nucleus in 1938, and the physicists Lise Meitner and her nephew, Otto Frisch, who published a paper in January 1939, giving the theoretical explanation for Hahn's and Strassmann's results.

In Britain, physicists at a number of British universities, including Cambridge, Liverpool, and Birmingham, studied uranium fission. They tried to replicate the result, work out the theoretical basis for uranium fission, and consider two questions: first, might it be possible to use uranium fission chain reactions to build a facility that could produce usable power; generate electricity, perhaps. And with war brewing in Europe, the second question would be hard to avoid asking: could uranium fission be used to produce an atomic bomb?

In 1939, the tentative answers most physicists were offering to these questions were: possibly yes, and probably no. Yes to power generation, but the atomic bomb seemed wildly impractical.

We've already met Sir Henry Tizard, the English scientist who before the war led a committee created to investigate the problem of air defense. It was Tizard's committee that initiated and oversaw the development of radar. Now, the British military queried Tizard and his committee on the feasibility of an atomic bomb. Tizard judged such a thing unlikely; on the other hand, if such a thing could exist, it would constitute a grave threat. It would be safer to study the problem until physicists could say with absolute certainty whether or not it was possible, rather than ignore the problem and run the risk that the Germans might solve it first.

Australian physicist Marcus Oliphant, a former student of Ernest Rutherford, became a professor of physics at the University of Birmingham in 1937, with a remit to build a nuclear physics program at the university. One of his first steps in that direction was to recruit the German theoretical physicist Rudolf Peierls. Peierls had been studying at the University of Cambridge's Cavendish Laboratory in 1933, when Adolf Hitler became chancellor of Germany, and as he was Jewish, he opted to stay in Britain rather than return to Germany. You can add him to your scorecard of Jewish German physicists driven out of their homeland by the Nazis who then went to work in Britain or the United States instead.

Otto Frisch, who should already be on your scorecard of Jewish German physicists driven out of their homeland by the Nazis, was at this time working with Danish physicist Niels Bohr in Copenhagen. In the summer of 1939, Mark Oliphant invited Frisch to visit Birmingham to discuss the paper he had published earlier that year with his aunt Lise. The war broke out while Frisch was at Birmingham and he too opted to stay in England. Oliphant arranged a position at the university for him.

As you'll recall from episode 327, radar research was hugely important to the British at this time, perhaps the most important war-related scientific work going on in the country, and many British physicists were involved in that work, including Mark Oliphant. But Peierls and Frisch were still technically German citizens and therefore enemy aliens, which excluded them from the top secret radar project. Ironically, since radar was too sensitive a topic to allow them to get involved with, they turned instead to the study of uranium fission, which was at this time not secret and therefore open to them.

In France, physicist Francis Perrin defined the concept of "critical mass," that is, the minimum amount of uranium required to sustain a nuclear chain reaction. Perrin's first calculations put the amount at 40 tons, give or take. In 1939, shortly after the war began, Peierls published his own paper on the problem. His calculations produced a similar result, and Peierls concluded that an atomic bomb was not feasible.

But in Copenhagen, Niels Bohr was considering mathematical models of an atomic nucleus, and with uranium fission the number one topic on the minds of physicists, he naturally applied his model to the uranium nucleus, for insights into how and why fission occurred. But here's the thing: naturally occurring uranium consists almost entirely of two isotopes, U-238 and U-235. Recall that isotopes are atoms of the same element that differ in the number of neutrons they have in their nuclei. Uranium is almost all U-238 and only a small fraction, about .7%, is U-235.

Bohr's work suggested that the nucleus of U-235, the rare form, was far more likely to capture a neutron and therefore far more fissile, as they say.

This caught the attention of Otto Frisch, Bohr's former colleague, who began to ask himself: if you could somehow prepare a sample of uranium that was all U-235, what would its critical mass be? Frisch used Peierls's methodology to make the calculation and arrived at a stunning conclusion: the critical mass of U-235 would be measured not in tons, but in kilograms.

The implications were staggering. If these calculations of Peierls and Frisch were correct, an atomic bomb would not only be feasible, but it would be small enough to carry on a bomber and drop on an enemy city from the air. These earlier calculations, that gave critical masses in tons, ruled out a bomb dropped by air, though you might consider putting it on a ship and sending the ship into an enemy port. You may recall that was the scenario laid out in the famous letter written by Leo Szilard, signed by Albert Einstein, and delivered to Franklin Roosevelt by Alexander Sachs in October 1939.

Frisch and Peierls wrote their own letter—well, more of a memo—and sent it to Marcus Oliphant, outlining their findings. They told no one else, as they were well aware how dangerous this information might be. Oliphant shared the memo with the British government, which spurred action from several government agencies. British intelligence was instructed to look into what was going on with atomic research in Germany. The government investigated and secured sources of uranium ore, just in case. Archibald Hill, a British scientist, Nobel Prize laureate, and now the science attaché at the British Embassy in Washington, was instructed to sound out the Americans to see if they were researching an atomic bomb. He reported back that yes, indeed they were.

In April 1940, a committee was formed to further investigate the prospects of an atomic bomb, which was eventually named the MAUD committee. It acquired its name in a circuitous way. Neils Bohr, now living in German-occupied Copenhagen, had sent a telegram to Otto Frisch which, among other things, asked after a woman named Maud. The reference was obscure and was at first believed to be some kind of code, although it turned out that Maud was a real person, Niels Bohr's former maid, now living in England. Still, it inspired the idea of naming the committee the MAUD Committee, with M-A-U-D spelled in all capital letters to give the impression it was an acronym for something. It wasn't; that was just a bit of misdirection.

French intelligence reported that the Germans were showing an interest in heavy water, which was alarming because heavy water was thought possibly useful in operating an atomic reactor. At this time, the only commercial source of heavy water was a plant operated by Norsk Hydro, a Norwegian hydroelectric company. The French had arranged to buy up Norsk Hydro's entire stock and ship it to France for use by French researchers. The French were able to pass that stock of heavy water on to the British before France fell, which was the good news. The bad news was that Norsk Hydro's plant was in Norway, which was now occupied by the Germans, meaning that Germany had secured the world's only heavy water plant for its own use. Was that just an accident, or was securing that plant part of the German motivation for invading Norway? No one on the Allied side knew the answer to that.

By summer 1940, the British government was in the remarkable position of overseeing a number of different secret research projects, one or more of which could potentially turn the tide of the war. There was radar, which we discussed in episode 327. There was the atomic bomb, which I just told you about. There was ASDIC, which I mentioned in episode 319. This technology used sound waves to locate a submarine underwater, not unlike the way radar uses radio waves to locate an airplane. There was plastic explosive, which is just what it says on the tin. It's an explosive material that can be cut, shaped, and applied in the field, making it very useful for battlefield demolition, for blowing up, let's say, bridges or railroad tracks or fortifications.

There was the proximity fuze, which could explode a bomb when it got near its target without actually having to come in contact with the target, making it useful especially against ships or airplanes. And there was the jet engine, a technology pioneered by a 21-year-old RAF cadet named Frank Whittle. The jet engine used internal combustion, not to turn a propeller, but to ignite a fuel-air mixture and blow it out the back of the engine in a stream of hot gas. This technology had the potential to propel airplanes at speeds far beyond what a propeller was capable of.

I could go on. There were more projects under investigation, but the ones I've described were the ones that seemed to have the greatest military potential.

But the summer of 1940 was also a grim time for the Allied cause, as you already know. France fell, and the Luftwaffe bombing campaign against Britain had begun in earnest. Radar was a top priority, of course, as Britain was under attack. British industry was running at full speed to produce fighter planes to fend off the Germans and factories were being bombed. So long as the Luftwaffe was bombing British facilities and killing British civilians, stopping them was job one and every available resource had to be reserved for that purpose. There was no time or money to spend on such things as, for example, building and test-flying jet planes. Jet planes might prove quite valuable in the long run, but in the short run, the Germans were doing their best to pummel Britain into capitulation, and if they succeeded, there would be no long run.

So what can be done? Henry Tizard, the scientist who was overseeing so much of this research, approached Winston Churchill with a wild idea. Although Europe was still the place where most leading-edge scientific research was conducted, you couldn't deny that the Americans were excellent engineers. Americans just loved to build the newest, the biggest, the fastest, of anything, and their factories could crank out new products by the metric ton. And, of course, the United States was at peace, and even if it should enter the war, American factories were beyond the reach of German bombers.

So, Tizard proposed to the prime minister, suppose we simply took all this top secret research to America and gave it to the Americans to develop and build, in exchange for which they'll sell the stuff back to us when it was ready.

I really wish I could have been in the room when Tizard laid out this proposal to Churchill. I would love to have seen the look on his face. Churchill is the person who, three years from now, will remark that "In war-time, truth is so precious she should always be attended by a bodyguard of lies." The British government had made strenuous efforts to keep all these programs secret. And now, Henry Tizard, the person tasked with overseeing most of Britain's top secret research, walks into Number Ten and calmly proposes that we…give it all away? Have you taken leave of your senses?

But wait, let's think about this for a minute. Tizard was right about the Americans. They undeniably had the world's best manufacturing facilities. They would surely accept an offer such as this one gladly, and supply Britain with these modern wonders faster than Britain could hope to provide them from its own industrial base. And it would help make America safer, too. It would demonstrate to President Roosevelt the value of a close relationship with Britain. It would create trust.

And it might possibly leave President Roosevelt feeling indebted to the British, at a time when Churchill was desperately begging him for those fifty destroyers to help fight the U-boat menace.

Not everyone in the British government was keen on this idea, but Archibald Hill, the science attaché, was tasked to sound out the Americans and see if they were receptive to the proposal. He reported back that the Americans were receptive to the idea and recommended the government proceed.

{music: Handel, *Water Music*]

On August 29, 1940, a small group of British scientists boarded a British ocean liner in Liverpool. With them they brought a locked metal strongbox that contained Britain's most important military secrets. The trip took about a week and must have been nerve wracking, as German U-boats were prowling the Atlantic.

Henry Tizard was not aboard this ship. He had left earlier and was in Canada to consult with officials of the Canadian government on ways Canada could contribute to the development of these projects. The rest of the group headed straight for Washington.

Tizard met with his American counterpart, Vannevar Bush, chair of the National Defense Research Committee, a group that had hastily been organized after the fall of France, and arranged a series of meetings between his group and US government officials and researchers. They set up an office at the Shoreham Hotel, near the British Embassy, where they hosted these meetings.

Tizard himself briefed Bush on British jet engine research. The US government was at that time already researching jet engines itself, but Tizard convinced Bush that the British were so far ahead that it made more sense to abandon the American program and simply license the British technology. Eventually, General Electric would manufacture British-designed jet engines in the US. The first American jet fighter, the Lockheed P-80 Shooting Star, would enter service at the very end of the war.

At this time, the most important American military secret was the Norden bombsight. It had been developed by the US Navy over a period of ten years and was the pride of American engineering. The Norden bombsight was a complex device meant for use on bombers. As you might guess from the word bombsight, a bombardier would look through the eyepiece of the bombsight at an image of the ground below, with crosshairs superimposed. The idea was that at any given moment, a bomb released from the plane would land precisely at the center of the crosshairs.

But that basic description doesn't give the Norden bombsight enough credit. The device included a gyroscopic stabilizer that would keep the bombsight in proper alignment even if the plane were not level, or was shaking. It also incorporated an analog computer that would automatically receive information concerning wind speed and the speed of the aircraft and adjust the crosshairs accordingly. If the plane was not flying at the proper bearing to pass directly over the target, the Norden bombsight would show that too and tweak the plane's heading automatically.

The Norden bombsight spared the bombardier from the need to consult tables and manually calculate the bomb's trajectory.

In Britain, the RAF became aware of the development of the Norden bombsight by 1938. It was advanced beyond anything the British had and the RAF made an effort to acquire some from the Americans. But the Norden bombsight was a Navy project, and the US Navy had a low opinion of the British military at the time, and feared the British would allow the Norden to fall into German hands. They refused.

That same year, 1938, a French military observer was injured in the crash of an American bomber, which I told you about in episode 332. This triggered a minor scandal over the Roosevelt Administration providing arms to European countries and forced Roosevelt to publicly pledge not to share advanced US military technology with other countries, by which was primarily meant the Norden bombsight.

The British persisted. They contacted the US Army, which was also using the bombsight in the Army Air Corps, and offered to trade some British bomber technology for the Norden, but the Army refused, on the grounds that the Norden was a Navy project, so it was up to them. Prime Minister Neville Chamberlain wrote a personal letter to Franklin Roosevelt requesting the opportunity to purchase the Norden bombsight, but Roosevelt also refused.

The reasons for rebuffing the British were more political than technical. By 1939, the existence of the Norden bombsight was public knowledge. Members of Congress spoke of it in their debates over military policy. In April 1939, the US Army invited George Pirie, the British air attaché, to Fort Benning, in Georgia, to watch a demonstration. The outline of a battleship had been drawn on the ground, and the spectators were told to watch a B-17 bomber bomb the "battleship." As the spectators watched the sky for the arrival of the bomber, six bombs exploded in rapid succession on the imaginary "deck" of the imaginary "battleship." Pirie reported at least thirty seconds passed after the bombing before the B-17 that had dropped the bombs became visible.

These observations only whetted the appetite of the RAF for the Norden, but the Americans continued to resist, even though by late 1939, articles were beginning to appear in American science magazines describing the bombsight and how it worked. By 1940, the manufacturer was publicly boasting that the Norden bombsight was accurate enough to allow a high-altitude bomber to drop a bomb into a pickle barrel.

Tizard and his group made one further plea to the Americans to share the Norden as part of their information exchange, but the Americans still refused. The best they would offer was to give the British details on the size of the bombsight and where and how to mount it on their planes, allowing the British to reserve a spot for the device in their bombers for the day when the Americans decided it was time to let the British have them.

With the benefit of hindsight, you know and I know that the most important bit of research the Tizard Mission discussed with the Americans was atomic research, but neither the British nor the Americans saw it that way at that time. This was September 1940; Frisch and Peierls had not yet written their memorandum, and the prevailing view was still that the feasibility of an atomic bomb was very much in question. The concept of an atomic power plant that might be used to generate electricity, on the other hand, was taken seriously, though most experts in the field thought this would take many years to develop. The war would likely be over before a practical power plant could begin operating.

I'll talk more about atomic research in a few minutes, but first let's take a look at what the British did think was the most important bit of research under discussion. That would be radar. The Tizard Mission came to the US bearing information on British radar research, research which had led to the radar network in Britain that was a critical component in the fight against German bombers. The British delegation was quite surprised—and I suspect more than a little disappointed—to learn that the US Navy had its own radar project going, and was even beginning to equip American ships with radar equipment.

The Americans had in fact developed radar systems that operated at higher frequencies, and thus shorter wavelengths, than anything the British had in the field. You may recall I discussed some of this in episode 327. Shorter wavelengths are good in radar for three reasons. First, they allow for shorter antennas, since the length of the antenna is related to the wavelength of the signal. Second, radar can't detect objects smaller than its wavelength, and third, shorter wavelengths bounce off the target and reflect back at greater strength, meaning that shorter wavelengths made the radar both more sensitive and to smaller targets.

The Americans had working radar systems with frequencies of 200 megacycles per second, which works out to a wavelength of 1.5 meters, or about five feet, with is pretty remarkable. This radar would be able to detect enemy aircraft easily.

But then the Americans shared with the British something even more amazing. They were experimenting with radar frequencies a couple of orders of magnitude higher: into the gigacycle range. Frequencies this high would give you wavelengths in the ten centimeter range, around four inches. A radar that operated at those frequencies would be able to detect a submerged submarine by its periscope, which sounded incredible. But the Americans had hit a stumbling block. The device they used to generate radio signals at this frequency was called a magnetron. Magnetrons are vacuum tubes, and in 1940 vacuum tubes were everyday technology. But magnetrons are different. They aren't used for amplification; they force electrons to move in circles inside the device, which generates radio waves.

So far so good, but here's the problem: at higher frequencies, magnetrons become increasingly inefficient. You have to pump more and more power into them to generate the same strength of signal. The Americans were finding that high frequency, high power magnetrons generated a lot of heat and were tricky to maintain. One little mistake and the metal parts of the magnetron would melt, destroying the device.

I'd like to think Henry Tizard's reaction, after the Americans explained all this, was to clear his throat and say something like, "I see. Well then, I have good news for you chaps."

Inside that metal strongbox that the British delegation had brought to America were lots of papers and blueprints, and exactly one sample object. I imagine the box rattled quite a bit when anyone shook it. This object inside was the absolute latest thing in radio technology, just developed a few months ago in Britain.

It was called a cavity magnetron.

A cavity magnetron is a magnetron in which the metal anode has a ring of circular holes drilled into it, hence the name cavity magnetron. When a cavity magnetron is powered up, electrons resonate around the circular holes. Since the circumference of these holes is small and electrons move very fast through metal, they resonate at a very high frequency and generate radio waves in very short wavelengths. In our time, we call this wavelength range *microwaves*.

The cavity magnetron not only produced very short radio waves, it did so much more efficiently than earlier magnetrons. They were precisely the solution the Americans were looking for.

Cavity magnetrons would not demand nearly as much power and would not be as delicate and as prone to self-destruction.

The importance of the cavity magnetron cannot be understated. It allows the construction of radars with extremely short wavelengths, which have the benefits I mentioned a few minutes ago; that is, they give you a radar that is much more sensitive to much smaller targets, but wait, there's more. Since the length of the transmitting antenna is related to the wavelength, these 10 centimeter wavelengths allow for a 5 centimeter antenna, small enough to fit practically anywhere. Compare that to the tall metal towers the British had to build for their Chain Home radar stations.

Also, the cavity magnetron doesn't require nearly as much power, which means the radar equipment itself can be much smaller. Not only would fitting it into a naval vessel, even a submarine, now be a simple matter, we are now talking about a device that can be installed aboard an aircraft.

We saw how Chain Home, that early and relatively primitive radar system, substantially reduced the threat of enemy bombers by giving an early warning that would allow fighters time to intercept. Imagine if every fighter plane had an onboard radar system and every one of them could spot enemy bombers at a distance of tens or hundreds of miles. Imagine if every naval bomber had onboard radar that would allow it detect enemy ships beyond visual range, even submarines, and even, as I said, detect a submerged submarine by its periscope.

The cavity magnetron would revolutionize aerial warfare and it would revolutionize naval warfare, not least by creating a much larger anti-ship and anti-submarine role for aircraft.

The American side was naturally delighted with the cavity magnetron. They saw at once its value, and this British gift would allay much of the suspicion and hostility toward the British among US government and military leaders.

The Tizard Mission traveled to a General Electric laboratory in New Jersey, where they demonstrated the use of the cavity magnetron. The US government immediately contracted with AT&T, the American Telephone and Telegraph Company, to manufacture cavity magnetrons. The first batch was available in a matter of weeks, and AT&T would make over a million of them by the end of the war.

The Tizard Mission next traveled to New York City and Columbia University to compare notes on atomic fission research. You already know that a year earlier, in October 1939, after Franklin Roosevelt received that famous letter, he ordered an investigation into atomic fission. In February 1940, the US Navy gave Columbia a $6,000 research grant, which Enrico Fermi and Leo Szilard were using to build an experimental atomic reactor.

Their goal was to build a reactor that would generate heat, which could in turn be converted into electricity. At this time, Fermi was still skeptical of the feasibility of an atomic bomb, even after the Tizard Mission told him that British physicists were coming around to the view that it was possible and that the critical mass required might be much smaller than previously thought.

I should mention that a Canadian physicist, George Laurence, was independently working on a smiliar atomic fission project in Ottawa. The Tizard Mission had already met with him.

Henry Tizard and his delegation returned to Britain in October 1940. Their mission had been a resounding success. As for atomic research, Tizard's group gave a mixed assessment of the possibility of an atomic bomb. They offered that an atomic power plant was possible, but it would take years to work out the details of how to build one, meaning that atomic power was not likely to become a reality before the end of the war. Nevertheless, it was a promising post-war technology, and Tizard recommended the government continue to research it.

Ah, but that was before the Frisch-Peierls memorandum, which they drew up two months later, in December 1940, which led to the creation of the MAUD committee. The MAUD Committee sponsored research at four British universities: Cambridge, Oxford, Liverpool, and Birmingham.

Much of the research involved isotope separation. Frisch and Peierls had shown that the critical mass of U-235 was as little as five kilograms. Yet this isotope constitutes less than one percent of the uranium found in nature. The remainder is almost entirely U-238, which is much less suitable because its nuclei don't capture neutrons nearly as readily as do the nuclei of U-235. Also, when a nucleus of U-235 captures a neutron, it splits, releasing more neutrons and a lot of energy. When a nucleus of U-238 captures a neutron, that doesn't happen. What does happen? Hold that thought for a moment.

What this means is: even if Frisch and Peierls are correct and a few kilograms of U-235 can be made into a bomb of mind-boggling power, such a weapon is still not feasible unless a method could be found to separate the necessary isotope from the U-238, and in industrial quantities. That's a tall order. U-235 is less than one percent of the uranium collected from a uranium mine. That means you would have to process a minimum of half a ton of uranium to get enough U-235 for one bomb. A whole ton might be a more realistic estimate.

By the twentieth century, chemists knew how to separate out different chemical elements using chemical processes. Elements that had commercial value, like aluminum, could be separated and produced in commercial quantities. But separating isotopes was a whole new level of difficulty. Different isotopes of the same element have the same number of electrons and therefore they react with other chemicals in the same way, which would seem to rule out chemical extraction.

The only difference between isotopes is the weight of the atom, so isotope separation would have to involve a process that separates the uranium into individual atoms and then sorts them by weight. Researchers at these universities considered the problem. Their conclusion was that such a process would be complex and difficult, but that given enough time and money, it would be possible to build a plant capable of producing perhaps as much as a kilogram of U-235 every day. Whether a Britain fighting a desperate war against the Axis could afford to spare that many resources on a project that would take several years to come to fruition, well, that was a different question, and it was not one you could farm out to a team of scientists to figure for you.

A group at Cambridge was considering a whole other question. Just before the fall of France, that heavy water that French intelligence had secured from Norway was shipped to Britain and stashed at Windsor Castle, of all places. I suppose they figured if Windsor Castle was safe enough for the Princesses, it would be safe enough for the heavy water as well.

Along with the water came a team of French physicists, who, shortly after arriving in England, considered the question of what happened when the nucleus of an atom of the more common U-238 absorbed a neutron. In theory, the nucleus should absorb the neutron, turning it into U-239, which would be extremely unstable. It would emit a beta particle, an electron, and change into a hypothetical element 93, the next element down on the periodic table, past uranium, which was at this time at the bottom of the table as the element with the greatest atomic number.

They further concluded that this nucleus of element 93 would also be unstable. It would emit a second beta particle and become element 94. And here's the interesting bit: element 94 would absorb neutrons readily and fission just as well as uranium-235. This meant that perhaps the whole problem of uranium isotope separation could be sidestepped. It might be simpler to bombard the common U-238 with neutrons, transmute it into element 94, and use *that* in your bomb. Since uranium was named after the planet Uranus, physicist Nicholas Kemmer proposed that the hypothetical elements 93 and 94 be named neptunium and plutonium.

The MAUD committee issued its final report in June 1941, concluding that an atomic bomb was indeed feasible. In response to the report, the British government set up an atomic bomb research and development program, which was given the intentionally misleading name Tube Alloys, which suggested the program was actually about something very different.

We'll pick up the story of Tube Alloys in a future episode, but for now I'll note that in June 1940, two American physicists, Edwin McMillan and Philip Abelson, had published a letter in the American journal *Physical Review*, in which they independently laid out the same hypothesis the French team was working on: that U-238 could be transmuted into element 93, and then element 94. The British were deeply disturbed that the Americans were openly talking about these matters, given the high stakes involved in who got an atomic bomb first, and a formal British government protest was issued to the US government, asking them to kindly shut up about this stuff, if you'd be so kind.

McMillan and Abelson were part of a research team at the University of California led by chemist Glenn Seaborg. In late 1940, independently of the British program, Seaborg's team produced elements 93 and 94 at the Berkeley Radiation Laboratory. They got the naming rights, as the first to produce the new elements, but as sometimes happens, they independently came up with the same idea to name them neptunium and plutonium. Seaborg chose Pu as the chemical abbreviation for plutonium, because it amused him. P-U, get it?

When U-238 absorbs a neutron, you get Np-239. This isotope proved to be short-lived, with a half-life of around 60 hours. Then it decays into Pu-239, which has a much more practical half-life of about 20,000 years; plenty of time to accumulate a bomb-sized amount before it decays away.

The Americans had learned their lesson, and the production of neptunium and plutonium would be kept secret until 1948.

We'll have to stop there for today. I thank you for listening, and I'd especially like to thank Richard for his kind donation, and thank you to Paige for becoming a patron of the podcast. Donors and patrons like Richard and Paige help cover the costs of making this show, which in turn keeps the podcast available free for everyone, so my thanks to them and to all of you who have pitched in and helped out. If you'd like to become a patron or make a donation, you are most welcome; just visit the website, historyofthetwentiethcentury.com and click on the PayPal or Patreon buttons.

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I'm pleased to be able to tell you that a short story of mine appears in the just-released fantasy anthology, *Artifice and Craft*. It's a collection of stories about magical artifacts. It is available as an ebook or a paperback at Amazon, Barnes and Noble and Kobo.

And I hope you'll join me next week, here on *The History of the Twentieth Century,* as we consider another important military technology that will play a big role in the story of the Second World War: cryptography. A military has to get messages from the commanders to the front lines and certainly doesn't want the enemy listing in. Hence the use of codes and ciphers. The Germans thought they had an unbreakable one. The Enigma Machine, next week, here, on *The History of the Twentieth Century.*

Oh, and one more thing. Much of the research into the atomic bomb in Britain and the United States was driven by the fear that the Germans had their own project going and might well be ahead of the Allies.

In fact, this was not so, although no one in the West would know it until after the war. The Germans had researchers looking into the problem, but Germany never created the kind of highly centralized, heavily funded crash research program the British and the Americans created. The Germans were also hampered by the fact that many of their best atomic physicists had been driven out of the country by Nazi anti-Semitic policies. Many young people who might have become talented physicists were drafted into the Army, especially after 1941.

Germany's leading atomic physicist was Werner Heisenberg. Early in the war, he and a team of physicists concluded that an atomic bomb was possible, but development would take at least five years, likely too late to make a decisive contribution to the war. Fear of the Nazi state was also a factor. If a large and expensive research project were created, and it expended much in time and resources, but failed to produce a working bomb, it would have had, in Albert Speer's words, "extremely disagreeable consequences."

By early 1942, the German government and military dropped the atomic bomb project, but continued research into the use of atomic fission to generate power, but by 1943, with the war turning against Germany, interest even in this project began to wane.

[music: Closing War Theme]