PROFESSOR: I just came across a couple of interesting quotes about cybernetics. What did cybernetics have to do with any of this? Well, an awful lot. Here's a quote from Jerry Wiesner. "We were all fired up by Norbert Wiener's cybernetics. We have explored the far-ranging implications of the complex concepts of information and communication theory. It ranged from man-made communications to computing systems to the sciences of man, inquiries into the structure and development of the nervous system, the phenomena of inner life and behavior in relation to other men."

So you get the sense of, like, the whole interdisciplinary thing, which is a big topic, of course, on our campus today. RLE was one of the major kind of early points in that. "Neurophysiologists and other biologists, linguistics, economists, social scientists, and psychologists recognized almost intuitively the usefulness and relevance of feedback information theory to their fields. For all of them, the concepts of information theory, coding, feedback, prediction, and filtering provide new pathways to explore pathways that seemed to wind unendingly."

So this whole idea-- this is another one of these places where you see the relationship between the institutional structures at MIT, how the labs are organized, what the overall policy is that's coming from the federal government to support the work, and actually the content of the work, what sorts of things people are studying, how they're thinking about these problems, what the innovations are. And, I think-- and this is one of the threads I want to communicate to you today-- there's a real common thread in a lot of what MIT does in these realms, including SAGE and Lincoln Labs and that stuff, going back from probably before the war around computing and interaction and all the different aspects of communications.

The Department of Linguistics itself is formed by research from RLE in 1961.

There's actually a real relationship between, for those of you familiar-- anybody know what Chomsky and linguistics is? So Noam Chomsky, who is the sort of founding father, in a lot of ways, of modern linguistics, created this idea in the '50s called generative grammar, which is the idea that the structures of language are built into the brain. They're not things that you learn as a toddler or as baby. And that's one of the special things that makes human brains different from all other kinds of brains.

And that's called generative grammar-- that the basic grammars are some that is inherently inside of you. A very radical idea, at the time, for a number of different reasons, partly because it was connected to what's called the cognitive revolution in psychology. Up until that point, the kind of leading paradigm, even in Cambridge psychology, was behaviorism led by B. F. Skinner at Harvard. The idea that, well, it's too complicated to understand what's going on inside either our brains or anybody's, any animals' brains. We're just going to look at the behaviors, the inputs and the outputs, measure the behaviors, and try to understand that anything that's going on inside only matters if it's expressed in a particular behavior.

Well, around this time period, led by many people around here, there's a thing called the cognitive revolution, they call it now, where people rejected that view. And they began looking inside what thinking was all about, very much driven by parallel developments in computing, in AI. And in some sense, the whole idea of psychology at MIT was superseded by what? Cognitive science. Which now we have a Department of Brain and Cognitive Science, which was sort of-- do we have a psychology department here? No. We used to, at one point, but we don't anymore. It was sort of folded in. It's interesting. It's a separate topic and way to think about what those differences are.

Partly, I'm dwelling on this because tomorrow is the symposium, the last of the 150th Anniversary Symposia, which is on Brains, Minds, and Machines, and is a new research initiative that's trying to look at the problem of intelligence by combining AI, cognitive science, neuroscience, and linguistics. And these things are all not that far apart, again, from this early history, but they've developed separately, in some ways, for the last 50 years, and the idea is to tie them together. So if you're familiar with AI, there's not been a lot of neuroscience in AI. But now there's an attempt to bring a lot of that together. It's going to be a really interesting, exciting thing.

I have to introduce the symposium tomorrow night, and I'm working on my comments. And, usually, when I introduce these symposia, I talk about what happened at MIT before the people in the room were there. And then, when they got up and they talk about their own experiences, then they cover the last 50 or 60 years. There's not much that happened at MIT in linguistics or in psychology or in anything cognitive before Marvin Minsky and Noam Chomsky and a few of these other sort of critical people.

Interestingly, the whole efforts-- these things also manifested themselves in biology. How do you think, in the 1950s, biology took up some of this influence from cognitive science or, particularly, from communications theory? What's the word that people use to describe DNA? A code. The whole idea of DNA as a code and biology as a kind of informational science emerges right at this time, not only at MIT, a lot of other places, but very much taken up there. Last year we read an article about that, but we compressed the syllabus a little bit. OK.

The political context during those years-- after the war, again, the Radiation Lab dies down. The country is really demobilizing. Troops are coming back from the war. Everybody's going away from the military back to civilian life, until 1949, 1952. Critical events happen then. Anybody want to guess?

Russians explode an H-bomb in 1949, much, much sooner than anybody expected, and the Korean War starts in 1950. And that's really the beginning of the Cold War. So you really have this-- it's not correct to think about the Cold War as just the continuation of World War II. There is this sort of brief-- but it is a kind of 5-year period where everything's shrinking before the Cold War really gets going.

And then you begin, during the '50s, you really have the civilian sense of being under threat by nuclear warfare. It was before my time, but perhaps your parents or even your grandparents will remember. In the 1950s, if you were in an elementary school in this country, you were trained how to respond to a nuclear attack when you were in school. And you'll hear the phrase "duck and cover," which so many people were trained to do. Hide under your desk, pretty much, which I'll leave it as an exercise to the reader to what that'll do for you when there's a nuclear weapon coming.

And so during this period, in some sense, it's the golden age of science policy. People often talk about that. And we'll come back to this after Sputnik, where scientists are involved in high-level decision making in a way they've never really been since then. In the world of computers, all the way up through 1960, three-quarters of the world of computing was simply run and funded by the government.

So there was hardly any computation to speak of. And the quarter that was not there was mostly in the business world of punch cards and IBM punch card machines. And a lot of that work was done in high-end computational at Los Alamos, fluid dynamic simulations and things for nuclear weapons. So during the Cold War, you have all kinds of new kinds of institutions emerging, in addition to new technologies.

Outside of MIT, you have the Rand Corporation. Anybody hear of the Rand Corporation before? It's still around. You still hear them issuing reports and things. I have colleagues who work there. Founded in 1946 by the Air Force, and that's the place that pretty much invented the term "think tank."

So you have these kind of not governmental-- Rand is not part of the government-- but it's a not-for-profit corporation where they do a lot of large-scale strategy, operations research, nuclear strategy. I mentioned already the Office of Naval Research, which sort of carries on the OSRD tradition for the 10 years after the Second World War. And they came up in the reading because they funded the early part of Whirlwind and lots of different types of new theories, from engineering science-- you hear that phrase coming up a lot at MIT in that period-- systems engineering, systems dynamics, systems analysis, operations research. I mentioned cybernetics, control theory, general systems theory. And all this stuff is sort of buzzing around.

And before I show you this film about Whirlwind-- well, let me show you the film about Whirlwind. OK. And so then, the other one I called up is the-- you'll remember from the reading that they build Whirlwind. It starts out as this sort of flight simulator thing. Rather quickly, Jay Forrester has these huge ambitions for it and starts into this just large machine computation project. And then they switch their Navy funding into Air Force funding, and they look at this problem of air defense.

Starting in the early '50s, there's a physicist at MIT named George Valley. And they start looking at this whole business about how do we defend the continent, which is an interesting question. Remember, we talked last time, or the time before, about anti-aircraft control. SAGE is really the exact same thing, just the updated '50s version of it, right? How do you shoot down airplanes that are attacking you?

And air defense is a typical problem that civilian scientists like, and that government, especially elected officials, like because it plays well politically. It seems to be, morally, a little bit more comfortable than offensive weapons. Of course, you can shoot someone down if they're are about to drop bombs on you. The military, also, generally dislikes it because the people who run the world regarding aircraft in the military-- even at this point, they were the Air Force-- the Air Force doesn't like to think a lot about shooting down airplanes. It's not one of their favorite hobby topics. And they generally aren't big on defense. They want to go out and kill the enemy and offense.

So you constantly see this question of air defense rising up in scientific circles. It's still true today, actually, with things like missile defense. And they put this system together called SAGE-- and, again, you read about it-- sort of continental air defense system, I think, partly comes from the way that engineering really dominated here, above the other sciences. And in many of these other schools were-- where the engineering is sort of separated off as a separate school-- but the really high-prestige work was going to the mathematicians.

I also think that, actually, a lot of the history of computing was written later by mathematicians. And so they kind of remade it the way they wanted it to. You can see-- actually, even Norbert Wiener does that, John Von Neumann. John Von Neumann plays a role in the ENIAC project very, very late and does some very important fundamental, theoretical work, but it's basically an engineering project.

Whereas here, partly because of the military connection, partly because of the Rad Lab, there's always this focus on the human relationship and the real-time interaction, and partly because they're enabled to do these big projects and kind of build these big, experimental systems, rather than having one single. There's a great quote. It's from later on, where a university administrator is told that they just, the University, just bought a giant computer for millions of dollars, and now they need to form a department of computer science. And the administrator says, that's ridiculous. We just bought a giant air conditioning unit for millions of dollars. Nobody's telling me I need to make a department of air conditioning science.

And so the struggles of sort of-- is the computer just a big, glorified calculator, or is it something fundamentally new-- are all happening during this period, too. Anybody know when the Computer Science Department here is founded? Everything I'm showing you here is from the '50s, 1950 to 1956. When does MIT create the CS part of EECS? 1968. Takes a long time to actually recognize that there's a new science there.

As I said, this is really IBM PR. So they were showing this to maybe generals and other people who would be their military customers or just generally the public. It's not very technical. It's, like, got the kids on the playground, like defending your people sort of thing. But you see throughout this the computers are there as these control centers. And this is real-time interactive computer graphics, which is going on nowhere else in the world at the time.

And the idea of a computer, not as this kind of calculator/switcher, but as this interactive-- not just interactive but also very much networked kind of computer. Some of the things you saw that were really done for the first time with SAGE and

Whirlwind, real time, they mention graphic displays. Modems were invented for this system.

You don't even use modems anymore. Does anybody have a modem that they use these days? I haven't used one in, probably, close to 10 years at this point, but used to use them a lot. Real-time memory allocation, all kinds of stuff that you use in the software engineering world. And SAGE was really the first big software project, too. It really taught the American industry how to organize these big software projects. And there were many others that were built that were similar to it.

And as the film kind of makes clear, it's oriented towards civilians. It's built to make civilians feel comfortable. It's not built because the military wants to go out and get the Soviet Union. That's what they do for a living. And it's built to make people feel comfortable. And was pretty much obsolete by the time it was operational, so it had, essentially, no military impact despite all the money that was spent on it. But it had some technological input.

Nobody's really ever was able to know if it would have worked if we were actually attacked. But there was a brief period where air attack by Soviet bombers over the North Pole was a great fear of people. What ended that fear or made it irrelevant?

AUDIENCE: ICBMs.

PROFESSOR: ICBMs. Where this system wouldn't work against ICBMs. But you still see that fear. And all the debates about missile defense in the last 20 years-- Patriot missile during the Gulf War and all that stuff-- is just an extension of this kind of fear. So this is sort of what's going on around here in the '50s. I have a couple more videos, let me see which ones.

And a lot of people really actually did question, is this really the kind of MIT that we want to be living in-- big military projects, lots of money flowing in, lots of focus on building large systems-- as opposed to research projects or kind of individual scientists doing things? And that's where-- and I want to say a little bit before we move on, and Roz Williams mentioned this. I don't think we've assigned it this year for reading.

Was a bunch of people at MIT got together in 1949. It was called the Committee on the Educational Survey, but it became known as the Lewis Report. And, again, Roz Williams mentions it. The Lewis-- who it was named after was her grandfather, Doc Louis of chemical engineering. Other people on the committee were Stratton, who I mentioned, Elting Morison, who was a historian who actually founded the department that I head now, Viki Weisskopf, who was a famous Manhattan Project-era physicist. Jerry Wiesner we've talked about. Gordon Brown we talked about. John Burchard, who was the first Dean of Humanities and Social Sciences, and Harold Hazen, who was the Dean of Engineering at the time that we talked about before.

And there were these problems that were on peoples' mind at the beginning of the Cold War. I'll read you a couple of quotes from it, which are pretty interesting. "We continue to claim that our primary mission is to teach, but other activities have assumed an unprecedented role at MIT. Service to the community and to the national government has always been recognized as a primary obligation, but now the dollar volume of government contracts, government-sponsored research, amounts to far more than the academic budget.

Postwar government funds have been used to maintain a very large technical staff without the privilege of tenure. And the major part of the Institute's personnel is now dependent on the continuation of short-term financial support. Government money has made available to us magnificent facilities that have become a permanent part of the Institute and that involve continued responsibility for their maintenance."

So there was this problem of just big size. Like how do you maintain it? Once the Institute grew that big, people had to-- it's like a big animal in a cage that you need to shovel money into all the time. Whereas before, the Institute was primarily focused on undergraduate education, and it was really a kind of technical institute college kind of environment. It became much more focused on research. And these sponsored projects, particularly military sponsored, were bigger and bigger.

They asked, "Is all this work genuinely creative? Can it, indeed, be justified on the ground that it strengthens our educational program? Have our staff members not on occasion been lured by prestige that accompanies an enlargement of activities without considering the loss in their professional competence that the undertaking of added administrative burdens may entail?

So these were all real questions that come up for the next 60 years, in a way, about-- are the faculty members now big managers managing big research projects more than real thinkers sitting down and actually thinking things through? "Is there not a danger that the interests and energy of our faculty are being diverted from education to income-producing work? And secondly, many large projects emphasize design and construction problems-- like Whirlwind, SAGE-- engineering development or applications of science rather than fundamental scientific inquiry. We must be careful lest the great preponderance of activities of this type divert interest from the more fundamental aspects of scientific research.

And the third concern is the preponderance of military projects in the sponsored programs. Two difficulties-- first, national security requires some of it be done in secret. And second, it would be unfortunate for MIT to become regarded as an institution that is dependent on the development of war weapons as it is for an industrial organization to be [? required ?] in a similar light. We suggest that future planning should look forward to the possibility of increased emphasis on activities more directly related to the public welfare."

This is a very interesting moment where major people at MIT get together and they say, is this really the world that we want to live in? What's happening to MIT? Is this really a good idea? And again, that's 1949, right-- really, the year before the Cold War really hits. And a lot of people feel those concerns were sort of buried throughout the '50s, in a way, as the Institute became more and more dependent on these things.

A couple other things to mention from that period. Baker House is built in 1947, and it's really the beginning. We've talked about this before, I think, of the residential part of campus growing on the west side of Mass Ave. and then on down the street, of course. The other dorms are built then.

The mid-century convocation is 1949, when Winston Churchill comes to town and speaks. And, again, sort of says MIT has an obligation to think, not just about the sciences and technology it's creating, but what are the social implications of those technologies. And that's when-- the School of Humanities and Social Sciences is founded, essentially, right after he says that in 1949.

And also at that mid-century convocation is the inauguration of James Frank Killian-- James Killian, James R. Killian, forget his middle name-- as president. He's the first alumni, alumnus, to become president, which is kind of interesting. It took almost 100 years for that to happen. And he's as much of a kind of executive manager, not a career scientist, in the way that his predecessor Karl Compton was. He really ran MIT during World War II when Compton, as we mentioned, was off around the globe getting these weapons into service.

So what is the end of this sort of early Cold War period? When does the world that this film is describing really come to a shocking end?

AUDIENCE: Sputnik.

PROFESSOR: Yeah. October 4, 1957 you have Sputnik. We read a piece about that. And there is this just this incredible sense of shock. You can see from this video-- I actually don't remember what the year on this was-- 1956, so right before then. And there's a sort of sense of arrogant confidence that we're doing everything right, and the whole world follows us. Couple people raised this in the response papers, too.

And then Sputnik is launched. And it's this incredible shock to the American system because suddenly-- it's somewhat similar to the explosion of the Soviet H-bomb. Remember, we come out of the war. We have this world-changing new weapon and nobody else has it. And then, not only the Soviets get that one, but they get the A-bomb. They get the H-bomb, also, in very short order.

And there's a lot happening in the '50s, and there's a lot of debate going on. And people see space, somewhat like computing, as sort of like this exotic new field. Nobody's quite sure what it's good for, but it must be important for the military somehow. And there's a lot of debate about that.

Meanwhile, President Eisenhower is this sort of interesting, ironic figure in that we have a military general in the White House, which doesn't happen that often in American history. And yet, at the same time, he's a conservative Republican. He wants to keep government small. He wants to rein things in and control military spending as best he can. He actually calls military spending theft at one point.

But in a certain sense, he's pushed by the forces of history in ways that he's not able to control and is, actually, not very sensitive to what Sputnik means. And a lot of people aren't, even as soon as it first goes up. And somebody mentioned this about-- why wasn't the US first?

Well, partly the US wasn't first because they didn't see that being first was going to be a priority. And it wasn't, necessarily, an objective comparison of US technical competence versus Soviet technical competence. That's how most people in the world, including in Congress and the American public and the media, read it, but it wasn't necessarily that way.

Eisenhower was very concerned about some of the legal implications of-- if you send a satellite over somebody's territory, is that considered an invasion, or is the space above your-- it had already been legally established that air space is like territory. You can't go into it without permission. But that wasn't established about orbital space. And they were actually, in some ways, happy.

One of the Assistant Secretaries of Defense immediately wrote, "The Russians have, in fact, done us a good turn in establishing the concept of the freedom of international space." And now we can overfly them with impunity because they've done it to us. And so, there was this sort of question. Eisenhower said, "Sputnik does not rouse my apprehension not one iota. They've put one small ball into the air."

Yet, the press assumed that this meant Soviet superiority in technology. They sort of pushed the panic button. People in Congress, particularly Lyndon Johnson, took every opportunity to rub it in. Let me see if I have the quote. Because the US military said, oh, that's not a big deal. We have four projects that are going to get that going, at the time.

And Johnson said, in public, he said, knowing that we have better rockets on the drawing boards is not very reassuring. It's like being told that, I suppose, our next model will have tail fins and automatic windshield wipers, which was sort of the sarcastic comment about what we're going to do. What they hadn't really recognized was that space was this incredibly, symbolically, potent thing and that people responded to it way out of proportion to what the direct implications of it were.

If the US had decided that being first in space was important, they probably could have rushed ahead and gone first in space. They didn't. They had some bureaucratic infighting. They had the unfortunate failure of another rocket right after there. And the world really changed, in 1957, from a science and technology point of view in this country.

I teach a lot about science policy. And one of the things you learn about science policy in this country is that practically every agency that exists in the federal government concerned with science and technology arose in response to a crisis of one kind or another. The most recent example is the Department of Homeland Security, which was created after 9/11. No matter what a good idea they thought it might have been or not been beforehand, it was a response to crisis.

And after Sputnik, you had several things which were really quite important for MIT and for the development of technology. One was reorganizing R&D in the Defense Department to avoid what they called technological surprise. And that involved creating a new agency called the Advanced Research Project Agency, called ARPA, which was founded in 1958. Its first director was a professor from MIT named Jack Ruina, who's still around. And I'll talk about that a little bit in a minute.

Vastly increased accelerations in R&D funding and also, of course, the NACA, National Advisory Committee for Aeronautics became what? NASA, National Air and Space Administration in 1958. Both those agencies were founded in 1958. And then there's also the National Defense Education Act in 1958.

This may sound like a long time ago, but most, if not many, of your professors-- if they're older, age 50-- were probably educated with funds from that Act, including President Susan Hockfield. She came here-- in her inaugural speech she said, I was a post-Sputnik child. I was educated and got into science because there was a huge push in scientific education in the late '50s and early '60s to get kids into science. And I was one of the beneficiaries of that. So we're very much living in this kind of post-Sputnik world in that way.

And I want to talk then a little bit about ARPA and DARPA. Show you a couple more movies that take this whole same story, in a way, into another realm. People have heard of DARPA before this, right? Has anybody not heard of DARPA? So, obviously, it's most famous because the internet started as the ARPANET and was created in very much this period, slightly after, but only in the early '60s.

And one of the things about computing-- one of things that's special about DARPA was that it's not the Office of Naval Research or the Air Force Office of Scientific Research or the Army Research Lab. ARPA reports directly to the Secretary of Defense, so it's outside of all of these inter-service rivalries. And it doesn't own-- in fact, it tends to stay away from things like big ships and big airplanes, much like the OSRD did, and focus on these technologies that are so far out and wacky that nobody really knows what they're good for.

At the time, space was one of them. In fact, ARPA was responsible for space until-- it was only a few months NASA was created-- and then they had space taken away from them. And computing was another one. That everybody had the sense it was good for something but nobody really knew what. And so let me show you a coupleof images, couple of other neat little films about what some of the ARPA computing work did.

So that's another kind of late '50s version of this whole idea of machine control, which is Air Force still and not ARPA funded. But then you get into the ARPA-funded stuff. So this is sort of the next logical step in a lot of this work. And Ivan Sutherland is someone who's, remarkably, still alive today, too. Not that he's remarkably still alive,but.

He went from here out to the University of Utah where he founded the computer graphics program there. And practically every fundamental concept in computer graphics came out of either his work or his lab. And then his students went on to found Silicon Graphics, Adobe, many of the other really critical-- a lot of them worked for Industrial Light and Magic, the George Lucas company and sort of migrated west, continuing into Hollywood. Pixar, that was the other one I was trying to think of.

And that, again, comes from this. We didn't watch that part of the film on SAGE, but they had these light pens in SAGE, too, as the beginning of this sort of graphical user interface. And then the last one I want to show you about has to do with time-sharing. So Corbato is still around. I saw him last week, and he still teaches in computer science.

And they came up with this time-sharing system where-- I mean, how many of you use a console window ever on your Mac or PC? So, basically, that's the idea behind time-sharing. That you have a computer there, before a graphical interface, that you could type commands and programs to, and it would respond to you immediately. Before that, you had only batch processing, where you'd put your punch cards in at night, and you go home and come back the next morning, and there would be the thing.

And they're again, following this thread. There was this idea that you could be so much more creative with a computer if you could sit there and hack away at it, and it would respond to you in real time. And that's really where time-sharing comes from. That led to a thing called Project MAC in the 1960s, which was a DARPA funded-- it was the predecessor to the Laboratory for Computer Science, which is now CSAIL.

And Project MAC was run by Bob Fano, who I mentioned before. And had all these different kinds of creative computing things inside it, including a lot of Minsky's work in AI, although they split out and formed a separate AI lab. Then they came together with CSAIL. And all these sort of time-sharing experiments, the origins of a lot of the late-night hacker culture from MIT, come from people working late at night on Project MAC projects.

A lot of the early computer games, *Spacewar* and whatnot, were developed in that context. And even a lot of the early later stuff for PCs, like spreadsheets, sort of came out of a Project MAC sort of setting. And then I also mentioned, of course, the internet, or the early ARPANET, one of the first nodes on the ARPANET was MIT.

A lot of the first routers were built by a company called Bolt, Beranek, and Newman, which still exists here, sort of down the street. So there's this sort of continuous thread that's then updated through all these different crises and periods and whatnot. And through the '60s, that's sort of how this very, very heavily military still, but sort of different agencies and different contexts bears on the campus.

I think you're right on. I mean, I think the atomic bomb had a lot to do with-- it's hard for us to imagine, but before World War II, two things. First of all, science was mostly the realm of pointy-headed professors and was very interesting and philosophically important but didn't always feel like it had a big impact on daily life and certainly not on public policy, per se. Again, the US government was hardly involved in the scientific world. Maybe in the world of agriculture it seemed to have a big impact. Most of industry didn't have a lot of science associated with it.

And it really took the atomic bomb, not just for technology, but also for science itself, the idea that it-- like something that presidents should care about. I mean, even-- you look at the scientific revolution and the Copernican view of the universe-- doesn't affect the way I govern my kingdom an awful lot. And secondly, same thing with technology, where the idea today that whoever has the best technology wins the war was just not an accepted idea. And there was no real evidence for it up until that point. Maybe a little bit here in the Naval arms race around the turn of the 19th century, the turn of the 20th century.

But today, almost everyone who is a leader in the military is trained in engineering in one way or another, not everybody but a very large amount of them. That was not true, even at the beginning of World War II. Military science was this other thing. There was this whole sort of tradition about fighting wars. There still is, still very prominent.

And it took World War II to really bring those two ideas together. And even then it was still a little bit under question because it was really about who had the most planes and the most tanks, not always the best tanks and the best guns. Then, to some degree, you can say that Bush sort of served as the president's science adviser during the Second World War.

But, again, most of the decisions to be made were either grand political decisions for the president as far as how to be allied with the Soviet Union and how to work with the British. And at the same time, military decisions-- where do we invade? At what time do we do it? And there's technologies that bear on that, but they're not things that rise to the presidential level.

It's really during the Cold War that you see the prevalence of atomic weapons and ICBMs. Again, ICBMs don't really come out until the late '50s. It's all through the Cold War you're living with bombers and nuclear bombs that are as big as this room that you need a huge bomber to deliver. That's why something like SAGE came out.

It's only around the late '50s you get this sense of mutual assured destruction, where we've got all these missiles ready to go, and they've got all these missiles ready to go. That's the world that dominated the next 30 years or so. And that's where arms control, different technical issues, become merged with politics in a way. And the presidential science adviser-- it varies from administration to administration-- but it's never been as prominent a position as it was when Killian and Wiesner were in that job. Nixon actually outright abolished it in the '70s, didn't want it all.

Anybody know why that's a troubled position? So it's sort of science policy talk more than an MIT talk, but it's relevant. There's an inherent contradiction in being the president's science advisor.

AUDIENCE: It's not pure science [? anymore ?]

PROFESSOR: That's true. There's a lot of people who do that. So, first of all, are you representing to the president the conclusions of the scientific community, or are you representing the president's opinion and his policy goals to the scientific community? Right? And those things can easily be 180 degrees at odds.

In fact, the story was-- this was all kind of leaked in the newspaper-- that George W. Bush asked Chuck Vest to be science adviser. And Vest said no because he felt he would be forced to take positions on things like climate change that he didn't think were going to be acceptable to him. So, if you look at what the Secretary of Defense does, or even the head of NASA, their job is to take the president's policies and implement them through the agency.

And any time a big decision comes up you'll always see them on TV saying, well, that's for the president to decide. Robert Gates doesn't decide whether we're in Afghanistan or not. That's the president's job to decide that. Well, what happens when-- in the defense world, at least there's an understanding that decisions on defense are sort of partly political and whatnot. In the science world that's not so clear.

And there's any number of cases where the president's policy preferences are at odds with what the science says, and that was very clear in the previous administration. But I'm sure that John Holdren, who is now the president's science adviser, who is a much more powerful guy and better-respected science adviser and scientist than the previous guy was, gets pulled in a lot of competing directions all the time. So it's a very difficult job and not everyone succeeds at that.

I thought it was interesting that, even in the little, short film clip I showed you about the APT programming language, the guy on the board said, well, now there's a new kind of person in here who is the kind of machine-oriented programmer. And he's going to take these requirements and-- let me give you a little background on David Noble, which is actually interesting. He was a professor here in the kind of early to mid-1980s and was in STS and did a lot of collaboration with the engineering departments.

And he wrote this book that was extremely critical of both the Air Force and MIT's role in numerically-controlled machine tools. And he was turned down for tenure a couple years later, and ended up suing MIT. He said because he was a Marxist, and they turned him down for tenure because he was a Marxist. MIT's response was, you didn't get denied tenure because you're a Marxist. You got denied tenure because you're a jerk. And that's actually legal. It's not legal to deny tenure to someone because of their politics. It is legal to deny tenure to them because of their personal style of interaction.

I don't know many of the stories there. And I actually only have met the guy once. He died about three months ago at a fairly young age. And he's a well-respected historian. And he's always raised these sort of questions about these kinds of arrangements. And it's very worth reading it because of the questions it raises, although I do think he misses a couple of things-- kind of like what you said.

In his world-- and I don't remember if this comes through in that essay or if it's in the larger book-- people who operate computers are managers, and people who operate machines are workers. And anything like numerically-controlled machine tools has that worker-- white-collar managers oppressing the workers. I mean, first of all today, almost everybody sits in front of a computer. Many, many jobs-- some of them are high-level executives and some of them are blue-collar operatives-- but the fact that you're using a computer has almost nothing to say about what level job you're in.

And in the world that he came out of, he only had this association of white-collar managers. So anytime anything became computerized, it also became white collarized for him. Where, actually, we actually know today that the opposite is often the case. That when something becomes computerized, the skill level of the people who operate the computer is lower than the skill level of the people who did it before it was operated.

And it's funny because he actually wrote an essay, after he wrote the book, about a study of machine tools in Sweden, where he was like, oh look, they did it this way. It's much more democratic and open, the way they use numerically-controlled machine tools. And there's an implication in his work that a given technology has a given social organization that comes along with it because of what's inherent in the technology. That's basically what he says in that "Command Performance" piece.

And the jargon in the field is called, it's deterministic. A certain technology dictates a certain set of social conditions. But actually, if there's one thing we know from research in the field is that you can have lots of different social organizations around any particular technology. You can use the internet as a tool of authoritarian repression, or you can use the internet as a tool of people's liberation. Depends how you use it, but the tool itself can be used in different ways.

I don't think that Noble would have seen himself, at the time, as a technological determinist, although, to some degree, all Marxists are technological determinists because Marx was a technological determinist. He said-- I'm not going to get the quote exactly right, but it's sort of like-- the spinning wheel gives you feudal society. Industrial production gives you capitalist society. And he, more or less, put it that way. And we actually know that's just empirically incorrect.

What Noble did say that I think is really valuable to keep in mind that underlies a lot of the stuff that we saw in the video is that-- what are the implications of all of this military funding going to support university research and engineering research and scientific research? And I've tried to show the connections between where the money comes from and what the ideas are that got created. And I think one of the most legitimate criticisms of it is that military systems end up focusing almost exclusively on performance.

And that's kind of the title of his piece, "Command Performance." That everyone was always pushing toward thinner wings and more precise tools and, obviously, faster airplanes, bigger bombs, heavier rockets. You don't care about costs. You don't, necessarily, care as much about schedule, other things which are sort of related like maintainability, sustainability. Lots of other ways to think about how a system performs besides simply performance. You know, an interesting example of that was the-- has anybody ever heard of the SST? What was the SST?

AUDIENCE: Boeing's supersonic transport [INAUDIBLE]. Newer version of the Concorde.

PROFESSOR: Right. So Boeing was trying to make, in the '60s, a supersonic transport--it was actually a competitor to the Concorde-- that would be Mach 3. And it was a big American project. And the idea was, gee, the Wright brothers were going at 20 miles an hour, and we went 200 miles an hour in 1940. And we're doing 500 miles an hour with jet aircraft in the '60s. Clearly, the whole world is going to go supersonic.

And if you focus only on performance, as the military does, and sure enough, military systems go supersonic. And that's the faster, the better, generally. Also just straight economics of-- I just read this the other day. The Concorde took as much fuel to put 100 people across the Atlantic as a 747 takes to put 400 people across the Atlantic. So, just run the numbers on that.

AUDIENCE: Also, there was the huge noise problem with the Concorde.

PROFESSOR: Noise problems.

AUDIENCE: Anyone who lived anywhere near the place where it lands with the rumbling.

PROFESSOR: Exactly. So actually it's a very interesting moment because, in the civilian world, the cancellation of the SST and a lot of other things that happened in 1970 are all about this sort of, like, you know what? Performance isn't the be all and end all. There are other things that matter with our systems like, especially, cost because that's a straight economic one. But also environmental impact in a bunch of different ways, whether it's noise or emissions. Reliability is a big one that often ends up being cost.

And the reason I'm bringing this up, partly, is it gets us to a little bit later part of MIT's life in the 1980s. What's happening in the 1980s? Maybe this is the Sputnik moment of the 1980s. Actually, it's not as much of a moment. What causes the US a big crisis of confidence in the 1980s?

AUDIENCE: There was a fuel crisis.

PROFESSOR: OK, the fuel crisis precipitates it for sure. That's in the '70s really, 1973. What's the big issue in the '80s?

AUDIENCE: Iran-Contra. Iran-Contra, or is that the late 70's?

PROFESSOR: Yeah, that's political more. That's '80s. But it's the Japanese car companies start eating our lunch. And we have the greatest car industry in the world-- General Motors and Henry Ford, and we invented it all. And suddenly, Toyota and Honda, which were making motorcycles, start coming in. And not only are they doing well economically, but their cars are better. They get better mileage. They're much higher quality. And the American car companies just will not listen or learn from it.

And then people say, very much like with Sputnik, what do you mean? We're the most technologically advanced nation in the world with the biggest economy. How is it that these car companies from this little island that we defeated in World War II are now doing so much better than us? And it led to this thing called the crisis of competitiveness. You may hear that phrase sometimes. It was a big issue in the '80s.

And one of the things people said was, gee, are we not spending enough on R&D? Now we're spending tons and tons on R&D, but it's all in the military realm or so heavily in the military realm. And the military is focusing on performance-- very, very high-speed computers, very, very advanced materials for this, that, and the other thing. And none of that technology is getting out of the lab into the field as much.

MIT does a big study in-- I want to say it comes out in about 1988-- called *Made in America.* And it's edited by Richard Lester, who is now the head of nuclear engineering, Michael Dertouzos, who is the Director of the Computer Science

Laboratory, a few others, Lester Thurow, who is the Noble Prize winner, Dean of the Sloan School. And *Made in America* sort of says-- how do we get the same level of achievement in the manufacturing industry in this country that we've got in the military industry?

And there's a whole series of concrete steps that they suggest to do that. One of them is creating a dual master's program, which is still here, called-- it was called Leaders for Manufacturing, where you get a master's at Sloan and a master's in engineering. They changed the name, and I think it's Leaders for Global Systems or something now. So the competitiveness crisis very much came up as, like, this military focuses too much on performance, too much only on-- if you look in AeroAstro, it's all about supersonic, or dynamics, and not enough about more efficient engines or cleaner engines. And there really was a kind of shift after the '80s toward that.

Interestingly enough, another flip side of that, which a lot of people don't realize-- because someone mentioned it in one of your response papers that-- well, you know, it looks like when I'm in my double E classes, I end up learning a lot about consumer technology. And I'm building mobile technology and mobile this and that. And where does all that stuff come from? Where do we end up developing advanced, small RF and microwave integrated circuits?

I can tell you that stuff wasn't originally developed for the cell phone industry. That was all military communications stuff. And Qualcomm and a lot of those other big companies really developed a lot of those techniques early in that world. Then, there is a general consensus, probably somewhere in the '90s, the sophistication of computation and information technology in the commercial world exceeded that of what happens in the military world.

Now I go to meetings and half the problem is, how does the Navy and the Air Force take advantage of all the amazing stuff that's coming out instead of having obsolete electronics and all those things. But that was somewhere in there. What's their concern? Well, actually it was something that was raised by Norbert Wiener, late in his career in the early '60s, that all of this automatic technology was going to put all the workers out of work. And I think the Air Force was then concerned-- gee, is there going to be a workers' revolt, and we're going to be facing a communist revolution sort of thing?

So when people talked about social implications of automation, they talked about technological unemployment, essentially. Some of which did come to pass, and there's certainly fields today. I think, today, it gets more called outsourcing than it does called replacing workers, but it has the same effect on unemployment in this country.

And it is interesting, especially at a place like Boeing, where all the engineers at Boeing are basically workers. They're unionized. And Boeing, these days, makes big decisions based on their relationships with their unions, both machinists and the engineers. And so, again, the clean distinction between factory workers as blue collar and white-collar engineers-- engineers in many places are more and more like blue-collar workers in a lot of ways, partly because of CAD and computer-aided design.

How many people in here have ever designed a circuit, actually designed a new circuit that no one's built? I mean, I can open up my CAD software, and I get a library of all these demo circuits, and I can sort of copy and this sort of thing. And there's certainly changes that have come into what engineering practice means in a lot of different fields because of computer-aided design in different ways. Which, arguably, maybe makes it easier to outsource jobs in ways than it was before.

Running a university has become a 24-hour job in a way that maybe it wasn't always before, partly for reasons that all jobs have become so 24-hours. And it's just a very big complex place, and it's harder for-- it's hard to picture an MIT president taking a simultaneous job in the government. I don't remember what Killian did, if he stepped down when he took that job, or if he did them both at the same time and for how long.

And yet, at the same time, the presidents do-- like, Chuck Vest chaired one of the big review committees on the space station, and it's called the Vest Report. And it was kind of a midway design review in the early '90s, and the cultural authority of being the MIT president, I think, had a lot of impact there. And he sat on the President's Council on Competitiveness.

And I don't know what Susan Hockfield's official titles are that way. But she does-- when Obama rolled out a big energy initiative two or three years ago that was part of his administration's science policy, she was standing right there next to him on the stage. So she's very involved with presidential science advice in that way.

And I think it's also true that different presidents just emphasize different parts of the role. There is a sense-- and Chuck Vest was extremely enthusiastic about this-- where, from this earlier history of a lot of these things you've read about by now, there is a sense that the president of MIT is not just in Washington speaking for MIT, but is speaking for the research enterprise in general and research universities in general. And that the kind of privilege of the bully pulpit that you get from being the president of MIT is not used to go down to Washington to just scoop up more money for Cambridge. Clearly, we've seen that happen quite a lot in the history. But also to go down and speak for research overall and why it's important to maintain that in the economy.

And when Vest became president, which I think was '91, was really right after the fall of the Berlin Wall. And there was this thing people kept talking about called the peace dividend. And there was the sense that all of that DOD funding-- and some of it really did-- was about to fall off the cliff. And people were really questioning, why are we spending money on universities at all.

When Newt Gingrich was Speaker of the House, he basically wanted to end it altogether, and Vest, and a lot of related similar people, really spoke out against that. By the way, that's about to happen again. And I do think you'll see Susan Hockfield in Washington speaking on that behalf. Anybody see her? She was on *Charlie Rose* a couple of months ago with the President of Harvard talking about almost exactly that topic.

So I think there's a lot of behind the scenes work that goes on. It's not necessarily secret or hidden, but it doesn't have a big public role. And at the same time-- you know, MIT has an office in Washington. And the guy who runs it is a very experienced guy, and they are registered lobbyists. And they're extremely effective at taking MIT professors and showing them around Washington.

And I know this because about 2 and 1/2 years ago, I was part of a group that wrote a report on space policy. And we called these guys up-- we developed it in parallel with them. And within a few weeks, we were sitting in the room with the transition team for Obama, who was working on NASA, and the people in the White House who work on space policy. And that's what lobbyists do. They open the door, and they get you in there.

Now they're not lobbyists in the sense of they go down and say, give us more money, but they have to be registered because they are performing that function. Now, MIT hasn't always had that office in Washington, and may not always have that office in Washington, but there's a lot of that sort of stuff that goes on. So, it is harder to picture-- again, I think it has much to do with just the demands on one's time than happened before. Fundraising-- most of what the president does these days is fundraising as far as out on the road, getting the alumni excited about what's going on here. And that's a pretty time-consuming job. Any other comments about that?

It's not an exaggeration to say the field of computer science was created by DARPA over about 25-year period from 1960 to 1985 or so. And then from Star Wars, which is a separate agency but similar kind of thing. Just wouldn't exist without that kind of money. Still today, a lot of the CSAIL funds are from DARPA, in a lot of different ways, or other parts of the military.

How many people here have worked on an industrially-funded project? Nobody? How many people here know where the funding comes from for the projects you work on? Only a few. OK, interesting. So you know, again, the military funding is not as big as it was. I think it's very clear to say the mindset of that kind of work does not dominate the way that it did during the period when we were watching those. But there's still a lot of it, and the industrial funding has its own set issues, too.

And then there's always new forms of this kind of thing. What's down the street there-- down the street, it's right over there-- is the Koch Institute that opened up just, what, a month ago. And that would seem to be, oh, how perfect. It's endowed by a private individual. Doesn't have any of the strings that government or industrial funding comes with or any of the sort of implications, but what were the issues there that came up? Anybody read about it when the Koch Institute was opened? Well, that man, David Koch, he has a lot of funding for other kinds of political-- well, not other kinds-- but political. He funds a lot of Tea Party, right-wing conservative stuff in the country.

I mean, MIT is very clear about what the boundaries are for what's acceptable when money is accepted. I mean, there's any number times. It's happened to me. I had, essentially, a contract with an oil company that wanted to fund some of the work I did C, but they had a restriction in what the contract was supposed to say about intellectual property.

That's actually the place it most comes up. That was just totally unacceptable, both to me and to the lawyers at MIT, who looked at it, and we ended up not taking the money because you couldn't work under those conditions. And those things get massaged in a lot of different ways, but people have a pretty clear sense of their intellectual freedom and aren't always willing to sell that off in that way. So, there's all sorts of things.

Another one that comes up a lot now is foreign governments. And we have a lot of potential arrangements with foreign governments that raise interesting questions. Like, say the government of India were to come to MIT and say, we'd like to give you $50 million to help study poverty. Well, a lot of professors on campus would say, I don't feel comfortable taking research money from a country that has x numbers of hundreds of millions of poor people in their country and shouldn't be MIT's role in the world to take money from governments that have very, very serious pressing things.

Or Saudi Arabia, where they don't allow women students or women professors or Jewish students or Jewish professors on their campuses. Should we go into collaborations with them? So it's actually pretty hard to think about a source of funding that comes to the Institute that doesn't have some kind of complicated set of circumstances around it. And that's one of the interesting things in your own work but also, as a historian, to look at this about how those things get negotiated in any given era.

There's certainly, clearly, things that are just off limits that won't be done. There are other things that are pretty easy, like the National Science Foundation, where they come and they give you money and your only job in response is to write a paper. And there's a lot of things that are kind of in the middle.

I actually happen to think that some of the military funding, particularly the DARPA funding, is actually a lot freer and has fewer strings attached than the NSF funding because the NSF is always peer reviewed. And you're always being pulled by other people in your field who want you to do what they do. Whereas with, sometimes, with what-- it's a little bit less true now than it used to be-- with DARPA funding, they can really just give you the money and let you do want you want to do because they're a little bit protected politically because they're within the DOD.