[MUSIC PLAYING]

DAVID KAISER: Rockets, incredibly powerful clocks-- soon, lasers-- what hasn't been impacted by these things?

SARAH HANSEN: Today on *Chalk Radio,* my guest is David Kaiser, a professor in the physics department at MIT, who also teaches the history of science. His course, Einstein, Oppenheimer, Feynman: Physics in the 20th Century was recently shared on MIT OpenCourseWare. Professor Kaiser is such an interesting person to get to interview. Simply thinking about how to interview someone responsible for teaching the history of, well, everything from the Big Bang to how hippies saved physics-- and, yep, that is the title of one of his books-- was humbling.

There was so much here that we wanted to share with you, so we decided to air this interview in its near entirety. Professor Kaiser explains the earliest moments of the universe and how those moments help us understand our current night sky. We talk about how culture, politics, and even physical spaces shape how science gets done and what we might be getting wrong about Einstein. We'll also get his take on Oppenheimer, both the man and the motion picture, and how film plays a role in his course at MIT. I think you're really going to enjoy this. Thank you for being here today.

DAVID KAISER: Thank you.

SARAH HANSEN: Let's talk physics first.

DAVID KAISER: Mm-hmm.

SARAH HANSEN: Inflationary cosmology.

DAVID KAISER: Yeah.

SARAH HANSEN: What is that, and how does it help us understand our world?

DAVID KAISER: It's really our leading explanation for some of the earliest moments in cosmic history. It unfolds on what to, on an ordinary human scale, seems like an impossibly short span of time. Most models of inflation we think about happening over a tiny fraction of one second when the universe was impossibly smaller than what we see around us today. And when I say a tiny fraction, I mean something like a billion, billion, billion billionth around 10 to the minus 36th of a second, or thereabouts, give or take. Tiny, tiny.

SARAH HANSEN: Wow

DAVID KAISER: You know, a human blink is something like, I don't know, a thousandth of a second. This is just exponentially shorter literally than the blink of an eye. And yet-- again, according to our best understanding, so much happened in that tiny, tiny cosmic blink that set the universe on the path that we actually now see, and measure, and can think more about to the present day.

So it was a period of very rapid-- in fact, basically, exponentially fast-- stretching of space. That's the inflation part. Like an inflating balloon, it doesn't go like that for very long, but long enough to increase the size of the universe exponentially larger than anything it would have been prior to that. And that really sets the conditions for our otherwise more familiar and very well tested model of the Big Bang.

My very dear friend, my mentor, and now my colleague, Alan Guth-- also here at MIT-- Alan likes to say that inflation, which he helped to invent, it puts the "bang" in the Big Bang. This is what really sets the conditions for what otherwise has to unfold for our very now decades older and very well tested model of the Big Bang. The Big Bang itself didn't explain what set the universe stretching at a certain rate.

It didn't explain why it would have passed through certain phases, been hot now and cold later. And those are things that inflation begins to plausibly fill in and explain. And one last thing I'll mention is an unexpected sort of byproduct of that is that it gives, really, a first principles explanation for why there's anything in our universe at all, why the universe is not a uniform smudge of just average, average vanilla everywhere.

SARAH HANSEN: Yeah.

DAVID KAISER: And, in fact, when we look around, when the astronomers use fancy telescopes-- if everyone's walking around just casually looking at the sky at night-- we see one of the most stark features of our observable universe is it's very lumpy. There are regions where there's very dense concentrations of matter and then enormous voids where nothing much happens at all. I usually say it's like some parts are right by the Stata Center. And, otherwise, they're really quiet and boring, like over at Harvard. I'm kidding.

SARAH HANSEN: Aw. [LAUGHS]

DAVID KAISER: The point is-- I'm teasing. But there is A--

[LAUGHS]

SARAH HANSEN: Yeah.

DAVID KAISER: --distribution to where the stuff is to the matter and energy and activity in our universe. And how did that ever take that form? And inflation gives us a really incredible framework to really calculate quantitatively, not just to wonder about in a cartoon level-- to calculate in very fine-grained detail the initial, unavoidable quantum jitters going all the way back to Heisenberg's Uncertainty Principle, that matter must have been subject to even during inflation. And those originally very short, short, small scale quantum fluctuations on this model get stretched unbelievably fast to be the size of galaxies, or even beyond galaxies, having started much smaller than the size of an atom.

And it sets in motion the initial very minor lumpiness. And then over time, the areas that are happening to be slightly more lumpy, slightly more mass than average, those attract more mass or matter to them through ordinary gravitational attraction. Regions that happen to be just ever so slightly under dense, a little less dense than average, those get basically further and further evacuated by the neighboring lumpy or more massive parts.

And we can fill in that simple sounding story-- a lot of hand-waving story-- now with some very sophisticated calculations and simulations compared with really fine-grained measurements on the sky. And the match is breathtaking. That was a long answer, but I think inflation is really-- it's best understood as a framework--

SARAH HANSEN: OK.

DAVID KAISER: --for trying to understand some of the earliest moments in cosmic history and how it set our universe onto a path that we can now try to make sense of in more recent times.

SARAH HANSEN: Wow, It's just fascinating. It's so interesting. And that in and of itself might be enough to fill an entire career--

[LAUGHTER]

--right?

DAVID KAISER: Yes.

SARAH HANSEN: But yet you have this intense interest in the history of science and physics.

DAVID KAISER: Mm-hmm.

SARAH HANSEN: And I'm so curious how that started for you.

DAVID KAISER: It goes back a ways, not quite to the time of the Big Bang. It feels like that as I get older--

SARAH HANSEN: [LAUGHS] OK.

DAVID KAISER: --that it's been that long. Not quite that long. But it goes go back to my teenage years, a high school student.

In hindsight, other historians have filled in. That really turned out to have been a golden age for popular science publishing. I was a lucky beneficiary, as many of my peers or cohorts were, reading books in, say, the early mid-1980s. That's the period I have in mind when I was basically a younger high school student.

And so there were lots of really high-quality books-- some written by practicing scientists, some written by very careful and excellent writers who are science journalists or science writers who had a strong background of the science as well. So I was just gobbling these up as a kid. And some of those books from that time period used a kind of history-- or maybe I'd say chronology-- to motivate, to tell a story, to put something like a human face on what can otherwise sound like abstract ideas-- whether it's about quantum theory, or the Big Bang, or relativity and gravitation, and black holes, whatever.

And so by the time I entered my undergraduate studies, I was hooked. And I remember very clearly-- it was before even classes had begun-- my very first few days on campus as an undergraduate, I was talking with someone who had become a very important physics mentor to me. And I shared all these youthful enthusiasms about these amazing stories about Albert Einstein, and Niels Bohr, and all these-- they felt, to me, like giants on a mountaintop.

SARAH HANSEN: Yeah.

DAVID KAISER: And it was Joe Harris, who was an expert in relativity, longtime physics professor. By the time I got to know him, he said, you know, there's a whole field of study called The History of Science. He left off that, dummy. Like, how did you not know that? I didn't know. I had never heard of it.

But Joe very sweetly said, there's actually more to that than just heroic tales of lonesome geniuses-- which is the kind of books that I've been absorbing. They were, frankly, very, very hero worshippy with hindsight. And it was Joe Harris who said, there's so much more interesting human stories to be told.

And it's not only individuals. It's institutions, it's broader cultures, it's politics, it's geopolitics. It's the stuff of World War and everything in between.

And so Joe gently encouraged slash nudged me to go meet with actual card-carrying historians of science. And I was lucky-- very lucky-- to fall in with two of them. So I met, very early, Richard Kremer and Naomi Oreskes, and I never looked back. So they took me under their wings, and I began doing a double major-- essentially, a double major-- as an undergraduate. Because they showed me, there really is-- there's a discipline study of history, including the history of science, that really can go beyond these fairly one-dimensional stories, as I say, that I loved but, really, maybe ultimately were a bit limiting that I read in those earlier books.

SARAH HANSEN: Hmm, there's something so interesting about putting a face to science--

DAVID KAISER: Yeah.

SARAH HANSEN: --a story that makes it so much more accessible to everybody. Tell me a little bit more about something-- I've heard you say that science doesn't exist on its own, that it's always happening in a context shaped by an institution, shaped by the people around the scientists. Tell me a little bit more about those ideas.

DAVID KAISER: Yeah. On the one hand, it's a straightforward observation. Scientific research is now and has always been done by people-- by humans, right. Not always by-- by sometimes a very select or even elite group of people-- but people, by humans.

And so it has always, by definition, been a human activity. How could it be otherwise, right? And so once we dig into that, once we start from there, then we start to say, well, humans tend to organize themselves in various ways.

Or we think about institutions. Those change over time and space. It's not one kind of institution in which something like the disciplined study of the natural world has unfolded. There's been lots of kinds of institutions that changed over time and across space. The institutions themselves aren't just plopped down in a vacuum.

Who wants that? Who supporting that kind of research toward what ends? What do people want out of moving into those kinds of spaces? What do they hope to be able to learn, or contribute, or why do they think they're doing it?

And once we start asking those questions about the people, about groups of people, about larger groups that might be supporting directly or indirectly-- those groups of people-- then, suddenly, we have a real history with a capital H. It's really in the flow of human events. And it's not cordoned off as being somehow separated from the other elements that my colleagues in history are immersed in all the time.

SARAH HANSEN: Let's talk a little bit about your course-- the Einstein, Oppenheimer, Feynman-- Physics in the 20th Century. So this is really bringing together the physics and the history of science into this fascinating course. Could you share some of the main goals of the course that you have for learners?

DAVID KAISER: Yeah. I guess I really have at least two big sort of high-level goals that I like to bring forward when I teach the class. And one is it really should help students-- especially students in physics, but not limited to that-- get a sense of a couple of the contours of the field. In other words, it can be a-- I sometimes joke it's like a smorgasbord or a tasters menu-- a buffet of what I still consider some of the most mind-stretching, strange sounding delicious ideas at the core of modern physics. And that means things like quantum theory. It means things like relativity, and gravitation, and cosmology, and astrophysics.

There's plenty I get-- I have to leave out because of time. But we get to really sit with early ideas about nuclear physics and where that leads to. So that part one is it's a roadmap to some of the areas still of great, great excitement to the research frontier in physics today. They didn't come from nowhere. They've evolved on sometimes a rocky, bumpy path-- plenty of blind spots along the way.

So part one is, what does the field look like now and how do we get there? Number two, coming back to what we talked about just a moment ago, how has this collective-- community-shared body of knowledge-- developed? And that brings us right back to, it's people and institutions set sometimes in very dramatic times-- historical moments, war time, fighting fascism, the nuclear age-- lots of scary things, worldly events.

And that those, I say, weren't separated from the march to better understand quantum theory, or nuclear physics, or the cosmos. So it's a way to try to see, how do ideas and institutions knit together and together change across time and space? It's not one versus the other. It's an evolving framework of ideas and institutions. And that pairing, that double vision, I find really helpful and a lot of fun, then, to try to engage with the class as well.

SARAH HANSEN: Yeah. One thing that this makes me think of is when students become aware of how institutions and physics interact. They may begin to question their own institutions.

DAVID KAISER: Mm-hmm.

SARAH HANSEN: Like, are women really represented--

DAVID KAISER: Right.

SARAH HANSEN: --in this field? And if they're not, then what impact is that having on what's being studied and what's being discovered?

DAVID KAISER: Absolutely. No, that's a great point. And something-- I've taught this course maybe 10 or 11 or 12 times over the years. I teach it roughly every other year, so I've had a chance to do it in a number of times.

And one thing I found adding more and more to the syllabus over time-- there's room for more still, it's still an evolving course. Our question is exactly the sort that you're pointing to. And I'm lucky because some of my own historical work has focused on that, written in first round for fellow specialists. But more and more of my colleagues in the field-- in the history of science and in physics both-- have been asking those questions. And not just asking them, but really doing careful, empirical, archival research, interviews from more recent periods.

There's more stuff that I can learn from and also more stuff I can assign and teach. So the reading list has been evolving. It'll continue evolving exactly on that baseline theme. This is done by people in times and places.

That is non-trivial, we'd say. There's a lot going on there. Who's been invited in, who's felt welcomed in, and with what consequence, intellectually, as well as for the broader-- the viewpoint more broadly of the scientific community?

SARAH HANSEN: Absolutely, and I'm wondering if that's one reason there's no textbook for the course.

DAVID KAISER: You know, partly. It's also-- it's still a somewhat unusual course. I have friends who teach similar courses elsewhere, so it's not this is the only one. And I've learned a lot from their versions of their courses.

But I really haven't found the one source that brings it together. And what's one of the things that's so special about this course here-- that I enjoy, in particular, I should say about the course-- is that it really is aiming first and foremost for physics majors. We can get into a bunch of equations, even though-- and we'll talk soon. I'm sure the assignments are not typical problem sets. I love the kinds of assignments we get to do.

But in the course of a class discussion, or during office hours, these are mostly-- they're not entirely young physics students. So that's one kind of shared skills and shared reference points that we, together, can draw upon in the class. And to combine that with readings about the rise of Nazism or very context-heavy studies of women in science after the war, I haven't yet found one source that really knits them together in the way that I would want to keep the material moving forward.

So it's a grab bag. Again, I revise the reading lists pretty much every time I teach it, but there's a pattern to it that I feel pretty comfortable with now. And that really is picking and choosing some papers-- short papers by people like Albert Einstein that our students really can read and really make sense of-- as well as works by historians, philosophers, sociologists, media theorists, or whomever else. And so bringing those together-- and let's sit with those together-- is really fun. And that means let's just put them together on a website instead of looking for one book that does it all.

SARAH HANSEN: Yeah. Yeah, and I have to say, the course is now on OpenCourseWare. It's an open educational resource, so now other people can remix those readings, change them around, supplement them, and it becomes a shareable resource, which is just great.

DAVID KAISER: It's very exciting to me, as well, and I'm eager to see what other smart folks will do with it. Here's my best take at it. What-- other people are going to do something else, which is great.

SARAH HANSEN: Yeah, exactly. So let's get into the details a little bit.

DAVID KAISER: Yeah.

SARAH HANSEN: Let's pick Einstein, Oppenheimer, or Feynman-- some of your title characters. Maybe pick one and tell me a little bit about how his context was shaping the science that he was doing.

DAVID KAISER: Yeah, each of them, of course, are stand-ins for generations--

SARAH HANSEN: OK.

DAVID KAISER: --and so we talk about many more individuals than, of course, only those three. I did choose that title the very first time I ever taught the course with MIT students in mind. So what's going to catch their eye if they see a handwritten poster on the wall?

SARAH HANSEN: Yeah.

DAVID KAISER: But-- anyway. So we spend a good chunk of the course thinking about Albert Einstein and the times of Albert Einstein, if not only his individual person. And I think, again, what's fascinating is that everyone more or less has heard the name. Everyone at MIT more or less has some ideas and maybe even some more detailed knowledge of some of the contributions to the scientific field that Einstein himself had created-- or he and his small circle.

And, yet, it's not always well-known the world he was immersed in, the ups and downs that he, himself, was facing individually-- but, again, even beyond the realm of just the individual. And so one thing I find helpful is he was very, very ambitious and was mostly thwarted as a young person. And I find that actually helpful to sit with for a little while, not to point fingers but say, there was a kind of mismatch.

And partly why he wasn't so successful was because he was extremely arrogant as a young man and also cut all his classes. As a good thing to remind my students--

[LAUGHTER]

--don't cut your classes. Here's a pro tip.

So Einstein got by basically borrowing the notes from a small circle of very good friends, one of whom then became his first wife-- Mileva Maric, who was a much more diligent physics student and math student at the time than he was in University. Other friends who went on to very distinguished careers in mathematics and physics-- and Einstein, as a young person, would basically delve into things he cared about and literally blow off or ignore things that he wasn't into, including if he wasn't impressed by a given faculty member. And that's not great advice. I always say Einstein was kind of a dummy. He was no Einstein as a young person.

SARAH HANSEN: Right. [LAUGHS]

DAVID KAISER: And that's worth sitting with, again, at the individual level. And then we can see, well, how was he beginning to ask questions that sometimes were on familiar terrain for the experts who were already the kind of esteemed giants in the field when he was up and coming. He would ask what I think were often recognizable questions, but really from, we might say, left field, often with an unusual twist. And that's also fun to sit with.

So the question-- we can say, oh, I get it. I want to understand-- I understand why that was a pressing challenge of the day. It fits into this body of work. Why is he doing things that looked, then, to his contemporaries, pretty odd ball? What do we do with it today?

SARAH HANSEN: Yeah.

DAVID KAISER: And there's two kinds of oddball-ness that we can have fun with. One is, we can read, how did other people react to his work in real time, as we do a lot. The early reception, for example, of relativity, I think, is just fascinating, and a lot of my friends in history have written brilliant things on that.

But also, especially with a room full of physics students-- most of whom have had at least some formal training, let's say, in special relativity before-- it doesn't look the same as what we do today either. There's a strangeness that was commented on by contemporaries in the early 1900s. There's a different kind of strangeness, as we as a community have learned and assimilated this. And now we teach it in different ways than what made sense either to Einstein or, indeed, to his contemporaries.

And so there's a remoteness which I find very helpful as an historian. It's not just what we all expect. It doesn't just look like what we did yesterday in our classes. Now, why not?

That's an opening. Then you say, well, why? What made sense to them there, why do we do things differently now, and how can we begin to tell a more complicated kind of ups-and-downs story that stretches out, in this case, over many decades-- roughly, a century-- and not just assume that because we still remember Einstein's name, we know what he thought he did? And that's really-- we can sit with, this looks familiar but strange-- this is strange, but now I can see familiarity. You can do a lot of work with that kind of juxtaposition.

SARAH HANSEN: Yeah, that's interesting. And I know the course focuses a lot on science communication--

DAVID KAISER: Mm-hmm, yeah.

SARAH HANSEN: --writing, in particular. And one of the assignments asks students to peer review a piece by Einstein.

DAVID KAISER: Yes.

SARAH HANSEN: [LAUGHS] Tell me about that. And how do students feel about doing that? That's a little bit intimidating, no?

DAVID KAISER: It could be, but we work up to it. And so, again, my friends in humanities and myself would call this kind of assignment a very typical assignment. It's a close reading of a primary source.

SARAH HANSEN: OK.

DAVID KAISER: Take any history class, or literature, or art history, or anthropology. That's a critical skill to both read it and say, what do I think the author is trying to convey, what's the structure of the author's argument, what's the basis of the evidence to go from step one of the argument to step two-- these are incredibly valuable analytic skills. And then to write-- in this case, a brief paper-- four or five double-spaced pages, not terribly long-- where the students practice articulating, going through the argument. And as I say, it's a close reading of a primary source, because there's no library work. You don't have to read three more books and say what other people said Einstein was doing.

Just sit with this text as a text-- and, in fact, only the first few pages of the text, just an excerpt-- and say, here's what I think the author is doing to make an argument. And then the student says, and is it compelling? Is it of value?

Is it a trustworthy argument? Are there gaps? Does it make sense, or is it strange?

And so part of what I remind them before they work on the paper is that many, many, many people who read Einstein's-- this very paper, in real time, back in 1905-- they thought it was a very strange paper, as well. It looked bizarre. It didn't follow their own standards or expectations from the day, much as it doesn't follow ours today either, despite differences between those two.

It looks strange to the experts then. And very few people read this thing and said, oh, I get it now, I am reformed.

SARAH HANSEN: [LAUGHS] Right.

DAVID KAISER: The first response to Einstein's work in relativity was no response at all. And so we put ourselves back in the mindset-- this is coming from a, basically, little-known civil servant patent clerk-- not a fancy university professor-- who's writing things in an unusual convention in style, making some really curious sounding arguments.

OK, let's sit with that. Here. Read these first five pages of Einstein's paper.

Write four or five pages on your own. And that-- it's meant to restore some of the strangeness again. Pretend you don't know about what we all have learned in the hundred plus years since.

Unusual paper, not already famous author-- let's read this on its merits. And I always say, the papers I enjoy reading most are the students who reject this. This is a bizarre looking paper. This shouldn't be published like that. And I think they're often right.

SARAH HANSEN: Yeah.

DAVID KAISER: So that's why we try to do a little more conceptual work by taking that excerpt pretty seriously.

SARAH HANSEN: And while we're talking about him being a patent officer-- which I did not know, actually--

DAVID KAISER: Yeah.

SARAH HANSEN: --what was the impact of his travels to and from the patent office that shaped how he was understanding the physical universe?

DAVID KAISER: I love this part. And this I really take from a very dear friend and colleague of mine, Peter Galison. I signed one of Peter's enormously influential and, frankly, just fun articles on this project. He went on to write a whole book about it. But for the course, we read an article from Peter Galison.

And among the things that Peter does is he reconstructs, just as you say, literally the path that Einstein walked in Bern, Switzerland when he was a young-- in his mid 20s-- from his apartment-- rather modest apartment-- to his desk at his day job, at one of the many branches of the Swiss Patent Office in Bern, Switzerland.

And what was so interesting that Peter was able to find is that Einstein was passing not just one or two clocks, he was passing a brand new set of special clocks that had just been installed around the time Einstein was making, literally, this daily commute, this walking journey. These were clocks that were coordinated so they would show not just similar time, but really lockstep time long before the age of satellites and GPS and fancy things that we do to synchronize clocks today. But they were, really, a brand new invention just coming online around the year 1900 plus or minus, in many parts, certainly, of Europe.

And so what was most surprising about Einstein's first paper on what comes to be called The Special Theory of Relativity-- the paper he wrote while at the patent office in 1905-- was he was thinking all the time about how could one coordinate clocks at a distance? It's not so straightforward. And the solution that Einstein famously very abstractly describes, in this very abstract paper, is we can use light beams, things like electromagnetic waves, radio waves. Now we might use lasers because we're fancy. But the same basic idea-- waves that are going to travel at a known speed.

Einstein gets more and more concerned about the speed of light in general. And would it be the same for all observers? This becomes a core that he writes down, these strange looking first few pages of this article that the students read so carefully. But one of the things he convinces himself of is that the speed of light should be a constant, independent of one's state of motion.

I could be standing still on the sidewalk. I could be on a fast moving train. We know Einstein loved trains.

He often thought about moving fast on trains-- and that me and the sidewalk, my friend on the train, should measure the speed of light to be the same speed even though we're moving at very different speeds from each other. So, suddenly, you have something like a standard bearer. There's something universal, at least Einstein had convinced himself, that's not only a measurable, but it's not going to change situation-by-situation.

That sounds like a pretty good way to start standardizing clocks-- one clock, a sort of central clock which you set by whatever means you want. You can say, that's my official time, and then you beam out timestamped radio waves because those are going to travel at a known speed. And if the distance you are from that central clock, then how long the light beam has traveling to get to you-- so you know how much to offset your clock.

SARAH HANSEN: Oh, wow.

DAVID KAISER: And, in fact, this wasn't-- that part wasn't Einstein's idea. He was generalizing from it, I think, in really, rather, amazing ways. Again, I'm just learning this now, I say, from Peter Galison's historical work.

And so one of the earliest uses of the Eiffel Tower was actually to be a beacon to send out standardized radio waves of Standard Central Paris Time.

SARAH HANSEN: Really?

DAVID KAISER: That people were worried about this in an age of more and more trains moving more and more rapidly across more and more of continental Europe-- you don't want to have different clock settings at the start and end of a train journey, because that could lead to a terrible thing. Crashes-- and, let alone, hard to schedule.

SARAH HANSEN: Yeah.

DAVID KAISER: So the real-world demands-- civilian and military-- is a time of, still, great unrest. The Franco-Prussian War of 1871 and 1872-- all these things are real-world concerns during Einstein's own youth and as he's growing up in that world. So there are lots of clever engineers and scientists thinking about trying to make sure clocks were comparable.

Some people said, let's use radio waves. Einstein was growing up where that was more and more becoming a fact of life. Literally, as he walked to his office, some of the clocks he passed in the streets of Bern were some of these newly coordinated or synchronized clocks.

SARAH HANSEN: Yeah. What I find so interesting is that your take on this, and your colleagues take, it's not just like institutes and culture and politics that shape how science is done. It's the physical spaces themselves.

DAVID KAISER: Yes.

SARAH HANSEN: And that's what I find particularly new about this.

DAVID KAISER: I agree. And then we can trace it back the other direction. Once some technologies like those become common or standard, how does that act back on the worlds of institutions, politics, culture? So they're not separated, and they're also not only flowing sort from one to the other. It really is a fascinating model as opposed to a frustrating model. I think seeing these eddies moving in multiple directions-- again, I find that just fascinating.

SARAH HANSEN: Yeah. So I have to ask you about the Oppenheimer movie--

DAVID KAISER: Yes.

SARAH HANSEN: --for a second. So I saw it in preparation for this interview. I brought my snacks, stayed the full three hours.

DAVID KAISER: Good.

SARAH HANSEN: It was great. So what did you think of the movie? And what did they get right, and what did they get not right?

DAVID KAISER: I was really impressed by it. I've only seen it once. I saw it in the theater.

SARAH HANSEN: Yeah. First of all, this must-- this is your jam.

DAVID KAISER: It's my jam. And it's other world-- it's like pinching myself.

SARAH HANSEN: It's like they made it for you.

DAVID KAISER: Well, for a small set of my friends, at least. It's very delightful, and exciting, and a little bit strange.

SARAH HANSEN: Yeah.

DAVID KAISER: I'll share a quick story. I worked with a wonderful, wonderful younger scholar who was on his dissertation committee-- Shawn Mullet, Historian of Science. And I saw Shawn just recently after the film had been released. I hadn't seen him in quite some time, and he said-- he described it-- he had an out-of-body experience in the theater, because he hadn't realized that the person he focused most of his thesis on-- an otherwise not well-known figure who'd been a PhD student of Oppenheimer's at Berkeley in the 30s-- that he-- an actor playing him-- walks into this major production and says these things that Shawn said, yeah, that's basically what he would have said.

So Shawn didn't even know to expect the lesser known characters whom a few of us have focused so much. So that was my feeling, as well. So I was impressed by the film, very much cinematically.

I know the book on which it was based quite well, and I've taught that book in other classes. I knew the authors pretty well. And so when I heard that would be the basis for the movie, I was a bit more confident.

And I thought the attention to historical detail, overall, for the film was amazing and much more than I would have expected. Of course, there's a license, because you have to fit nearly 700 pages to three hours on the screen. Lots have to be creatively done there. But I thought the filmmaker, Christopher Nolan and the whole team, were, really, to my mind, very impressive at their goal of conveying still-relevant big feelings, thoughts, ideas and emotions while also being accurate to very specific historical documents.

I knew when this actor says this line, I know exactly what it's being quoted from. It's line-by-line from this or that hearing that was held in 1954. And that level of attention to historical detail I found really terrific. And to put it together in a way that these artistic folks can do was very moving to me.

SARAH HANSEN: Hmm. That's great. I'm curious about the Trinity Test in the movie, and particularly about the communities that were downwind of that test. And I'm wondering if, in general, those narratives tend to be left out of the historical narrative, or what your take is on that.

DAVID KAISER: It's a great point. So there are, thankfully, many, many historians, and anthropologists, and sociologists, and public health officials, and scientists themselves who have, in more recent years, gone back and filled in some of that essential historical work. So we as a specialist community know much more about that than even we did, let's say, 20 years ago, let alone 70 or 80 years ago.

So there's more to draw on. When I teach this material, there's more that I can read and share with students, as well. More to be done, but more than there used to be, as well.

What I find fascinating is, related to that, it's not only-- it is included, but not limited only to folks who happen to be in close proximity to that one explosion, but also to the hundreds of thousands of workers-- certainly, tens of thousands at very specific large plants during the second World War who were given very little information about the very, very harmful materials they were handling.

So one thing that we talked about a lot in the class the film could maybe have done more to illustrate-- but, certainly, we spend a lot of time with this in the class that's now on OCW-- is that the Manhattan Project, depending on what counts, employed-- formerly employed-- anywhere from 125,000 to 500,000 people during the war, depending on what categories you lump together. Huge-- it's not Oppenheimer and 12 geniuses on a mountaintop by any measure. Hundreds of thousands of people-- the vast majority of whom were given very little information about what they were actually handling or why.

It was, of course, a highly secret, classified project during the war, and so much so that there was internal kinds of classification. And so, in addition to the so-called Downwinders, people who were actually employees of the project at huge industrial plants-- like in Oak Ridge, Tennessee-- like in Hanford, Washington-- these were put together in a real hurry to produce larger amounts of fissionable materials to scale from micrograms to kilograms. That's a large shift in a wartime setting-- very time-sensitive.

And they had to do that by using really poisonous conventional material, let alone the special nuclear materials. Some of the epoxies, some of the dissolvents-- they're horrible, horrible materials. And we now know, again, through historical work over the more recent decades how little those workers were informed even though they were on the project, let alone the people who happened to live, say, in New Mexico near the test site.

And so I'm not trying to belittle. I think being near the first explosion would not have been good. And as we now know, in hindsight, that was the first of many, many above-ground explosions that were done by the-- after the end of the war to test next generations of bombs.

So you have an accumulation. One blast might or might not have an immediate effect. Many, many, many-- over, now, decades-- that's not a good thing to be near, of course.

And even during the war, prolonged exposure, even for two or three years to these highly, highly toxic substances-- not all good. And there are, indeed, now documented intergenerational, elevated bad health outcomes at other sites like that. So we now know a lot about that.

Now, sometimes people will say, but nuclear weapons were literally brand new in this time period. Did people just not know what the risks would be? And I think that's giving some folks too quick a pass.

The public health community knows a lot more now than then. Of course, there was a lot known even then about some of the dangers-- the health dangers-- of certain kinds of radiation. So I don't think the fact that people know more now means that it was a reason not to have been much more carefully informing workers and neighbors-- let's say-- people living near at the time.

So it's, in one way, a teachable moment. This is war time. The Cold War came next. That's not to excuse it.

Can we try to understand how that ever could have seemed like a reasonable policy for the United States government to have adopted in secret? Not to endorse it, but say, how could that have been? And then, with that knowledge, what might we try to do now moving forward?

SARAH HANSEN: Yeah. Yeah, no. Thank you. I wasn't aware of that aspect of this, so thank you.

DAVID KAISER: Mm-hmm.

SARAH HANSEN: I want to move you, now, before we talk in more detail about the course, but just to the Cold War. OCW works with community college faculty who are adopting and adapting OCW content. And I had the pleasure of speaking with a history professor as part of the Maricopa Community Colleges. And he had a question for you.

DAVID KAISER: Great.

SARAH HANSEN: Because he knew I'd be I'd be interviewing you. He's interested in history, and the impact of technology, and all of those things. And he says-- his name is Paul Hyder-- how did the technology that ignited the Cold War influence changes in American culture?

DAVID KAISER: What a great question. Thank you. And thank you, Paul.

First of all, what technologies might we have in mind? That would certainly include things like nuclear weapons, that would include, also, lots of very fancy electronics, some of which was actually pursued here at MIT during the war for the radar project-- at least as impactful on the course of the war itself, and also, with hindsight, we know, unbelievably important for the Consumer Electronics revolution that was soon to come, and much beyond. So we can think about the modern electronics-- the shift from vacuum tubes to transistors, which happens very soon after the end of the war-- all kinds of extremely precise kind of microwave technologies that are hidden from us yet we still use all the time to this day.

That leads to communications. Soon, it leads to rockets and satellites, part of which also had a war time, of course, origin. And so when we start knitting these things together not so long after the end of the Second World War-- rockets, incredibly powerful clocks-- soon, lasers-- what hasn't been impacted by these things?

And some of it is for further wartime-like weaponry of increasingly lethal and fancy kinds, of course-- that we might associate that with a Cold War, first and foremost. But it also leads to things that many of us simply might take for granted today. A project I've been having a lot of fun working on as a historian is on some of the early history of the Global Positioning System-- or GPS. So that's not coming out in 1946, it's operational already by the mid-to-late 1980s. But you can draw this really very careful direct set of connections to a lot of this wartime or wartime surplus stuff coming out of the second World War.

And that gets us to things like atomic clocks, atomic frequency standards-- clocks that will be accurate to nanoseconds on a day and not much, much more jitter than that-- to, again, things like lasers, or other very accurate electromagnetic signaling devices, to very rapid computer chips. You put those together on satellites moving high above our heads and, suddenly, many, many people in the world, around the world, have devices in our pockets where we can learn to roughly 1 meter accuracy where we are. And that comes from an unbelievable assemblage of, basically, quintessential Cold War technologies, most of which were actually put together for military purposes first.

GPS itself was originally a classified military technology. Drawing on basic ideas about physics and engineering-- but getting an awful lot from more direct Cold War spin-off kinds of developments. And so once we get to something like GPS, how I find my way when I'm lost in my own kitchen, because I have a terrible sense of direction-- then what wasn't touched, is really-- I turned the question around. I like Paul's question a lot. But it'd be harder to answer what hasn't been affected, even in very kind of ubiquitous, mundane, daily life by a whole set of technologies, and, also, the things we've learned about how the world fits together, that we can draw a pretty straight lines back to this enormous, confusing, often very scary and deadly time of the second World War and the early Cold War.

SARAH HANSEN: Yeah. So interesting. I have so many more questions about that, but I will move us on. I just wanted to touch on another film, which is *Containment.* You watch that in the course. Could you tell us what that film is about and what kind of discussion it generated in the course?

DAVID KAISER: It's a fascinating film. It was a documentary, roughly 90 minutes, which I would say was perfect because the class time is 90 minutes. So I'm not asking students to do more than they would invest in a lecture session anyway.

The film was made by Peter Galison, the same colleague I mentioned earlier with Einstein's clocks. Peter is a remarkable film maker, as well as a historian and a physicist. He and a team made this film, as you say. It came out only a few years ago. And it's a nonfiction documentary about efforts to contain, basically, nuclear waste from, now, generations of the nuclear age-- not just for weapons from weapons development, but also from civilian nuclear power.

And there's just many, many kinds of very, very long-lived waste products, some of which are still very dangerous to people, and the environment, and to animals of every kind, and that don't lose their toxicity very quickly. So some of those half lives of some isotopes of plutonium are measured in tens of thousands of years. So if you have a so-called "hot"-- if you have a radioactive sample here now-- it's not going to be safe for longer than there's been written language. It's getting our heads around that kind of time scale.

So this fascinates Peter. It fascinates me. But Peter made this film some years ago.

And they're really just trying to trace through-- up to quite contemporary times as the film was really being made-- what are different ways to grapple with a different kind of legacy of the nuclear age? It's one thing to think about mutually assured destruction, and brinksmanship, and how this drove domestic and international politics-- and we talked about some of those things even in this class. Those remain incredibly important. We still have to worry about nuclear weapons to this day with active war and in parts of the world, so these are not merely bounded historical questions there.

And what I've really had my eyes open to, from work like Peter's, and other scholars, is there are other dimensions that also haven't gone away, that also stem from the onset of the nuclear age. And that needn't lead one to one-side civilian nuclear power-- love it or hate it. It's not going to be decided as a vote or a coin toss. But what I think the film does, for me, in a very effective way, is make visible for us what, in my head, was otherwise-- I didn't-- it was very abstract.

The amounts of waste of really dangerous stuff has to go somewhere, and the community has yet to find a really foolproof way of dealing with that. And it has effects on communities-- mostly poor, mostly communities of color. Like the story of the Downwinders, we have versions of that going on to this day, not only from above-ground nuclear testing, but from related activities.

And, again, it could have been pursued with intentions we might understand during the Cold War-- or trying to provide civilian power. It's not that it's about heroes and villains, it's about trying to understand a wider range of impacts and some very dear costs from, again, quintessential Cold War technologies that haven't gone away. They're not merely historical. They haven't literally been contained. So the film called *Containment* is how, among other things, we contain this ongoing legacy, because we haven't found a great way to do it yet.

SARAH HANSEN: So just to wrap us up here, I'm really curious what you've learned about yourself as an educator over the 10 or so times you've taught this course.

DAVID KAISER: I love teaching this class. I still love it. I'm going to teach it this Spring.

I'm so delighted I can do it in person again and really see and interact with students not only via screen. So I'm excited to do it again. It's a class that I get excited about every time I get the chance to teach it.

One thing I've learned about myself is which I've really value is that it's OK not to know stuff. And so when I was a young professor, I don't think I was alone in this. I felt like I better just know what are the-- any question that comes up, I better-- it's my job to know. And it took a few iterations to say it's my job to help us all figure it out, which is very different from being a wizard who just knows everything. No one's like that-- no reason to think that's the right goal.

And so to be at even a few more steps in the collaborative "let's learn about this together," which has been good for me, and, hopefully, helpful setting a better group-learning philosophy, let's say, for the class as a whole. I used to do a thing-- now I give a last lecture for the class to try to wrap up threads. It's included on the OCW set.

Before I developed that-- one of the lectures, the 25th lecture for the class-- I used to do a game for the last class sessions. I used to call it "stump the chump," but I stole that from the *Car Talk* guys--

SARAH HANSEN: Yeah. [LAUGHS]

DAVID KAISER: --I think. I just love the phrase.

And it was like, the floor is open. We've covered some amazing ground. This term from early 19th-century physics-- the course actually starts well before the 20th century and, by now, pretty several steps into the 21st century. We've got a lot of stuff on the table that we got to really sit with together over the semester. We-- myself, the students, the teaching assistants-- what's left, what do you want to know about-- and just let the students just ask questions at random, and to make myself, again, kind of vulnerable in an exciting way to them.

Because, first of all, these are, as I said before, just unbelievably talented young people. And they don't have all the answers either, but they're so curious and engaged. And they're engaged right up through the end of the semester, which I'm just grateful for.

They're still showing up, and they're still reading. "And I read this, and I'm curious about that." And, "I heard this thing in the other class."

That's one of the great gifts of making a life in a university. And so it was that experience when I realized I should ask them any question they want to ask and let them know that, wow, that's a great question. I appreciate the question.

I have no idea. Let's go work on this together. And that's something I've learned about myself, that, frankly, it's more fun for me-- hopefully, a bit more interactive for the students, as well.

SARAH HANSEN: Hmm. That's great. That's great, thank you. What advice do you have for other educators who may want to engage their students in thinking about the history of science?

DAVID KAISER: Well, there's a lot. And I think there's more and more-- hopefully, helpful and interesting-- resources out there. Again, I'm so delighted that this course is now available. And it's all through Creative Commons licensing, and the slides are there, and readings. And people should make of it what makes most sense for them and for their immediate pedagogical goals.

And it's not only this. There are lots and lots of, I think, really high quality materials out there-- published articles and books, many of them very accessible now, not only kind of written for a small circle of specialists-- lots of creative multimedia things. Courses like this and a few Google clicks away can get to other, I think, exciting materials from very talented colleagues, and you-- and then the instructors can make it modular, can pick and choose.

It might be that they want to include one special class session and not revamp their entire class. I'm sure they have other learning objectives and things they really want to cover in their existing classes, but there could be, maybe, inspiration to tweak-- to add one more reading, maybe one extra class discussion, and maybe that leads to the next time. So I think what's nice is to think about a scale.

And if the overriding theme is that this is done by people in times and places we're all fallible, we can try our best. We do better when we have a larger community and we have more eyes and hands that work together. We can try to convey that, I think, really important lesson through history and the history of science. And you can get that across with, I say, with one extra reading and one class session, as well as maybe a whole semester or beyond.

SARAH HANSEN: Yeah. That's really helpful to think about it in terms of scaling up. What else would you like to add that we haven't addressed about teaching physics, history of science--

DAVID KAISER: Well, another thing that I really love about this class is that it's mostly physics majors. It's not required. There's no prerequisites. But it fulfills what, at MIT speak, is CIM-- which means Communications Intensive in the Major. So it helps physics students fulfill a major requirement. Others can take it as an elective, and they do very well.

But what that means is, what we practiced in the class is mostly writing. It's a big class. I haven't figured out how to do oral communication, which is also critical. Students will get that in some of their other classes, of course. But at least clear, concise writing, building on a range of sources, making an argument, having a structure-- that those are skills that are at least as important as remembering where the factors of 2 pi go in these very important problem sets.

And so I always joke that my friends and colleagues in our department here, they'll teach our physics majors how to calculate really well. Our students calculate great. There's no question. Let's make sure we're not losing other really important skills, as well, or giving them the short shrift, so to speak.

And so that's one thing I loved working on in this class, is we get to sit with these amazing ideas and read original physics papers, as well as work by historians, and philosophers, and essay and media studies, and well beyond, and try to put a conceptual story together about ideas that I still just dearly love in physics itself. But we're going to practice talking about those, making arguments about those, adducing evidence about change over time in a way that the students don't always have that same opportunity in all their other otherwise really quite wonderful classes. And I just-- so I love the opportunity to work on those particular kinds of skills with students who are immersed in this fun set of material.

SARAH HANSEN: Do they ever come with anxiety about writing, and how do you tackle that?

DAVID KAISER: Many of them do. Many of them do. And I find that curious, because the students who are coming to MIT, by and large, have done extremely well in high school, including in classes that had heavy writing compared to-- so it's not like they never wrote a five-page essay before, or even, by the end of the class, a 12-page essay.

So one thing-- but, nonetheless, the anxiety, I think, for some is, is legitimate. I think they either haven't exercised those muscles in a while, or they feel intimidated now that they're at university, not in high school-- whatever it may be. So one thing I find that helps is actually break down the process into smaller parts. And so each of the essays builds on the previous one.

So I don't ask the students to write a 12-page research paper on day three. That would be silly. But we say, let's write four pages, double-spaced.

That's just a handful of paragraphs. Like I say, no need to go to the library. Let's get a close reading of one source.

Let's work on transition sentences, let's work on topic sentences, let's work on evidence and footnoting-- just little pieces that are not going to blow their minds. They are absolutely up to the task. Let's sculpt it so it's really pretty-- user friendly. Go over it with them, they can rewrite it if they want.

Then, for paper two, OK, let's do that. Let's make it maybe six or seven pages-- just a little bit more. Let's build on 3 to 5 readings, not just 1-- but just baby steps out so that each component of this can be kind of sat with and practiced. Instead of just dropping it all at once, say, OK-- just come back and tell me when you've written your paper. And likewise for the last one.

Another feature that I really admire about MIT'S communications-intensive courses, generally, is that at least one paper must be formally rewritten as one of the assignments. And then in my class, and I think many of my colleagues, we make it an option-- students can rewrite any of the papers. And why is that important?

I've been writing stuff for a long time. I write essays. I write books. I have to rewrite my own stuff all the time. Revision is itself a skill that maybe, again, doesn't get quite the emphasis in some other classes.

So it's not just that we can break down topic sentence, transition sentence, footnotes, argument structure. But, also, you're going to come back to this with fresh eyes. You'll get feedback from myself, from teaching assistants, maybe from some of their own peers.

And revising is itself a cool skill. And no one's born knowing how to do that either. We can work on that.

So I like that expansiveness, taking the whole semester to go from modest, contained, well-defined little bit, and then say you can do it. And now let's add in a few more moving parts. And I find that-- and the students do very well with that. They're very successful, I think, because we can just demystify some of the steps along the way.

SARAH HANSEN: Yeah, absolutely. And it also shows that it's not an innate skill. You're not a good writer or a bad writer. It's a skill that you develop.

I have a lot of people on this podcast who talk about math that way-- a lot of MIT professors--

DAVID KAISER: Yeah.

SARAH HANSEN: --who do math [LAUGHS] for a living-- and they say, I wasn't a natural mathematician in high school. But someone told me-- in fact, our previous guest-- someone had to tell her, you're having a hard time not because you are bad at this, but because it's hard. [LAUGHS]

DAVID KAISER: Right.

SARAH HANSEN: And then she treated it like a language, and learned, and practiced. And what you're saying is the same with the writing, that it's a skill that can be practiced.

DAVID KAISER: It is. And I look back on my own training from some of the folks I mentioned earlier. Naomi Oreskes-- when I was an 18-year-old, a first-year college undergraduate-- she was so unbelievably generous with her time. And Rich Kremer was, as well-- the other historian.

The number of drafts they must have sat and/or suffered through of mine--

SARAH HANSEN: [LAUGHS]

DAVID KAISER: --either way-- and it was just cogent and constructive. And we can work on things at this scale, and then we'll build towards those. What did I know? And it's not like I learned it when I was 18 and had it down by the time I was 19. Of course not.

And in my own career as an historian, I've been able-- I've been very lucky to work with really, really good editors

SARAH HANSEN: Yeah.

DAVID KAISER: And I've been learning this-- and still learning-- and still practicing now. I've been doing it for a long time. So I still enjoy the-- it's still something that I get to practice and learn about from experts for whom, this is their day job. And so to bring some of that, again, demystification, no one's born doing this. And there are-- and it's learnable. And these smart, smart kids are good at learning stuff, right.

SARAH HANSEN: Yeah.

DAVID KAISER: So we can help them along with that much as they're being helped along and flourishing on the full gamut that they're having in their other classes, as well.

SARAH HANSEN: Yeah. Well, David, thank you so much. This was really delightful.

DAVID KAISER: Well, thank you. I'm really so glad to be able to talk with you. And I'm really delighted that class is now up there and available more broadly.

[MUSIC PLAYING]

SARAH HANSEN: Oh, we are, too. We are, too. Thank you.

DAVID KAISER: Thank you.

[MUSIC PLAYING]

SARAH HANSEN: That was our conversation with David Kaiser, MIT Professor of the History of Science and Physics. He's the Instructor for the MIT course called STS 042J-- Einstein, Oppenheimer, Feynman-- Physics in the 20th Century. His teaching materials from that course are available on our MIT OpenCourseWare website. You can download, use and remix his open educational resources in your own teaching and learning.

Thank you so much for listening. Until next time, signing off from Cambridge, Massachusetts, I'm your host, Sarah Hansen, from MIT OpenCourseWare. MIT *Chalk Radio's* producers include myself, Brett Paci, and Dave Lishansky. Show notes for this episode were written by Peter Chipman. David Kaiser's OCW core site was built by Cathleen Nalezyty. Jason Player made our episode cassette animation on YouTube. We're funded by MIT Open Learning and supporters like you.

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