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DAVID KAISER: Welcome to 8.225/ STS.042. Just a quick announcement-- hopefully, you saw the message also through the Canvas course site, as well. We're going to do a similar routine for this coming week as we had done earlier this week, which is to say students' main assignment for Monday's class session this coming Monday is to watch, on your own time, at your own schedule, at your leisure, another documentary film. This one's also about a little less than 90 minutes, so it's comparable to a class session time.

This film is called *Containment.* It was made by Peter Galison, some of whose work we've read before, and some of his colleagues worked on the film. And it takes some of the threads we've been talking about even further up more recent in time. I think it's a fascinating, again, very engaging, at times very troubling documentary. And so the main assignment is to watch that.

So for today, it'll be a more familiar style class session. I have a bunch of slides. So I want to carry the story forward a bit further in time compared to just the developments immediately during the Second World War, which we've been focusing on for several class periods in a row.

And so today is looking into the period that came to be called the Cold War, in looking at some aspects of nuclear questions during the Cold War, much, much more beyond that that we can't cover in detail in class. But I want to at least introduce some things along the lines we've already been talking about. So today, as usual, almost always there's three main parts to the class. We're going to start by talking about, what do people mean when they talk about this phrase, the atomic secret?

And as we'll see, that gets bound up with questions about both espionage and possible implications of espionage during the Second World War, and also about what's called proliferation, other countries besides the United States or the immediate US-UK-Canada partnership during the war that led to the Manhattan Project, how and when did some other countries begin to develop their own nuclear weapons. And that whole bundle of themes and topics we'll talk at least briefly about for the first part of class today.

Then we'll talk about the US decision to actually pursue a different kind of nuclear weapon, the hydrogen bombs or fusion weapons. And again, you got some of this introduced near the end of the film, *The Day After Trinity.* And I'll just talk a bit more about how those decisions played out in the US context.

And then the third part will be pretty quick. But I just want to make sure we all know that the policy challenges posed by nuclear weapons hardly disappeared in 1945 or 1950. So the last part will be a look at some of the international treaties that came and went over the longer period beyond just the 1950s, stretching later into the Cold War. So that's really just a much briefer sketch, just to make sure we're clear that these issues really did have a very long, a long tail. And in fact, of course, many of the issues are still relevant to this day. That's where we're heading today.

So as we saw both in the previous lecture and also I think very evocatively in the film *The Day After Trinity,* the Manhattan Project was this really unprecedented, sprawling scientific and technical project, ultimately employing about 125,000 people at 30 or maybe 31 sites, distinct sites across the United States and parts of Canada. It was just enormous. It included some of the, at the time, world's largest factories ever constructed at all, some of those at the isotope separation plants in Oak Ridge, likewise, the billion cubic feet or cubic meters-- billion cubic something-- of concrete poured at the Hanford site to host these enormous, enormous nuclear reactors to do things like create kilograms of plutonium instead of only micrograms.

Just a reminder, this was a project on an unprecedented, industrial scale, as well as involving lots of complicated questions for science and engineering along the way. So that work was done in secret during the war. And as I mentioned briefly, some of those sites like Oak Ridge and Hanford were literally not even on the map at the time. The existence and the location of the sites was considered too sensitive to put even on simple maps of, say, the state of Tennessee, for example, or Oak Ridge. But the secrecy was-- some part of the secrecy was removed quite dramatically at the end of the Second World War when the nuclear weapons were used against Hiroshima and Nagasaki. And suddenly, this was worldwide news, no longer only top secret.

So what I was curious about a number of years ago-- and I wrote an article that was part of the readings for today-- was how did people react to what had previously been treated as very, very top secret once the fact of the weapons was no longer a secret? And so the way to think about that that I pursued was, what did people mean when they use the phrase, the atomic secret? They use that phrase all the time, especially in that first decade after the end of the war, in all kinds of settings and media.

What did people mean? What did they think the term the atomic secret referred to? And one thing I want to prime us for just days before the next election here in our current days, is that a lot of these discussions, maybe not so surprisingly, were unfolding in the midst of and reflective of domestic politics, not only domestic-- there are lots of international things going, on as well-- but a lot of the rhythms of what changed, what kinds of conversations seemed to dominate at different times.

I think we can make sense of that by thinking about a timeline of domestic, often electoral politics. When's the next congressional midterm, especially when's the next presidential election? How are those elements of a familiar US rhythm of public discourse? How are those wrapped up with some questions that, on the face of it, didn't seem to be tied up in an obvious way with those kinds of political jockeying?

So the very first public response that got a lot of play in literally days and weeks after the news about the bombings of Hiroshima and Nagasaki, the first response was there is no secret. The response to the question, what's the atomic secret, was to say there is no secret. And that was especially advocated or promulgated by a group that came to be called the Federation of American Scientists or the FAS. Their very first title was a Federation of Atomic Scientists.

And this included many, many folks who had been at various wartime Manhattan Project installations, including Los Alamos, but also at Oak Ridge, Tennessee, less so at Hanford, though some, and also at the Met lab in Chicago. And they very soon after the war founded a journal that's still around today, just celebrated its 75th anniversary, called *The Bulletin of the Atomic Scientists.* This was really a kind of lobbying effort, by their own terms.

Their goal was to educate members of the public, including politicians and journalists and other policymakers, but also American citizens and voters more generally, about what they thought everyone should know about the new nuclear age. And their first response, which got a lot of media play literally starting in September 1945, was that there is no secret, which is to say, there's no way to keep these things the unique possession of only the United States, that many, many countries with advanced industrial capabilities and smart scientists can, and very likely will, develop their own weapons. Because there is no single thing you could lock down to prevent them from doing it.

A related version, a kind of a variation on that theme, which again, got a lot of airplay in op eds and newspaper editorials, in magazine features, and so on, was that there had been one secret, but that's no longer secret at all. The secret was-- given what we know about, say, the behavior of uranium nuclei and slow neutrons, the secret that remained was, could such a thing ever be built? Could a nuclear weapon that released its energy from the runaway chain reaction of fissioning nuclei, was that physically possible?

And now that's not a secret, because it had been demonstrated quite dramatically and very publicly that such a thing was possible. So that's a kind of variation on the theme that there is no secret. Or we'd say, well, the secret is now, if there was a secret, it was that it could be done, and that's no longer secret.

And again, just to remind us, that message was being deployed not in a vacuum. It wasn't being articulated only for a sake of public information. That was part of the earnest goal of many of these organizers, but it was also in the midst of some very, very heated, politically divisive debates within US Congress among the punditry, let's say, or the commentators, about what to do in this suddenly new post-war world about atomic energy, about nuclear reactions generally.

And there were two-- very quickly, like within weeks of the official Japanese surrender, there were two competing bills introduced into the US Congress with very different proposals for what to do after the war. Basically, what do you do with the Manhattan Project, is what it really came down to. Should there be-- both these bills assumed there would be some continuation of something like the Manhattan Project.

An option that was not on the table was shut it all down and walk away. That was not considered in any serious way at the time. So instead, what seemed like the relevant options, what were reflected in these dueling pieces of legislation or proposed legislation, was number one, continue on something like the World War II basis, meaning explicit military control. The Manhattan Project, as you may remember, was really overseen by the War Department vis-a-vis the Army Corps of Engineers. That's why the Army General, Leslie Groves, was the ultimate head of the Manhattan Project, even though he had many scientific directors working with him.

So option one was continue that, that there should be basically a War Department or soon a Defense Department military control of a kind of postwar version of the Manhattan Project. And the competing bill was to have a civilian agency. As I said, there was no bill that said, let's have no atomic project moving forward.

So it was basically, should there be continued military or a shift to a civilian agency control of anything having to do with nuclear reactions, whether it's for reactors for power generation or for weapons. And these discussions about, is there an atomic secret or not, those are being deployed in the context of a very concerted political fight over these very different visions for the legislative future of atomic energy. So we need to be careful not to read these editorials in a vacuum.

There was another phase-- and this is what I write about a bit more in that article-- that didn't just stop by saying there is no secret. And so here it was really interesting to look at what were widely circulating, often quite influential, requoted statements, either by scientists or by journalists or by policy makers, including things like congressional testimony, but also in broad circulation magazines, of people articulating other answers to that question, what is the atomic secret?

And what I found really interesting-- I didn't expect this going in when I was starting this work-- was that in several years after the end of the war, really right through late 1948, there was a pretty distinct pattern to these next set of responses, that even when people said there does exist something called the atomic secret, the nature of that secret-- all these different observers seemed to agree or be consistent, the nature of the secrets had to do with industrial capacity with materials, with how do you build factories that work.

It was not about-- it was explicitly not about single formulas or text-based information that could, at least in principle, be smuggled out or aid some rival nation. But it was about large-scale industrial processes like, how do you pour a billion cubic meters or cubic feet of concrete and build these enormous industrial scale reactors, I mean, that kind of stuff, as opposed to, oh, slow neutrons will trigger, have a higher reaction rate.

And so three close variations of that you can cluster from this very wide number, dozens and dozens and dozens of widely circulating op eds and opinion pieces and policy proposals and so on, they say, well, yeah, there are atomic secrets. There are things that legitimately should still be kept secret. But they have nothing to do with text-based information.

It was things like, how do you deal with the fact that uranium hexafluoride will burn through existing industrial gaskets, when we talk about those gaseous diffusion tanks at Oak Ridge. Or how do you scale up a reactor from a research reactor like Enrico Fermi's very first pile that he helped oversee the whole Chicago team? How do you go from that to bringing in DuPont contractors to scale up these unbelievably large-- largest in the world at the time-- reactors and related power plants?

Those kinds of things were secret. These folks argued they should remain secret. And they were not in danger of being quickly replicated, because they depended on a huge material basis.

Now, one of the things that starts to happen in the midst of these discussions was not only a debate in the US about the proper handling of these things moving forward-- military or civilian oversight of a new agency and so on-- but also that some secrets might indeed have already been shared, or something illicit might have actually slipped beyond the carefully controlled perimeters of the wartime Manhattan Project. And this was really shocking, a series of these kind of revelations, some of which became very sensational.

One of the very first happened three days after the official end of the Second World War. So in the first week of September 1945-- this became more broadly known a few months later, but widening circles of people knew about this as early as the first week of September. It became international news by February of '46, so it was not too long later.

So what happened was there was an employee of the Soviet embassy in Canada named Igor Gouzenko. And he and his family defected. They were about to be restationed back to the Soviet Union. They didn't want to leave. And so Gouzenko defected. He said, basically, he wanted to stay in Canada, he and his family.

To help make his case, he left with troves of documents from the Soviet embassy. He had been a cipher clerk. He worked in encryption, basically, for the Soviets as a Soviet agent during the war, stationed in Canada. And he took with him out of his office file cases full of secret documents that indicated wartime Soviet espionage vis a vis both UK and Canadian projects. This was, as you can probably imagine, a big, big, big surprise when this news finally broke broadly a few months later.

So here he is. This is actually Gouzenko under a hood. This was, like, constant nightly news. He was in public, but always shielded, his face was shielded. In fact, the family went into something like witness protection.

So the Canadian government eventually relented, and he and his family were able to stay in Canada. And they were given new identities, much like witness protection kind of program within the United States. So he would go on TV, but be hooded. It was variegated.

Again, you can imagine the sensationalism of this. And he was a kind of fixture throughout 1946. So it turns out these materials covered many forms of attempted and sometimes successful espionage. But it included, as a little minor part of all the things he took with him, clues that led to a trail that ultimately led investigators to a British physicist named Alan Nunn May, who'd been trained at Cambridge, who had spent most of the war years working as part of the Manhattan Project in Canada at what was called the Chalk River nuclear reactor site.

There were many, many reactors built in many Manhattan Project installations, the biggest of which were at Hanford. There were other kind of experimental designs being worked on, including at this site near Ottawa, under the auspices of the Manhattan Project. So the British delegation had dozens and dozens, probably hundreds of physicists and engineers who spent the war years at various Manhattan Project sites.

Nunn May was one of them working at the reactor. He had been previously a member of the Communist party in Britain. He had a kind of sympathy toward the Soviet Union, by his own later admissions. And he was very concerned that the Allies' wartime ally, meaning the Soviet Union, which was fighting on the same side by that point as Britain, Canada, and the United States, was somehow not part of this otherwise information sharing program for the Manhattan Project.

The Manhattan Project was explicitly a three-nation cooperation, US, UK, and Canada, even though in the broader wartime context-- so reasons May at least-- the Soviets were our allies, as well, "our" meaning the Allied side. And yet, there was not the same kind of extension of cooperation or sharing. So he took it upon himself, as became clear from investigators following these leaked documents from Gouzenko, and ultimately, Alan Nunn May just confessed to it when confronted, that he had passed along physical samples from the reactor site to a Soviet agent and ultimately with the intention of getting them to aid the Soviet project.

So Nunn May was giving literally physical samples of radioactive materials, in this case, both U-233 and enriched 234. And in his mind, this would help speed their program. They could see the levels of purity or purification or enrichment that would be needed, and so on.

This was, as he knew, clearly against the rules. And yet he convinced himself this was somehow OK because of the fact that the Soviet Union was officially an ally of these other countries. So that was the first atomic espionage revelation that came from this very sensational defection from the Soviet clerk.

And again, what was being traded, what was being moved around, were physical samples of material. Here's a uranium, an enriched uranium sample, a small trace amount that nuclear chemists back in the Soviet Union might be able to make progress on. It was not about paperwork.

That characterization, however, began to change starting in September of 1948. So you have dozens and dozens of these articulations, what is the atomic secret until this time. And they really follow this pattern of being about material industrial things, not about texts or formulas. And this is very, I think, quite a sharp break in the characterization of the so-called atomic secret, starting with this report in September 1948.

This was a very attention-grabbing report by a US congressional committee, the so-called House Committee on Un-American Activities. It was often abbreviated as HUAC for House Un-American Activities Committee. This was a group, at the time a standing committee, a permanent committee. It wasn't actually permanent, it was at the time what's called a standing committee, had been set up in the 1930s, but as many of you might know, became very active in the US soon after the Second World War and really led the charge in a kind of anti-communist series of investigations and efforts.

So one of the first things they did after the war to get a lot of attention was hold some very high-profile hearings about supposed or alleged communist infiltration of Hollywood and of the broader kind of educational entertainment industry. And the allegation was that all these left-leaning communists were going to poison the minds of honest Americans by seeping propaganda into movies that people would watch without realizing they're being brainwashed. That was the level of the kind of discourse at the time.

Their next big set of headline grabbing revelations was actually about so-called atomic secrets, about allegations of nuclear espionage. And the way they chose to characterize it over and over and over again, which is a relentless, relentless similarity, was actually about text. It was about secret formulas or single pieces of paper that could be smuggled out as if it were kind of a James Bond movie and somehow aid a rival nation-- by this point they were mostly concerned about the Soviets-- in somehow producing a weapon from text alone.

And that was quite a different framework than all these emphases on industrial capacity material. So their first foray into the atomic secrets kind of landscape was this kind of blockbuster report that they released with great fanfare in September 1948, where among the many, many claims they made was that there had been a so-called Scientist X. And they made sure they knew who it was, but they weren't going to release the name. It even heightened the mystery of it all. The Scientist X during the war, an employee of the Manhattan Project, had given what they called a complicated formula to a known communist agent in spring of '43 with the express goal of helping the Soviets make their own nuclear weapon.

So here's an excerpt from their report. It's a very lengthy report, but here's where they describe part of this episode in particular. They say, Scientist X read to this alleged communist agent-- he was actually a well-known labor organizer in the San Francisco Bay Area, who might indeed have been a Communist agent, I don't know. What he was known at the time was being a pro-labor activist. At the time those were often conflated in public discourse.

Anyway, what they wrote was that the Scientist X read to this other person a complicated formula which this other person copied down, like F equals MA. And they'll go, let me scribble that down. Scientist X gave his reason for asking the agent to copy it down that the formula was in the handwriting of some other person, and that he, Scientist X, had to return the formula to the University of California radiation laboratories in the morning.

And as I write in the article, this is like medieval. It's like literally the handwriting of the scribe is infused with nuclear power, and that one equation is enough to lead to proliferation of weapons. And therefore it has to be carefully ferreted back to the lab before anyone notices that one scrap of paper missing. If all it takes to produce a weapon is a stolen scrap of paper as opposed to a billion pounds or a billion cubic feet of concrete, then it sounds like a very scary issue indeed, doesn't it?

What's interesting is to go back to the much later declassified Military Intelligence Division report on which HUAC was basing this allegation. Military Intelligence Division was a version of a kind of domestic FBI attached to the war department during the war that was conducting all kinds of surveillance during the war, including of the Manhattan Project sites. So this was originally classified. Many, many years later it was declassified.

This is the portion of the transcript that seems to match closest to what HUAC was claiming. And I want to be clear-- the case of this transcript wasn't the simplest or complete truth either. I'm just saying, what was the documentary base on which these later claims were made five years later?

If you go back to the 1943 intelligence reports, they describe a very different scene. This alleged communist agent, the local labor activist, had asked the scientist for copies of an article that had already been published. In fact, it goes on to say, a research article published in the *Physical Review,* which is by definition not classified, let alone some scrap of paper and handwriting. And the intelligence agents had recorded this perhaps verbatim dialogue.

What shows up in quotations in the report is the scientists responding, quote, I could certainly get reprints of it. I could get you a copy of the article. But this would give the Soviets no knowledge at all that would be helpful for making bombs. After all, the details of nuclear fission had been published in the open literature. The synthesis of plutonium at University of California had been published in the open literature.

And at least, as the once classified intelligence report suggests, what was being traded was paper-based, not some handwritten formula and something that the scientist himself said would be of no particular value. It wouldn't tell them anything they didn't already know. But that's certainly not how HUAC spun this, because remember, the transcript from the Intelligence Division was still highly classified. So HUAC could basically try to control the message. And so they held these very public hearings under the Klieg lights, these very famous lights. It was really all the rage.

And they began what other observers at the time called a trial by newspaper. This was not a criminal proceeding, so there was no rules of evidence or cross-examination. This was a kind of public-- not even a hearing, a public testimony, let's say, not subject to legally binding protections for anyone involved. And yet the committee could then selectively and strategically leak information, which they proceeded to do for months and months. So they released their own big report and then would kind of surreptitiously, or not so subtly, leak additional information to various trusted newspaper reporters and keep this in the headlines, and likewise, not just newspapers, but very broad circulation magazines, as well.

And I want to remind ourselves-- it took me a while to piece this together at first-- why would they do this in September of '48 if the Intelligence Division had already vetted this in 1943? And I realized, oh, September 1948 was right before a big and highly, highly contested presidential election in the United States, the election in early November of '48. And this was one way to try to score political points, as happens before and since, as we were quite familiar with, of one party trying to convince voters the other party shouldn't be trusted with sensitive matters, including things like nuclear energy.

So this was, at least in part, a kind of political opportunity, which I don't want to suggest was unusual-- as we know, that happens before and since-- but it helps us make sense of the timing of it. This was as much about presidential election politics as it was any kind of new revelation about espionage. And what interested me was actually the shift in how HUAC chose to characterize the most dangerous or seemingly most important elements of what it takes to make nuclear weapons. It goes from industrial capacity to a single slip of paper that could be very carefully smuggled out of the country.

And then following that report in a very, again, sensationalistic report released in September of 1948, then you see just again a huge proliferation of news media, congressional testimony, public lectures, and all the rest, all addressing the question, what is the atomic secret, but now all clustering around this kind of text, not material or industrial capacity. So again, people might disagree on what the atomic secret is, but there's a new clustering. It's no longer about hard stuff to ship overseas, but about simple stuff, like things you could write down on a piece of paper.

And here's an example that I find very haunting or telling. When Albert Einstein was featured yet again on the cover of either *Time* magazine or *Life* magazine-- I can't remember which-- they put his famous equation in the mushroom cloud as if the bombs were made from that equation, as if that equation had had any particular role in designing, let alone developing, testing, and using these new kind of technical devices.

And so when people said there is an atomic secret, they would give the answer to say it's either these so-called complicated formulas, or it's things like information about the nuclear stockpile-- the US has this many weapons ready versus that many that could be smuggled out on a piece of paper; the size and shape of the bomb-- that would have implications for things like delivery systems, what kind of airplane or boat might you need; a blueprint or some kind of sketch about that very complicated implosion mechanisms we talked a bit about-- but that was the secret and you could have a single diagram that would somehow give it all away; or other kind of so-called general principles of bomb design.

So again, there's lots and lots of-- a kind of variance in what people think the atomic secret is. But they're clustering now in a very different characterization of both how science and technology works and of what's most careful to guard. And I found that shift really very, very interesting.

And once again, this is not playing out in a vacuum. Not only was there the US election season to think about, but even about a year later more dramatic developments that again just kept this theme in the news, really for years. So again, as some of you might know, late in August of 1949 so four years after the end of the Second World War, the Soviet Union did succeed in secretly detonating its own first nuclear weapon. It was a fission bomb, a plutonium weapon using an implosion mechanism remarkably similar to that which was tested at the Trinity test and then ultimately used in the bomb over Nagasaki. So it was a very similar kind of device that the Soviets detonated in secret in their own territory in August of '49. The US authorities nicknamed it Joe I, not really in honor, but in reference, in joking reference to Joseph Stalin who was still the leader of the Soviet Union.

Then about three to three and a half weeks later, US President Harry Truman announced to great dramatic fanfare that the US had detected the Soviet test. The Soviets did not announce it. In fact, they kept it secret. The Soviets had been announcing all along until then that they had detected weapons.

That turned out to have been intentional propaganda and misinformation. And when they actually did successfully detonate a bomb, they didn't announce it. Three weeks later, the US President announced it instead.

And what I find super interesting is actually another really interesting book by my friend Michael Gordon, whose work I mentioned previously. Michael wrote this book called *Red Cloud at Dawn.* And he does I think a really fascinating reconstruction of the decision making process within the US government about whether and how to announce that the US teams had detected the Soviet bomb.

In brief, the worry was that if the US announced that the US government knew the Soviets had detonated the bomb, would that give away too much of our own espionage and surveillance infrastructure? It turns out the US gained confidence about this detonation with these kind of high altitude aircraft that were already in or at least very close to Soviet airspace that already would have been seen as problematic or maybe provocative. And these planes were equipped with certain kinds of detectors to find trace amounts of certain radioactive materials. And a few days after the actual detonation, these planes found compelling evidence for certain rare isotopes that seemed to be only associated with that kind of implosion weapon.

So the question was, do you even say anything? Because then will the Soviets know that we have these planes in or near their airspace? I just find that fascinating. So not only yes, we know, but we can't tell you how we know. It's one of these again quintessential kind of Cold War episodes. You can read more about that in Michael's book.

Anyway, the point is, Truman-- the balance, the decision was indeed to announce it, but with no official announcement of how the US knew. But now this became, again, really shocking in many parts of the world, including in the US. The so-called US monopoly over nuclear weapons had been shattered. Now the country that had emerged as the greatest kind of political rival in the post-war scene, meaning the Soviet Union, had its own weapons of mass destruction.

And what's interesting is that until that time, US authorities kept saying that the Soviets are still five years away. The very first assessments right after the end of the war were that the Soviet Union would need at least five years to make their own weapon. That turns out to have been actually pretty close. The challenge was that every year or continuously US authorities would keep making these updated estimates, and they keep saying the Soviets are still five years away. That became, therefore, less and less accurate, as you can imagine.

So the first estimates were pretty reasonable. In 1948 it was no longer reasonable to say the Soviets will need until 1953 to make their own bomb. So when so-called Joe I, when this first Soviet weapon was detected and successfully detonated, that really seemed like a big, big shock, even to the insiders in the US who, so to speak, should have known better. And so this just again ramps up the kind of Cold War jockeying and therefore the discussions about things like, is there an atomic secret, and what should we do about it?

Now, soon on the heels of that, again, very surprising information for many people in the United States-- soon after that, starting in late January 1950, other news broke that there had been at least one more example of atomic espionage from the Manhattan Project during the war. This also involved a member of the British delegation, who, like Alan Nunn May, had been sent over to North America as part of the British team to work on various Manhattan Project sites. In this case, it was this individual, Klaus Fuchs. Here's his badge photo from Los Alamos.

So Fuchs was actually originally from Germany. He was a very early anti-Nazi, and we were talking about this a little bit during office hours earlier today. There was a phrase that came into common usage in the United States after the war called prematurely antifascist. That was code for someone who's probably a communist, because in the earliest days in Germany, the groups that were most actively trying to oppose the Nazis even before the Nazis took over were the communists. This was a kind of left-right kind of battle.

And so if you were against the Nazis before you had quote-unquote legitimate reasons to be against the Nazis, then it meant you were a communist. At least it seemed to imply that. Really remarkable there was no room for anything in between. So Fuchs was one of these left-leaning, perhaps indeed communist members who had been prematurely anti-fascist. When the Nazis took over, he then had to get out of Germany fast.

So he emigrated to Britain as so many young physicists and mathematicians did. He then got involved with a British uranium project and then was sent over to North America. He first worked at Oak Ridge for quite some time in detail and things like isotope separation and then was relocated to Los Alamos and worked on many aspects, or at least a few aspects of the project from there. And then he went back to Britain after the war and worked on the British nuclear efforts at Harwell, not so far from Oxford.

And then again, one of these intelligence investigations finally led to suspicion about Fuchs. He confessed late in January 1950 that he had indeed been sharing materials with a Soviet agent throughout the war. That confession then led to other investigations, many of them still now back in the United States.

And that led to the arrest of people, including very famously Julius and Ethel Rosenberg, a husband and wife pair who were based in New York City. They weren't at Los Alamos, but Ethel Rosenberg's brother, David Greenglass, had been stationed at Los Alamos as an army machinist. He was not a trained scientist, but he was one of the many, many, many technicians who was on site at Los Alamos. He, like his sister, had, at the very least, left-leaning political sympathies.

And during the war, perhaps with Fuchs' help-- or in any case, the investigation of Fuchs led to this other ring-- Greenglass had been smuggling out some things or trying to get information from Los Alamos with the intention of getting it to the Soviets. And it seems that his brother-in-law, Julius Rosenberg, helped in ferreting this information out.

So when this came to light, there was a very, again, hugely sensational trial in the United States for the Rosenbergs. Greenglass agreed to testify against his family, so he was given, basically, immunity. He cut a deal. So even though Greenglass was the one who actually stole the materials, he cooperated with the prosecution. And the trial turned out to be against Julius and Ethel Rosenberg and a third defendant, Morton Sobell.

And so here's an example of what was entered into evidence for the prosecution of David Greenglass, if I remember correctly, redrawing from memory the kinds of sketches he had acquired during the war and had tried to get to the Soviets. And this was a fairly crude sketch of the implosion mechanism for a plutonium bomb. So again, what's fascinating, the trials stretches out over 1951, again, daily updates in the newspapers and nightly news. And to aid the prosecution the Atomic Energy Commission, which was this kind of postwar successor to the Manhattan Project, they actually declassified what was then being called the single most closely guarded atomic secret, which was this implosion mechanism.

So to help the prosecution gain a conviction of the Rosenbergs for espionage, the government agency literally declassified what they were at the same time claiming was the single atomic secret that presumably could be written down on a single piece of paper and smuggled out to another place. In fact, at one point-- I write about this in the paper-- when testimony about this was being given by Greenglass under oath, they partially emptied the courtroom gallery of everyone except journalists. So if you want to keep something secret, I would think you would get the journalists out and let the jury stay and let the other civilian onlookers stay. They did the opposite, so really just mixed messages about what is or is not the most potential or serious atomic secret. The point is, this is all about text-based diagrams or formulas and not about industrial capacity.

And again, as you may know, the Rosenbergs were found guilty. They were ultimately executed soon thereafter. And there's lots and lots and lots that's been written about that. Many, many things were once classified and over the decades have become declassified.

There's more to be said, but it seems that Julius Rosenberg very likely was guilty of at least some of the things he was accused of. It's much less clear that Ethel Rosenberg was guilty of the things for which she was convicted. And there's all this stuff that was later found out of prosecutorial strategies to go after Ethel Rosenberg hard in the hopes that Julius would confess, and they both-- neither confessed, so anyway, a really messy, messy trial.

Also it looked like some not proper coordination between the prosecution and a judge. It was a mess in terms of just legal procedure. And I think no matter what side one comes down historically about the efficacy of nuclear espionage, I don't think anyone claims this was a clear or clean trial, thousands of pages written about it. But that's just the upshot. The point is it's coming on the heels of these quite dramatic revelations about wartime espionage.

So once this was, or at least parts of this was becoming part of the public record, many commentators, especially the United States at the time and even since then, have reached toward these examples of espionage-- Alan Nunn May, the Greenglass-Rosenbergs connection, Klaus Fuchs, and then others that have since come to light, a handful of others, to say, well, that must explain why and how the Soviets actually did succeed in making a nuclear weapon so soon compared to estimates. Remember it wasn't so soon compared to the original estimates, so soon compared to the later estimates, which proved to have been inaccurate. And so the idea was, in a sense, that they cheated, that they only caught up with the Allied effort because they had all the benefits of espionage.

Once again, I want to give a shout out to my friend and colleague Alex Wellerstein, who has a fantastic set of online materials at his blog. It's a blog with footnotes. This is actually like a scholarly blog. And he has a great piece, actually from a number of years ago by now, about hand-drawn diagrams from one of the heads of the Soviet nuclear weapons project, Igor Kurchatov, to the equivalent of the Leslie Groves figure, Lavrentiy Berea, from early 1946, which you can see this handwritten Cyrillic that look like pretty compelling versions of an implosion design, the implication being that Kurchatov really was benefiting from some of these kinds of purloined worksheets and figures that people like Greenglass and Fuchs were able to supply.

On the other hand, since the fall of the Soviet Union, many more materials from Soviet sources have become available to scholars within Russia and elsewhere. And the story, again, like most stories, gets a bit more complicated. Here are some really interesting more recent analyzes by Alexey Kozhevnikov-- we've read some of his work for the paper II assignment-- and also, again, Michael Gordon's book that I mentioned, that espionage, I think it's fair to say, clearly played some role in the Soviet program. But it's not so straightforward what the efficacy was, let's say what the role was. And there's lots-- again, the more one looks, the more complicated the story gets, rather than simple, which is-- maybe that's how it often is in history.

So here are some of the salient points. There's much more that these other folks go into that I find really interesting. The information that was obtained via espionage-- and some of it clearly was obtained via espionage-- to within the Soviet Union was often treated as suspect because at least some of the folks there didn't know if they were being fed intentional misinformation. Was this a kind of information war after all? And so were these things being planted so that Soviet agents might be duped into getting unhelpful information?

And so often these would be doled out to various internally rivalry groups within this very large Soviet program. It grew to be very, very big, much like the Manhattan Project. And so you have competing groups that would almost have a kind of peer review, for lack of a better term.

One group would be told, this is from the American project, and we think it's real. Go with it. Another group would be told basically, we think this is garbage. Poke holes in it. And so it's not like they said, here's the answer, go do it.

Likewise-- again, it became clear only decades later-- the Soviets wound up pursuing many, many roots in parallel, much as the US or the Allied project had done during the war, even with the knowledge of the efforts that had proven to be most effective in the US case. So typically for the US project, if there were four different ideas to separate fissionable uranium from the more stable isotope, the response from General Groves was usually, try all four. If there's a war on, give it all you got, try all of them. We'll go with whatever is quickest.

And yet, and afterwards, some would prove to have been more effective than others. It seems clear that the Soviets often did the same thing, even knowing which wound up being the most effective version in the wartime Manhattan Project. The Soviets would often set up parallel efforts instead of only trying the one that had seemed most effective.

So that's not a huge savings of time or effort either, and also even more tricky that a lot of these very, very complicated devices, these bombs like the implosion design, depended on very specific properties of non-nuclear materials, both epoxies-- kinds of glues or adhesives-- certain kinds of, literally, the wiring to try to make sure that you have sub microsecond accuracy for the firing circuits, but also these different kinds of conventional explosives that burn at different rates. So you're trying to make this shaped ingoing pressure wave. And the Soviets had different forms of TNT equivalent. So they weren't just copying-- they couldn't just copy the blueprints, even if they had rather complete blueprints.

So it's not to say the espionage was irrelevant. I'd hardly think that's the case. But it's also seems pretty inaccurate to say the Soviet bomb was merely a product of copying the Manhattan Project. And so again, we get the real life experience of these complicated human endeavors that didn't fit into the neat stories that were being told then or since.

So in the meantime, again, coming back to things that really caught my attention about the way espionage and so-called atomic secrets were being characterized throughout the US at this time, was after the news about Klaus Fuchs did become very broadly known-- it was major newspaper news by late January of 1950-- there was a kind of slippage that became very common. I find this actually very chilling, a slippage, not to say all German communists who came to the United States were actually bad. That might have been one conclusion people might have unfairly drawn, but that wasn't where people went. The conclusion reached often was that all theoretical physicists are suspect.

Let that sink in for a second, that because of Klaus Fuchs, because of his perfidy and because of his what was often called his warped mentality, his infantile, naive sense of how the world should work as characterized by his critics, that that's a sign of physicists who have been too poorly trained in the humanities. That part I like. That's why we have GIRs here in past courses, right?

The allegation was these narrow-minded scientists hadn't learned about government and history and literature and human affairs. So they have baby ideas about how the world works, including kind of idealized notions of world government or of communist utopias. And so therefore, theoretical physicists as a group are dangerous.

If you think the bomb was made by equations, if you think the bomb is essentially text made real, and therefore the most dangerous things are formulas and engineering diagrams as opposed to billion cubic feet of concrete, if theories are dangerous because they make bombs, and if theorists have this kind of warped or unbalanced education where they're more susceptible to so-called communist propaganda than well-trained economists or whatever else, then that's a double danger, right? Because the bombs are allegedly made by theorists, using kind of reifying equations. I find that just stunning that people would have come to those conclusions knowing that the Manhattan Project required unprecedented industrial capacity with experts from metallurgy and chemical engineering and electrical engineering and many, many areas well beyond theoretical physics. And so you have this really strange way of thinking about scientific and technical progress, let alone thinking about individuals who majored in one field of study or another.

And again, that doesn't die down very quickly. As late as 1956, there's a case of a federal judge sentencing a Cornell grad student to jail time. The grad student had been accused of being a member of the Communist party. The student pled the Fifth Amendment against self-incrimination in court. That was not at the time recognized as a legitimate defense. That was righted a few years later with the Warren court.

So he was held in contempt and sent to jail, not only for not cooperating, but because the federal judge was convinced that younger generation of pure scientists engaged in research in physics-- by which he meant this Cornell theoretical physics grad student-- had succumbed to communistic propaganda. Again, that's a remarkable leap or slippage between bombs or formulas and theorists or commies. That seems to go well beyond the evidence at the time about some instances of espionage that indeed were serious, but might have had a range of possible outcomes.

Let me pause-- oh, the last part, the last slide before we pause, this again starts to have real world implications of many kinds. One that, again, I found rather surprising is if you go back and look in the Congressional record, which is now thankfully digitized, go up and count all of the hearings in the first decade after the end of the Second World War that this House Un-American Activities Committee held that involved any academics. They held all kinds of hearings about labor organizers, about school teachers, about Hollywood script writers. But they held lots and lots of hearings about academics, again, with this fear about poisoning impressionable youth.

And you count up by anything you want to count-- the number of witnesses who were subpoenaed to testify, the number of hearings on specific topics, or the number of days devoted to those hearings-- by any measure, you see that they were overwhelmingly drawing on theoretical physicists in particular, much more than, say, chemists, much more than economists or philosophers or political scientists who actually once studied things like communist world systems or demand side economics or anything else. So the people who HUAC deemed most dangerous and most in need of these kind of interrogation high profile congressional hearings were people who by then they could associate with nuclear secrets which were formulas which were dangerous.

And so this begins having a long tail. And there were just dozens and dozens of careers that were really destroyed because people chose to plead the Fifth Amendment or the First Amendment or had been briefly members of a Communist Party for a study group in 1935 and found it boring and left, and suddenly that came back to haunt them and were fired from tenured, as well as tenure track positions and all the rest, a very strong amount of blacklisting that went on that, again, many scholars have since begun to document.

But you see, I can only make sense of charts like this by thinking about what were the depictions of how science and technology work, let alone what's the most important part behind making nuclear weapons. So let me pause there. There's a lot to chew on. The next parts will be quicker.

So Gary asks, was Nixon in the House? Yes. So part of the famous HUAC hearings did involve a very young member of Congress, Richard Nixon, before even his first run for president, let alone his later runs. And so this was a bipartisan committee. It was a standing committee of the House. But then as now, the majority party could appoint the chairpeople, and so on.

So during this particular period it was chaired by some Republicans who clearly were out against the Democrat Harry Truman for re-election. Again, that's not that's neither surprising or illegal. We have a two-party system in this country, for better or worse. But the way that the committee was activated had a very, very clear and very impactful partisan slant. The Alger Hiss case was exactly part of the exact same period, exactly right, Gary.

Lucas says, you seem to know a lot about Soviet espionage during the Manhattan Project. What about German or Japanese wartime espionage? Very good. I don't know of any, and that's a fascinating question, Lucas. I can't think of a single instance. I'll turn to the TAs if any of them have come across it. I don't know of any.

That's really interesting. There have been a handful more, like three or four more instances of wartime espionage, again, in aid of the Soviets or intended aid of the Soviets, often from US citizens during the war from the Manhattan Project that were totally unknown at the time and came to light literally decades later, but still only a handful. And all the ones I know of were people with the intent of helping the Soviets, which again, as I remind all of us, the Soviets were a wartime ally of the US, the UK, and Canada. And I'm not saying that excuses it, but that was often highlighted as a motivation for many of these folks.

I'm not endorsing that behavior, but many of them would say the Soviets are losing many more members of their army than we are on behalf of the Allied front, these kinds of arguments for which I can understand where that was coming from at least. And I don't know of a single instance of even attempted, let alone successful espionage from the US projects, either for Germany and Japan. There was a lot more in the other direction. We talked briefly about US surveillance of the German nuclear project, including kidnapping nuclear scientists and all that.

Johan asks, was physics in Allied occupied Germany-- what was physics like in Allied occupied Germany and Central Europe? Oh, very good question. That's a big topic. So the short answer is there was a lot of efforts soon after the war under something that became known as the Marshall Plan to do a heavy investment by the United States in many parts of the world, including Germany, to try to help them reinvest and reestablish a kind of civil society, partly as a bulwark against further temptations, it would have been called at the time, to align with the Soviets; partly, some revisionist historians have said, to make more markets and make it easier to trade for American commercial interests-- I think that's true. I think sometimes it's overblown, but certainly was part of the calculation-- and also for these kinds of geostrategic alliance efforts.

So there was a kind of strategic use of redevelopment or rebuilding aid generally. And as some of my colleagues like John Krieger and other historians have shown, a fair amount of support for basic research in the sciences in many countries of Europe were undertaken with a similar kind of aim by the US, including by private US-based foundations, as well as US government dollars. Sometimes-- we now know those foundations were a cover for CIA money. It was basically money laundering to buy influence or buy good relations with otherwise left-leaning scientists in France, for example, or to avoid what looked like to have an influence of communist thinking in certain otherwise influential cultural figures, including lots of scientists.

So there was often very, in terms of dollars that were spent, very generous funding on basic sciences and institutes, including Niels Bohrs Institute, but many in France, many in what would become Western Germany, many in Italy, many joint summer schools and educational efforts under NATO, as well as just the US. And again, there was frankly a mixture of incentives or kind of strategic thinking behind that on the US side, much of which came to light only decades later, including, as I say, literal money laundering, as well as, let's say, more transparent funding that nonetheless had a range of motivations behind it. So anyway, more to be said, but that's a fascinating question.

Alex asks, is it possible the AEC declassified this so-called most closely guarded secret in order to draw attention away from industrial secrets? That's really interesting, Alex. Maybe. Certainly that would be consistent with their motives. But what I find interesting is that it really was-- frankly, it was a kind of double speak.

And again, my ability to find a kind of benevolent explanation in this instance is strained, seeing just how much was going on behind the scenes improperly, and in some cases I think actually illegally with a coordination between prosecution and the judge or between federal agencies and journalists. There was a lot of very intentional leaking of otherwise protected information for strategic purposes.

And again, I don't mean to say that was brand new. That's been happening as long as humans have kept secrets. But there was a lot of I think very strategic kind of flows, basically of smear campaigns. I mean, that's really what I think it could be called. And even if the people being smeared had done terrible things that deserved punishment-- and I think in many, many cases that seems like a fair conclusion-- the means by which it was done were often at least as troublesome or as worthy of careful evaluation years later.

So I don't know. It's just-- honestly, it's a cesspit. When you start digging this stuff, it doesn't inspire one for human nature. I guess very few things in history do. But a lot of this gets super messy. And again, I can appreciate what people thought were the stakes. I mean, nuclear weapons, now the Soviets have one.

All these people were active in espionage. You can see this kind of drumbeat of drama. So I don't mean to suggest that cool heads would have prevailed today. I don't think they would have. But nonetheless, with the fullness of time, with fuller documentation of what was going on in many parts of the world, not only within the United States, I think we can reevaluate many of these maneuvers that were done in this kind of high fever moment and maybe try to learn from them moving forward, put it that way.

Let me move on. Let me go to these next parts. They'll be quicker. But let's press on to next parts for today and talk about this next section on the decision in the United States to pursue a new kind of nuclear weapon, the hydrogen bomb. And again, we saw some of this in the film, *The Day After Trinity.*

So in October 1949, a few years into the nuclear age, the Atomic Energy Commission's General Advisory Committee was often called the GAC, which was a civilian advisory committee to the civilian Atomic Energy Commission with many experts, some of whom were just outside consultants, many of whom were Manhattan Project veterans, but otherwise not full-time involved in the nuclear effort afterwards. This Advisory Committee of approximately a dozen people wrote a top secret report recommending to the federal government not to pursue the development of this new kind of weapon, the hydrogen bomb. In fact, some committee members actually argued that such a weapon would be, in their words, an evil thing in any light. And we'll see more about what these weapons were in a few minutes.

But they were saying that there were all kinds of reasons not to pursue them. And at least some of these members made an explicitly moral or ethical argument that these weapons are, in the parlance of today, weapons of mass destruction that could only be used against civilians. These are no longer in any sense weapons for a military theater.

That was a top secret report, though it, again, angered certain powerful political figures who were very gung ho on trying to develop things like hydrogen weapons. And Oppenheimer began to stand out more and more in many of these people's minds as a kind of drag on the system, that he was perhaps intentionally trying to sway his own colleagues on the General Advisory Committee. He chaired the general Advisory Committee at the time. Was he exercising undue influence on them, was he trying to lobby against a new kind of weapon that some people thought the nation needed in order to secure the peace, and so on.

So this played a very, very large role in the eventual security hearing against Oppenheimer, the result of which was that he was stripped of his security clearance and no longer consulted for the federal government, starting in 1954. So the H-bomb decision was fraught on many, many levels over many years. That's the idea. It was associated-- became closely associated with Oppenheimer because he chaired this GAC committee.

The GAC committee report was highly classified. In fact, the text was only declassified and widely available starting in the 1980s, decades later. Now you can find it easily online in many, many places. And if you go back and read the actual report, it does indeed argue against the development of a hydrogen weapon, but not because of ethical worries and not because the members of the GAC were striking a kind of pacifist tone or an anti-nuclear tone, by any means.

In fact, the report advocates a very aggressive nuclear stance. And they argue against hydrogen weapons, as we'll see in a few, for several reasons. Because the committee worried that it would derail too much of what they considered a critical effort to make more and more working weapons of the World War II type, that any effort to make as yet unproven hydrogen bombs would actually be too disruptive to the arsenal for other kinds of nuclear weapons, which the group said were essential to go on full speed ahead.

So not only was Oppenheimer not being some pacifist dove saying all bombs are bad, they were actually-- Oppenheimer's own committee and Oppenheimer's cover letter and so on makes it clear that he individually, and the committee broadly, were advocating an aggressive expansion of the nuclear weapons capabilities. And it was only this Minority Report included as an appendix-- written not by Oppenheimer, but by other members, Enrico Fermi and Isidor Rabi-- that also raises additional reason not to pursue a hydrogen bomb where they speak briefly, but in explicitly moral tones.

That wasn't Oppenheimer at all, in fact, and it doesn't seem to have reflected his views at the time. And we know that, because Oppenheimer was doing lots of consulting until his clearance was stripped. So even after the 1949 report from the General Advisory Committee, he was leading all kinds of study groups for classified advice on nuclear issues.

Another example of the many, many was conducted in the summer of 1951. It was held on Caltech's campus, but again, it was all classified work sponsored by the US Army and the Air Force called Project Vista and had many, many parts. But one of those had to do with nuclear strategies for different kinds of stats as vis-a-vis the Soviet Union.

And the subcommittee that Oppenheimer actually chaired recommended that hundreds of nuclear weapons should be deployed throughout Western Europe, including West Germany and Allied NATO bases all around Western Europe with actual working tactical weapons that could be used and should be used, they argued, to repel a potential invasion from the Soviet army. The worry at this point was that the Soviet army, in terms of numbers of troops, was just so much larger than any of the NATO-affiliated armies that if it were a conventional warfare fought in the early '50s, the Soviets would just roll over anyone else, was the fear.

So this group said, well, then we'll just use usable tactical nuclear weapons on the battlefield to repel an otherwise numerically superior Soviet invading force. So Oppenheimer's own committee pushes for a first-use nuclear policy, which was incredibly aggressive at the time, that not only should these weapons be deployed, but we should use them first, even if the other side doesn't use nukes first. By this point the Soviets had their own [INAUDIBLE].

So this wasn't greeted with fanfare by everyone who could see it. In fact, it made more enemies with the Air Force because this seemed to cede more control over nuclear weapons to the Army than the Air Force. There's always this internal rivalry and tension. So the Air Force said, we should be the only ones who handle nuclear weapons because we have the big bombs and the big planes, and we can deliver them. So Oppenheimer made more internal enemies, but not because he was saying, get rid of nuclear weapons, because he was saying, make more of them, and be ready to use them aggressively. I find that chilling.

Meanwhile, what were some more of the arguments within the actual 1949 GAC report? Why else did they say not to pursue a hydrogen weapon and instead to focus on implosion fission weapons? 2 and 1/2 years-- or I guess 1 and 1/2 years after the end of the war in April of '47, the US still only had components for seven bombs. They weren't even assembled.

If there had been a sudden change in the geopolitical situation, and there was deemed to be some need to start using bombs as they've been used at the end of the Second World War, there were only parts for seven bombs even nearly two years later after the end of the War. Two years after that, or two and 1/2 years after, that the entire stockpile was still only 235 weapons. Of course, that was a closely guarded secret at the time. That's one of the things that has since been declassified. So that was very, very much on the minds of members of the GAC who had security clearance to know all these things. They argue, saying, we should be concentrating on building up a stockpile of weapons we know how to make and that we know could be effective, militarily effective in their estimation?

Likewise, they go on to say, the delivery systems, which by that point mostly meant aircraft, would limit the size of hydrogen bombs. The idea was that any design that might work-- and there were at that point no workable designs. All the ideas seemed to require enormous factory-scale associated equipment like cryogenics and so on. You'd have to ship like a small factory, part of which would then blow up, was at least the thought.

How could you possibly get these things to a military target? They're going to be too large even for the biggest bombers in the Air Force's fleet. So we don't know how to make them, they're saying, and if we could make them, they wouldn't be practical for delivery. Remember this is long before rockets, this is long before Sputnik, and so on.

So as they write in their own report, their classified report, there appears to be no chance of hydrogen weapons being an economical alternative to fission weapons based on what they called the strict criteria of damage area per dollar. If we want to have a kind of nuclear arsenal, they're arguing, let's make it of weapons we know how to make and that we know could be delivered.

There are even more esoteric challenges that the group was wrestling with, again, in the report, in the classified report, as well as other classified briefings. So at the time that the GAC wrote this report, all the known projected hydrogen bomb designs-- none of which had been tested or built yet-- all of the prototype ideas required huge amounts of tritium. That's a heavy isotope of hydrogen. They're called hydrogen bombs, but ordinary hydrogen it was feared wouldn't be enough. You needed many more neutrons per hydrogen nucleus.

You needed a heavy isotope called tritium. Tritium, then as now, was very rare and very expensive to produce. The naturally occurring amounts are trace. So again, much like plutonium, the idea is you'd have to make tritium in reactors. And the designs called for kilograms worth of tritium per bomb, just like they called for tens of kilograms worth of plutonium. Producing just 10 grams-- not even not even a whole kilogram, producing 10 grams of tritium at the time meant taking reactors offline that otherwise would have been producing plutonium for the known design of nuclear weapons.

And so they go through this calculation. The US would forego 100 or more fission bombs per hydrogen bomb even if the designs would work because the materials that would be needed were so rare. And it was a direct trade-off, a zero sum game, they argued, in how you produce the fissionable materials versus the fusion fuel.

So they make this report saying, for all these tactical and strategic reasons, we advise against a crash course development of a hydrogen bomb, that was delivered to many US officials, including the president. Nonetheless, really just weeks later on the very last day of January, 1950, the US President, Harry Truman, announced publicly that he was nonetheless ordering the crash course development of a hydrogen bomb-- that was a public announcement-- and at the same time, then ordered a gag order so anyone with information about this could no longer speak to the press. So he makes a public announcement, then limits other public discussion.

And again, looking back, you say, oh, but what about all this smart input from the GAC? They had clearance, they were experienced, they made good arguments. Again, with hindsight, I can see how Truman might have felt like his hand was forced, not only because of arguments about tritium rates of production, but also because of what else was changing in the world around him, around many people.

Remember only weeks before he had announced to the world that the Soviets now had their own nuclear weapon, that announcement about so-called Joe I. One week after that, the communists in China won militarily. They beat the nationalists.

China had had an ongoing Civil War. The US had backed one side. The other side won, the explicit Chinese Communist Party. So now it looked like many people read that as a kind of domino effect of further communist expansion, first the Soviets, now the Chinese. That was at least how it was often read or interpreted in the US.

And then just days before Truman's announcement, Klaus Fuchs confessed to espionage, saying, yes, I really was stealing stuff from wartime Manhattan Project to give to the Soviets. So in some sense, we can understand how Truman might have arrived at that decision, even though there were, one might say, at least understandable and I think maybe compelling reasons given on the other side. Remember this is all before there was a single notion of how to actually make a hydrogen bomb. Truman was saying, we'll work harder at it, basically.

So more than a year after his announcement in March of 1951, under high secrecy, there was a first really important conceptual breakthrough we now know. It wasn't known widely at the time. And that was introduced by these two individuals-- Stan Ulam, who was interviewed in *The Day After Trinity* a mathematician who worked at wartime Los Alamos and stayed much of his time at Los Alamos, and the theoretical physicist Edward Teller.

And the two of them were working together and kind of bouncing ideas back and forth. And together around the same time, they helped refine this idea in secret that's now called the either Teller-Ulam or Ulam-Teller idea. There's a real fight afterwards about who deserves more credit. So Ulam does seem to have gotten to the main idea first. Even teller seemed to grudgingly admit that. So I tend to call it Ulam-Teller.

The idea, again, is physically very interesting if we think only about the laws of nature for a moment. The idea was not to try to ignite a fusion reaction only based on the very high temperatures released by a fission bomb, but actually using radiation pressure. So these fission bombs give out tons of very high energy X-ray radiation in addition to producing a lot of heat. The early efforts to try to cook, to try to start a fusion reaction going, fusing very light nuclei together and thereby releasing energy, had all relied on heating the fusion fuel to very high energies and using a nuclear weapon fission bomb as a so-called trigger to heat up the fusion fuel.

And none of them seem to work. You couldn't heat it fast enough or all these kinds of concerns. It didn't seem to be feasible. And what Ulam and Teller together really put forward was that those fission bombs do more than just give off heat. They give out unbelievable amounts of very high energy radiation X-rays.

And people knew since long before Compton scattering days that radiation carries momentum. It can exert pressure. So then they realized if they could begin building a kind of cylindrical design and channel or focus that very high intensity very high energy radiation from this trigger, this fission bomb trigger, explode a kind of plutonium bomb at one end of a cylinder and funnel or lens the X-rays onto the fusion fuel, then it actually might ignite the fuel and might require much, much less tritium because the reaction might be more likely to get started.

That was still just literally a thought. That was certainly not proven, but it was the first new conceptual insight after years of thinking about hydrogen weapons. So again, just the timeline I find just astonishingly fast. We saw Truman makes this announcement at the very last day of January, 1950. A little over a year later-- still, of course, top secret-- Stan Ulam and Edward Teller introduced this really quite compellingly new idea to at least start working on-- will it work, won't it work? A

Little more than a year after that, the US establishes a second full-scale top secret nuclear weapons lab in California, not too far from Berkeley in Livermore, California, largely at the urging and the lobbying of Edward Teller and other political allies. So there was Los Alamos operating at full tilt, plus the second lab at Livermore. And the kind of gallows humor, the joke soon developed at Livermore that the main competition was actually Los Alamos, that the Soviets weren't the competition. The second lab had to prove its worth vis-a-vis the first lab. There was a real internal rivalry, much like Army versus Air Force and Navy and all these kinds of things.

And again, just remarkably quickly, in November of '52-- so a year and a 1/2 after this first kind of sketch of a new idea to proceed-- the first working hydrogen bomb device was detonated by the US in the Pacific on the Enewetok Atoll with an explosive yield that was indeed 1,000 times more powerful than the bombs that had been used against either Hiroshima or Nagasaki. So the wartime fission bombs were measuring outputs in the tens of thousands of tons, so tens of kilotons of conventional TNT. And these hydrogen bombs were setting the scale up by a factor of 1,000. The first one ever tested had an explosive yield of more than 10 million tons equivalent of TNT.

And then again, as you probably know, that was just the beginning of an enormous race of doing above-ground nuclear tests between the US and the Soviet Union and eventually other countries, as well, France and other countries, Britain and some others. We're not so clear who's doing what when, but certainly in these early years, mostly the US and the Soviet Union. This is a plot just of the number of above-ground tests, not even including their yield or their radioactive fallout or anything else.

As you can see, the US was doing-- this is the Trinity test. That's the first. These are only test detonations. Here's the one in 1945, several more in 1946, the first Soviet test in 1949. By the time we get to the mid 1950s, the US conducted nearly 80 above-ground nuclear tests in that year alone. That's more than one per week.

That's extraordinary, the pace of this. And almost all of these now were variations of the hydrogen bombs, no longer these seemingly small-- not so small, but by comparison small fission bombs. And then again, you see a brief pause here and then another huge expansion of the above-ground testing regime.

Let me pause there, take a few questions, and I'll get to the last part real quickly. Jade asked, what happened in the pause? Do you mean the pause in the testing? We'll come to that in a moment. So that's a great question. We'll see in a second

Yeah, so very good question-- did the notion of physicists having these warped or unbalanced educational backgrounds affect their perceived credibility? It did in some quarters. So many people who were either career politicians or career military strategists said, perhaps with good reason, that why should I listen to any of these funny college professors?

That's usually a fair comment. They have no experience with, say, military strategy, for example, or with procurement or the supply chain or anything like that. So there were plenty of arguments that came down to basically, these people don't have sufficient relevant expertise. And that's a perfectly valid critique I think. It was also often used selectively because they didn't seem to make that critique against physicists like Edward Teller, who were arguing a position that was more in line with their own position.

So again, I think that argument has merit and was also nonetheless deployed kind of selectively or strategically. So that argument was made. It's not an invalid argument. And yet again, its actual usage was, in hindsight, maybe not so clear cut as it could have been.

And for example, there were plenty of university chemists and physicists who were advocating-- not just Teller, who were advocating the aggressive development of hydrogen weapons. And they were very eagerly listened to and given credit as being the relevant experts in classified congressional testimony, for example. So the who has the relevant expertise question was a fair one, but again, it was used-- it was deployed, let's just say, in a variety of ways.

Other questions there? I'm almost at time. Let me start this next part. We can talk more about this next week, as well. But just to say the US effort to develop more and more of these hydrogen bombs continued.

Here was what turned out to have been the largest above-ground test by the US ever conducted in March of 1954, the so-called Castle-Bravo bomb, 50% more explosive even than that first Ivy Mike shot. This one became well known for many reasons, not just because it was the record holder, but also because this was a larger explosive yield than the designers had expected, in fact, more than twice as explosive as the designers themselves had predicted. And that meant that the fall-out from it, there was more radioactive debris from it, and it traveled further than expected. Also it was an unlucky break with the wind.

So the effects of this above-ground test in the Pacific were much more extensive than anyone had planned on. And what happened was there was a Japanese commercial fishing boat, a private fishing boat, very far from the test site, but it turns out not far enough, given just how far, hundreds of miles, the fall-out eventually began to flow. And so the fall-out did fall onto this fishing boat. Many people on the boat became sick very quickly with radiation sickness, quite severely sick.

And this was no longer secret. This was now people in Japan who were clearly showing ill effects from a US above-ground test. That's one of the first times that questions about fall-out or the dangers of radioactivity become commonly discussed in the broader kind of mass media within the United States.

As we've talked about a few times from good questions in the class, it's not that no one knew about radioactivity or its dangers. But it wasn't usually talked about very broadly until events that somehow couldn't be denied, media coverage like that Japanese fishing boat accident, but a very horrible accident from that 1954 test. That begins to trigger much more community activism and scientist activism against above-ground testing because of the dangers of fall-out.

The United States, among the most successful campaigns, has the kind of popular face. One of the fingers in front of it, was Linus Pauling, who'd already won the Nobel Prize in chemistry. He was not working on the Manhattan Project. He was an outsider scientist, but a very smart one, who was also very media savvy. And he was among the first to draft these kind of large-scale petitions with many other leading public figures to stop above-ground testing.

Another I think just completely fascinating example was started a few months later by a different group of several nuclear scientists, biomedical and public health experts, and civilians who had experience in political organizing, members of the local league of Women Voters, for example, but otherwise were not scientists, in the Saint Louis area. They call themselves the Committee for Nuclear Information. And they began this very famous baby tooth survey. I don't know if any of you will have heard of it.

The idea was that because of all the above-ground testing, much of it within the continental United States, not just far away from the US in these Pacific Islands, but even lots of tests of the Nevada test site and elsewhere, that we were in a sense bombing our own population, not with the immediate blast, but with these long-term and potentially long-lived effects of radioactive fall-out. And as evidence of that, the idea was that radioactive fall-out would land in the grass, the cows would graze, their milk would carry radioactive elements, children would drink the milk, and it would be taken up in the bones. It would be taken up in everyone's bones, but children's bones were especially easy to access because they lose their baby teeth.

So here you have this perfect reservoir of calcium-rich bone material from humans that's absorbing some of these radioactive fall-out elements like strontium 90, which were already by then known to be pretty bad, iodine isotopes, as well. So the idea was brilliant-- send us your children's baby teeth. We'll send you these standardized little information cards. Send us literally the teeth, and we can test them in the Saint Louis Washington University laboratory and see just how extensive the radiation poisoning of the US continental United States has been, due to the US's own above-ground testing.

That was a brilliant political maneuver. And you can see it was this mixture of-- we might today call it citizen science. But it took some real political acumen from the League of Women Voters volunteers, as well as from these concerned scientists.

And then this finally led to a unilateral moratorium on US testing starting in '58 in direct response to that. The US stopped testing, while the Soviets didn't stop. But then the US went back to testing once the Soviets started testing more and more massive weapons.

And the real pause came actually after the Cuban Missile Crisis in October 1962, which seemed to have really shocked enough highly placed people, both in the United States and the Soviet Union. And that led fairly swiftly to the signing of the Limited Test Ban Treaty. It was called limited because it limited above-ground testing. It drove all testing underground, of which then it continued extensively for decades.

But the idea was to stop at least the previous pattern of 80 or more above-ground tests in a given year. It really took a series of citizen activism, scientists getting involved on many fronts, as well as these really, I think, quite chilling and very dangerous kind of nuclear standoffs, all these coming together by the early 1960s to lead to a sense that above-ground nuclear testing was to be stopped.

Let me pause there just to say that these next few slides are just to say the debates didn't end with that. It was then debates about delivery mechanisms, about missiles, about how many warheads should be on a missile, should there be anti-missile, anti-ballistic missile systems, and so on. Here's a preview for that next film. Because of all of this above-ground testing before it was driven underground, there is to this day lingering ill effects throughout, for example, the continental United States, though not limited to that, where 3,000 square miles of the continental United States have now by the US federal government been deemed officially uninhabitable because the remnant radiation levels are still too high.

And that's the kind of thing that this next film called *Containment* tells us much more about. So the decades long and ultimately, in this case, thousands of millennia long environmental impacts of this relatively brief period of Cold War nuclear activity, that leaves a tail much, much longer than only the early tests and early test bans. And that's just a preview for the film.

So finally, just the last slide-- but these nuclear issues have never been outside of society. I guess that should be obvious. But the scientific debates which were difficult and sometimes conceptually very rich, they were not happening in a vacuum, and nor were changing notions of what scientists' own roles can or should be.

Are they subject to special scrutiny because they're somehow the wizards of dangerous materials? Are they politically naive and therefore shouldn't be trusted? Should they be speaking out because they have special insight or knowledge? We haven't resolved these questions to this day, but they get really churned up and really amplified as burning questions I think during this period of the early and mid Cold War.

So those are things we can again continue to think about later in the term. So again, I'm sorry to run a little bit long. I'd be glad to stay late and answer questions, but that's what I want to get across for now.

Iyabo asks, was there competition similar to Livermore Los Alamos during the Manhattan Project? No, in that case, it really was just the Manhattan Project. There were different facilities that were not doing the same thing, so in that sense, they weren't rivals. Oak Ridge was doing different things than Hanford. With Los Alamos and Livermore, both they had overlapping missions, more directly overlapping missions. And I think that bred more of a kind of immediate rivalry. So I think that was part of a difference. That's a good question. Again, sorry to run late. I'd be glad to stay on a bit longer if people have more questions, but we'll delve more into this next time.

Thanks, everyone. Stay well.